Arc Welding of Copper Alloys

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Copper, Brass and Bronze, otherwise known as the “Red Metals”, may look the same initially but are actually quite different and can be tricky with regards to maintenance welding onboard.

Copper and copper alloys

Copper is used in a wide range of products onboard due to its excellent electrical and thermal conductivity, good strength, good formability and resistance to corrosion. Pipe and pipe fittings are commonly manufactured from copper and its alloys due to their corrosion resistance. They can be readily soldered and brazed, and many can be welded by gas and arc welding.

One of the most important properties of copper is its ability to fight bacteria. After extensive antimicrobial testing, it was found that 355 copper alloys, including many brasses, were found to kill more than 99.9% of bacteria within two hours of contact. Copper kills microbes by interfering with the electrical charge of the organisms' cell membranes. Normal tarnishing was found not to weaken the antimicrobial effectiveness.

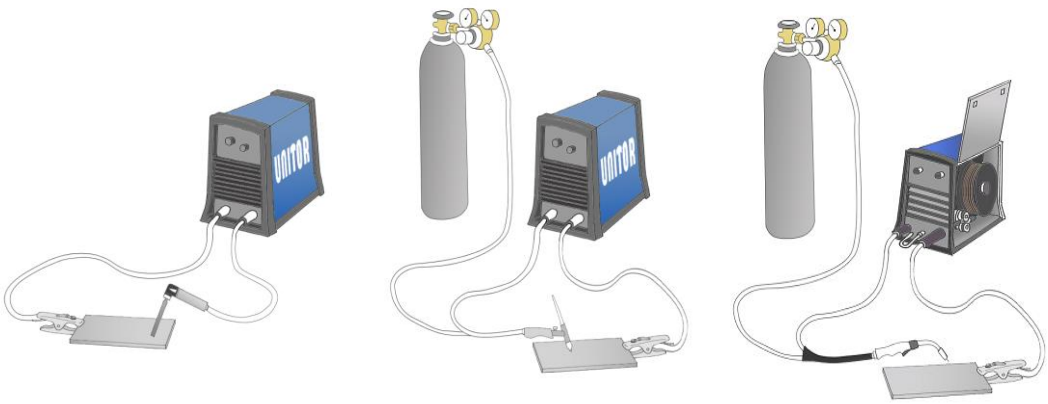
The corrosion resistance of copper and copper-base alloys in seawater is determined by the nature of the naturally occurring and protective corrosion product film. The film is largely cuprous oxide, with cuprous hydroxy chloride and cupric oxide being present in significant amounts on occasion. The corrosion product film thicknesses range from 280nm* for copper to 440nm* for Alloy C70600 (90:10 copper-nickel). The film is adherent, protective, and generally brown or greenish-brown in colour.

Copper ranks as the third-most-consumed industrial metal in the world, after iron and aluminium. About 60% of that copper goes to make electrical wires, telecommunication cables and electronics. The rest goes to roofing and plumbing (20%), and industrial machinery (15%). Copper is used mostly as a pure metal, but when greater hardness is required, it is put into such alloys as brass and bronze (5% of total use).

In the following paper it will only be referred to welding of copper and copper alloys by the use of welding equipment that one finds onboard. That will normally be welding machines for Manual Metal Arc (**MMA**) welding using coated electrodes (stick electrodes). This type of welding machines will in most cases also have the ability to perform Tungsten Inert Gas (**TIG**) welding. An increasing number of vessels also have welding machines that can perform Metal Inert Gas (**MIG**) welding. Maintenance welding of copper and copper alloys will therefore in this article concentrate towards MMA, TIG and MIG welding processes. For Brazing: For further details go to TE Andersen consulting web site under Welding Library under Gas welding, Brazing & Cutting "What you should know about brazing". The US and Canada have different naming of this welding processes. Therefore, please note below conversion from European to American naming of the processes:

Manual Metal Arc (MMA) welding (Stick electrode welding).	Shielded Metal Arc Welding (SMAW)
Tungsten Inert Gas (TIG) welding.	Gas Tungsten Arc Welding (GTAW)
Metal Inert Gas (MIG) welding.	Gas Metal Arc Welding (GMAW)

*nm: nanometer (1 nanometer= 10^{-6}mm)



MMA (SMAW) TIG (GTAW) MIG (GMAW)

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What makes copper and copper alloys more demanding to weld?

Besides the alloying elements that comprise a specific copper alloy, several other factors affect weldability. These factors are the thermal conductivity (heat conductivity) of the alloy being welded, the shielding gas (if TIG or MIG welding), the type of current used during welding, the joint design, the welding position, and the surface condition and cleanliness.

Effect of Thermal Conductivity. The behaviour of copper and copper alloys during welding is strongly influenced by the thermal conductivity of the alloy. In pure copper the heat conductivity is 8 times that of steel. When welding commercial coppers and lightly alloyed copper materials with high heat conductivities, the heat of the arc can rapidly be spread from the weld through the base material. Therefore, the type of current and shielding gas must be selected to provide maximum heat input to the joint. This high heat input counteracts the rapid removal of heat away from the localized weld zone. Depending on section thickness, preheating may be required for copper alloys with lower thermal conductivities. The interpass temperature (the temperature during welding) should be the same as for preheating. Copper alloys are not post-weld heat treated as frequently as steels, but some alloys may require controlled cooling rates to minimize residual stresses and hot shortness. Hot shortness is a tendency for some alloys to separate along grain boundaries when stressed or deformed at temperatures near the melting point.

Several alloying elements have pronounced effects on the weldability of copper and copper alloys. Small amounts of volatile, toxic alloying elements are often present in copper and its alloys. As a result, the requirement of an effective ventilation and fume extracting system to protect the welder is more critical then when welding ferrous metals.

Zinc reduces the weldability of all brasses in relative proportion to the percent of zinc in the alloy. Zinc has a low boiling temperature, which results in the production of toxic vapours when welding copper-zinc alloys.

Tin increases the hot-crack susceptibility* during welding when present in amounts from 1 to 10%. Tin, when compared with zinc, is far less volatile and toxic. During the welding tin may preferentially oxidize relative to copper. The results will be an oxide entrapment, which may reduce the strength of the weldment.

Beryllium, aluminium, and nickel form tenacious oxides that must be removed prior to welding. The formation of these oxides during the welding process must be prevented by shielding gas or by fluxing, in conjunction with the use of the appropriate welding current. The oxides of nickel interfere with arc welding less than those of beryllium or aluminium. Consequently, the nickel silvers and copper-nickel alloys are less sensitive to the type of welding current used during the process. Beryllium containing alloys also produce toxic fumes during the welding.

Silicon has a beneficial effect on the weldability of copper-silicon alloys because of its deoxidizing and fluxing actions.

***** Both hot-cracking and solidification cracking refer to the formation of shrinkage cracks during the solidification of weld metal.

Oxygen can cause porosity and reduce the strength of welds made in certain copper alloys that do not contain sufficient quantities of phosphorus or other deoxidizers. Oxygen may be found as a free gas or as cuprous oxide. Most commonly welded copper alloys contain deoxidizing element, usually phosphorus, silicon, aluminium, iron, or manganese.

Iron and manganese do not significantly affect the weldability of the alloys that contain them. Iron is typically present in some special brasses, aluminium bronzes, and copper-nickel alloys in amounts of 1.4 to 3.5%. Manganese is commonly used in these same alloys, but at lower concentrations than iron.

Free-Machining Additives. Lead, selenium, tellurium and sulphur are added to copper alloys to improve machinability. Bismuth is beginning to be used for this purpose as well when lead-free alloys are desired. These minor alloying agents, while improving machinability, significantly affect the weldability of copper alloys by rendering the alloys hot-crack susceptible. The adverse effect on weldability begins to be evident at about 0.05% of the additive and is more severe with larger concentrations. Lead is the most harmful of the alloying agents with respect to hot-crack susceptibility.

Welding Position. Due to the highly fluid nature of copper and its alloys, the flat position is used whenever possible for welding. The horizontal position is used in some fillet welding like outside corner joints and T-joints.

Precipitation-Hardenable Alloys. Precipitation hardening, also called age hardening or particle hardening, is a heat treatment technique used to increase the yield strength of malleable materials, including copper alloys. The most important precipitation-hardening reactions are obtained with beryllium, chromium, boron, nickel, silicon, and zirconium. Care must be taken when welding precipitation-hardenable copper alloys to avoid oxidation and incomplete fusion. Whenever possible, the components should be welded in the annealed condition*, and then the weldment should be given a precipitation-hardening heat treatment.

