



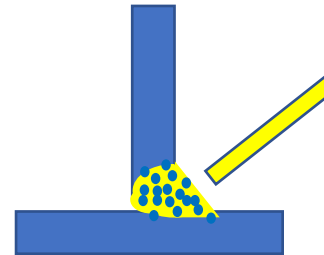
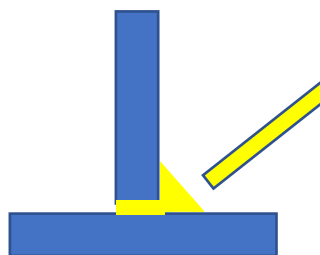
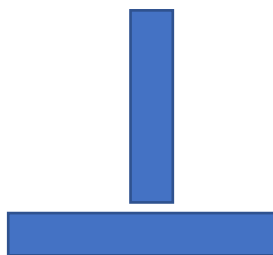
# Brazing & Soldering 06.12.19

By Leif Andersen, TE Andersen Consulting.

In the past cadmium brazing rods and lead-based solders have dominated the market, but this is set to change with the implementation of EC RoHS (Restriction on use of Hazardous Substances) and WEEE (Waste Electrical and Electronic Equipment) directives. The same goes for boric acid and borax in fluxes that have been re-classified and categorized as toxic to reproduction. Likewise have soft solder fluxes containing Rosin (colophony) come under scrutiny because of causing cases of industrial asthma. In the below information about brazing and soldering this will be further explained.

Brazing can be performed manually, mechanised or automated. In the below we will only be referring to manually performed brazing using an oxy acetylene torch/soldering iron in connection with repair work and prefabrication in the workshop onboard. TIG and MIG processes used for brazing is informed and explained in a separate article found in the Welding Library under "TIG & MIG Brazing for maintenance work onboard."

When doing brazing, the parent material is not melted as in welding but brought to the bonding temperature. The bonding temperature is when the brazing alloy melt and flow out and bind to the surface of the base material. The binding will to a large extent be a mechanical bonding (inter-atomic attraction) resulting in a permanent metallic bond. The metallic bond is characterized by a shallow interchange of atoms between filler and parent metals of approximately 0,4nm (nanometer). The nanometre is a unit of length in the metric system (1nm= 0.000001mm).



Brazing is to a large extent a mechanical bonding. The base material is not melted.

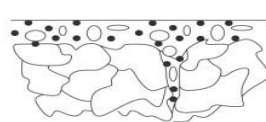
Welding is a chemical bonding where the base material is melted and mix with the consumable.



Crack filled with oxides



Crack and surface cleaned



Brazing alloy flows out on surface and down in crack and cervix



Result after brazing alloy have solidified

A clean surface with sufficient flux is necessary to make this happen. The key factors in determining the quality of a brazed joint are the method of brazing, the composition of the brazing filler metal and the flux. Joint surfaces must be carefully cleaned if the best bond quality is to be obtained. Oxides must also be reduced, and/or oxide formation during heating must be prevented. Brazing onboard a vessel will be carried out in air, which means that self-fluxing filler metals (copper-phosphorus) or a separate flux must be used.



## The Flux

The flux consists of a mixture of various metallic salts, and is applied to the joint surfaces as a paste or as a powder. Heating drives off the carrier (often water), before the salts melt and react with the oxides on the joint surfaces. The choice of flux depends on the type of workpiece material and the brazing temperature of the filler metal. Without the flux to suspend water vapor, grease and oxides, a film will prevent the brazing alloy from getting sufficient bonding. The function of the flux is therefore to dissolve impurities, detach them from the surface and the rod, and keep them in suspension. The flux liquefies approx. 100°C (212°F) before bonding temperature. Flux used to consist mostly of borax, also known as sodium borate, sodium tetra borate, or disodium tetra borate. It is a mineral, and a salt of boric acid. It can be in powder form consisting of soft crystals that dissolve easily in water or as a ready mixed liquid paste.



Regarding flux used in brazing processes: According to the European CLP regulation, toxic substances such as boric acid and borax have been re-classified and categorized as toxic to reproduction “can affect fertility and can damage the child in the mother ‘s womb”. Some flux manufacturers have therefore developed new types of flux, including flux coated or flux cored brazing rods that have no boric acid and borax products. Brazing product range containing no CMR properties (Carcinogen, Mutagen, Reprotoxic) are therefore in compliance to REACH. REACH is the European Community Regulation on chemicals and their safe use. It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances. The aim of REACH is to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances



### Borax ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ ):

Is able to melt metallic oxide except barium, aluminium, chrome and magnesium. Borax is only used for silver brazing or braze welding but boric acid or fluoride or chloride of other alkali metal is mixed for general use.

### Boric acid ( $\text{H}_3\text{BO}_3$ ):

In general, mixture of 70% of boric acid and 30% of borax is used and its melting point is 875°C.

### Borates:

Boric acid soda is used and the reaction is similar to borax.

Avoid contamination of the flux by always placing the cap back on the flux container after use. If a liquid flux has dried out it can be put right by adding distillate water.

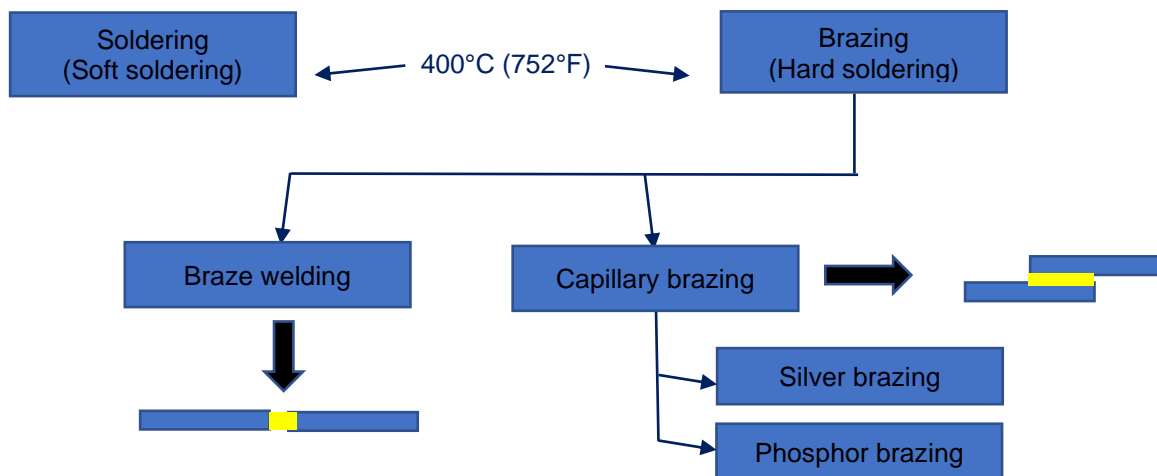


### Filler Metal (consumable)

For use as a filler material, a metal or alloy must have a lower melting point than the workpiece material, and must be able to wet the workpiece material. In addition, when molten, it must flow sufficiently to enable proper filling of the joint. The resulting alloy must provide the necessary mechanical and physical properties, while the filler metal must not be vaporised to any significant extent during the heating process, as this could result in poor fusion. It will for many applications be an advantage if the consumable is flux coated or flux cored. If the consumable is in the form of a bare rod the flux must be painted on to the rod.

