



B1-B5 Refrigerant Circuit Joining Technologies

Length: 140 minutes

Theory / demonstration

Learning targets

- ✓ Know the theoretical basics of brazing
- ✓ Understand the importance of high quality brazed joints
- ✓ Know the differences between brazing rods and their range of use
- ✓ Acquire an overview of the right brazing tools for specific purposes
- ✓ Gain practical experience in brazing operation
- ✓ Distinguish between “Well” & “Poorly” brazed joints

Agenda B1 – B5 Refrigerant Circuit Joining Technologies

 **B1** Mechanical joining technologies

B1 Thermal joining methods

B1 Refrigerant transfer tube joining processes in general

B1 International standards to be considered

B2 Basics of brazing

B2 Brazing equipment and components

B2 Brazing with fittings

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B3 Brazing operation requirements

B4 Brazing the joint

B4 Brazing Dos and Don'ts

B5 Brazers competency certification

Mechanical joining technologies

Systematic classification

Joining of components should be for general consideration:

- a) nondetachable (separation only by destruction)
- b) semi-detachable or detachable (reusable connection)

depending on the purpose of joining.

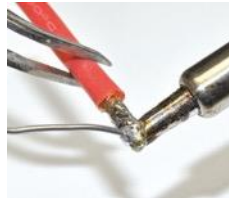
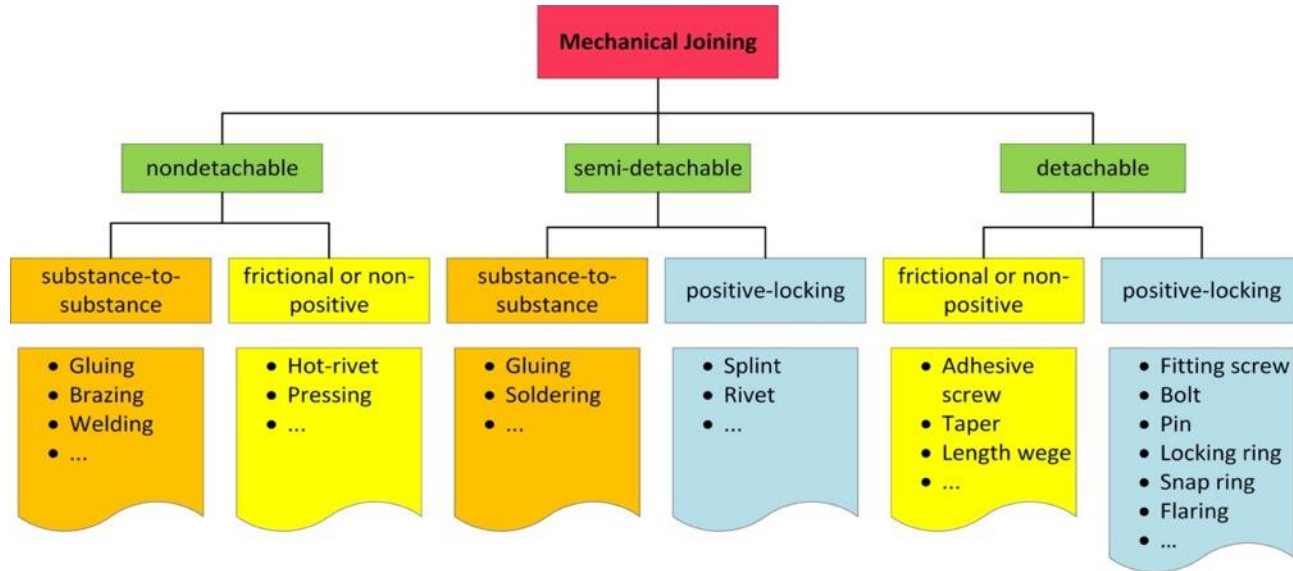
- For joining at least two or more components there are basically different possibilities, **the so-called three types of joining methods**, which are based on different physical principles.
- The connection should prevent separation of the bodies under the forces acting during operation and hold them reliably in place.

In general, a distinction is made here between:

1. a positive locking connection (with the use of a fastener min. two)
2. a frictional or non-positive connection (static friction)
3. a substance to substance material connection (atomic/molecular bond).

Mechanical joining technologies

Systematic classification



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Thermal joining methods

Thermal joining is the joining of metal parts (or also plastic) by a metal alloy (solder or filler material) under the influence of heat. The melting temperature of the filler material is below that of the other metals to be joined.

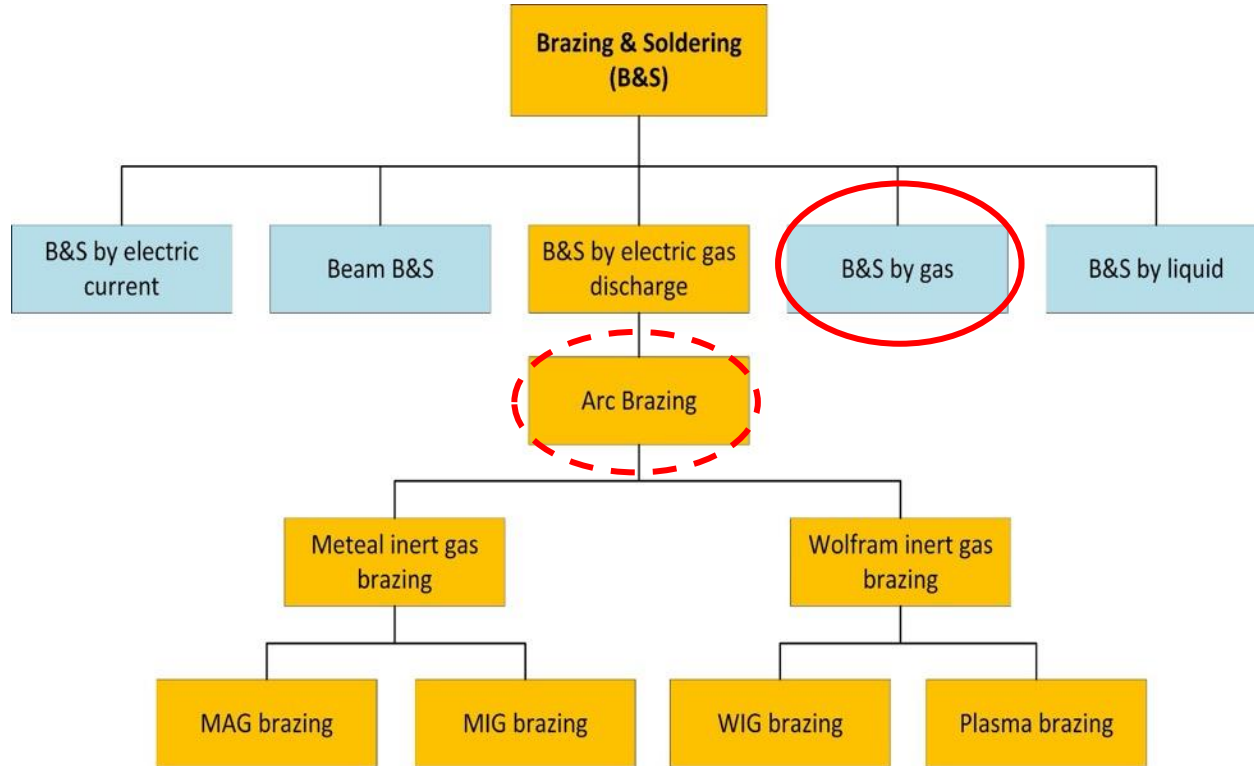
Classification according to soldering temperature (working temperature)

- up to 450 °C: > soft soldering
- from 450 °C: > brazing
- above 900 °C: > high-temperature soldering (in vacuum or under inert gas)

Classification of soldering processes according to energy source

- Soft soldering through: Solid bodies, liquid, gas, jet and electric current.
- Brazing through: Liquid, gas, electric gas discharge, jet and electric current.
- High temperature soldering through: Beam (e.g. laser) and electric current.

Thermal joining methods



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Red encircled areas represent commonly used applications in refrigeration technology

Thermal joining methods

Welding (ARC brazing) of copper tubes

According to EN 378-2:2016 and ISO5149-2:2014, welding is also permitted.

Like other metals, copper can also be welded (also known as ARC brazing). Arc brazing differs from conventional brazing techniques in the following ways.

- For copper tube welding, a nominal **wall thickness of at least 1.5mm (or more)** is recommended.
- The heat source is an electric arc.
- No Flux is required as a shielding gas is used to protect the joint from atmospheric contamination and the process is relatively easy to automate for large components.
- The braze material is deposited by a process known as short circuit transfer.

Thermal joining methods

Welding (ARC brazing) of copper tubes



© Conex - Bänninger

Copper fittings for welding
(source Connex/Benninger)




Example of welded
copper tube joint

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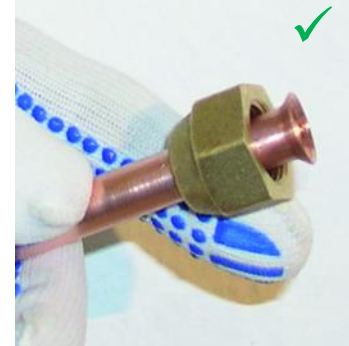
Refrigerant transfer tube joining processes in general

Flaring



See also chapter A7.6.2

- Flare joints often lead to leakage. Wherever possible, flared joints should be avoided, and joints should be made as durable as possible, for example by brazing, welding or pressing.
- Flared joints in refrigeration circuits can be used with annealed pipe only and only up to an outside diameter of 20 mm.
- Use torque wrench for tightening and apply correct torques
- For flammable refrigerants, if flared joints are necessary, it is advised to use industrial manufactured flared joints with brazing adapter.