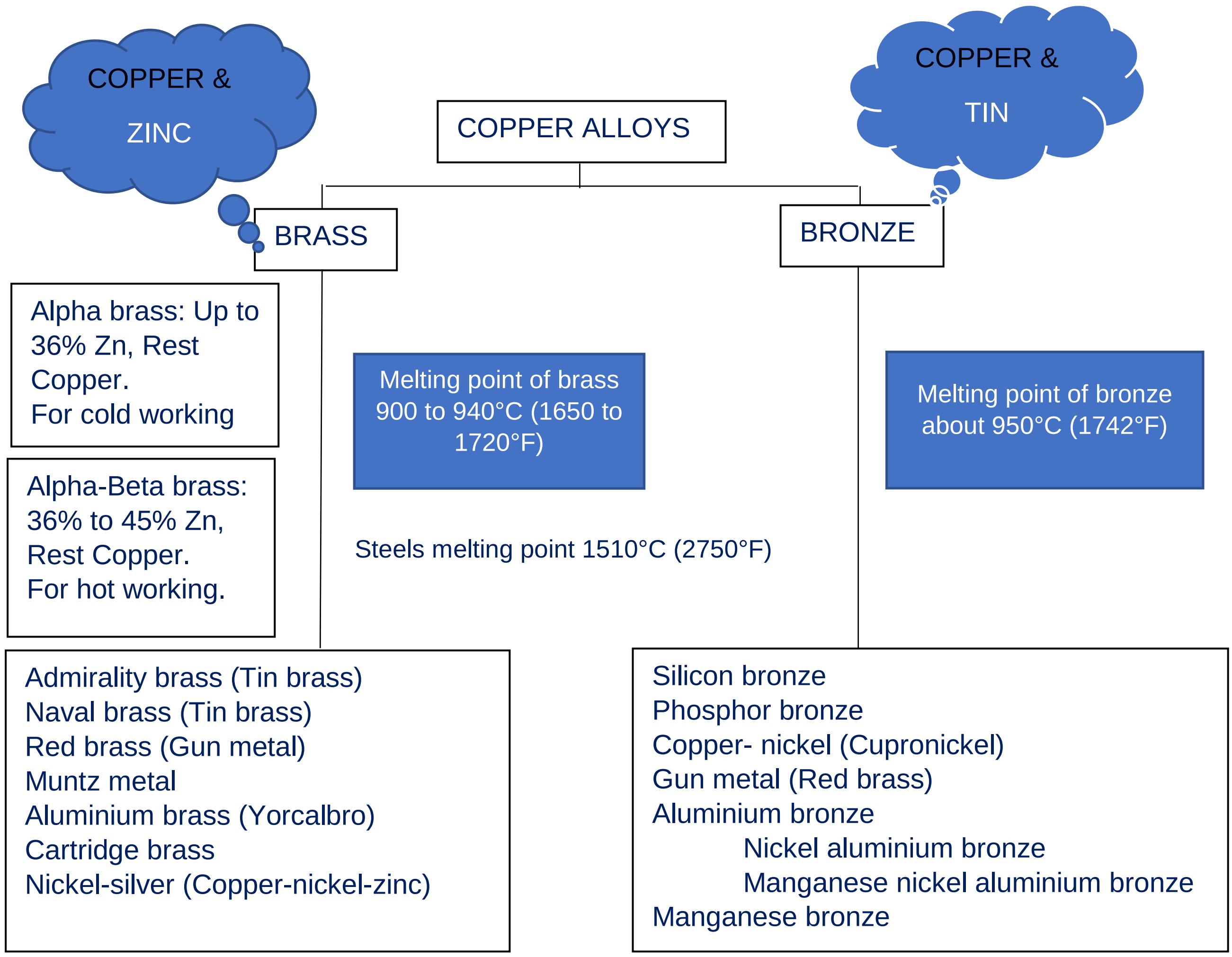
Hot Cracking. Copper alloys, such as copper-tin and copper-nickel, are susceptible to hot cracking at solidification temperatures. This characteristic is exhibited in all copper alloys with a wide liquidus-to-solidus temperature range. Severe shrinkage stresses produce interdendritic separation (separation between the metals crystal) during metal solidification. Hot cracking can be minimized by reducing restraint during welding, preheating to slow the cooling rate and reduce the magnitude of welding stresses, and reducing the size of the root opening and increasing the size of the root pass.

Porosity. Certain elements (for example, zinc, cadmium, and phosphorus) have low boiling points. Vaporization of these elements during welding may result in porosity. When welding copper alloys containing these elements, porosity can be minimized by higher weld speeds and a filler metal low in these elements.

Surface Condition. Grease and oxide on work surfaces should be removed before welding. Wire brushing or bright dipping can be used. Scale and oxides on the surfaces of aluminium bronzes and silicon bronzes is removed for a distance from the weld region of at least 13 mm (33/64"), usually by mechanical means. Grease, paint, crayon marks, shop dirt, and similar contaminants on copper-nickel alloys may cause embrittlement and should be removed before welding. Scale and oxides on copper-nickel alloys must be removed by grinding or pickling; wire brushing is not effective.

* Annealing, is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and reduce its hardness, making it more workable.

A simplified copper alloy diagram



In reality it is unfortunately more complicated. There are more than 400 copper alloys, each with a unique combination of properties, to suit many applications and environments. Sometime they are referred to by common names, such as Oxygen-free copper, Beryllium copper, Muntz metal, Naval brass, Gun metal or by a numbering system. For example, C64700. This number indicate that the item is a wrought Silicon Bronze (UNS number: Wrought: C64700). UNS =Unified Numbering System. Sometime it can also be confusing if the alloy is a Brass or a Bronze. Above you might have noticed that Gun metal are referred to both as a Brass and a Bronze. This simply because it contains about 5% tin and 5% zinc. Nickel-silver can also be difficult to place because of variation of alloying elements.

Bronze

The alloy of copper and tin are usually termed bronzes. The useful range of composition is 75 to 95% copper and remainder tin. In general, it possesses superior mechanical properties and corrosion resistance to brass. Bronze is characterized by its dull-gold colour. You can also tell the difference between bronze and brass because bronze will have faint rings on its surface.

Brass

Fundamentally brass is a binary alloy (An alloy containing two component elements) of copper with as much as 40% zinc. There are various types of brasses depending upon proportion of copper and zinc.

The major groups of copper and its alloys.

These major groups are:

- Coppers, which contain a minimum of 99.3% **Cu**
- High-copper alloys, which contain up to 5% alloying elements
- Copper-zinc alloys (brasses), which contain up to 40% **Zn**
- Copper-tin alloys (phosphor bronzes), which contain up to 10% **Sn** and 0.2% **P**
- Copper-aluminium alloys (aluminium bronzes), which contain up to 10% **Al**
- Copper-silicon alloys (silicon bronzes), which contain up to 3% **Si**
- Copper-nickel alloys, which contain up to 30% **Ni**
- Copper-zinc-nickel alloys (nickel silvers), which contain up to 7% **Zn** and 18% **Ni**
- Special alloys, which contain alloying elements to enhance a specific property or characteristic, for example machinability

It is not so important if we call it Bronze or Brass. The main thing in maintenance and repair welding is that we know the chemical composition in order to select the correct welding method, choose the right welding consumable/ filler and the right procedure. Edge preparation and cleaning will in most cases be first step. Some of the copper alloys will require pre-heating and that the interpass temperature (the temperature during welding) is observed. After welding some of the copper alloys will require Stress reliving.

NB. Volatile, toxic alloying elements like zinc, lead and even arsenic are often present in copper and its alloys. As a result, the requirement of an effective ventilation/ fume extraction system to protect the welder is more critical then when welding ferrous metals.

Base material alloy type and recommended consumable/ filler

Copper and copper alloys are divided into 9 major groups. In the below table you will however for welding reasons find this divided into 10 groups,

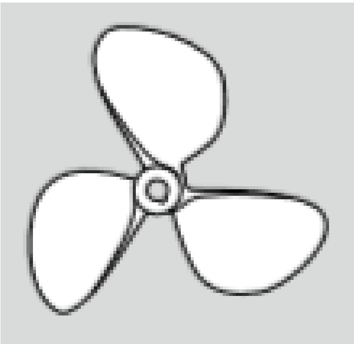
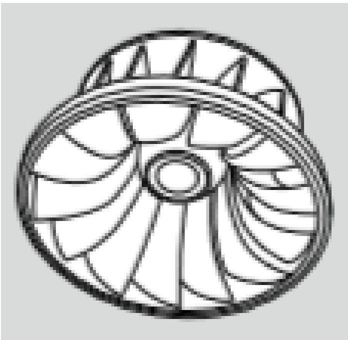
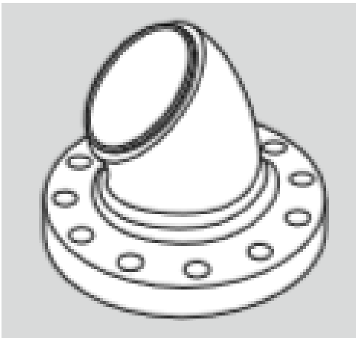
For welding consumables/filler material references are given towards AWS A5.6/ A5.7. There are also added a number of suppliers/ manufacturers and the brands they offer. Please make sure that the particular brand is according to the AWS specification in case changes have taken place.

Base Material	**Features and additional comments**	**Welding consumable AWS Classification**	
		Manual Metal Arc Welding Electrodes AWS A5.6	TIG /MIG Rods and Wires AWS A5.7
Copper 1 For more details	Covered electrodes ECu are designed to be welded with DC+ polarity. Copper rods and wire ERCu are generally available with a minimum copper content of 98%. These rods and wires are used to weld deoxidised and electrolytic tough pitch copper using TIG and/ or MIG welding. For copper consider brazing/soldering	**ECu** WA Alloy Co: Rainer 4A Philarc: Copper	**ERCu** WA Alloy Co: Deox copper Alloy no. 189 (TIG/MIG) Ampco metal: Copr-trode Lincoln Electric: LNM CuSn (MIG)
Silicon bronzes (Copper silicon), brasses 2 For more details	ECuSi covered electrodes core rod contain about 3% silicon with small amounts of tin and manganese. The electrodes are used primarily for welding copper-zinc alloys using DC+ polarity. ERCuSi-A copper silicon wires/rods contain from 2,8% to 4% silicon with about 1,5% manganese, 1% tin, and 1 % zinc. This filler wire is used for welding silicon bronzes and brasses well as to braze weld galvanized steel. The tensile strength of copper-silicon weld metal is about twice that of ERCu weld metal.	**ECuSi** WA Alloy Co: Rainer 6A Philarc: CuSi	**ERCuSi-A** WA Alloy Co: Silicon bronze Alloy no. 656 Ampco metal: Sil-trode Lincoln Electric: LNM CuSi3 (MIG) LNT CuSi3 (TIG) Oerlikon: Copperfil 3 (MIG)

