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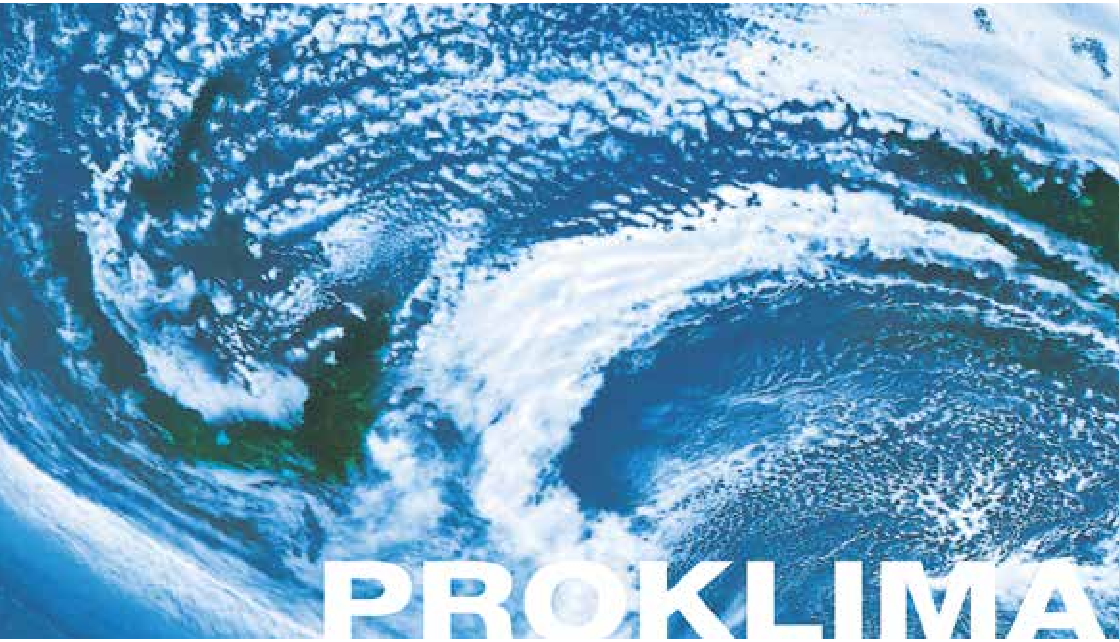

Good Practices in Refrigeration

On behalf of

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

Federal Ministry
for Economic Cooperation
and Development

Proklima International

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Since 1 January 2011, GIZ has brought together under one roof the capacities and long-standing experience of three organisations: the Deutscher Entwicklungsdienst (DED) GmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German technical cooperation) and InWEnt – Capacity Building International, Germany. As a federal enterprise, we support the German Government in achieving its objectives in the field of international cooperation for sustainable development. We are also engaged in international education work around the globe. GIZ operates in more than 130 countries worldwide.

PROKLIMA is a programme of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ). PROKLIMA has been providing technical and financial support for developing countries since 1996 to implement the provisions of the Montreal Protocol on Substances that Deplete the Ozone Layer.

Good Practices in Refrigeration

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Volkmar Hasse, Linda Ederberg and Rebecca Kirch

Preface

The phase-out of HCFCs and the introduction of various alternative refrigerants confronts both the servicing technicians and vocational trainers in the refrigeration and air-conditioning sector with specific problems. Refrigeration technicians are not yet sufficiently prepared to deal with the new technologies which will have to be introduced in the near future.

The manual 'GOOD PRACTICES IN REFRIGERATION' is the second edition of a booklet jointly published by the PROKLIMA Programme of the 'Deutsche Gesellschaft für Technische Zusammenarbeit' (GTZ) GmbH, the Brazilian 'Servico Nacional de Aprendizagem Industrial' (SENAI) and the 'Ministério do Meio Ambiente do Brazil' (MMA) in 2004, which had been widely used as part of the training courses on 'Best practices in refrigeration servicing and CFC conservation', which were implemented by PROKLIMA as part of the national CFC phase-out plan in Brazil.

This manual has now been updated to provide professional guidance on how to service and maintain refrigeration systems operating with new technology, e.g. ozone-friendly alternative refrigerants to CFCs and HCFCs. It addresses essential know-how on containment of HFC refrigerants which have a high Global Warming Potential (GWP) and are already widely applied. It also provides extensive information on the safe use of natural refrigerants, such as CO_2, Ammonia or Hydrocarbons, which are much more environmentally-friendly with zero or negligible GWP. These efficient but still relatively little used refrigerants are in fact suitable replacements for HCFCs in all applications of refrigeration and air-conditioning equipment.

Part I of this picture book addresses important tools and equipment for tubing; refrigerant handling and containment; for recovery, recycling, reclamation and evacuation, as well as measuring instruments. Part II focuses on the handling of servicing and maintenance of refrigeration systems, such as brazing, flaring, recovery, retrofit and recycling.

Illustrations should help the technicians to easily remember, identify and communicate elements of best practices in refrigeration.

Background

Ozone depletion and Montreal Protocol

In the 1970s, scientists discovered the dangerous impact CFCs have in the earth's atmosphere. CFCs were used as foam blowing agents, refrigerants and solvents. It was found that they destroy the ozone layer, so that aggressive UV-B radiation can reach directly the Earth's surface causing genetic damage in the cells of people, plants and animals. Therefore, in 1987, an international treaty was concluded at Montreal, Canada (the so called Montreal Protocol on Substances that Deplete the Ozone Layer), to prevent the ozone layer from further destruction and begin the phase-out of the use of CFCs and other ozone-depleting substances (ODS). Until November 2009, all states worldwide had signed the Protocol. They have worked effectively and successfully towards a substitution of CFCs which have been banned since 1 January 2010. In 2007, the treaty was adjusted to address the phase-out of HCFCs which are the last group of ODS. The refrigeration and air-conditioning sector, especially in many Article-5 countries, uses very large quantities of HCFCs and is therefore particularly relevant in the imminent HCFC phase-out.

Part I Tools and Equipment

Introduction to Part I

Proper and environmentally responsible servicing and maintenance of refrigeration systems requires special equipment, e.g. instruments for refrigerant leak detection, tools to measure gas pressure and temperature, as well as special equipment for the general handling and recycling of refrigerants.

The following chapters review various kinds of tools and equipment needed in modern workshops when working on refrigeration and air-conditioning systems.

Chapter 1: Tools for Tubing

Preface

In the following chapter we will describe tools and equipment for the handling of tubing.

Tools for Tubing

1


2


Figure 1: Tube cutter (wheel cutter)

Cuts copper, brass and aluminium tubing

1. Cutter for 6 to 35 mm tubes diameter
2. Cutter for 3 to 16 mm tubes diameter

Figure 2: Capillary tube cutter

For cutting capillary tubes without collapsing the tubes inside diameter
Cuts all sizes of capillary tubes

❶ ❷

Figure 3: Reamer and deburrer

Inner and outer reamer for copper tubing burr removal

❶ Inner-outer reamer for copper tubing
❷ Handy deburrer, blade can be swivelled

❶ ❷

Figure 4: Scouring pad and brush

Inner and outer cleaning and finishing with a

❶ Plastic scouring pad
❷ Fitting brush

Figure 5: Steel brush

Outside cleaning of copper, steel, brass, aluminium tubes

1 Steel wires

Figure 6: Pinch-off plier

Pinches off copper tubes up to 12 mm diameter

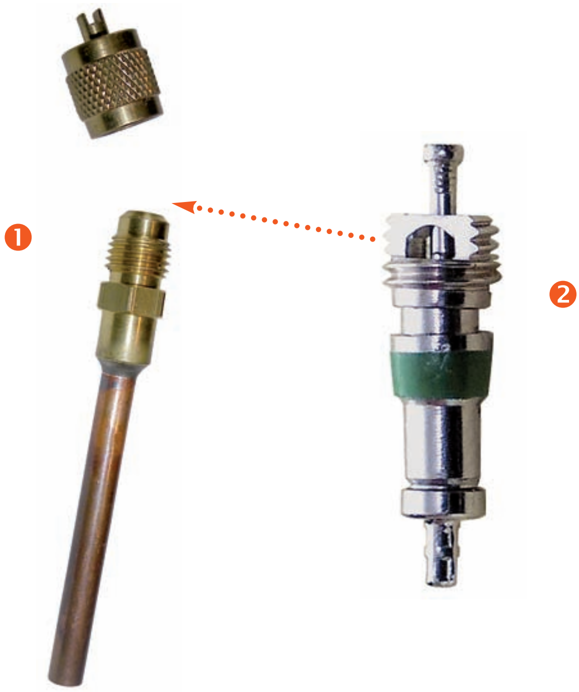


Figure 7: Extended copper tube with access valve (Schrader)

1. Straight solder with tube and service valve 1/4" male flare SAE
2. Valve core

If improperly installed a potential refrigerant leak source!
Not recommended for Hydrocarbon applications!

❶

❷

❸

Figure 8: Quick couplers 'Hansen'

❶ Assembly of quick coupler from tube to refrigerant hose
❷ Clamps directly on straight tubes with diameter from 2 to 10 mm
❸ Same as ❷, but for screwing

Working pressure from 13 mbar to 45 bar

Figure 9: Press system components for tubing

1. Tool set with fittings, connectors and adapters
2. Straight copper tube press connector
3. Elbow press connector
4. Press connector for suction pipe with capillary tube (domestic)

Figure 10: Telescope inspection mirror

Visual inspection of brazing joints

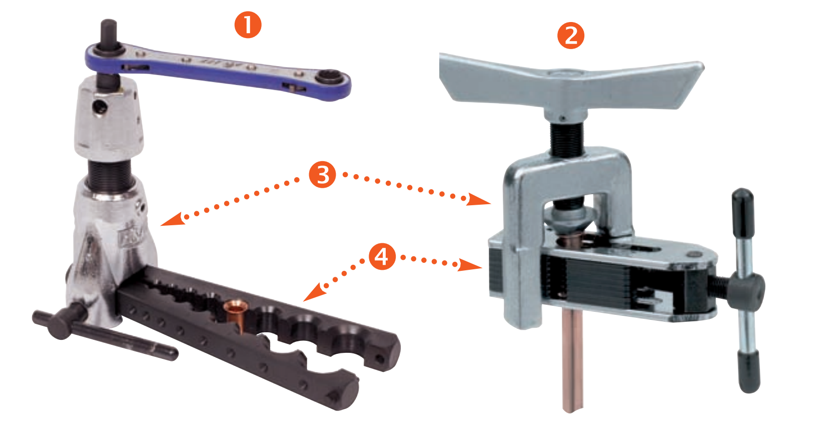


Figure 11: Flaring tool

1. Faceted flaring bar (holding tool) 6-8-10-12-15 and 16 mm (or inch size) with flaring cone
2. Iris-diaphragm flaring bar (holding tool) 5 to 16 mm with flaring cone
3. Clamp tool with flaring cone
4. Flaring bars to admit tubes with different diameter

Figure 12: Tube bender

1. Swivel handle tube bender for one specific tube size (available from 6 to 18 mm or inch sizes)
2. Triple head tube bender for tubes 6, 8 and 10 mm (or inch sizes)
3. Mechanical tube bender assembly with shoes and counter formers (different sizes)

Figure 13: Tube expander

1. Tube expander for annealed copper with replaceable expanding heads (10 to 42 mm or inch sizes)
2. Example of an expanded copper tube
3. Expander and headset

Figure 14: Brazing equipment

1. Propane/Oxygen brazing unit
2. Oxygen pressure regulator with hose assembly
3. Propane (only) brazing unit
4. Acetylene (only) brazing unit
5. Acetylene pressure regulator with hose assembly
6. Burner (torch)

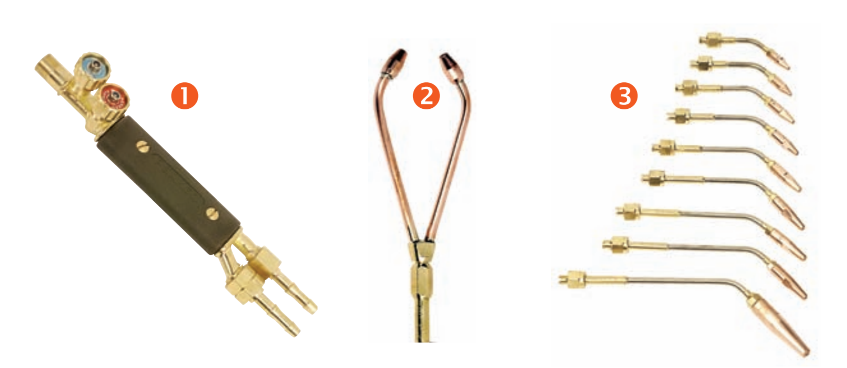


Figure 15: Torch (burner) and tips for Propane-Oxygen

Brazing of copper, brass and aluminium tubing

1. Torch handle with gas regulators
2. Twin-flame fork torch
3. Torch attachments different sizes with tips made of hard copper

Figure 16: Lighters

1. Igniter with spark flint (binder form)
2. Igniter with spark flint and tips cleaner (binder form)
3. Igniter with spark flint (pistol form)

'Cigarette'-lighters are dangerous to use with brazing equipment

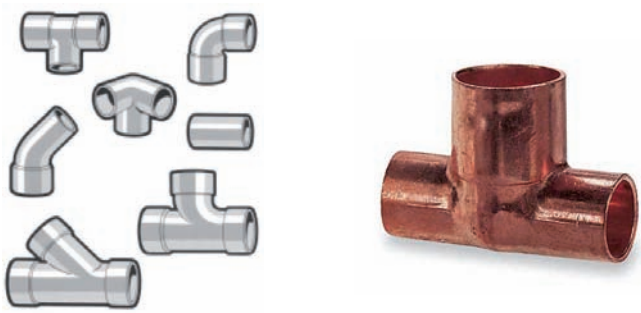


Figure 17: Example of fittings

Various design and diameter
Material: brass or copper

Rod	Cu	Ag	Zn	Sn	P	Melting Range °C
CP 203	Rest	–	–	–	5.9–6.5	710–890
CP 105	Rest	1.5–2.5	–	–	5.9–6.7	645–825 ❶
AO 106	35–37	33–35	Rest	2.5–3.5	–	630–730
AO 104	26–28	44–46	Rest	2.5–3.5	–	640–680 ❷
AO 203	29–31	43–45	Rest	–	–	675–735

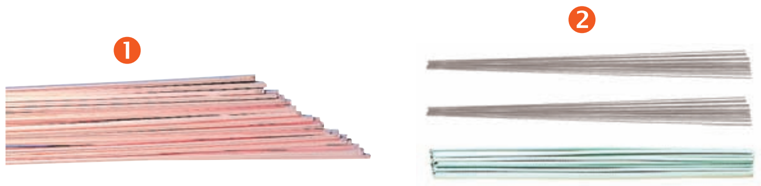


Figure 18: Brazing rods examples (solder)

❶ Recommended (solder) for copper/copper brazing
❷ Recommended (solder) for copper/brass brazing

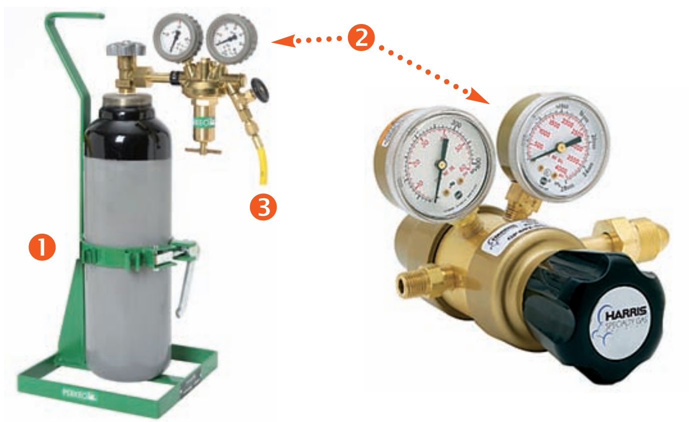


Figure 19: Nitrogen cylinder

❶ Nitrogen cylinder
❷ Nitrogen pressure regulator
❸ Nitrogen transfer hose with 1/4" female flare SAE connection

Common Types of Cylinder for Nitrogen and Oxygen			
Capacity [litre]	Diameter [mm]	Test pressure [bar]	Bottom type
5	140	250/300/345	convex concave
10			
5	140	450	convex concave
10			
6.7	160	250/300/345	concave
13.4			
13.4	204	250/300/345	concave
20			
40			
40	229	250/300/345	concave
50			
50	229	450	concave
67.5	267	250/300	concave
80			
80	273	450	concave

1

2

3

4

Figure 20: Cylinder and accessories for technical gases

1. Cylinder various sizes
2. Cylinder valve with safety valve
3. Standard guards (tulip shaped)
4. Standard guard (open-closed shaped)

Figure 21: Fire extinguisher

Powder – 2 kg

Chapter 2: Tools for Refrigerant Handling and Containment (RHC)

Preface

For the measurements of refrigeration or AC operation pressures and temperatures, for the purpose of refrigerant transfer and for system evacuation, a service gauge manifold is used. In the following we would like to describe different gauges and gauge sets and important tools for refrigerant handling and containment.

The Service Gauge Manifold

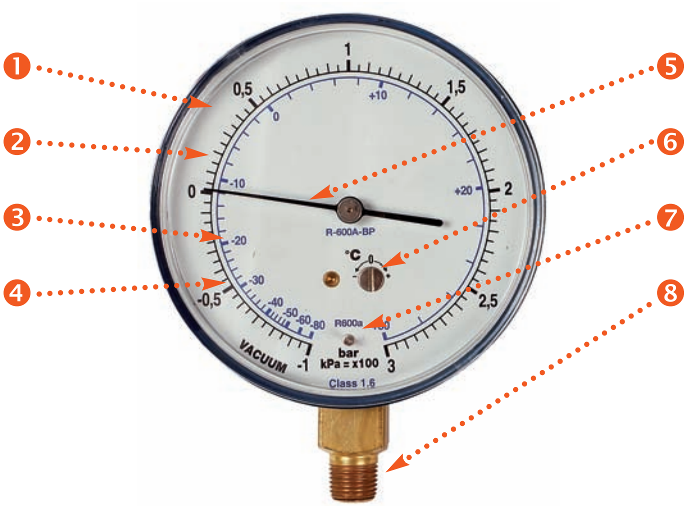


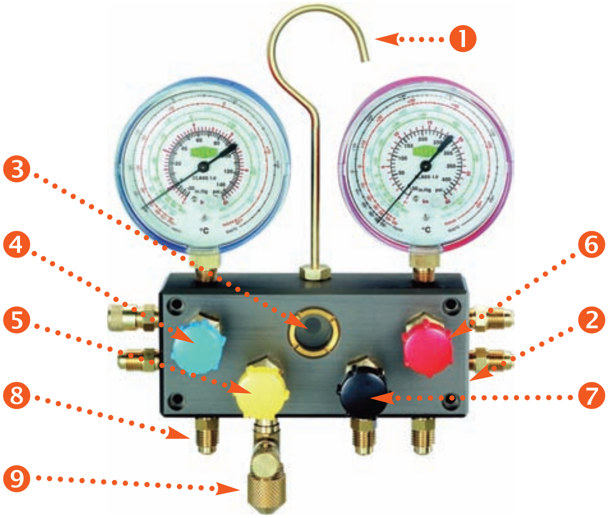
Figure 1: The pressure gauge

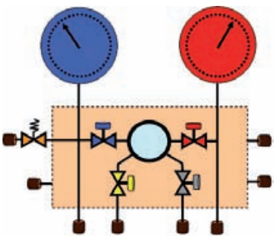
1. The pressure gauge body with transparent removal protection cap
2. Scale with graduation
3. Temperature scale (in °F or °C)
4. Pressure scale (in bar, PSI, kPa…)
5. Pointer
6. Calibration screw
7. Refrigerant indication
8. Brass connection with thread

We have three different pressure gauges!
- **The low pressure gauge**
- **The high pressure gauge**
- **The vacuum gauge**

For easy handling the pressure (low/high) gauges are assembled together with a brass or aluminium body and valves.

We differentiate 2, 3, 4 and 5-valve service gauge manifold sets.





Schematic view of the above 4-valve service gauge manifold

Figure 2: Example of a 4-valve service gauge manifold

1. Support bar
2. Manifold body
3. Sight glass for refrigerant flow
4. Low pressure valve
5. Vacuum pump valve
6. High pressure valve
7. Valve connection for charging cylinder or recovery unit
8. Hose connection 1/4" male flare SAE
9. Vacuum hose connection 1/4" and 3/8"

3
2
1
4
5

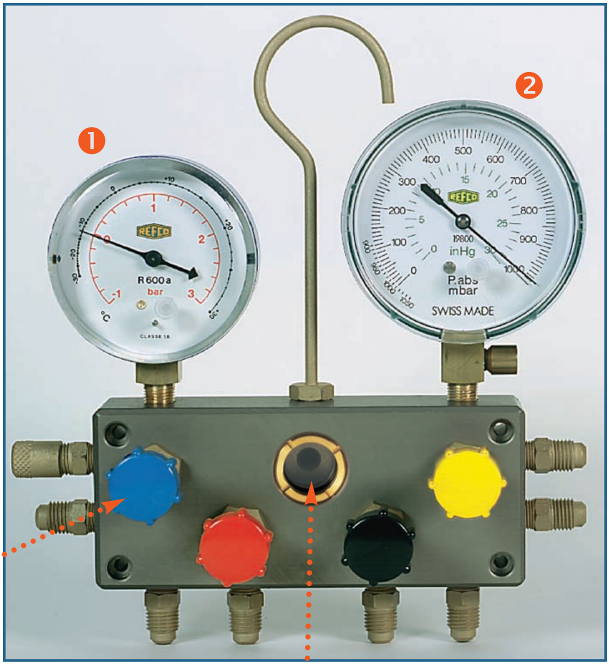


Figure 3: Manifold gauge set for HC refrigerant R600a

1. Low pressure gauge for refrigerant HC-R600a
2. Vacuum gauge
3. Support bar
4. Valves
5. Sight glass for refrigerant flow

A perfect service gauge manifold set should have a vacuum gauge
Vacuum gauges are installed regularly at a 4 or 5-valve service gauge manifold

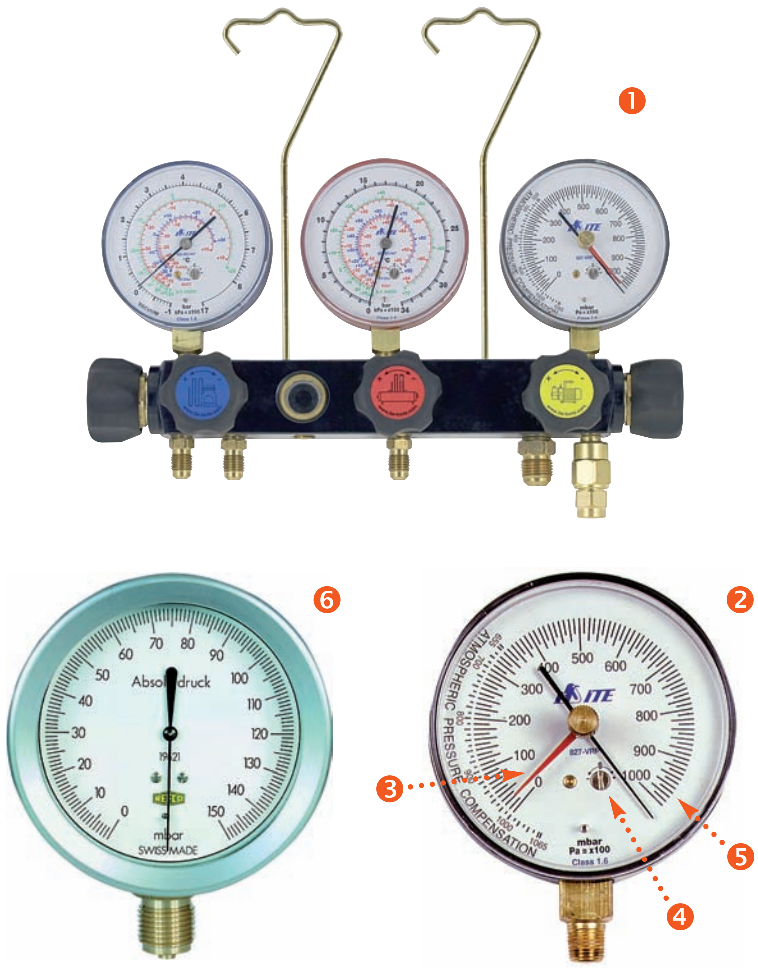


Figure 4: The vacuum gauge

1. 5-valve service gauge manifold with vacuum gauge
2. Relative vacuum pressure gauge – measuring range 0 to 1000 mbar
3. Maximum reading pointer (adjustable)
4. Calibration screw
5. Pressure scale
6. Absolute vacuum pressure gauge – measuring range 0 to 150 mbar