Refrigerant transfer tube joining processes in general

Thermal joining by fuel gas and flame

- Our main focus for thermal joining in RACHP production, installation and servicing technologies is on the thermal joining by gas and flame

Fuel gases must be selected according to the heating requirements.

Typical examples include:

- Natural gas / air
- Natural gas / oxygen
- Propane / air
- Propane / oxygen
- Acetylene / air
- Acetylene / oxygen

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International standards to be considered

European standard EN378:2017-3 (ISO 5149-3) Part-2 covers the safety and environmental aspects of the design, construction and installation of refrigeration systems.

- Joints must not be damaged by freezing of water on the outside. Soft soldered joints are not suitable for refrigeration pipework.
- Copper tubes for brazing should be in accordance with EN 12735–1.
- Brazing may be applied to tubes up to 54 mm diameter, larger tubes should be welded (ARC brazing).
- For durable and reliable copper tube joining, fittings should be used according to EN 1254–1 (up to 108 mm diameter).
- DIN 8905-1:1983-10; Tubes for refrigerating systems with hermetic and semi-hermetic compressors; outside diameter up to 54 mm; technical delivery conditions
- EN 14276-1:2011-05; Pressure equipment for refrigerating systems and heat pumps - Part 1: Vessels

International standards to be considered

- EN 1254-1:1998-03; Copper and copper alloys - Plumbing fittings - Part 1: Fittings with ends for capillary soldering or capillary brazing to copper tubes
- EN 1254-4:1998-03; Copper and copper alloys - Plumbing fittings - Part 4: Fittings combining other end connections with capillary or compression ends
- EN 1254-5:1998; Copper and copper alloys - Plumbing fittings - Part 5: Fittings with short ends for capillary brazing to copper tubes
- ISO 17672:2017-1; Brazing - Filler metals specifies the compositional ranges of a series of filler metals used for brazing. The filler metals are divided into seven classes, related to their composition, but not necessarily to the major element present.
- EN 1045:1997-08; Brazing - Fluxes for brazing - Classification and technical delivery conditions
- EN 12735-1:2020; Copper and copper alloys - Seamless, round tubes for air conditioning and refrigeration - Part 1: Tubes for piping systems
- ASTM B280; Standard specification for seamless copper tube for air- conditioning and refrigeration field service
- DIN2607:2002-5; Tube bends - For butt-welding of copper

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Basics of brazing

Special requirements for the use of copper

- The outstanding, diverse properties of copper materials have made them ideal for the use in refrigeration and air conditioning technology and has been state of the art in this fields for decades and is anchored in the relevant standards and regulations.
- It should be noted that only pipes and fittings in accordance with these standards and regulations for RACHP technologies are used in order to be able to follow OSH requirements and to assert technical and legal warranty claims if necessary.
- Copper is an extremely low-temperature material and shows increasing strength and elasticity with decreasing temperature. This distinguishes copper materials fundamentally and decisively from all other technical materials.
- The material copper can therefore be used for temperatures from -269°C to $+250^{\circ}\text{C}$.
- Copper is suitable for almost all commonly used refrigerants (including most of our natural refrigerants). These are in particular all safety refrigerants, Carbon dioxide and combustible hydrocarbon refrigerants, and mixtures thereof.

Basics of brazing

Special requirements for the use of copper

- **R717 Ammonia:** Use is technically possible, but not currently authorized. The use of copper materials for the standardized water-reduced ammonia refrigerant for small refrigeration systems is indeed proven and thus state of the art in science and technology.
A corresponding change in relevant regulations has not yet taken place.
- **R744 Carbon dioxide:** Only usable in absolutely dry condition. For these applications, exemplarily the new K65 (make WIELAND / Benninger) tube system is available. Tubes and fittings are made of the high-strength copper alloy Wieland K65 which has already been used with success in electrical engineering and the automotive industry. K65 makes safe and economical installation of refrigeration systems with operating pressures up to 120 bar possible
- **R764 Sulphur Dioxide:** Only usable in absolutely dry condition.

Basics of brazing

Why high quality brazing matters

Purpose:

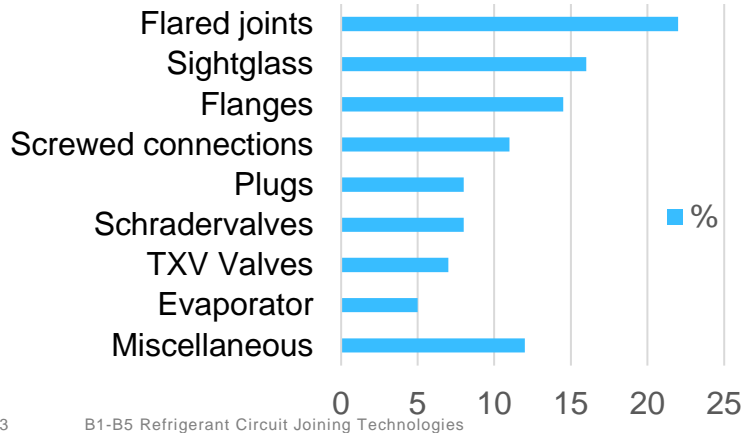
- Achieving sealed refrigerant circuits
- i.e. avoiding detachable (e.g. screwed) connections

Significance for RAC technologies:

- Permanent joint connections reduce the risk of leakage and increase system reliability.



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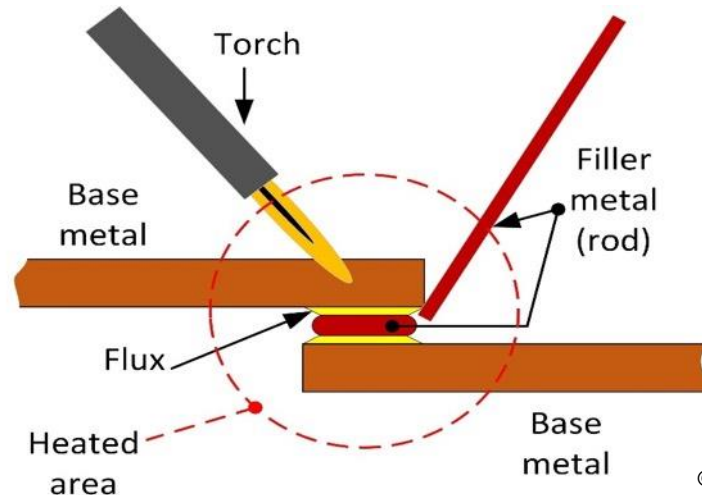


Commonly:
Tightness of
Refrigeration
Systems

Basics of brazing

Definitions

- Brazing is different from welding, as it does not involve melting of paring components
- Brazing creates joints that can withstand pressure, vibrations, shocks and tension etc.
- Used for copper/copper, copper/aluminum or copper/steel connections



Basics of brazing

Definitions

The base metal (i.e. the metal(s) you are attempting to join) is never actually melted, as in conventional welding, but the base metal must reach the proper temperature to allow molecular bonding with the filler metal.

- Working temperatures up to 450°C → soldering.
- Working temperatures above 450°C → brazing.
- The filler metal has a melting temperature above 450°C (840°F) but below the melting point of the metals that are joined.
- Brazing is a process that allows the joining of similar or dissimilar metals by using a third metal (filler metal) as “glue” and applying heat.

Comparison of soldering, brazing & high-temperature brazing

	Soldering	Brazing	High-temperature Brazing
Temperature	< 450°C	> 450°C	> 900°C
General working temperatures	220°C to 250°C	630°C to 890°C	800°C to 1200°C
Application	<ul style="list-style-type: none"> • Pipe installations for drinking water up to and including 28 mm outer diameter • Heated water up to 110°C • Electrotechnics, Electronics 	<ul style="list-style-type: none"> • Gas, LPG and oil installations • Pipes with operating temperatures above 110°C (e.g. solar or hot water heating systems) • Floor heating pipes • Drinking water • RACHP sector 	<ul style="list-style-type: none"> • Due to the high technical complexity, high-temperature brazing is particularly suitable for industrial production.
Advantages	<ul style="list-style-type: none"> • Reduced risk of corrosion at temperatures < 450°C, therefore preferred for drinking water 	<ul style="list-style-type: none"> • Higher shear strength and allows for higher operating temperatures • High strength, durability and quality (RACHP sector) 	<ul style="list-style-type: none"> • The joints often reach the strength of the base materials, which is why vibration stressed components are often brazed at high temperatures.
Disadvantages	<ul style="list-style-type: none"> • Higher effort for cleaning of pipes • Weaker connection 	<ul style="list-style-type: none"> • Hard and semi-hard copper tubes lose their strength during brazing because they are annealed by the high working temperatures 	<ul style="list-style-type: none"> • The filler materials must be of high purity.