Base Material	Features and additional comments	Welding consumable AWS Classification	
		Manual Metal Arc Welding Electrodes AWS A5.6	TIG /MIG Rods and Wires AWS A5.7
Phosphor bronzes (Copper tin), brasses 3 For more details	The ECuSn-A composition contains about 5% tin, and the ECuSn-C composition has about 8% tin. Both electrodes are deoxidized with phosphorus. The electrodes can be used for welding bronze, brass, and also for copper if the present of tin in the weld metal is not objectionable. These electrodes frequently are used for casting repairs. The ECuSn-C electrodes provide weld metal with better strength and hardness than ECuSn-A electrodes and are preferred for welding high strength bronzes. ERCuSn-A rods can be used for TIG welding process for joining phosphor bronze. Preheat and interpass temperature of 200°C (400°F) is required specially for heavy sections.	**ECuSn-A** Philarc: Bronze-A **ECuSn-C** WA Alloy Co: Rainer 3A Unitor: Tinbro-341 Drew: SN Tin bronze Philarc: Bronze	**ERCuSn-A** WA Alloy Co: Phos bronze A Alloy no. 518 Lincoln Electric: LNT CuSn6 (TIG) Bøhler: UTP384
Copper-nickel alloys (Cupro-nickel) 4 For more details	Copper-nickel covered electrodes ECuNi and wire/rods ERCuNi normally contain 70% copper and 30% Nickel. This is also the case even if the base material contains 90% copper and 10% Nickel. These filler metals also contain titanium to deoxidize the weld pool. ECuNi covered electrodes is suitable for surfacing and cladding provided buttering layer is made (normally buttering is made with pure nickel). For joining preferably use TIG welding, or if thicker materials MIG welding and consumable ERCuNi	**ECuNi** WA Alloy Co: Washington alloy 187 Daiko: Daico 187 Lincoln Electric: Tech-rod 187 Special Metals: Monel 187	**ERCuNi** WA Alloy Co: Washington alloy 67 Unitor: Icuni 30-239 (TIG) Icuni W-239 (MIG) Drew: CNT Copper Nickel (TIG)

Base Material	Features and additional comments	Welding consumable AWS Classification	
		Manual Metal Arc Welding Electrodes AWS A5.6	TIG /MIG Rods and Wires AWS A5.7
Aluminium bronzes, brasses, silicon bronzes, manganese bronzes 5 For more details	ECuAl-2 covered electrodes for electrode welding contain 6,5 to 9% aluminium. ERCuAl-2 wire and rods for TIG and MIG welding contain from 8,5 to 11% aluminium. ERCuAl-2 weld metal has a higher strength than the ECuAl-2 weld metal. Both filler metals are used for joining aluminium bronze, silicon bronze, copper-nickel alloys, copper-zinc alloy, manganese bronze and many combinations of dissimilar metals. ERCuAl-A1filler metal is an iron-free aluminium bronze. It is used as a surfacing alloy for wear resistant surfaces having relatively light loads, for resistance to corrosive media such as salt and brackish water and for resistance towards commonly used acids. Not recommended for joining.	**ECuAl-A2** WA Alloy Co: Rainer 5A Ampco metal: Ampco-trode 10 Unitor: Albronze-344 Drew: Aluminium bronze Philarc: Al-Bronze CuAl-A2	**ERCuAl-A1** WA Alloy Co: Aluminium bronze A-1 Alloy no. 610 Ampco metal: Ampco-trode 7 Unitor: Ialbro W-237 (MIG) Drew: AB Aluminium bronze (TIG) Lincoln Electric: LNM CuAl8 (MIG)
	ECuAl-B covered electrodes contain 7,5 to 10% aluminium and produce deposits with higher strength and hardness than the ERCuAl-A2 rods/wires. These electrodes are used for surfacing applications and for repair welding of aluminium bronze castings of similar compositions. ERCuAl-A3 are used for repair welding of similar composition aluminium bronze castings using TIG and MIG welding. Their high aluminium content produces welds with less tendency to crack in highly stressed sections. For more details on other filler alternatives see “5 For more details”.	**ECuAl-B** Ampco metal: Ampco-trode 160 Philarc: Al-Bronze CuAl-B	**ERCuAl-A2** WA Alloy Co: Aluminium bronze A-2 Alloy no. 618 Ampco metal: Ampco-trode 10 (TIG) Unitor: Ialbro-237 MF (TIG) **ERCuAl-A3** Ampco: Ampco-trode 150 WA Alloy Co: Aluminium bronze A-3 Alloy no. 624 Aufhauser: C624 Aluminium bronze A-3 (MIG)

Base Material	Features and additional comments	Welding consumable AWS Classification	
		Manual Metal Arc Welding Electrodes AWS A5.6	TIG /MIG Rods and Wires AWS A5.7
Nickel-aluminium bronzes 6 For more details	Copper -nickel-aluminium electrodes and rods/ wires ECuNiAl and ERCuNiAl are used to join and repair both wrought and cast nickel aluminium bronze materials. These electrodes may be used for applications requiring good corrosion resistance, erosion or cavitation resistance in both salt and brackish water.	**ECuNiAl** Ampco metal: Ampco-trode 46 Philarc: CuNiAl	**ERCuNiAl** WA Alloy Co: Nickel-aluminium-bronze alloy Ampco metal: Ampco-trode 46 Lincoln Electric: LNM CuAl8Ni6 (MIG)
Manganese-nickel-aluminium bronzes 7 For more details	ECuMnNiAl covered electrodes and ERCuMnAl wire/ rods are used to join manganese-nickel-aluminium bronzes of similar composition. These consumables are used in applications requiring resistance to cavitation, erosion and corrosion.	**ECuMnNiAl** Ampco metal: Ampco-trode 46 Philarc: CuMnNiAl	**ERCuMnNiAl** WA Alloy Co: Manganese-nickel-aluminium alloy Ampco metal: Ampco-trode 46 (TIG)

Base Material	**Features and additional comments**	**Welding consumable AWS Classification**	
		Manual Metal Arc Welding Electrodes AWS A5.6	TIG /MIG Rods and Wires AWS A5.7
Brasses (Copper-Zinc), (Naval brass) 8 For more details	ECuSi covered electrodes core rod contain about 3% silicon with small amounts of tin and manganese. The electrodes are used primarily for welding copper-zinc alloys using DC+ polarity. The RBCuZn-A rods contain 1% tin to improve corrosion resistance and strength. These rods are primarily used for Oxy Acetylene welding of brass and for braze welding of copper, bronze and nickel alloys. RBCuZn-A can also be used for TIG welding. ERCuSi-A copper silicon wires contain from 2,8% to 4% silicon with about 1,5% manganese, 1% tin, and 1 % zinc. This filler wire is used for welding silicon bronzes and brasses well as to braze weld galvanized steel. The tensile strength of copper-silicon weld metal is about twice that of ERCu weld metal. NB. Also consider copper-tin alloys such as Cu-5%Sn (ECuSn-A/ ERCuSn-A) and Cu-8%Sn (ECuSn-C/ ERCuSn-C). Check out 8 For more details	**ECuSi** WA Alloy Co: Rainer 6A Philarc: CuSi	**RBCuZn-A** WA Alloy Co: Naval bronze Alloy no. 470 **ERCuSi-A** WA Alloy Co: Silicon bronze Alloy no. 656 Ampco metal: Sil-trode Lincoln Electric: LNM CuSi3 (MIG) LNT CuSi3 (TIG) Oerlikon: Copperfil 3 (MIG)
Manganese bronzes 9 For more details	RBCuZn-B rods contain additions of manganese, iron and nickel that increase hardness and strength. A small amount of silicon provides low fuming characteristic. The RBCuZn-C are similar to RBCuZn-B in composition except that they do not contain nickel. The mechanical properties of as-deposited weld metal from both rods are similar to those of Naval brass. ECuAl-A2 high strength welding electrodes resists corrosion, cavitation, erosion, and metal to metal wear. It is also excellent for overlays on cast irons, steels and copper.	**ECuAl-A2** WA Alloy Co: Rainer 5A Ampco metal: Ampco-trode 10 Unitor: Albronze-344 Drew: Aluminium bronze Philarc: Al-Bronze CuAl-A2	**RBCuZn-B** WA Alloy Co: Nickel bronze Alloy no. 680 **RBCuZn-C** WA Alloy Co: Low fuming bronze alloy Alloy no. 621

Base Material	Features and additional comments	Welding consumable AWS Classification	
		Manual Metal Arc Welding Electrodes AWS A5.6	TIG /MIG Rods and Wires AWS A5.7
Nickel-silver (Copper-nickel-zinc alloys) (German silver) 10 For more details	RBCuZn-D Nickel Silver is a bare brazing rod used widely as a replacement for high cost silver brazing alloys when higher brazing temperatures are acceptable. The weld deposits have a very high tensile strength, good ductility and excellent corrosion resistance. Nickel Silver weld deposits are also readily machinable and will not work harden when put into service. Rods can also from some manufacturers be flux coated. ERCuNiAl are used to join and repair both wrought and cast nickel aluminium bronze materials. These wires/rods may be used for applications requiring good corrosion resistance, erosion or cavitation resistance in both salt and brackish water. ERCuSi-A copper silicon wires contain from 2,8% to 4% silicon with about 1,5% manganese, 1% tin, and 1 % zinc. This filler wire is used for welding silicon bronzes and brasses well as to braze weld galvanized steel. The tensile strength of copper-silicon weld metal is about twice that of ERCu weld metal.		**RBCuZn-D** WA Alloy Co: Nickel silver Alloy no. 773 **ERCuNiAl** WA Alloy Co: Nickel-aluminium-bronze alloy Ampco metal: Ampco-trode 46 Lincoln Electric: LNM CuAl8Ni6 (MIG) **ERCuSi-A** WA Alloy Co: Silicon bronze Alloy no. 656 Ampco metal: Sil-trode Lincoln Electric: LNM CuSi3 (MIG) LNT CuSi3 (TIG) Oerlikon: Copperfil 3 (MIG)

* Oxy Fuel welding (OFW) is a group of welding processes which join metals by heating them with a fuel gas flame or flares with or without the application of pressure and with or without the use of filler metal. OFW, Oxy Fuel welding includes any welding operation that makes use of a fuel gas combined with oxygen as a heating medium.

