



Module B: Refrigerant circuit joining technologies

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Introduction to the Refrigeration & air conditioning training guide

The refrigeration, air-conditioning and heat pump (RACHP) sector is facing many changes over the next years. Many refrigerants currently used will be phased-out or phased-down in the close future under the Montreal Protocol and its Kigali Amendment because of their harm to the environment. This includes their ozone-depleting and climate-damaging properties. Additionally, the energy efficiency of a unit is becoming more and more important. For skilled workers in the RACHP sector, this results in many challenges as new technologies are entering the market.

There are several risks from working in the RACHP sector. On the one hand, environmental harm can be caused through the release of ozone-depleting and climate-damaging refrigerants during operating and servicing. On the other hand, the personal safety of the skilled workers handling the equipment and refrigerants as well as the safety of users of equipment has to be ascertained. Dangers include intoxication, refrigerant burns, suffocation, fire and explosion as well as electrical faults leading to fires and electrical shock or bad practice installations causing refrigerant leakages.

The reduction of greenhouse gases such as hydrofluorocarbons (HFCs) typically requires a combination of technology change, regulatory action and human capacity development. The technical characteristics of refrigerants change dramatically in view of their flammability, toxicity and/or operating pressure level with the transition from the predominantly used hydrochlorofluorocarbons (HCFCs) and (saturated) HFCs with high global warming potential (GWP) to climate friendly refrigerants, including natural refrigerants and a number of unsaturated HFCs (HFOs) with very low GWP.

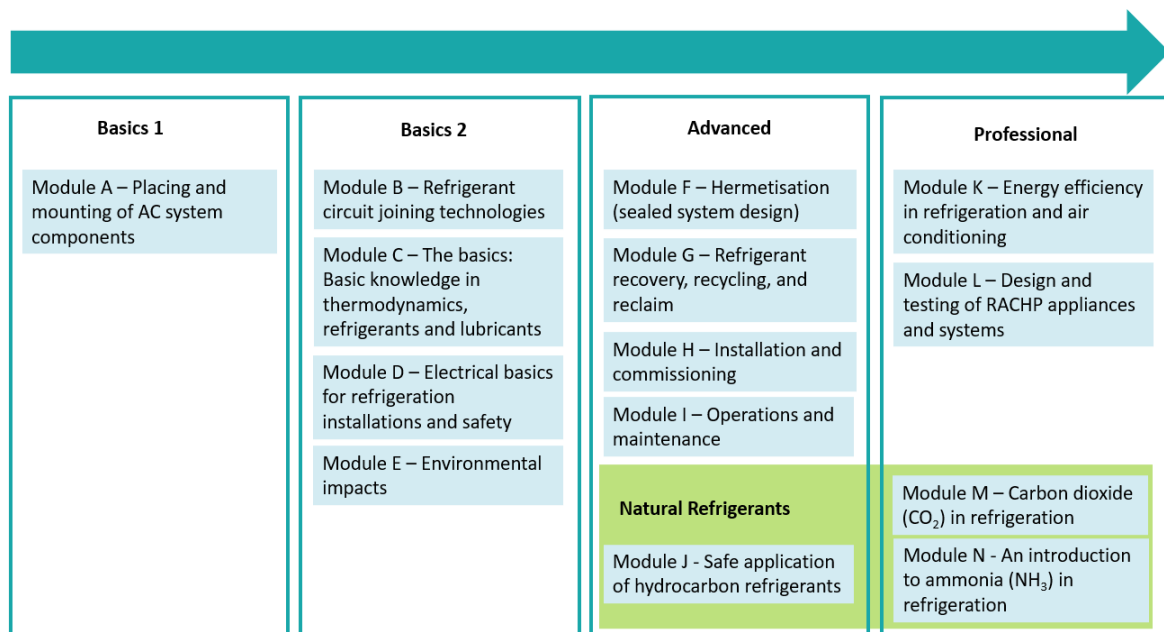
This module on brazing and other refrigerant circuit joining technologies is one part of a series of training modules on best practice guidelines in refrigeration and air conditioning, published by GIZ. Together, the modules form the basis for qualified work of skilled workers and address the mentioned challenges in the RACHP sector. The module content is based on international standards regarding the training of RACHP skilled workers as well as product and general RACHP safety standards. The set of modules range from basic knowledge necessary for skilled workers as well as more advanced qualifications involving the refrigerant circuit and professional level modules (see figure below), for example on energy efficient design or ammonia refrigeration. A good basis is necessary before starting on advanced modules.

The modules can be used to support a national quality infrastructure based on approved best practice codes and international standards. Essential instruments for its implementation include qualification, certification, accreditation, registration, monitoring and financial incentive schemes. Certification of skilled workers and companies is essential to sustainably increase competencies in the RACHP sector. Certification should always be linked to examination by an accredited institution and registration in a country database. Previously determined skills to assess are the basis for certification and an example is contained in the presented modules. The content of the modules is based on skills to assess in standards ISO 22712/EN 13313: Refrigerating systems and heat pumps – Competence of personnel.

Module B: Refrigerant Circuit Joining Technologies

The following modules are available:

Module A	Placing and mounting of AC system components
Module B	Refrigerant circuit joining technologies
Module C	The basics: Basic knowledge in thermodynamics, refrigerants and lubricants
Module D	Electrical basics for refrigeration installations and safety
Module E	Environmental impacts
Module F	Hermetisation (sealed system design)
Module G	Refrigerant recovery, recycling, and reclaim
Module H	Installation and commissioning
Module I	Operations and maintenance
Module J	Safe application of hydrocarbon refrigerants
Module K	Energy efficiency in refrigeration and air conditioning
Module L	Design and testing of RACHP appliances and systems
Module M	Carbon dioxide (CO ₂) in refrigeration
Module N	An introduction to ammonia (NH ₃) in refrigeration



In addition to this handbook, further material for trainers is available, such as trainer manuals, PowerPoint presentations, training agendas and handouts.

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Pictures and figures for this module have been provided by Vulkan Lokring, Perkeo, Rothenberger, ITE tools, Conex/Bänninger and Rolf Hühren (HEAT GmbH).

Module B: Refrigerant Circuit Joining Technologies

Symbols

The following symbols are used to structure the text and highlight important messages:



Incorrect uses or work processes are highlighted by a red x.



Correct uses or work processes are highlighted by a green check mark.



See chapter xxx

Textbox referring the reader to a different chapter



How to

Referring to instructions describing work routines



Safety relevant message



Message with direct relevance to flammable refrigerants

Other signs used in the document:



Electricity



Explosive materials



Asphyxiation

Black text boxes highlight specific topics or additional information.

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Learning outcomes of this module

In this module you will learn about the basics of refrigerant circuit joining technologies (in specific copper joining), understand the importance of high-quality brazed joints and the differences between detachable or non-detachable joints. You will also acquire an overview of the right brazing materials and tools for specific purposes. Last but not least, you will become familiar with the required safety precautions and the use of Personal Protective Equipment (PPE).

Basics 2 level	
Knowledge	<p>Participants acquire knowledge in:</p> <ol style="list-style-type: none"> 1. Describe and use state of the art technologies and general accepted code of practices for detachable and non-detachable refrigerant circuit joining methods 2. Know about observation and application of measures for occupational health and safety (OHS) and accident prevention regulations. 1. Know about observation and application of environmental protection and rational use of material resources and energy 2. Understanding of the legislations and standards applicable in the region of installation and operation 3. Know how to carry out an assessment, be able to demonstrate the safe use and handling with considering the characteristics of subjects like piping, joints, valves and pipe supports. 4. Acquire understanding of risks related to the use of fuel gases and compressed gases and develop basic understanding of safety precautions required for the handling of materials, tools and equipment. 5. Learn how to fill in the equipment records with all relevant information concerning the work specific task.
Skills	<ol style="list-style-type: none"> 1. Weld or braze leak-free joints on metallic tubes, pipes and components that can be used in refrigeration, air- conditioning or heat-pump systems 2. Use of brazing fuels and oxygen 3. Create piping and components joining connections with the use of pressing equipment 4. Use of Oxygen Free and Dry Nitrogen (OFDN) 5. Make/check pipe and component supports

List of abbreviations

Acronym	Definition
ASTM	American Society for Testing and Materials
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFO	Hydrofluoroolefins
LMRA	Last Minute Risk Assessment
LPG	Liquefied Petroleum Gas
MAC	Mobile Air-Conditioning
MSDS	Material Safety Data Sheets
OFDN	Oxygen Free Dry Nitrogen
OHS	Occupational Health and Safety
PPE	Personal Protection Equipment
RACHP	Refrigeration, Air Conditioning and Heat Pump
SAE	Society of Automotive Engineers

B1 Joining technologies overview

In RACHP applications, it is of utmost importance to avoid any leakage of refrigerant, both for technical and environmental reasons. You therefore need to know the various types of joining methods, choose the right method and be able to apply it in order to reliably connect refrigerant transfer tubes and circuit components. Depending on the type of application, there are different ways to join transfer tubes and components. In various cases also a mix of connection technologies are possible.

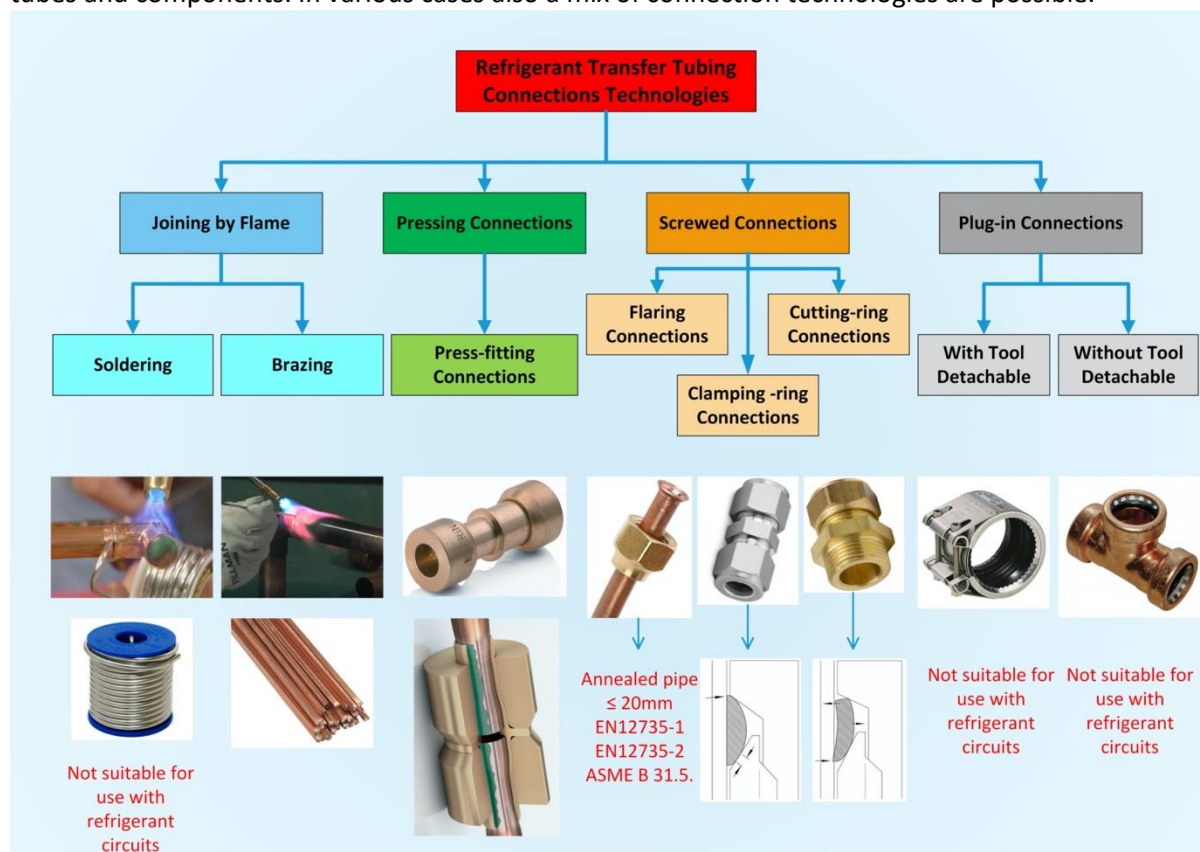


Figure 1-1: Refrigerant transfer tubing connections technologies (Source: HEAT GmbH)

☞ The focus of this module is on brazing, which is described in detail in chapters B2 to B5.

In addition, pressing connections for domestic refrigeration as provided by Lokring, are described in chapter B6.

B1.1 International standards regarding RACHP tubing

The 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).

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- For durable and reliable copper tube joining, fittings should be used according to EN 1254–1 (up to 108 mm diameter).
- Using filler metals compliant with the following listed standards is the preferred method for making non-detachable joints.

Other related standards:

- 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 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
- EN 14276-1:2011-05; Pressure equipment for refrigerating systems and heat pumps - Part 1: Vessels
- DIN2607:2002-5; Tube bends - For butt-welding of copper
- 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

Generally, the parent metals subject to brazing in RACHP shall conform to the requirements of the relevant standard for the application mentioned above.

Important subjects are:

- Copper and copper alloys. The specification covers seamless (refrigeration and air conditioning grade) copper tubes in soft, half-hard and hard tempers, suitable for use in the RACHP industry.
- Ferrous and non-ferrous metals including mild steel, carbon and low alloy steels, alloy steels, stainless, heat and corrosion resistant steels and brass.

B1.2 Classification of mechanical joining technologies

For joining at least two or more components there are basically three types of joining methods, which are based on different physical principles.

1. a positive locking connection (connection is made by the use of a minimum of two partners)
2. a frictional or non-positive connection (static friction)
3. a substance to substance material connection (atomic or molecular bond).

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The connection should prevent separation of the bodies under the forces acting during operation and hold them reliably in place. Joining of component can be either non-detachable, which means that the two components can only be separated by destruction after having been connected. Or they can be semi-detachable/detachable, where the connection can be undone and reused.

Which method is used depends on the purpose.

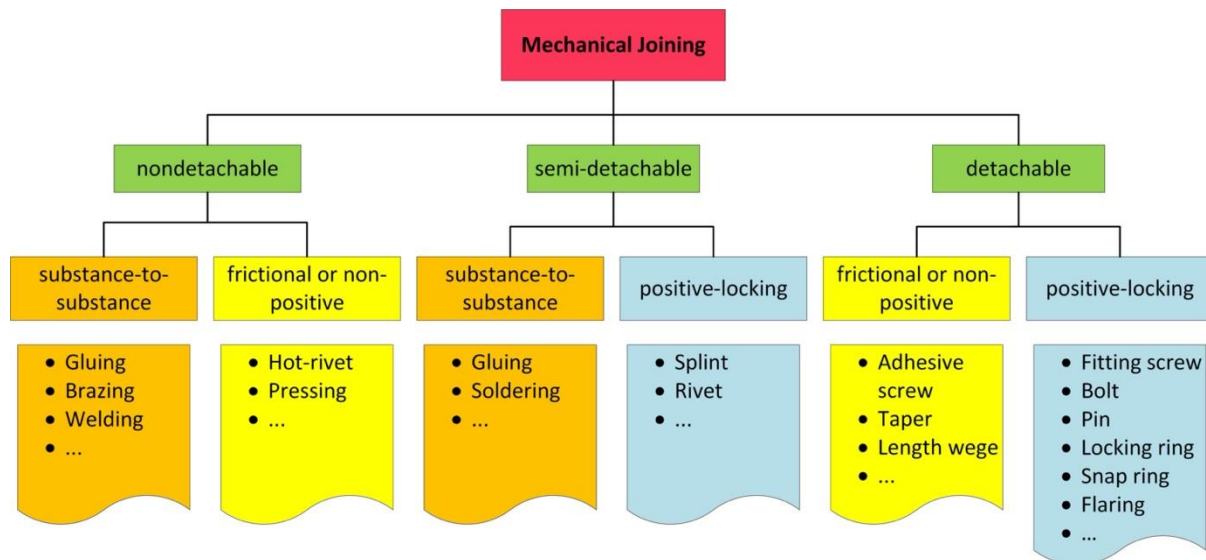


Figure 1-2: Systematic classification of mechanical joining technologies (Source: HEAT GmbH)

B1.2.1 Positive locking connections

To explain it simply, the components involved in a **positive locking connection** are in each other's way, effectively preventing loosening when operating forces are applied. The positive locking is achieved either by interlocking at least two work piecework pieces or by inserting a connecting element. These may include, for example, pins, bolts or even rivets.

The positive-locking connection is characterised by the fact that in the case of a load, forces act which are perpendicular to the opposing surfaces of the connecting partners.

In addition to riveting, this also includes, for example, the tongue-and-groove connection, the zipper, feather keys, shaft-hub connections or interlocking gears (gear wheels). For RACHP technologies, **flaring** is also considered as detachable positive-locking connection (see chapter B1.2.1.1).

B1.2.1.1 Flaring connections

According to EN378-1:2016 (and ISO5149-1:2014) a **flared joint** is a metal-to-metal compression joint in which a conical spread is made on the end of the tube.

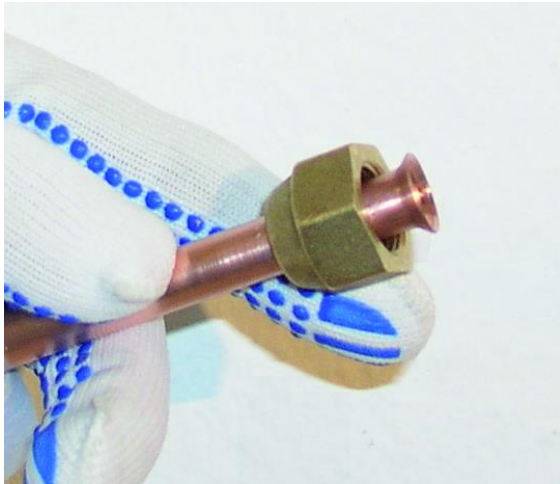


Figure 1-3: Flared connection for refrigerant transfer tubes (Source: HEAT GmbH)

➡ Further explanations of flared joints and manufacturing processes are provided with Module J, chapter J8.6.2.

Flared joints are not considered as “hermetically sealed connections”. According to European F-Gas regulation (Regulation (EU) No 517/2014), “**hermetically sealed equipment**” means equipment in which “all fluorinated greenhouse gas containing parts are made tight by welding, brazing or a similar permanent connection, which may include capped valves or capped service ports that allow proper repair or disposal, and which have a tested leakage rate of less than 3 grams per year under a pressure of at least a quarter of the maximum allowable pressure”.

Therefore, refrigeration systems in which refrigerant containing parts are connected by flanges, screw connections and/or flares or which contain semi-hermetic compressors are not regarded as hermetically sealed systems as defined by this Regulation. Schrader valves are permissible as secured valves.

B1.2.1.2 Quick Coupling devices / gas hose couplings

Gas hose couplings / quick couplings are used in industry and trade and belong to the group of detachable positive locking connections.