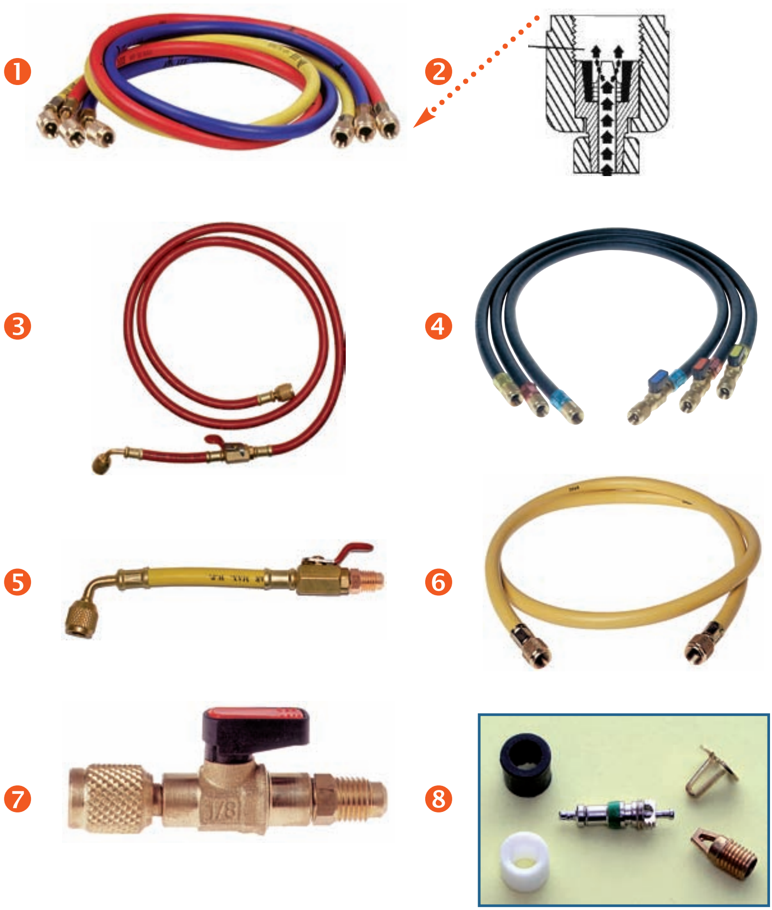


Figure 5: Refrigerant transfer hoses and accessories

1. Refrigerant standard hose with 2 x 1/4" SAE female flare connection
2. Adjustable and replaceable core-depressor (valve opener) 'schematic'
3. Refrigerant hose with inline ball valve, 2 x 1/4" SAE female flare connection
4. Refrigerant hose with 'end-mounted' ball valve for minimal refrigerant emission
5. Ball valve adapter for standard hose 1/4" SAE male/female connection
6. Vacuum hose 2 x 3/8" female flare SAE connection
7. Ball valve - 1/4" SAE male x 1/4" SAE female
8. Spare gaskets and core-depressors

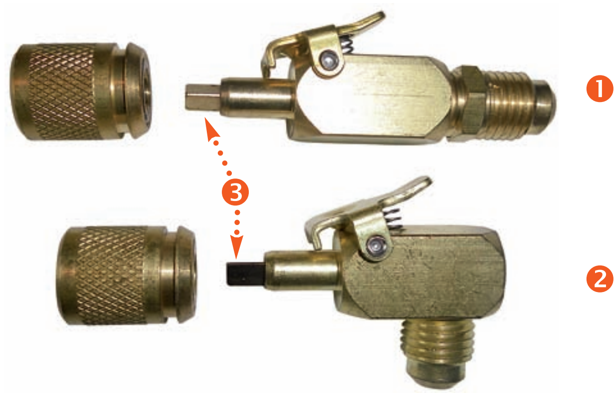


Figure 6: Service port quick coupler

1. Straight coupler for refrigerant hose 1/4" SAE flare male x 1/4" SAE flare female
2. Elbow coupler for refrigerant hose 1/4" SAE flare male x 1/4" SAE flare female
3. Core-depressor (valve opener)

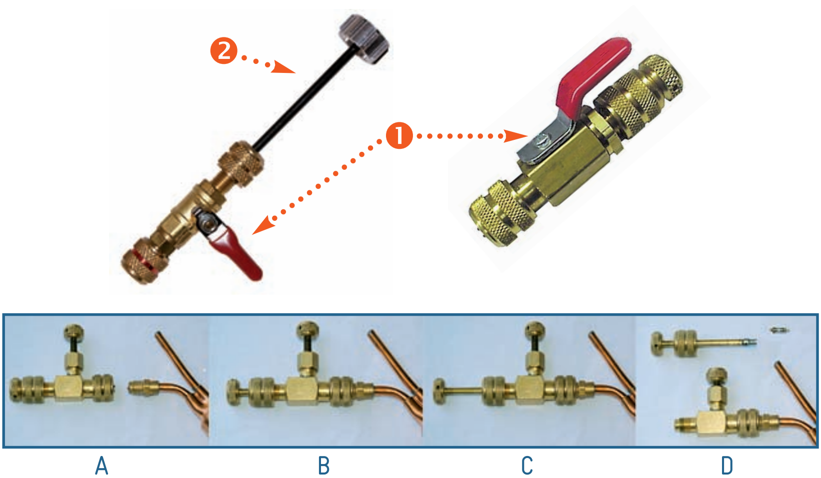


Figure 7: Core removal tools

Easy and quick core removal without refrigerant emission

1. Valve
2. Magnetic core holder

TOOLS AND EQUIPMENT

Figure 8: Core valve removal tool

For removing and replacing valve cores in 'Schrader'-valves and charging hoses
Tools contain spare valve cores

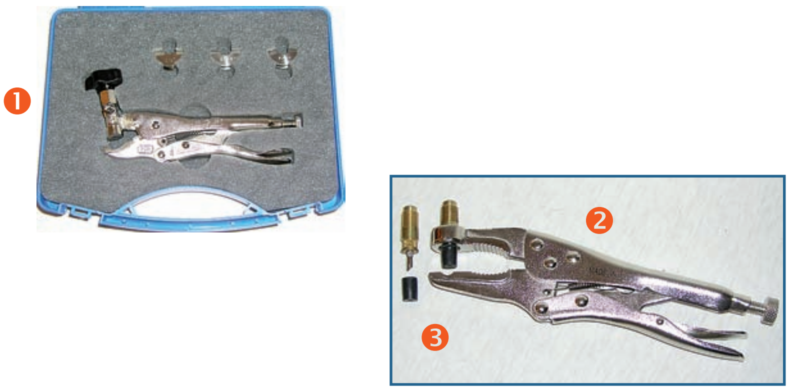


Figure 9: Piercing plier (adjustable)

Enables immediate piercing/access on any refrigerant tubing from 5 to 22 mm

1. Piercing plier for different diameter/with hand operated valve
2. Piercing plier/adjustable
3. Spare needle

Figure 10: Piercing valve

Enables piercing/access to any refrigerant tubing from 5 to 16 mm

ONLY for temporary system installation otherwise a potential refrigerant leak source!

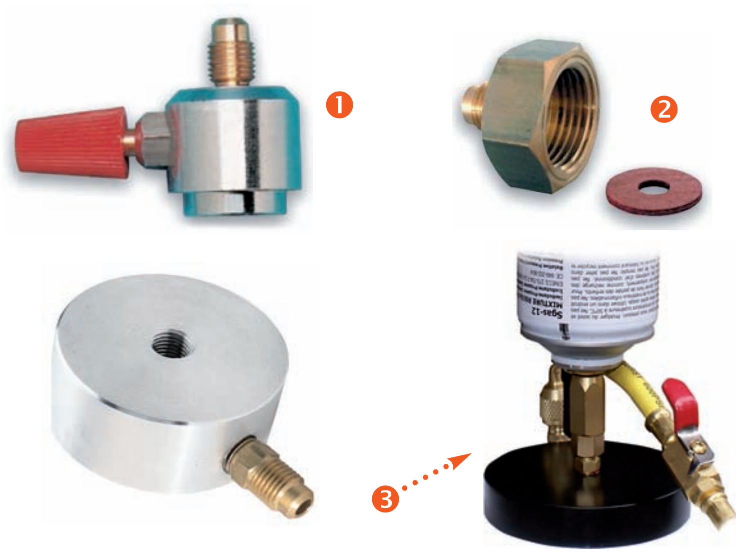


Figure 11: Charging hose and cylinder connectors

1. Can valve/extracting of refrigerants out of small disposable refrigerant cylinders
2. 21.8 mm adapter and gasket for connecting a charging hose with 1/4" SAE thread
3. Stand for liquid charge, disposable cylinder connection to ensure a firm standing of the cylinder on the charging scale

Figure 12: Automotive (MAC) manual quick service couplers for HFC-134a

1. Low pressure service valve 1/4″ male flare x 13 mm quick coupler
2. Low pressure service quick coupler 14 mm female x 13 mm quick coupler
3. High pressure service valve 1/4″ male flare x 16 mm quick coupler
4. High pressure service valve quick coupler 14 mm female x 16 mm quick coupler

Figure 13: Refrigerant recovery cylinder

1. Refrigerant recovery cylinder DOT standard (US) without OFP (overfill protection)
2. Liquid level float switch for recovery unit connection (cylinder installation kit)
3. Refrigerant recovery cylinder DOT standard (US) with OFP (overfill protection)
4. Refrigerant recovery cylinder EN standard (Europe) according ADR regulation (Transport of dangerous goods on roads)
5. Virtual cylinder cut
6. Liquid/vapour valve (double valve) with internal safety valve
7. Transfer line for gaseous refrigerant
8. Transfer line for liquid refrigerant (dip-tube)

Figure 14: Heating belt with thermostat

Speeds up refrigerant recharge time
Enables efficient refrigerant discharge
Working temperature 55°C/125°F – 300 W capacity

Figure 15: Refrigerant and oil contamination test kit

'Checkmate' test kit for field use
Quick and accurate determination of contaminant levels in oil and refrigerant

Figure 16: Oil test kit for mineral and alkylbenzene lubricant

The test kit is a single bottle test kit designed to give visual indication as to the acid content of both mineral and alkylbenzene lubricants. Simply place a sample of oil in the bottle, shake and look at the colour. If it remains purple, the oil is safe. If it turns orange, the oil is marginal and steps may need to be taken. If it turns yellow, the oil is acidic and needs to be changed or other steps need to be taken. Always read the manufacturer's instructions before use.

Figure 17: Oil test kit for polyol ester (POE) lubricants

The test kit is a single bottle test kit designed to give visual indication as to the acid content of polyol ester (POE) lubricants. Simply place a sample of oil in the bottle, shake and look at the colour. If it remains purple, the oil is safe. If it turns orange, the oil is marginal and steps may need to be taken. If it turns yellow, the oil is acidic and needs to be changed or other steps need to be taken. Always read the manufacturer's instructions before use.

Figure 18: Retrofit test kit

The retrofit process requires the removal of mineral based oil and replacement with polyol ester based lubricants.

When this is required, it is necessary to reduce the mineral based oils to acceptable levels to assure proper system operation.

The RTK (retrofit test kit) provides a simple method of determining the level of residual mineral oil in a system. It is ideal for field use as it provides a visual indication of three levels of mineral oil concentration: Greater than 5%, between 1% and 5% and equal to or less than 1%. Always read the manufacturer's instructions before use.

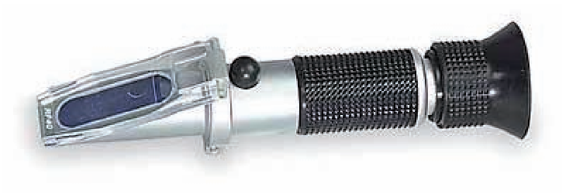


Figure 19: Refractometer

A precise optical instrument that allows the rapid and accurate determination of the refractive index of liquid solutions. It will specifically assist in determining the percentage of residual oil remaining in a refrigeration system when converting it to a new refrigeration oil.

Figure 20: Oil pump

1. Suction connection
2. Suction hose
3. Pump outlet with hose connection 1/4" SAE
4. Hand pump body

Chapter 3: Equipment for Recovery, Recycling, Reclamation and Evacuation (RRRE)

Preface

The following chapter gives an overview about important equipment used in the field of recovery, recycling, reclamation and evacuation of refrigeration systems.

Recovery Equipment

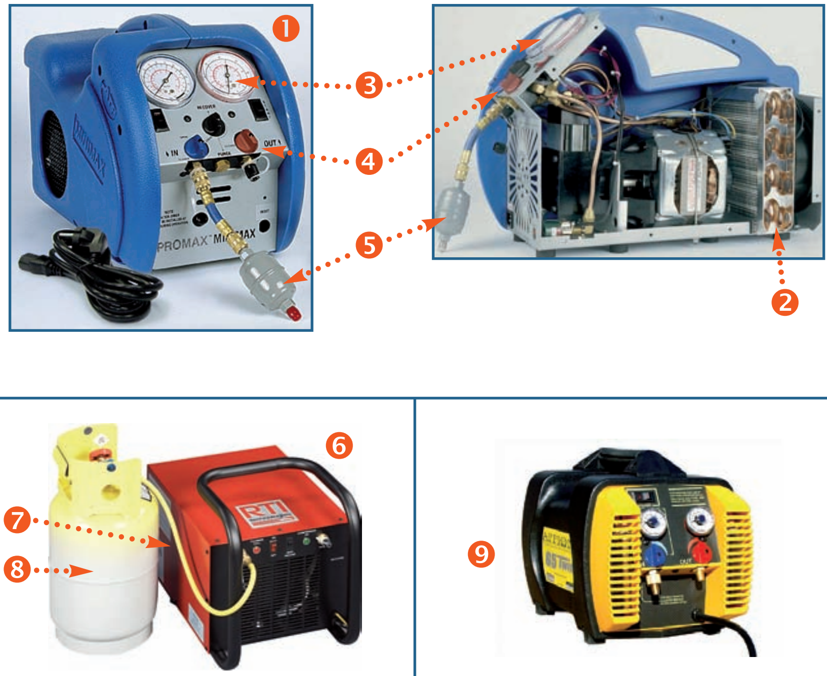


Figure 1: Refrigerant recovery unit

1. Recovery unit 'oil less' for commercial refrigeration and air-conditioning
2. Condenser and ventilator
3. High and low pressure gauges
4. Refrigerant inlet and outlet valves
5. Inline filter-drier
6. Recovery unit 'oil based' for small commercial, AC and domestic
7. Access cord for overfill protection (OFP)
8. Recovery cylinder
9. Recovery unit 'oil less' for all refrigerants including CFC-R11

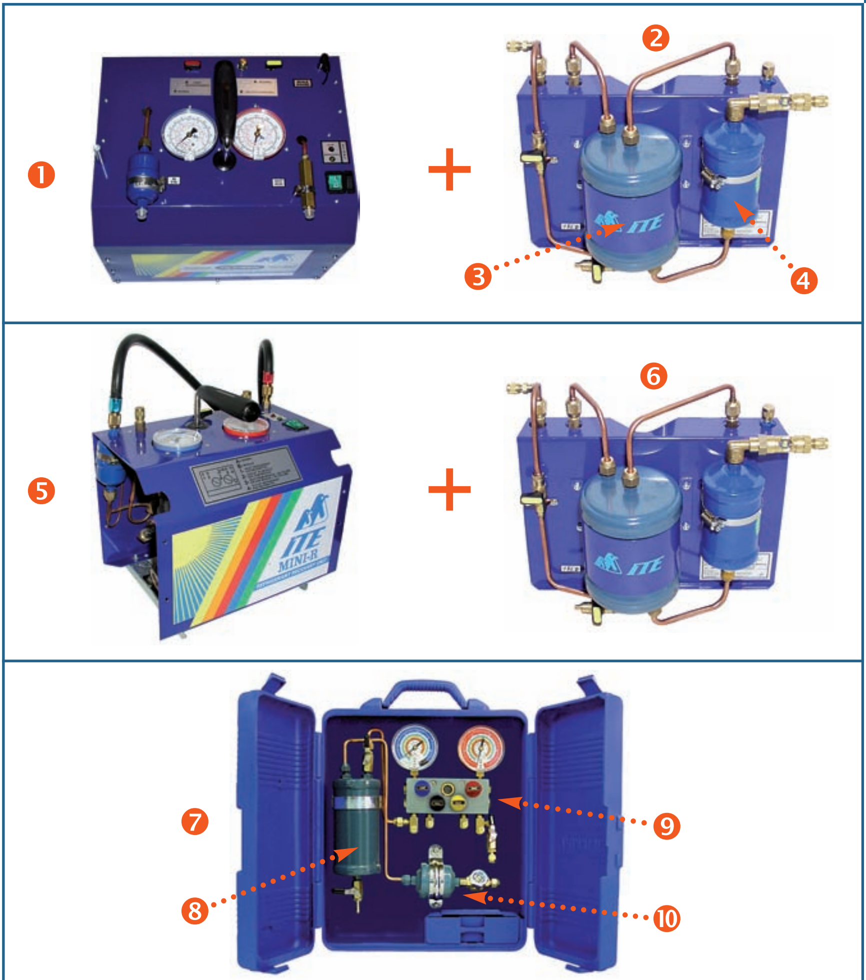


Figure 2: Refrigerant recovery and recycling unit

1. Recovery unit 'oil less' for commercial refrigeration and air-conditioning equipped with connective facilities for refrigerant recycling
2. Refrigerant cleaning module for recovery unit
3. Oil separator with oil drainage valve
4. Filter-drier with sight glass
5. Recovery unit 'oil based' for small commercial, AC and domestic
6. Refrigerant cleaning module for recovery unit
7. Cleaning module for all recovery units
8. Oil separator with oil drainage valve
9. Manifold gauge set with high and low pressure gauges
10. Filter-drier with sight glass

Figure 3: Recovery, recycling, evacuation and charging unit

1. Semiautomatic unit for refrigerant recycling and MAC application
2. Dual recycling MAC unit (for two different refrigerants use)
3. Internal and external high and low pressure gauges with hoses and quick couplers
4. Internal and external refrigerant cylinder with OFP and heating device
5. Automatic refrigerant service station for MAC, truck and bus
6. Automatic refrigerant service station for MAC
7. Semiautomatic service unit for MAC, commercial etc.

Figure 4: Refrigerant reclaim machine

1. Refrigerant reclaim machine for high refrigerant processing capacity and purity results
2. High and low pressure gauges
3. Control board with refrigerant selector handles up to three different refrigerants
4. Refrigerant reclaim machine small sized

Figure 5: Refrigerant recovery bag

1. Recovery bag for refrigerant CFC-R12 and/or HFC-R134a, refrigerant capacity up to 250 gr (R12) and 200 gr (R134a), maximum working temperature 60°C, maximum overpressure 0.1 bar
2. Accessories (hose and piercing pliers)

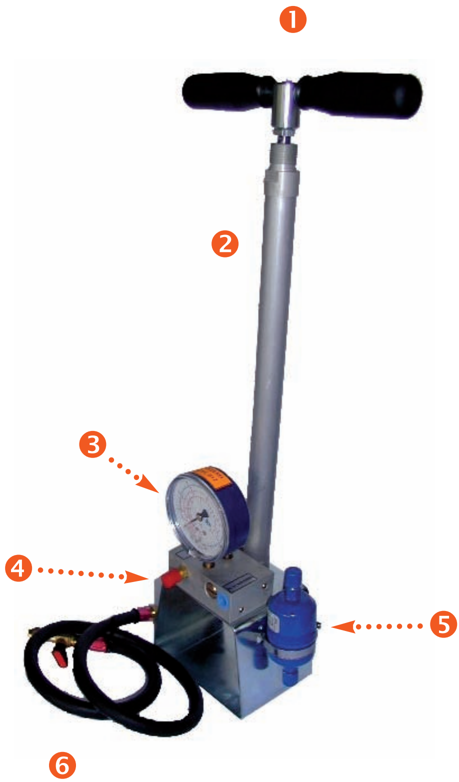


Figure 6: Refrigerant recovery hand pump

1 Recovery hand pump with handle, maximum overpressure 15 bar, piston stroke 20/300 mm, output at frequency with 30 strokes/min and constant suction pressure of 5 bar 0.14 kg/min vapour and 0.8 kg/min liquid, weight 1.9 kg, for using with CFC-R12 and HFC-R134a

2 Pump body with piston

3 Inlet pressure suction gauge

4 In- and outlet port connection 1/4" SAE male

5 Inline filter-drier size 032

6 Refrigerant transfer hose with ball valve for 1/4" SAE female

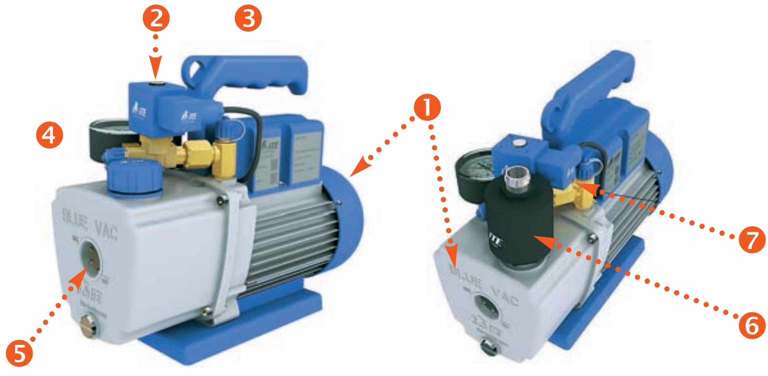


Figure 7: Vacuum pump

1. Double stage vacuum pump 40 L/min (1.44 CFM) to 280 L/min (9.64 CFM), ultimate vacuum down to 0.16 mbar (12 micron), gas-balast valve equipped
2. Solenoid valve
3. Handle with exhaust of purged air
4. Vacuum gauge (relative)
5. Oil level sight glass
6. Oil mist filter
7. 3/8" hose connection
8. Vacuum pump 198 L/min (7 CFM)
9. Vacuum pump oil container (different sizes)

Charging Equipment

Figure 8: Refrigerant charging and evacuation unit

1. Vacuum pump (double stage) with vacuum gauge
2. Manifold gauge set with high/low pressure gauge
3. Thermometer for charging cylinder
4. Charging cylinder with refrigerant scale and graduation

Figure 9: HC-R600a and HFC-R134a charging and evacuation unit

1. Vacuum pump (double stage)
2. Manifold gauge set with R600a / R134a low pressure gauges and vacuum gauge
3. Electronic charging scale
4. Refrigerant can support

Figure 10: Metric refrigerant charging cylinder

1. Thermometer or pressure gauge for refrigerant temperature/pressure indication
2. Valves for liquid/gas
3. Transparent scale with refrigerant graduation
4. Internal refrigerant cylinder
5. Refrigerant level indication glass pipe
6. Charging cylinder stand with refrigerant heater element

Figure 11: Charging arrangement for HCs

1. HC refrigerant drainage hose (min. 5 m long)
2. Refrigerant container for HCs 450 gr
3. Charging hose with adapters and valves
4. Electronic charging scale

Figure 12: Compressor lubricant charging/draining cup

1. 1/4" female SAE connection
2. Valve
3. Charging graduation oz/ml
4. PVC bottle

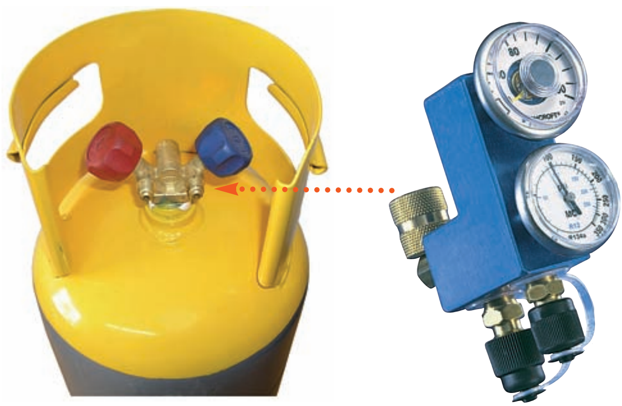


Figure 13: Non-condensable gases (NCGs) remover

Indicates and removes e.g. excess air (NCG) from refrigerant (CFC-R12 and HFC-R134a) containing cylinders

Chapter 4: Measuring Instruments (MI)

Preface

The following chapter will describe several instruments for the identification of leaks in refrigeration systems and different measuring tools for refrigerant charging, electrical values measurement and compressor capacity test. In addition, we like to present instruments for refrigerant identification and vacuum control.

