# Repair Welding of Seawater pipes

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BACKGROUND

Seawater pipe systems are used onboard vessels primarily for cooling purposes but also for firefighting and applications such as cargo hold cleaning.

Seawater, although corrosive, does not normally cause rapid catastrophic failures. For example, carbon steel immersed in seawater corrodes at about 0.1 mm/year (0,004"/year); whereas in diluted acid, it corrodes at 100 times that rate. Velocity is the most important single factor influencing design and corrosion in seawater systems. The seawater temperature will further accelerate the corrosion rate.

Essentially two types of system are found:

1) Low initial cost system is largely based on carbon steel and cast iron and require considerable maintenance. Corrosion of carbon steel in seawater is controlled by the availability of oxygen to the metal surface. Thus, under static conditions, carbon steel corrodes at between 0.1 and 0.2 mm/year (0,004"and 0,008"/ year), reflecting the oxygen level and temperature variations in different locations. Pitting corrosion will also occur. As velocity causes a mass flow of oxygen to the surface, corrosion is very dependent on flow rate and can increase by a factor of 100 in moving from static (zero velocity) to high velocity (40 m (131 ft) /second) conditions. The use of cement or organic coatings inside the piping will improve performance. Organic pipe linings are normally chloroprene or soft natural rubber. Repair by welding will of course be hampered by such linings and largely destroy them.

2) Seawater pipe system based on alloy materials which, if correctly designed and fabricated, will require less maintenance. The copper base alloys are velocity limited as impingement attack occurs when the hydrodynamic effect caused by seawater flow cross the surface of such alloys exceeds the value at which protective films are removed and erosion-corrosion occurs. Thus, these alloys, if they are to exhibit high corrosion resistance must be used at design velocities below this limiting value.

Stainless steels are not subject to impingement attack, but are prone to pitting and crevice corrosion under low velocity conditions. Stainless steel piping is not a preferred solution for seawater pipe applications.

Nickel base alloys such as Inconel Alloy 625, Hastelloy's C-276 and C-22 and titanium are not subject to pitting or crevice corrosion in low velocity seawater, nor do they suffer impingement attack at high velocity. However, price limits their use to special applications in seawater systems.

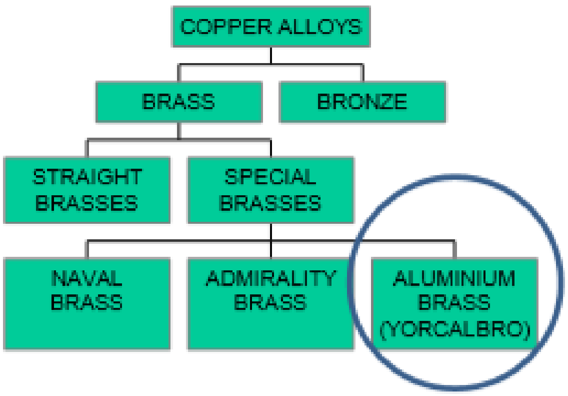
Two copper-base alloys have been widely used for seawater handling, namely aluminium brass (Yorkalbro) and 90-10 Cu-Ni although in recent years, particularly for large diameter piping there has been a strong trend towards 90-10 Cu-Ni.

In the following, we will look more closely at repair welding methods for the copper alloys.

COPPER ALLOYS FOR USE IN SEAWATER PIPING

Copper –zinc and copper –nickel alloys where developed specifically for seawater service more than five decades ago, initially for condensers and piping systems. The alloys in most frequent use have been Aluminium Brass also known as Yorkalbro, 90-10 Copper-Nickel also known as Cunifer 10, and 70-30 Copper- Nickel also known as Cunifer 30 or Cupronickel. These alloys have inherent resistance to macro fouling. This property has been advantageous in avoiding or reducing the necessity for biocide dosing in condensers and seawater systems and in reducing drag forces. Copper alloys containing in excess of about 70% copper give raise to the formation of an adherent cuprous oxide corrosion product, which is toxic to marine organism. Copper ions kill microorganism thus the bore of seawater pipes remain relatively smooth and free from marine growths.

ALUMINIUM BRASS/ YORKALBRO




This alloy used to be manufactured by Yorkshire Imperial Metals and later taken on by Yorkshire Alloys Ltd. Both these companies have ceased to trade. The composition is similar to today's CEN CW702R.