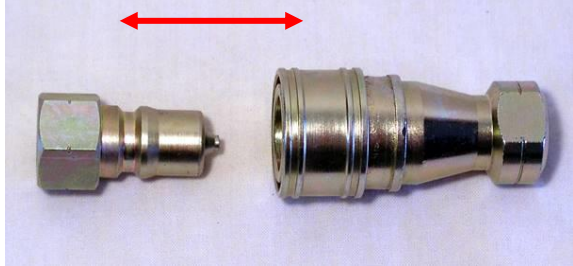

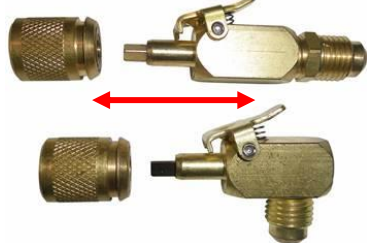
Quick couplings are required to supply machines or parts of machines (e.g. refrigerant circuit components) with gaseous and liquid substances.

The design depends on the intended use, the substance transferred in the transfer line (refrigerant, air, OFDN, oil, solvent, etc.) and the pressure conditions prevailing in the transfer line (vacuum or overpressure).




Split systems assembled by means of quick-acting couplings (see next chapter) shall not be considered as hermetically sealed installations irrespective of compliance with the tested leakage rate of less than 3 grams per year. Even if these quick-connect connections are transformed into irreversible connections during assembly, the equipment cannot be considered "hermetically sealed". The decisive factor is that an installation, i.e. a connection of two refrigerant-containing pipes, is carried out at the place of its future operation.

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With gas hose couplings (one-hand quick couplings), tools can be connected or hose lines extended quickly and without the use of specific tools. The gas hose couplings are available in various designs and for many technical gases including refrigerants, fuel gases and compressed air. Gas hose couplings are generally manufactured according to EN 561:2002-9 and are coded for different types of gas (fuel gas, oxygen or non-flammable gases).

 <p>Figure 1-4: Push-pull quick coupler for refrigerant and compressed gas transfer (Source: HEAT GmbH)</p>	<p>Push-pull quick coupler (HANSEN) for refrigerant and compressed gas transfer.</p> <ul style="list-style-type: none"> ➤ Ensures maximum flow when flushing refrigerant circuits. ➤ Suitable for pressure tests, evacuations as well as for refrigerant charging. ➤ Quick connection can be installed fast and tight during production, installation and servicing or RACHP systems. ➤ Ensures accurate and reliable handling on refrigerant circuit components under pressure and with very low refrigerant emission.
 <p>Figure 1-5: Push-pull quick coupler in combination with copper tube quick connector (rubber gasket) and 1/4" female SAE refrigerant hose connection (Source: HEAT GmbH)</p>	<p>Push-pull quick coupler for refrigerant and compressed gas transfer.</p> <ul style="list-style-type: none"> ➤ Quick coupler as shown with figure 1-4 ➤ Additional copper tube attachment with squeezing screw connection (rubber gasket) and 1/4" SAE refrigerant hose connector ➤ Use for refrigerated appliances manufacturing and servicing
 <p>Figure 1-6: Refrigerant transfer hose push-pull connector in small construction form for one-hand use (Source: ITE)</p>	<p>Refrigerant transfer hose push-pull connector in small construction form for one-hand use.</p> <ul style="list-style-type: none"> ➤ Male and female adapters are available for different hose and refrigerating system connection threads. ➤ These connectors are recommended for the work on domestic or commercial stand-alone refrigeration system and small split air-conditioning systems.

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 <p>A black cylindrical quick connector with a threaded end on the left and a straight end on the right. A red arrow points to the straight end with the label "Fixation".</p> <p>Figure 1-7: Copper tube quick connector for straight copper tube connection (Source: ITE)</p>	<p>Copper tube quick connector for straight copper tube connection.</p> <ul style="list-style-type: none">➤ Seal the entire circumference of the pipe.➤ Ensure maximum flow when flushing refrigerant circuits.➤ Suitable for pressure tests, evacuations as well as for refrigerant charging.➤ Mainly used for work on domestic or commercial stand-alone refrigeration system.
 <p>A manual quick coupler with a blue knob and a silver body, surrounded by several brass adapters and O-rings. A red arrow points to the coupler.</p> <p>Figure 1-8: Quick coupler with different connection adapters for the use on MAC systems (Source: ITE)</p>	<p>Manual quick couplers (colour coded) for the use on automotive air-conditioning refrigerant circuits.</p> <ul style="list-style-type: none">➤ Manual couplers adjust easily to service ports with varying dimensions.➤ Spring loaded depressor mechanism for service valve opening.➤ Can be removed from service ports regardless of knob position without losing refrigerant.
 <p>Two brass screwable quick connection systems are shown attached to a white panel. A red arrow indicates the direction of rotation for the screwable part.</p> <p>Figure 1-9: Screwable quick connection system for split air-conditioner or general refrigerant circuit use (Source: HEAT GmbH)</p>	<p>Screwable quick connection system for split air-conditioner or general refrigerant circuit use.</p> <ul style="list-style-type: none">➤ Suitable for pressure tests and RACHP system evacuation. Ensure maximum flow for refrigerant circuits operation.

B1.2.2 Frictional or non-positive connection

With a **frictional or non-positive connection**, the movement of the bonding partners is prevented by static friction. Friction requires normal forces, i.e. forces acting perpendicularly to the surfaces of the components to be joined. The normal forces press components against each other, so that when the components are pulled apart, static friction occurs which counteracts the movement.

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The shifting is prevented as long as the forces resulting from the static friction are not exceeded. Should this occur, however, the surfaces pressed against each other will glide.

Imagine clamping and holding an object between thumb and index finger – this is considered a frictional, non-positive connection. The knotting of ropes or laces, but also any clamping or screwed connections are frictional, non-positive connections as well.



Pressing as described in chapter 6 on Lokring pressing connections is considered a non-detachable, frictional, non-positive connection.

B1.2.3 Substance-to-substance connection

A **substance-to-substance connection** is characterized by the fact that the components to be joined are connected to each other by atomic or molecular bonds. This also explains the fact that this type of connection can only be loosened by destroying the connection.

Within this group, the joining processes can be further differentiated by whether the joint is produced by the filler metals of the same type or of a different type.

For RACHP technologies, **brazing**, **welding** and **gluing** are the most common substance-to-substance components joining methods. Advantages of these processes are the usually high transferability of forces (like pressure) and the small space requirements.

However, not every material is suitable and often complex pre-treatment steps are required for specific components joining methods (e.g. gluing, copper to aluminium and copper to brass brazing).

B1.3 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.

At the correct temperature, the molten solder flows between the two metal parts.

Under favourable conditions, a solid, tight and pressure resistant, corrosion-resistant, current- and heat-conducting connection is formed between the solder and the metals.

B1.3.1 Classification of brazing and soldering processes

B1.3.1.1 Classification according to soldering temperature (working temperature)

With other words, the *liquidus temperature of the filler material (solder) is decisive for the classification:

- up to 450°C: > soft soldering
- from 450°C: > brazing
- above 900°C: > high-temperature soldering (in vacuum or under inert gas; see ISO 857-2:2007-03 - Welding and allied processes - Vocabulary - Part 2: Soldering and brazing processes and related terms)

The application decides on the method used.

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* The liquidus temperature indicates the temperature of an alloy or glass below which the mixture of a homogeneous liquid phase begins to solidify. The temperature reached during homogeneous solidification, on the other hand, is called the solidus temperature.

Note: Brazed joints generally have a lower strength than welded joints, but almost always a higher strength than soldered joints.

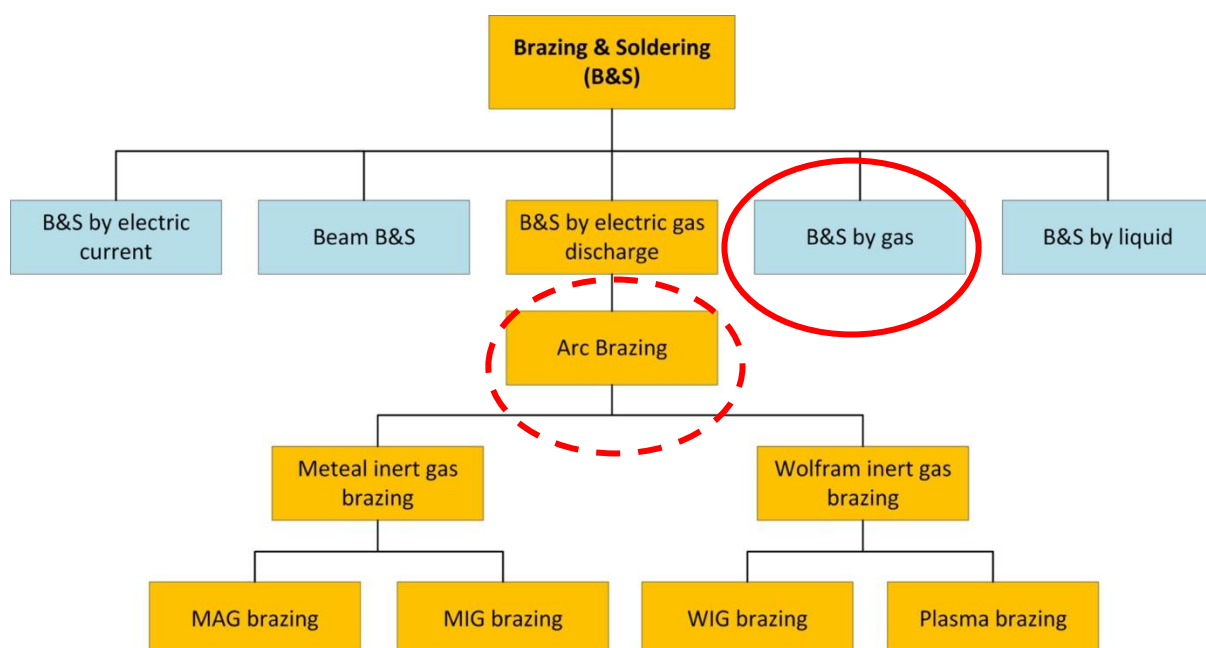


Figure 1-10: Classification of thermal joining methods by type of energy source (ISO 857-2:2007-03). Methods encircled in red represent applications commonly used in refrigeration technology (Graph: HEAT GmbH).

The common way to join refrigerant transfer tubing and circuit components is brazing with the use of a gas flame (also known as flame brazing). Arc welding processes are also possible for RACHP applications but found more in industrial refrigeration applications or appliances manufacturing.

B1.3.1.2 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 trough: Beam (e.g. laser) and electric current.

B1.3.1.3 Classification of the soldering processes according to the type of soldering joint:

- Soldering - coating of a work piece by soldering
- Joining soldering - Joining of one or more work pieces by using a solder.
The gap width (solder gap) influences the solder selection.

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Depending on the soldering gap it is called gap soldering (gap width < 0.5 mm) joint soldering (gap width > 0.5 mm).

The solder manufacturers recommend a gap width of 0.05 mm to 0.25 mm!

B1.3.1.4 Classification of soldering processes according to type of solder feeding:

- Soldering with solder attached,
- with solder attached or inserted,
- with solder depot,
- with solder coated parts
- and dip soldering.

B1.3.2 Welding (Arc brazing) of copper tubes

According to EN 378-2:2016 and ISO5149-2:2014, welding is also permitted but requires generally an additional examination (certification) beside the qualification as a refrigeration craftsman.

The purpose of the welder examination is to secure the quality of welding works. In the "regulated area", e.g. for pressure equipment, the use of certified welders is prescribed. In the "non-regulated area", the requirements of product liability require sufficiently qualified personnel.

Depending on the component design and construction, the body responsible for the area of application (regulated area) or the client (non-regulated area) requires the use of certified welders.

Like other metals, copper can also be welded (also known as arc brazing).

Arc brazing differs from conventional brazing techniques in the following ways:

- The heat source is an electric arc.
- No Flux is required, since 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.

However, the very specific properties of copper and copper alloys must be taken into account when welding.

The special features of copper during welding

For copper tube welding, a nominal wall thickness of at least 1.5mm (or more) is recommended. However, copper welding is mainly used for large diameters.

Welding copper is similar to welding steel, but it is more difficult because copper conducts heat better than steel and because copper has a melting point and no melting range.

To reach and maintain the working temperature at the weld, a higher heat input is required than for steel. If the heat input is too low, the required working temperature will not be reached; if the heat input is too high, the weld will melt away.

Welding copper therefore requires some practice and experience. Welding is usually first taught and learned on steel. With proficiency in steel welding, one has the prerequisites to consider the peculiarities of copper welding. Copper and steel welding certifications are in most cases obtained separately after the successfully completed training as a RACHP craftsman.

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There are essentially two possible methods for welding copper:

Gas fusion welding: In gas fusion welding with an acetylene-oxygen torch, the weld metal is shielded against atmospheric oxygen by the scattered flame.

Gas shielded arc welding (MIG or TIG welding): In shielding gas welding with an electric arc, an outflowing shielding gas (inert gas) provides this shielding. Depending on which gas is used, this is called either TIG welding (tungsten inert gas) or MIG welding (metal inert gas).

- In MIG welding, the arc burns between a melting wire electrode and the work piecework piece.
- In TIG welding, the tungsten electrode does not melt, but the filler metal is fed manually into the melting zone.

The material SG-CuAg (99% copper, 1% silver) according to ISO 24373:2018-11 is particularly suitable as a filler material for gas melting and TIG welding.

The filler material SG-CuSn (99% copper, 1% tin) according to ISO 24373:2018-11 is particularly suitable for MIG welding.

Fluxes are not required for welding, but fluxes based on boron compounds can be used (FH 21 or FH 30).

For the welded joint, the butt joint (I-seam) is selected as the seam form.

Fittings are available for bends (welding bends), T- and inclined branching's are to be produced by necking.



The welding of gas pipes and high-pressure pipes may only be carried out by a certified welder (welding examination according to EN ISO 9606-3:1999 Approval testing of welders - Fusion welding - Part 3: Copper and copper alloys).



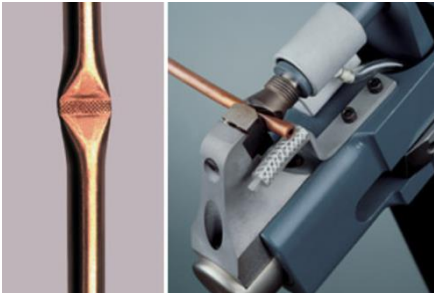
Figure 1-11: Copper fitting for welding (Source: Conex/Bänninger)



Figure 1-12: Example of welded copper tube joint (Source: HEAT GmbH)


B1.3.3 Flame joining (soldering & brazing)

Soldering and brazing are used in RACHP production, installation and servicing. These methods work with thermal input to create a reliable connection of refrigerant transfer tubes. Very generally, heat is introduced by means of a soldering iron, the flame of a brazing (soldering) torch, hot air, hot steam, heat radiation, laser or induction, in some cases also by ultrasound, electron beam or an arc (arc brazing). For example, today's industrial sealing of process tubes (charging stub) during the production of domestic refrigerators after charging them with flammable refrigerant is executed by ultrasound technology.

 <p><i>Figure 1-13. Example of ultrasonic brazing (welding)</i> (Source: Sonobond ultrasonics)</p>	<p>Ultrasonic refrigerant transfer tube sealing:</p> <ul style="list-style-type: none">➤ Ultrasonic copper and aluminium tube brazer➤ seals refrigerator/air conditioner tubing in refrigerant charged condition and produces quick and airtight bonds without the use of a flame.
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Our main focus for thermal joining in RACHP production, installation and servicing technologies is on the thermal joining by gas and flame.

Flame joining is a modern and economical process that can be mechanised and, unlike furnace brazing, requires little equipment. It has established itself wherever welding of different materials is difficult or even impossible.

 <p><i>Figure 1-14: Example of furnace brazing application</i> (Source: Bluewater thermal solutions)</p>	<p>Furnace brazing:</p> <ul style="list-style-type: none">➤ This technology is used mainly for industrial production processes and for the preparation of assembly products subject of further assembly processes and the machinery manufacturing.
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Flame joining in general is a thermal joining process for metallic materials that are joined with a filler material (solder alloy). The base materials remain solid and the combined materials can be largely dissimilar.

The flame melts the filler material, which then forms the joint. A suitable flux dissolves the surface oxides of the work parts and ensures good wetting behaviour of the filler material.

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Most commonly used, the intensive and powerful acetylene-oxygen flame for flame-joining ensures short warm-up times, especially for materials with high thermal conductivity, such as copper and copper alloys. However, other fuel gases like propane, methane and MAPP gas can also be used. The acetylene/oxygen flame is advantageous for certain components.

Advantages of the flame joining process:

1. Joining of different materials possible
2. High degree of mechanisation
3. Simple device handling
4. Easy availability of the necessary energy
5. Effective shielding of the solder joint by the flame
6. Good regulation of heat supply

What are the capabilities of flame-joining?

Whether a work piece can be joined by flame essentially depends on three properties of the work piece that is to be subject for joining:

1. **Suitability:** This depends on physical, metallurgical and chemical properties. The materials can be divided into 3 groups:
 - a) Materials that can be joined by conventional methods using a standard filler material and standard flux. (e.g. precious metals, nickel and nickel alloys)
 - b) Materials that can only be joined by a special filler material and a special flux. (e.g. carbides, chromium, ...)
 - c) Materials that can only be joined with special filler material, special fluxes and special processes.

The flame-joining suitability is better the less the material-related factors have to be considered as a precondition for the flame-joining execution of a specific construction.

2. **Flame joining possibilities:** This is a property that determines the preparation, finishing and execution of the flame-joining process. This can be, for example, the choice of the right flux.
3. **Flame-joining safety:** This is determined by the operating conditions and loads (temperature, corrosion, ...). Flame-joining safety is a design property. Safety is greater the less material combination, flame-joining conditions and component requirements have to be taken into account.

B1.3.4 [Flame brazing](#)

Flame brazing is one of the most commonly used methods of brazing. It is used both manually and with fully automated flame-joining systems for a wide variety of materials and applications. The torches used for flame brazing are operated with different flammable gases (e.g. hydrogen, acetylene, propane, etc.). There are also different types of oxygen supply (e.g. pure oxygen, compressed air, intake air) and various torches designs to achieve optimum heating depending on the component to be brazed.

Applications for flame brazing include:

- Copper tubes in RACHP installation technology
- Steel, copper and aluminium pipes
- Compressors for refrigerators and air conditioners
- Valves for refrigeration and air-conditioning technology

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- Carbide steel tools
- ...