### Type of Brazing

If the bonding temperature is below 400°C (752°F), we refer to the process as Soldering or Soft Soldering. If the bonding temperature is above 400°C (752°F) we refer to it as Brazing (In some literature also referred to as Hard Soldering). Brazing can again be divided into Capillary brazing and Braze Welding. Braze welding require joints similar to welding. The alloys used have a thick flowing viscosity and can bridge large gaps. Capillary brazing requires a joint consisting of two parallel surfaces forming a capillary joint (gap). The alloys used are thin flowing. Capillary brazing can further be divided into Silver Brazing and Phosphor Brazing.



Soft solders can also be used in capillary joints if the mechanical requirements towards tensile strength and working temperature are not setting limitations.

For your information:

The word solder comes from the Middle English word soudur, via Old French solduree and soulder, from the Latin solidare, meaning "to make solid".

The word Brazing comes from the Middle English word brasen "made of brass," from Old English bræsen, from bræs "brass." In fact, a near synonym of brazen is the English word brassy, which has the additional meaning of being loud and showy.

The word flux is derived from Latin fluxus meaning "flow".

The letter "æ" was used in the English language up to the 1400 and originate from Latin.



## Soft Solders

Soft Solders is commonly used in electronics, plumbing, and assembly of sheet metal parts. A soldering iron is the most common method to melt soft solder. Solder used for soft soldering is often found in the form of a wire that is wound on a spool. The wire sometimes has ducts filled with flux (flux cored). The most common solders used for soft soldering work are 60/40 or 50/50; these numbers are based on the percentages of tin (Sn) and lead (Pb) used to make the solder.



Lead is a heavy metal. Lead containing soft solders must never be used for applications in connection with food or drinking water. On July 1, 2006 the European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS\*) came into effect prohibiting the inclusion of significant quantities of lead in most consumer electronics produced in the EU. In the US, manufacturers may receive tax benefits by reducing the use of lead-based solder. Lead-free solder is today available and consist of a combination of metals with a high concentration of tin and smaller amounts of silver and copper. Also available are 95/5 that contain 95% tin and 5% antimony. Antimony in soft solders are not recommended in soldering of brass parts due to formation of brittle Sb-Zn intermetallic.



Soft solder on roll with or without ducts filled with flux (flux core)



Flux in separate tin

As heating source one can use a traditional soldering iron if the application is intricate electric wires and PCB's. A soldering iron will however not be a sufficient heating source if the application is for example a copper tubing assembly. If this is the case it will be better to use a propane/air or an acetylene/air torch with appropriate tip fitted. If only oxy-acetylene torch is available make sure to use a small size heating attachment and a neutral soft flame setting.

### \*RoHs

The Directive on the Restriction of the use of certain Hazardous substances in electrical and electronic equipment was adopted in February 2003 by the European Union. This directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment. It is closely linked with the Waste Electrical and Electronic Equipment Directive which sets collection, recycling and recovery targets for electrical goods and is part of a legislative initiative to solve the problem of huge amounts of toxic waste.



Propane/air torch



Soldering iron



There are three types of flux for soft soldering, Rosin type flux, Water soluble flux and No Clean fluxes. The water-soluble type is also referred to as organic acid type.

For electronic, the standard is to use rosin-core/rosin-flux when soldering.

Water-soluble organic acid fluxes is formulated for use in plumbing applications where copper and copper alloy tubes are being soldered. NB. The water-soluble organic acid type flux can damage the sensitive components on PCBs. Water-soluble fluxes have a high activity and require cleaning of the residues (with water) after soldering. Obviously therefore not so good for PCB's.

No Clean fluxes are "soft enough" not to "require" the removal of their residues due to their non-conductive and non-corrosive nature. These fluxes are called "NO CLEAN" because the residues left after the soldering operation is non-conductive and will not cause an electrical short circuit. Nevertheless, they leave a residue going from white to dark brown (depending on the soldering temperature) clearly visible.

Rosin (colophony) flux is made up primarily of rosin, which is extracted from the sap of pine trees, and contains the active ingredient abietic acid. There are three types of rosin flux — rosin (R) No activators, rosin mildly activated (RMA), and rosin activated (RA) — each of which have a different level of activators, the agents enabling the flux to deoxidize and clean.

World-wide cases of industrial asthma, related to rosin usage in soldering processes has been reported. Rosin free cored solder wire has been developed to help reduce the problem related to rosin usage. NB. Use rosin-free solders wherever possible. If you have to use rosin-based flux cored solder, use a combination of measures to reduce exposure like good general ventilation in the work area, temperature-controlled soldering irons, good worker posture and local exhaust ventilation. These preventive measures are easily achieved in a shore-based production facility but not onboard a ship. Therefore, make sure to change to rosin-free solders.

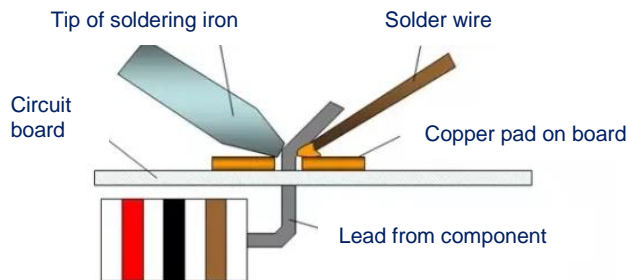
### **Soft Soldering using a soldering iron**

For electronic like PCB's use rosin-free solders wherever possible/available.

- 1) Be sure to wear safety glasses and protective gloves.
- 2) Work in a well-ventilated area because the fumes from the rosin type of flux can cause damage to your lungs if inhaled.
- 3) Never touch the element of the soldering iron. The temperature can be up to 400°C (752°F).
- 4) Always return the soldering iron to its stand when not in use. Never put it down on the workbench.
- 5) The soldering iron needs to be free of any old solder. A dirty tip means that you'll have to hold the iron on longer and risk heat damage to the PCB. Keep a wet sponge handy, and after the soldering iron is fully heated, softly scrape it against the sponge to remove old solder. The tip should be nice and shiny.



- 6) "Tin" the tip. This will protect the tip and allow heat to conduct better via the presence of new solder. On the hot iron, carefully apply a small amount of fresh solder and coat the tip. As soon as you tin the tip, start soldering the components together. After every few joins, clean and re-tin, and do the same before putting your iron away into storage.