Basics of brazing

Flux agent

- A flux is a chemical compound that can prevent oxidation of the metals. Oxidation is the reaction of the metal with oxygen from the air at high temperatures. Oxidation prevents the filler material from bonding with the metals and will therefore result in a bad connection.
- Fluxes used in the joining of copper pipework for refrigeration systems are required to be active over a temperature range (600°C to 750°C) and are normally based on alkali fluorides. Flux residues have to be removed after brazing as it may cause corrosion.
- **Note: The brazing filler metals shall mandatorily be associated with a flux defined by the manufacturer for use with that particular filler material on the corresponding tubes and fittings.**



Always wear appropriate personal protective equipment (PPE) as recommended by the manufacturer!

Generally observe the provisions of the MSDS!

Basics of brazing

Flux agent – similar & dissimilar materials to be brazed

- **Copper/brass or copper/red-cast connections:** Flux is always required.
- **Copper/copper connections:** Flux is not required if copper-phosphorous filler is used. The phosphorous component will act as flux in this case. This is possible with alloys CP 203 and CP 105. If this is used, it is recommended to cover the connection with a protective coating (e.g. 2-pack epoxy resin-based undercoat). Zinc dust paint should not be used!
- **Recommended flux during brazing:** Type FH 21 according to EN 1045 (universal brazing flux; working temperature 750°C to 1100°C, non-corrosive)
- Preplaced flux paste can be applied on the internal surfaces of a joint; this method applies particularly to joints of dissimilar parent metals.
- Some braze filler materials are coated by flux.



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Basics of brazing

Behaviour of flux

Freshly applied flux (room temperature)



Evaporating of water (ca. 100°C)



Paste dries and expands because of evaporation of chemically combined water (ca. 350°C)



Flux is melted clear, smelter is transparent (ca. 550°C)



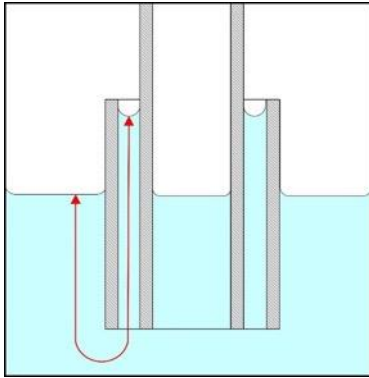

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Technical Materials

example
BrazeTech-
Paste brass

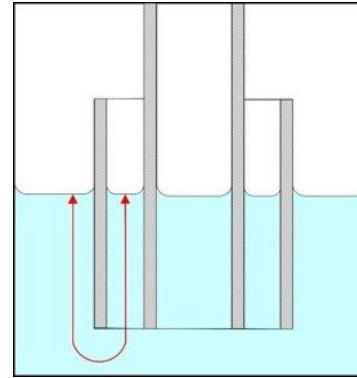
Basics of brazing

Capillary action

In brazing, a thin film of filler metal is sucked into the joints by capillary action. The bigger the gap, the less capillary action is possible.



Capillary action in effect at narrow gap: level of liquid inside the narrow pipe > level outside the pipe

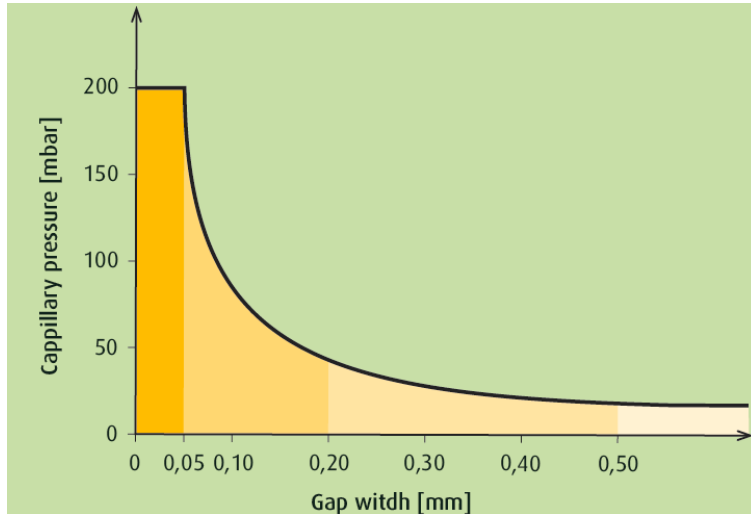


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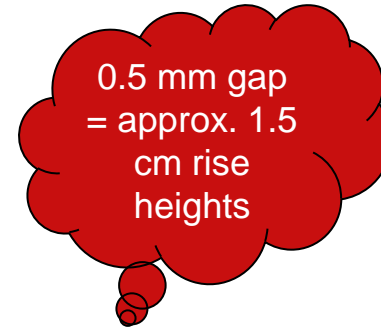
No capillary action at wide gap: level of liquid inside the narrow pipe = level outside

Basics of brazing

Capillary forces: maximum achievable gaps



© Umicore



Capillary brazing is
suitable for gaps
 ≤ 0.5 mm only!

With a parallel gap of 0.1 mm, the capillary pressure is at approx. 100 mbar (10 kPa).

This corresponds to a filler metal rise height of 10 cm (filler metal density = 10 g/cm^3).

The calculated rise heights have been confirmed in practical tests (Info by Umicore)

Basics of brazing

Filler material

- Brazing filler material (sometimes also called solder or brazing alloy) is the metal which is melted to fill the spaces between the surfaces of the components to be joined and forms a bond when it cools down. It consists of different metals to create certain properties and characteristics. These properties are for example the temperature at which it melts, its flow behaviour and the mechanical strength of the connection.
- The brazing process may be used with copper phosphorus rods or pre-fluxed silver rods or non-fluxed silver rods with externally applied flux.
- Especially the silver content has a decisive influence on the most important properties, such as the processing temperature, flow properties of the brazing filler material, mechanical strength and the time required for brazing. A higher silver content usually indicates more favourable properties.



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Basics of brazing

Selection of a suitable filler material

The choice of filler material depends on the materials to be connected.

Please note that for copper-copper connections, silver is not necessary in the filling material. Silver-free materials are generally cheaper:

- **Copper/copper connections:** Brazing filler material without silver content, e.g. copper-phosphorous solder L-CuP6 (CP 203)
- **Copper/copper connections:** Brazing filler material with low silver content, e.g. copper-silver-phosphorous solder L-Ag2P (CP 105), L-Ag5P
- **Copper/brass:** Brazing filler material with high silver content, e.g. L-Ag45Sn
- **Copper/steel:** Brazing filler material with high silver content, e.g. L-Ag45Sn



The higher the silver content, the more resistant for low medium temperature application and the lower the working temperature (WT)

Basics of brazing

Suitable filler materials for copper brazing applications

The choice of filler material depends on the temperature range the application will be operated in, as shown in

RACHP Application temperature	Silver content	Specification	Working temperature
$\leq -20^{\circ}\text{C}$	0%	L-CuP6	730°C
$\leq -20^{\circ}\text{C}$	2%	L-Ag2P	710 °C
$\leq -40^{\circ}\text{C}$	5%	L-Ag5P	700 °C
$\leq -70^{\circ}\text{C}$	15%	L-Ag15P	670°C
$\leq -200^{\circ}\text{C}$	$\geq 34\%$	L-Ag34 (45) Sn	630°C to 730°C



Do not use filler material based on tin or lead.

They are not suitable for the use with foodstuffs in appliances for refrigeration!

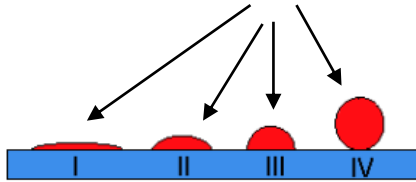
Lead is dangerous to human health.

Basics of brazing

Working temperatures of braze filler materials

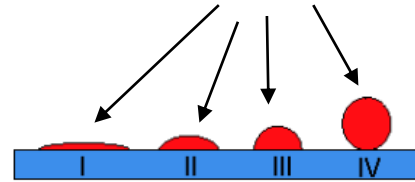
The rod which joins the filler metal to the base metals is also called braze solder (rod).