Figure 1-15: Examples of carbide steel tools, produced by flame brazing (Source: Carbide tooling group)

Carbide steel tools produced by flame brazing

- Various cutting tools
- Carbon tool and high-speed steels
- Usage for metal, wood and plastic material drilling

B1.3.5 Comparison of brazing, soldering and welding

- Brazing is a joining process with brazing alloy as filler material for the substance-to-substance joining of metallic work pieces. By definition, the brazing temperature is above 450 °C. Capillary brazing fittings according to DIN EN1254-1 (up to and including 108 mm nominal diameter) are used for brazed joints.
- Soldering follows the same process as brazing, but happens at temperatures below 450°C. The joints are not as strong as they are during brazing. Soldering is not permitted for use in refrigeration systems.
Soldering is most commonly used in electrical engineering and electronics. Soldering is carried out almost exclusively with soft solder.
- Welding joins two pieces of metal by melting the metals themselves enough that they become joined. A filling material is not always used, and the two metals being joined have to be similar. **Welding produces the strongest joints.**

Soldering is the oldest method to connect metals firmly together and has been used for more than 5,000 years.

Table 1 provides a comparison between soldering and brazing. Because of the higher strength of the connections, brazing is the preferred option for the RACHP sector.

Table 1: Comparison between soldering and brazing (Sources: Deutsches Kupferinstitut (2019), Umicore (2013))

	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 	<ul style="list-style-type: none"> • Gas, LPG and oil installations • Pipes with operating temperatures above 110°C (e.g. 	<ul style="list-style-type: none"> • Due to the high technical complexity, high-temperature brazing is particularly suitable

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	<ul style="list-style-type: none"> • Electrotechnics, Electronics 	solar or hot water heating systems) <ul style="list-style-type: none"> • Floor heating pipes • Drinking water • RACHP sector 	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.

B2 Brazing of RACHP piping – theory and practical considerations

B2.1 The application of flame brazing in the RACHP industry

Flame brazing is a highly important process in the RACHP industry. It makes it possible to join major components to a hermetically sealed system. Brazing creates joints that can withstand pressure, vibrations, shocks and tensions. This reduces refrigerant leakage and system faults and therefore increases the efficiency and lifetime of equipment. Brazed joints of good quality reduce refrigerant leakage and thereby increase the safety of systems with flammable refrigerants. At the same time, more safety precautions have to be taken during the brazing process with flammable refrigerants.



Every RACHP skilled worker must be competent in brazing. Brazers need constant practical experience on the job and regular refreshing to maintain the required level of skills and quality. This applies to the use of flammable refrigerants in particular!

When brazing refrigerant transfer tubes, special attention must be paid to a high grade of cleanliness. Under no circumstances should foreign materials such as metal shavings, tinder, flux or moisture get inside the tubing. Shavings and tinder could block the nozzle of the throttling device (expansion valve and also capillary tubes) and mechanically damage the compressor. Flux and moisture lead to the formation of aggressive acids in the refrigerant circuit in the long term, which potentially attack the windings of the electric motor (hermetic and semi-hermetic compressor) or may cause copper plating at metallic parts of the refrigerant circuit.

To avoid scaling inside the tubes, refrigerant-carrying tubes are therefore always brazed using an inert gas, e.g. by allowing oxygen free and dry nitrogen (OFDN) to flow through the tube to be brazed under very slight overpressure (see also chapter B4.1)

In refrigeration technology most commonly copper tubes, brass fittings and components are brazed.

Brazing is a process that allows the joining of similar or dissimilar metals by using a third metal, the so-called filler metal (solder or brazing alloy) as “glue” and applying heat. The base metal, i.e. the metals that are being joined, is never actually melted. It must however reach the proper temperature to allow molecular bonding with the filler metal. In the transition region of the copper surface to be joined, an alloy layer is formed whose strength is higher than that of the filler material. It is important that the filler metal has a melting temperature above 450°C, but below the melting point of the materials that are joined. The basic principle of brazing is illustrated in Figure 2-1. Brazing can be used for copper/copper, copper/aluminium or copper/steel connections. For specific cases a flux is applied before to clean the metal and prevent oxidation.

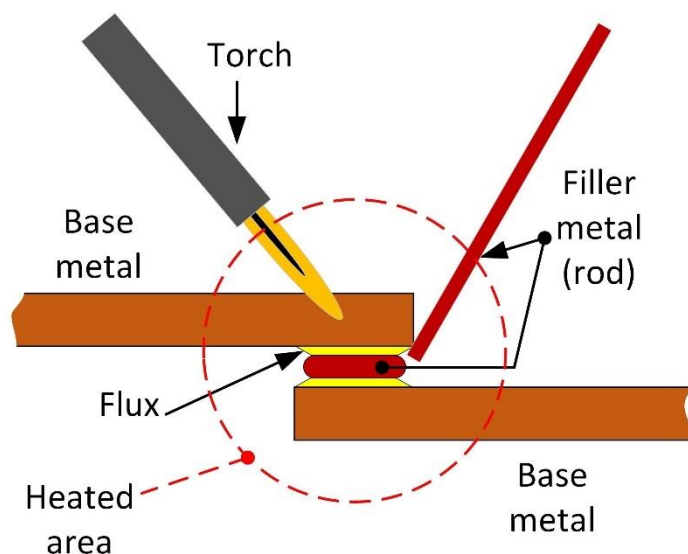


Figure 2-1: The basic principle of a brazing process (Source: HEAT GmbH)

Selection of fuel gases for flame brazing processes

Fuel gases must be selected according to the heating requirements. Typical examples include:

- a) Natural gas / air
- b) Natural gas / oxygen
- c) Propane / air
- d) Propane / oxygen
- e) Acetylene / air
- f) Acetylene / oxygen

Propane/oxygen and acetylene/oxygen are the most commonly used.

☞ The following sections will look at different ways of joining the copper metals, the filler material, the flux and the flames used. It will finally describe what is considered to be good brazing and give tips on how to achieve this.

B2.2 The use of copper tubes for RACHP system brazing

Because of various advantages, copper is used in almost all industries and areas of life. Copper is known for its excellent electrical conductivity in electrical cables, electric motors and generators.

In heat exchangers, the good heat conductivity of copper plays an important role for RACHP technologies. For pipe installations, the smooth surface, high strength and low wall thickness, good workmanship with a variety of joining technologies, gas tightness and resistance to environmental influences and corrosion resistance are the decisive advantages. The properties of copper materials make it predestined for the use in RACHP technology. If treated correctly, low-temperature embrittlement does not exist with copper materials.

For these reasons, copper materials have been considered state-of-the-art for decades and are anchored in the corresponding regulations. Copper pipes are used in accordance with standards and specifications to assert technical and legal warranty requirements if necessary.

Copper is resistant to almost all standardized refrigerants (including flammable substances) and the corresponding mixtures. Table 2 shows relevant material properties of copper.

Table 2: Material properties of copper (Source: Valves and instruments Plus Ltd.)

Properties	Value	Unit
Density	8.96	g/cm ³
Thermal conductivity at 20°C	293 – 364	W/(mK)
Coefficient of thermal expansion	0.017	mm/(mK)
Melting point	1085	°C

Copper alloys are extremely low-temperature materials and are therefore particularly suitable for components in refrigeration systems. Copper alloys show increasing strength and elongation with decreasing temperature.

This distinguishes copper materials fundamentally and decisively from all other technical materials; phenomena such as low-temperature embrittlement do not occur with copper materials.

Therefore, the material Cu-DHP (SF-Cu, oxygen-free, phosphorus-deoxidised, 99.9 % pure copper) can be used for temperature ranges from -269°C to 250°C.

B2.3 Preparation of copper tubes for all joining technologies

All pipes of the RACHP installation or even plug-in appliances should be arranged in such a way that the type of pipe is recognizable at any time and without major difficulties. Piping assembled and installed on site shall be marked by colour coding in accordance with DIN 2405:2003-01 (Pipelines in refrigerating systems and cooling equipment - Marking). This is not required if the piping flow is obvious by appearance. There is no European Standard for this, and colour coding should be according to national codes.

Irrespective of the connection technique used in each case, the copper tubes must be prepared in the same way.

The preparation begins with cutting the tubes to length. The tubes must be cut at right angles to the tube axis. When using a pipe cutter, care must be taken to ensure that the cutting wheels are sharp and that only low feed rates are used. Only in this way, can deformations of the tube ends be generally

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avoided. This is especially important for soft tubes. The use of fine-toothed metal saw is possible, but it must be avoided that swarf's enter the tube, as these would contaminate the refrigerant circuit.

After cutting, the pipe ends should be deburred inside and outside. Internal burrs left standing cause pressure losses due to narrowing of the cross-section. External burrs can damage the sealing element of press fittings and plug-in fittings.

B2.3.1 [Tools for copper preparation](#)

There are large number of copper preparation tools available worldwide with specific capabilities. With the following generic tools for the most important activities are listed.

Copper tube cutting

There are chipless (non-cutting) and chip producing (cutting) tube separation technologies. Tube cutters are a chipless technology and should be preferred when flammable refrigerants are in use and may be present at the work area (temporary flammable zones might form (see Chapter A4.5.3)). When using chip producing technologies (e.g. hacksaws), care must be taken to remove the chips from the tube afterwards.

The following tools are used for cutting copper pipes:

- Tube cutter
- Hacksaw with small gap between teeth

Examples are shown in Figure 2-2 to Figure 2-7.



Figure 2-2: Tube cutter 1/8" up to 5/8" (Source: ITE)



Figure 2-3: Tube cutter 3/16" up to 7/8" (Source: Perkeo)

 <p>Figure 2-4: Tube cutter plier 4 to 12.7 mm (5/32" to 1/2") (Source: Vulkan Lokring)</p>	 <p>Figure 2-5: Tube cutter 1/8" up to 1/4" (Source: Rothenberger)</p>
 <p>Figure 2-6: Tube cutter for 12-15-18-22mm Working radius (25-35mm) (Source: Rothenberger)</p>	 <p>Figure 2-7: Hacksaw for tube-cutting (Source: Haas-Tools)</p>

Copper tube cleaning

Oxide layers and foreign matter and scales must be removed from the brazing fitting and joint before brazing, otherwise they can prevent the brazing filler material from joining the work pieces. This is possible with the use of a wire brush or cleaning fleece. If necessary, tubing material can be blown out with OFDN before assembly and brazing process. Copper tubes prepared for transport should be sealed with caps or pinched off, fitting stored in clean transport boxes or plastic bags.

 <p>Figure 2-8: Heavy duty 4 row wire brush (Source: Bueromarkt AG)</p>	 <p>Figure 2-9: Abrasive mat (Source: Vulkan)</p>
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Figure 2-10: Sand paper grain 120 (Source: Desertcart)



Figure 2-11: Use of sand paper at copper pipes (Source: HEAT GmbH)



Figure 2-12. Fitting brush (Source: ITE)

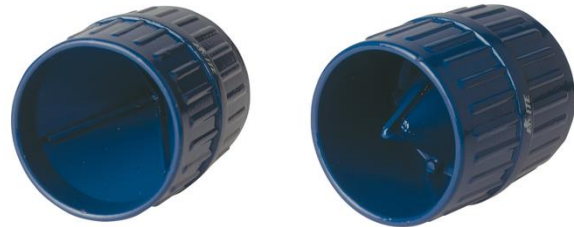


Figure 2-13: Tube reamer (inner/outer) (Source: ITE)



Figure 2-14: Heavy duty inner tube deburrer (Source: G&J Hall Tools)



Figure 2-15: Deburrer - pen style with spare blades (Source: ITE)

B2.4 Flux agent

A flux is a chemical, non-metallic 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. Provided that the work pieces are sufficiently cleaned, the fluxes can remove surface oxidation films, which prevents the filler material from wetting the work pieces; they can also prevent the formation of new surface oxidation films.

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! *Usually brazing gloves and goggles are sufficient.*

Generally observe the provisions of the Material Safety Data Sheet (MSDS)!

The brazing time depends on flux. The flux needs about 4 to 5 seconds to clean the capillary gap surface. However, the dissolving capacity is limited in time. After about 4 minutes the flux saturates with oxides and no more oxides can be dissolved. A new oxide layer is formed again.

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.

Fluxes for brazing should have the following marking:

- Manufacturer or supplier mark
- EN 1045:1997-08 - Brazing - Fluxes for brazing - Classification and technical delivery conditions
- Flux type abbreviation
- Working temperature



Figure 2-16: Flux with relevant markings (Source: Perkeo)

Residues of fluxes of group FH21 can be removed mechanically after the brazing process, for example with a steel brush.

B2.5 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.

Brazing filler is often provided as rods, but also available as wire, strips or preformed (such as rings). Rods are most commonly used in the RACHP sector. Other shapes are often used for serial production.

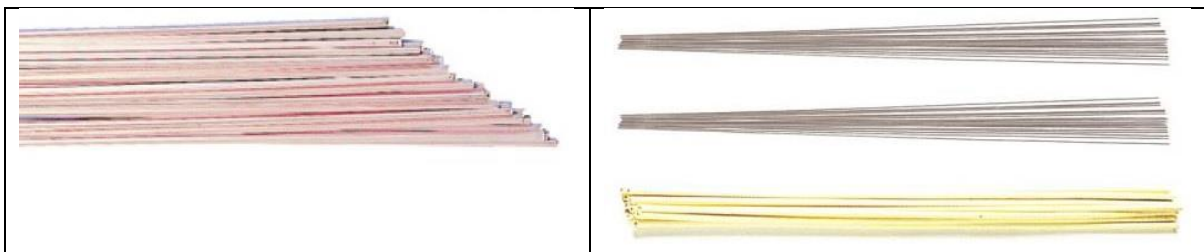


Figure 2-17: Brazing rods (left), silver rods and flux covered silver brazing rods (right) (Source: Perkeo)

Filler materials should have the following marking:

- Manufacturer or supplier mark
- ISO 17672:2017
- Short name of the solder

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The type of brazing filler material depends on the position and accessibility and on the application of the refrigerant transfer pipe, e.g. the required/maximum allowed pipe temperature during operation.

The consumption of filler material (solder) is about 3 times of the outer tube diameter.

Example: A 22 mm copper tube joint (7/8") requires for brazing about 7 cm (2.8") filler material (solder)

B2.5.1 [Selection of a suitable filler material for RACHP brazing application](#)

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 choice of filler material depends on the temperature range the application will be operated in, as shown in Table 3:

Table 3: Suitable filler materials for brazing applications (Source: depending on manufacturer, here: Perkeo)

RACHP Application temperature	Silver content	Specification	Working temperature
≤ -20°C	0%	L-CuP6	730°C
≤ -20°C	2%	L-Ag2P	710°C
≤ -40°C	5%	L-Ag5P	700°C
≤ -70°C	15%	L-Ag15P	670°C
≤ -200°C	≥ 34%	L-Ag34 (45) Sn	630°C to 730°C

It is possible for brazing filler material containing phosphorous to be used with tubing routed in ceilings or walls, and indeed such materials are preferable for cost reasons.

With copper-copper material pairing, brazing with the phosphorus-containing filler materials, flux is (depending on the RACHP application) not necessary because the phosphorus component acts as a flux.



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.

B2.5.2 Brazing temperatures

The ideal temperature used for brazing depends on the chosen filler material as they melt at different temperatures. It always has to be below the melting temperature of the base metals.

Error! Reference source not found. shows the differences between copper only and silver-containing materials. Silver-containing materials have very good wetting conditions at much lower temperatures.

	Wetting behaviour	Copper only (L-CuP6)	Silver (L-Ag45Sn)
I	Very good wetting	730°C	670°C
II	Good wetting	710°C	640°C
III	Bad wetting	650°C	600°C
IV	No wetting	600°C	550°C

Figure 2-18: Working temperatures of two different brazing filler materials (Source: HEAT GmbH, based on manufacturers information)

B2.6 Classification according to the shape of the brazed seam

Gap soldering is the most commonly used method for connecting pipes. This can be done by using fittings between pipes (see Brazing with fittings below) or by using two pipes whose endings have been swaged or expanded (see hand crafted fittings below). Between the pipe and the fitting, or between two pipes, there has to be a narrow gap. During brazing, capillary forces cause the liquid filler material to rise into the gap, ideally filling it completely. This capillary action happens against gravity. Figure 2-19 explains the capillary effect in general.

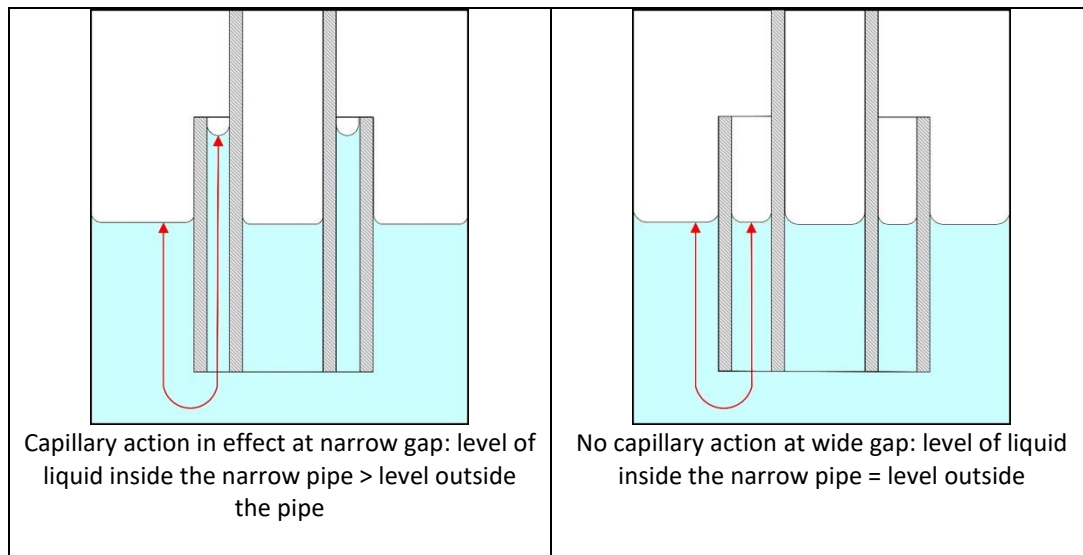


Figure 2-19: Schematic presentation of the capillary effect (Source: HEAT GmbH)

A soldered joint is correctly shaped if the filler material is drawn completely into the brazing gap when heated by the capillary pressure and there is diffusion between the brazing filler material and the base material.

B2.7 Brazing with the use of fittings

Pipes are connected through fittings and the fitting has to be connected to the pipes through brazing at all connection points (soldering is not permitted for the manufacturing of refrigerant transfer tubing).

Fittings are used for the vast majority of copper tube design and joining. Fittings for brazing are commercially available and there are differences between fittings for plumbing and refrigeration circuits. Refrigeration type fittings are manufactured specifically for the refrigeration industry and are based on the outside diameter measurement of refrigeration grade copper tube. Refrigeration grade quality material should be used with regard to pressure resistance and cleanliness. Quality and certification marks must be available.

Capillary brazing fittings are available up to 108mm (about 4 inches) according to EN1254-1:1998. Brazing of larger tube dimensions (≥ 54 mm) may require additional/separate brazers competences assessment certification according to ISO13585:2012 and for different tube dimension and production ranges.

If copper pipes need to be connected to threaded devices or mountings, transitions (fittings) are required. Threaded adapters are usually made of red-brass or brass.