Copper & copper alloy details

In the below “details” you will find the Unified Numbering System (UNS) being used. The Unified Numbering System is the accepted alloy designation system in North America for wrought and cast copper and copper alloy products. The UNS is managed jointly by the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE). The designation system is an orderly method of defining and identifying coppers and copper alloys; it is not a specification. It eliminates the limitations and conflicts of alloy designations previously used and at the same time provides a workable method for the identification marking of mill and foundry products. In the designation system, numbers from C10000 through C79999 denote wrought alloys*. Cast alloys are numbered from C80000 through C99999.

*Wrought alloys is obtained after being subjected to various mechanical processes including rolling, extruding and forging. It means that the solid metal was processed into its final shape -including sheets, plates, bars, tubing, angles and channels.

For welding consumables/filler material references are given towards AWS A5.6/ A5.7 and ISO designations.

1 **Copper**

Composition:

- There are a number of types, or grades, of what is essentially pure copper. These grades differ slightly in purity and in the types of "impurity" elements contained, but all contain at least 99.3% Copper. Deoxidized copper is used in many of the pipe systems onboard. The principal uses being for tubes/pipes for gas and water supply.

  The oxygen in copper is usually removed by the addition to the melt of phosphorus as a copper-phosphorus hardener, or boron in the case of castings. This gives a material that can readily be brazed or welded without fear of embrittlement through contact with hydrogen. It is therefore ideal for use in plumbing systems and domestic gas supply. High conductivity (HC) electrolytically refined copper is used for most electrical applications onboard such as wires and cables, busbars and windings.

- High copper alloys are where we find beryllium copper (0,2 % aluminium, 1,6% - 2% beryllium, 0,2% silicon). Deoxidized and High alloy copper can be in the form of wrought and cast.

Properties:

- Copper is low in the reactivity series. This means that it doesn't tend to corrode. Again, this is important for its use for marine pipe systems. On to that it is non-magnetic and non-sparking plus biofouling resistance. Excellent electrical and heat conductivity.

Applications:

- Due to the naturally occurring resistance to seawater corrosion and intrinsic biofouling properties copper have long been widely used in the components of seawater systems. Applications include seawater piping, heat exchangers and fuel lines. Copper DHP (Deoxidized High Phosphorus - CW024A) is commonly used for tubing in marine environments. However, other alloys such as aluminium brass or copper-nickels are preferred if flow velocities become too high for copper.

Welding:

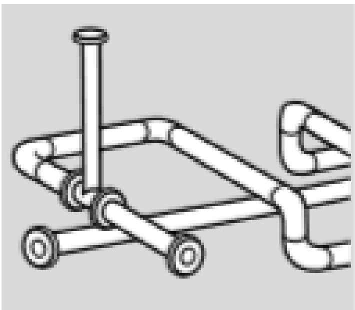
- Copper 99,3% minimum – Wrought: C10100 to C1599 | Cast: C80000 to C81399
- High alloyed Copper - Wrought: C16000 to C19999 | Cast:81400 to 83299
  Always consider Brazing as an option when considering welding copper. The choice should be based on pipe wall or plate thickness of the object and /or the size. A soft metal in its pure, unalloyed state, copper welds fair.

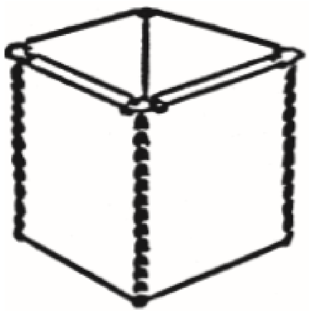
  Oxygen-free coppers are readily joined by welding. Whereas oxygen-bearing copper is not recommended for welding because high temperatures cause a major reduction in its strength and ductility. Welding is not recommended for free-machining copper because these alloys are very susceptible to cracking. Nor is it suggested for precipitation-hardenable copper alloys. High temperatures will overage the heat affected zone and lower its mechanical properties.

  Commonly weldable coppers (tough pitch, phosphorus deoxidised) are typically welded with Cu1897 and Cu1898 filler metal. TIG welding can be performed up to 6mm thickness preferably in flat position. Shielding gas: up to 2mm (5/64") Argon. Over 2mm (5/64") Argon Helium gives deeper penetration. Pulsed current can be used for TIG welding. Filler: ERCu (Cu1897) MIG Spray transfer with pulsed current for thicker metals over 6mm (15/64). For MMA Ecu (Cu1898) fillers are recommended.

  NB. ERCuSi-A (Cu6560), ERCuSn-A (Cu5180), ECuSi (Cu6560), ECuSn-A (Cu5180) and ECuSn-C (Cu5210) are also used where good electric or thermal conductivity is not a major requirement.

  The high thermal conductivity of copper requires preheating to achieve complete fusion and adequate joint penetration. Preheat requirements depend on material thickness and size of object to be welded (total mass). Preheating of copper in general can vary from 300°C to 500°C (570°F to 930°F).





2 Silicon bronze

Composition:

- Silicon bronze has an average composition of 3% silicon, 1% manganese and rest copper.

Properties:

- It possesses the good general corrosion resistance of copper with higher strength and toughness.
- It can be cast rolled, stamped, forged and pressed either hot or cold and can be welded by all the usual methods.

Applications:

- Silicon bronze is widely utilized for parts of boilers, tanks, stoves or where high strength as well as corrosion resistance is required. Typical applications cover pressure vessels and hot-water storage tanks, heat exchanger tubes, valve stems, tubes for hydraulic lines and pump shafts.

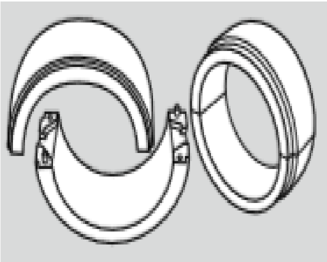
Welding:

- Silicon Bronze – UNS numbers: Wrought: C64700 to C66100 | Cast: C87300 to C87900

  Silicon bronzes are arguably the easiest of all the bronzes to weld. Unlike many other copper alloys, their thermal conductivity is relatively low (similar to that of steel) and you can use relatively high welding speeds compared to other copper alloys. These alloys should be stress relieved or annealed prior to welding, slowly heated to the desired temperature, and then rapidly cooled through the critical temperature range. Silicon bronzes are readily weldable with ERCuSi-A and ECuSi (Cu 6560) filler metal respectively.

  NB. ERCuAl-A2 and ECuAl-A2 (Cu6180) may also be used.

Pre-heating is unnecessary. Apply hot peening for each welding pass, to refine the crystal structure thereby improving the mechanical properties. Weldments must be rapidly cooled and interpass temperature should not be over 70°C (158°F) thereby avoiding the likelihood of hot cracking.
Stress reliving temperature for weldments made in Silicon Bronze C65500: 340°C (650°F).



3 **Phosphor bronze** C50100-C52400 **(Copper -Tin alloys)**

Composition:

When bronze contains phosphorus, it is known as phosphor bronze. The composition of the alloy varies according to whether it is to be forged, wrought or cast. A common type of phosphor bronze has the following composition Copper is 93.6%, tin is 9%, and phosphorus is 0.1 to 0.3%.

Properties:

- The alloy possesses good wearing qualities and high elasticity.
- The alloy is resistant to saltwater corrosion.

Applications:

- Cast phosphor bronze are used in bearings and gears and connectors
- Bearings of bronze contain 10% tin and small addition of lead.
- This is also used in making gears, nuts, for machine lead screws, springs, pump parts, linings, bellows and many other such applications.

Welding:

- Phosphor Bronze – UNS numbers: Wrought: C50100 to C52400 | Cast: C90200 to C91700
  Unleaded phosphor bronze alloys has fair weldability. But, under stressed conditions these alloys are subject to hot cracking. Hot peening of each layer of multipass welds will reduce welding stresses and the likelihood of cracking. So like tin brass, to high heat inputs and slow cooling rates should be avoided. You can carefully weld leaded phosphor bronze using TIG/MIG welding. Keep in mind that weldability of these alloys decreases as lead content increases. The most frequently used phosphor bronze alloy for TIG and MIG welding is ERCuSn-A (Cu 5180) filler metal. Preheating: not required for thin sections, Thick sections require preheating to 200°C (480°F). Interpass temperature should not exceed 250°C (480°F). Preheating of the phosphor bronzes helps in obtaining complete fusion, less porosity, but columnar grains and hot cracking. MMA covered electrodes: ECuSn-A (Cu5180) and ECuSn-C (Cu5210). For maximum ductility, the welded assembly should if possibly be post weld heat treated to 480°C (900°F).

  There are subfamilies of bronzes among the cast copper alloys: First listed are the copper-tin alloys, C90200 to C9177, or tin bronzes. “G” bronze (C90300) is a casted copper alloy listed under Phosphor bronze but its chemical composition is 88% Copper, 8% tin and 4% zinc so often referred to as a Gun metal. Fair weldability using MMA, TIG and MIG welding.
  Next come the copper-tin-lead alloys, which are further broken down into leaded tin bronzes, C92200 to C92900. M” bronze (C92200) is in a group of casted leaded tin bronzes also referred to as Navy “M” bronze, steam bronze. The alloy is specified for corrosion resistant valve fittings and other pressure retaining products. The C92200 alloy can be used for pressure retaining parts at temperatures up to 290°C (550°F) MMA, TIG and MIG welding not recommended.

4 Copper Nickel (or Cupronickel)

Composition:

- This is an alloy that can contain anywhere from 2% to 30% nickel.

Properties:

- This material has a very high corrosion-resistance and has thermal stability. This material also exhibits a very high tolerance to corrosion cracking under stress and oxidation in a steam or moist air environment. Higher nickel content in this material will have improved corrosion resistance in seawater, and resistance to marine biological fouling.

Applications:

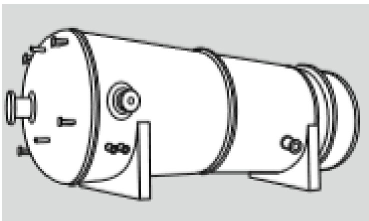
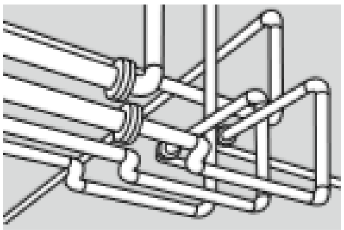
- This material is typically found in marine equipment like sea water piping, valves, pumps and heat exchanger end plates and tubes.