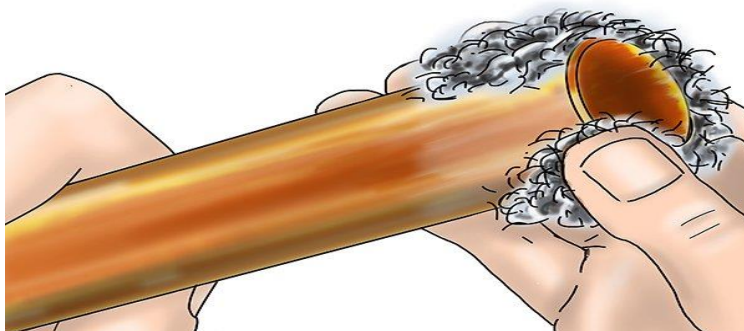


- 7) Hold the iron in your dominant hand and the solder in your other hand. When soldering two components together, you want to touch the area where they join with the soldering iron. Hold it there for about a second, then slide the solder underneath the tip of the iron, sandwiching it to the PCB. Hold it for another second or two, feeding in how much solder you need. Pull away the solder first, and continue holding the iron for another second. This allows the solder to continue to melt and pool, forming a good joint.
- 8) Then, remove the iron. The total process shouldn't take more than 5 seconds, and usually you're aiming for 3-4. Wait a few seconds and don't disturb the solder. It cools very quickly, but moving or blowing on the joint will cause it to deteriorate. A good connection should be smooth and uniform, and its sides will be concave.
- 9) Solder onboard can contain lead, so be sure to wash your hands thoroughly after handling solder brazing consumables.

### Soft Soldering using propane/air torch, acetylene/air torch, oxy-acetylene torch.

For plumbing use Water-soluble organic acid flux/ flux cored wire.

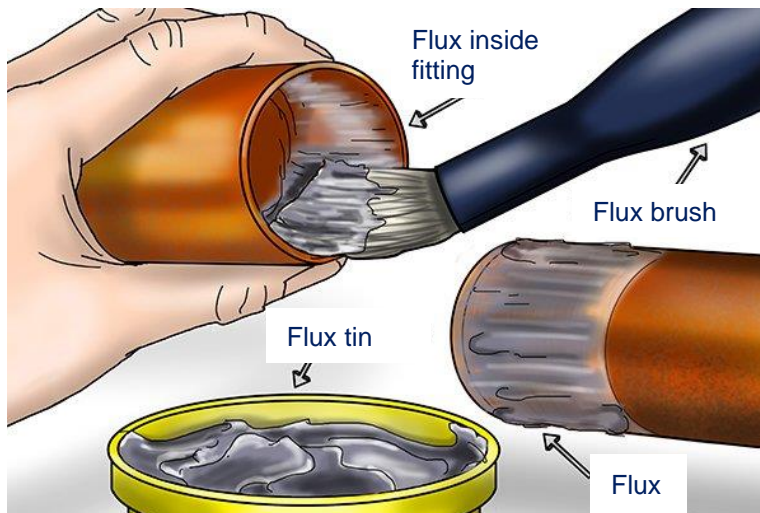
- 1) Wear safety glasses, protective gloves and make sure to work in a well-ventilated area.
- 2) Pre clean the area to be soldered with an abrasive such as wire wool. Emery and sand paper should not be used as they cause silica particles to become embedded in the surface which will prevent the soldering wetting.







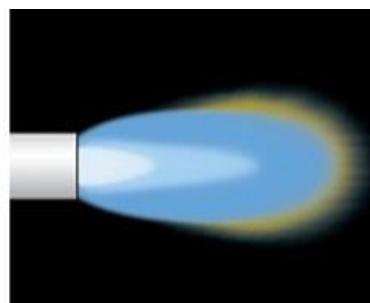
- 3) Make solder joints fit tight prior to soldering. Solder won't fill gaps, and it flows best over a smooth, well-fit joint. This is of special importance when soldering capillary joints.
- 4) If capillary assembly pre paint additional flux on the parts before assembly. Don't be stingy with the flux. Flux helps solder flow.



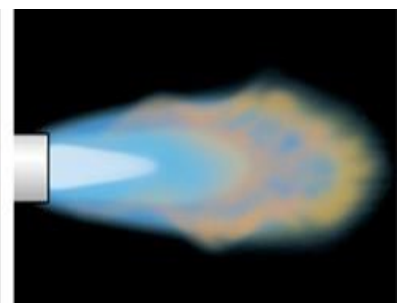
- 5) If a propane/air torch or an acetylene/air torch set the flame intensity according to the size of the soft solder assembly.
- 6) If an oxy- acetylene torch: There are three basic flame types: Oxidizing flame, with more oxygen than acetylene, Neutral flame, with an even mix of oxygen and acetylene and Carburising flame, with less oxygen than acetylene. Use a soft neutral flame that you can just barely hear.



Oxidizing flame



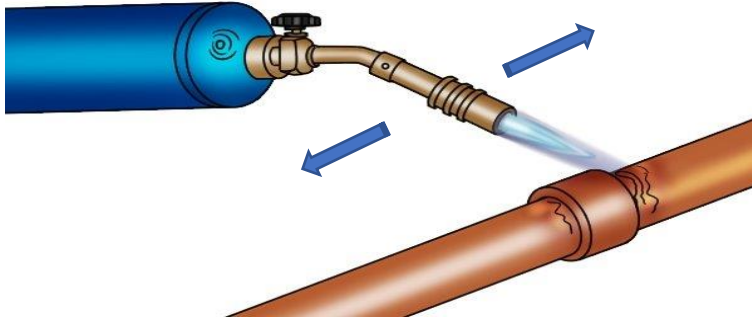
Neutral flame



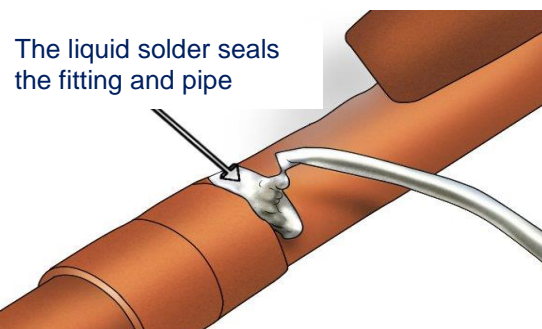
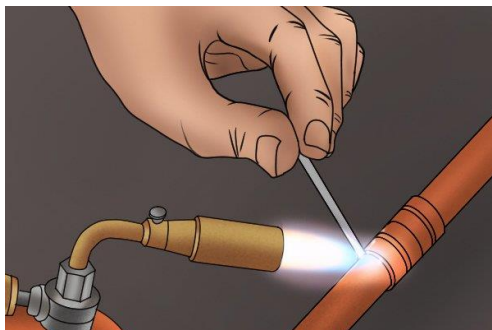
Carburising flame



- 7) Heat evenly by moving the torch in continuous motion until the pre-placed flux melts.



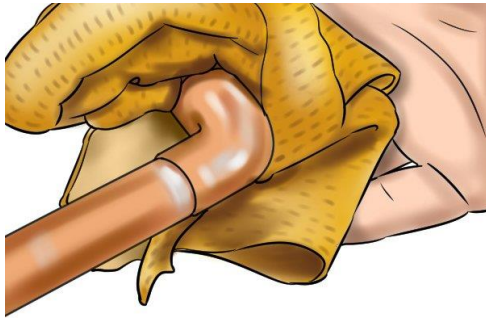
- 8) Keep heat distribution in mind. Consider the amount of metal in each of the pieces you're soldering together. If one component is 75% of the total piece and the other component is 25%, spend 75% of the soldering time heating the larger component and 25% heating the smaller component. Also take the type of base material into consideration. Copper will be a good conductor of heat and transport the heat fast away. Stainless steel is a bad conductor and will easily overheat.
- 9) If small intricate assemblies heat indirectly, not directly towards the joint.
- 10) When the joint is hot enough, move the flame aside and touch the joint with the solder to see that it flows out. The solder will soften in the heat and flow into the gap between the pipes, creating a tightly fitted joint.
- 11) Remove your torch as soon as your solder flows. Watch for the shiny flash of melting solder; when it happens, remove your torch instantly. Overheating your metal can cause it to become brittle or melt.