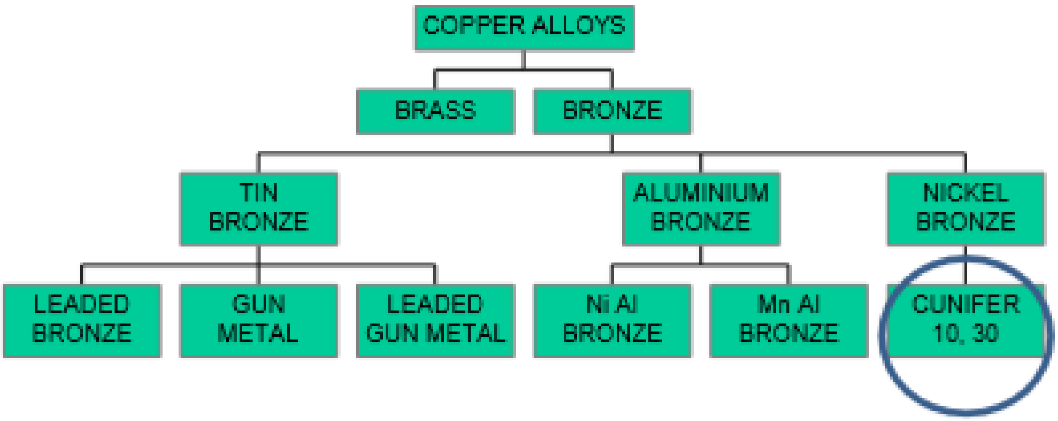
| Standards | UNS No | ISO | CEN | BSI |
|---|---|---|---|---|
| Designation | C68700 | CuZn20Al2As | CW702R | CZ110 |

Aluminium brass was used widely for seawater system in ships, generally with few problems except when it was inadequately stress relived leading to stress corrosion cracking in some cases. The alloy is more durable than copper pipes and allows higher flow rate. A flow rate of up to 2,5m/second (8,2ft/second) is permitted in aluminium brass pipes compared to 0,75m/second (2,5 ft/second) in copper pipes. A small addition of arsenic (As) of 0,02 to 0,06% is added in order to poison marine growth and prevent build up inside the pipes. The aluminium (Al) further help creating a tuff oxide, preventing corrosion.

| Chemical composition | Cu | Zn | Al | As |
|---|---|---|---|---|
| % | 76- 79 | Rem. | 1,8- 2,3 | 0,02- 0,06 |

The Aluminium brass has been losing in importance to Copper- Nickel alloys due to relatively poor resistance to stress corrosion cracking and the fact that it is not without problems with regards to fabrication and welding.

COPPER –NICKEL ALLOYS (Cupronickel)




There are two main copper-nickel alloy grades used in the marine service, which are generally available in most product forms.

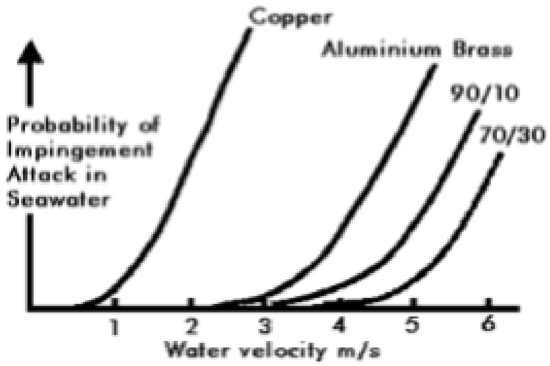
| Standards | UNS No | ISO | CEN | BSI |
|---|---|---|---|---|
| 90/10 CUNIFER 10 | C70600 | CuNi10Fe1Mn | CW352H | CN102 |
| 70/30 CUNIFER 30 | C71500 | CuNi30Fe1Mn | CW354H | CN107 |

These are copper base alloys with either 10% or 30% nickel, and are described as 90-10 and 70-30 copper-nickel respectively. Both alloys contain small but important additions of iron and manganese, which have been chosen to provide the best combination of resistance to flowing seawater and overall corrosion resistance. The 30% nickel alloy is stronger and can withstand higher seawater velocities.

| Chemical composition | Cu | Ni | Fe | Mn |
|---|---|---|---|---|
| 90/ 10 CUNIFER 10 | Rem | 9 -11 | 1-2 | 0.5-1 |
| 70/30 CUNIFER 30 | Rem | 29-33 | 0.4-1 | 0.5-1.5 |