Leak Detecting Instruments

Figure 1: Electronic leak detector

Detects all halogenated refrigerants. Points leaks as small as 3 gr per year.
Variable frequency audible alarm. Visual leak indication.
Mechanical pump and flexible metal probe.

1. Flexible metal probe with sensor
2. Keypad
3. Additional spot lighting

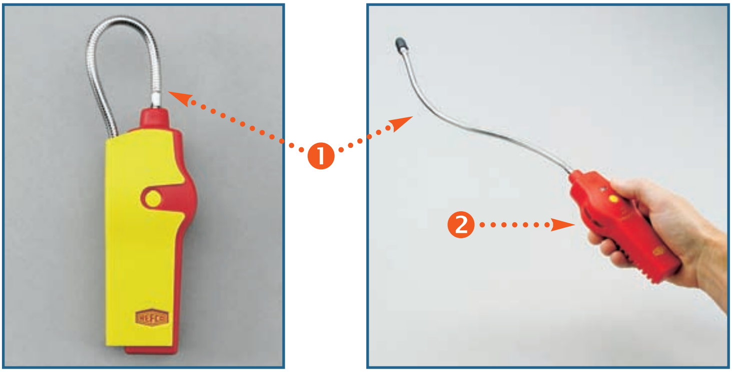


Figure 2: Electronic leak detector for HC refrigerants

Sensitivity less than 50 ppm (Propane, Iso-Butane, Methane)

1. Flexible metal probe with sensor
2. Keypad

Figure 3: Halide leak detector (banned use in EU)

Portable halide leak detector kit Propane operated

1. Propane cylinder, valve and flame head
2. Sniffle hose
3. Blue flame (no refrigerant detection)
4. Green flame (refrigerant detection)

Figure 4: UV leak detector

Transportable ultra violet (UV) leak detection kit indicates leaks about 3.5 gr per year for all common refrigerants in AC and refrigeration systems

1. High intensity UV/blue lamp (100 Watt)
2. Dye for refrigerant cycle injection
3. Fluorescence enhancing glasses
4. Hose with adapter and connections
5. Injection pump

Figure 5: Leak detection spray

Non-corrosive, high viscosity and non-freezing leak detector spray

Measuring Instruments

Figure 6: Refrigerant identifier

Infrared refrigerant identifier determining weight concentration of:
A) CFC-R12, HFC-R134a, HCFC-R22, HCs and air
B) HFC blends, e.g. R404, R407, R410, etc.

1. LCD display
2. Inlet filter
3. Printer
4. Connection hose with adapter

Figure 7: Refrigerant identifier for HCFC-R22

Identifier to verify presence and quality of HCFC-R22 refrigerant
Pass / fails indication of 95% pure refrigerant
Confirms the refrigeration system / cylinder content in less than five minutes

Figure 8: Electronic vacuum gauges (commonly used) examples

1. Electronic vacuum gauge, measuring range 50 to 5000 microns
2. Digital vacuum gauge, range 0 to 12,000 microns (different units selectable)
3. LED display
4. LCD display
5. Hose connections

Figure 9: Refrigerant charging scale

1. Electronic charging scale for cylinder and refrigeration system charging, capacity 50 kg, accuracy +/–0.5%, resolution 2 gr
2. Electronic charging scale for small hermetic refrigeration systems (domestic), capacity up to 5 kg, resolution 1 gr
3. LCD display

Figure 10: Spring-type charging scale

1. Fixture
2. Graduation for weight
3. Adjustment kit for maximum filling amount
4. Feeder hook
5. Connection cord for overfill protection (OFP)

Figure 11: Electronic thermometer

1. Electronic thermometer for up to two probes, measuring range –50°C to 1150°C
2. Electronic thermometer equipped with three probes
3. Electronic hand thermometer with one probe, measuring range –50°C to 150°C
4. Refrigerator and freezer thermometer, range –50°C to 50°C

Figure 12: Digital clamp on meter

Noncontact ampere measurement, voltage and resistance measurement
LCD display and holding function for easy reading

1 Ampere measuring clamp
2 Measurement selector
3 LCD display
4 Test leads

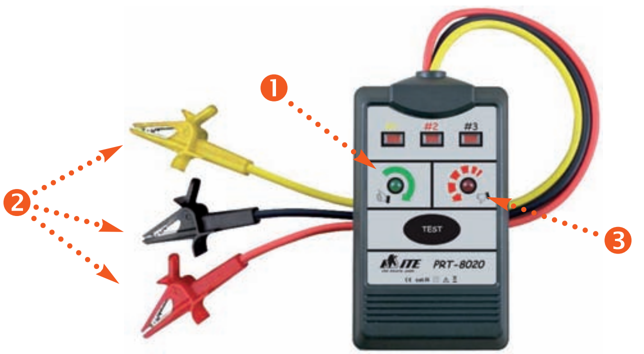


Figure 13: Rotating field meter

Rotating field identification for e.g. scroll-compressors

1 Rotating field to the right
2 Connection clamps for three phases
3 Rotating field (wrong) direction (left)

Figure 14: Auto range digital multimeter

Tests batteries, capacitors and resistors components

1. Measurement selector
2. Test leads

Figure 15: Anemometer and thermometer

Air velocity measurement for AC systems

1. Vane sensor with integrated thermometer
2. Measuring device for temperature and air velocity

Figure 16: Sound level meter

Measuring of sound level on refrigeration and AC equipment
Measuring range 40 to 140 dB

1. Sensor
2. Digital display
3. Key pad

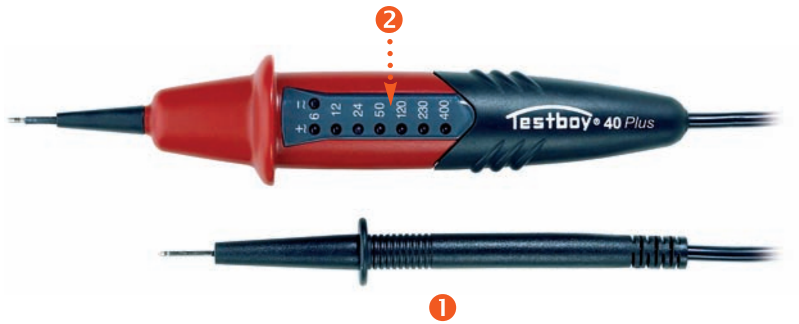


Figure 17: Mains tester

Electrical tester, DC Voltage 6 to 220 Volts, AC Voltage 24 to 480 Volts

1. Mains tester with lead
2. LED display

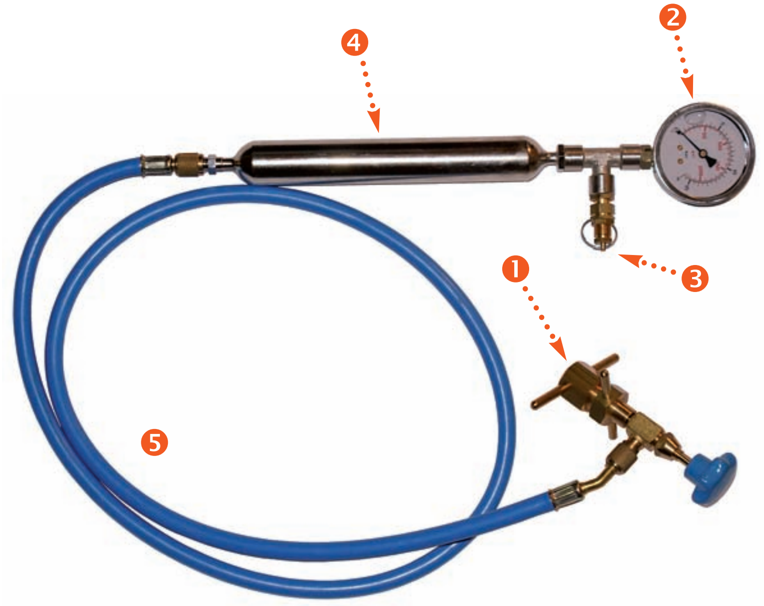


Figure 18: Hermetic compressor tester

Easy to use tool for testing the compressor's capacity

Use with dry Nitrogen only!

1. Quick coupler
2. Pressure gauge
3. Adjustable safety valve
4. Pressure tank
5. Refrigerant charging hose

Part II Skills and Operation

Introduction to Part II

Part II provides detailed know-how on professional state-of-the-art service and maintenance of refrigeration systems, including system assembling and commissioning. In addition, expertise is provided on skills such as bending, flaring, brazing and pressing of pipe work needed in the repair of domestic refrigeration and air-conditioning systems. This is especially important for systems containing flammable Hydrocarbon refrigerants which have to be treated with extra care.

Chapter 5: Assembling a Refrigeration System

Preface

Beside the installation of the main refrigeration system components, the refrigerant pipe work has to be carried out in a perfect clean and proper manner.

The most common pipe work you will find on refrigeration systems is made of copper. It is sized by the actual outside diameter and comes in lengths of 5 to 6 m (16 to 20 feet) in hard copper and coils of 15 to 50 m (50 to 165 feet) in soft copper.

There are two common types of copper piping:

- Hard Copper (rigid copper)
- Soft Copper (annealed copper)

Specially designed and prepared copper pipes are used in refrigeration as they can be used for higher pressures. They arrive from the producer sealed at both ends to prevent contamination by moisture or dust etc ...

Soft Copper
Soft, flexible copper tube is really more versatile than a rigid copper pipe. It comes in much longer lengths which are rolled and requires fewer joints which reduce leak potential. Due to its fairly flexible nature it can be positioned and shaped easily which saves time.

Hard Copper
Hard Copper piping is rigid and is identified by size and name. This type of piping makes a neater installation, but it is more time consuming and difficult to install than soft tubing. It needs very little mechanical support to keep it in position, compared to soft copper.

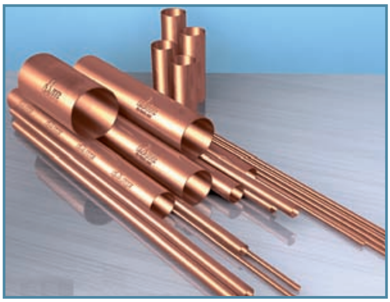


Figure 1: Soft and hard copper comparison

The table below shows common pipe sizes:

European Standard					
Copper Coils (annealed) INCH			Copper Coils (annealed) METRIC		
Diameter	Length (m)	Wall (mm)	Diameter	Length (m)	Wall (mm)
3/16″	50	1	4 mm	25	1
1/4″	30	1	6 mm	25	1
5/16″	50	1	8 mm	25	1
3/8″	30	1	10 mm	25	1
1/2″	30	1	12 mm	25	1
5/8″	30	1	15 mm	25	1
3/4″	15	1	16 mm	25	1
7/8″	15	1	18 mm	25	1
			22 mm	25	1

Table 1: Soft copper (annealed) European standard

US Standard		
Copper Coils (annealed) INCH		
Diameter	Length (Ft)	Wall (mm)
1/8″	50	0.76
3/16″	50	0.76
1/4″	50	0.76
5/16″	50	0.81
3/8″	50	0.81
1/2″	50	0.81
5/8″	50	0.89
3/4″	50	0.89
7/8″	50	1.14
1 1/8″	50	1.21
1 3/8″	50	1.40
1 5/8″	50	1.52

Table 2: Soft copper (annealed) US standard

European Standard					
Rigid Copper Straight Length INCH			Rigid Copper Straight Length METRIC		
Diameter	Length (m)	Wall (mm)	Diameter	Length (m)	Wall (mm)
1/4″	4 or 5	1	6 mm	5	1
3/8″	4 or 5	1	8 mm	5	1
1/2″	4 or 5	1	10 mm	5	1
5/8″	4 or 5	1	12 mm	5	1
3/4″	4 or 5	1	15 mm	5	1
7/8″	4 or 5	1	16 mm	5	1
1″	4 or 5	1	18 mm	5	1
1 1/8″	4 or 5	1	22 mm	5	1
1 3/8″	4 or 5	1.24	28 mm	5	1.5
1 5/8″	4 or 5	1.24	35 mm	5	1.5
2 1/8″	4 or 5	1.65	42 mm	5	1.5
2 5/8″	4 or 5	2.10	54 mm	5	2
3 1/8″	4 or 5	2.50	64 mm	5	2
3 5/8″	4	2.50	76 mm	5	2
4 1/8″	4	2.50	89 mm	5	2
			108 mm	5	2.5

Table 3: Rigid copper (hard) European standard – inch/metric

US Standard					
Rigid Copper Straight Length INCH					
Diameter	Length (Ft)	Wall (mm)	Diameter	Length (Ft)	Wall (mm)
3/8″	16.4	0.76	1 5/8″	16.4	1.53
1/2″	16.4	0.89	2 1/8″	16.4	1.78
5/8″	16.4	1.02	2 5/8″	16.4	2.03
3/4″	16.4	1.07	3 1/8″	16.4	2.29
7/8″	16.4	1.14	3 5/8″	16.4	2.54
1 1/8″	16.4	1.21	4 1/8″	16.4	2.79
1 3/8″	16.4	1.40			

Table 4: Rigid copper (hard) US standard

The refrigeration capacity of the system is influenced by pressure drops in the pipe work. Such pressure loss not only results in a decrease in cooling capacity but also in an increase in the compressor's power consumption.

Sizing of the piping system is determined by the following factors:

- Pressure drops
- Flow velocity
- Oil return

For the assembling of the selected refrigeration system (demo unit) the following pipe diameters are selected:

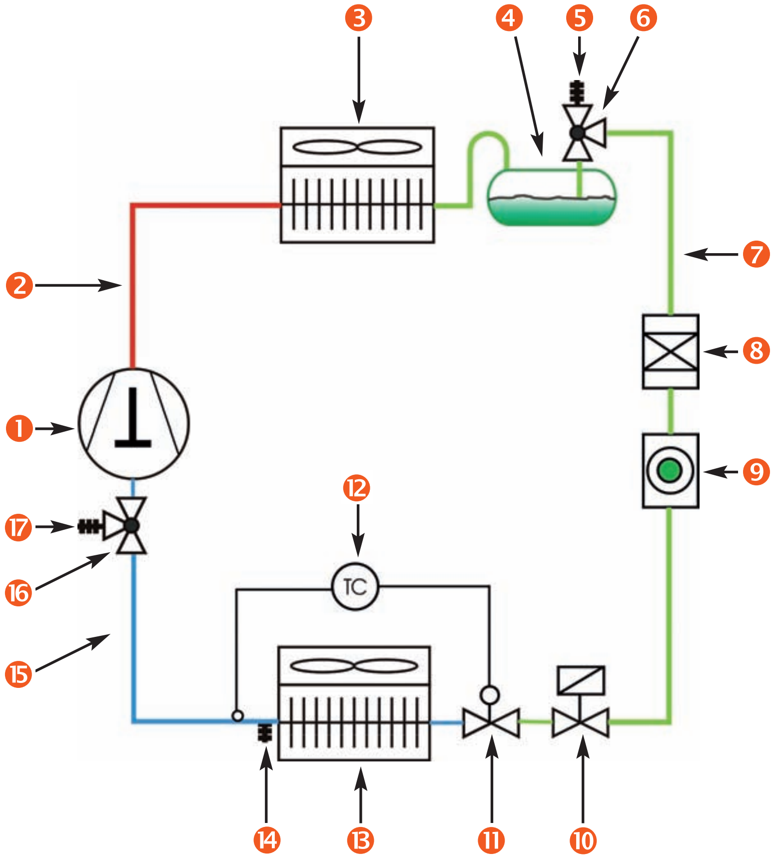
- Suction pipe 10 mm
- Liquid pipe 6 mm

System Design and Selection Criteria

Item	Qty.	Unity	Part	Reference	Dimensions/ Range
1	1	Piece	Hermetic condensing unit	DANFOSS SC 15 GXT2 Refrigerant HFC-R134a Ref. capacity –5°C/830W Power input 600W 230V/1Ph/50Hz	HxWxD/mm 296x333x451 Weight 21.6 kg
2	1	Piece	Evaporator	KUEBA DFA 031 Refrigerant HFC-R134a Ref. capacity –5°C/900W Surface 4.9 m^2 Fan 230V/1Ph/50Hz/29W	HxWxD/mm 165x580x510 Weight 10 kg
3	1	Piece	Th. expansion valve	DANFOSS TN 2	3/8" Inlet 1/2" Outlet
4	1	Piece	Th. expansion valve with inlet strainer	DANFOSS Size 01	
5	1	Piece	Filter-drier	DANFOSS DML	6 mm/1/4" flared male x 6 mm/1/4" flared male
6	1	Piece	Sight glass	DANFOSS SGN	6 mm/1/4" flared male x 6 mm/1/4" flared female
7	1	Piece	Solenoid valve	DANFOSS EVR 3	6 mm/1/4" flared male x 6 mm/1/4" flared male
8	1	Piece	Capillary tube thermostat	DANFOSS KP 62	Temperature range –40°C to +65°C

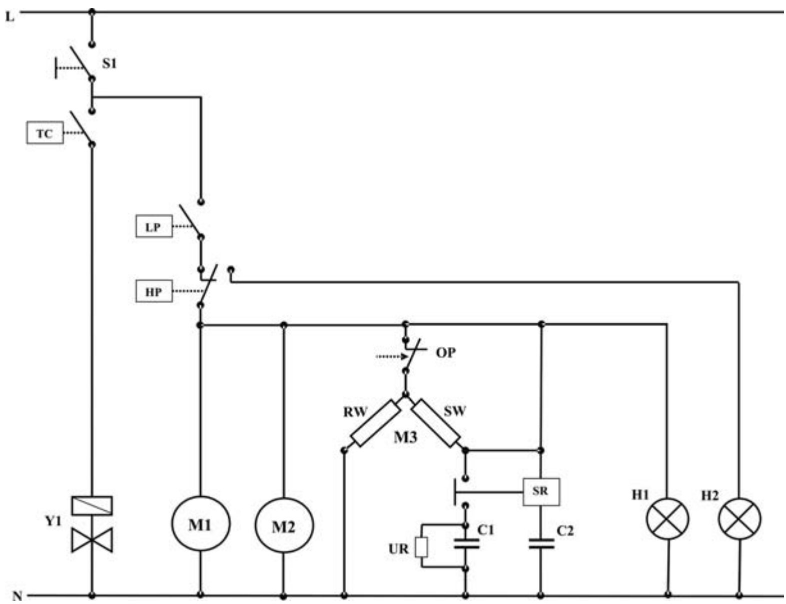
Item	Qty.	Unity	Part	Reference	Dimensions/ Range
9	1	Piece	Dual pressure switch	DANFOSS KP15	LP – 0.7 to 4 bar HP – 8 to 32 bar
10	5	m	Soft copper pipe	Liquid pipe	6 x 1 mm/1/4″
11	5	m	Soft copper pipe	Suction pipe	10 x 1 mm/3/8″
12	3	Piece	Brass union coupling		10 mm/3/8″ 5/8″ UNF
13	6	Piece	Brass SAE nut for union coupling		10 mm/3/8″ 5/8″ UNF
14	1	Piece	Brass SAE nut Expansion valve outlet		1/2″/10 mm hole 3/4″ UNF
15	1	Piece	Brass SAE Nut Expansion valve inlet		3/8″/6 mm hole 5/8″ UNF
16	2	Piece	Brass SAE nut/ filter-drier and sight glass		1/4″/6 mm hole 7/16″ UNF
17	2	Piece	Brass SAE nut/ solenoid valve		1/4″/6 mm hole 7/16″ UNF
18	1	Piece	Forged brass tee with valve core/evaporator measurements		3/8″ Pipe – 7/16″ UNF
19	1	Piece	Master switch with housing	MOELLER – SVB	230V/1Ph/50Hz
20	1	Piece	Indicator light	green	230V/1Ph/50Hz
21	1	Piece	Indicator light	red	230V/1Ph/50Hz
22	1	Piece	Cable connection box	HENSEL D9045 5 Openings	98x98x58 mm
23	6	m	Electrical cable flexible		3 x 1.5 mm^2
24	40	Piece	Cable fastener		
25	10	Piece	Copper pipe clips		6 mm/1/4″
26	10	Piece	Copper pipe clips		10 mm/3/8″
27	1	Piece	Perforated plate (metal)		500 x 800 mm
28	50	Piece	Sheet screws		
29	8	m	Hollow punch		36 x 36 mm
30	2	Piece	Floor stands		36 x 36 mm
31	4	Piece	Angel 45°		
32	2	Piece	Frame angel 90°		
33	18	Piece	Screw set frame		M8 x 40 mm

Table 5: Complete list of material (parts as selected or similar)



1 Hermetic compressor
2 Discharge pipe
3 Refrigerant condenser
4 Refrigerant receiver
5 Service connection
6 Shut-off valve
7 Refrigerant liquid pipe
8 Filter-drier
9 Refrigerant sight glass
10 Solenoid valve
11 Thermostatic expansion valve
12 Capillary tube with sensor
13 Refrigerant evaporator
14 Service connection
15 Suction pipe
16 Shut-off valve
17 Service connection

Figure 2: The refrigeration system layout (refrigerant flow schematic)



230V/1Ph/50Hz

L	Electr. connection ‘phase’	RW	Running winding (compressor)
N	Electr. connection ‘neutral wire’	SW	Start winding (compressor)
S1	Main switch (on-off)	M3	Refrigerant compressor
TC	Thermostat	SR	Start relay
Y1	Solenoid valve	UR	Unload resistor (C1)
LP	Low pressure switch	C1	Start capacitor
HP	High pressure cut-off	C2	Running capacitor
M1	Condenser fan motor	H1	Indicator light ‘operation’ green
M2	Evaporator fan motor	H2	Indicator light ‘high pressure’ red
OP	Overload protection (compressor)		

Figure 3: The electrical wiring diagram (pump-out/pump-down)

Main Components for System Assembling

Condensing unit
Hermetic

Refrigerant HFC-R134a
Voltage 230V/1Ph/50Hz
Refrigeration capacity 875W
t_0 –5°C/amb.temp. 32°C
Maximal amb.temp 43°C

Figure 4: Condensing unit

Evaporator
Air forced

Refrigerant HFC-R134a
Voltage 230V/1Ph/50Hz
Refrigeration capacity 950W
t_0 –5°C
1 Ventilator/29W
Surface 4.9 m^3
Lamella spacing 4.2 mm

Figure 5: Evaporator

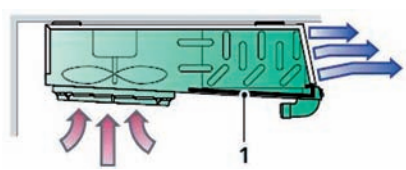
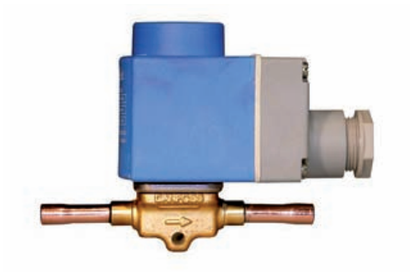


Figure 6: Evaporator air circulation (schematic)

Thermostatic expansion valve

with internal equalization
Refrigerant HFC-R134a
flare/flare connection
inlet size 1/4" (6 mm),
outlet 1/2" (12 mm)

Figure 7: Thermostatic expansion valve



Solenoid valve

Normally closed (NC)

Refrigerants: CFC, HCFC, HFC
Inlet/Outlet 1/4"/6 mm
Min. opening differential
pressure 0.0 bar
Brazing or flaring connections

Figure 8: Solenoid valve

Filter-drier

Optimized for HFC refrigerant
Brazing or flaring connections
Inlet/Outlet 1/4"/6 mm SAE

Figure 9: Filter-drier

Sight glass

with colour indicator for moisture content in refrigerant
Ambient temperature:
–50°C to +80°C
Max. working pressure: 35 bar
Inlet/Outlet 1/4"/6 mm SAE

Figure 10: Sight glass

Thermostat

with capillary tube

Ambient temperature:
–40 to +65°C

Figure 11: Thermostat

Dual pressure switch

LP – 0.7 to 4 bar
HP – 8 to 32 bar

Figure 12: Dual pressure switch

Master switch

with Housing

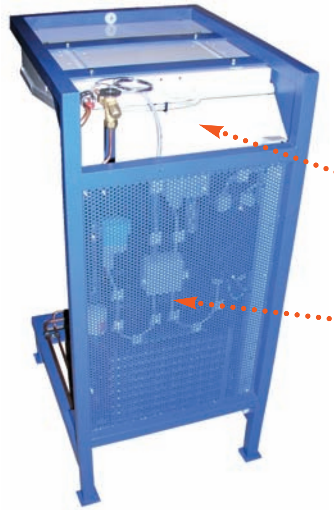
230V/1Ph/50Hz

Figure 13: Master switch (photo courtesy of Moeller GmbH)

Front view of the refrigeration system

- Cut hollow punch and assemble frame
- Install stand and angle
- Place evaporator
- Place condensing unit

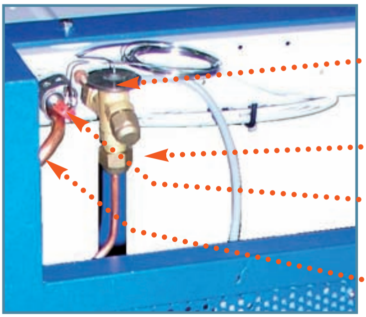
Figure 14: Refrigeration system (front view)



Rear view of the refrigeration system

- Evaporator section
- Install perforated metal plate

Figure 15: Refrigeration system (rear view)



Detail evaporator

- Expansion valve with nozzle installation
- Inserted nozzle and fix flare-nut
- Temperature sensor with capillary tube
- Brass tee with valve core connection at suction line (outlet evaporator)

Figure 16: Evaporator in detail

Install dual pressure switch for high and low pressure control

- Dual pressure switch

Figure 17: Dual pressure switch in detail

References

Install refrigerant circuit components including piping

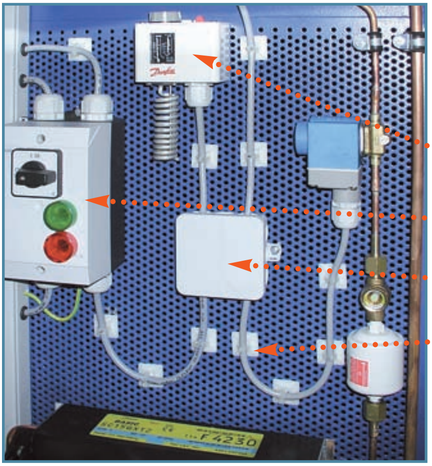
- Solenoid valve
- Flare-nut (example)
- Sight glass
- Filter-drier

Bending of copper tubes

Brazing

Flaring

Figure 18: Refrigerant circuit components



Install electrical components

- Thermostat
- Master switch
- Cable connection box
- Install and fix electric cable

Figure 19: Electrical components

References

Bending of copper tubes

Brazing

Flaring

Install remaining pipe work

- Suction line
- Liquid line
- Process pipes for dual pressure switch

Figure 20: Pipe work installation

Commissioning

The operational reliability and service life of a refrigeration system primarily depends on the degree of contamination, the moisture and non-condensable gases (e.g. air) contained in the refrigeration cycle and the hermetic design and construction (leak tightness).