Accurate dimensions in fittings, transitions and connectors have to be used for a satisfactory joint and care must be taken to ensure that the clearance between the surfaces of components is exactly as specified to allow for capillary action.

Note for pipes 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.
- ➔ The narrower the gap, the higher the capillary fill pressure.

Example:

- 0.5 mm gap results in about 1.5 cm rise height
- 0.1 mm gap results in about 10 cm rise height

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:

- Piping according to EN 12735-1, DIN 8905-1 or standards of the American Society for Testing and Materials (ASTM)
- Fittings according to EN 1254-1/ EN 1254-4 or ASTM

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

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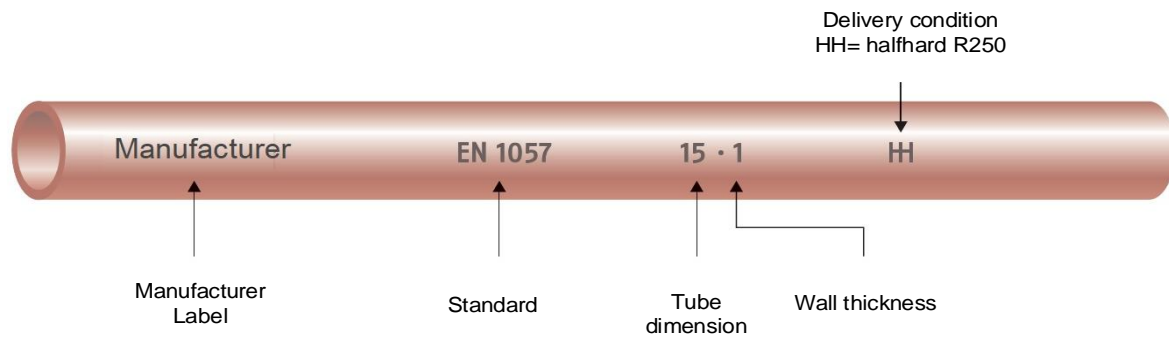


Figure 2-20: Manufacturers tube marking (Source: Heat GmbH)



Figure 2-21: Copper fitting marking (Source: Conex/Bänninger)



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.



Figure 2-22: Example of various copper fittings for refrigeration (Source: Indiamart)

B2.8 Brazing without fittings (swaging, expanding, joint extraction)

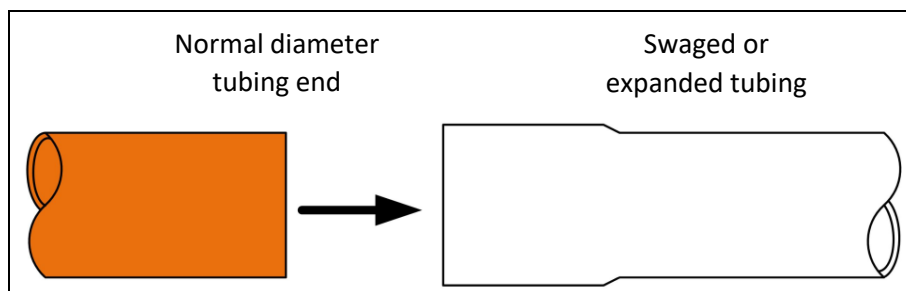
In addition to brazing with fittings, there are also two cases in which tubing can be brazed without fittings:

1. Handcrafted joints by the use of swaging and expanding tools
2. Branches forming (extracting) for joining with t-pieces and inclined branches

In the case of handcrafted joints, one end of the pipe is widened with a swaging or expanding tool to make a joint.

Swaging and expanding tools are almost similar. The swaging tool requires a hammer in order to punch the swaging tool into the copper tube, expanding is performed by the use of an expanding tool and the selectable tube expander head.

The swaging and expanding tubing processing's are from the practical results almost similar. The result should be a perfect copper tube joining seam.



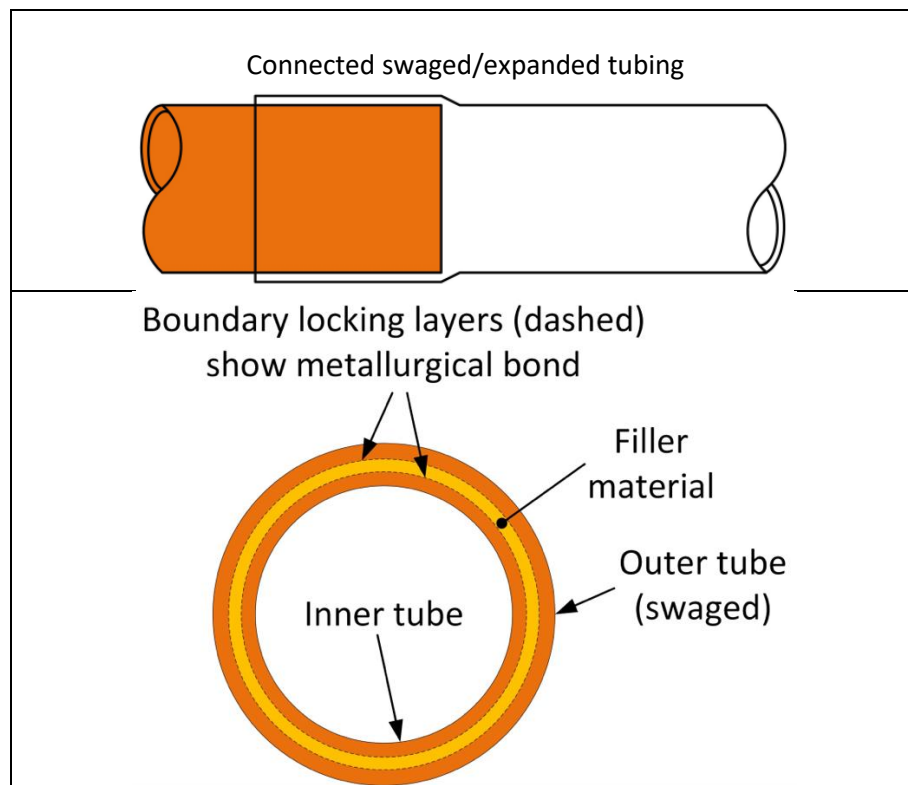


Figure 2-23: Swaged or expanded tubing design shape (Source: HEAT GmbH)

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. 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.

All these working techniques require very precise work, with the correctly selected tool, in order to achieve a brazing gap width (max. 0.5 mm) that allows for a capillary effect and thus capillary brazing.

Care must be taken to ensure that the tube is not widened beyond the gap size specified for brazing. Swaging and expanding are generally accepted for the use of a soft copper (annealed) tube only. Extracting works also with rigid copper tubes. All these processes are time consuming as the copper tubes have to be prepared for the brazing process by careful cutting, deburring, joint manufacturing and surface cleaning.

Swaging Tools



Figure 2-24: Swaging punches for the use with hammer (Source: ITE)



Figure 2-25: Swaging bar and die (Source: ITE)



Figure 2-26: Swaged joint (Source: HEAT GmbH)

Expanding tools



Figure 2-27: Set of expanding heads (Source: ITE)



Figure 2-28: Expanding tool (Source: ITE)



Figure 2-29: Expanded joint (Source: HEAT GmbH)

Extracting T-pieces and inclined branches tools



Figure 2-30: T-Extractor (Source: Rothenberger)



Figure 2-31: T-piece driller and cam pincer (Source: Rothenberger)



Handcrafted sleeves or branches must be executed very precisely to achieve a brazing gap that allows capillary action and therefore brazing.



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.

Manufacturing processes for joining connections (for brazing without fittings)



Swaging, Expanding, Extraction

Preparation

- Prepare the copper tube or section to be worked on
- Clean thoroughly the outer and the inner surface of the copper tube
- Remove burrs and sharp edges
- Use a swaging bar and swaging punch or cone (see figures Figure 2-24 and 2-25)
- Use an extraction tool for manufacturing a T- connection or declined branch
- Fix (hold) the copper tube by a swaging bar or suitable vice

Swaging/expanding

- Insert the swaging punch or expander into the end of the copper tube to be widened.
- Centre and aligned to the longitudinal axis of the copper tube in an absolutely straight way
- Force the swaging punch with the use of a hammer into the tube end to form the copper joint
- The swaging joint can also be produced with the use of a swaging cone in the similar way to the flaring process.

T-branch extraction

- Fix the tube for joint manufacturing with a suitable vice
- Drill a hole within the copper tube with the correct size for insertion of the extraction tool.
- Turn the extraction toll with the use of the ratchet until completion of the T-branch union.
- Insert the T-branch tube and prepare for brazing
- After swaging or expanding copper tubes or T- joints, ensure that they are neat and clean
- Gaps for filler material penetration are according to the specified requirements

B3 Brazing safety and tools

B3.1 Safety requirements and Personal Protective Equipment (PPE) during brazing

Basic safety requirements during brazing work encompass the following:

- Accident prevention
- Site safety
- Safety of equipment and tools
- Fire precautions and alarm procedures

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- Adequate ventilation
- Permission for hot work (if needed)

Personal Protective Equipment (PPE)

When carrying out brazing processes precautions shall be taken to protect exposed parts of the head, body and clothing against heat and hot metal particles by wearing adequate protective clothing:

1. Wear gloves to protect against heat and hot particles, usually made from leather. Other proprietary brand gloves are available made from a heat resisting material known as “Kevlar”.
2. Body Protection: Engaged personnel shall wear flame retardant overalls wherever practical for all brazing operations. Additional arm protection may be needed in restricted work areas.
3. Eye Protection: It is necessary to protect the eyes against heat and glare which may cause eye strain, but more important from flying hot particles. There are various types of goggles or safety glasses. Operator preferences and visual activity will influence the individual’s choice.
4. Breathing protection masks (for small particles) are necessary for protection against higher levels of fine dust, mists and metal fumes. Use a mask with low breathing resistance and reduction of fogging of eyewear. The mask should have a flow valve to reduce heat build-up.
5. Head and Foot Protection: Where there is a risk of injury from falling objects and contact with hot work pieces etc., both these items of PPE shall be worn.
6. Construction site: When working on construction sites, it may be necessary to provide weather protection.



See Module J, chapter J2 for more information on general workplace safety and PPE

B3.2 Brazing tools (examples)

All brazing equipment comprising regulators, flash back arrestors, hoses, torches, nozzles and cylinders shall be maintained and checked in accordance with the applicable standards and regulations (national/international), both on a daily and annual basis. Results of these inspections should be recorded, and the records kept.

Examples for tools are shown in

Table 4 and the following figures.




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B3.2.1 Brazing units

Because of the higher working temperatures, different heat sources are used for brazing than for (soft) soldering as shown in

Table 4:

Table 4: Different brazing units recommended for RACHP brazing (Sources for all pictures: Perkeo)

Oxygen-propane	Oxygen-acetylene	Oxygen-acetylene
		
For small pipe joints ≤ 28mm	For small pipe joints ≤ 28mm 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: ~ 0,5 bar	Working pressure: Oxygen: 2.5 bar Acetylene: 0.25 – 0.5 bar

B3.2.2 Brazing torch with attachment and nozzle

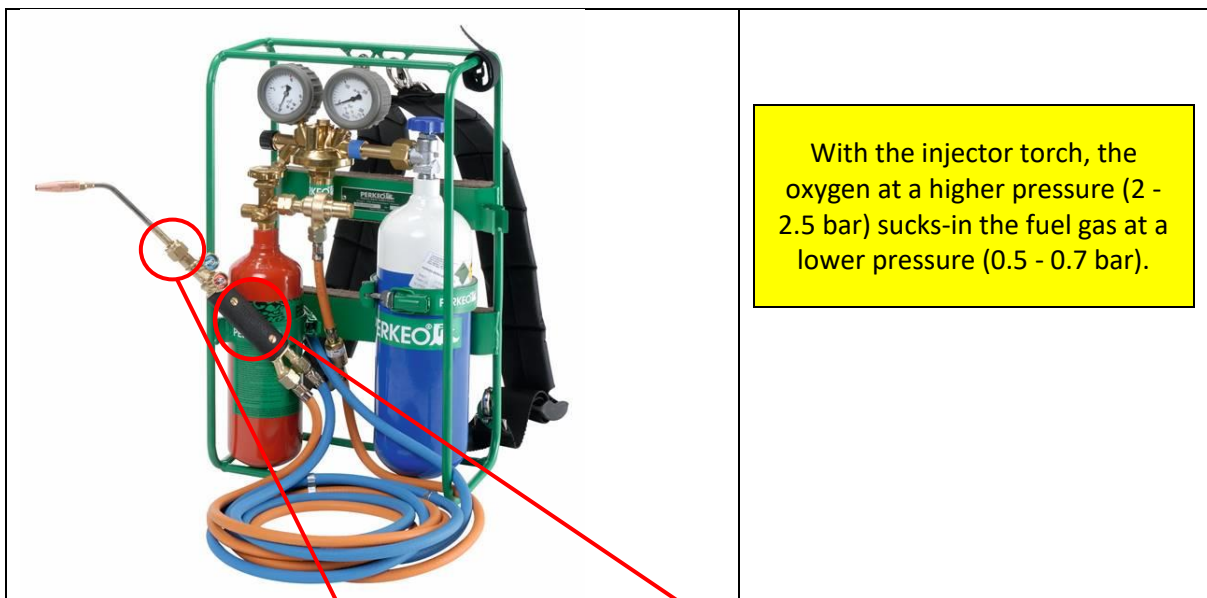
The Injector torch for brazing purpose.

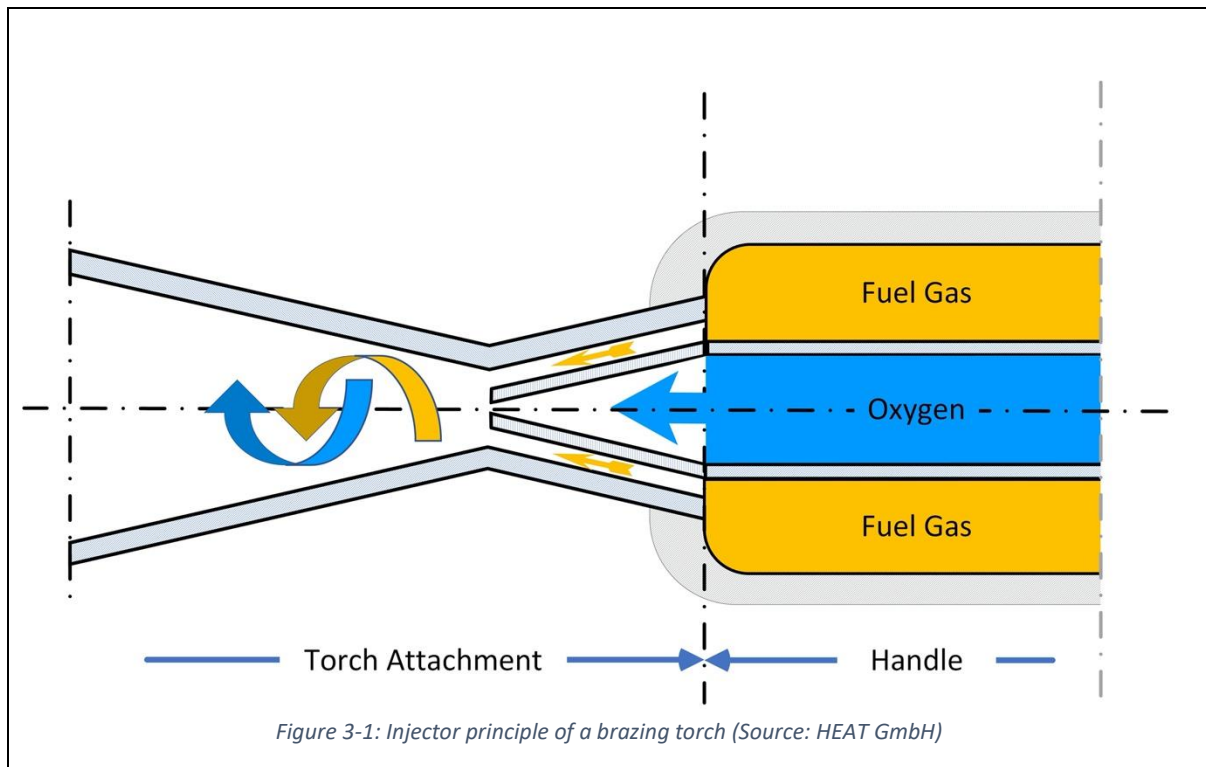
In Europe, injector torches are used almost exclusively as brazing and welding torches. An injector consists of a tube with a constriction. In the middle before the constriction, another, thinner tube

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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 (see figure 15).

The principle of the injector works with vapours and liquids of all kinds and is to be found more frequently in mechanical engineering.





The handle (see Figure 3-2) contains the valve for fuel gas with red handwheel and the valve for oxygen, recognisable by the blue handwheel. To avoid confusion, the gas and oxygen hoses have different connections. The fuel gas hose is screwed on with a 3/8" left hand thread (notched union nut). The oxygen hose has a 1/4" right-hand thread. The hoses also have different colours to match the handwheels. The acetylene gas hose is red or orange for LPG, while the oxygen hose is blue (see Figure 3-7 and Figure 3-8).

The intensity of the flame is adjusted depending on the pipe diameter. For this, differently sized torch attachment nozzles (inserts) can also be selected (**Error! Reference source not found.**). Smaller nozzles are used for small diameters. There are also shower-burners (Figure 3-5), which are used for better heat distribution at the work-piece. A "flexible" fork torch attachment (Figure 3-6) is specifically used for refrigeration appliances (and heat exchanger) manufacturing (and servicing).

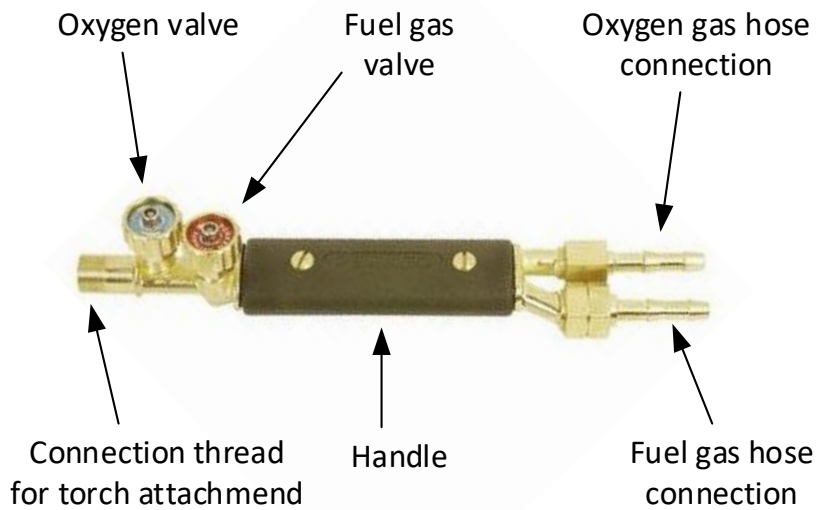


Figure 3-2: Brazing handle for acetylene or propane combustion gas (Source: HEAT GmbH)

The torch attachment (and nozzle) is held in the handle with a union nut. In general, it is sufficient to tighten the nut by hand. There is also a gasket on the torch attachment. It ensures a gas-tight separation of gas and oxygen.