- 12) Hold the torch with your nondominant hand. This gives you greater ability to manipulate the solder more easily.



- 13) Water soluble flux residues must be cleaned of using water. If flux residues are left on base material surface, they can start corrosion.

There is a wide range of cored solder wires available from a large number of suppliers. Below gives name of some suppliers/manufactures and their products. In case of product changes please check product data with suppliers/manufactures before purchase.

Table 1) Soft solder consumables, Lead- and cadmium-free

Supplier/Manufacturer	Product	Chemical composition	Melting range	Classification	Characteristics
Fontargen	A-AF 611	Ag 3,5% Sn Rest	221°C (430°F)	DIN EN ISO 3677 S-Sn96,5Ag3,5	Soft solder wire with flux core. Steel, stainless steel, copper and copper alloys. <b>Rosin based flux</b>
Saldflux	Tinalloy 35	Ag 3,5% Sn Rest	221°C (430°F)	DIN EN ISO 3677 S-Sn96Ag4 / (Sn96,5Ag3,5)	Bare wire. Must be used with FLUX T. Steel, stainless steel, copper and copper alloys. <b>Rosin based flux</b>
Lucas Milhaupt	Silvabrite-S	Ag 5% Sn Rest	221°C- 245°C (430°F)	ASTM B32 Sn9	Bare wire. Must be used with Silvabrite Paste Soldering flux. Zinc-chloride type of flux.
Castolin Eutectic	157	Ag 3,5% Sn Rest	221°C (430°F)	-	Bare wire. Must be used with 157 flux. Highly halide activated flux. Water based. DIN8511F-SW12
Wilhelmsen Ships Service	Tin 241 Ag	Ag 3,8% Cu 0,7% Sn Rest	230°C (446°F)	DIN EN 61190 Sn96Ag04Cu0,7	Soft solder wire with flux core. Steel, stainless steel, copper and copper alloys. <b>Rosin based flux</b>
Felder Lottechnik	ISO-Core RA SAC	Ag 3,8% Cu 0,7% Sn Rest	217°C (423°F)	DIN EN 61190 Sn96Ag04Cu0,7	Soft solder wire with flux core. Steel, stainless steel, copper and copper alloys. <b>Rosin based flux</b>
Warton Metals	Omega II	Ag 2,8% Cu 0,5% Sn Rest	217°C (423°F)	M-OR-L0 flux type ROLO J-STD-004B	<b>Rosin-free flux*</b> Soft solder wire with flux core. Also, halide-free
Alpha Assembly Solution	ALPHA FT-2002 Rosin Free	Ag 3% Cu 0,5% Sn Rest	217 - 221°C (423 - 430°F)	J-STD-004 ORLO classification J-STD-006C SAC30	<b>Rosin-free flux**</b> Soft solder wire with flux core. Also, halide-free
Multicore	Multicore Loctite Ecosol105 96SC	Ag 3,8% Cu 0,7% Sn Rest	217°C (423°F)	RoHS Compliance	<b>Rosin-free flux</b> Soft solder wire with flux core.

\*Flux Percentage 1, 2 or 3%

\*\* Flux Percentage 1.4% & 2.2%

Cu: Copper Sn: Tinn Ag: Silver



Lead-free solder does not have the best reputation, in part due to technical issues with the soldering process. Most lead-free solder alloys melt at a higher temperature (about 220-250°C (428-482°F)) than tin/lead solder (about 180-190°C (356-374°F)). Thus, changing from leaded to lead-free solder will require a change in soldering iron tip temperature. The typical tip temperature for leaded soldering is 320-370°C (600-700°F). For lead-free the temperature needs to be increased to 370-425 °C (700-800°F). In addition to the higher tip temperature, the dwell time needs to be increased. A solder joint can be completed with lead-based solder in less than a second. Using lead-free solder, this time needs to be extended to avoid cold solder joints.

**Health hazard:** Leaded solder contains lead. If ingested, lead accumulates in the fatty tissues in the body, including the myelin sheath surrounding the nerve fibres in the brain. This can lead to brain damage, in particular in infants and small children. This is mostly an issue with lead casting where the lead is heated to near its boiling point. The temperatures used in soldering are much lower. The main risk of lead exposure is from the lead that rubs off from the solder onto your fingers. Please make sure that you do not eat or drink while soldering. Wash your hands thoroughly when you are done soldering. Avoid using rosin(colophony)type flux.

Soft solder should never contain lead. The flux should be rosin-free.

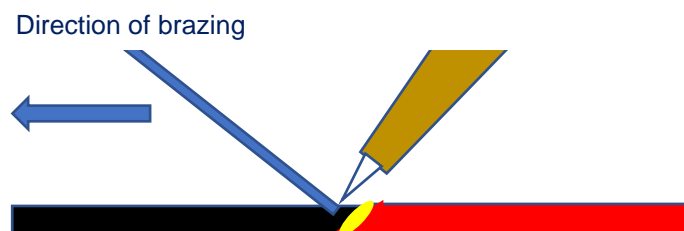
- 1) RoHS 2.0 Directive 2011/65/EU
- 2) RoHS 3.0 Directive 2015/863/EU
- 3) European Union Regulation (EC) 1907/2006 (REACH)

Shelf Life: Solder has an expiration date. For the alloys mentioned, it is recommended that solder wire is used within three years of manufacturing.

### Braze welding

Braze welding is the use of a bronze or brass filler rods coated with flux to join steel or copper alloys. The rods consist mostly of Copper (Cu) and Zinc (Zn) and sometime a small amount of Silver (Ag), The name comes from the fact that no capillary action is used and that the welding technique are very similar to welding.

For braze welding we use the Leftward “welding technique”.





There is a wide range of braze welding consumables available from a large number of suppliers. Below gives name of some suppliers/manufactures and their products. In case of product changes please check product data with suppliers/manufactures before purchase.

Table 2) Braze welding consumables, Lead- and cadmium-free.