Silver braze solder (L-Ag45Sn)



I = very good wetting	730°C
II = good wetting	670°C
III = bad wetting	600°C
IV = no wetting	550°C

Copper braze solder (L-Ag5P)



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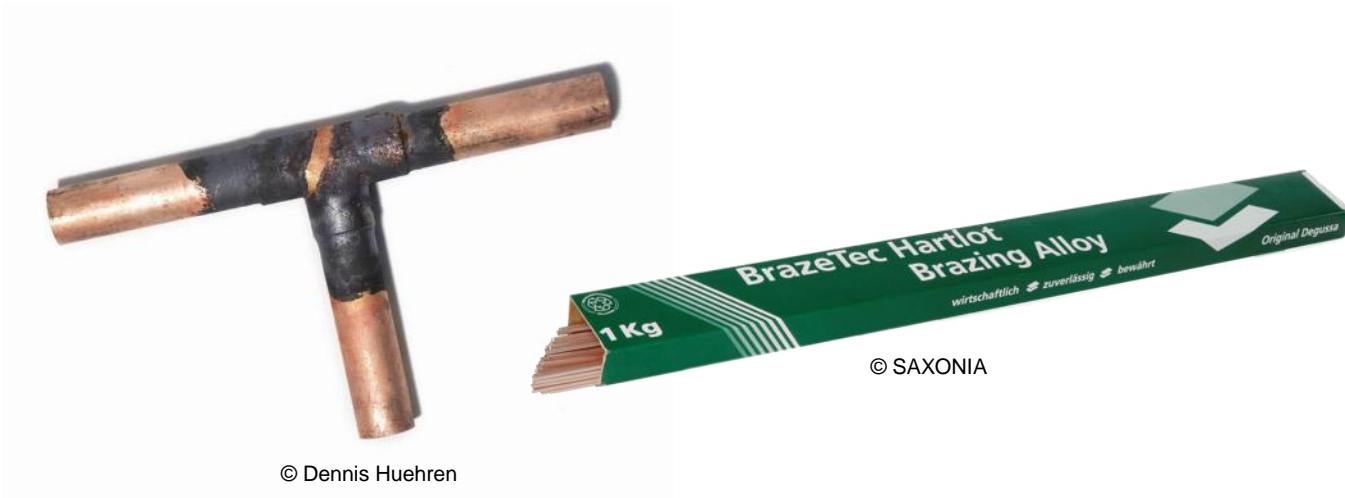
I = very good wetting	815°C
II = good wetting	710°C
III = bad wetting	650°C
IV = no wetting	600°C



Using braze solders with working temperatures that are too high will cause brittle cracks!

Basics of brazing

CuP copper phosphorus filler materials



Copper to copper connections:

- Copper braze solder with low silver content like L-Ag2P or L-Ag5P.
- The fluxing action is achieved by formation of copper metaphosphate.

Basics of brazing

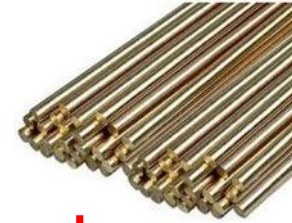
Brazing of copper to brass or copper to steel



© Dennis Huehren
Copper to brass joint (uncleaned)



© SAXONIA
Silver brazing solder flux coated



+



Flux
© SAXONIA

Copper to brass or copper to steel connections:

- Braze solder with high silver content like L-Ag45Sn.
- Flux needs to be added.

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Brazing equipment and components

Adjust working pressure:
(atomizer type)

Working pressure:

- Oxygen: 2.5 bar
- Acetylene: 0.25 – 0.5 bar
- Propane: ~ 1.5 bar

Oxygen-acetylene






Oxygen-propane



© PERKEO

Brazing equipment and components

Oxygen-propane	Oxygen- acetylene	Oxygen-acetylene
 <p>A green metal frame holding a red propane cylinder and a blue oxygen cylinder. It features two pressure gauges, a torch, and various hoses. A 'TUV' safety logo is visible on the left.</p>	 <p>A red acetylene cylinder mounted on a green metal stand. It includes two pressure gauges, a torch, and hoses.</p>	 <p>A blue oxygen cylinder and a brown acetylene cylinder mounted on a green metal frame with wheels. It includes two pressure gauges, a torch, and hoses.</p> <p>© PERKEO</p>
For small pipe joints $\leq 28\text{mm}$	For small pipe joints $\leq 28\text{mm}$; More difficult to use because of bigger flame size	For brazing and gas welding of all diameters
Handy for service use	Handy for service use	For the use at workshop- and construction site
Working pressure: Oxygen: 2.5 bar Propane: ~ 1.5 bar	Working pressure: Acetylene: $\sim 0,5$ bar	Working pressure: Oxygen: 2.5 bar Acetylene: 0.25 – 0.5 bar

© PERKEO

Brazing equipment and components

The injector torch

- With the injector torch, the oxygen at a higher pressure (2 - 2.5 bar) sucks-in the fuel gas at a lower pressure (0.5 - 0.7 bar).
- The principle of the injector works with vapours and liquids of all kinds and is to be found more frequently in mechanical engineering.



Braze torch attachments
different size



Brazing torch



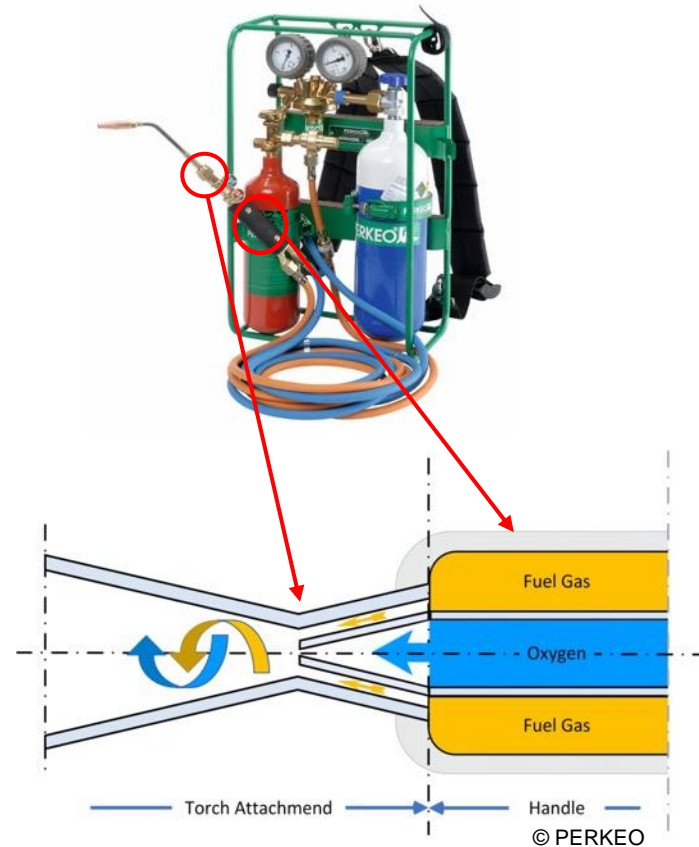
Igniter with
spark flint

© ITE Tools

Brazing equipment and components

The injector torch

- An injector consists of a tube with a constriction.
- In the middle before the constriction, another, thinner tube opens out. Oxygen flows out of this tube at high pressure.
- This creates a suction effect and the gas from the outer tube is sucked in.
- In the extension behind the constriction both gases mix and are ignited at the nozzle outlet.



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Brazing with fittings

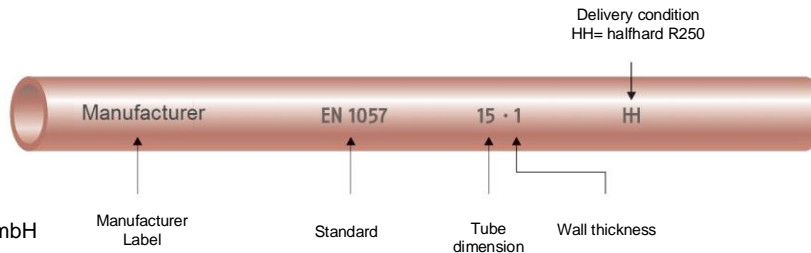
Pipes are connected through fittings and the fitting has to be connected to the pipes through brazing at all connection points.

Note: For connections up to 54 mm outside diameter:

- Equally wide distance (brazing/solder gap) between components
- Minimum gap: 0.02 mm
- Maximum gap: 0.5 mm. At higher gaps, the capillary action is not strong enough. Selection of filler material is different.
- The narrower the gap, the higher the capillary fill pressure.

For best results, the gap should be narrow and even. The easiest way to achieve this is by using standardised material as they ascertain coordinated dimensional tolerances:

- ❖ Manufacturers who produce their tubes and fittings according to the standard, label their products with a manufacturer's mark and a quality mark.



© Conex - Bänninger

Brazing with fittings



Industrial copper fittings achieve the best results in RACHP projects with the required pressure resistance and reliability.



Brazing connections for refrigerant transfer pipes for the use with flammable refrigerants should be done using copper fittings only.

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Brazing without fittings

Swaging and expanding tools

- In addition to brazing with fittings, there are also two cases in which tubing can be brazed without fittings
- Accuracy needed (gap ≤ 0.5 mm for capillary brazing)
- Good for constructing a joint from same sized tubes by making one side larger
- Swaging probably less accurate than expanding (depends on tools)
- Swaging tools are less expensive than expanding tools
- Generally copper tube preparation steps are the same



© ITE Tools

Brazing without fittings

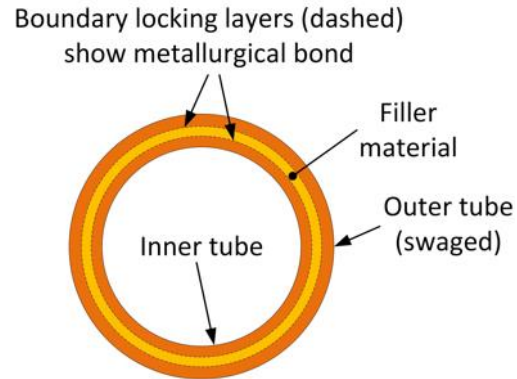
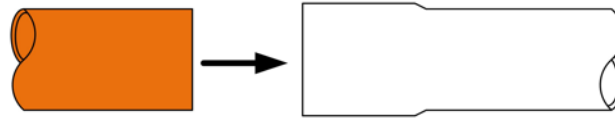
Swaging and expanding process

- Place the tube in correct size hole of swaging/flaring block
- Position tube up of size equal to outside diameter + 3 mm
e.g. 6 mm tube will need 9 mm projection
- Tighten both the wing-nuts of swaging block
- Select punch of suitable size and apply to it a thin film of oil
- Fit punch to clamp and fit this assembly to swaging block just above tube
- Apply force to clamp/punch carefully
- Dismantle above assemblies and remove duly swaged tube from swaging block
- Application of the expanding tool works also without swaging block
- After joint preparation clean tube, remove remaining burrs and prepare for brazing



Brazing without fittings

Swaging and expanding process



Brazing without fittings

Extraction T- pieces and inclined branches tools

- Accuracy needed (gap ≤ 0.5 mm for capillary brazing) as usual
- Tools used: Extractor; cam pincer; and t-piece driller
- Good for constructing of branches from suction or liquid-line headers
- Extracting branches from copper tubes requires accurate working procedures
- Extracting tools are sensitive, require care with maintenance and are expensive
- Generally copper tube preparation steps are the same

These connections are not allowed for RACHP installations using flammable refrigerants.