The gasket is the precondition for the proper functioning of the torch.



Figure 3-3: Brazing torch attachment with mixer and nozzle (Source: Perkeo)

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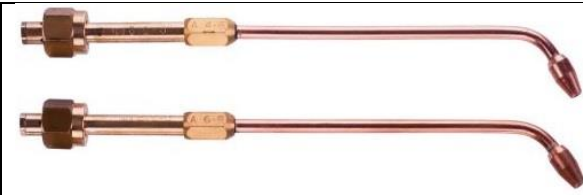


Figure 3-4: Nozzles attachment for brazing (sizes 2 to 5) for acetylene or propane combustion gas (Source: Perkeo)



Figure 3-5: Brazing (shower) nozzle attachment for larger copper tube diameters and high energy flow; acetylene or propane (Source: www.Perkeo)



Figure 3-6: Fork nozzle attachment (Source: Perkeo)

- Flexible Fork Torches - Specially designed for the refrigeration manufacturing and servicing industry.
- Optionally for the use with acetylene-oxygen, propane-oxygen or natural gas-oxygen



- Medium pressure hoses up to 6 bars
- Inner diameter 4mm/4mm

Figure 3-7: Hose packages with flash-back arrestors for propane combustion gas and oxygen (Source: Perkeo)



- Medium pressure hoses up to 20 bars
- Inner diameter 6mm/6mm

Figure 3-8: Hose packages with flash-back arrestors for acetylene combustion gas and oxygen (Source: Perkeo)



B3.2.2.1 Brazing nozzle (tip) sizing

Table 5 of torch nozzles needed for brazing **refrigerant grade copper tube**. The actual selection of the correct nozzle size will be made by the skilled worker based on the pressure of the oxygen and acetylene. Other factors that should also be taken into account include whether the pipe is brazed with copper-phosphorus rods only or with silver containing brazing rods. It is also important to verify if the brazed joint has to be made to a compressor valve body where there might be a large heat sink or where a large flame could cause damage.

Table 5: Example guidance for selection of torch nozzles (Source: depending on manufacturer)

Examples of regular brazing nozzles (tip) sizes									
Tube size inch	Tube size metric (mm)	Tip sizes							
		2	3	5	7	10	13	18	25
Capillary	Capillary								
1/4	6								
5/16	8								
3/8	10								
1/2	12								
5/8	16								
3/4	18								
7/8	22								
1 1/8	28								
1 3/8	35								
1 5/8	42								
2 1/8	54								
2 3/8	≥ ~60								
≥ 2 5/8	≥ ~67								

B3.2.2.2 Acetylene torch “popping”

Occasionally it happens that the acetylene oxygen flame suddenly goes out with a loud “bang” and ignites again on the hot work piece and continues to burn normally. This is called the acetylene torch flame flash-back or “popping”. It is more annoying than dangerous and occurs more frequently during welding than during brazing, as the torch becomes hotter during welding. However, pay attention if it happens more often and the torch keeps popping while brazing. 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.

It becomes 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 (welding), but heats up the handle until it gets too hot to hold. In order to avoid serious accidents from flashbacks it is advised to use flashback arrestors in line with the brazing equipment.



Note:

If a flashback occurs in an application, the effects can become very dangerous!

Burst handles and hoses, fires at the pressure reducer or in the worst case the explosion of the compressed gas cylinder or the gas tank could occur.



Figure 3-11: Hose burn from flashback in oxygen and acetylene hose (Source: EIGA)



Figure 3-12: Extinguishing and cooling of a burning acetylene cylinder (Source: EIGA)

B3.2.2.3 Flashback arrestors

The installation of flashback arrestors (see Figure 3-7) is an indispensable condition for all brazing, welding or cutting procedures. Requirements for the design of flashback arrestors are described with EN 730, EN 746 and ISO 5175.

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As a single bottle safety device, the flame arresters are used both on a single bottle, on the handle and on flame cutting machines.

Today, each flashback arrestor has at least three safety features:

- the gas return insurance
- the flame barrier
- the temperature-controlled cut-off valve

A possible gas return, and thus the formation of an unwanted gas mixture, is prevented by a spring-loaded gas return valve. The formation of a highly explosive gas mixture is impossible. A filter protects the fine mechanics against contamination. At the heart of the flashback arrestor is a hollow cylinder made of sintered stainless steel. This is essential for stopping a flashback.

The mechanism works because of the highly porous structure of the material. The flames lose themselves in the fine ramifications of the sintered body, lose their energy and become cold. In this way, every flashback is extinguished in fractions of a second. The temperature-controlled cut-off valve is the third important safety element. Before the valve can reach a critical temperature, an integrated plastic body melts and triggers a spring-loaded valve. The gas supply is stopped immediately. The critical ignition temperature cannot be reached. The burn-back is stopped and remains without consequences.

Maximum safety is achieved when a safety device is used on both the handle and the pressure regulator. It is important that both the fuel gas and oxygen lines are protected separately. Flashback arrestors must be replaced regularly.

B3.3 Risk of acetylene decomposition

Acetylene decomposition is the worst case that can happen in our workshop area: The gas decomposes into its chemical components hydrogen and carbon (soot). This leads to strong heating in the bottle and an accompanying increase in pressure. In the worst case, the bottle can explode and fly several hundred meters. The bottle tears open lengthwise and looks like a burst sausage.

Acetylene decomposition can be caused by a fire at the pressure reducer or by external heating, welding torches or electrode holders suspended from the pressure reducer, which are still warm and touch the bottle wall, or by a flash-back of flame from the torch (repeated flash-back). To prevent this, flash-back arrestor is installed behind the pressure reducer.

Acetylene decomposition has already started when the cylinder wall feels warm beginning from the top of the valve or when gas with soot or unusual odour comes out.

What to do if an acetylene decomposition occurs?

In the "more favourable" case, the bottle can still be touched by hand. First close the cylinder valve and screw off the pressure reducer. Then you take the bottle outside, let the gas flow out and cool the bottle with water, doing so from behind a safe cover. If your own means are not sufficient for this, immediately call the fire-brigade for assistance. Since exploding bottles can fly several hundred meters far, it is recommended to clear the surrounding area.

If the bottle is so hot that you can no longer touch it with your bare hand, it gets very nasty. This may have been caused by a fire at the pressure reducer or cylinder valve due to the brackets not being tightened firmly enough. In this case you must immediately call the fire brigade, open all windows and

doors (because of danger of a room explosion) and clear the area. Bottles in which acetylene decomposition has taken place must not be used again. They must be clearly labelled, and the bottle supplier and filling plant must be notified.



Acetylene reacts chemically with copper. The result is copper acetylide, which looks like reddish-brown tarnished copper and is even more explosive. Therefore, acetylene must not come into contact with copper. Gas hoses must not be extended with copper pipe pieces as hose connectors. Apart from the danger of explosion, the strength of such a hose connection is very doubtful.

B3.4 Igniting and adjusting the torch flame

Flint stone lighters (Figure 3-10) can ignite the torch safely without open flames. They should therefore always be used. The use of commercial cigarette lighters is 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 oxygen is also shut off first during flame extinguishing.

Adjustment of the flame

For achieving optimal brazing results, the flame should be adjusted correctly to a slightly reducing flame as shown below. This is the case when the light blue flame core (primary flame) is sharply separated from the dark blue flame edge (secondary flame). The size of the flame is better controlled with the different sized nozzles (tips) rather than with the fuel gas valve.

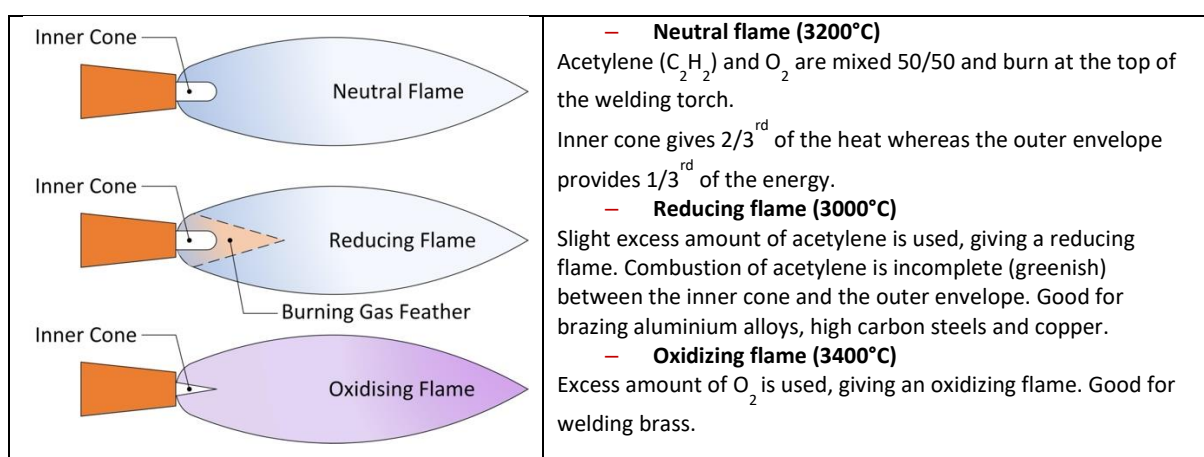


Figure 3-13: Recommended torch flame adjustment (Source: HEAT GmbH)

If a white or more or less yellow tip appears above the flame core, the flame has excess gas (reducing flame). In this case, the fuel gas valve is throttled, or the oxygen valve is opened further.

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If the flame is thin and looks glassy-violet, it has excess oxygen (oxidising flame). Then the fuel gas valve is opened further or the oxygen valve is throttled.

Note:

With acetylene the flame core shines brighter than with LPG.

For brazing with acetylene, it is recommended that a slight excess of acetylene be added to the acetylene-oxygen flame (see figure 3-13 > reducing flame). Brazing is maintained at lowered flame temperature (about 3000°C) and ensures a better brazed joint quality. This is not advisable for other gases such as LPG.

Hard flame: If the gas-oxygen mixture exits the torch attachment nozzle at a high flow rate, this is referred to as a hard flame.

Soft flame: If the gas mixture exits at a low flow rate, this is called a soft flame.

The flow velocity increases with the gas and oxygen pressure (observe manufacturer's instructions). The "hardness" of the flame, i.e. the flow velocity, is correct when the flame burns horizontally, and its tip does not point upwards. If the flow velocity is too high, the flame will break off.

The gas-oxygen flame becomes much hotter than the gas-air flame. Air consists of about four fifths nitrogen and one fifth oxygen. Nitrogen almost does not participate in combustion but is heated in the flame. The hot nitrogen escapes with the exhaust gas and drags heat away. This cools the flame. With the gas-oxygen flame, this heat removal is omitted. That is why it becomes hotter.

Apart from acetylene, other gases such as hydrogen, natural gas and various liquified fuel gases are used in flame brazing and welding technology. Although they are not suitable for welding iron and steel, they are sufficient for brazing and flame cutting.

Generally, LPG (propane) is recommended for portable and mobile brazing equipment. A liquefied gas cylinder contains many times more energy than an acetylene cylinder of the same weight. As liquefied gases, the gases propane and butane are mainly filled into cylinders. In Central Europe, propane is mainly offered, which can be removed from the cylinder with sufficient pressure even with lower ambient temperature conditions (wintertime outside). The disadvantage of liquefied gas as fuel gas of any chemical composition is the higher oxygen consumption. Propane needs four times as much oxygen as acetylene.

B3.5 Oxygen handling for brazing and welding

Oxygen is most commonly involved for brazing in refrigeration technology.

Oxygen itself is not combustible but is essential for combustion. Oxygen is slightly heavier than air. Air contains 21 % of oxygen. With a higher oxygen content in the air, everything burns much stronger. For example, a smouldering cigarette could burn like a torch. Also, hardly inflammable protective clothing or iron wires burn with a higher oxygen portion.



Oxygen must not be used to "ventilate" rooms. If the air contains more than 25 % oxygen, there is an increasing risk of dangerous fires and explosions.

Attention!
Damaged regulators, controls and instruments, hoses or torches including worn out gaskets, have to be replaced immediately! These must not be used under any circumstances!



Warning!
Pure oxygen leads to explosive ignition of oil and grease. Therefore, the thread for the valve protection cap of the oxygen cylinder must not be oiled. Pressure reducers, hoses, burners and valves must also be free of oil and grease.



In order to store enough oxygen (or other gases such as air, nitrogen and various protective gases) in cylinders, they are filled at a very high pressure of 200 bar.

Note:

There are still old oxygen cylinders in circulation which are filled with a pressure ratio of 150 bar combined with pressure regulators for 150 bar. These regulators must not be connected to oxygen cylinders with a filling pressure of 200 bar, as they are not burnout-proofed (according to ISO 2503:2015-12). In accordance with these standards, adjustable oxygen pressure reducers must successfully complete a burn-out test with pressure surges both with the control valve closed as well as with the control valve opened.

B3.6 Acetylene Developer

In 1862 the German chemist Friedrich Wöhler developed a process in which calcium carbide in connection with water reacts to form acetylene. This gas, when burned with oxygen instead of air, gave a flame temperature of 3000 °C compared to 1900 °C for the Bunsen burner flame. This high flame temperature was reported in 1895 but not exploited until about 1901, when a commercial oxyacetylene welding apparatus was developed in France. The first oxy-acetylene welding shop in the United States was set up in 1906, and in 1907 the technique was adopted at the Brooklyn Navy Yard.

This simple technology to produce acetylene for brazing, welding and cutting has last until today.

Acetylene developers ensure an independent and inexpensive gas supply and are a good alternative to acetylene bottles wherever regular deliveries are not possible or high transport and delivery costs are incurred from the filling plant for the bottles. The acetylene developers can offer a high standard of safety and are simple and convenient in use for the operator.



Figure 3-13: Acetylene developer (Source: Perkeo)



Figure 3-14: Carbide grains (Source: Perkeo)

The gas developer is immediately ready for use after filling with carbide and water.

Simple and robust construction with protected arrangement of the fittings and for the connection with regular hoses and burner (see Figures 3-2 to 3-10).

Fully automatic operation. The control valve secures an appropriate gas generation and prevents any post-gasification.

Constant operating pressure, which can be regulated at the control valve if required.

Developer chamber and gas container can be separated by valves, so that no harmful air space is created when recharging.

The mud catcher is removable. This is where the developer water is filled in and where the carbide sludge is located after gasification.

Acetylene gas generators comply with regulatory requirements construction and safety regulations.

Gasification of coarse piece of carbide in grain size 50/80 mm ensures maximum gas yield.

B4 Brazing operation, laying of refrigeration pipes

Refrigerant pipework and fittings according to the standards mentioned in chapter 1.1 are supplied by the manufacturer with an internal surface finish that meets the requirements of refrigerant circuits. However, this only applies if pipes remain closed (with sealing plugs) until the final processing within the pipework and the fittings remain in their original packaging. After opening the original sealing, the responsibility for the required cleanliness of the inner surfaces lies with the skilled craftsmen.

Detailed information on the correct installation of refrigerant piping can be found in the relevant technical regulations (e.g. DIN EN 378, ISO5149, EN14276), see also chapter B1.1.

Openly routed copper pipes in refrigeration systems generally do not require any additional corrosion protection. In special cases (e.g. aggressive environment e.g. salty humid coastal areas or some food

processing areas), however, protective measures may be necessary. In case of doubt, the pipe and fitting manufacturers should be consulted.

Modern refrigerants generally result in higher operating temperatures and pressures than those previously used. When using capillary fittings, the respective fitting manufacturer must be consulted about the possible areas of application, in particular the maximum permissible operating pressures.

B4.1 Inert gas brazing (brazing with protective gas – Inertisation)

Oxidation of the copper has to be avoided during brazing. Oxidation can be recognized by a light to dark brown discoloration on the copper tube. To achieve this, flux is applied on the outside of the pipe. This is not possible on the inside of the pipe. In RACHP systems, oxide layers are removed from the inner walls by refrigerant and oil during operation. This introduces contamination, which may lead to component failure, for example of the compressor. It can also cause significant delays during commissioning as filters will have to be changed or cleaned under unfavourable conditions.

One way of avoiding copper oxide (also called scale or tinder) on the inside walls of the pipes and fittings is to flush the pipe with an inert gas during brazing whenever possible. It is recommended to use oxygen free dry nitrogen (OFDN). OFDN will replace the oxygen in the pipe so that it cannot react with the copper. It will further prevent moisture from getting into the pipe.

There are other inert (protective) gases, such as noble gases, OFDN and their mixtures. Forming gases, mixtures of nitrogen (or another inert gas) and hydrogen, are commercially available. For safety reasons, the hydrogen content must not exceed a maximum value of 4% by volume.



See Chapter A5.5.3 for more information on OFDN



Inert gas brazing

- Follow steps of cleaning, applying flux and fixing the work pieces (in B4.2)
- Attach OFDN hose to pipe assembly
- Adjust to a low flow of about 0.2 bar. Be careful to avoid the build-up of pressure within the pipe work during brazing as this will result in badly brazed joints. In a straight open copper tube, the flow of OFDN should be slightly noticeable only.
- It is possible to check this by leading the flow of nitrogen into water. Bubbles show that the flow is sufficient and there is a guarantee that oxygen cannot enter the piping.
- Conduct brazing process according to instructions (in B4.2)
- Turn off OFDN supply after brazed joints have cooled down. cooling-down of the brazed joints

Tools

- OFDN compressed gas cylinder with pressure regulator
- Connection hose
- Brazing section adapter as shown with Figure 4-11 to Figure 4-12

Figure 4-1 shows an exemplary arrangement for inert gas brazing.

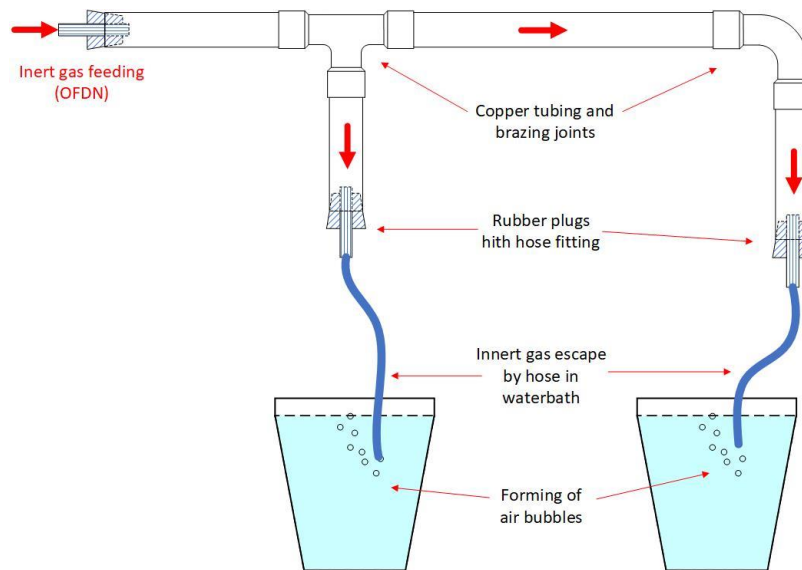


Figure 4-1: Exemplary arrangement for inert gas brazing (Source: HEAT GmbH)

Another copper pipework connection possibility for smaller systems is to install a schrader valve connection at the specific piping section in order to maintain an inert gas flow (OFDN).