WATER VELOCITY

The below is the relationship between water velocity and probability of impingement attack in seawater for copper, aluminium-brass, 90-10 Cu-Ni, and 70-30 Cu-Ni.




| | |
|---|---|
| Copper | 0.75 m/s (2,5 ft/s) |
| Aluminium brass | 2.5 m/s (8,2 ft/s) |
| 90-10 Cu-Ni | 3.0 m/s (9,8 ft/s) |
| 70-30 Cu-Ni | 3.5 m/s (11,5 ft/s) |

The real choice is between 90-10 Cu-Ni and aluminium brass. Both materials are technically suitable, provided the system is designed to the water velocities given above and both have been successfully used in many seawater systems. However, the current trend is towards the use of 9010 Cu-Ni, the reasons for this being:

1) It has better weldability. Although aluminium brass can be welded using TIG welding and suitable filler materials, this is a relatively difficult procedure.

2) It has high stress corrosion resistance. 90-10 Cu-Ni does not normally require any stress relief heat treatment after welding. Aluminium brass requires stress relief to avoid the possibility of stress corrosion cracking to which it is susceptible in seawater.

3) It has a good track record. Remarkable result considering the large tonnage of the alloy in use throughout the world. Only limited number of failures involved excessive turbulence, suggesting current design velocities may be conservative.

Most of the world's Navies have standardized on 90-10 Cu-Ni for piping in surface vessels, thus ensuring worldwide availability of facilities for fabrication of the alloy. The use of 70-30 Cu-Ni is confined to submarines where its high strength is advantageous.

INDENTIFYING THE ALLOYS APPART

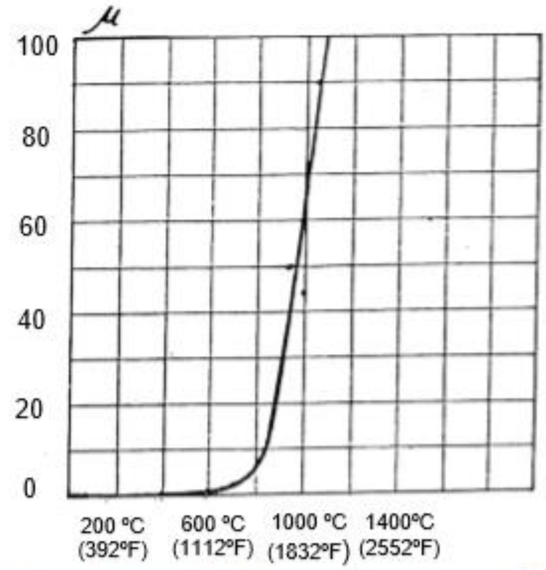
Use a file: Cunifer: The high content of Nickel relives a silvery appearance. The small amount of iron makes it slightly magnetic. Aluminium brass:  Will have a yellowish copper colour because of the zinc content and is non-magnetic.


Cu-Ni

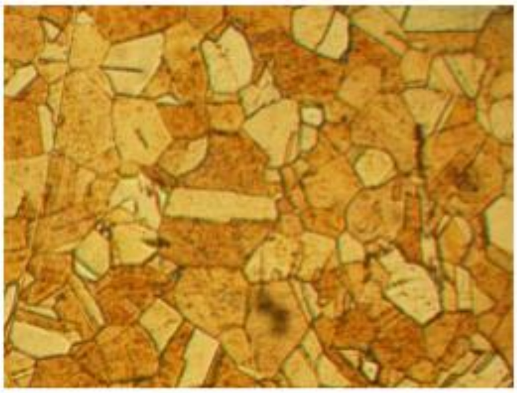

Aluminium brass

THE PROBLEM WITH COPPER ALLOYS

Metals consist of grains. The size of the grains can be measured in µ. 1µ is 1/1000 of a millimetre. When heated above 600 ºC (1112 ºF) the copper grains start to grow and can reach sizes that makes the pipe walls close to porous. This is why Silver brazing (capillary brazing) is one alternative for repair. Silver brazing takes place at around 600- 700 ºC (1112- 1292ºF).