Supplier/Manufacturer	Product	Chemical composition	Melting range* Solidus-Liquidus	Classification	Special note	Characteristics
Fontargen	A-210	Cu 60% Mn 0,15% Sn 0,20% Si 0,30% Fe 0,25% Zn Rest	875-895°C (1607-1643°F)	DIN EN ISO 3677 B-Cu60Zn (Si)-875/895	Bare rod. Need additional flux.	Brazing rods for joining and surfacing copper, brass, bronze, aluminum bronze, cast iron and steel. May be used for brazing galvanized steel without destroying the galvanized surface.  Additional flux:  Fontargen: Flux F100 Boric acid borax: No info
Saldflux	SILVER WELD 1 FRC	Cu 59% Si 0,3% Ag 1,2% Zn Rest	860-890°C (1580-1634°F)	EN 1045 FH 21 (Boron compound)	Flux coated rod. <b>Borax based</b>	
Lucas Milhaupt	CDA 681	Cu 58% Sn 1% Fe 1% Zn Rest	865-887°C (1589-1629°F)	AWS RBCuZn-C	Bare rod and Flux coated rod. Boric acid/ borax: No info	Saldflux: Flux BW/1 Boric acid borax: No info
Castolin Eutectic	38418 (18 NXF)	Cu 58% Ag 1% Zn Rest	870-895°C (1598-1643°F)	ASME SFA5.8 Class RBCuZn-B B-Cu60Zn(Ag) 870/895	<b>Flux coated rod No boric acid or borax</b>	
Drew Marine	BR Flux coated rod	Cu 58% Sn 1% Fe 1% Zn Rest	880-890°C (1616-1634°F)	ISO 3677 B Cu 59 ZnSnSi 880-820	Flux coated rod. Boric acid/ borax: No info	Lucas Milhaupt: Handy Flux Hi-Temp Boric acid/borax: No info
Wilhelmsen Ships Service	FC-Bronze 261	Cu 60% Mn 0,30% Sn 0,10% Ag 1% Zn Rest	870-890°C (1598-1634°F)	ISO 3677 B Cu 59 ZnAgSi 870-890	Flux coated rod. Boric acid borax: No info	<b>Castolin Eutectic: 18M Green flux. No boric acid or borax</b>  Drew Marine: BF Flux Boric acid/ borax: No info  Wilhelmsen Ships Service: Bronze Flux 261PF Boric acid/ borax: No info

\*Melting range: The solidus temperature is the highest temperature at which the part remains solid i.e. the start of melting. The liquidus temperature is the lowest temperature at which the part is molten i.e. complete melting.

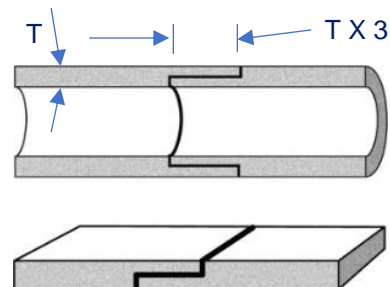
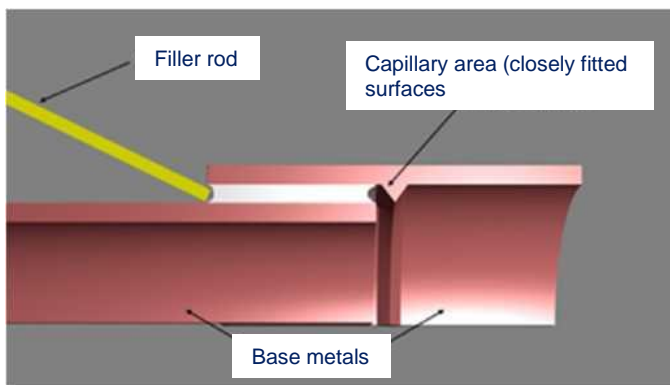
Cu: Copper Mn: Manganese Sn: Tinn Si: Silicon Fe: Iron Zn: Zink Ag: Silver

There are a number of other braze welding alloys like nickel wear resistant alloys for overlaying and special alloys for cast iron. In order to simplify, this have not been added to the table.



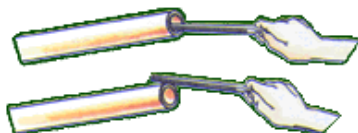
### Capillary brazing

Capillary brazing, sometimes known as a silver soldering is brazing using a high amount of silver-based filler. These silver alloys consist of many different percentages of silver and other metals, such as copper, zinc, cadmium and phosphor. For capillary brazing to be successful one depends on the capillary process that allows thin flowing alloys to flow into the joint between two parallel metal parts. The suction force that is created in a capillary joint can be measured in mille bar. The general rule of thumb for capillary joint design is that the overlap  $L$  should be  $> 3$  times the thickness of the thinnest partner or a minimum of 5 mm. The gaps in both joints should typically be between 0,05 mm and 0,25 mm depending on ability to control the gaps and the desired brazing temperatures. In capillary brazing, its only strength in what gets in between the two parallel surfaces.



Typical capillary joints for pipe and plates. Note that the overlap should be plate or wall thickness X 4.

For capillary brazing use the following brazing technique.



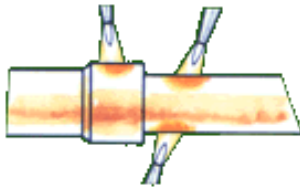
Degrease all parts. Remove inside and outside burrs.



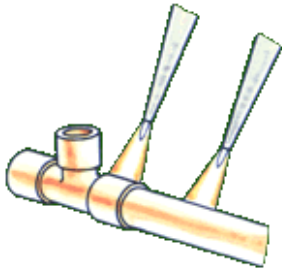
Clean surface with abrasive such as wire wool. Emery and sand paper should not be used as they cause silica particles to become embedded in the surface which will prevent the brazing from wetting.



Paint flux onto the surfaces before joining the parts. To pre paint flux on the parts to be joined is important even if one uses a flux coated rod. Pre painting the flux will take care of the oxides as they start to form during the heating process.



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

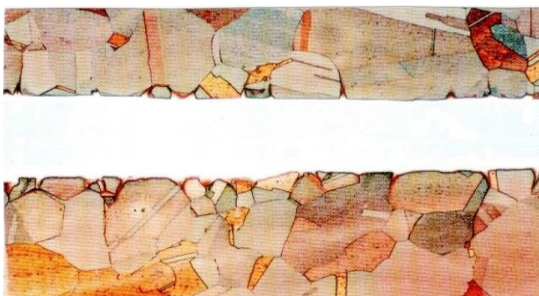


Melt of a droplet of the rod in the joint and spread it out moving the flame continuously.

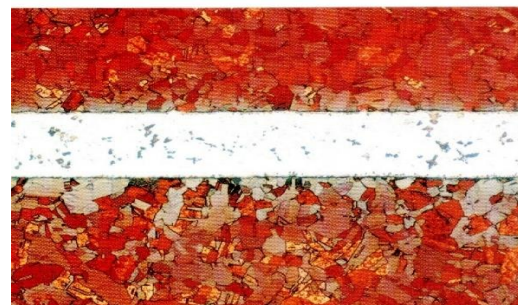
Silver brazing alloys consist of alloys of silver, copper, zinc and sometimes also cadmium. They flow easily, with low working temperatures of 600-800°C (1112-1472°F). They can be used with all brazing methods, and for almost all materials except aluminium and magnesium alloys. When brazing seawater pipes like York Albro and Cunifer always use Silver brazing alloys with more than 50% silver. If less, the seawater will corrode the alloy away very quickly. Manufacturers of Cunifer pipes recommend from 50-60 % silver used in brazing rods for Cunifer.



Capillary brazing rods alloyed with silver will have enhanced capillary flow, improved corrosion resistance and improved strength. High silver content will reduce melting point thereby shortens the duration of the brazing process.



Two parallel copper surfaces forming a capillary joint. Note the copper grains.



The silver alloy has melted into the grain Structure and secure a good bonding.