Figure 4-2: Schrader valve at a prepared copper cap for tubing connection (OFDN) (Source: HEAT GmbH)



Figure 4-3: Schrader valve at a squeezed copper tube for OFDN supply (Source: HEAT GmbH)



When hydrocarbon refrigerants are present, use OFDN to render these pipe sections inert. Inert gas brazing is important to avoid oxidation – independent of the refrigerant used.

B4.2 The process of brazing

Prepare by having available all necessary tools and permits.

The next sections outline the brazing process in 6 steps:



Figure 4-4: Brazing process steps

Step 1: Cutting and cleaning



Copper tube cleaning

- Thick layers of grease or oil can be first wiped off e.g. by an old rag.
- Oxide layers can be removed with the use of a steel brush or cleaning pad
- Abrasions and residues of cleaning agents must be removed, e.g. by blowing out the pipe with OFDN
- Polished components do not require any cleaning

Tools

- Wire brush
- Reamer, deburrer
- Metal-free cleaning pad, plastic fleece, all “grit-free” or sandpaper (abrasion resistant)
- OFDN

It is not recommended to use steel wool in RACHP brazing technology as residues have to be prevented in the pipe. Grinding residues must be removed in any case.



Figure 4-5: Deburring with “inner and outer deburrer” (Source: HEAT GmbH)



Figure 4-6: Outer area cleaning with cleaning pad or wire brush (Source: HEAT GmbH)



Figure 4-7: Deburring with pen-styled deburrer (Source: HEAT GmbH)



Figure 4-8: Inner cleaning with wire brush (Source: HEAT GmbH)



Figure 4-9: Assembly cleaning before brazing (Source: HEAT GmbH)

Step 2: Applying flux (if applicable)

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Fluxes protect the surface from oxidising during brazing. For copper-to-copper connections (depending on the work-task), phosphorus containing filler material (or with silver content) are the first choice.

Following the completion of a brazed joint the flux residue must be removed.

The use of coated or cored brazing rods can preclude the use of fluxes in a paste form.



Applying flux

- Decision if flux is required (copper-to-copper no flux is required)
- Apply flux evenly to the cold work piece with the brush before assembly to ensure complete flux coverage throughout the capillary joint
- The flux is applied with a coated filler material rod (silver-solder)
- If flux in paste form is used, take care to remove residue from inside the refrigerant circuit as it can negatively affect compressor components.

Tools

- Brush or similar
- Flux

Most fluxes are slightly corrosive and skin contact, particularly with wounds, should be avoided. In any case before use, read the Material Safety Data Sheet (MSDS)

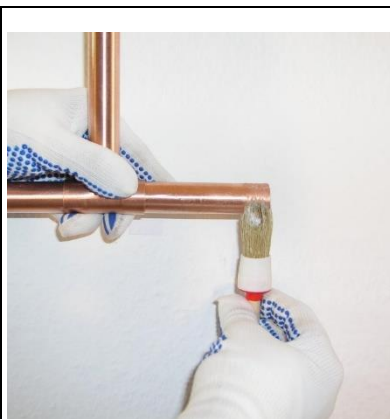


Figure 4-10: Applying flux (Source HEAT GmbH)

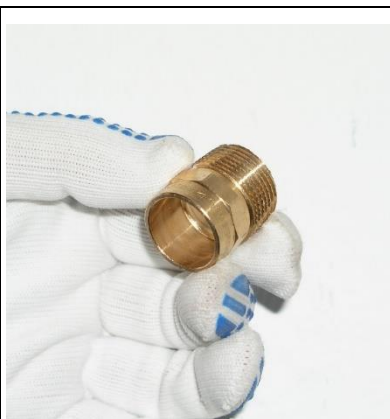


Figure 4-11: Brass adapter (Source HEAT GmbH)

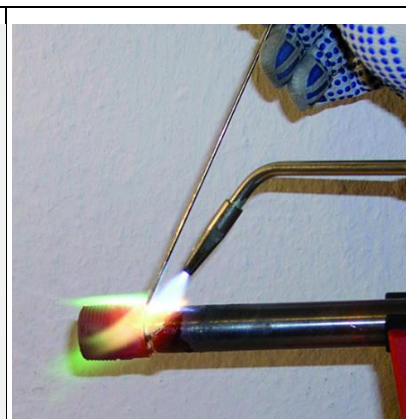


Figure 4-12: Brazing of brass adapter to copper piping (Source: HEAT GmbH)

Step 3: Fixing the work pieces

Parts need to be stable for a good braze line. This is especially important to maintain an even gap for capillary action. At the same time, the piping joints to be brazed must be accessible with the heat source, the filler material and fluxes (if applicable).



Fixing work pieces

- Use tools to keep piping joints in place for brazing process.
- Set brazing gap at between 0.02 mm and 0.5 mm (necessary preconditions met with the use of state-of-the art fittings)

Tools

- Tristand or similar for assembly at installation site (see figure 64/65)
- Ceramic bricks (if applicable)
- Vice grips
- Pliers



Figure 4-13: Example of a tristand with vice for supporting pipework installations (Source: Anglia Pipe Tools)



Figure 4-14: Example of tube vice for table mounting (Source: Anglia Pipe Tools)

Step 4: Brazing the joint: Heating and applying filler material

Heating for brazing must be uniform over the whole joint area, so that the brazing temperature is reached equally, the filler material melts and spreads to bond with the parent metal surface within the joint. Care must be taken to avoid local overheating.

The consumption of filler material (solder) is about 3 times of the outer tube diameter.

Example: A 22 mm copper tube joint (7/8") requires about 7 cm (2.8") filler material (solder) for brazing



Preparation: Igniting and adjusting the torch flame

- First open the oxygen valve and then the acetylene valve on the handle slightly and ignite immediately.
- By regulating the acetylene valve and readjusting the oxygen valve, a soft flame (neutral or slight acetylene/propane reducing flame) is adjusted.
- Depending on the size of the brazing work piece, the working pressure of the brazing equipment is set to 1.8 to 2.5 bar for oxygen and 0.2 to 0.8 bar for acetylene.
- The flame should be slightly reducing, which means a lower oxygen supply (see also chapter B3.4)



Brazing

1. Preheat
 - Preheat the entire area to be brazed. The goal is to heat the entirety of both parts (three parts for T-pieces) being brazed.
 - Also heat the inner tube of the joint to be brazed to ensure the effectiveness of the capillary effect.
2. Heat to working temperature
 - Evenly heat the individual joint to be brazed.
 - Avoid overheating, which may melt the surface. The brazing temperature on the part should be reached in max. 3 minutes for the selected brazing filler metal. The inner cone of the flame should not touch the work piece – only the outer zone. The correct working temperature is maintained if the joint to be brazed is red from heat.
3. Apply brazing filler material
 - Apply filling material to the joint line once the flux is melted to an even transparent layer and the brazing temperature is reached. The colour of the work piece should be dark red.
 - Do not apply the flame directly to the brazing rod - let the temperature of the parts melt the filler material.
 - Continue heating the parts until the filler material (rod) melts and flows into the joint.
 - When brazing large pipe diameters, the brazing seam is pulled around and the filler material is melted down into zones.
4. Finish bond line of joint
 - Continue heating the joint evenly and add additional brazing filler material.
 - Take care to melt the brazing filler material on the work piece and not in the flame.
5. Extinguishing the 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.

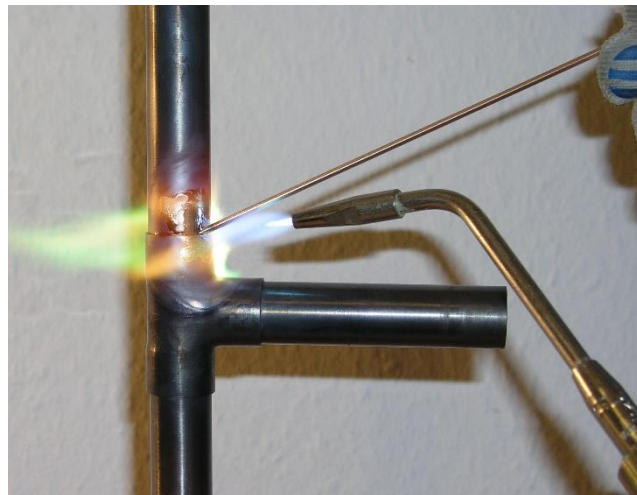
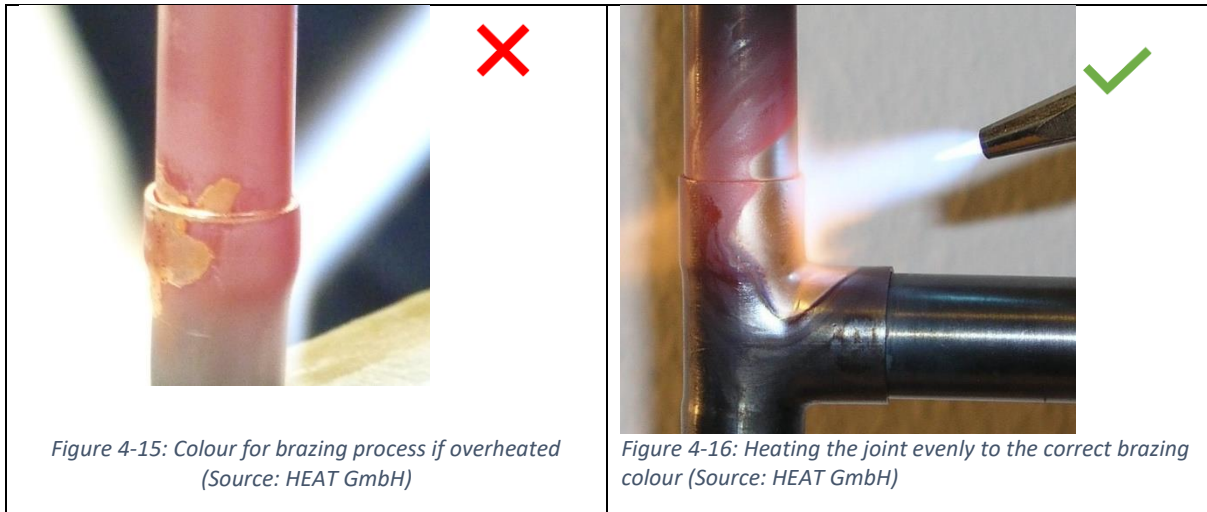


Figure 4-17: Applying filler material (Source: HEAT GmbH)

Tools

- Safety goggles and gloves (fine particle mask)
- Fire extinguisher
- Bucket of water
- Brazing unit (Propane or acetylene)
- OFDN supply when inert gas brazing is applicable
- Flux (if applicable)
- Filler material
- Igniter with spark flint

Step 5: Cooling down

The work piece is cooled down at ambient air until the braze metal has solidified. Do not shake the joint during the cooling process as it takes time to solidify as it cools down from its melting range temperatures.

The component can be removed from the fixtures afterwards.



Figure 4-18: Cooling-down of the heated joint at ambient air (Source: HEAT GmbH)

Step 6: Removing flux residues and other impurities





Removing flux residues

- Corrosive flux residues have to be removed after brazing with water or mechanically e.g. with a brush or damp cloth.
- Brazing oxide layers and foreign particles are to be removed from the surface (e.g. with the use of a steel brush).
- Remaining flux at the piping potentially leads to corrosion
- Properly brazed joints look smooth and clean and do not require any rework.

B4.3 Quality of brazed joints

Brazed joints that are well done have a smooth, clean and good quality appearance. Examples for good and bad joints are shown in the pictures below in *Figure 4-19* and *Figure 4-20*.

 Dos	 Don'ts
<ul style="list-style-type: none"> ✓ Always wear appropriate personal protective equipment. Check that the fire extinguisher is available. Have all necessary MSDS available and read them. ✓ Before any brazing activity, check equipment for damages. ✓ Purge with OFDN (or other applicable inert gas) when brazing whenever possible. ✓ Follow manufacturer's instructions for braze in parts – e.g. to protect service valves with wet rags or heat-reducing material or not to use wet rags for certain expansion valves. ✓ Check if you have the right tools and materials (e.g. filler material, flux) for different kind of connections. Necessary amount of filler material is 3 x OD per joint to be brazed. ✓ Heat joining pieces evenly. ✓ Maintain minimum gap between joints, in specific whilst brazing without fittings. ✓ Use clean pipes, remove burrs. ✓ Use heat protection hat if applicable. ✓ Use industrial copper fittings to achieve the best pipe installation results. ✓ Heat the tube first to conduct heat inside the fitting, then ensure that fitting is up to temperature and the flame is directed towards the fitting. ✓ Brazing activity finally should not last longer than five minutes (depending on the size of work piece). For specific equipment follow manufactures installation instructions ✓ Always use a support fixture (if applicable) this can also make the process of brazing easier. ✓ Deposit the filler metal immediately next to the joint, so that the material does not spread out over the outer surface but flows directly into the joint. ✓ Maintain air-circulation at the workplace. ✓ Obtain permit of work and inform persons linked to your job. ✓ Remove the flux residue after the brazing process is complete. 	<ul style="list-style-type: none"> ✗ Do not braze within a short distance from combustible gas or oxygen transfer hoses or other combustible materials. ✗ Never overheat the brazing joint. ✗ Do not use brazing filler materials whose melting temperature is close to the melting temperature of the base metals. ✗ Do not let flux or water penetrate the inner tubing arrangement. ✗ Mark the area for brazing (section off) ✗ Do not work in a dirty environment. ✗ NEVER handle brazing equipment with visible damages (hoses and tools). ✗ Do not use unclean metal surfaces for forming the joint. ✗ Do not use wrong flux composition that does not fit for the metals being used. ✗ Do not cover the surface area with flux completely before starting the brazing process. ✗ Do not assemble the joints in the wrong position with faulty alignment for the brazing process. ✗ Incorrect torch flame adjustment leads to deposition of carbon or causing excessive oxidation. ✗ Do not ignite flames with cigarette lighter. Check that there is no cigarette lighter within the work area or in your pocket. ✗ Do not leave unused / unfinished tubing open to atmosphere (close with appropriate plugs). ✗ Do not store copper tubing materials and fittings together with other materials. ✗ Do not leave the flux residue as this can lead to weakened joints since the flux material is potentially corrosive. ✗ Do not hurry, keep your time for good pipe installation results.

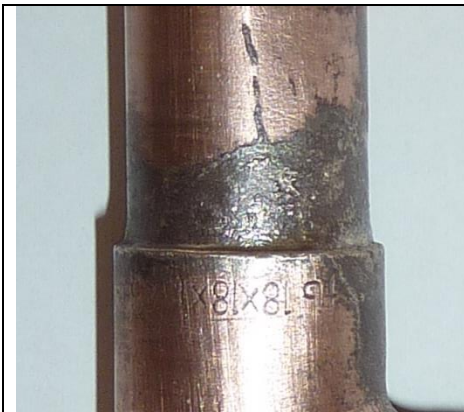


Figure 4-19: Example of good brazing joint (Source: HEAT GmbH)



Figure 4-20: Example of bad brazing joint (Source: HEAT GmbH)



Figure 4-21: Example of state-of-the art refrigerant circuit piping (Source: HEAT GmbH)

B5 Brazers' competence certification

The international standard ISO 13585-2012 (replacing EN 13133-2000) describes the essential requirements for brazers qualification and is listing terms and conditions, examination criteria, inspection procedures and the area of application for a brazers' competence test certificate.

Module B: Refrigerant Circuit Joining Technologies

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, testing and assessment requirements.

Brazing competencies assessment is especially important where flammable refrigerants are used in common field practices.

The qualification test shall take place in a workshop but simulate the on-site limitations. For example, 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 brazer should perform on-site workshop brazing operations in the selected joining technique to be judged.

For brazing qualification assessment (according to ISO13585- 2012), 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.

A typical RAC brazers examination specimen and exemplary examination criteria (e.g. dimensions, filler material, etc.) are shown in figure *Figure 5-1* to *Figure 5-2*.

For domestic refrigeration a brazers examination specimen is shown with figure *Figure 5-3*.

Assessment criteria for the brazing assessment may include: Visual inspection, radiographic inspection, ultrasonic inspection, peeling inspection, others.