Welding:

- Copper Nickel – Wrought: C70100 to C72950 | Cast: C96200 to C96900

Copper nickel alloys are the most commonly used in welded fabrication projects. Phosphorus and sulphur levels in these alloys is less than 0.02% to ensure good welds. Most copper nickel alloys do not contain a deoxidizer. Therefore, fusion welding requires the addition of a deoxidized filler metal. This lowers the risk of porosity in the weld. For copper nickel with a 10% nickel composition (C96400), and for copper nickel with a 30% nickel composition (C96200), an ERCuNi (Cu 7158) filler with 30% nickel must be used. For further details go to TE Andersen consulting web site under Welding Library "Repair Welding of Sea water pipes". TIG welding is preferred welding method for copper-nickel alloys with section thicknesses up to 2 mm (5/64"). MIG welding preferred welding process for non-leaded copper-nickel alloys thicker than approximately 2 mm (5/64"). Spray or short-circuiting transfer. Argon shielding gas for TIG welding. Preferred shielding gas for MIG welding Argon or Argon-helium. Argon-helium mixes give better penetration on thick sections. Flat is preferred welding position. Filler MMA welding both wrought and cast forms: Copper-nickel electrode ECuNi containing 30% nickel. Special care is needed to ensure complete slag removal for every run. No preheating or post heating normally necessary. Interpass temperatures should be maintained below 65°C (150°F).

Stress relieving temperature for weldments made in Copper Nickel C70600 to 71500: 538°C (1000°F)

5 Aluminium Bronze

Composition:

- Aluminium bronze has an aluminium content range of 6% – 12%, an iron content of 6% (max), and a nickel content of 6% (max).

Properties:

- These combined additives provide increased strength, combined with excellent resistance to corrosion and wear.

  Applications:

  This material is commonly used in marine hardware, sleeve bearings and pumps or valves that handle corrosive fluids.

  Welding:

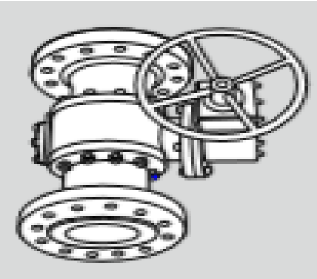
- Aluminium Bronze – Wrought: C60600 to C64400 | Cast: C95200 to C95900

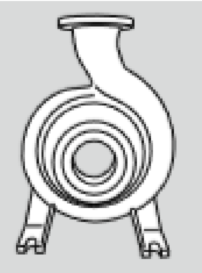
  The low electrical and thermal conductivity of aluminium bronze alloys enhances their weldability. However, is it crucial to remove all of the aluminium oxide layer (Al_2O_3) on the surface of the material before welding. For aluminium bronze alloys with less than 7.8% aluminium, ERCuAl-A3 (Cu 6240) and ERCuAl-A1 (Cu6100) are ideal filler metals. While alloys with aluminium content greater than 7.8% are better suited with ERCuAl-A2 (Cu6180) and ERCuAlNi (Cu6328). Aluminium silicon bronze (with 2% Silicon), C64200, is best repaired with ERCuAl-A1 (Cu6100).

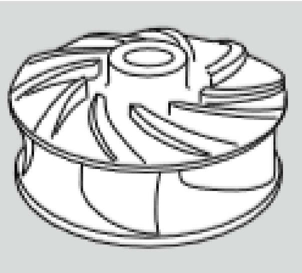
  Filler metal for MMA welding should be ECuAl-A2 (Cu6180) or ECuAl-B (Cu6220). In MMA welding use a short arc length and stringer beads. Each bead must be thoroughly cleaned for slag before the next bead is applied to prevent slag inclusions. MMA welding should only be used where TIG or MIG welding is inconvenient or not available.

  Preheat and interpass temperature depends on thickness of the part to be repaired. Normally the preheating temperature will be from 100°C to 250°C (212°F to 480°F). Where thickness of part is less than 20mm (25/32”) preheating will normally not be required.

  Stress relieving temperature for weldments made in Aluminium Bronze C61400: 340°C (650°F)







6 Nickel Aluminium Bronze

Composition:

- Nickel Aluminium Bronze is classified under Aluminium Bronzes. Broadly, the Nickel Aluminium Bronzes can be classified as alloys containing 6-13% aluminium and up to 7% iron and 7% nickel. The more common alloys normally contain 3-6% each of these two elements. Manganese up to approximately 1.5% is also added, both as a deoxidant and a strengthening element.

Properties:

Nickel Aluminium Bronze is an excellent choice for applications involving heavy loads, abrasive wear resistant, friction and corrosion. Because of its excellent resistance to erosion- corrosion and cavitation attack, nickel-aluminium bronze has become the standard propeller alloy.

Applications:

- Alloy 63000, 63200, Pump shafts, valve stems
- Alloy C95500, Ships propellers
- Alloy C95800, Ships propellers, Pumps, valves and fittings

Welding: See “Special notes regarding welding of Aluminium Bronze, Nickel Aluminium Bronze and Manganese Nickel Aluminium bronze.”

- Nickel Aluminium Bronze – Wrought: C60600 to C64400 | Cast: C95200 to C95900

7 Manganese Nickel Aluminium bronze

Composition:

- Manganese Nickel Aluminium bronze is classified under Aluminium Bronzes. This is a separate family of alloys which contain up to 14% manganese with additions of iron and nickel.

Properties:

- The alloy can contain 7-8,5% aluminium and up to 2-4% iron, 1,5-3% nickel and 11-14% manganese.

Applications:

- The C 95700 alloy used for ships propeller, pump casings and impeller material

Welding:

- See “Special notes regarding welding of Aluminium Bronze, Nickel Aluminium Bronze and Manganese Nickel Aluminium bronze.”
- Manganese Nickel Aluminium Bronze – Wrought: C60600 to C64400 | Cast: C95200 to C95900

Special notes regarding welding of Aluminium Bronze, Nickel Aluminium Bronze and Manganese Nickel Aluminium bronze

The welding of nickel aluminium bronze alloys is not complicated and can be accomplished by most welders. However, the aluminium rich oxide film which is so important for corrosion resistance can make welding difficult if not the correct welding method/ procedure is used. The right choice of welding process, correct welding practices and the experience of the welder can ensure a sound joint. It is important that oxides, which can form on the base metal as the part is heated or are present prior to heating, do not form inclusions in the weld bead. Pre-weld and inter-run cleaning are therefore of prime importance.

Welding Processes:

Welding is sometimes prohibited for certain critical applications relating to Naval Standards. Maintenance welding is used for the repair of propellers that may become damaged in service or for reclamation of worn surfaces or areas that have been machined incorrectly. Soldering, brazing or oxy-acetylene welding processes are not recommended due to the nature of the protective aluminium-rich oxide film that forms on aluminium bronze. These alloys are not particularly prone to cracking unless their aluminium content is below 9%.

Recommended Welding Processes:

- Tungsten Inert Gas (TIG)
- Metal Inert Gas welding (MIG)
- Manual Metal Arc (MMA)

The TIG process is most suitable for the welding of thin material and for localised smaller repairs. As the TIG process is localised and relatively slow, it is excellent for joining more delicate parts. The TIG Pulsed Arc process has a more controlled heat input, which can be used for thin gauge material and for limiting the extent of the heat affected zone. In this process a lower current is used for striking the arc but is pulsed at regular intervals with a high current to increase the degree of fusion without overheating the weld pool.

The most efficient way of welding nickel aluminium bronze and nickel aluminium manganese bronze, is by the MIG process. It allows the deposit of filler metal at a high rate. Due to the rate of metal deposition, this process is not recommended for thin gauge material or delicate welds. As with TIG welding, this process can be modified using a pulsed current, which facilitates a much more controlled heat input and leads to a more uniform weld deposit.

Apart from joining operations, MMA welding using covered electrodes can be used for tasks such as building up bearing surfaces, overlaying for corrosion resistance, and repair welding. Some grades of nickel aluminium bronze electrodes are also applied for welding ferrous materials and a range of dissimilar metal combinations.

Welding consumables:

Aluminium Bronzes	ECuAl-B	ERCuAl-A3 (Cu6240)
Nickel Aluminium Bronzes	ECuNiAl	ERCuNiAl (Cu6328)
Manganese Nickel Aluminium bronzes	ECuMnNiAl	ErCuMnNiAl (Cu6338)

Preheating temperature will be from 100°C to 250°C (212°F to 480°F) depending on material thickness of the part to be weld repaired.

8 Brasses (Copper zinc)

Composition:

Fundamentally brass is a binary alloy of copper with as much as 50% zinc. There are various types of brasses depending upon proportion of copper and zinc.

C20500-C49080 Wrought alloys

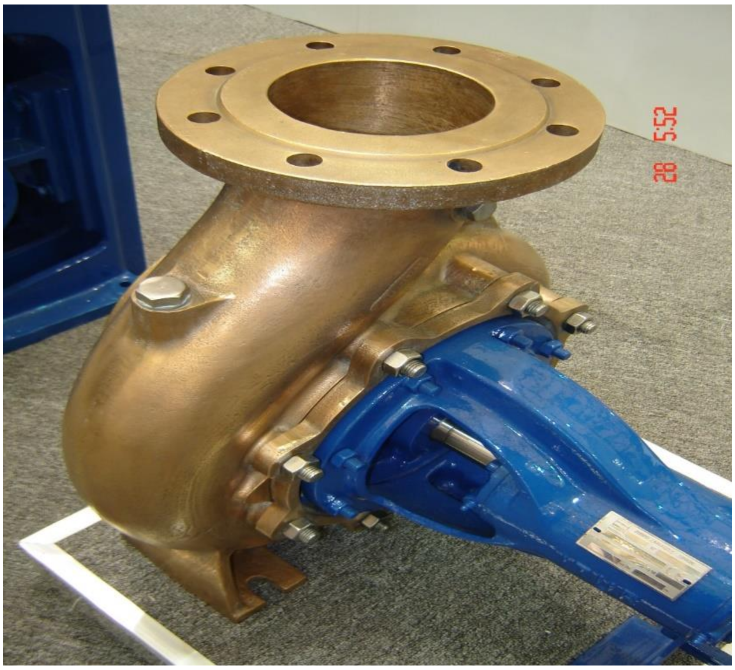
C66400-C69950 Wrought alloys

C83300-C86800 Cast alloys

Properties:

Commercially there are two main varieties of brasses. Alpha brass that contains up to 36% zinc and rest copper for cold working. Alpha-Beta brass that contains 36 to 45% zinc and remainder are copper for hot working. The effect of zinc on copper:

- The tensile strength and ductility of brass both increase with increase in content of zinc up to 30% zinc.
- With further increase in zinc content beyond 30%, the tensile strength continues to increase up to 45% of zinc, but ductility of brasses drops significantly.