Improved hermetisation of the refrigeration cycles enables a reduction of substances entering and escaping from the system during operation. All these facts and backgrounds enable the operation in an environmentally protective and energy-efficient manner.

The previously assembled refrigeration system provides for system commissioning several service connections. These service connections are located as follows:

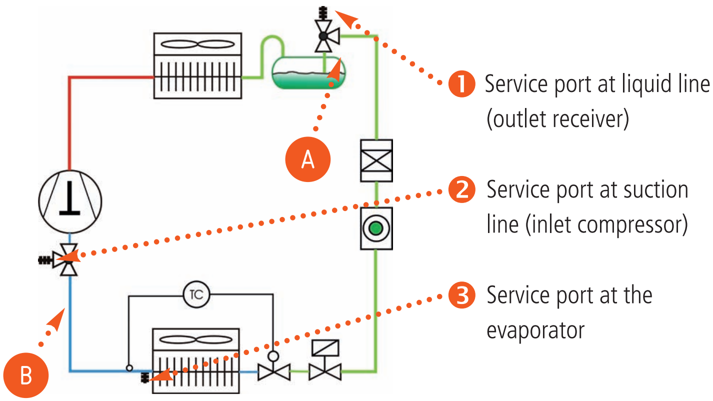


Figure 21: Service connections overview

References

Tools RHC Page 23 Figure 6+7

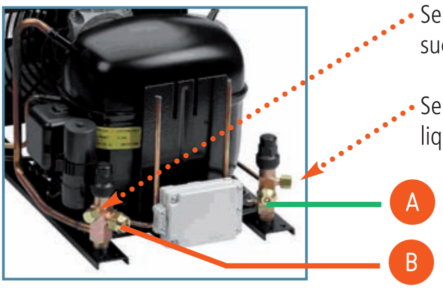


Figure 22: Service connections in detail

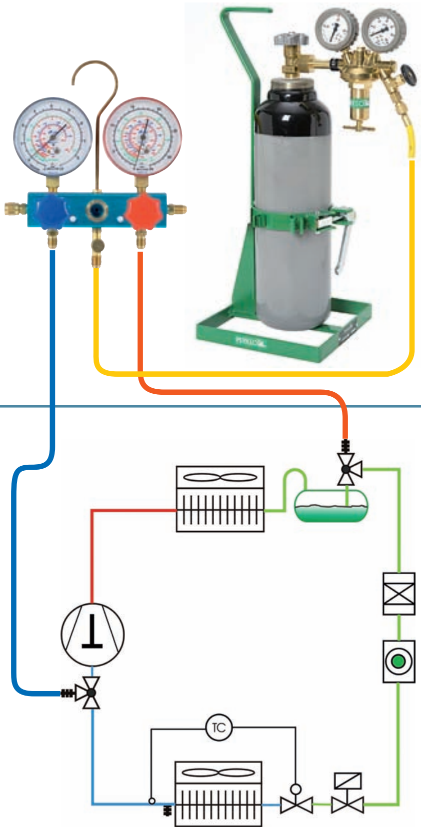
Pressure Leak Test

This leak test provides information on the overall leak tightness of the refrigerated system.

Only dry Nitrogen must be introduced into the refrigerated system.

Transferring the dry Nitrogen gas from both, the high and low pressure side up to a system pressure of a maximum of 10 bar.

NEVER USE OXYGEN (e.g. shop-air) FOR PRESSURIZING A REFRIGERATION SYSTEM.



Connect the Nitrogen cylinder's pressure regulator to the manifold gauge set centre port.

Connect the high pressure gauge to the system's high side service port.

Connect the low pressure gauge to the system's low side service port.

Figure 23: Pressure leak test

References

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- Pressurize the refrigeration system up to a maximum of 10 bar dry Nitrogen.
- Close the pressure regulator and hold the pressure in the system.
- Observe the pressure at gauges. If leaks exist, pressure will drop. Some leaks are audible and can be identified by the sound of discharging gas.
- Check all connections, flares and joints with soap water solution. Identify leaks by bubbles formed by discharging Nitrogen.
- Repair leaks.
- If necessary repeat leak test.

Figure 23a: Example of a leaky connection (see bubbles)

Evacuation

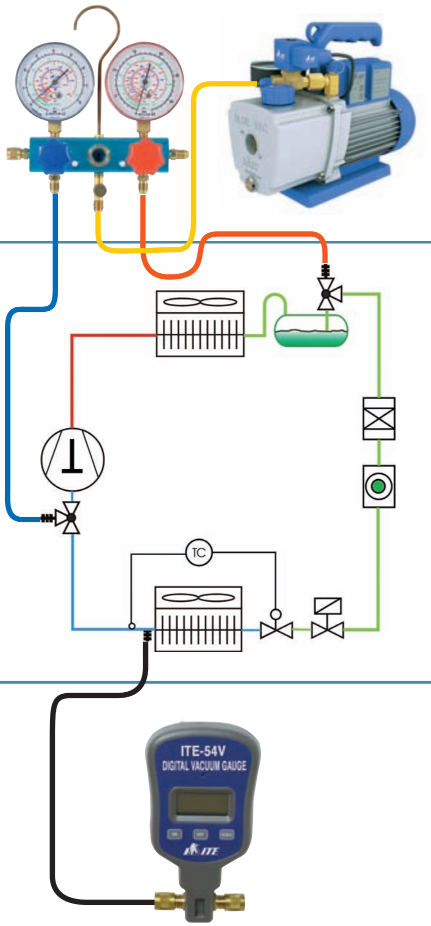
Most importantly, the evacuation of a refrigeration system is a matter of reducing the content of non-condensable gases such as air and Nitrogen. Additionally, introduced humidity during the assembling process must be removed before system operation.

The pressure measured finally with the vacuum process should be about 0.5 mbar (50 Pa, 375 micron) or better.

If possible, a system should be evacuated on both, high and low pressure sides. To be able to ensure the specified vacuum, it is therefore necessary (if possible) to measure the pressure with a vacuum gauge in the system and not directly at the vacuum pump.

Short hoses with large diameter (e.g. 3/8") are best for evacuating and greatly reduce the time required for evacuation. Most manufacturers recommend evacuating down to at least 250 microns. You may even come across specifications requiring a 50 micron evacuation. To achieve vacuums that are so low, you would have to use large diameter and very short connections between the vacuum pump and the system. Standard flexible hoses (1/4") just don't seal enough and also present too much restriction flow to achieve those types of vacuum.

References



Connect the vacuum pump to the manifold gauge set to the centre port.

RRRE
Page 37
Figure 7

Connect the vacuum gauge to the service port at the evaporator's outlet service port.

Run the vacuum pump and read the vacuum indicated at the vacuum gauge.

MI
Page 45
Figure 8

Figure 24: Evacuation of a refrigeration system

Charging

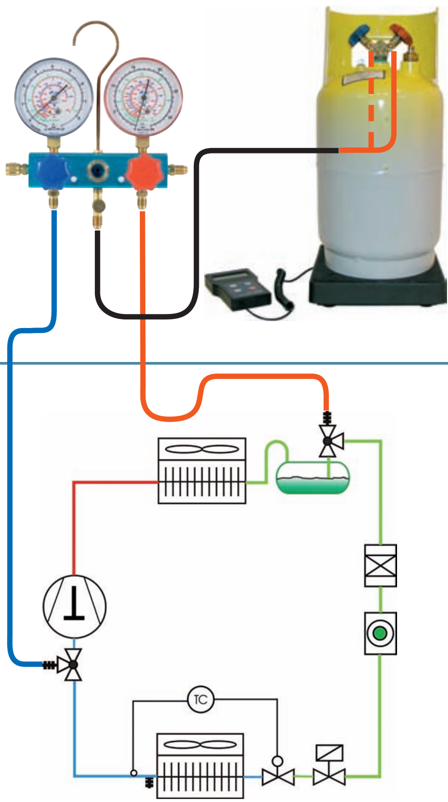
The compressor must never be operated without refrigerant or under vacuum. A damage of the compressor would result.

If the **filling capacity of the plant is known,** liquid charging of the refrigerant into the high side of the system can be carried out with the plant at rest, against vacuum, using a charging cylinder or scales.

Be extremely careful when charging liquid refrigerant to the low side of the system. Liquid (in large amounts) must never enter the compressor. For this reason prevent the compressor from the so called 'liquid hammer' while charging refrigerant. R134a is a single substance refrigerant and may therefore be charged into the system from the refrigerant cylinder in vapour or liquid form.

If the charging amount is yet to be determined, first fill in refrigerant until the low pressure switch responds and the compressor can be started. In general, it is sufficient to charge half of the rated quantity to be able to operate the compressor during the charging operation without compressor damage. Measure the charged amount of refrigerant.

References



Connect the refrigerant charging cylinder on scale to the manifold gauge centre port. Purge the air out of the charging hose.

MI
Page 46
Figure 9

Figure 25: Charging of a refrigerant system

System Check and Final Leak Test

After the charging process the adjustment and functioning of the safety devices and other control devices must be checked. The system must be operated until sufficient system conditions are visible. Meanwhile temperature and pressure values should be recorded and the system must receive a label showing actual figures e.g. type and amount of refrigerant charged. After disconnection of gauges and hoses a final leak test has to be performed.

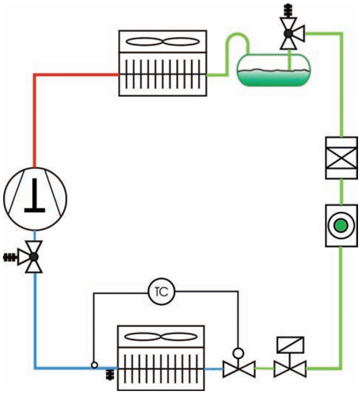


Figure 26: Overview of a refrigerant system

References

MI
Page 41
Figure 1
Page 42
Figure 2

Once again use soap water and/or an electronic leak-detector and you will find that there are common places to check. The following lists some very common leak locations:

- Flare-nuts
- Service valve: packing, access fitting, mounting
- Cracked brazed joint in piping
- Rotted evaporator end bends
- Pipes rubbing together
- Cracked ferrous brazed in accessory

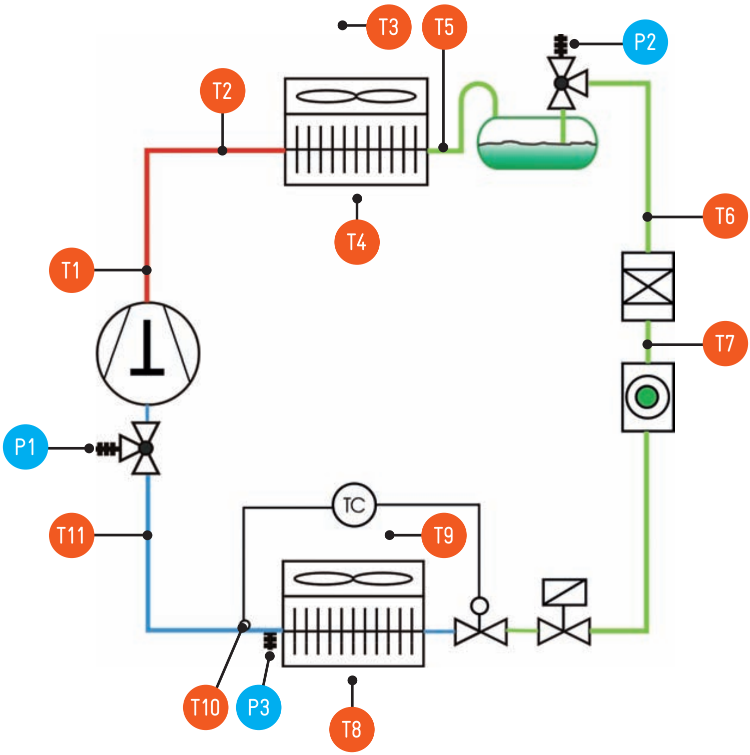


Figure 27: Measuring spots for temperature and pressure

References	MI Page 47–Figure 11, Page 48–Figure 12, Page 50–Figure 17

Start-Up Data Sheet			
Technician name			
Address			
Telephone & fax no.			
Registration no.			
Installation/Appliance DATA			
Type of installation		Model and no.	
Date started		Date finished	
Operating Data			
Refrigerant type		Refrigerant charge	
Type of lubricant		Lubricant charge	
Suction pressure P1		Condensing pressure P2	
Suction pressure evap. P3			
Discharge temp. T1		Hotgas temp. T2	
Air temp. ent. cond. T3		Air temp. leav. cond. T4	
Temp. ref. leav. cond. T5		Temp. liquid ent. filter T6	
Temp. ref. leav. filter T7		Air temp. ent. evap. T8	
Air temp. leav. evap. T9		Temp. gas leav. evap. T10	
Temp. gas ent. comp. T11			
LP-switch cut-off		HP-switch cut-off	
Electrical Data			
Power supply (voltage)	L1	L2	L3
Overall ampere reading	L1	L2	L3
Current draw compressor	L1	L2	L3
Current draw fan evapor.			
Current draw fan cond.			
Other Installation Data			
Discharge line diameter		Discharge line length	
Liquid line diameter		Liquid line length	
Suction line diameter		Suction line length	
Insulation suction line		Altitude diff. compr./evap.	
Type of condenser		Type of evaporator	
Type of filter-drier		Type and size of receiver	
Remarks:			
Signature technician			
Date			

Table 6: Start-up data sheet

Chapter 6: Bending, the Process

Preface

Because of its exceptional formability, copper can be formed as desired at the job site.

Copper tube, properly bent, will not collapse on the outside of the bend and will not buckle on the inside of the bend.

Because copper is readily formed, expansion loops and other bends necessary in an assembly are quickly and simply made if the proper method and equipment are used.

Simple hand tools employing mandrels, dies, forms and fillers, or power-operated bending machines can be used.

Both annealed tube and hard drawn tube can be bent with the appropriate benders. The proper size of bender for each tube size must be used.

Always follow specific safety regulations!
(see also chapter safety)

Portable bending machines, suitable for bending tubes up to and including 54 mm outside diameter (OD) are available, indeed some smaller benders up to 22 mm can be carried in a tool kit. For tube sizes larger than 54 mm, fixed power benders are the only satisfactory option. All bending machines work on the principle that the tubing is bent between matched formers and back guides, which support the OD of the tubing, thus eliminating the risk of collapse of the tube wall.

References

Bending Process Steps


Figure 1: Inappropriately treated copper tube

Only the use of sealed and interiorly clean and dry copper tubes is permitted.

This bad example shows an inappropriately treated and stored copper tube.

Collapsed tube

No seal plug for tube inside protection.


Figure 2: Tube-holding

Positioning

The bending tool diameter must match the copper tube diameter.

With the handles at 180° and the tube holding clip raised out of the way, insert the tube in the forming wheel groove.

TT
Page 11
Figure 12


Figure 3: Tube-holding position

Bending start position

Place the tube-holding clip over the tube and bring the handle into an approximately right angle position, engaging the forming shoe over the tube.

The zero mark on the forming wheel should then be even with the front edge of the forming shoe.

TT
Page 11
Figure 12

References


Figure 4: Bending of the tube

Bending the tube

Bend by pulling the handles towards each other in a smooth, continuous motion.

The desired angle of the bend will be indicated by the calibrations on the forming wheel.

TT
Page 11
Figure 12


Figure 5: Removing of the bent tube

Tool removal

Remove the bent tube by pivoting the handle to a right angle with the tube, disengaging the forming shoe.

Then release the tube-holding clip.

TT
Page 11
Figure 12


Figure 6: Bending process

Bending copper and tool example

TT
Page 11
Figure 12 (1)

		References
 Figure 7: Example of bent copper	**Bending copper and tool example**	TT Page 11 Figure 12 (3)
 Figure 8: Bending copper tool	**Bending copper and tool example**	TT Page 11 Figure 12 (2)

Piping should be designed to use a minimum number of bends and fittings. It is most important to minimize pressure drop in the suction line so plan your piping layout around the optimum route for the suction line.

If you are manually bending some soft copper and you accidentally kink the pipe, cut out and discard the kinked section and try again. It is much easier to correct the problem now than it is after the system is in operation. There is no excuse for allowing unnecessary pressure drop to affect a system for its entire operational life.

Chapter 7: Brazing, the Process

Preface

Brazing and soldering techniques are the most common methods of joining copper tubes and fittings.

Since modern technologies and best practices have been introduced and regulations have been developed for the sectors of refrigeration and air-conditioning, the only technical standard in this field is BRAZING.

Good brazing joints are strong, durable and stay tight! Brazing is necessary to provide joints that can withstand vibration, temperature and thermal cycling stress.

The basic theory and techniques of soldering and brazing are the same for all diameters of copper tubes. The only variables are the filler metal and the amount of time and heat required to complete a given joint.

Soldering is the joining process that takes place below 450°C (840°F) and brazing as a process that takes place above 450°C (840°F), but below the melting point of the base metals. Most brazing is done at temperatures ranging from 600°C to 815°C (1100°F to 1500°F).

Brazing carried out while using copper-phosphorus (CP) filler metals is the preferred method for making non-detachable joints. No flux is needed as the vaporised phosphorus will remove the copper oxide film. Flux used for brazing may also contaminate the environment inside tubing and must be removed after the brazing process. **Nitrogen introduction as protective gas (very low flow rate inside the pipe assembly during brazing process) is a common method to avoid oxidation.**

Purging refrigerant pipelines whilst brazing with dry Nitrogen.

When heat is applied to copper in the presence of air (oxygen), oxides form on the surfaces of the tube. This is very harmful for a durable functioning of the refrigeration system in general but primarily for the compressor's lubricating system. Oxide scale on the inside of refrigerant pipelines can lead to problems once the refrigerant and the lubricant is circulating in the system. Refrigerants have a scouring effect that will lift the scale from the tubing and this can be carried through the system and lead to form sludge.

The formation of oxides when brazing can be easily prevented: this is achieved by slowly passing Nitrogen through the pipework whilst the heat is being applied.

The previously mentioned brazing techniques are approved and accepted standards for brazing in the refrigeration and air-conditioning sector.

Basic steps for brazing and joining copper tubes and fittings:

1. Measuring and cutting
2. Reaming
3. Cleaning
4. Assembly and support
5. Nitrogen introduction
6. Heating
7. Applying the filler metal
8. Cooling and cleaning

Always follow specific safety regulations!
(see also chapter safety)

References

Brazing Process Steps

Figure 1: Cutting tube

Cutting tube

Use a wheel cutter rather than a hacksaw in order to prevent swarf entering the tube.

TT
Page 5
Figure 1

Figure 2: Removing of burrs

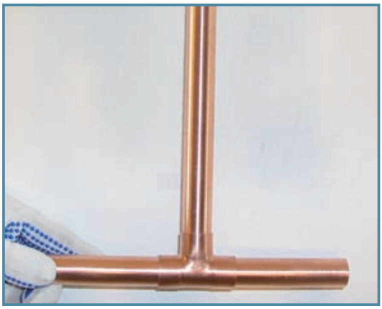
Removing internal burrs

A deburrer, reamer or round file can be used to remove internal burrs.

TT
Page 6
Figure 3

Figure 3: Further processing with file

Prevent the entering of swarfs into the tube and fitting arrangement.

		References
 Figure 4: Cleaning of surfaces	**Cleaning the surfaces** For surface cleaning use a abrasive plastic scouring pad. Prevent cleaning particles or swarf from entering the tube.	TT Page 6 Figure 4
 Figure 5: Fitting cleaning with brush	**Cleaning the fitting** For interior fitting cleaning use a properly sized fitting brush.	TT Page 6 Figure 4 (2)
 Figure 6: Assembly of pipe and fitting	**Assembly** Put the pipe and fitting or expanded pipes together and make sure you maintain the right joint depth.	

References

Purge tubes

Purge residues out of the tubes before brazing. Use dry Nitrogen for purging.

TT Page 15 Figure 19

Nitrogen transfer hose

Figure 7: Application of Nitrogen flow

Apply Nitrogen flow

Prevent oxide formation on the inner surface of the tubes.

Once the refrigerant is circulating in the system, oxide scale on the inside of the tubes can lead to serious problems.

Slowly pass Nitrogen through the pipework, the far end of the pipework to be open to the atmosphere, without building up a pressure.

Flow rate should be about 1 to 2 liter per minute. Flow rate sensitively can be felt easily on the back of a moistened hand.

TT Page 15 Figure 19

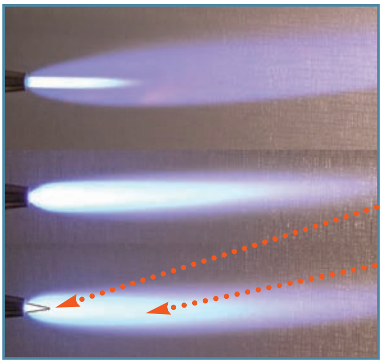


Figure 8: Torch adjustment

Torch (flame) adjustment

Adjust the torch for a slightly reduced flame.

Blue flame

Green ‘feather’

Light torch flame only with safe lighters!

TT Page 13 Figure 15 Page 14 Figure16

References

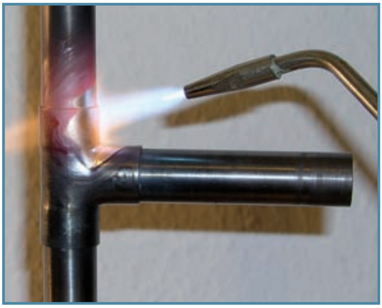


Figure 9: Heat application

Apply heat

Apply heat uniformly **to both, tube and fitting,** by moving the torch around to ensure even heating before adding the filler material (rod).

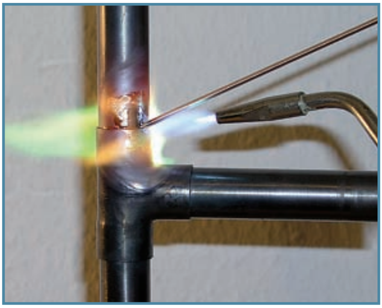


Figure 10: Filler application

Apply filler

As the heated area gradually changes colour to red **(a cherry red but not a bright red),** apply filler material (rod) by lightly brushing the tip of the stick into the shoulder of the fitting.
Care should be taken not to **over-heat** the tube!