They are also not allowed with LPG pipes, heating oil installations and gas pipes.



© ITE Tools

Brazing without fittings

Extraction T- pieces and inclined branches process

- In the case of hand-made branches, first a hole is drilled in the header tube and then the T-piece or inclined branch is manufactured with special extracting tools.
- Pincing (two) marks are shaped in order to avoid tube to reach in the flow area of the main pipe
- In this extracted joint, the branched outlet pipe is inserted and finally brazed. The diameter of the outlet pipe must always be smaller than the size of the header.



© Rothenberger

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Brazing operation requirements

Safety matters



Every RACHP skilled worker must be competent in brazing. Brazers need constant practical experience on the job to maintain the required level of skills and quality, and regular retraining.

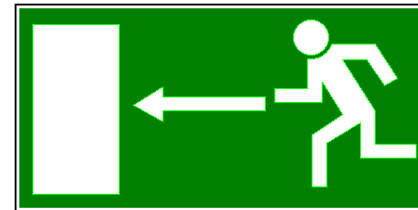
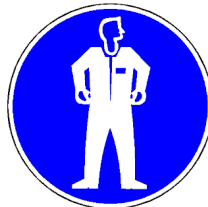
This applies to the use of flammable refrigerants in particular!

Brazing operation requirements

Safety matters

Basic safety requirements during brazing work:

- Accident prevention
- Site safety
- Safety of equipment and tools
- Fire precautions and alarm procedures
- Permission for hot work (if needed)



Brazing operation requirements

Challenges of brazing

Attention: poorly brazed joints may look similar to well brazed joints, but can have **VERY low strength**.

- The metal used to bond the two parts may be different in colour than the parts being bonded. This can present a problem.
- Long-term effects of dissimilar metals in constant contact may need to be examined for special applications.



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Filler metal not entirely penetrated



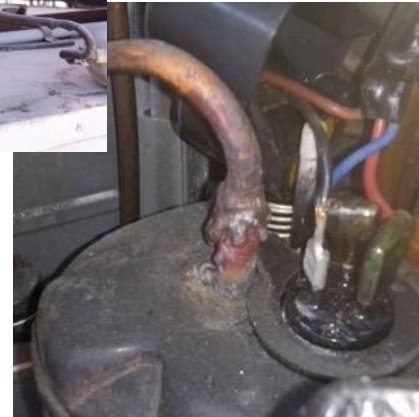
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Overheated joint connection, indicated by small bubbles

Brazing operation requirements

Challenges of brazing

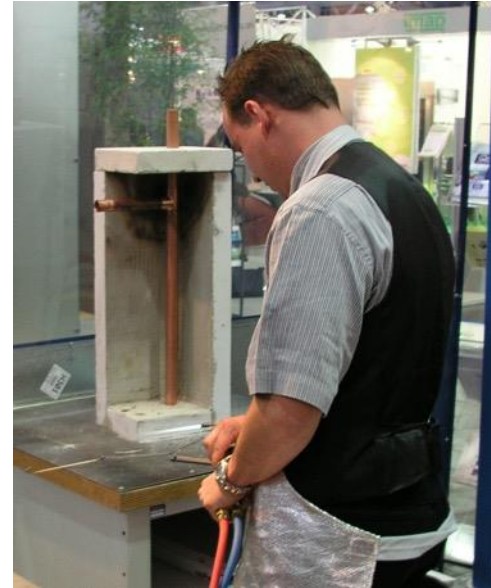
Attention: inadequate competencies and lack of adequate materials challenge generally equipment functionality and tightness and pose hazards to the workers, public and the environment.



Brazing operation requirements

General preparation for brazing

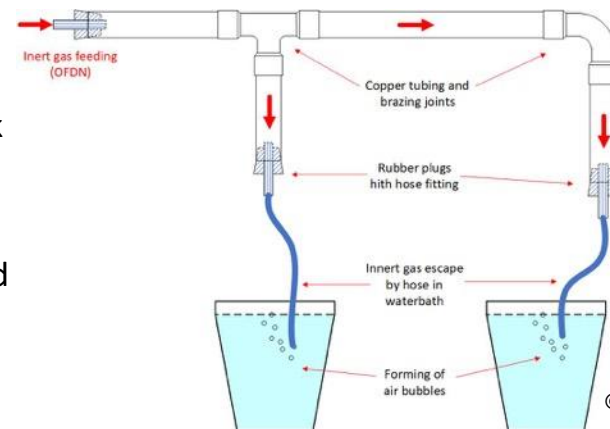
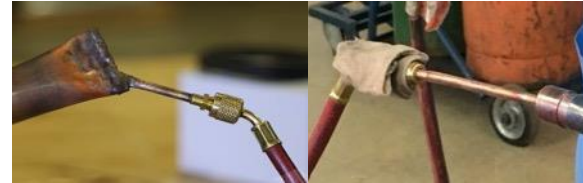
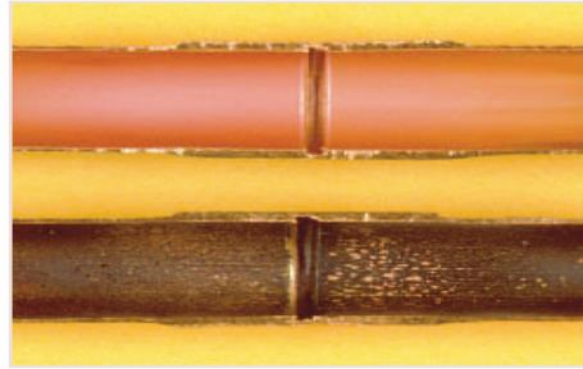
- Assemble all materials needed for brazing. This includes parts, torch, OFDN, flux, solder, fixtures, handling tools, and safety equipment.
- Clean the parts to remove any oil, rust, or other contaminants. Use a wire brush if necessary to remove any rust.
- Assemble and fix the parts in place - the parts need to be stable for a good braze line.
- Ceramic bricks, vice grips, pliers, and clamps must be available at the brazing site for fixtures.



Brazing operation requirements

Brazing with nitrogen

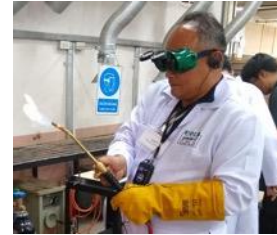
- A refrigeration cycle must be clean, dry and hermetically sealed.
- Humidity and tinder in a refrigeration cycle leads to damage in the compressor and general system failures.
- Interaction with oil, tinder, moisture and high temperatures will cause creation of strong acids.
- Use of Oxygen Free and Dry Nitrogen (OFDN) for inert gas brazing process with very low flow rate (just to displace the oxygen)!
- The use of nitrogen is prescribed by all compressor manufacturers and manufacturers of RACHP equipment.
- Tinder is harmful in interaction with oil and will block filters and valves.
- Use 99.99 OFD purity (technical gas 4.0)
- The use of nitrogen is an approved technical standard in all fields of refrigeration and air-conditioning installation, service and maintenance



Brazing operation requirements

Igniting and adjusting the torch flame

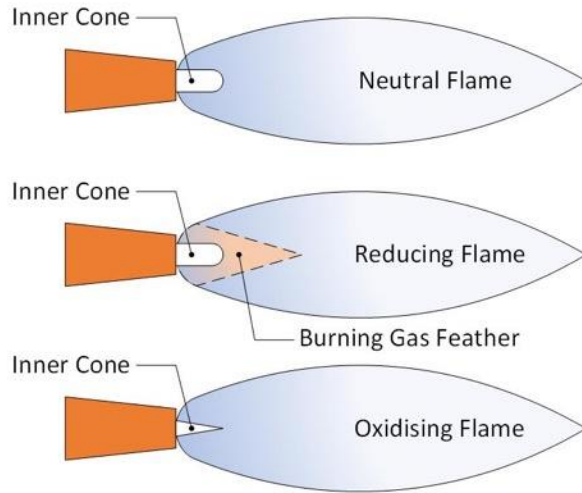
- Flint stone lighters can ignite the torch safely without open flames. They should therefore be always used instead of commercial cigarette lighters (prohibited). **When igniting the flame, no easily flammable objects or materials should be located nearby, and the room should be ventilated. The brazing section should be clearly marked and sectioned off.**
- **To start up a brazing torch with acetylene as the fuel gas, first open the oxygen valve slightly and then the acetylene valve.** Now you ignite the gas mixture at the nozzle and regulate the brazing flame with the valves. If the acetylene will be ignited first without oxygen supply, the strongly sooty flame could impair the brazing torch. When extinguishing, the acetylene valve is closed first.
- **If LPG gas (propane) is used, only the fuel gas valve is opened and then ignited.** Oxygen is only added afterwards.
- The size of the flame is better controlled with the different sized nozzles (tips) rather than with the fuel gas valve.