There are various classes of brasses such as Cartridge brass, Muntz Metal, Leaded brass, Admiralty brass, Naval brass and Nickel brass all depending upon the proportion of copper and zinc plus a number of other alloying elements.

Brass alloys	Copper (Cu) %	Zinc (Zn) %	Tin (Sn) %	Aluminium (Al) %	Lead (Pb) %	Arsenic (As) %
Admiralty brass C44300 (Also referred to as Arsenical brass)	**69**	**30**	**1**			**0,04**
Naval brass C46400	**59**	**40**	**1**			
Leaded Red brass C83600 (Gun metal)	**85**	**5**	**5**		**5**	
Muntz metal C28000	**60**	**40**				
Cartridge brass C26000	**70**	**30**				
Aluminium brass C68700 (Yorcalbro)	**77,5**	**20,5**		**2**		**0,04**

Tin Brass is an alloy that contains copper, zinc and tin. This alloy group would include **Admiralty brass** C44300 (also referred to as Arsenical brass), **Naval brass** C46400 and free machining brass. The tin has been added to inhibit dezincification (the leaching of zinc from brass alloys) in many environments. This group has low sensitivity to dezincification, moderate strength, high atmospheric and aqueous corrosion resistance and excellent electrical conductivity. They possess good hot forgeability and good cold formability. These alloys are found used for marine hardware like for ships inlets for seawater, in heat exchangers and condenser tubes, baffles, valve stems, screw machine parts, pump shafts and corrosion-resistant mechanical products.

Naval brass and admiralty brass have only fair weldability (40% and 30% Zinc) but is with sufficient consideration weldable using the TIG or MIG welding process. Welding using the manual metal arc (MMA) process is not recommended for naval/admiralty brass or any other high zinc-bearing copper alloy. The shielding gas used for TIG and MIG welding will vary according to whether welding thin or thick sections. Argon is generally used if the section is less than 3mm thick, however, when welding thick sections, a mixture of 75% helium with 25% argon may be used. Components thicker than 10mm (25/64") are not normally TIG welded - unless MIG welding methods are unavailable/inappropriate. MIG can be used for welding brasses over 3mm (1/8") thick.

MIG welding should be performed in the flat position with spray transfer conditions, however, some acceptable fillet welds may be produced in the horizontal position. Filler metals for MIG or TIG welding brasses should not contain zinc. This is as previously mentioned because the zinc tends to vaporise in the arc, leading to zinc loss and porosity in the weld.

Leaded red brass C83600**,** also referred to as **Gun Metal** is considered both a brass (5%Zn) and a bronze (5%Sn). Gun metal contains 5% zinc, 5% tin, 5% lead and 85% copper. Lead is added to improve castability and machinability. Zinc improves its fluidity. Originally used for making guns (88% copper, 8-10% tin, 2-4% Zn). The alloy is used for pump and valve housing, impellers bearing bushes, glands, and boiler fittings, etc.

Muntz metal C28000 is a form of alpha-beta brass with about 60% copper, 40% zinc and a trace of iron. Out of interest regarding its name: It is named after George Fredrick Muntz, a metal-roller of Birmingham, England, who commercialised the alloy following his patent of 1832. This alloy is stronger, harder and more ductile than normal brass. While hot working between 700°C to 750°C (1290°F to 1380°F), it does not respond to cold working. Applications: Industrial applications include baffles and tube sheets for condensers and heat exchangers. Also, a wide variety of small components of machines, bolts, rods, tubes, electrical equipment as well as ordnance works. It is widely employed in producing such articles which are required to resist wear.

Cartridge brass. C26000, also known as yellow brass and 70/30 brass, is copper alloyed with zinc. Cartridge Brass has a warm yellow tone and is most commonly found in tube, sheet and plate form. The alloy is commonly called cartridge brass because it has traditionally been used for ammunition cartridges and shells. Cartridge Brass, also known as Spinning Brass, is capable of undergoing severe forming and drawing. Cartridge brass has a wide range of uses, including fasteners, tubing for instruments and machines, heat exchangers, pump cylinders, fittings and ammunition cartridge cases. The welding processes recommended for Cartridge brass alloys include oxyacetylene welding, brazing/soldering, TIG and MIG welding. MMA welding is not recommended for these alloys.

Aluminium brass C68700 (Yorcalbro) Application areas: Condenser, evaporator and heat exchanger tubes. Also popular for seawater piping. Its gradually been replaced by copper nickel alloys (Cupronickel). Only TIG and MIG welding is recommended welding process.

Welding Brasses

With the exception of alloys containing lead (Pb), all brasses are weldable. Those with low zinc are the most easily welded. Low-zinc brasses, less than 20% zinc, have good weldability. Low-zinc brasses are shown to have good weldability using TIG welding. By comparison, high-zinc brasses, over 20%, have only fair weldability. Lastly, cast brasses are only marginally weldable. High leaded brasses are considered un-weldable. Preheating is not usually necessary, although preheats of up to 250°C (482°F) have been applied to thick-section material.

The main problem with welding the alloys is weld metal porosity caused by the zinc boiling off during melting. Zinc melts at 420°C (788°F) and boils at 910°C (1670°F) so brazing using an oxy-acetylene torch and a copper-silver filler is a possible alternative to welding, being capable of providing joints with adequate mechanical properties and without the porosity problems. Boiling the zinc may also result in large amounts of zinc oxide in the welding fume and this can be a health and safety issue. Brasses may be welded using MMA, MIG or TIG welding.

Filler metals are available although these are generally based on copper-silicon or copper-tin alloys due to the problems of transferring zinc across the welding arc. A typical MIG/TIG filler metal would be the 3% silicon alloy ERCuSi-A (Cu 6560). Successful welds can also be made using copper-tin alloys with 5%Sn, ECuSn-A/ ERCuSn-A (Cu5180) and Copper-tin alloys with 8%Sn, ECuSn-C/ ERCuSn-C. (Cu5210). These can be obtained as both MIG wires, TIG rods and as MMA electrodes. Preheat and interpass temperature 250°C to 350°C (480°F to 660°F).

Leaded red brass/Gun metal is not recommended to weld by MIG welding. Coated MMA Electrodes gives a fair result. Gun metal (low lead) recommended filler ECuSn-A (Cu 5180), ECuSi (Cu 6560), ECuAl-A2 (Cu 6180). NB. Leaded brasses are generally regarded un-weldable.

ERCuSn-A, ECuSn-A (Cu5180) and ECuSn-C (Cu5210) give good colour match with many brasses. This can be of importance in some repair cases. Silicon bronze filler metals ERCuSi-A and ECuSi (Cu6560) feature lower thermal conductivity and can therefore be used with lower preheating temperature and have better fluidity. Aluminium bronze filler metals ERCuAl-A2 and ECuAl-A2 (Cu6180) provide good joint strength for high zinc brasses. In TIG and MIG welding argon will normally be used. The weldability of brasses with MMA is not as good as TIG and MIG. If MMA welding is to be performed it require larger welding groove angles in order to gain good penetration and avoid slag entrapment. Preheating depend on material thickness, welding process and zinc content. The preheating temperature can be lowered for high zinc brasses but will normally vary between 100°C to 350°C (212°F to 660°F).

Muntz metal and Cartridge brass is not recommended to weld by MMA welding. Preferred method is TIG or MIG welding using Silicon Bronze filler rod ERCuSi-A (Cu6560). TIG and MIG welding with silicon bronze is technically TIG /MIG brazing because the metal being welded/brazed has close to same melting point as the silicon bronze filler rod.

Aluminium brass (Yorcalbro) is not recommended to weld by MMA welding. Aluminium brass recommended filler metals for TIG welding ERCuAl-A2 (Cu6180). For MIG welding recommended filler ERCuAl-A1 (Cu6100). For further details go to TE Andersen consulting web site under Welding Library “Repair Welding of Sea water pipes”

Stress relieving temperature for weldments made in Red brass C23000: 230°C (550°F).
Stress relieving temperature for weldments made in Naval brass C46400 to C46700: 260°C (500°F).

9 Manganese Bronze

Composition:

Manganese bronze alloys can operate under very high loads and speeds. Besides excellent mechanical qualities, these alloys have good corrosion resistance.

Properties:

The standard alloy in this group is high tensile C86300, which is comprised of copper, manganese, aluminium and iron. It contains 60 to 66% copper, 22 to 28% zinc, 2 to 4% iron, 5 to 7,5% Aluminium with 2,5 to 5% manganese.

- This alloy is highly resistant to corrosion.
- It is stronger and harder than phosphor bronze. It has poor response to cold working but can be easily hot worked.

Applications and Welding:

Manganese Bronze – Cast: C86100 to C86800

Welding should be performed preferably using MMA coated electrodes. As can be noted below welding is only recommended for the alloys C86100, C86200 and C86300. Recommended filler ECuAl-A2 (Cu6180)

C86100 (Manganese bronze) Bearings, Bushings, Gears, Marine Castings, Marine Racing Propellers.

Welding: MMA Good, TIG/MIG Fair.