TT
Page 15
Figure 18

Figure 11: Filler in detail

Complete joint

To complete the joint, an even build-up of solder should be **just** visible arround the shoulder of the fitting.

Filler (rod)

References

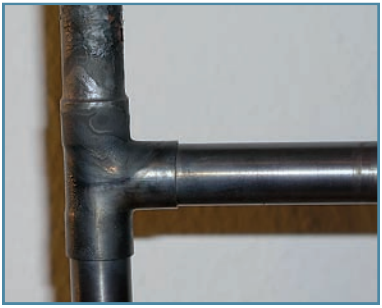


Figure 12: Heat removal

Remove the heat

Remove the heat until the molten brazing alloy solidifies to a tan black colour (approx. 10 to 15 seconds).

Finnish brazing

After brazing is completed, the joints are normally left to cool in the air.

Stop the flow of Nitrogen.

However, if necessary, the joint may be cooled with a wet rag.

Figure 13: Flux application

Brass to copper tube brazing

This combination of materials requires the use of e.g. a water solble flux. Apply a small amount of flux to the end of the tube and to the inside surface of the fitting. Avoid spilling of flux inside the tube and fitting, as the residue needs to be removed on completion.

References

Figure 14: Brass adapter

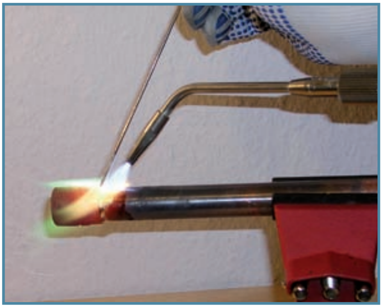


Figure 15: Brass adapter brazing

The procedure for these joints is essentially the same as for copper to copper brazing, only that more heat should initially be concentrated on the brass fitting to bring it to temperature.

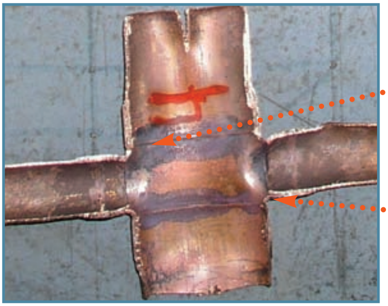
TT
Page 15
Figure 18

Take care not to overheat the fitting. Dull red colour is sufficient.

Use brazing rods with higher content of silver (Ag).

Improve your Skills

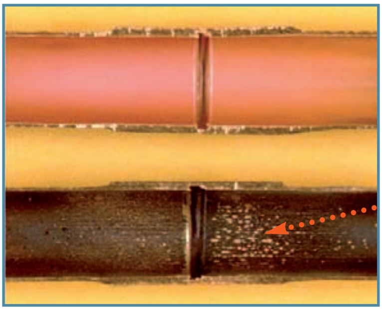
Cut a section of a joint with fitting to examine the penetration of solder in the fittings capillary.



Penetration of solder (perfect)

Penetration of solder (insufficient)

Figure 16: Brazed copper-T examples/cut away



Example of Nitrogen protective brazing

Straight brazing copper/copper joint with Nitrogen

OXIDE FORMATION

Straight brazing copper/copper joint without Nitrogen

Figure 17: Nitrogen protective brazing examples

Chapter 8: Flaring, the Process

Preface

Because of its exceptional formability, copper can be formed as desired at the job site.

Flaring is a mechanical way of joining pipe work.

While a copper tube is usually joined by soldering or brazing, a mechanical joint may be required or preferred at times. Flared fittings are an alternative when the use of an open flame is either not desired or impractical.

Flared joints (and screwed connections) should be kept as minimal as possible. Leak prevention requires the design of a 'sealed system' as far as possible. Check the availability of 'brazed in' components and use them wherever possible!

In particular, flared joints must not be used to connect expansion valves.

Always follow specific safety regulations!
(see also chapter safety)

References

Flaring Process Steps

Figure 1: Cutting the tube

Cut the tube

Use a wheel cutter rather than a hacksaw in order to prevent swarf entering the tube.

TT Page 5 Figure 1

Figure 2: Removing of burrs

Remove internal burrs

A deburrer or reamer can be used to remove internal burrs.

TT: Page 6 Figure 3

Figure 3: Cleaning the surface

Clean the surfaces

Dirt, debris and foreign substances should be removed from the tube end by mechanical cleaning.

TT: Page 6 Figure 4 (1)

References

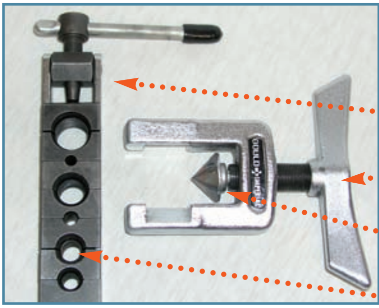


Figure 4: Flaring tools

The flaring tool (example)

The flaring tool consists of:

Flaring bar (holding tool)

Clamp tool

Flaring cone

Holding bores different diameters

TT
Page 11
Figure 11

Figure 5: Flaring arrangement

Assemble the flaring tool with tube and flare-nut

Place the flare-nut over the end of the tube with the threads close to the end being flared. Insert the tube between the flaring bars of the flaring tool. Opening of the flaring bars must match the diameter of the tube being flared.

TT
Page 11
Figure 11

Figure 6: Flare fabrication

Fabricate the flare

Align the compression cone on the tubing's end and tighten the screw. As you turn the handle, the cone flares the tubing's end.

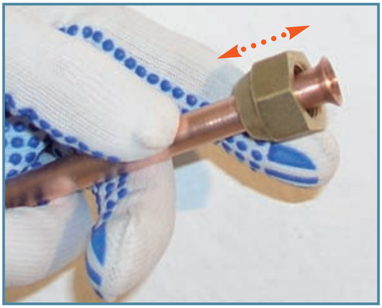


Figure 7: Flare inspection

Inspect your work

Inspect your work after removing the tubing from the flaring tool. If the tube end has splits, cut off the flared portion and repeat the process.

It is essential to examine the tight position of :

- male flare union
- female flare-nut
- flared copper tube

Tight and clean fitting is requested.

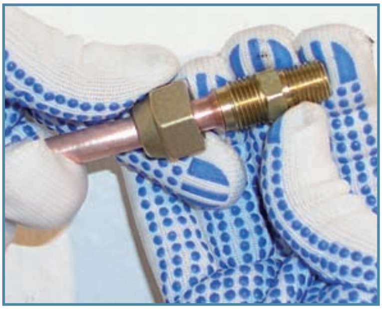


Figure 8: Flared connection positioning

Assembling

Position the flare union against the flared end of the tubing and slide down the nut. The fitting should be easily tightend by hand if done properly. Additional pipe jointing or sealing compound (e.g. oil) is not necessary.

References

Figure 9: Flared connection tightening

Tightening

It is now time to tighten the joint by placing one wrench on the union and one on the nut. Do not 'over-tighten' a flare joint!

Once the parts fit by hand, give them a half turn on each nut/wrench to create a gas tight join.

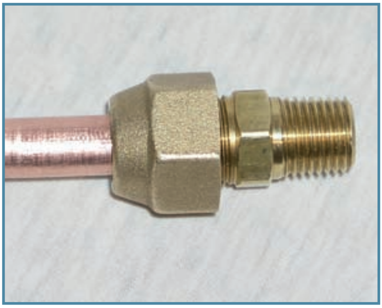


Figure 10: Copper tube with flare, flare-nut and adapter

Final result

Chapter 9: Domestic Refrigeration

Preface

Domestic refrigerators are amongst the most common electric appliances in the world, for instance being present in 99.5% of European and American homes. They may consist of either a cooling compartment only (a larder refrigerator) or a freezing compartment only (a freezer) or contain both.

Some refrigerators are now divided into four zones for the storage of different types of food:

- –18°C or 0°F (freezer)
- 0°C or 32°F (meats)
- 4°C or 40°F (refrigerator)
- 10°C or 50°F (vegetables), for the storage of different food types.

The following chapter is about the maintenance and repair of the domestic refrigeration systems.

First Steps

Figure 1: View of a refrigerant circuit

Before opening a hermetic refrigerant cycle it is essential to have first visible, sensitive and audible impressions which can directly lead to fault identification.

The first system cycle evaluation consists of:

(1) Heat transfer at the condenser
(2) Temperature of the filter-drier
(3) Noise level of the compressor
(4) Heat emission of the compressor
(5) Situation of hoar frost at the evaporator
(6) Capacity of the compressor

- With refrigerant shortage (leak) the refrigerant entrance at the condenser is warm, the outlet cold
- With iced-over evaporator the heat transfer is very low
- With reduced compressor capacity the heat transfer is very low

References

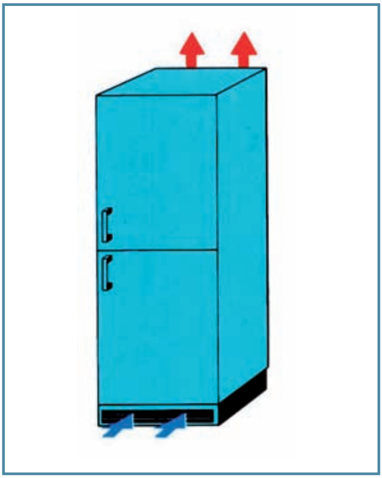


Figure 2: Freezer air circulation

Placing a fridge/freezer

It is very important that the fridge/freezer is placed with sufficient surrounding for heat transfer (air circulation).

Pay attention that the condenser is free of dust or dirt and that no items obstruct the ventilation area.

Placing of a fridge/freezer close to other heat sources must be avoided.

It is necessary to clean the condenser regularly.

Figure 3: Freezer temperature measuring

Figure 3a: Refrigerator wall (evaporator area) with hoar frost

Use a common thermometer and a glass of water for inside temperature measurements.

MI Page 47 Figure 11 (4)

The evaporator must not be iced-over. This will hinder the heat absorption in the refrigerated area.

Check that there is a sufficient ice formation (hoar frost).

The fridge/freezers door gasket must lie perfectly close at the body.

Use a hair-drier to work on spots where the gasket does not fit.

References

Figure 4: Sensor positioning

Connect the sensor of the electronic thermometer to the securing clip of the thermostat sensor to measure switch-on and switch-off temperatures.

Check that the lighting switches off while you close the door.

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Page 47
Figure 11

Figure 5: Temperature adjustment range

Adjust the thermostat slightly above medium position of the temperature adjustment range.

e.g.: Position 4 of range 7
Position 2.5 of range 4

Does the thermostat cut-off? Compare cut-off/cut-on temperatures with the thermostat manufacturer's technical information.

Refrigerant Cycle Opening

If a hermetic refrigerating system is to function correctly and to have a reasonable long life, it is essential that the amount of impurities present in the system, i.e. moisture, foreign gases, dirt etc., are being kept at a minimum.

This fact must be taken into consideration when repairs are to be made and the necessary precautions must be taken. Before commencing repairs, especially those which require the opening of a hermetic refrigerant cycle, make sure that all other possible faults have been eliminated and that an exact diagnosis of the problem has been made.

If the first system cycle evaluation and measurements indicate that it is necessary to open the hermetic system, we have to proceed as follows:

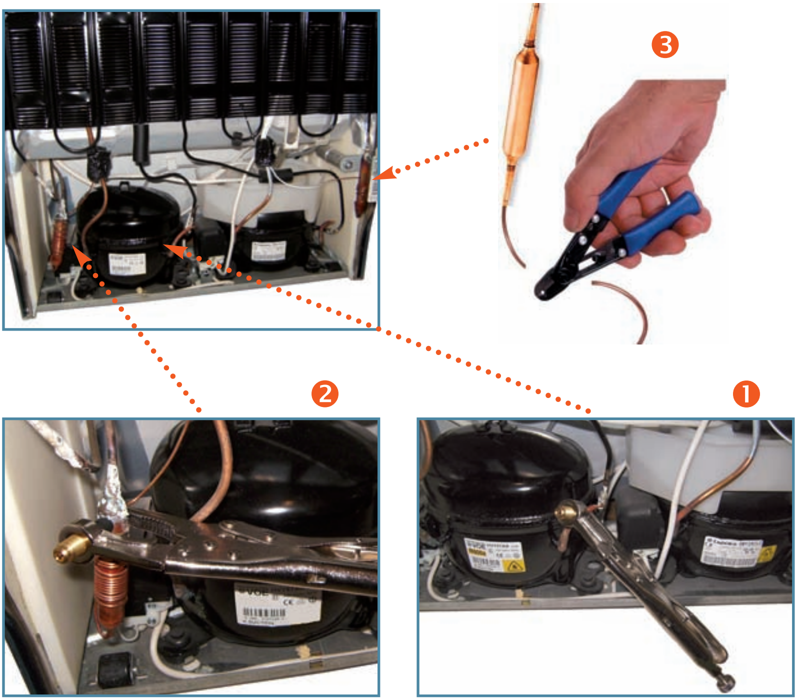

Figure 6: Steps when opening a refrigerant cycle

References TT Page 5-Figure 2, RHC Page 24-Figure 9

Figure 7: Placement of piercing plier at process pipe

For gauge connection and pressure/temperature reading, place piercing plier connected with refrigerant hose to the process tube (charging tube) at the compressor. Continue system cycle analysis with operating compressor.

References

RHC:
Page 24
Figure 9

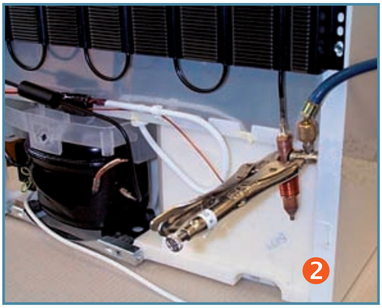

Figure 8: Placement of an additional piercing plier at the filter-drier

For refrigerant gas recovery, place one additional piercing plier directly on the filter-drier's surface (high pressure side). This enables refrigerant gas recovery from both, high and low pressure sides of the system. Additional, if the capillary tube is mechanically blocked, refrigerant will remain at the high pressure side of the system. For further explanation of the refrigerant gas recovery process see also chapter 'refrigerant recovery, recycling and containment in the field'.

References: RHC Page 24 Figure 9

Figure 9: Cutting of the capillary tube

After entire emptying of the refrigerant cycle, cut the capillary tube at the filter-drier outlet (distance from filter-drier approx. 3 cm).

Avoid burrs and deformation of the capillary tube.

References: TT Page 5 Figure 2

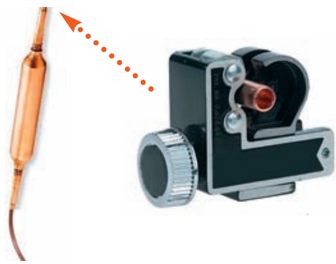

Figure 10: Cutting of the filter-drier

Cut the filter-drier with a tube-cutter if sufficient condenser tube length (steel) is available. This action enables you to remove bounded humidity and residues together with the filter-drier.

References: TT Page 5 Figure 1

References

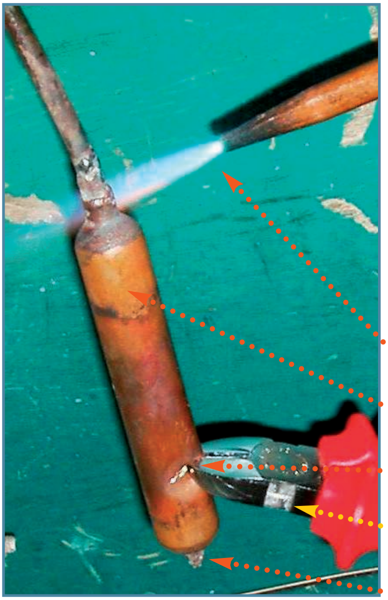

Figure 11: Destruction of a filter-drier

If a sufficient tube length is not available, proceed as follows:

For safety reason, destroy the filter-drier with a side cable cutter plier close to the filter-drier outlet. Unbraze the filter-drier and clean the steel tube of the condenser's outlet thoroughly with a wire-brush.

- Brazing torch
- Filter-drier
- Destroyed filter section
- Side cable cutter
- Here the capillary was cut in figure (9)

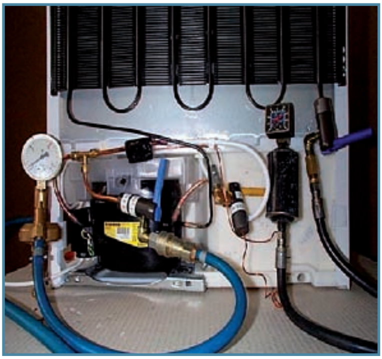

Figure 12: Capacity test

If a reduced hermetic compressor capacity is assumed, complete a capacity test.

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Figure 18

Figure 13: Nitrogen connection to the process pipe

Dry Nitrogen (N_2) is connected now to the valve on the process pipe.

The pressure regulator of the Nitrogen supply cylinder is adjusted to a maximum of 10 bar. The Nitrogen flow will enter the system passing the process tube, the compressor, the evaporator with the connected capillary tube and the condenser.

References

RHC
Page 24
Figure 9

Flushing the System with Nitrogen N2

Nitrogen discharges now at the open end of the condenser (previously connected to the filter-drier inlet) and the open end of the capillary tube. Hold a rag at both open ends because remaining compressor lubricant may come with the purged Nitrogen. The Nitrogen flushes the system and takes humidity etc. The blowing process also allows the localization of any obstructions in the piping.

Plan the repair work so that the refrigerating system will not be open for more than 10–15 minutes.

Assemble the special equipment required for the repairs.
Assemble any spare parts required.

System Assembling – Create a Hermetic System

While assembling the refrigerated section, service valves (Schrader valves) must not be used because of the high risk of leakage. Domestic appliances require a sensitive and accurate refrigerant charge and the correct charging amount is very low compared with commercial or air-conditioning systems. For domestic appliances only a few gram of leakage per year will reduce the refrigerators/freezers efficiency resulting in increased electricity consumption.

Prevent intentional leaks and provide a hermetic system (refrigerant cycle) without screwed connective service ports.

References

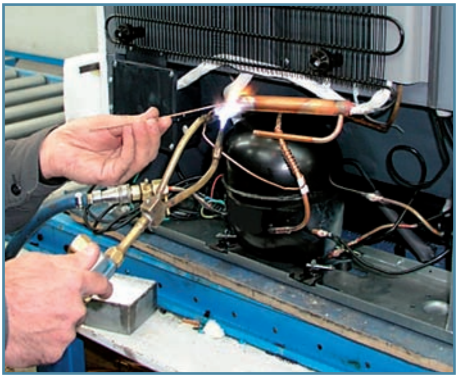

Figure 14: Brazing of the filter-drier

When brazing the filter-drier and the capillary tube, note that the thin capillary cannot withstand high temperatures due to the risk of melting and the torch's heat must therefore be confined from the filter.

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Page 15
Figure 18

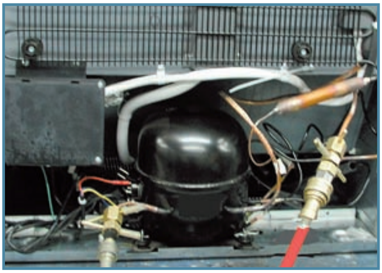
Preferably install a filter-drier with additional process tube (high pressure side) if available.

Use copper brazing rods (solder) with approximately 1.5% to 4% of silver content and phosphorus for copper-copper connections.

Use silver brazing rods (solder) coated with flux or separate flux paste for copper-steel connections.

TT
Page 7
Figure 5

Clean all brazing joints **thoroughly** with a wire brush and check the condition (appearance) with an inspection mirror.

		References
 Figure 15: Connection of quick coupler and refrigerant cycle	Connect the quick coupler now to the prepared refrigerant cycle at low and high pressure side using the service quick coupler.	TT Page 9 Figure 8
 Figure 16: Evacuation and charging station	Connect the evacuation and charging station to the previously connected quick coupler. 1. Low pressure side 2. High pressure side	RRRE Page 38 Figure 8
 Figure 17: Nitrogen cylinder with pressure regulator	Connect the Nitrogen cylinder to the charging station. Pressurize the system with dry Nitrogen while transferring the gas from both, the high and low pressure side up to a system pressure of a maximum of 10 bar.	TT Page 15 Figure 19

Chapter 10: Domestic Refrigeration HC

Preface

Hydrocarbons (HCs) are widely used in today's modern refrigeration appliances (capillary tube operational domestic and small commercial systems). Within the foreseeable future, CFC, in particular for servicing purpose, will become unobtainable. In new production of household appliances CFC-R12 is widely replaced by HFC-R134a and HC-R600a. HCs will become more important in the future, as most fluorinated gases have a high impact on global warming.

HC refrigerants are flammable if mixed with air and ignited, and should therefore only be used in appliances which fulfil regulated safety requirements.

In order to carry out service and repair on HC systems, the service personnel must be properly trained to be able to handle a flammable refrigerant. This includes knowledge on tools, refrigeration cycle components and refrigerants, and the relevant regulations and safety precautions when carrying out service and repair.

The refrigerant must be stored and transported in approved containers. Best possible in 450 g aluminium cylinder (within two containers maximum transported in a service car). In general, replaced compressors containing refrigerant (not only HC containing compressors) residues must be sealed before being transported.

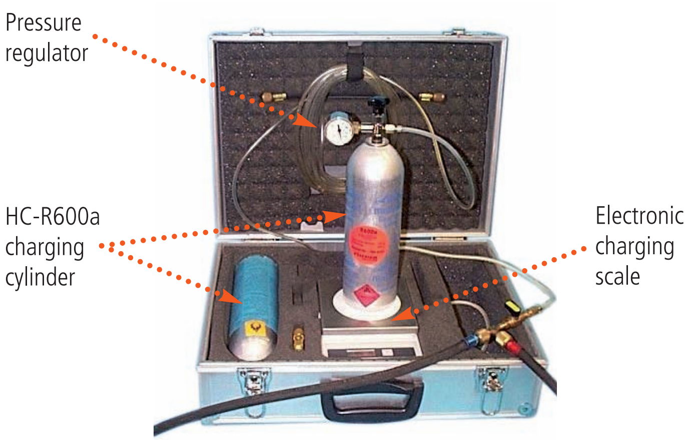


Figure 1: HC Refrigerant charging set

Important Note:

For safety reasons a practical limit of 8 g/m³ of Hydrocarbon refrigerant should not be exceeded in a closed space or room.

HCs are heavier than air. The concentration (if refrigerant is exposed) will always be highest at floor level.

Do not release the refrigerant close to basements, canalisation etc. The working room/area must be always sufficient ventilated.

To avoid any dangerous circumstances, open flames should be avoided. The best possible way for domestic appliances service and repair is to use e.g. LOKRING connections and joints.

The use of dry Nitrogen for system service and repair plays an important role:

- Refrigerated system flushing
- Leak test
- Removal of sectional restrictions (dirt or residues)

Abstract:

The service technician is familiar with the dangers related to flammable HC refrigerants.

- There is no risk of sparks forming near the work area.
- Do not smoke or use naked flame or other means of heat. Therefore, no brazing on the system is preferred.
- Electrical appliances used during the service must not produce sparks.
- Arrange good ventilation in the work area.
- Do not let the refrigerant flow into basement openings, low lying rooms, sewer systems etc. as HCs are heavier than air.
- Safety rules for handling, storage and transport of combustible refrigerant applicable in the various countries must be followed.

First Steps

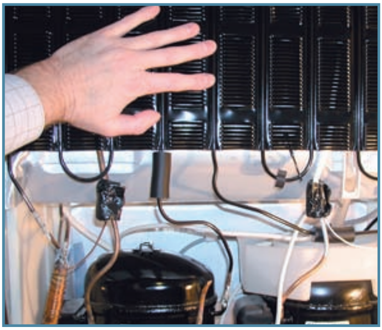


Figure 2: View of a refrigerant circuit

Before opening a hermetic refrigerant cycle it is essential to have first visible, sensitive and audible impressions which can directly lead to fault identification.