The grain size in copper alloys depending on temperature. 1µ = 1/ 1000mm



Copper grains 400 X magnification

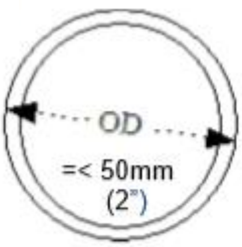
WELD REPAIR ALTERNATIVES

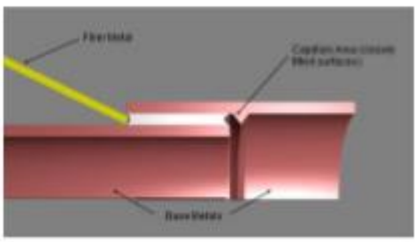
Aluminium brass and 90-10 Cu-Ni pipes have thin pipe walls. Electrode/ Stick welding is therefore normally not an alternative because of heat input and the danger of burn through. Best methods will be either silver brazing or TIG welding. The preferred method depends on pipe diameter/mass of metal.

Aluminium brass and 90-10 Cu-Ni are essentially copper alloys and good conductors of heat. It can therefor take long time to heat up a big size pipe to the required bonding temperature of a silver brazing alloy.

Silver brazing

Use silver brazing if pipe diameter is equal to or less than Outer Diameter (OD) 50 mm (2") and if the joint itself is a capillary joint.



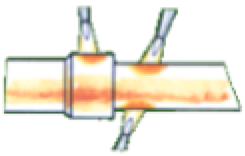



For silver brazing to be successful one depends on the capillary process that allows thin floating alloys to flow into the joint between two metal parts. When brazing seawater pipes like aluminium brass and 90-10 Cu-Ni pipes always use Silver brazing alloys with more than 50% silver. If less, the seawater will corrode the alloy away very quickly. Manufacturers of Cu-Ni pipes recommend from 50-60 % silver used in brazing rods.

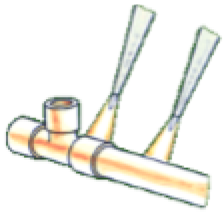
Remove inside and outside burr.

Clean surface with wire wool.

Paint flux onto the surfaces before joining the parts.



Use a neutral flame. Heat evenly by moving the torch in continuous motion until the pre- placed flux melts.



Melt off a droplet of the rod in the joint and spread it out moving the flame continuously.

Emery and sand paper should not be used for cleaning as they cause silica particles to become embedded in the surface which will prevent the brazing wetting. To pre paint flux on the parts to be joined is important even if one use a flux coated rod. Pre painting the flux will take care of the oxides as they start to form inside the joint during the heating process.

**Silver brazing consumables with more than 50% Ag**

| Supplier/ Manufacturer | Product | Chemical composition | Melting range | Classification | Special note | Characteristics |
|---|---|---|---|---|---|---|
| Fontargen | AF 314 XL BF | Ag 55%<br>Sn 2%<br>Zn 22%<br>Si 0,1%<br>Cu Rest | 630 - 660°C (1166 - 1220°F) | EN ISO 17672: Ag 155Si<br>EN 1044: Ag 103<br>DIN 8513: L-Ag55Sn | **Flux coated rod No boric acid or borax** | Cadmium free, seawater resistant, high strength silver rods for joining all types of steel, stainless steel, copper, copper alloys, nickel, nickel alloys, cast iron, Yorkalbro pipes (aluminiumbrass), cunifer pipes type 90/10 and 70/30.<br><br>Additional flux:<br><br>Fontargen: F300 H Ultra NT. No boric acid or borax<br><br>Saldflux: F25 No boric acid or borax<br><br>Lucas Milhaupt: Handy flux. H361. **Boric acid and/or borax**<br><br>Castolin Eutectic: FP38976 Paste (1802Atmosin Powder) No boric acid or borax<br><br>Drew Marine: SF Flux Boric acid/borax: No info<br><br>Wilhelmsen Ships Service: AG-60/45 Flux 252 PF flux<br>Boric acid/borax: No info<br>On York Albro: Albro Flux 263 PF<br>Boric acid/borax: No info |
| Saldflux | Saldflow 56 | Ag 56%<br>Cu 27%<br>Sn 5%<br>Zn Rest | 620-655°C (1148 - 1211°F) | ISO 17672<br>AG 156<br>EN 1045<br>Fh 10 | Flux coated rod.<br>Boric acid/ borax: No info | |
| Lucas Milhaupt | Silvaloy 560 flux coated | Ag 56%<br>Cu 22%<br>Sn 5%<br>Zn Rest | 618-652°C (1144 - 1206°F) | AWS BAg-7 | Flux coated rod. H361. **Boric acid and/or borax** | |
| Castolin Eutectic | 38256N XF (1020 XFC) | Ag 57%<br>Cu 21%<br>Sn 2%<br>Zn Rest | 625-665°C (1157 - 1229°F) | ISO/FDIS 17672<br>AG 156<br>No boric acid or borax | **Flux coated rod No boric acid or borax** | |
| Drew Marine | SL 60 | Ag 56%<br>Cu 22%<br>Sn 5%<br>Zn Rest | 620-650°C (1148 - 1202°F) | DIN EN ISO 3677<br>B-Ag55ZnCuSn-620/650 | Flux coated rod. Boric acid/borax: No info | |
| Wilhelmsen Ships Service | AG 60 252 | Ag 55%<br>Cu 21%<br>Sn 2,5%<br>Zn Rest | 630 - 660°C (1166 - 1220°F) | DIN EN ISO 3677<br>B-Ag55ZnCuSn-620/660 | Flux coated rod. Boric acid/borax: No info | |