Regarding Silver brazing alloys that contain cadmium: The inclusion of Cadmium (Cd) in brazing consumables has three related advantages: It reduces the alloys bonding temperature; it shortens the duration of the brazing process and it lowers the cost of brazing. With other words, it has the same effect as silver, and is less expensive than silver. This is tempting many manufacturers and suppliers of brazing consumables to add Cadmium alloyed brazing products on their product range. However, Cadmium is a Heavy Metal. Its melting point is 321°C (610°F) and its boiling point 767°C (1413°F). It will therefore easily form metallic fumes that will react with the ambient air to form cadmium oxide. Exposure to these fumes can cause metal fever with progression to pulmonary edema (fluid in the lungs) that can lead to death. Inhalation exposure to cadmium fumes at comparatively low levels may result in serious-potentially- fatale acute effects in humans. The most commonly used cadmium brazing rods contain 25% cadmium. Cadmium can also enter a human organism trough drinking water or food where cadmium brazing rods have been used for joining. Due to the toxicity of cadmium, filler metals containing this substance must not be used unless full evacuation of brazing fumes is provided.

In Europe the use of Cadmium brazing rods is no longer allowed. Always check the labels and tech sheets if cadmium is present.



According to the Commission Regulation (EU) N ° 494/2011 of 20 May, 2011, using and marketing of brazing rods that contain more than 0,01 weight-% cadmium is no longer allowed in the EU after 10 December 2011. This regulation is binding and valid in each EU Member State.

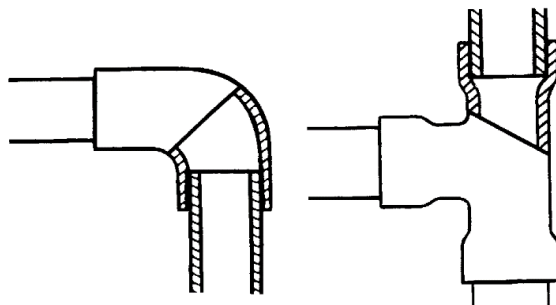
This means that from December 10, 2011 on it was no longer allowed to work with silver brazing rods containing cadmium (e.g. AG306 L-Ag30Cd or AG304 L-Ag40Cd). Moreover, also the production of these brazing rods was forbidden from this date on.

There is a wide range of silver brazing consumables available from a large number of suppliers. Below table give names of some suppliers/manufactures and their products. In case of product changes please check product data with suppliers/manufactures before purchase.



Table 3) 45% Silver brazing consumables, Lead- and cadmium-free.

Supplier/Manufacturer	Product	Chemical composition	Melting range	Classification	Special note	Characteristics
Fontargen	AF 320 XL BF	Ag 45% Sn 2,5% Zn 25,5% Cu 27% Si 0,1%	640 - 680°C (1184 - 1256°F)	AWS A5.8: Bag-36 EN ISO 17672: Ag 145Si EN 1044: Ag 104 DIN 8513: L-Ag45Sn	<b>Flux coated rod</b> <b>No boric acid or borax</b>	Cadmium free silver rods for joining of all types of steel, stainless steel, copper, copper alloys, nickel and nickel alloys, cast iron and hard metals. This type of brazing rods gives a very good joint and can be used for brazing nipples, sleeves and unions to copper pipes.
Saldflux	Saldflow 45	Ag 45% Cu 27% Sn 2,5% Zn Rest	640-680°C (1184 – 1256°F)	ISO 17672 AG 145 EN 1045 Fh 10	Flux coated rod Boric/acid borax: No info	
Lucas Milhaupt	Silvaloy 452 Flux coated	Ag 45% Cu 27% Sn 3% Zn Rest	640-682°C (1184 – 1260°F)	AWS Bag-36	Flux coated rod. H361. <b>Boric acid and/or borax</b>	Additional flux:
Castolin Eutectic	38245N XF (1666 XFC)	Ag 45% Cu 25% Sn 2% Zn Rest	660-700°C (1220-1292°F)	ISO/FDIS 17672 AG 145	<b>Flux coated rod</b> <b>No boric acid or borax</b>	Fontargen: F300 H Ultra NT. No boric acid or borax
Drew Marine	SL 45	Ag 44% Cu 30% Zn Rest	680 – 740°C (1184 – 1364°F)	DIN EN ISO 3677 B-Ag44CuZn-680/740	Flux coated rod. Boric acid/borax: No info	Saldflux: F25 No boric acid or borax
Wilhelmsen Ships Service	AG 45 253	Ag 44% Cu 30% Zn Rest	680 – 740°C (1184 – 1256°F)	DIN EN ISO 3677 B-Ag44CuZn-675/735	Bare rod. Need additional flux AG-60/45 Flux 252 PF flux	Lucas Milhaupt: Handy flux. H361. Boric acid and/or borax  Castolin Eutectic: FP38976 Paste (1802Atmosin Powder) No boric acid or borax  Drew Marine: SF Flux Boric acid/borax: No info  Wilhelmsen Ships Service: AG-60/45 Flux 252 PF flux. Boric acid borax: No info



Typical Capillary joints



Table 4) 50% Silver brazing consumables, Lead- and cadmium-free

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

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



Phosphor brazing filler metals are based on alloys of copper and phosphorus, and may also contain silver. They are used almost exclusively for brazing copper and copper alloys. As phosphorus reduces copper oxide, the metal is self-fluxing, and so no additional flux is normally needed. These filler metals are not suitable for brazing steel or nickel, as phosphides can be formed and embrittle the joint zone. On seawater pipes, do not use Phosphor brazing rods.

Special notes when repairing refrigerants/ air-conditioned installations onboard:

Phosphor in Brazing rods are very popular when repairing refrigerants/ air-conditioned installations onboard. These refrigeration systems use copper in piping and parts like elbows and T- joint connections. Copper-phosphorous alloys are as mentioned self-fluxing when joining copper to copper. That no flux is needed on copper makes them popular. The self-fluxing characteristic occurs because the phosphorous element possesses a greater affinity for oxygen than for the copper. The phosphorous also combines with oxygen in the air and the flame if an oxy- acetylene torch is used. These alloys may also be used on brass and bronze but will then require a flux. Phosphor does not decompose zinc oxide, so flux is needed for brass/ bronze.

There is a wide range of phosphor brazing consumables available with a variation of silver content. In order to simplify, only the most used and popular 15 % Silver content type have been added to the table. Below table give names of some suppliers/manufactures and their products. In case of product changes please check product data with suppliers/manufactures before purchase.