C86200 (Manganese bronze) Boat Parts, Brackets, Bushings, Cams, Clamps, Frames, Gears, Gun Mounts, High Strength Machine Parts, Hooks, Marine Castings, Marine Racing Propellers, Rudders, Screw Down Nuts, Shafts, Structural Parts, Struts, Valve Stems, Worm Gears.

Welding: MMA Good, TIG/MIG Fair.

C86300 (High strength manganese bronze) Boat Parts, Brackets, Bridge Pins, Bushings, Cams, Clamps, Covers for Marine Hardware, Electrical Components, Frames, Gears, Gib, High Strength Machine Parts, Hooks, Hydraulic Cylinder Parts, Large Valve Stems, Marine Hardware, Propellers, Rudders, Screw Down Nuts, Heavy Load Bearings, Struts, Switches.

Welding: MMA Good, TIG/MIG Not recommended.

C86400 (Leaded manganese bronze) Bearing Cage Blanks, Bearings, Boat Parts, Brackets, Bushings, Cams, Covers for Marine Hardware, Electrical Components, Electrical Equipment, Fittings, Fixtures, Lever Arms, Light Duty Gears, Machinery Parts, Marine Fittings, Propellers, Pump Fixtures, Roller Bearings, Screw Down Nuts, Switches, Valve, Stems.

Welding: MMA Not recommended, TIG/MIG Not recommended.

C86500 (Manganese bronze) Boat Parts, Brackets, Clamps, Compressors, Covers for Marine Hardware, Frames, Gears, Hooks, Lever Arms, Machinery, Machinery Parts, Machinery Parts requiring High Strength, Ships Propellers for salt and fresh water, Rudders, Struts,

C86700 (Leaded manganese bronze) Bearings, Brackets, Cams, Fittings, Lever Arms, Machinery Parts, Marine Hardware, Moderate Duty Gears, Ships Propellers, Screw Down Nuts, Valve Stems.

Welding: MMA Not recommended, TIG/MIG Not recommended.

C86800 (Nickel manganese bronze) Ships Propellers, Fittings.

Welding: MMA Not recommended, TIG/MIG Not recommended.

If welded: Stress relieving may be required to minimize stress corrosion cracking.

10 **Nickel-Silver (Copper-nickel-zinc alloys)**

Composition:

Nickel is added to copper-zinc alloys to make them silvery in appearance for decorative purposes and to increase their strength and corrosion resistance. Nickel-silver is sometime referred to as German silver.

Properties:

The C75200 Nickel-silver “65-18” alloy contain 63 to 66,5% copper,0,25% Iron, 0,05% lead, 0,5% nickel, reminding is zinc.

- Nickel Silver have excellent mechanical properties, generally have high thermal and electrical conductivity, and resistant to corrosion.
- Nickel Silver can be wrought, rolled and machined. The properties of nickel silver alloys include silvery-white in colour, hard, malleable, ductile and nonmagnetic.

Applications:

- Its electrical resistance makes nickel silver ideal for heating coils, while its corrosion resistance is well-suited for marine fittings and plumbing fixtures. Some other applications include jewellery, musical instrument components, screws and side fasteners.

Welding:

Nickel silver– Wrought: C73150 to C79900 | Cast: C97300 to C97800

Preferred method for joining nickel- silver is brazing / soldering. Brazing rod RBCuZn-D (C77300). Nickel silver rods is also available pre-flux coated with the correct amount of flux. No dipping or preparatory work is necessary. Preheating may be desired for some applications. Welding can be performed using TIG welding. Like brass, the weld quality decreases if lead is present. Unleaded nickel silver alloys are considered suitable to weld. Leaded nickel silver alloys are not. Also similar to brasses, alloys with lower zinc content have better weldability. These low-zinc nickel silver alloys are readily weldable with ERCuNiAl (Cu 6328) and ERCuSi-A (Cu 6560) filler metals.

Welding processes

Copper and most copper alloys can be joined by arc welding. Welding processes like Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) that use gas shielding are generally preferred, although Manual Metal Arc Welding (MMA) can be used for many noncritical repair applications.

Argon, helium, or mixtures of the two are used as shielding gases for TIG and MIG welding. Generally, argon is used when welding material is less than 3 mm (1/8") thick, has low thermal conductivity, or both. Helium or a mixture of 75% helium and 25% argon is recommended for welding of thicker sections of alloys that have high thermal conductivity. Unfortunately, Argon-Helium mix shielding gas is not easily available from the bigger ship suppliers so very often repairs onboard will have to be performed with Argon as shielding gas.

TIG Welding is well suited for copper and copper alloys because of its intense arc, which produces an extremely high temperature at the joint and a narrow heat-affected zone (HAZ).

In welding copper and the more thermally conductive copper alloys, the intensity of the arc is important in completing fusion with minimum heating of the surrounding, highly conductive base metal. A narrow HAZ is particularly desirable in the welding of copper alloys that have been precipitation hardened. MIG welding is preferred for section thickness above 3 mm (1/8") and for the joining of aluminium bronzes, silicon bronzes and copper-nickel alloys.

MMA welding can be used to weld a wide range of thickness of copper alloys. Covered electrodes for welding of copper alloys are available in standard sizes ranging from 2.4mm (3/32") to 5.0mm (3/16").

Recommended welding parameters

MMA welding DC+ polarity (DCRP*)

Electrode diameter	Amperage
2,4mm (3/32")	50-110
3,2mm (1/8")	90-160
4,0mm (5/32")	130-180
5,0mm (3/16")	150-225

* Direct current revers polarity

TIG welding DC- polarity (DCSP*) or AC HF**

Rod diameter	Amperage 1	Amperage 2
1,6mm (1/16")	70-120	70-150
2,4mm (3/32")	120-160	140-230
3,0mm (1/8")	170-230	225-320
4,0mm (5/32")	220-280	175-300
5,0mm (3/16")	280-330	200-320

Amperage 1= For iron- or nickel based alloys Amperage 2= For copper and copper alloys

* Direct current straight polarity

** Alternating Current with High Frequency.

Tungsten electrodes preferably with 2% Cerium or 2% Lanthanum. Avoid use of Thoriated electrodes.

MIG welding DC+ polarity (DCRP*)

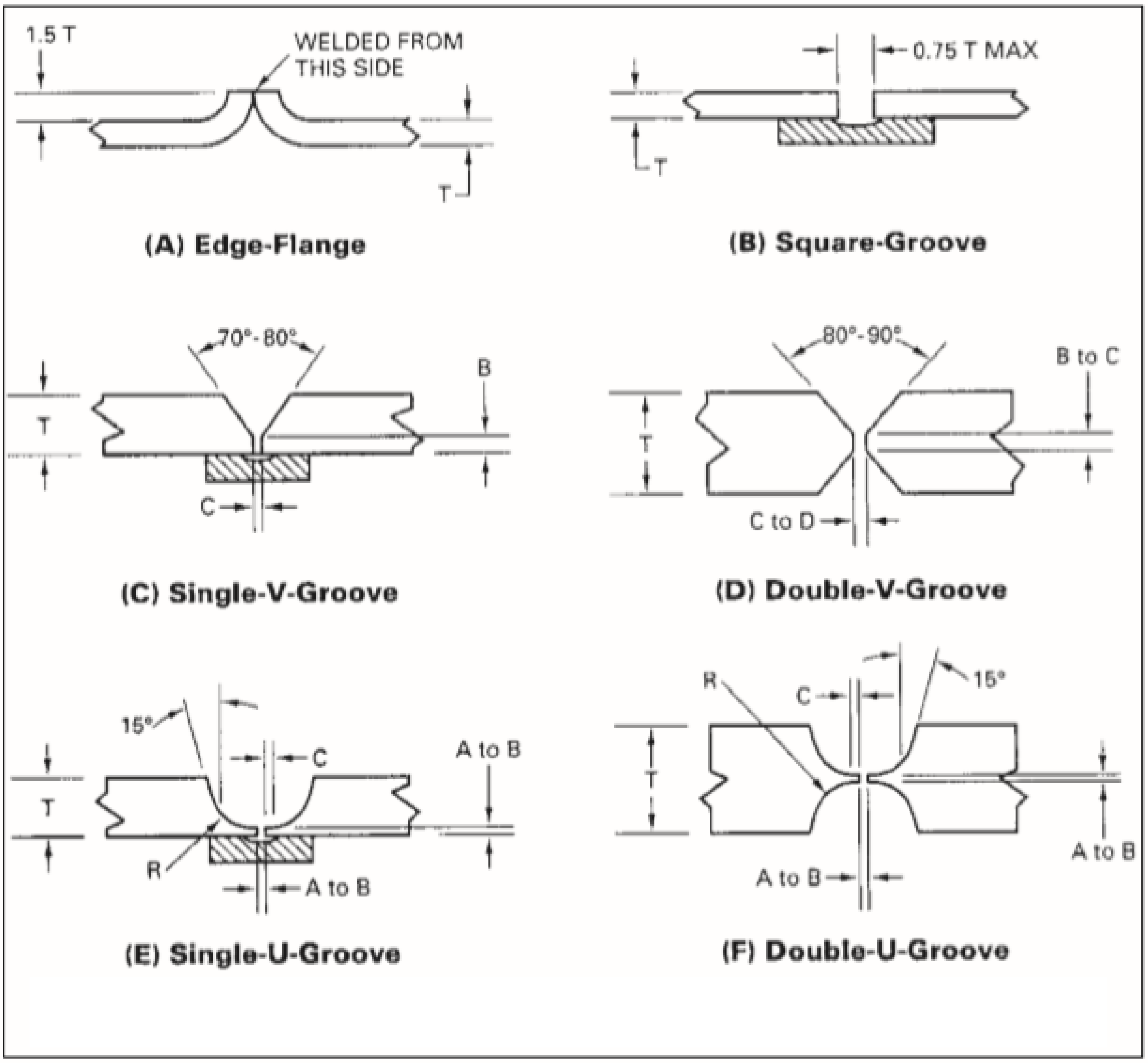
Wire diameter	Voltage	Amperage
0,9mm (.035")	20-26	100-200
1,0mm (.045")	22-28	100-250
1,6mm (1/6")	29-32	250-400
2,4mm (3/32")	32-34	350-500