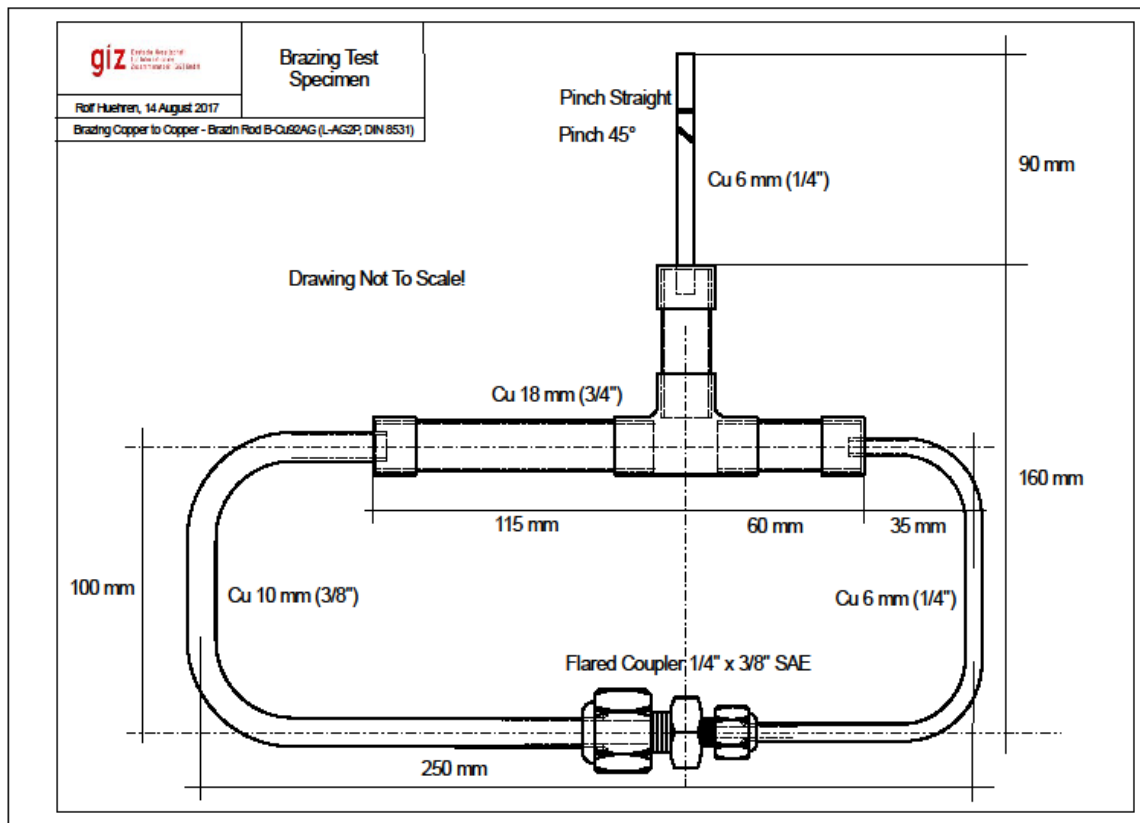


Figure 5-1: Drawing of "Brazing Test Specimen" for brazers' certification (Source: HEAT GmbH)



Figure 5-2: Practical brazers' examination specimen example (including bending and flaring) (Source: HEAT GmbH)

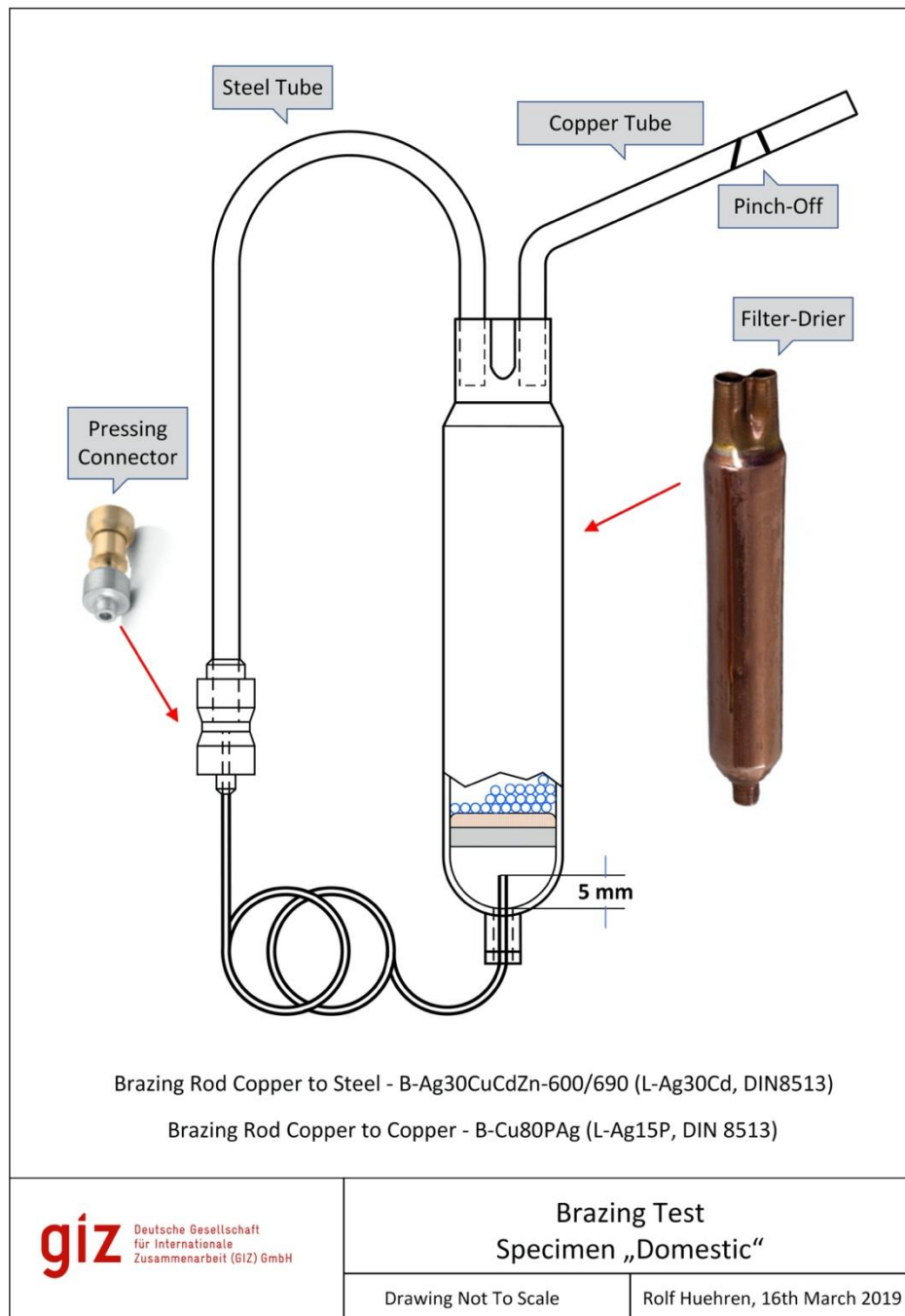


Figure 5-3: Brazing test specimen "Domestic Refrigeration" (Source: HEAT GmbH)

B6 Lokring pressing connections

This chapter describes Lokring tube connection assembly version 00¹, braze-free tube connections (pressing) for servicing and original appliances production for domestic refrigeration appliances.

Lokring is a patented tube connection system comprising of various connectors and tools assortment for every repair situation in refrigeration appliances.

Lokring tube connections can be made without large force application being necessary, using simple hand assembly tools. Lokring ensures a clean, permanent and exceptional mechanical tube connection with permanent technically hermetic gas-tightness. This is especially important if flammable refrigerants are in use.

Permanent technically gas-tight plant components.

No releases of flammable gases are to be expected from plant components that are permanent technically gas-tight. This includes non-detachable pipe connections that have been produced by welding, brazing or pressing.

The benefits of Lokring pressing connections:

- Suitable for flammable refrigerants
- Customer-friendly onsite service
- Clean, efficient and reliable
- Repair work can be performed during business hours and public access
- Repair work in situations where there is a fire hazard (flammable refrigerants)
- Use of lightweight hand assembly tool without physical exertion
- No brazing-related quality problems

Areas of Applications:

- Household refrigeration appliances (refrigerators, freezers, wine coolers, water dispenser etc.)
- Ready-to-use refrigeration equipment (refrigeration cabinets, bars, lockers, chillers)
- Refrigeration equipment for catering (sales counter refrigerators, flow-through coolers, portable cooling systems)

One application system with a variety of connection possibilities:

- Straight connections
- Straight reducing connections
- Capillary connections
- Elbows
- T-connections
- Connections with schrader valve
- Stoppers

With the range of connection components, it is possible to:

- Replace a compressor
- Replace a dryer
- Replace a charging tube

¹ The assembly version is determined on the basis of the last two figures in the article name. Example: Lokring 6 NK Ms 00

Module B: Refrigerant Circuit Joining Technologies

- Repair leaky refrigerant transfer tubes

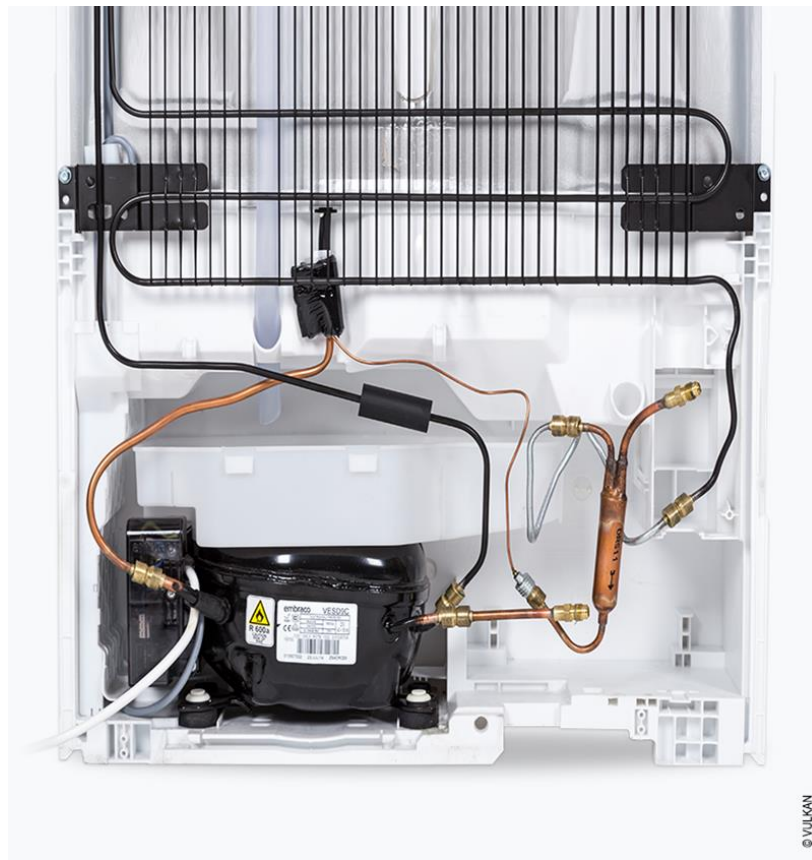


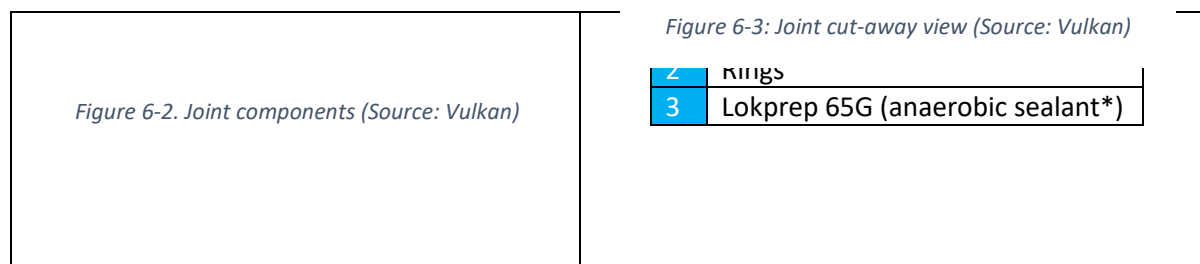
Figure 6-1: Lokring repair and servicing possibilities (Source: Vulkan)

Lokring tube connection components comply with the applicable requirements and are type-examination tested according to:

- ISO 14903:2017-12; Refrigerating systems and heat pumps - Qualification of tightness of components and joints
- EN 378-2:2018-04; Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation

B6.1 Functional principle





The functional principle is to join rings, the joint and the anaerobic sealant Lokprep* using a special assembly tool in order to form a permanently technically gas-tight connection.

** Lokprep is an important component of the Lokring connection technology. With mandatory application, Lokprep will compensate for any unevenness in the tube surface such as longitudinal grooves or surface porosity and stays elastic, thus ensuring that every Lokring connection is hermetically sealed. Anaerobic adhesives and anaerobic sealants through-hardened in the absence of air or oxygen. They are designed for fastening and sealing applications in which a tight seal must be formed without light, heat or oxygen. The expiry date of the substance, indicated on the container label, should not be exceeded at the time of use.*

Metal tubes can have longitudinal grooves on the surface from production. These production-related faults can be compensated quite easily by moistening the tube ends to be connected with Lokprep fluid before assembly. Because of its capillary characteristic, it can even flow into microscopic cavities and fill these out completely. Lokprep is not an adhesive!

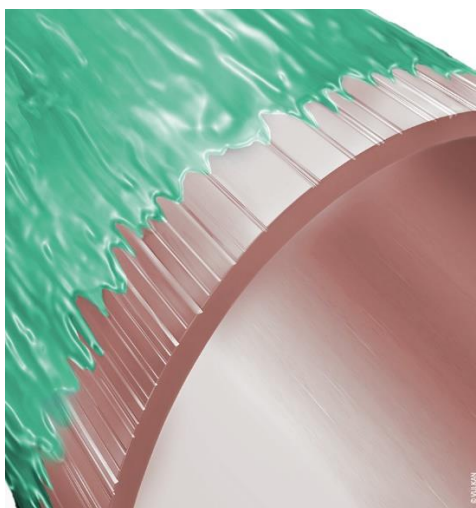


Figure 6-4: Lokprep appearance on a metal tube with grooves (Source: Vulkan)

B6.2 Assembling tools and consumables

The assembly (pressing) tool is specially developed for the Lokring assembly. It comprises of a patented lever mechanism for assembly with minimum effort. Assembly jaws are easy to change for different tube diameters. Both handles bend for use in hard-to-reach areas.



Figure 6-5: Lokring assembly tool
(Source: Vulkan)

1. Loktool HMRK-V



Figure 6-6. Lokring assembly jaws (Source: Vulkan)

1. Loktool MB 8 for tubes outer \varnothing 1.6 – 8.5 mm (1/16" – 5/16")
2. Loktool MB 10 for tubes outer \varnothing 9 – 11 mm (3/8")
3. Loktool MB 12 for tubes outer \varnothing 12 – 13 mm (1/2")



Figure 6-7: Loktool VME (Source: Vulkan)

For single-sided pre-assembly of Lokring connector type 00

1. Loktool VME 3 for connector size 3 mm
2. Loktool VME 5 for connector size 5 mm (3/16")
3. Loktool VME 6 for connector size 6 mm (1/4")
4. Loktool VME 7 for connector size 7 – 7.5 mm
5. Loktool VME 8 for connector size 8 mm (5/16")



Figure 6-8: Loktool NTR-8 (Source: Vulkan)

- For assembling a T-branch.
- Suitable for Lokring T-connectors or T-reducing connectors type 00.
- For assembly, the insert is simply inserted into the assembly jaw.



Figure 6-9: Loktool NAV 11 (Source: Vulkan)

Basic tool for assembling Lokring NAV connections



Figure 6-10: Lokring NAV-E (Source: Vulkan)

Assembly insert for NAV 11 assembly tool for assembling Lokring NAV connections

1. Lokring NAV-E 6 for connection size 6 mm (1/4")
2. Lokring NAV-E 8/7 for connection size 7 - 8 mm (5/16")
3. Lokring NAV-E 9.53 for connection size 9.53 mm (3/8")



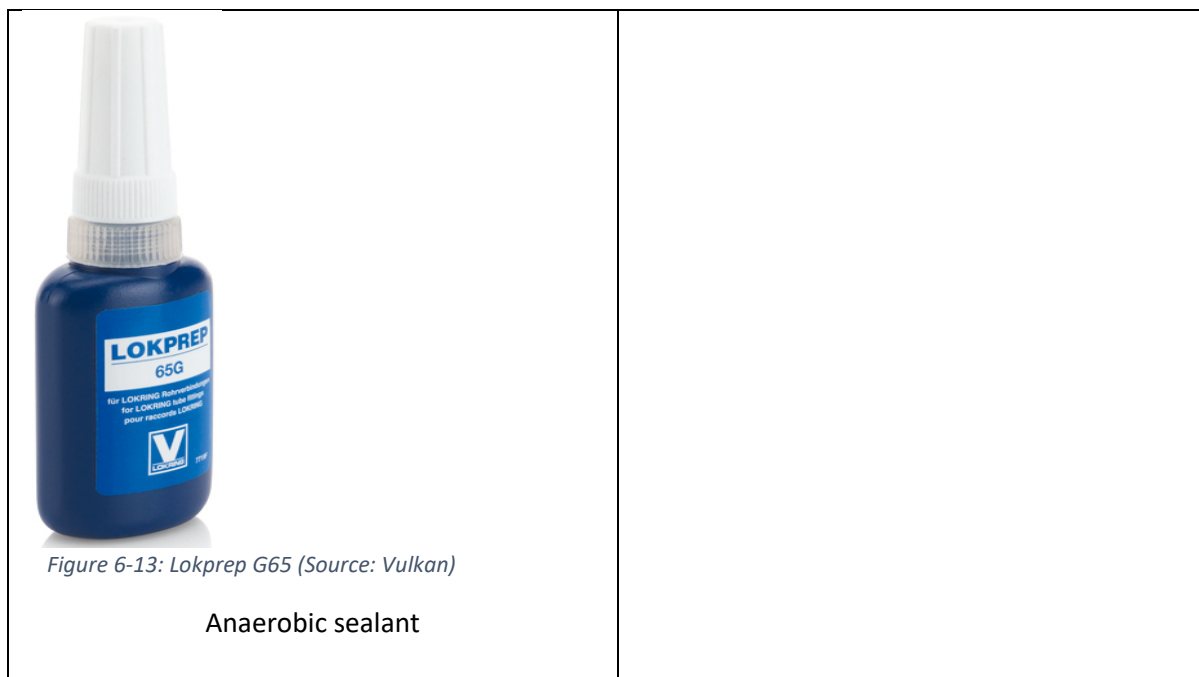
Figure 6-11: Abrasive mat (Source: Vulkan)

- For cleaning tube ends without scratching.
- Suitable for all surfaces.
- Solvent-resistant.
- Dimensions: 158 mm x 224 mm



Figure 6-12: Sandpaper (Source: Vulkan)

- For cleaning tube ends.
- Grain 120
- Dimensions: 230 mm x 280 mm



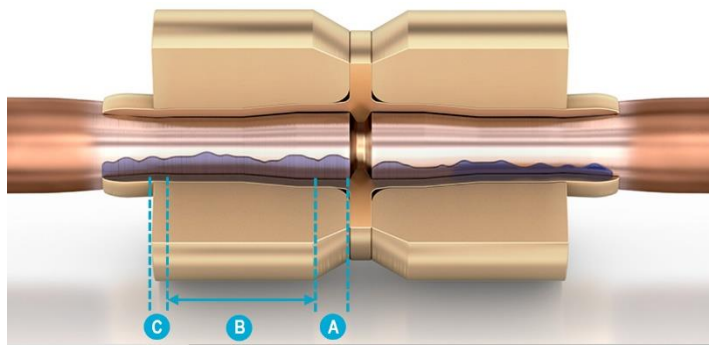
B6.3 Lokring union joints technical specifications

Lokring tube connections are available in material of brass and aluminium and in tube diameter ranges of 1.6 mm to 11 mm (1/16" to 3/8") for brass and 2 to 9 mm (5/64" to 5/16") for aluminium.

Maximum operation pressure	25 bar (360 psi)
Admissible refrigerants	HCs, HFCS and mixtures (not suitable for CO ₂ and NH ₃)
Minimum tube wall thickness	0.5 mm
Temperature ranges	-50°C up to 150°C (-58°F up to 302°F)
Testing standards	EN378:2-2016; EN ISO 14903:2017-12
Approvals	TÜV, UL (File SA12004)

The typical Lokring union joint consists of two Lokring's and one tubular joint for the acceptance of the two tube ends. Because of the conical inner contour of the Lokring and the special outer contour of the joint, the diameter of the connection is reduced during assembly to such an extent that the joint and the tube create a hermetically sealed metal-to-metal connection. The permanent technical gas-tightness of the fitted connection is ensured by the state of permanent elastic pre-tension, which is produced by the radial forces of the Lokring's acting in the opposite direction to the tube-joint connection.