The first system cycle evaluation consists of:

(1) Heat transfer at the condenser
(2) Temperature of the filter-drier
(3) Noise level of the compressor
(4) Heat emission of the compressor
(5) Situation of hoar frost at the evaporator
(6) Capacity of the compressor

- With refrigerant shortage (leak) the refrigerant entrance at the condenser is warm, the outlet cold
- With iced-over evaporator the heat transfer is very low
- With reduced compressor capacity the heat transfer is very low

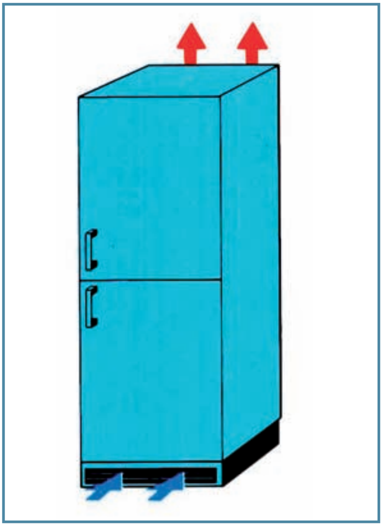


Figure 3: Freezer air circulation

Placing a fridge/freezer

It is very important that the fridge/freezer is placed with sufficient surrounding for heat transfer (air circulation).

Pay attention that the condenser is free of dust or dirt and that no items obstruct the ventilation area.

Placing of a fridge/freezer close to other heat sources must be avoided.

It is necessary to clean the condenser regularly.

		References
 Figure 4: Freezer temperature measuring	Use a common thermometer and a glass of water (as indicated above) for inside temperature measurements. The evaporator must not be iced-over. This will reduce the heat absorption in the refrigerated area. Check that there is a sufficient ice formation (hoar frost). The fridge/freezers door gasket must lie perfectly close at the body. Use a hair-drier to work on spots where the gasket does not fit.	MI Page 47 Figure 11 (4)
 Figure 5: Sensor positioning	Connect the sensor of the electronic thermometer to the securing clip of the thermostat sensor to measure switch-on and switch-off temperatures. Check that the lighting switches off while you close the door.	MI Page 47 Figure 11 (1-2)
 Figure 6: Temperature adjustment range	Adjust the thermostat slightly above medium position of the temperature adjustment range. e.g.: Position 4 of range 7 Position 2.5 of range 4 Does the thermostat cut-off? Compare cut-off/cut-on temperatures with the thermostat manufacturer's technical information.	

Refrigerant Cycle Opening

If a hermetic refrigerating system is to function correctly and has a reasonable long life, it is essential that the amount of impurities present in the system, i.e. moisture, foreign gases, dirt etc., is being kept at a minimum.

This fact must be taken into consideration when repairs have to be made, and the necessary precautions must be taken. Before commencing repairs, especially those which require the opening of a hermetic refrigerant cycle, make sure that all other possible faults have been eliminated and that an exact diagnosis of the problem has been made.

If the first system cycle evaluation and measurements indicate that it is necessary to open the hermetic system, we have to proceed as follows:

References

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Figure 9

Figure 7: Placement of piercing plier

For gauge connection and pressure/temperature reading, place piercing plier connected with refrigerant hose to the process tube (charging tube) at the compressor. Continue system cycle analysis with operating compressor.

References

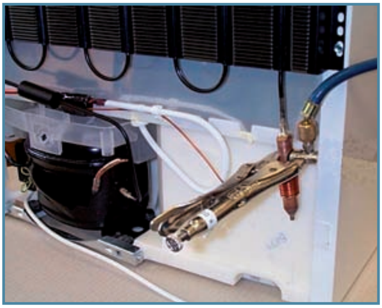

Figure 8: Placement of additional piercing plier

To remove the refrigerant gas, place one additional piercing plier directly on the filter-drier's surface (high pressure side).

The hose (vent line) is carried outside and connected to the 'free ambient', e.g. through a window opening.

The vent line must have an inner diameter of minimum 10 mm or 3/8".

RHC Page 24 Figure 9

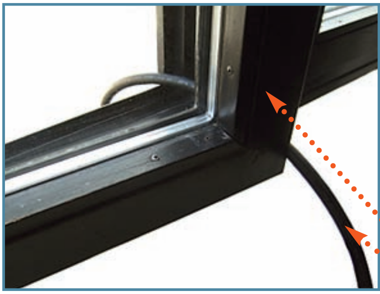

Figure 9: Open window as vent line

The end of the hose is carried through, e.g. an open window.

This will be a 'vent line' to remove the flammable refrigerant to the safe outside area.

- Open window or door
- Vent line

RHC Page 22 Figure 5 (6)

If the compressor **does not** have to be replaced, the oil is degassed in the compressor by letting the compressor run for about one minute.

Never start the compressor under vacuum; it would risk damaging of the motor.

References

As follows, the system can be 'blown through' with Nitrogen.

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Figure 9

Nitrogen will flush the system while taking residues of refrigerant and venting to the ambient atmosphere.

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Page 15
Figure 19

Figure 10: Nitrogen flush

After flushing the Nitrogen, the cylinder pressure regulator is closed.The vent line at the filter-drier is dismounted.

- Connect the vent line to vacuum pump outlet on the exhaust port.
- Connect the hose of the vacuum pump suction port to the valve on the filter-drier.

	References
• Suction hose connected to the piercing pliers on filter-drier	RHC Page 24 Figure 9
• Suction hose connected to the vacuum pump suction port • Vent line on exhaust port of the vacuum pump	RRRE Page 37 Figure 7
• Vent line to the outside area	RHC Page 22 Figure 5 (6)

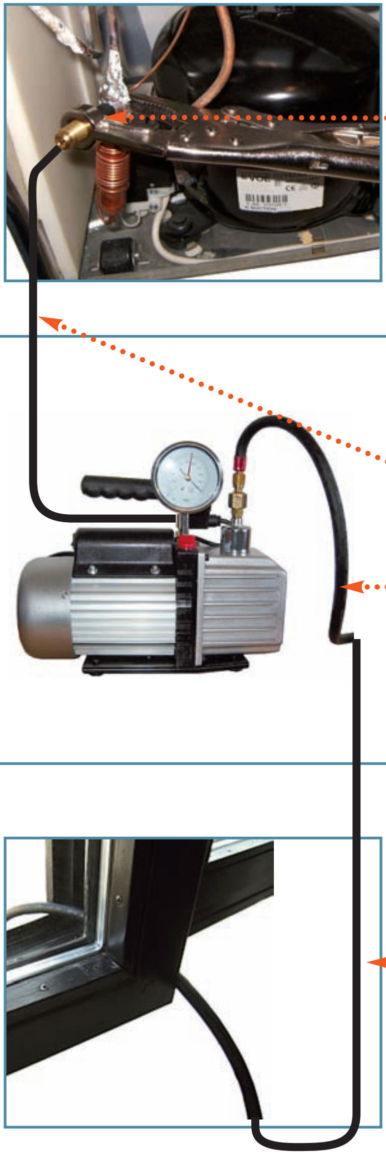


Figure 11: HC refrigerant recovery with vacuum pump and vent line

The refrigerating system is now ready for the first evacuation. Evacuate to a pressure of approximately 5 mbar.

The vent line must have a minimum inner diameter of 10 mm (3/8")!

There must not be any appreciable overpressure at the exhaust port of the vacuum pump, as this may damage the vacuum pump!

End the first evacuation process through switching off the vacuum pump.

The Blowing Process

Open the valve on the Nitrogen tank pressure regulator and flush the total arrangement of refrigeration system, piercing pliers, vacuum pump and vent line by less than 1 bar (low pressure).

Regulate the working pressure with the reducing valve and equalize the pressure into the system.

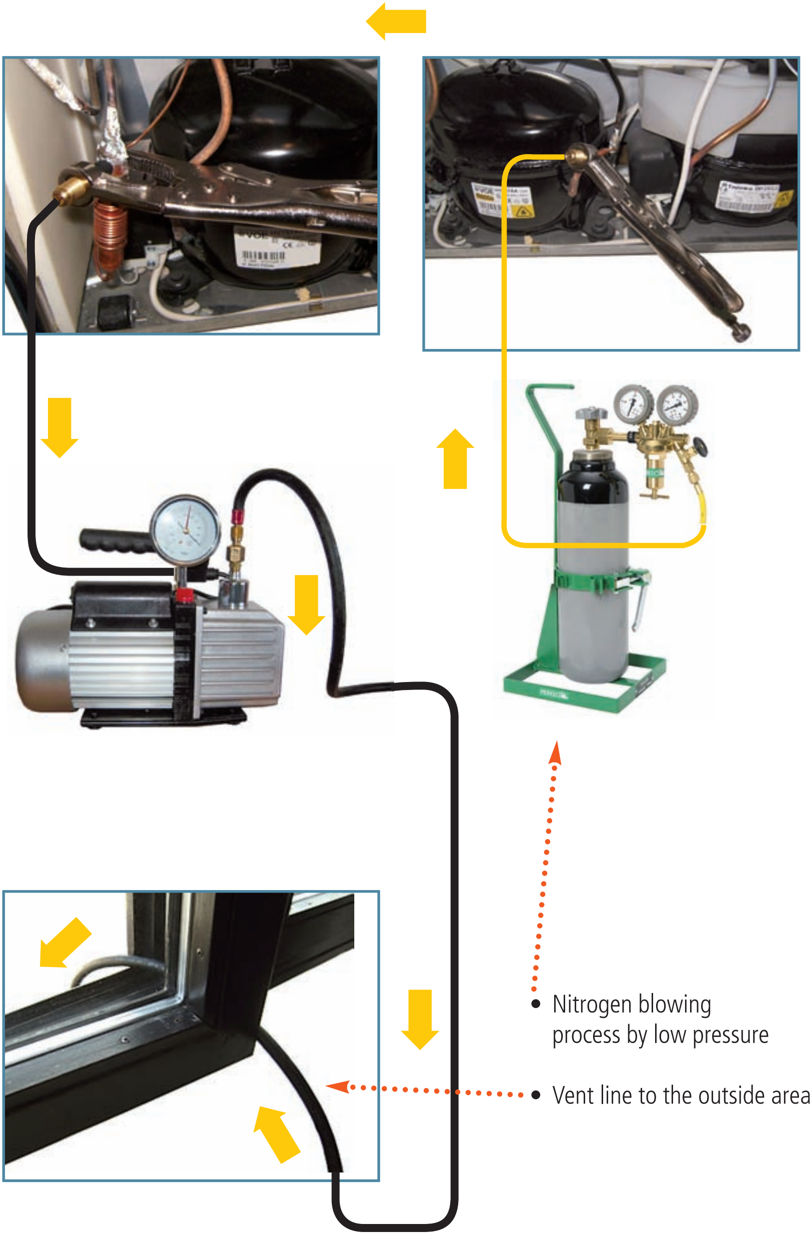


Figure 12: Nitrogen blowing process

References

Removing Filter-Drier / Compressor Capacity Test

After the entire blowing of the refrigerant cycle disconnect the vacuum pump and vent line.

Cut the capillary tube at the filter-drier outlet (distance from filter-drier approx. 3 cm).

Avoid burrs and deformation of the capillary tube.

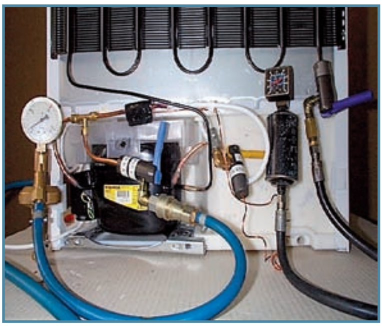
Figure 13: Cutting of the capillary tube

TT
Page 5
Figure 2

Cut the filter-drier with a tube-cutter if sufficient condenser tube length (steel) is available.
This action enables you to remove bounded humidity and residues together with the filter-drier.

Figure 14: Cutting of the filter-drier

TT
Page 5
Figure 1



If a reduced hermetic compressor capacity is assumed, complete a capacity test.

Figure 15: Adjustment for a capacity test

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Figure 18

Evaporator and Condenser Check

References

Figure 16: Nitrogen flow adjustment

Dry Nitrogen (N_2) is connected now to the valve on the process pipe.

The pressure regulator of the Nitrogen supply cylinder is adjusted to a maximum of 10 bar.

The Nitrogen flow will enter the system passing the process tube, the compressor, the evaporator with the connected capillary tube and the condenser.

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Figure 9

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Figure 19

Nitrogen discharges now at the open end of the condenser (previously connected to the filter-drier inlet) and the open end of the capillary tube. Hold a rag at both open ends because remaining compressor lubricant may come with the purged Nitrogen. The blowing process also allows the localization of any obstructions in the piping.

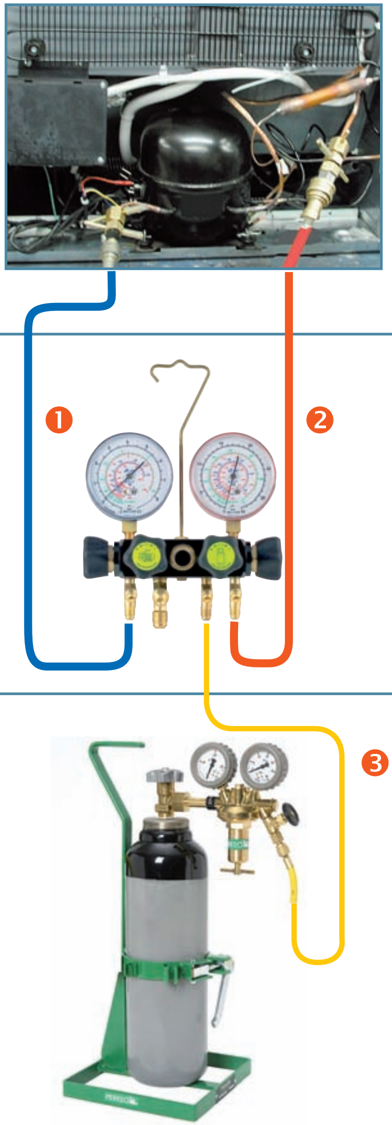
Plan the repair work in a way that the refrigerating system and new parts will not be open for more than 10–15 minutes.

- Assemble the special equipment required for the repairs.
- Assemble any spare parts required.
- Mount a service filter, which is larger than the filter originally used and (if possible) with additional process pipe connection. The filter-drier must be hermetically sealed until it is mounted.

The refrigerating system is prepared for assembly using a tube joining system by pressing connections.

References

Leak Test



Connect the quick coupler now to the prepared refrigerant cycle at the low and high pressure side using the service coupler.

TT Page 9 Figure 8

Connect a 4-valve manifold gauge set to the system.

1. Low pressure side
2. High pressure side
3. Nitrogen supply

RHC Page 19 Figure 2

Connect the Nitrogen cylinder to the centre port of the manifold gauge set.

Pressurize the system with dry Nitrogen while transferring the gas from both, the high and low pressure side up to a system pressure of a maximum of 10 bar.

TT Page 15 Figure 19

Figure 17: Connection system for a leak test

Carry out a leak-test ...

1. By standing pressure with closed valves and gauge for pressure observation. For very small leaks a pressure test may take up to 24 hours. A pressure drop indicates a leak.

and

2. With soap water and a brush, adding this liquid to all joints while observing if the liquid creates bubbles. Bubbles indicate a leak.

Figure 18: Bubble indicating a leak

References

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Figure 5

Bring all pipes carefully into the correct position (e.g. protruding tubes).

If the system is identified as leak free, blow off the Nitrogen into the atmosphere.

Evacuation and Charging the System

The system is now ready for the final evacuation and charging. To keep the content of non-condensability and humidity in the system to a minimum, the system must be evacuated to a vacuum as low as possible before charging is carried out (0.5 mbar, 50 Pa, 375 micron). The vacuum attained must be checked with a vacuum gauge.

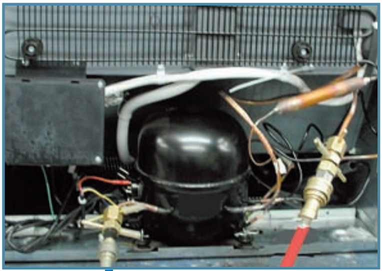
General rule for evacuation time required:

1. One side evacuation at the compressor's process tube only, minimum time required is 30 minutes.

2. Two side evacuations at the compressor's process tube and the filter-drier's process tube, minimum time required is 15 minutes.

Check for stability of the vacuum by closing the valve for the vacuum pump. If the vacuum gauge needle falls appreciably, possible leakage in the system is indicated or hose connections of the service equipment to the refrigerator/freezer are not properly fitted.

References



Connect the quick coupler now to the prepared refrigerant cycle at the low and high pressure side using the service coupler.

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Figure 8

- 4-valve manifold
- Vacuum pump with vacuum gauge
- HC refrigerant charging cylinder on scale

RHC
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Figure 2

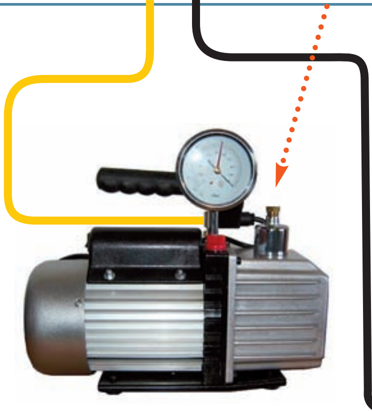


Figure 19: Two side system evacuation and charging

When a stable vacuum has been achieved, close the valve for the vacuum gauge and commence charging.

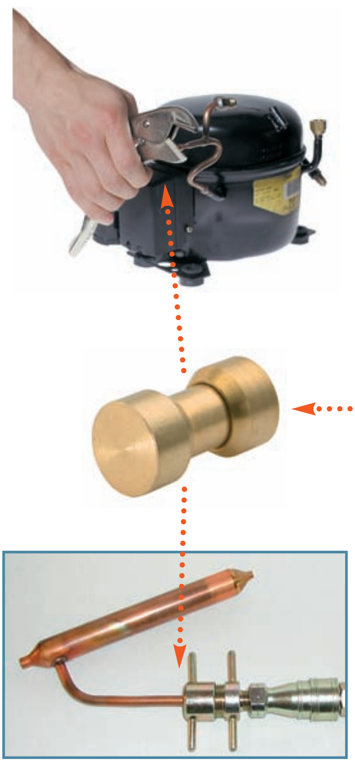
The amount of refrigerant to be added is specified in grams or oz on the rating plate.

Charging process:

1. Charge 1/3 of the total charging amount gaseous into the refrigerated system.
2. Switch on the compressor.
3. Add the remaining charging amount slowly into the system.
4. Observe the gauge and check the system's operating situation.

References

Seal the System



1. Pinch the process tube(s) with pliers twice. One pinch-off in 90° to the process pipe and one in 45° to the process pipe.

2. Remove pinch-off pliers.

3. Seal the process tubes using a stopper device[1].

- Stopper device

Same process at the filter-drier's process tube (if present).

TT Page 7 Figure 6

Figure 20: Pressing equipment for system sealing

[1] Stopper device, e.g. manufactured by Lokring.

References

Figure 21: Final leak test with electronic leak detector[2]

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Figure 2

System check and final leak test

After the charging process the adjustment and functioning of control devices must be checked. The system must be operated until sufficient system conditions are visible.

Meanwhile temperature and pressure values should be recorded. After the disconnection of gauges and hoses a final leak test has to be performed.

Use again soap water and/or an electronic leak-detector and you will find that there are common places to check. The following lists some very common leak locations:

- Flare-nuts
- Service valve: packing, access fitting, mounting
- Cracked brazed joint in piping
- Rotted evaporator end bends
- Pipes rubbing together
- Cracked ferrous brazed in accessory

[2] e.g. STARTEK from REFCO

Chapter 11: Pressing, the Process

Preface

Alternatively to brazed joints, especially in domestic refrigeration and for systems operated with Hydrocarbons (combustible refrigerants like R-600a and R-290), and also for the use in small and medium AC systems and MAC, pressed tube connections are a safe and reliable solution.

The tube pressing connection technology[3] represents a proven method of producing hermetically sealed metal-to-metal tube connections.

Features of the tube pressing connection technology:

- Permanent hermetically metal-to-metal sealing
- Unproblematic connection of tubes consisting of different materials
- No special preparation of the tubes necessary
- Easy and fast assembly

Pressure and Temperature Area

The above mentioned tube connections are designed for a working pressure of 50 bar (depending on the tube material) with fourfold security and for the range of temperature from –50°C up to +150°C (–58°F up to 302°F).

Material Affiliation

The tube connections are made of the materials aluminium and brass.
Brass connectors, both '00' series, for tube diameters 3/8" (9.53 mm) and above, and all sizes of '50' series are usually supplied with connectors (adaptors) made from steel, with a yellow coloured zinc plate galvanization.

The affiliation of the connectors depends on the material of the tubes to be connected and is shown in the following figure.

[3] Tube connections manufactured e.g. by 'Vulkan Lokring Rohrverbindungen GmbH'

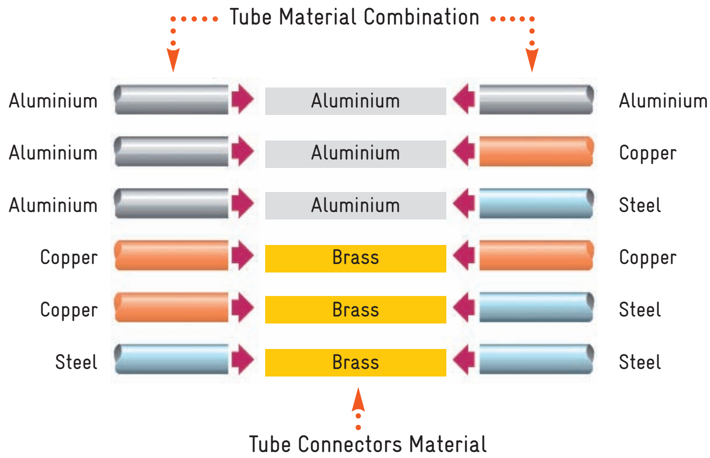
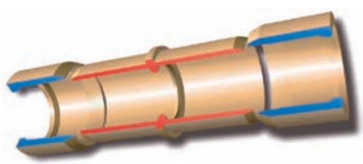
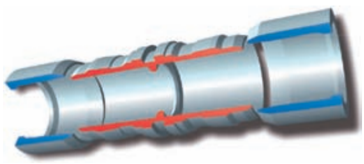


Figure 1: Tube connectors material combinations



Tube connection coupling
for double sided assembly (series 00)



Tube connection coupling
for single sided assembly (series 50)

Figure 2: Tube connection couplings

Example of a tube connection coupling

A tube connection coupling consists of two tube connections and one tubular joint for the acceptance of the two tube endings.

In condition of delivery, the tube connections are pre-assembled on the fitting, the bigger end of the conical bore is pressed onto the outwards fit of the joint.

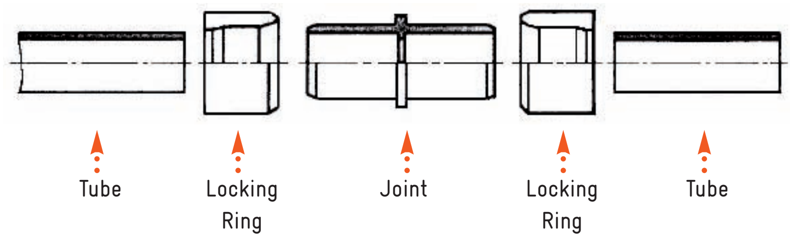


Figure 3: Tube connection coupling

During assembly the tubes which are to be connected have to be pushed into the fittings end. With the use of a 'hand assembling tool' the locking rings are pushed over the fitting.

Due to the special inner profile of a tube connector (e.g. Lokring), the diameter of the connection is reduced until it is in absolute close contact with the outer surface of the tube which is to be connected, and pinches it by a tight reduction.

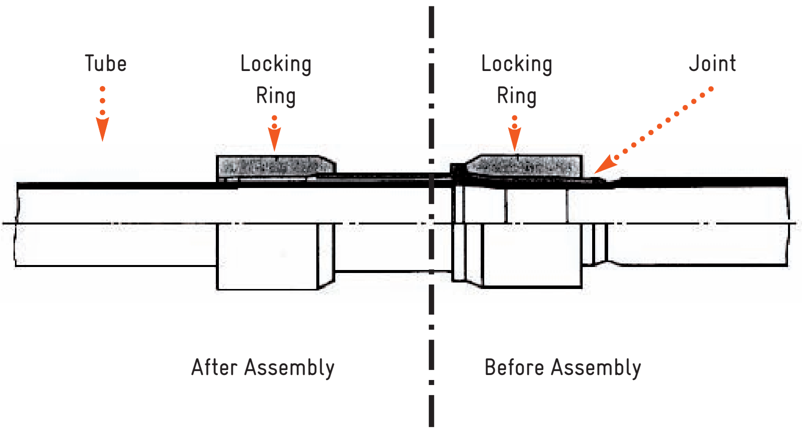


Figure 4: Tube coupling

Safety Recommendations

Despite the high metal/metal pressure it is not always possible to seal deep surface porosity and longitudinal grooves which might have a negative effect on the tightness of the tube connection.