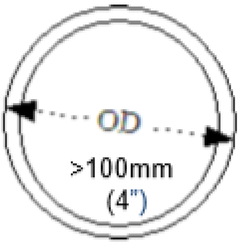
Ag: Silver, Cu: Copper, Sn: Tinn, Zn: Zink Si: Silicon

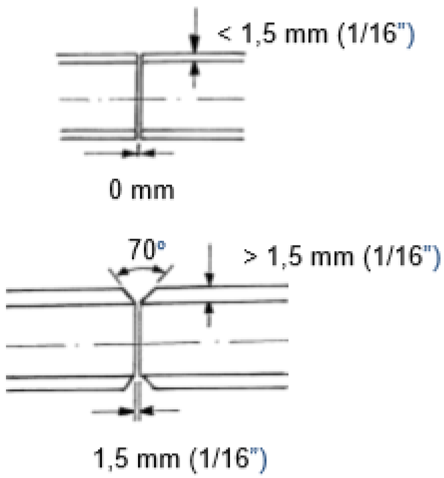
Wilhelmsen Ships Service: UNITOR AG-60 252 When used on Cu-Ni pipes use together with: AG 60/45 Flux 252 PF. When used on aluminium brass pipes use together with: ALBRO FLUX 263 PF The reason for using a special flux for aluminium brass is the aluminium in the alloy require a flux to match the tough aluminium oxides.


Tungsten Inert Gas (TIG) welding is a welding process that consist of a welding power source with a special TIG torch where a non-melting tungsten electrode create a high temperature arc towards the work surface. If a direct current (DC) power source the torch must be connected to - polarity. The process makes use of an inert gas Argon that protect the weld zone toward oxidation during welding. The TIG welding process have similar welding technique as used in Gas welding.

Use TIG welding if pipe diameter is equal to or bigger than Ø100mm (4”). TIG welding can be used with caution down to OD 50mm (2”). Remove inside and outside burr. Clean surface with wire wool. For aluminium brass paint flux onto the inside surfaces of the pipes. This will improve penetration. Weld in down hand position if possible. Tack weld pipes before welding.

For aluminium brass: If need to weld more than one run, the welding area must cool down to 150ºC (302ºF) before continuing (interpas temperature). Weld bead and area covering approx. 15 cm (6”) on either side of bead should be stress relived by annealing from 300 ºC (572ºF) to 400ºC (752ºF) for 30 to 40 min.




TIG welding consumables:
Aluminium brass (Yorkalbro) is not recommended to weld by MMA welding (Electrode stick welding). Aluminium brass recommended filler metals for TIG welding ERCuAl-A2 (Cu6180). For MIG welding recommended filler ERCuAl-A1 (Cu6100).

Aluminium brass: Wilhelmsen Ships Service UNITOR IALBRO 237 MF + IFLUX- 238 PF. The UNITOR IALBRO 237 MF (Mini Flux) is a flux-coated rod. The flux help reduce the aluminium oxide in the pipe material and improve welding conditions. The pre painted IFLUX-238 PF will perform the same on the inside of the pipe improving weld penetration.

Cu-Ni pipes: Wilhelmsen Ships Service: UNITOR ICUNI-30-239 or Drew Marine: AB Aluminium bronze. A consumable with 30% nickel is recommended by pipe manufacturers for the welding of the 90-10 and 70-30 Cu-Ni alloys. Because of the higher nickel content, the weld metal is stronger than the 90-10 Cu-Ni base metal.

UNITOR IALBRO 237 MF


UNITOR IFLUX- 238 PF

UNITOR ICUNI-30-239