Module B: Refrigerant Circuit Joining Technologies



A	Insertion area
B	Stabilisation and sealing area
C	Main sealing area

Figure 6-14: The Lokring functional principle (Source: Vulkan)

Material combinations

With the assortment of brass and aluminium unions and connectors it is possible to produce connections between the materials copper, steel and aluminium.

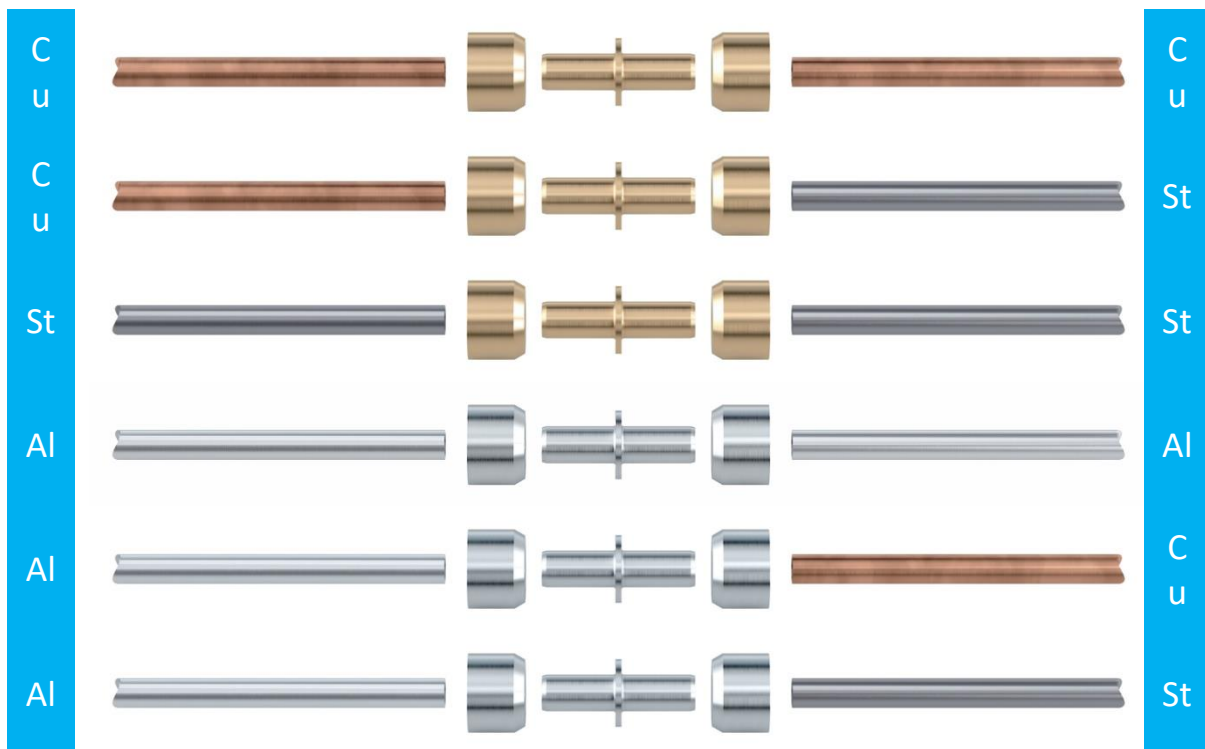
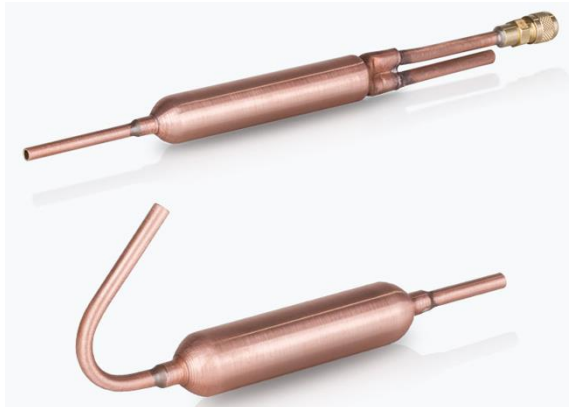










Figure 6-15: Material combinations possibilities (Source: Vulkan)

B6.4 Examples of types of joints, connectors and components

 <p>Figure 6-16: Lokring filter-drier with pressing tube adapter (Source: Vulkan)</p>	<p>Lokring filter driers</p> <ul style="list-style-type: none"> • Specially designed for LOKRING application. • For all HC and HFC refrigerants. • Protects the refrigeration circuit against moisture, acids and dirt particles. • Desiccant: XH-9 <p>XH-9 is a molecular sieve desiccant with strong refrigerant drying capability. Uncontrolled system moisture can freeze capillary tubes and expansion valves, corrode metal parts, and plug expansion devices with sludge. Water can enter the system when it is manufactured or during servicing processes.</p> <p>Note: With every intervention into the refrigerant circuit it is mandatory to change the filter-drier.</p>
 <p>Figure 6-17: Lokring straight brass connector (Source: Vulkan)</p>	<p>Straight brass connector in various diameters</p>
 <p>Figure 6-18: Lokring straight aluminium connector (Source: Vulkan)</p>	<p>Straight aluminium connector in various diameters</p>
 <p>Figure 6-19: Lokring straight brass reducing connector (Source: Vulkan)</p>	<p>Refrigerant tube to capillary tube connector (reducing connector)</p>

 <p>Figure 6-20: Lokring brass stopper (Source: Vulkan)</p>  <p>Figure 6-21: Lokring copper charging tube with schrader valve (Source: Vulkan)</p>	<p>Charging tube with stopper for hermetically sealing tube ends</p> <p>Copper charging tube with 1/4" SAE schrader valve connection for charging, sealing and servicing of refrigeration circuits</p>
 <p>Figure 6-22: Lokring straight brass connector with schrader valve (Source: Vulkan)</p>	<p>Straight connector with schrader valve. For connecting copper and/or steel tubes with identical tube outer diameters. With 1/4" SAE schrader valve port connection.</p>
 <p>Figure 6-23: Lokring brass T-reducing connector (Source: Vulkan)</p>	<p>Brass T-reducing connectors type 00</p> <ul style="list-style-type: none"> • For connecting copper and/or steel tubes with different tube outer diameters • Allows insertion of a capillary tube into the suction line.
 <p>Figure 6-24: Lokring NAV connection (Source: Vulkan)</p>	<p>NAV connection</p> <ul style="list-style-type: none"> • Allows the use of LOKRING on the short tube ends of a compressor. • Can only be used in conjunction with the NAV assembly tool and the corresponding NAV assembly insert.

B6.5 Assembly instructions




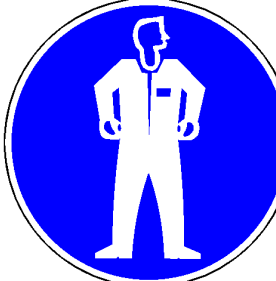

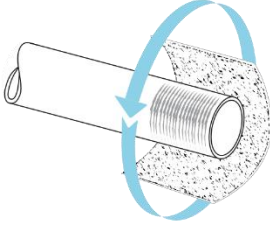
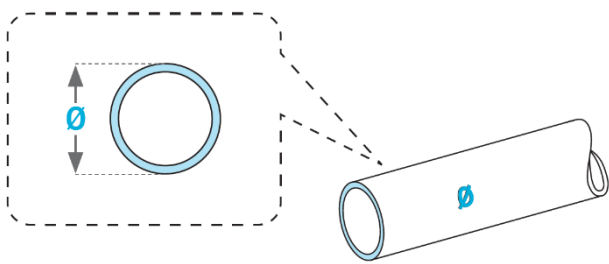
			
<p>Always wear appropriate personal protective equipment (PPE) as recommended by the manufacturer! Generally observe the provisions of the MSDS!</p>	<p>Safety glasses, goggles or face shield to protect against splashing. Personal eye protection should conform to EN 166</p>	<p>Nitrile rubber or Viton™ gloves are recommended. Cotton or other absorbent gloves should not be worn. Gloves should conform to EN 374.</p>	<p>Employee must wear appropriate protective clothing and equipment to prevent any possibility of skin contact with this substance. Wash before eating, drinking, or using toilet facilities.</p>
 <p><i>Figure 6-25: Cleaning of copper tube ends with abrasive mat (Source: Vulkan)</i></p>		<p>Tube preparation: Clean the tube ends with stripes of an abrasive mat in a rotational motion to ensure that they are clean and free from paint or other surface impurities. Take care that the internal burr is removed from the tube.</p> 	



Figure 6-26: Example of the use of a calliper gauge (Source: HEAT GmbH)

Lokring joint identification and selection:

Determine the outer tube diameter \varnothing using a digital calliper gauge.



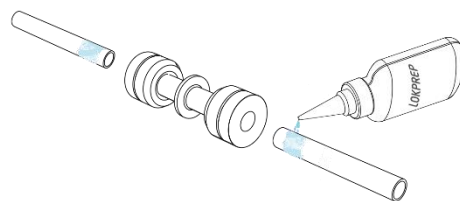
Select the required connector.



Figure 6-27: Applying LOKPREP to a pipe end (Source: Vulkan)

Lokprep anaerobic sealant application:

Apply Lokprep onto the tube ends.



Curing time of Lokprep starts after it is applied onto the tube.



Figure 6-28: Inserting the tube ends into the Lokring connector (Source: Vulkan)

Make a tube joint:

Insert both tube ends into the Lokring connector until the tubes reach the inner stop.

Rotate the Lokring connector through 360° to distribute the Lokprep 65G evenly.

Make the Lokring connection within 20 seconds after applying Lokprep.

Respect the correct curing time of the Lokprep 65G before pressurizing.

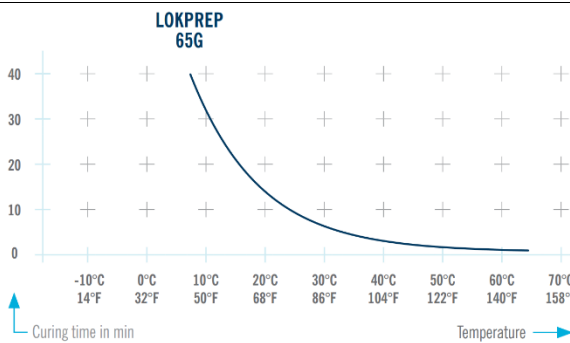
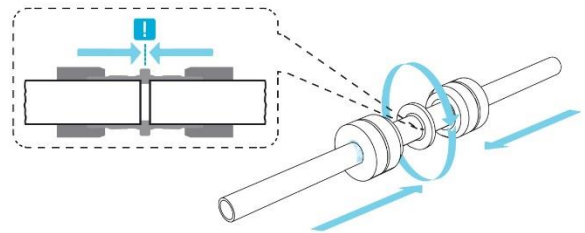


Figure 6-29: Graph for the definition of the curing time (Source: Vulkan)

The curing time of Lokprep:

The curing time for Lokprep 65G depends on the ambient temperature and can be taken from the chart. Curing time of Lokprep starts after it is applied onto the tube.

Curing time increases when temperature decreases.

Exemplarily the curing time at 30°C (86°F) ambient temperature is about 6 minutes, but at 10°C (50°F) 30 minutes.

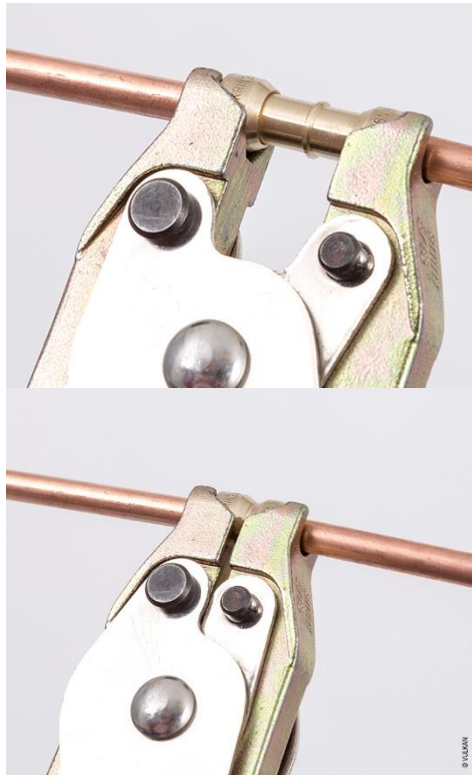


Figure 6-30: Example of pressing a straight brass connector (Source: Vulkan)

How to use the assembling tool:

Insert the connector even and completely into the jaws of the assembly tool (as shown with the picture).

Press the tube connection until the rings of the Lokring connector are flush to the assembly stop of the Lokring connector.

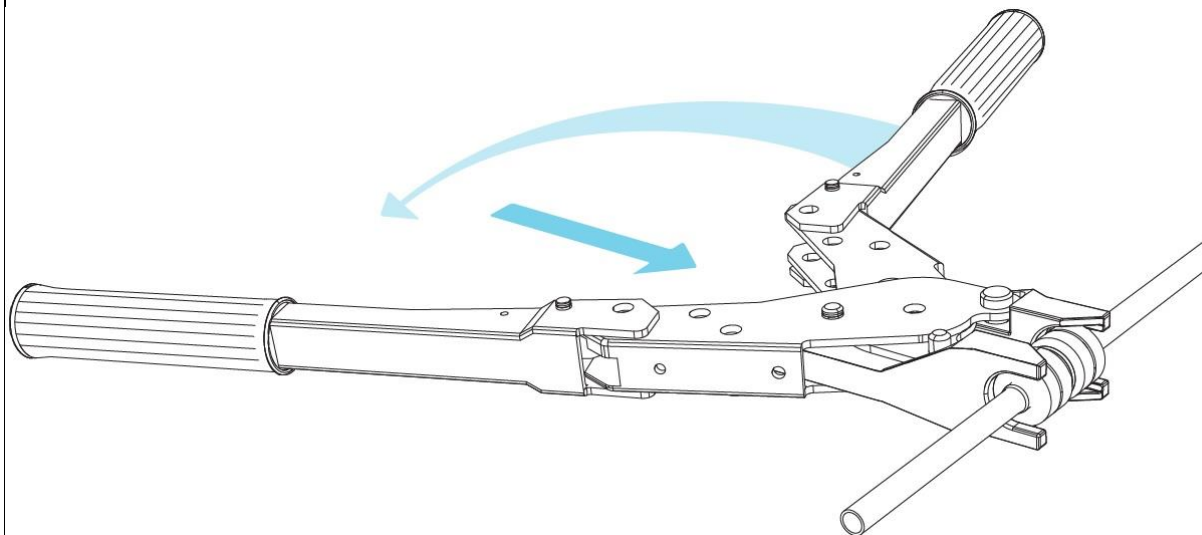
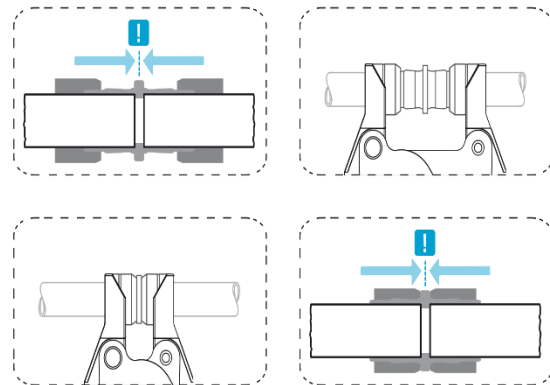

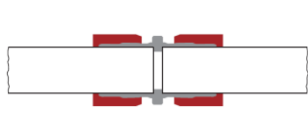
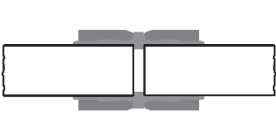
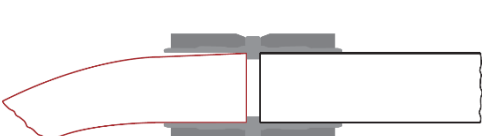



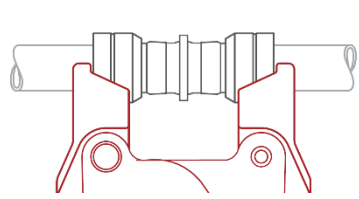
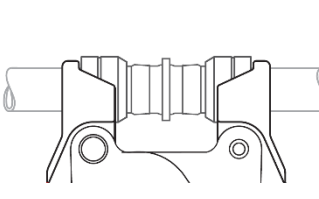
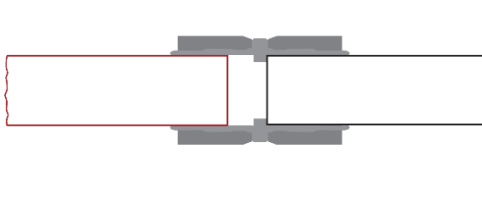
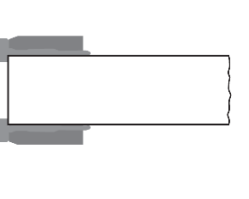
Figure 6-31: Schematic view of the use of the assembly tool (Source: Vulkan)

Module B: Refrigerant Circuit Joining Technologies

	<p>Refrigerant circuit commissioning: Respect the curing time (rule of thumb min. 10 minutes) of the Lokprep 65G.</p> <p>The refrigerant circuit is now prepared for:</p> <ul style="list-style-type: none"> ➤ pressure testing ➤ evacuation ➤ charging with refrigerant ➤ operation
<p>Figure 6-32: Appearance of a finished pressing connection (Source: Vulkan)</p>	

B6.6 Examples as assembly aid

Assembly steps			
Inserting the tube ends into the connector			
			
<p>Wrong: Rings have not been pressed through to the assembly stop.</p>	<p>Right: Rings have been pressed flush to the assembly stop.</p>	<p>Wrong: The bending point is too close to the joint end.</p>	<p>Right: The tube has to be led straightly out of the joint.</p>

The process of pressing, use of the assembly tool			
			
<p>Wrong: Assembly jaws are not set in place correctly.</p>	<p>Right: Assembly jaws are set flush correctly.</p>	<p>Wrong: The tube is not pushed in as far as the inner stop.</p>	<p>Right: Push the tube in until you can feel the inner stop.</p>

B6.7 Refrigerant circuit servicing after Lokring assembly

The refrigerant circuit now may have connections for circuit access at low side (compressor) and high side (filter drier).

It is recommended to leave the appliance operational after servicing in hermetically sealed condition. Preferably there should not be any valve connections (schrader) left at the system, having in mind that capped valves bear potential of leakages with normal operation. Since plug-in refrigerators and freezers have very small charge amounts with R600a (or R290) refrigerant, smallest refrigerant leakages will reduce the appliance energy efficiency.

Execute regular refrigerant circuit servicing activities by applying best servicing practices

- Functional check of a fridge
- Discharge of the refrigerant (HC venting)
- Recovery of refrigerant
- Repair with Lokring at several connecting points of the refrigerant circuit
- Evacuation
- Charging of refrigerant using a sensitive weighting scale
- Sealing of the refrigerant circuit
- Functional check of the repaired fridge
- Leakage detection (final check)



Figure 6-33. Exemplary refrigerant circuit servicing arrangement (Source: Vulkan)

B7 Bibliography

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