In order to obtain additional safety, the surfaces of the tube ends have to be moistened with an anaerobic liquid. It settles in the unevenness of the tube surface and hardens there. The curing time is dependent on various factors. After the curing of the liquid, the connection can be loaded with pressure or vacuum.

Lokprep **65G**

Anaerobic filling and sealing
Medium contains methacrylic ester

Available in 15 or 50 ml

Figure 5: Lokprep, anaerobic liquid

Figure 6: Hand assembling tool

Figure 7: Assortment box for refrigeration

Connection Examples

Lokring connector (double sided assembly) made of brass for joining of tubes 1.6 to 11 mm

Brass connectors for tube materials:
Cu/Cu; Cu/St; St/St

Figure 8: Lokring connector brass

Lokring connector (double sided assembly) made of aluminium for joining of tubes 2 to 11 mm

Aluminium connectors for tube materials:
Al/Al; Al/Cu; Al/St

Figure 9: Lokring connector aluminium

Lokring reduced connector (double sided assembly) made of aluminium for joining of tubes

Aluminium reduced connectors for tube materials:
Al/Al; Al/Cu; Al/St

Figure 10: Lokring reducer aluminium

Figure 11: Lokring tee connector

Lokring tee connector (single sided assembly) made of brass for joining of tubes 6 to 28.6 mm

Brass tee connectors for tube materials: Cu/Cu; Cu/St; St/St

Figure 12: Lokring tee reducer with capillary tube insertion

Lokring tee reduced connector (double sided assembly) made of brass for joining of tubes e.g. ø 6 mm and ø 2 mm with tee ø 6 mm: Lokring 6/6/2 NTR Ms 00 (capillary tube insertion)

Brass tee reducer for tube materials: Cu/Cu; Cu/St; St/St (e.g. domestic appliances)

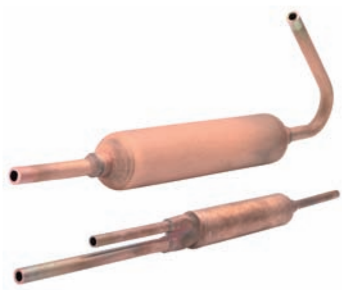


Figure 13: Filter-drier with tube ends

Assembly of the Tubes

Figure 14: Tube cleaning in a rotational motion

Surface cleaning

Before assembling the tube connection, clean the tube ends with a scouring pad.

To avoid longitudinal grooves clean the tube ends in a rotational motion (not in longitudinal direction of the tube).

Figure 15: Coating with Lokprep as anaerobic liquid

Apply anaerobic liquid

The ends of the tubes have to be coated with an anaerobic liquid.

Figure 16: Rotating connection assembly

Rotate connection assembly

The tube ends have to be inserted into the tube connection until the stop.
For a better distribution of the anaerobic liquid the tube connection has to be rotated at 360°.

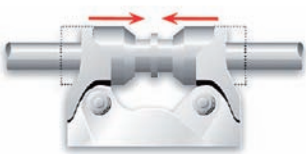
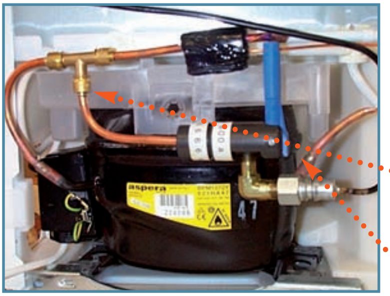


Figure 17: Pressing the tube connection

Press locking rings

Tube connector assembly with hand assembly tool.



Example tee connector

Tee connector assembly and quick service connector

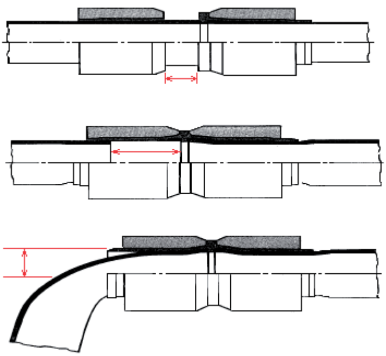
- Lokring tee connector
- Quick service connector

Figure 18: Example of a tee connector

Compressor assembly

Compressor assembly with Lokring couplers

Figure 19: Example of a compressor assembly



The tube locking ring has not been pushed to the end

The tube has not been inserted to the end

The bending point is too close to the joint ending

Figure 20: Assembly faults

Final Leak Check

After all couplers and connectors are done, check system for leaks. Use dry Nitrogen to pressurize the system up to a maximum pressure of 10 bar.

Chapter 12: Refrigerant Recovery, Recycling and Containment in the field

Preface

The transfer of any kind of refrigerants into storage and recycling cylinders is a dangerous practice. For this reason we always have to work according to strict safety regulations. Read carefully refrigerant manufacturer`s safety advices for the handling of refrigerants.

Think before acting!

Pressured and liquified gas may quickly create dangerous situations. Through improper use, liquid gas can cause severe injury to skin, eyes and respiratory tracts.

This picture shows a hand affected by contact with liquid refrigerant.

Figure 1: Affected hand

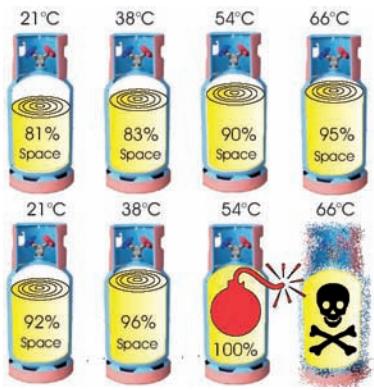
Safety Recommendations

There is always a strict smoking ban in all work areas. Work areas must be ventilated if refrigerant is present. Refrigerants are heavier than air and reduce the content of oxygen in the air. Refrigerants are not visible and do not smell. Breathing refrigerants may not be noticed and lead to a blackout and/or death.

The touch of voltage-carrying operating supplies causes life threatening situations.

Special care should be taken:

- Not to overfill the refrigerant cylinder.
- Not to exceed the working pressure of each cylinder. Check stamping on cylinder!
- Safety codes recommend that closed tanks are not be filled over 80% of volume with liquid.
- Never transport an overfilled cylinder.
- Not to mix grades of refrigerant or put one grade in a cylinder labelled for another.
- To use only clean cylinders, free from contamination by oil, acid, moisture, etc.
- To visually check each cylinder before use and make sure all cylinders are regularly pressure tested.
- Recovery cylinders have a specific indication depending on the country (yellow mark in US, special green colour in France) in order not to be confused with refrigerant container.
- Not to store a filled cylinder at a high ambient temperature and exposed to the sun.



Starting with cylinder 80% full by volume

Starting with cylinder 90% full by volume

Figure 2: Cylinder temperature and internal liquid expanding space

References

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Figure 13

Refrigerant expands when it gets warm and may cause tank explosion if overfilled.

Figure 3: Examples of bursted cylinders

The cause was for each overfilling with refrigerant.

References

Figure 4: Cylinder with separate liquid and gas valves

Cylinder should have separate liquid and gas valves and be fitted with a pressure relief device.

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Figure 13

Photos courtesy of Manchester Tank & Equipment

Purchased Refrigerants

Purchased refrigerants are packed in both disposable and returnable shipping containers. Disposable cylinders often indicate very bad practice. CFC refrigerants even purchased today often have a bad quality (contaminated). These containers are generally discarded after use and a lot of refrigerant is released into the atmosphere due to disposable cylinders.

Refrigerant manufacturers have voluntarily established a colour code system to identify their products, with both disposable and reuseable cylinders painted or otherwise distinguished by the following common refrigerant colours and identification:

R-11 Orange	R-12 Grey	R-22 Medium Green	R-502 Orchid
R-134a Light Blue	R-404 Orange	R-507 Blue Green	R-407C Med. Brown

Table 1: Refrigerant cylinder colours

These cylinders are not recommended for refilling!

Only use DOT or TÜV standard approved refrigerant recovery cylinder for recovery purpose!

Figure 5: Disposable refrigerant cylinder

References

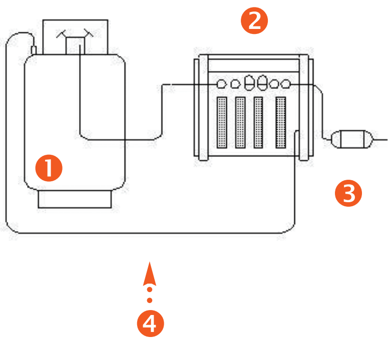

Figure 6: Recovery with OFP connection (float-switch)

There are three different possibilities for overfill protection (OFP)!

1. The cylinder is equipped with a liquid level float switch.

Recovery unit will cut-off if 80% of filling volume is achieved.

1 Recovery cylinder
2 Recovery unit
3 Inline filter with hose (inlet)
4 OFP cable connection to recovery unit

RHC Page 27 Figure 13

Figure 7: Connection of OFP to the socket at the recovery cylinder

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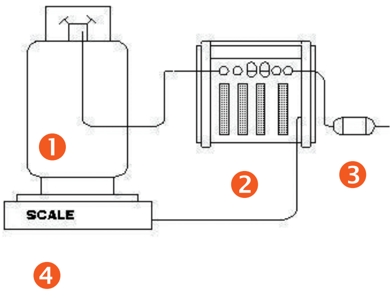
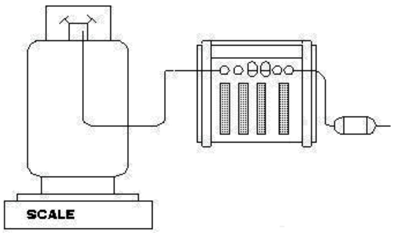
Figure 8: Arrangement of recovery cylinder and recovery unit with OFP connection

		References
 Figure 9: Recovery with cylinder on weighing scale and connected OFP	2. Recovery cylinder is placed on scale. Recovery unit will turn off if the adjusted weight amount is achieved. 1 Recovery cylinder 2 Recovery unit 3 Inline filter with hose (inlet) 4 Weighing scale with connection to the recovery unit	MI Page 46 Figure 9 (1)
 Figure 10: Arrangement of cylinder, scale and recovery unit for manual observation	3. Recovery cylinder is placed on scale. Operator turns off the recovery unit manually if 80% of cylinder charge is achieved.	MI Page 46 Figure 9 (1)

Warning: An 80% shut off switch does not always prevent overfilling. Any technician using an 80% shut off switch must be aware of the liability and safety risks that come along with their use.

Further explanation of this topic can be found in the section below 'Methods of refrigerant recovery – push and pull-method'.

Refrigerant Recovery Process

Using recovery units

Recovery units are connected to the system by available service valves, or line tap valves, or line piercing pliers. Some of them can handle refrigerants in both liquid and vapour form and some have onboard storage vessels.

Take care not to let the compressor suck in liquid refrigerant if the compressor is not protected against liquid strokes.

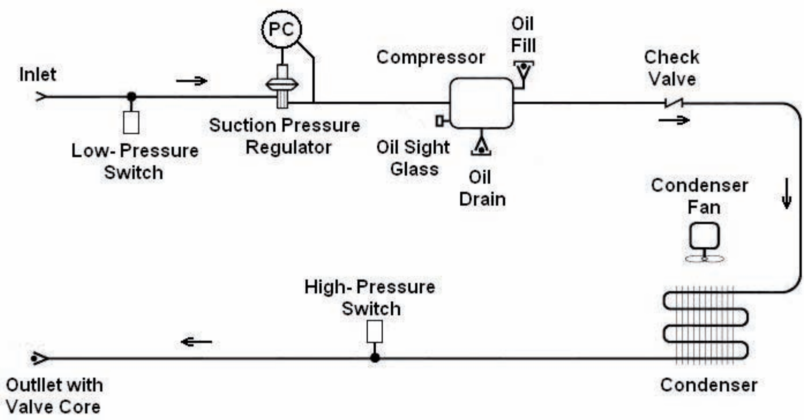


Figure 11: Refrigerant flow chart example (recovery unit)

The above sketch demonstrates a recovery unit layout example with liquid stroke protection (suction pressure regulator) and an oil based compressor.

There are three types of recovery apparatus available. These are self-contained, system dependent and passive:

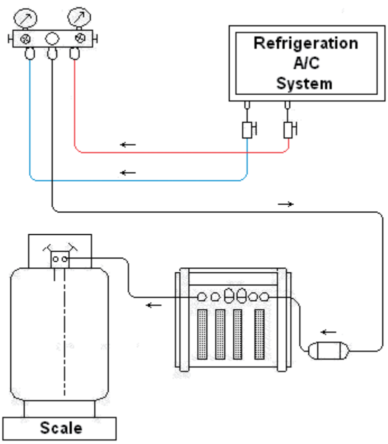
Self-contained:
A self-contained recovery unit has its own compressor (or other transfer mechanism) to pump refrigerant out of the system. It requires no assistance from any component in the system that is being recovered.

System-dependent:
System-dependent recovery equipment, on the other hand, relies upon the compressor in the appliance and/or the pressure of the refrigerant in the appliance to assist in recovery of the refrigerant. Recovery that uses only a chilled recovery tank falls under this category.

Passive:
Passive recovery refers to a deflated bag (recovery bag), e.g. for small domestic appliances, which is used to store small amounts of refrigerant near or slightly above atmospheric pressure (0.1 bar).

Methods of Refrigerant Recovery

The methods of recovery depend upon the type of refrigerant being recovered. This is usually divided into two general groups: High pressure, where the boiling point of the refrigerant is between –50°C and 10°C at atmospheric pressure, and low pressure where the boiling point is above 10°C at atmospheric pressure. High pressure refrigerants include CFC-12, HFC-134a and HCFC-22, while low pressure refrigerants are CFC-11, CFC-113, HCFC-123 etc.



Gas recovery

The refrigerant charge can be recovered in vapour recovery mode as shown in this sketch.

On larger refrigeration systems, this will take appreciably longer than if liquid is transferred.

Connection hoses between recovery units, systems and recovery cylinders should be kept as short as possible and the diameter as large as practicable.

References

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Figure 12: Vapour recovery mode

References

Liquid & oil recovery

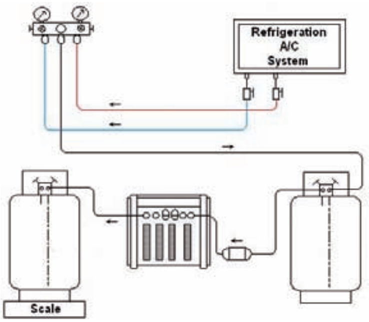

Figure 13: Recovery system with two cylinders for liquid and oil separation

If the recovery unit does not have a built-in liquid pump (system depending) or is otherwise not designed to handle liquid, then liquid can be removed from a system using two recovery cylinders and recovery unit. The recovery cylinders must have two ports and two valves, one each for liquid and one each for vapour connections.

This recovery set-up will also act to separate the oil from the cylinder connected to the inlet port of the recovery unit.

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Figure 9

'Push and pull' liquid refrigerant recovery method

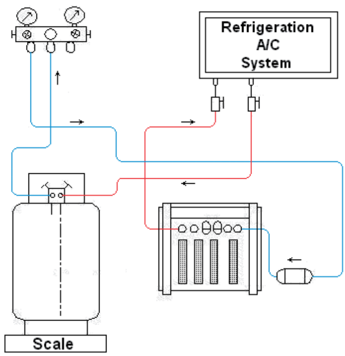

Figure 14: 'Push and pull'-recovery system

The recovery unit will pull the liquid refrigerant from the disabled unit when decreasing the pressure in the recovery cylinder.

Vapour pulled from the recovery cylinder by the recovery unit will then be pushed back to disabled unit's vapour side.

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Figure
9 (1)

Note: Refrigerant recovery 80% shut off switches

The 80% shut off sensors were originally intended to be a safety feature for refrigerant recovery.

On most machines these switches simply turn off the recovery machine without stopping the flow of refrigerant. This can result in an overfilled cylinder, becoming extremely dangerous for the technician. This is a known hazard in these common situations:

1. During push-pull procedures, once a siphon is started, merely powering off the machine, but does not prevent the tank from overfilling.

2. When using a tank with a large amount of cold refrigerant and recovering from a system at a higher temperature, turning the machine off will not stop the refrigerant from migrating to the coldest point (in this case, the recovery tank) eventually overfilling the tank even with the machine off.

Warning: An 80% shut off switch does not always prevent overfilling. Any technician using an 80% shut off switch must be aware of the liability and safety risks that come along with their use.

Reminder: 80% shut off switches are not 'walk-away' features!

No process involving temporary connections and systems under pressure should ever be left unattended!

Test Refrigerant and Lubricant for Contamination

To carry out refrigerant and oil tests it is necessary to remove a sample of refrigerant and oil from the compressor or refrigeration system without undue release of refrigerant. The procedure for this will vary depending on the arrangement of shut-off valves and access to the refrigerant and oil available on the unit.

References

Figure 15: Oil-test at compressor suction line

Figure 16: Refrigerant test at cylinder

Proprietary test kits are available which permit the refrigerant to be tested for water contamination and acidity.

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Figure 17: Taking oil-sample from a hermetic compressor

It is possible to test the oil in some systems for acidity.

Acid in the oil indicates that a burnout or partial burnout has taken place, and/or that there is moisture in the system, which can cause a burnout.

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Figure 18: Taking oil-sample from a semihermetic compressor

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Reuse of Refrigerant

Recovered refrigerant may be reused in the same system from which it was removed or it may be removed from the site and processed for use in another system, depending upon the reason for its removal and its condition, i.e. the level and types of contaminants it may contain.

Potential contaminants in a refrigerant are acids, moisture, non-condensable gases and particulate matter. Even low levels of these contaminants can reduce the working life of a refrigeration system.

Contaminated refrigerants (including those from a unit with a burn-out hermetic compressor) are reusable provided they have been recovered with a recovery unit incorporating an oil separator and filters (recycling unit).

Recycling units may be directly connected to the serviced system (e.g. MAC) or clean the stored refrigerant from recovery or storage cylinder.

Main cleaning components of a common recycling unit are in general:

1. Compressor
2. Thermostatic expansion valve (TEV) or Constant Pressure Regulator (CPR)
3. Suction-accumulator or oil-seperator with oil-drain valve
4. Filter sections (one or more)
5. Non-condensable gases purge device (manual or automatic)
6. Condenser
7. Storage cylinder

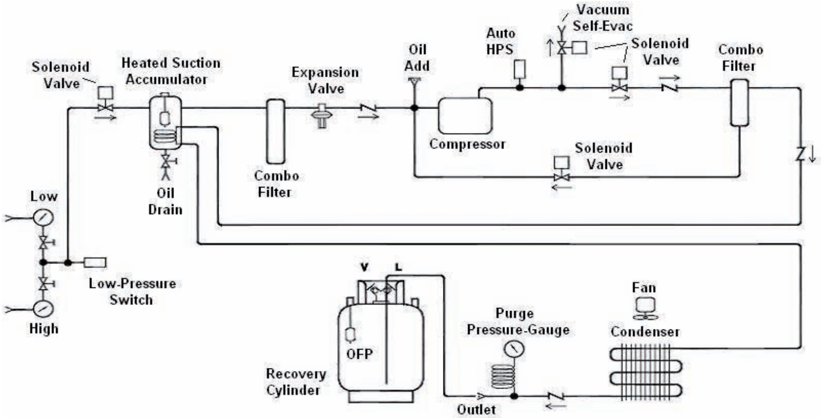
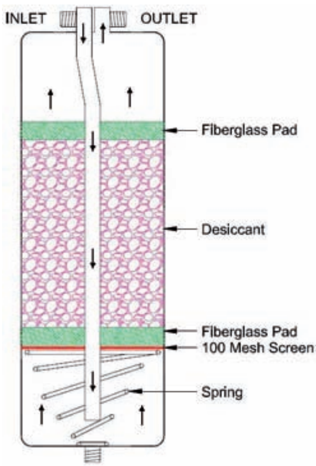


Figure 19: Refrigerant flow chart example of a recycling unit



Removal and absorption of:

- Acid
- Moisture
- Particulate matter

Recycling filter must be regularly changed according to manufacturers' recommendation and refrigerant contamination state.

Figure 20: Example combo-filter (recycling filter)

Recovery from Mobile Air-Conditioning System (MAC)

Vapour transfer

Mobile air-conditioning systems are normally equipped with service valves on the compressor's high and low pressure side. The refrigerant charge on such a system is rather small and therefore only vapour transfer is required.

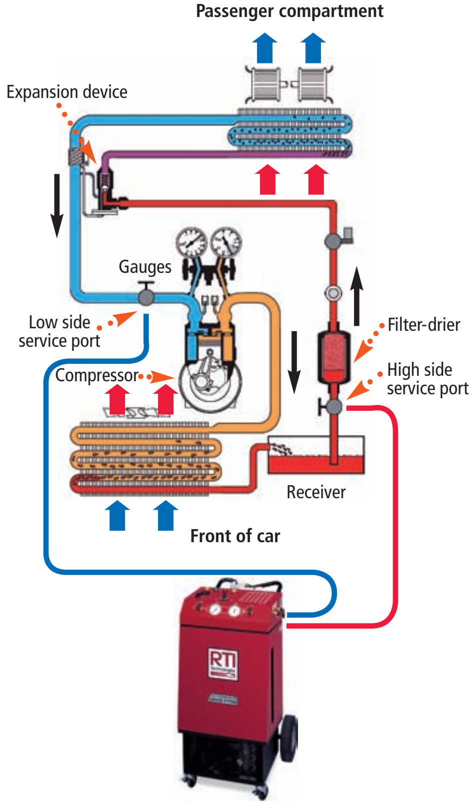


Figure 21: Mobile air-conditioning system connected to a 'refrigerant handling' unit

Connect both refrigerant hoses from the MAC servicing unit low and high pressure side to the air-conditioning system's service ports as indicated.

Connect quick service couplers to the service hoses if required.

Automatic and/or manual air-conditioning system service procedure follows:

- AC system data monitoring and evaluation
- Refrigerant recovery
- Refrigerant recycling
- AC system repair
- AC system leak test
- AC system evacuation
- AC system charging

References RRRE Page 34-Figure 3

Recovery from a Domestic Refrigerator

Domestic refrigeration appliances have to be hermetically sealed – without exception.

It is possible to recover refrigerants from a hermetically sealed system, which has no service valves. A piercing plier or a line-tap valve should be fitted to the refrigerant cycle (in most cases the process tube or charging tube). These valves are only for servicing purposes and should never be left permanently in place. Always remove these temporary valves to provide a sealed hermetically system after service and repair.

Because of the small charge of refrigerant, only vapour recovery is needed.

It is recommended to install valves (piercing plier or line-tap valve) on both and low pressure side (if possible).

Figure 22: Installation of piercing pliers

References

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Figure 9

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Figure 10

Various refrigerant recovery technologies for domestic appliances

For the purpose of refrigerant recovery at small capillary systems we differentiate the use of, e.g.:

1. Recovery unit and recovery cylinder
2. Refrigerant recovery hand pump with recovery cylinder or bag
3. Refrigerant recovery with vacuum pump and recovery bag

Figure 23: Placement of recovery cylinder

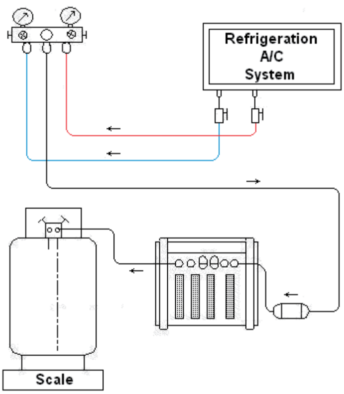

Figure 24: Recovery with recovery unit and cylinder

Refrigerant recovery with recovery unit

- Place the recovery cylinder on scale.
- Connect the recovery unit outlet port to the liquid port of the recovery cylinder.
- Connect the center port to the manifold gauge set to the inlet port of the recovery unit. Incorporate an inline filter-drier.
- Connect low and high side of the manifold gauge set to the refrigerator's low side (process tube) and high side (filter-dier).
- Recover refrigerant.

References

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Figure 1

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Figure 2

References

Refrigerant recovery hand pump with recovery cylinder or bag

- Connect the recovery hand pump outlet port to the recovery cylinder or connection port of the recovery bag.
- Connect the refrigeration system (process tube and/or filter-drier) to the inlet port of the recovery hand pump. Incorporate an inline filter-drier.
- Recover refrigerant.