Table 5) Phosphor brazing consumables, Lead- and cadmium-free

Supplier/ Manufacturer	Product	Chemical composition	Melting range	Classification	Characteristics
Fontargen	A 3015	Ag 15% P 5% Cu Rest	645-800°C (1193 - 1472°F)	DIN EN ISO 3677 B-Cu80AgP-645/80 AWS A5.8 B CuP-5	Fluid copper-phosphorus alloy with high silver content and high ductility, even at low temperatures. Suitable for capillary brazing of copper and some copper alloys. Recommended for joints with strong thermal load and vibrations. Joint-brazing at working temperatures between -70 °C and +150 °C (-94 to +302°F). Do not use in Sulphur us environment and on Fe- and Ni-alloys. Can be used for brazing brass or bronze with the adding of flux.  Additional flux for use on brass and bronze:  Fontargen: F300 H Ultra NT. No boric acid or borax  Saldflux: F25 No boric acid or borax  Lucas Milhaupt: Handy flux <b>Borax based</b>  Castolin Eutectic: 1802 Atmosin No boric acid or borax
Saldflux	Silverfos 15	Ag 15% P 5% Cu Rest	645-800°C (1193 - 1472°F)	ISO 17672 CuP 284 AWS A5.8 B CuP-5	
Lucas Milhaupt	Sil-fos 15	Ag 15% P 5% Cu Rest	643-802°C (1189 - 1476°F)	AWS A5.8 B CuP-5 ISO 17672 CuP 284	
Castolin Eutectic	38115BS (RB 5283)	Ag 15% P 5% Cu Rest	645-800°C (1193 - 1472°F)	ISO 17672 CuP 284 AWS BCuP-5 DIN 8513 L-Ag15P EN 1044	

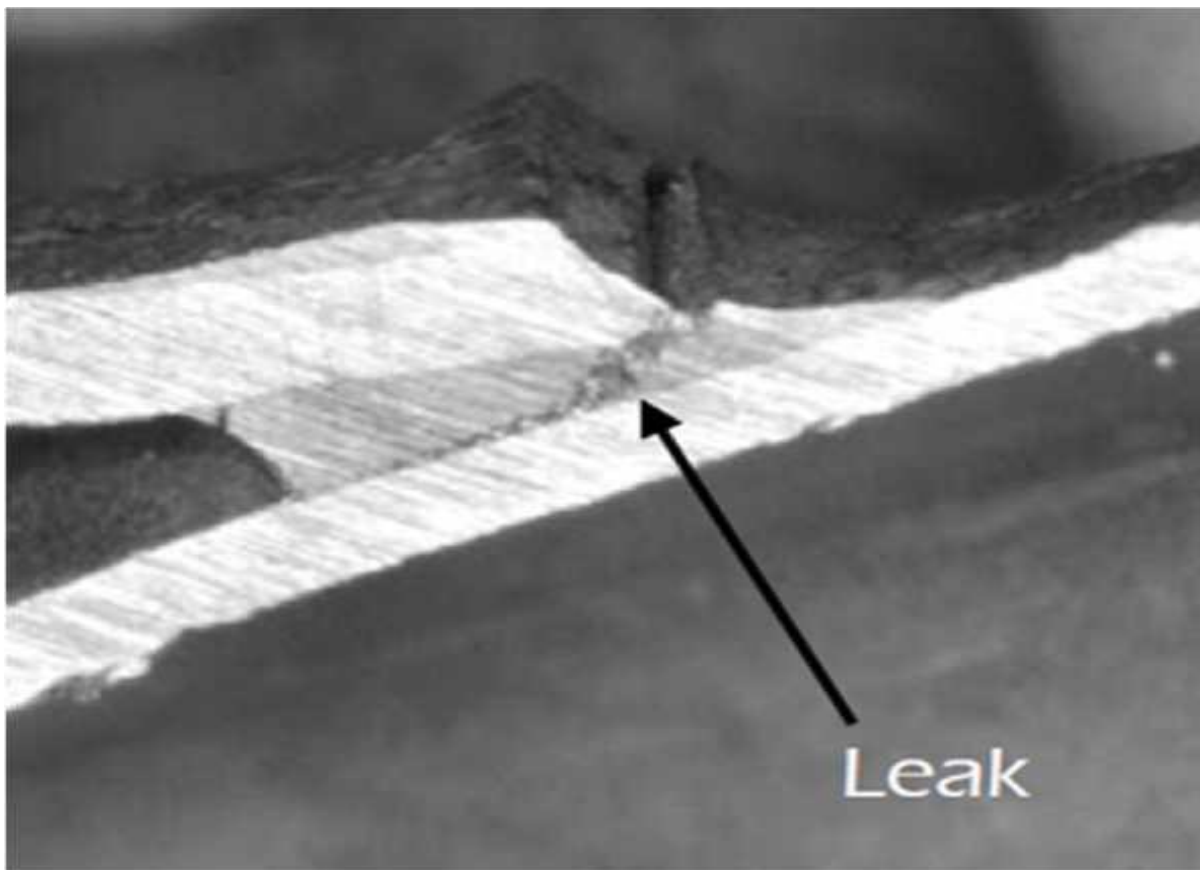
Ag: Silver      P: Phosphor      Cu: Copper

The 15% silver plus 5% phosphor rods works well to “bridge” gaps. They have the highest joint ductility of the entire phosphor brazing rod family to best withstand the stresses inherent in refrigeration applications.



Copper-phosphorus and silver-copper phosphorus brazing alloys are widely used in joining copper to copper in air without the use of a flux (thanks to its phosphorus content). The addition of silver to copper/phosphorus improves ductility and electrical conductivity in the alloy and it reduces its melting range. These filler metals can be used for brazing brass or bronze with the adding of flux: the self-fluxing action fails to work because of the presence of the zinc oxide on the brass. These alloys should not be used on ferrous or nickel-based alloys, on copper nickels with more than 10% nickel, to avoid formation of brittle, intermetallic phosphide compounds.

Please note: The use of phosphor-brazing rods on copper pipes and parts used in refrigeration/ air-condition installations where R-22 is the media: R-22 consist of Chlorine, hydrogen, fluorine and carbon. It is always mixed with some mineral oil circulating inside the system. The phosphor grains can be washed out of the deposit by this mixture. In a microscope, it comes out as tiny small channels in the deposit, where the phosphor has been. Result is leaks developing. Another major negative effect of phosphorous on copper is the reduction in ductility. In the range of 8.0 - 8.5% phosphorous content, the material becomes extremely difficult to form in both hot and, especially, cold forming. The phosphides segregate at grain boundaries and cause intergranular embrittlement. Avoid in environments with presence of Sulphur dioxide and hydrogen sulphide. The phosphorus-rich phase rapidly corrodes in presence of Sulphur and the joint fails.







## Aluminium brazing

Aluminium melts at 660°C(1220°F). The aluminum oxide melts at 2038°C (3,600°F). That is three times the temperature of aluminum and causes a problem when it comes to brazing. Aluminum also has high thermal conductivity and a very short temperature range between liquidus and solidus. The aluminium's oxide layer is a thin, but dense and stable oxide layer with a thickness of 2 to 10 nm (nanometer). During brazing or soldering, the aluminum will oxidize so readily that special fluxes must be employed such as an organic amine-based flux (up to 285°C(545°F)), inorganic fluxes (chloride or fluoride up to 400°C (752°F)), and complex Fluor aluminate salts (above 550°C(1022°F)). Due to the already mentioned concerns over atmospheric pollution and hazardous waste disposal, the electronics industry has been gradually shifting from rosin flux to water-soluble flux, which can be removed with deionized water and detergent, instead of hydrocarbon solvents.