© PERKEO GmbH

Brazing operation requirements

Types of flames in oxy-acetylene & LPG brazing



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- Neutral flame (3200°C)
Acetylene (C_2H_2) and O_2 are mixed 50/50 and burn at the top of the welding torch. Inner cone gives 2/3rd of the heat whereas the outer envelope provides 1/3rd of the energy.
- Reducing flame (3000°C)
Excess amount of acetylene is used, giving a reducing flame. Combustion of acetylene is incomplete (greenish) between the inner cone and the outer envelope. Good for brazing aluminium alloys, high carbon steels.
- Oxidizing flame (3400°C)
Excess amount of O_2 is used, giving an oxidizing flame. Good for welding brass.

Brazing operation requirements

Extinguishing the torch flame on the brazing unit

For acetylene, when extinguishing, the acetylene valve is closed first.

If LPG gas (propane) is used, the oxygen is also shut off first during flame extinguishing.

- For brazing joints placed vertical on top of each other, brazing is executed from bottom to top.
- When brazing large pipe diameters, the brazing seam is pulled around and the filler material is melted down into zones.
- Care must be taken, that foreign particles are not trapped during brazing. If possible, after the brazing process, the brazed sections should be flushed (and trapped particles are blown out) with OFDN.
- OFDN flow is maintained until the work piece is cooled down

Brazing operation requirements

Acetylene torch “popping” -1-

- Occasionally it happens that the acetylene oxygen flame suddenly goes out with a loud “bang” and ignites again on the hot workpiece and continues to burn normally. This is called the acetylene torch flame flash-back or “popping”.
- The “popping” is a result of the high flame speed and low ignition temperature of the acetylene. The causes can be incorrect flow conditions in the torch attachment, a blocked torch attachment orifice or too low acetylene pressure.
- The remedy is to cool down the torch attachment (in water), clean the torch attachment orifice with the appropriate nozzle needle or increase the acetylene pressure.
- In case of acetylene cylinder burning emergency steps are necessary (including involvement of fire department)



© EIGA

Brazing operation requirements

Acetylene torch "popping" -2-

- It dangerous when the flame "flashes back" into the torch and continues to burn with a whistling noise in the torch mixing tube.
- This releases the energy of the primary flame, which is then missing during brazing, but heats up the handle until the technician lets it fall.
- In order to avoid serious accidents from flashback occurrences it is advised to use **flashback arrestors** inline with the brazing equipment.



If a flashback occurs in an application, the effects can become very dangerous! Bursted handles and hoses, fires at the pressure reducer or in the worst case the explosion of the compressed gas cylinder or the gas tank.



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B4 Brazing Dos and Don'ts

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Brazing the joint

Step 1 – cleaning

Oxide layers and foreign matter such as rust and scales must be removed from the brazing joint either mechanically or chemically.

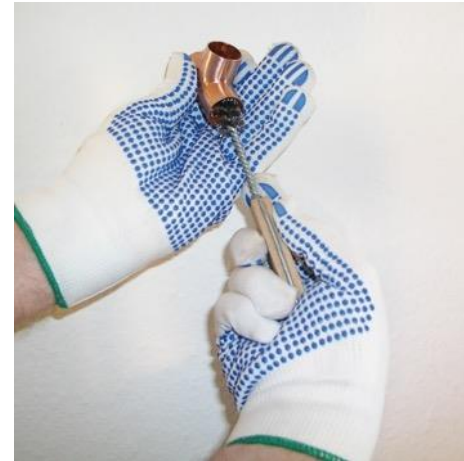
Tools:

- With strong contamination first clean with a rag
- Metal-free cleaning pad
- Metal brush

Thick layers of grease or oil can be wiped off or removed with solvents (e.g. acetone) for sensitive components.

Polished components do not require any cleaning.

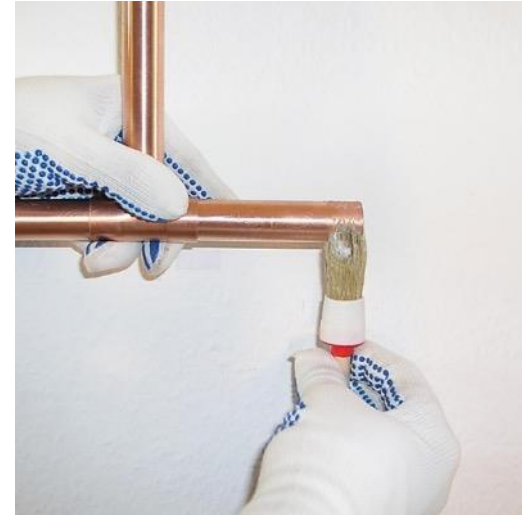
Any remaining oxide will be dissolved by the flux.



Brazing the joint

Step 2 – applying flux

- Decision if flux is required (copper to copper no flux ...)
- The flux paste is applied to the cold work piece using a brush or other suitable equipment.
- The flux is applied with a coated filler material rod (silver-solder)
- Most fluxes are slightly corrosive and skin contact, particularly with wounds, should be avoided.



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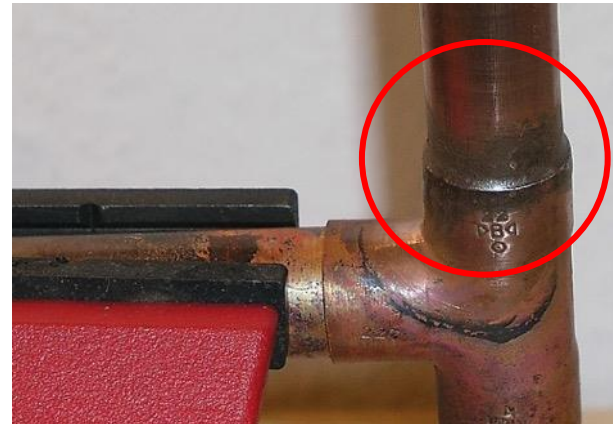
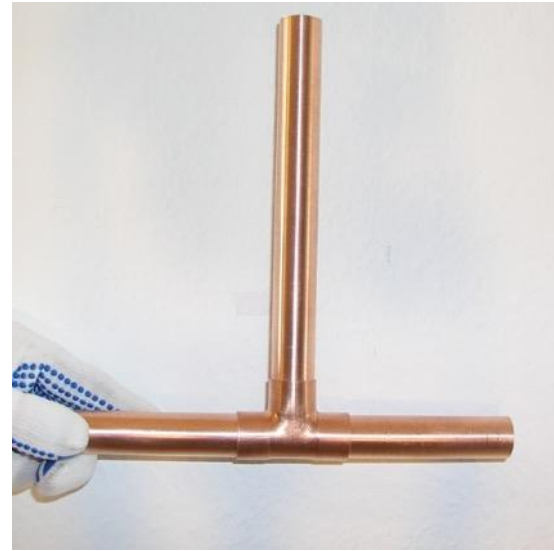
Always wear appropriate personal protective equipment (PPE) as recommended by the manufacturer!

Generally observe the provisions of the MSDS!

Brazing the joint

Step 3 – Fix the workpiece for brazing

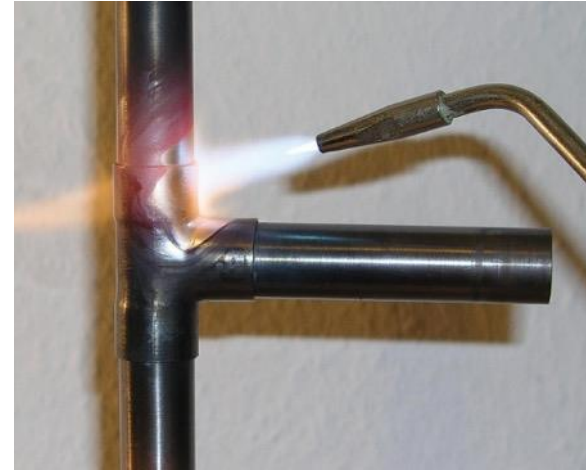
- The parts to be joined must be fixed in the correct position until the brazing filler metals sets.
- A narrow brazing gap of between 0.05 mm and 0.2 mm is to be set whenever possible.
- Maintain OFDN flow for inert gas brazing



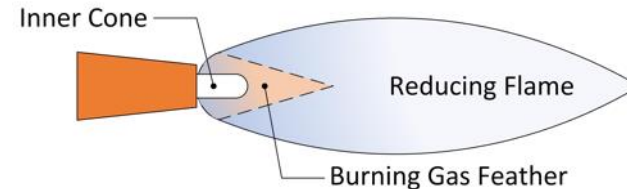
Brazing the joint

Step 4 – heating the brazing joint evenly

- The flame should be slightly reducing – lower oxygen supply.
- The brazing gap must be heated evenly all over to brazing temperature so that the brazing filler metal can fill the gap.
- Place the flame (brushing) over the surface of the part and avoid overheating
- The brazing temperature on the part should be reached in max. 3 minutes for the selected brazing filler metal.
- Inner cone of the flame should not touch the work piece – only the outer zone.