* Direct current revers polarity

Welding joint preparation

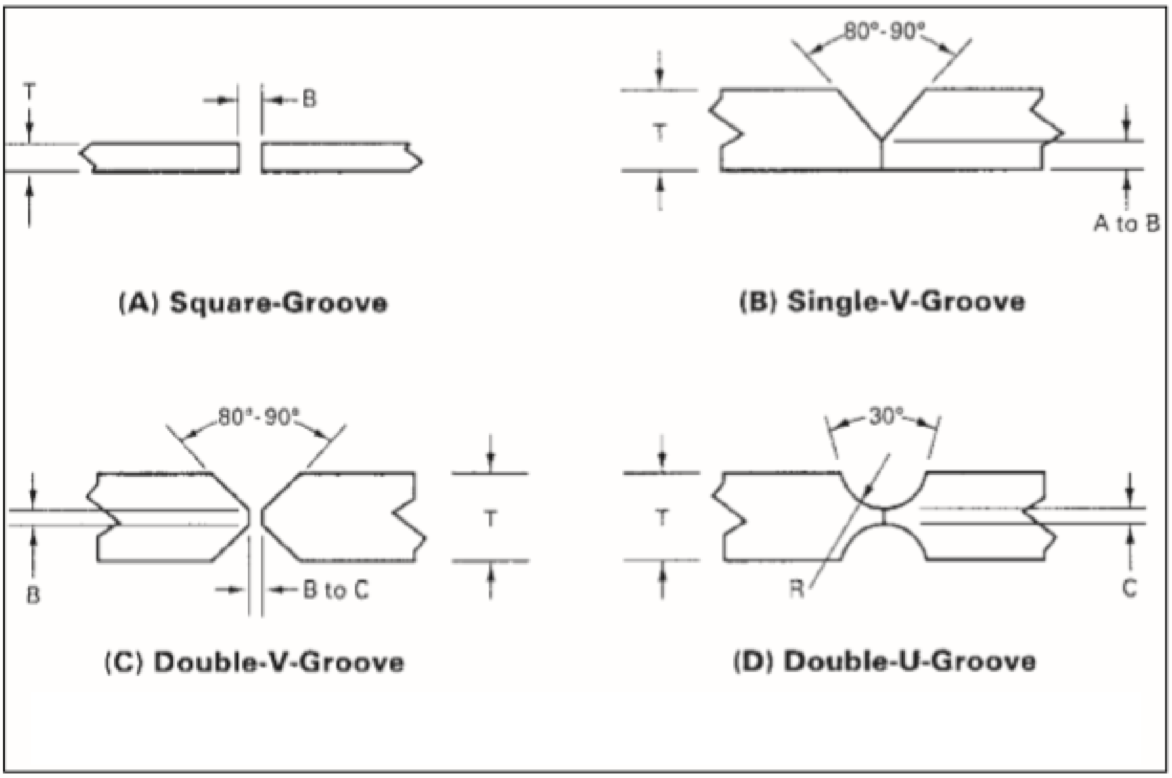
Recommended welding joint preparation for copper and copper alloys are shown in below figure, which are appropriate for MMA, TIG and MIG welding. These joint designs have larger groove angles than those used for steel. The larger groove angles are required provide adequate fusion and penetration for copper and copper alloys that have higher thermal (heat)conductivity. Welding joint surfaces and adjacent surfaces must be cleaned and made free from oil, grise, dirt, paint and oxides prior to welding.

Joint preparation for MMA and TIG welding:



Note: A= 1,6mm (1/16”), B= 2,4mm (3/32”), C=3,2mm (1/8”), D=4,0mm, R=3,2mm (1/8”), T= Thickness

Joint preparation for MIG welding:



Note: A= 1,6mm (1/16"), B= 2,4mm (3/32"), C=3,2mm (1/8"), R=6,4mm (1/4"), T= Thickness

Edge preparation can be done by grinding, plasma gouging or air carbon arc gouging.

Copper alloys used in marine applications

To identify the different copper alloys apart can be close to impossible without having access to the item's technical specification. Most vessels will have documentation giving information towards what the individual items onboard are made from. For some parts the documentation even informs towards welding procedures including recommending type of consumable. Therefore, always start checking out the available documentation onboard first of all. The below list might be to some help.

Wrought

Copper alloy	Number	Application
DHP copper*	C1220	Hull sheathing. piping
PDO copper**	C14200	Hull sheathing. piping
Beryllium copper (High alloy copper)	C17000	Repeater housings
Cartridge or 70 :30 brass	C26000	Hardware components
Muntz metal	C28000	Tube sheets
Admiralty, arsenical	C44300	Heat exchanger tubing
Naval brass, arsenical	C46500	Tube sheets
Phosphor bronze	C51000	Bolting, boat shafting. marine wire rope. naval ordnance
Phosphor bronze	C52400	Naval ordnance, bearings, gears
Aluminium bronze	C61400 C61300	Sleeve bearings, and water boxes
Nickel Aluminium bronze	C63000 C63200	Pump shafts, valve stems,
Silicon bronze	C65500	Bolting, boilers, tanks

Copper alloy	Number	Application
Aluminium brass	C68700	Condenser and heat exchanger tubing
Copper-nickel	C70600	Condenser and heat exchanger tubing. piping and water boxes-shipboard. power, industrial and desalination plants. waterflood and offshore oil
Copper-nickel (Cupronickel)	C71500	Condenser and heat exchanger tubing, Seawater piping and water boxes-shipboard. Power industrial and desalination plants, waterflood and offshore oil
Copper-nickel (Cupronickel)	C72200	Condenser and heat exchanger tubing

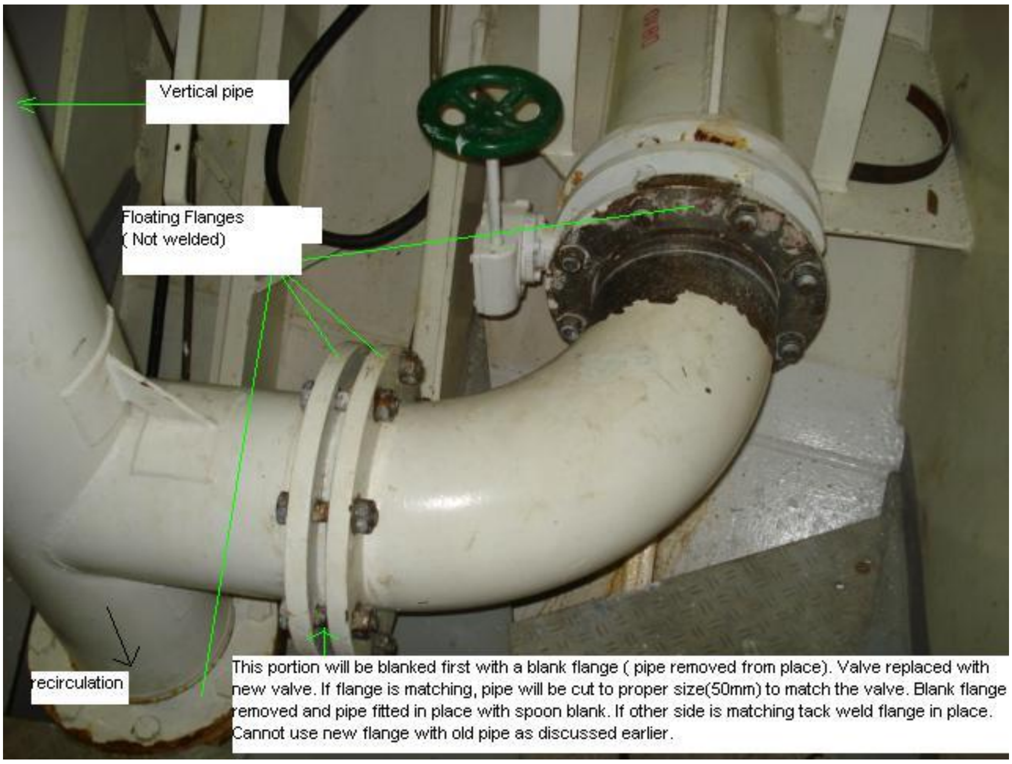
*DHP Deoxidized High Phosphorus copper. Commercially pure copper, which has been deoxidized with phosphorus, leaving relatively high residual phosphorus content. Copper alloy 1220 is not susceptible to hydrogen embrittlement, but is relatively low electrical conductivity due to the amount of phosphor
**PDO Phosphorus Deoxidized copper.

Cast alloys

Copper alloy	Number	Application
Leaded red brass/ Gun metal/ Ounze metal	C83600	Plumbing fittings, Pump and valve housings, Impellers, glands and boiler fittings
Manganese bronze	C86500	Ship propellers
G Bronze*	C90300	Pumps. valves, naval ordnance. Tail shaft sleeves
M bronze**	C92200	Pumps, valves
Aluminium bronze	C95200	Waterflood and seawater pumps
Nickel Aluminium bronze	C95500	Propellers
Manganese Nickel Aluminium bronze	C95700	Propellers

Copper alloy	Number	Application
Nickel Aluminium bronze	C95800	Pump, valves and fittings. Ship propellers.
Copper-nickel (80:20) Cupronickel	C96300	Tail shaft sleeves for ships
Copper-nickel (70:30) Cupronickel	C96400	Pumps. valves, fittings

*"G" bronze (C90300) is a casted copper alloy listed under Phosphor bronze but its chemical composition is 88% Copper, 8% tin and 4% zinc so often referred to as a Gun metal.
** "M" bronze (92200) is in a group of casted leaded tin bronzes (C92200 to C92900) also referred to as Navy "M" bronze, steam bronze. The alloy is specified for corrosion resistant valve fittings and other pressure retaining products. The C92200 alloy can be used for pressure retaining parts at temperatures up to 290°C (550°F)



Repair welding of Cunifer 10 pipes onboard