Aluminium often has other elements added to improve strength, rigidity, corrosion resistance, machinability, and formability. Some additives cause no problem for brazing, but magnesium is the exception. Magnesium-containing aluminium alloys (5xxx and 6xxx series) are used to provide better corrosion resistance in some applications (seawater resistant aluminium). The magnesium oxide reforms very quickly and does not allow brazing wetting to take place. Titanium and some exotic additives such as vanadium and chromium may also cause problems. The 1xxx (99% Al or higher), 2xxx (copper added), 3xxx (manganese added), 4xxx (silicon added), and 7xxx (zinc added) series are generally brazeable.

Brazing of aluminium can be done with either soft solders (**Sn**-based, lower temperature) or brazing (**Zn**-based, higher temperature) and with appropriate fluxes to fit processing temperature ranges.

There is a wide range of aluminum brazing and soldering consumables available from a large number of suppliers. Below gives name of some suppliers/manufactures and their products. In case of product changes please check product data with suppliers/manufactures before purchase.

Lead-free and cadmium-free alloys that are commonly used to **solder** aluminium include 91Sn9Zn and 70Sn30Zn. Other variations are 60Sn/40Zn and 80Sn/20Zn, which are in the Sn family.

Table 6) **Sn**-based Aluminum brazing consumables, Lead- and cadmium-free.

Supplier/Manufacturer	Product	Chemical composition	Melting range	Classification	Special note	Characteristics
Meltolit	230AL	Sn 97% Cu 3%	230-250°C (446 - 482°F)	DIN EN ISO 9453 Sn97Cu3	Flux core	Soldering of aluminum and aluminum alloys and Aluminium-to-Copper
Harris	Al-Solder 500	Sn 85% Zn 15%	199-250°C (390 - 482°F)	-	Bare rod	Harris: Stay-Clean aluminum flux Kapp Alloy & Wire: Kapp Golden Flux**
Kapp Alloy & Wire	Kapp Alloy 9	Sn91% Zn 9%	199°C (390°F) Eutectic*	-	Bare rod	Amines and complex inorganic fluorides

\*Eutectic: Solidus and liquidus are the same.

\*\*Flux is rated by D.O.T. As A Corrosive Hazard - Can Not Be Shipped by Air.



Lead-free and cadmium-free alloys that are commonly used to **braze** aluminium include 98Zn2Al, 85Zn/15Al, 90Zn/10Al, and 97Zn/3Al.

Table 7) **Zn**-based Aluminium brazing consumables, Lead- and cadmium-free.

Supplier/Manufacturer	Product	Chemical composition	Melting range	Classification	Special note	Characteristics
Fontargen	A-AF 631 NH	Zn 98% Al Rest	382-407°C (720 - 765°F)	DIN EN ISO 3677 S-Zn98Al2	Flux core.	Brazing of aluminum and aluminum alloys. Suitable for aluminum/copper-joints. Additional flux: Fontargen: F600ZA Saldflux: Flux A Lucas Milhaupt:--- Castolin Eutectic: 190NHR
Saldflux	Alusald 22	Zn 98% Al Rest	426-482°C (799 - 900°F)	ISO 3677 S-Zn78Al22	Bare rod or flux cored	
Lucas Milhaupt	AL 822	Zn 78% Al Rest	482-521°C (900 - 970°F)	-	Flux core.	
Castolin Eutectic	38522 BFC	Zn 78% Al Rest	430-460°C (806 - 860°F)	DIN 8513 DIN1707 L-ZnAl22	Flux core.	

Soldering/brazing temperatures of 225 to 490°C (437-914°F) are well below the 660°C (1220°F) that is the aluminium melting temperature. Less distortion of the aluminium component is expected by soldering than by brazing.

### What's the advantage of brazing?

- 1) With brazing if you do not get it right the first time you can reheat the joint and repair it without having to disassemble or completely reinstall the affected parts.
- 2) Brazing can be used on dissimilar metals and materials.
- 3) Strength: With the proper joint design and correct selection of brazing materials, brazed joints will be stronger than the base materials being joined.
- 4) Fact: Carbide tools are some of the most abused tools and must withstand the highest amount of push, pull and impact. Most carbide tools rely on brazing processes to keep the carbide segments in place.
- 5) Brazing is Easy to learn.

### What's the limitation of brazing?

- 1) Temperature. Brazed joints can melt and loose all mechanical strength under high service temperatures.
- 2) Brazing-alloys are generally more expensive than welding alloys.
- 3) Colour of brazing-alloy may be different from that of base metal.
- 4) Brazed joints require a high degree of base-metal cleanliness.



### Safety in brazing

Soft solder:

Do not use led containing soft solder and flux containing Rosin (colophony).

Brazing:

Do not use cadmium brazing rods and brazing flux that contain boric acid and borax.

Make sure to work in a well-ventilated location preferable with fume extractor. Prolonged exposure to flux fumes is a health hazard. It is good practice to set up a small fan to blow the flux fumes away from the work area while soldering.

Wash your hands thoroughly after handling solder and brazing consumables.

### What brazing and solder product should you keep onboard?

There is a wide range of brazing and soldering consumables available from a large number of suppliers. Different ships will have different needs. The below is therefore a suggestion in order to limit the number of different alloys. Regarding the amount of each type, keep in mind that most fluxes will have a 3 years shelf life.

- Soft solder for pcb and electrician jobs (Rosin free). Note table 1.
- Soft solder for pipefittings. Note table 1.
- Braze welding product for large gap joints. Note table 2 (There are a number of other braze welding alloys like nickel wear resistant alloys for overlaying and special alloys for cast iron. These should be added according to needs.
- Silver 45% brazing alloy for capillary joints copper to braze/ bronze. Note table 3.
- Silver >50% brazing alloy for capillary joints on seawater pipes (Yorkalbro/Cunifer) and stainless steel. Note table 4.
- Phosphor brazing alloy for capillary joints on copper pipes. Note table 5.

Keeping brazing alloys for aluminium onboard should be evaluated according to needs. The number of aluminium repair cases will normally be lower compared to copper, brass, bronze, steel and stainless steel. Table 6 and 7 list suppliers and products if in need.

### Additional information regarding rosin

Colophony (or rosin as it is sometimes called) is a common cause of occupational sensitization. In the UK it ranks in the top five causes of occupational asthma and the top 10 causes of contact dermatitis. It is also a cause of rhinitis and eye irritation, and perhaps of headache and allergic alveolitis. It is an 'old fashioned' small molecular weight chemical used in the early days of the plastics industry as a basis for semisynthetic resins. It is derived from the resin of pine trees, either by direct tapping of the sap, by extraction from dead stumps (wood rosin), or from tall oil left over after paper manufacture (tall oil rosin); the latter two products tending to have more oxidised resin acids than native colophony. Colophony consists of a variable mixture of resin acids, some of which are relatively unstable, and a neutral fraction. Occupational asthma usually results from inhalation of the fume from heated colophony in soft soldering fluxes, or occasionally in hot melt glues or depilatory mixtures. However, cases have occurred in a chemical worker with colophony heated to 90° C and from unheated colophony dust. Colophony or colophony derivatives have caused occupational asthma when added as a deodorant to coolant oils and floor cleaning products.

Nearly all of the workers who have asthma from colophony are exposed to solder flux fumes.