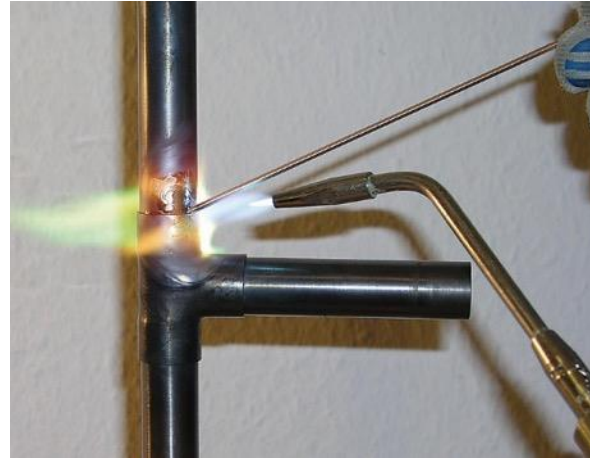
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Brazing the joint

Step 5 – placing the brazing filler metal

- The brazing filler metal can be placed on the brazing gap when the flux is melted to an even transparent layer and when the brazing temperature has been reached.
- Add enough filler material to ensure a good bond line.
- Do not apply the flame directly to the rod, let the temperature of the parts melt the filler material
- The brazing filler metal fills narrow brazing gaps and rises upwards against gravitational force.
- Avoid overheating. This may damage brazing filler metal and the work piece.
- Flux fumes should be exhausted.



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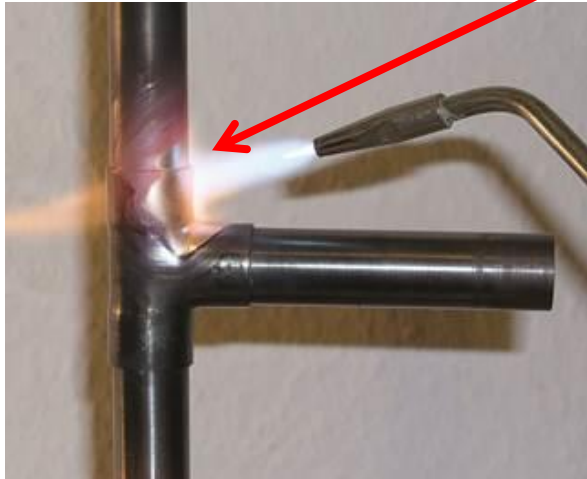


Rule of thumb for filler material quantity:
3 x tube OD

Brazing the joint

Step 5: Applying heat to a filler material / temperature levels

Cherry Red = between 700 and 800°C!
Good for L-Ag5P (copper braze solder)



At slightly higher temperature ($> 700^{\circ}\text{C}$), the copper brazing solder starts to melt, visible by cherry red colour

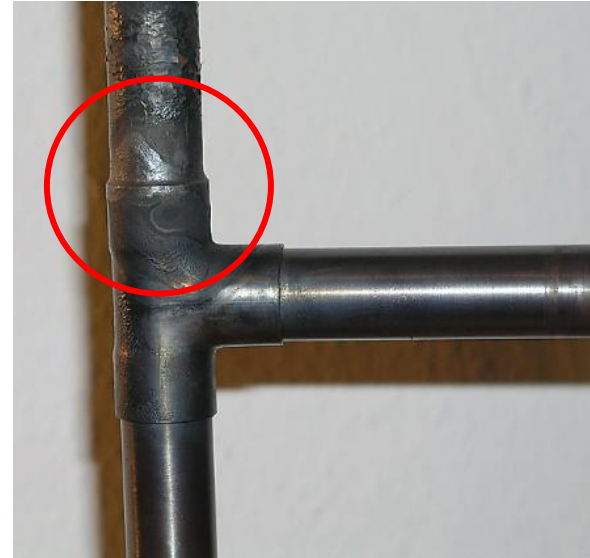


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Phosphor starts to melt at lower working temperature (visible by the greenish flame), working as a flux.

Brazing the joint

Step 6 – cooling down

- When the brazing filler metal has filled the brazing gap, the work piece must be left to cool at the fixture (open air) until the braze metal has solidified.
- OFDN flow is maintained until the work piece is cooled down.
- The component can be removed from the fixture afterwards.



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Brazing the joint

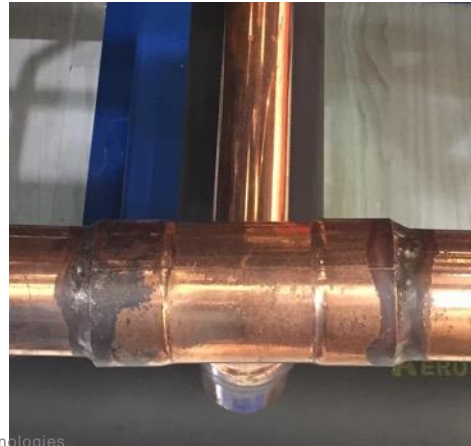
Step 7 – removing flux residues

- Corrosive flux residues have to be removed after brazing.
- As far as possible, remove leftover flux with water or mechanically e.g. with a wire brush.
- Flux residues may lead to corrosion
- Properly brazed joints look smooth and clean and do not require any rework.
- Paint will not stick to areas covered with flux.



Oxidation is already working

✓
Neat and perfect



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 **B4** Brazing Dos and Don'ts

B5 Brazers competency certification

Brazing Dos and Don'ts

- ✓ Before any brazing activity, check equipment for damages.
- ✓ Use clean pipes, remove burrs
- ✓ Always purge with nitrogen when brazing.
- ✓ Protect the service valves with wet rags or heat-reducing material.
- ✓ Use only recommended fillers for various joints.
- ✓ Maintain minimum gap between the joints.

- ✗ NEVER handle brazing equipment with visible damages (hoses and tools).
- ✗ Do not braze within a short distance from combustible gas or oxygen transfer hoses or other combustible materials
- ✗ Do not use unclean metal surfaces for forming the joint.
- ✗ Do not overheat the brazing joint.
- ✗ Do not let flux or water penetrate the inner tubing arrangement.
- ✗ Do not leave unused / unfinished tubing open to atmosphere (close with appropriate plugs).

Key take-aways

- ✓ Mechanical tubing joining technologies, including brazing, are easy if basics craft skills are known and required knowledge is obtained
- ✓ Always use the right tools and materials for different kind of technologies
- ✓ Always maintain OHS standards for all work areas
- ✓ Have the MSDS for commonly used materials and substances available
- ✓ Recognise key advantages of specific joining methods selected for the specific work task
- ✓ Only continuous practical work experience will lead to good results

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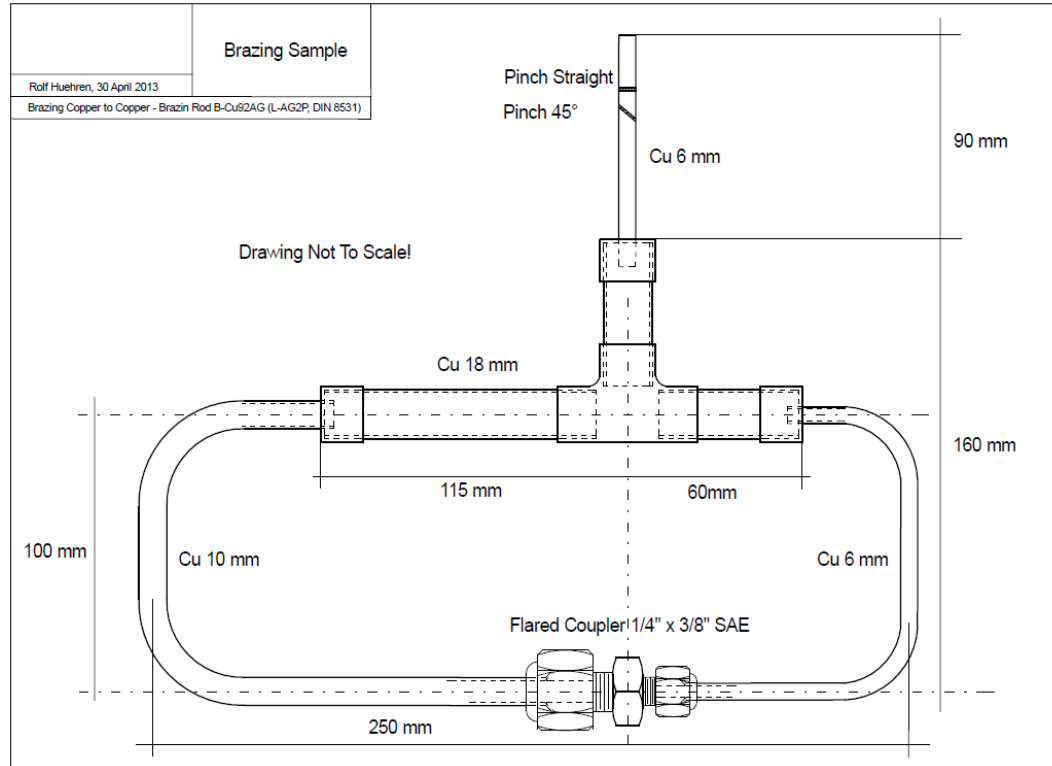
B5 Brazers competency certification

Brazers competency certification

- The international regulation ISO 13585-2012 (replacing EN 13133-2000) describes the essential requirements for brazing qualification and lists terms and conditions, examination criteria, inspection procedures and the area of application for a brazing competency test certificate.
- Required brazing competencies are varied among different RAC sectors (e.g. supermarket refrigeration, air-conditioning or stand-alone appliances). Manufacturer and installation companies therefore may describe specific application and testing requirements.
- Brazing competencies assessment is specific from importance where flammable refrigerants are used in common field practices
- Joint fixation/location: On-site brazing may require a brazer to make joints in close proximity to walls, etc. Joints may be horizontal or vertical. Similar constraints on access for torches may also be encountered in mass production. Qualification tests shall be designed to reproduce these conditions.
- The qualification test shall take place in a workshop but simulate the on-site limitations. It enables the ability of the brazer to perform on-site workshop brazing operations in the selected joining technique to be judged.
- Assessment criteria for the brazing assessment may include: **Visual inspection**, radiographic inspection, ultrasonic inspection, **peeling inspection**

Brazers competency certification

Practical work sample

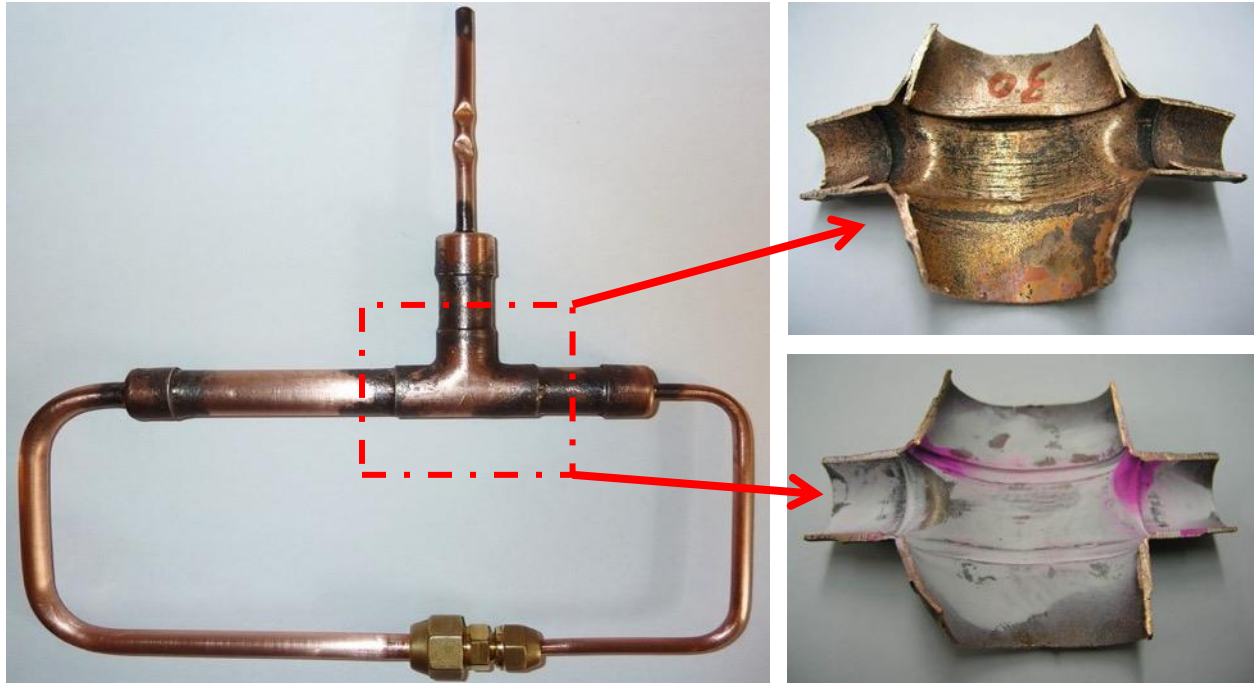


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Brazers competency certification

Qualification test of practical work sample

- For brazing qualification assessment the starting position for the test specimen fixation is pre-defined in order to have equal number of brazing joints in forced position with filler material flow direction against gravity.



Brazers competency certification

Visual inspection, inspection by destruction, peeling test

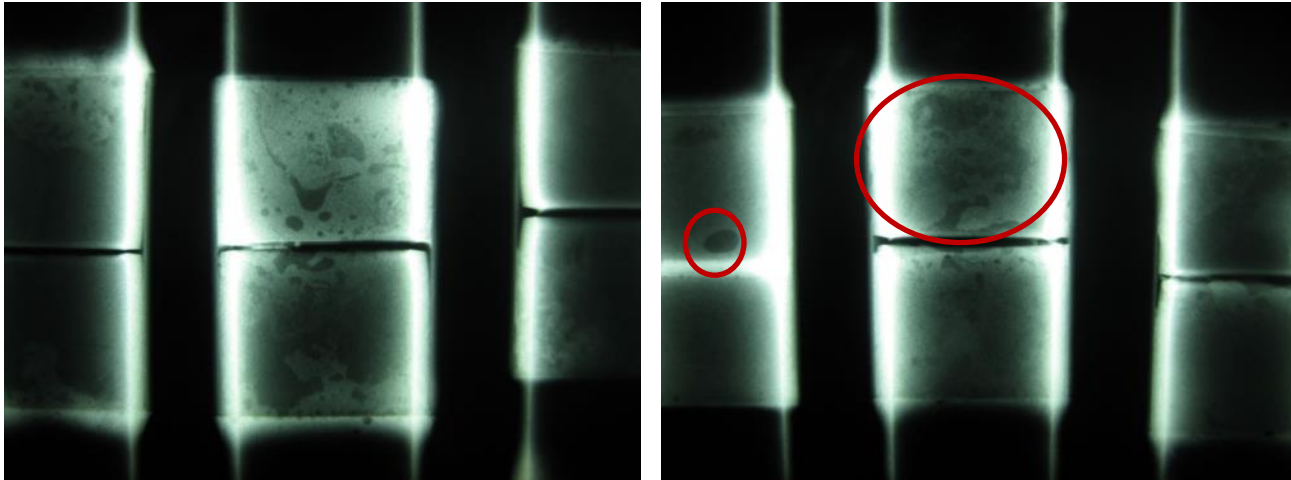


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- Braze solder penetration was not sufficient.
- This failure could result in a reduced pressure stability as well as a reduced stability against vibration.

Brazers competency certification

Brazing testing method / X-ray test

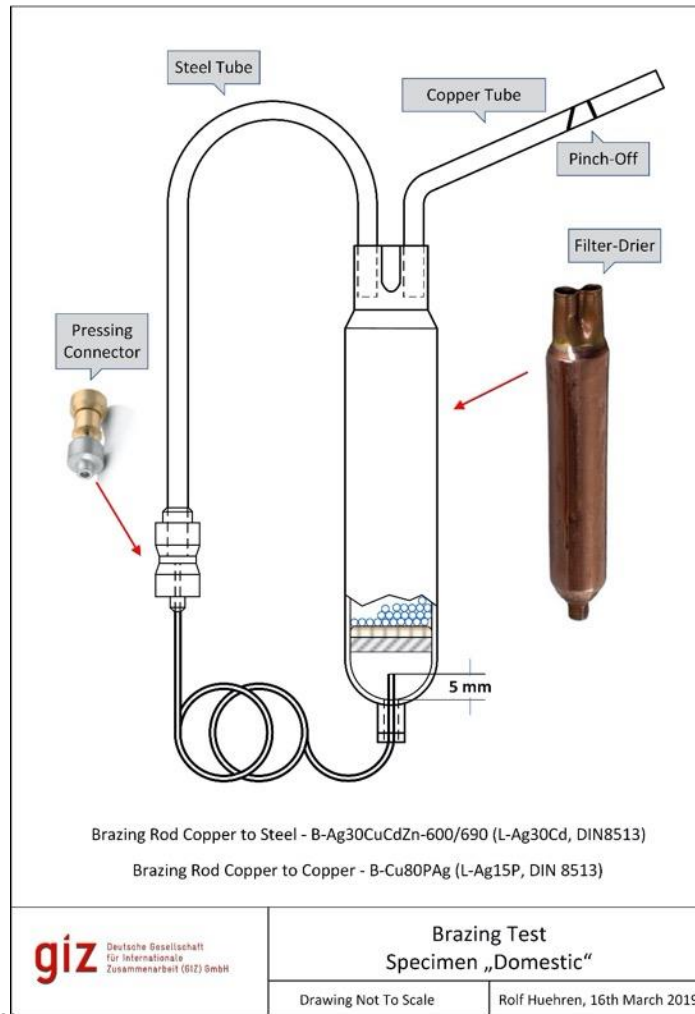


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- X-ray test makes a quality test possible without destroying the pieces.
- Easy to see inclusions
- Testing procedure is expensive

Brazers competency certification

Domestic refrigeration qualification test specimen



Thank you for your attention



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