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Figure 25: Connecting recovery hand-pump

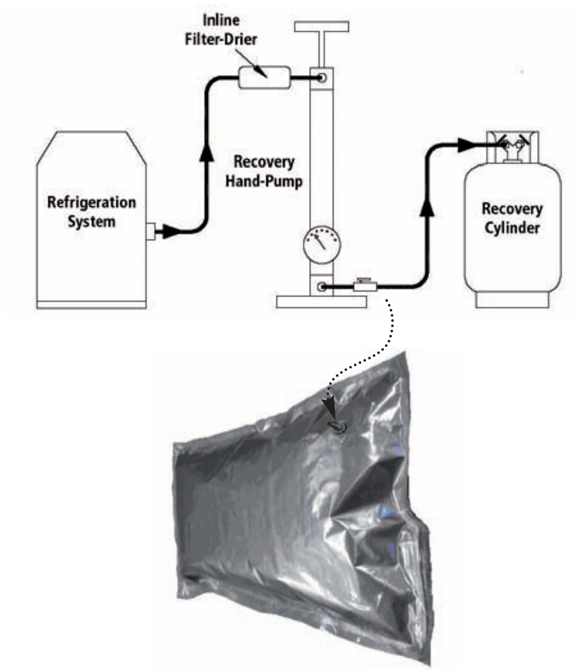

Figure 26: Recovery arrangement with hand-pump

Figure 27: Connecting recovery bag with piercing plier

Refrigerant recovery with vacuum pump and recovery bag

Step 1
Pressure equalizing

- The recovery bag is equipped with a 1/4" SAE male connection port with valve core.
- Connect the recovery bag to the piercing plier valve using a refrigerant hose with ball valve and core depressor. The ball valve with core depressor is placed at the recovery bag connection port and the core depressor opens the valve core while connecting.
- Install the piercing plier or line tap valve to the system and open the valve.
- Refrigerant will be transferred into the recovery bag.
- Close the valve (hose and piercing device) after pressure equalizing and remove the refrigerant bag.

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Figure 5

Figure 28: Connecting recovery bag with vacuum pump outlet

Step 2
Vacuum pump connection

- Connect the recovery bag to the vacuum pump outlet (exhaust port) using a refrigerant hose with ball valve and core depressor. The ball valve with core depressor is placed at the recovery bag connection port and the core depressor opens the valve core while connecting.

- Mount the refrigerant hose of the low pressure side of the manifold set to the piercing device and open the valve.
- Open the valves at the manifold set (low pressure and vacuum pump valve).
- Open the ball valve at the recovery bag inlet.
- Start evacuation.
- Evacuate the system for approximately 10 minutes.

There must not be any appreciable overpressure in the refrigerant bag, as this may damage the vacuum pump!

References

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Figure 9

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Picture 5

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Figure 7

Chapter 13: Retrofit

Preface

With the phase-out of CFCs and HCFCs, existing refrigeration and air-conditioning equipment operating with CFCs and HCFCs will ultimately need to be either replaced with new equipment or retrofitted with alternative refrigerants.

Retrofit is the process by which the equipment currently using an ODS refrigerant is made to run on a non-ODS refrigerant, without major effects on the performance of the equipment, and without significant modifications/changes for the equipment, ensuring that existing equipment operates until the end of its economic life.

Unlike a replacement, only some components of the existing system may need to be replaced.

Please refer to the tables 'refrigerant data' at the end of this chapter.

Retrofit in General

Involved changes

Typical retrofit may involve one or many of the following changes:

- Refrigerant
- Lubricant
- Desiccant filter (drier)
- Expansion valve
- Compressor (gearbox, speed, motor)
- Insulation and seal materials, elastomers
- For centrifugal chillers: purge systems, impeller/gearbox

Problems related to a CFC/HFC retrofit:

- Studies show from 1% less to 7% higher energy consumption than CFC-12.
- Problem of finding suitable lubricants: HFC-134a has very low solubility and mineral oil does not mix well in HFC-134a.
- Poor oil returns back to the compressor, resulting in a possible compressor failure.
- Fouling of expansion valves and heat exchanger surfaces, leading to reduced system performance.

Lubricants for alternative refrigerants:

- Polyol ester (POE) oils must be used with HFC refrigerants.
- Existing systems will require an oil flushing procedure because of chemical incompatibilities between the refrigerants and lubricants.
- System charged with retrofit refrigerant can lead to early system failure due to chemical reaction between the chlorine from CFC and lubricating oils.

Polyol ester synthetic oils are backwards compatible.
Therefore, they are acceptable for use with CFC-12, HCFC-22 and CFC-502.

Important notes for the use of lubricants:

- POEs more than minerals tend to absorb water.
- Therefore, they need to be handled with care before being used because of the increased water which may be present in the system.
- Proper evacuation is a must!
- A larger filter-drier may be required in a system which has been retrofitted to POEs to make sure that all of the excess water is removed.
- POEs dissolve materials that CFCs or mineral oil does not. Therefore, the filter-driers need to be frequently checked.

It is strongly recommended that the manufacturer-specified lubricant be used to ensure that it is compatible with all the components with which it is in contact.

Residual mineral oil

Acceptable residual mineral oil content in a retrofitted system:

Evaporation temperature	Residual mineral oil in the system
Less than –15°C	1 to 3%
–15°C up to –5°C	Approx. 5%
Above 0°C	5 to 10%

Table 1: Residual mineral oil content related to the evaporation temperature

Retrofit categories

Drop-in retrofit:

A switch-over to an alternative refrigerant without any changes in the refrigeration system.

Some mineral lubricating oil may be required to be replaced by Polyol Ester (POE)/ Polyalkylene Glycol (PAG) after thorough flushing of the system using dry Nitrogen and charging the required quantity of drop-in refrigerant.

Simple / economical retrofit:

A switch-over to an alternative refrigerant which only requires the change of a few incompatible parts such as gaskets, o-rings, filter-drier. Simple retrofits may result in some cases in slight decrease in either efficiency, capacity or both.

System optimisation or engineered retrofit:

A conversion to an alternative refrigerant which includes the replacement of major system components, such as compressor, heat exchangers, expansion device etc. with new ones that have been redesigned specifically for the alternative refrigerant.

Conclusions and statements

- It should be noted that properly working appliances are not recommended for retrofit until there is a need to open the refrigeration system for repair.
- Properly operating systems could just be operating without any harm to the ozone layer.
- For older RAC systems, it may be more cost-effective to replace rather than retrofit. In addition, new equipment will be more energy-efficient.
- Retrofitting involves two kinds of costs:

  - Cost of labour
  - Cost of components that need to be changed

- For cost calculation the problem of lubricant changing related to the refrigerant choice may play a significant role. A refrigeration or air-conditioning system with extensive pipe works and/or various amounts of evaporators and accessories (e.g. oil separator or liquid accumulators) must be flushed with the intended retrofit lubricant until certain remaining mineral oil containment in the system is obtained.

- A good opportunity to carry out a retrofit procedure is in connection with the regularly scheduled maintenance of a RAC system.

- The option of retrofitting will be considered in cases where the supply of CFCs is getting scarce due to a ban on importation of CFC by the country, and if no CFC is available at all.

The Practical Retrofit Process

Required data information collection:

1. Type of existing refrigerant
2. Type and brand names of all system components such as e.g. compressor (condensing unit), evaporator, condenser …
3. Size of liquid receiver
4. Type and brand names of primary control devices
5. Type and brand names of secondary control devices
6. Dimensions and length of pipe work
7. Altitude difference between compressor, evaporator and condenser
8. Specific features of the existing equipment
9. Monitored system data under functional condition like evaporation and condensing temperatures, electrical data, intended temperature of room or conditioned medium
10. History of system failures (in particular compressor burn-out)

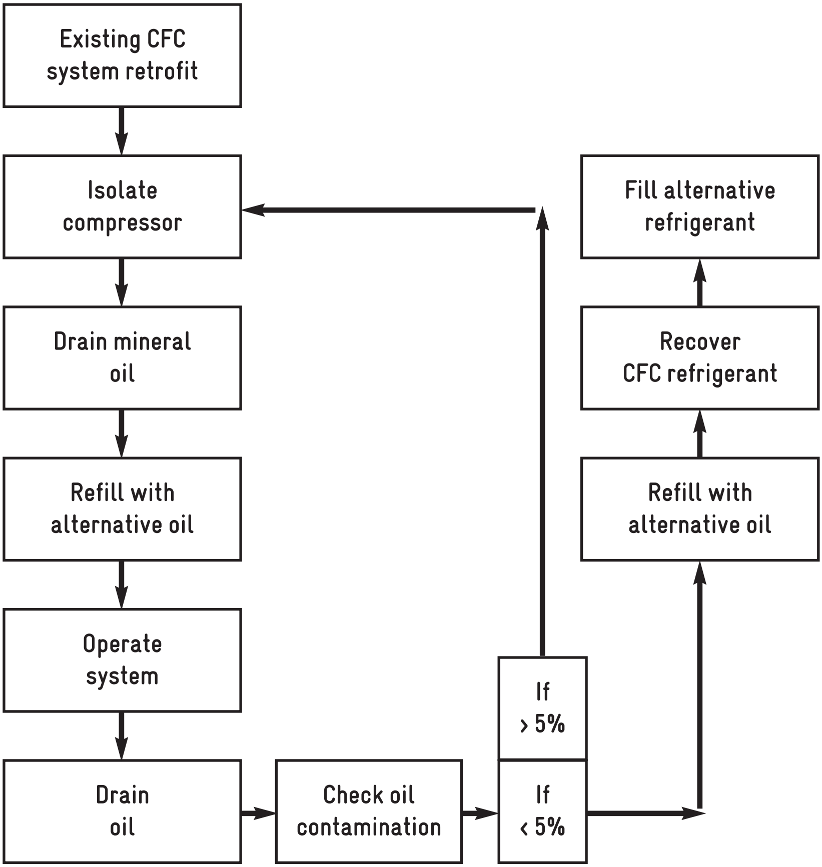


Figure 1: Retrofit process flow

Refrigerant charging

Use HFC blends to remove liquid only from charging cylinder. Once liquid is removed from the cylinder, the refrigerant can be charged to the system as liquid or vapour as desired. Use the manifold gauges or a throttling valve to flash the liquid to vapour if required.

The refrigerant storage cylinder must be checked for leakage, otherwise the composition of refrigerant can be altered. Refrigeration and AC systems should be clearly labelled after conversion to avoid future mixing of refrigerants.

- Charge the system with the alternative refrigerant.
  Caution should be taken not to overcharge!
- 75% of the CFC charge as a starting point.

The optimum charge will vary depending on the system design and operating conditions, but for most systems the best charge size will be 75-90% by weight of the original charge.

Start the system and let conditions stabilise. If the system is undercharged, add refrigerant in small amounts (still removing liquid from the charging cylinder) until the system conditions reach the desired level.

Attempting to charge until the sight glass is clear may result in overcharging of refrigerant.

Various pressure switches may need to be adjusted to maintain proper operating conditions, e.g.:

- Evaporator pressure regulators
- Cut-in and cut-out pressure switches
- Condenser fan cycling pressure switches
- Head pressure controls
- Crankcase pressure regulators
- Others

Due to the higher oil miscibility of HFCs and POE, verify proper compressor oil sump levels. Check with the compressor manufacturer for proper amperage load ratings.

For data monitoring and evaluation use the 'refrigeration system retrofit data sheet' provided at the end of the chapter.

Important notes:

Since all blends contain at least one flammable component, suitable measures should be taken to avoid entry of air into the system. A critical displacement of the ignition point can occur under high pressure when a high proportion of air is present. Besides this, pressure tests with an air/refrigerant mixture are not allowed.

Do not use 'shop-air' for pressure tests!

Dry, oxygen-free Nitrogen should be used.

Practical Issues

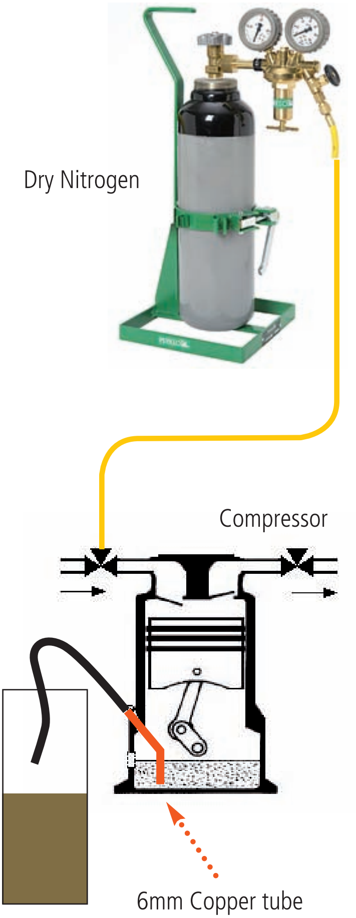


Figure 2: Oil change with dry Nitrogen

Oil change (drainage):

1. Check the system for leaks and repair if necessary.
2. Separate compressor while using pump down function or closing the compressor's shut-off valves.
3. If necessary recover remaining amounts of refrigerant using an appropriate refrigerant recovery technology.
4. Open the oil support connection at the compressor's crank-case.
5. Insert a 6 mm soft copper tube reaching the crankcase bottom.
6. Seal the tapped hole with tape or rubber seal and hold the copper tube.
7. Transfer a small amount of Nitrogen with low pressure into the crankcase.
8. The oil will be transferred (pushed) into a separate container.
9. Dispose of the oil (as contaminated waste) in an environmentally friendly way.

- Nitrogen supply and oil draining
- Contaminated oil

Figure 3: Oil changing procedure

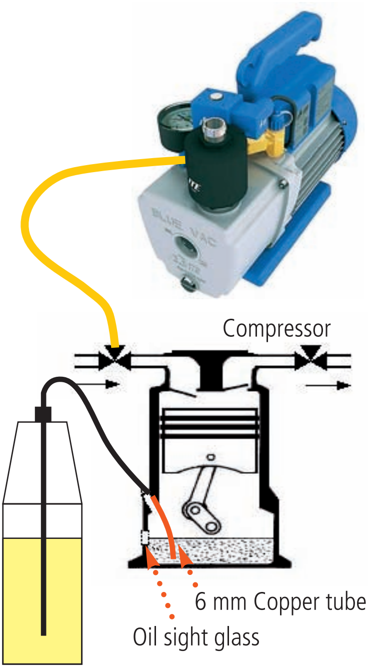
- Example for oil support connection

Figure 4: Oil support connection

Oil draining from a hermetic compressor:

- Disassemble the compressor
- Turn compressor upside-down
- Drain the oil through suction or process tube
- Refill small amount POE oil (150 ml) and shake the compressor
- Drain the remaining oil

Figure 5: Oil drainage from hermetic compressor



Oil change (refill):

1. Connect a vacuum pump to the suction shut-off valve.
2. Insert the free end of the 6 mm copper tube/hose assembly into a POE oil can reaching the bottom.
3. Switch on the vacuum pump.
4. The oil will be transferred (pulled) due to low pressure within the crankcase into the compressor.
5. Observe the oil level in the compressor's sight glass but use the same volume as removed within the draining process.
6. Stop oil flow.
7. Measure the charged amount of oil.
8. Evacuate the compressor.
9. Open the compressor's stop-valves.
10. Run the compressor.
11. Check system for leaks.

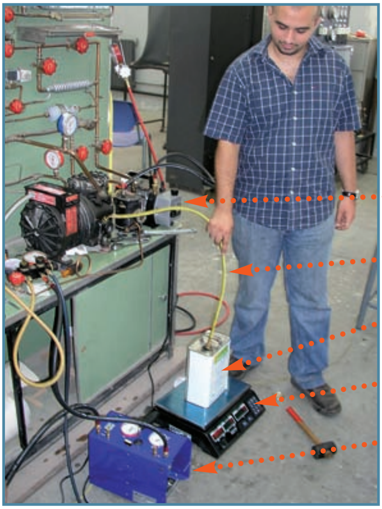
Figure 6: Oil change with vacuum pump

Due to the readiness of the fresh POE oil to absorb humidity, it is essential to use only small cans of fresh oil. Do not store open cans of POE for further use.

Oil filling process (example 1)

- Vacuum pump connection to the compressor's suction line stop-valve service port
- POE oil filling hose assembly

Figure 7: Oil filling process (in detail)



Oil filling process (example 2)

- Vacuum pump
- Hose assembly to crankcase
- Oil can with POE
- Weighing scale
- Recovery unit

Figure 8: Oil filling process

Refrigeration System Retrofit Data Sheet			
Service Company Name			
Address			
Telephone & Fax No.			
Registration No.			
Client Name			
Address			
Telephone & Fax No.			
Contact Person Name			
Installation/Appliance DATA			
Type of Installation		Manufacturer	
Model and No.		Serial No.	
Type of Compressor		Manufacturer	
Model and No.		Serial No.	
Operating Data			
Old		**New**	
Refrigerant Type		Refrigerant Type	
Refrigerant Charge		Refrigerant Charge	
Type of Lubricant		Type of Lubricant	
Lubricant Charge		Lubricant Charge	
Suction Pressure		Suction Pressure	
Discharge Pressure		Discharge Pressure	
Suction Line Temp.		Suction Line Temp.	
Discharge Line Temp.		Discharge Line Temp.	
Ambient Temperature		Ambient Temperature	
Room/Medium Temp.		Room/Medium Temp.	
LP Cut-Off		LP Cut-Off	
HP Cut-Off		HP Cut-Off	
Electrical Data			
Power Supply (Voltage)		Power Supply (Voltage)	
Current Draw Compressor		Current Draw Compressor	
Other Installation Data			
Discharge Line Diameter		Discharge Line Length	
Liquid Line Diameter		Liquid Line Length	
Suction Line Diameter		Suction Line Length	
Insulation Suction Line		Altitude diff. Compr./Evap.	
Type of Condenser		Type of Evaporator	
Type of Filter-Drier		Type of Filter-Drier	
Signature Technician	Date	Signature Client	Date

Table 2: Refrigeration system retrofit data sheet

RETROFIT – Equipment Label	
Company	
Technician Name	
Address	
Telephone & Fax No.	
Registration No.	
Refitted to Refrigerant HFC-R134a This system is only for the use with HFC-R134a and synthetic lubricant	
Refrigerant Charge	
Lubricant Charge (old)	
Lubricant Charge (new)	
Retrofitted by:	
Retrofit Date:	
Signature:	

Table 3: Retrofit equipment label data sheet

Refrigerant Data

CFCs (Phased out / Montreal Protocol)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
CFC	R-11	CFC-11 / CCl3F	1	4,750	A1
CFC	R-113	CFC-113 / CCl2FCClF2	1	6,130	A1
CFC	R-114	CFC-114 / CClF2CClF2	1	10,040	A1
CFC	R-115	CFC-115 / CClF2CF3	0.44	7,370	A1
CFC	R-12	CFC-12 / CCl2F2	1	10,890	A1
CFC	R-13	CFC-13 / CClF3	1	14,420	A1
CFC	R-400	R-12/114 (50.0/50.0)	1	10,000	A1
CFC	R-500	R-12/152a (73.8/26.2)	0.738	8,100	A1
CFC	R-502	R-22/115 (48.8/51.2)	0.25	4,700	A1
CFC	R-503	R-23/13 (40.1/59.9)	0.599	15,000	A1

Pure HCFC Refrigerants (Being phased out / Montreal Protocol)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
HCFC	R-123	HCFC-123 / CHCl2CF3	0.02	77	B1
HCFC	R-124	HCFC-124 / CHClFCF3	0.02	609	A1
HCFC	R-142b	HCFC-142b / CH3CClF2	0.07	2,310	A2
HCFC	R-22	HCFC-22 / CHClF2	0.05	1,810	A1

Pure HFC Refrigerants (controlled under Kyoto Protocol)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
HFC	R-125	HFC-125 / CHF2CF3	0	3,500	A1
HFC	R-134a	HFC-134a / CH2FCF3	0	1,430	A1
HFC	R-143a	HFC-143a / CH3CF3	0	4,470	A2
HFC	R-152a	HFC-152 / CH3CHF2	0	124	A2
HFC	R-161	HFC-161 / CH3CH2F - ethyl fluoride	0	12	
HFC	R-227ea	HFC-227ea / CF3CHFCF3	0	3,220	A1
HFC	R-23	HFC-23 / CHF3 - fluoroform	0	14,760	A1
HFC	R-236ea	HFC-236ea / CHF2CHFCF3	0	1,370	
HFC	R-236fa	HFC-236fa / CF3CH2CF3	0	9,810	A1
HFC	R-245fa	HFC-245fa / CHF2CH2CF3	0	1,030	B1
HFC	R-32	HFC-32 / CH2F2 - methylene fluoride	0	675	A2

HCFCs Blends (Being phased out / Montreal Protocol)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
HCFC Blends	R-401A	R-22/152a/124 (53.0/13.0/34.0)	0.033	1,200	A1
HCFC Blends	R-401B	R-22/152a/124 (61.0/11.0/28.0)	0.036	1,300	A1
HCFC Blends	R-401C	R-22/152a/124 (33.0/15.0/52.0)	0.027	930	A1
HCFC Blends	R-402A	R-125/290/22 (60.0/2.0/38.0)	0.019	2,800	A1
HCFC Blends	R-402B	R-125/290/22 (38.0/2.0/60.0)	0.03	2,400	A1
HCFC Blends	R-403A	R-290/22/218 (5.0/75.0/20.0)	0.038	3,100	A1
HCFC Blends	R-403B	R-290/22/218 (5.0/56.0/39.0)	0.028	4,500	A1
HCFC Blends	R-405A	R-22/152a/142b/C318 (45.0/7.0/5.5/42.5)	0.026	5,300	d
HCFC Blends	R-406A	R-22/600a/142b (55.0/4.0/41.0)	0.056	1,900	A2
HCFC Blends	R-408A	R-125/143a/22 (7.0/46.0/47.0)	0.024	3,200	A1
HCFC Blends	R-409A	R-22/124/142b (60.0/25.0/15.0)	0.046	1,600	A1
HCFC Blends	R-409B	R-22/124/142b (65.0/25.0/10.0)	0.045	1,600	A1
HCFC Blends	R-411A	R-1270/22/152a (1.5/87.5/11.0)	0.044	1,600	A2
HCFC Blends	R-411B	R-1270/22/152a (3.0/94.0/3.0)	0.047	1,700	A2
HCFC Blends	R-412A	R-22/218/142b (70.0/5.0/25.0)	0.053	2,300	A2
HCFC Blends	R-414A	R-22/124/600a/142b (51.0/28.5/4.0/16.5)	0.043	1,500	A1
HCFC Blends	R-414B	R-22/124/600a/142b (50.0/39.0/1.5/9.5)	0.039	1,400	A1
HCFC Blends	R-415A	R-22/152a (82.0/18.0)	0.041	1,500	A2
HCFC Blends	R-415B	R-22/152a (25.0/75.0)	0.013	550	A2
HCFC Blends	R-416A	R-134a/124/600 (59.0/39.5/1.5)	0.008	1,100	A1
HCFC Blends	R-418A	R-290/22/152a (1.5/96.0/2.5)	0.048	1,700	A2
HCFC Blends	R-420A	R-134a/142b (88.0/12.0)	0.008	1,500	A1
HCFC Blends	R-509A	R-22/218 (44.0/56.0)	0.022	5,700	A1

HFC Blends (controlled under Kyoto Protocol)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
HFC Blend	R-404A	R-125/143a/134a (44.0/52.0/4.0)	0	3,900	A1
HFC Blend	R-407A	R-32/125/134a (20.0/40.0/40.0)	0	2,100	A1
HFC Blend	R-407B	R-32/125/134a (10.0/70.0/20.0)	0	2,800	A1
HFC Blend	R-407C	R-32/125/134a (23.0/25.0/52.0)	0	1,800	A1
HFC Blend	R-407D	R-32/125/134a (15.0/15.0/70.0)	0	1,600	A1
HFC Blend	R-407E	R-32/125/134a (25.0/15.0/60.0)	0	1,600	A1
HFC Blend	R-410A	R-32/125 (50.0/50.0)	0	2,100	A1
HFC Blends	R-413A	R-218/134a/600a (9.0/88.0/3.0)	0	2,100	A2
HFC Blend	R-417A	R-125/134a/600 (46.6/50.0/3.4)	0	2,300	A1
HFC Blend	R-419A	R-125/134a/E170 (77.0/19.0/4.0)	0	3,000	A2
HFC Blend	R-421A	R-125/134a (58.0/42.0)	0	2,600	A1
HFC Blend	R-421B	R-125/134a (85.0/15.0)	0	3,200	A1
HFC Blend	R-422A	R-125/134a/600a (85.1/11.5/3.4)	0	3,100	A1
HFC Blend	R-422B	R-125/134a/600a (55.0/42.0/3.0)	0	2,500	A1
HFC Blend	R-422C	R-125/134a/600a (82.0/15.0/3.0)	0	3,100	A1
HFC Blend	R-422D	R-125/134a/600a (65.1/31.5/3.4)	0	2,700	A1
HFC Blend	R-423A	R-134a/227ea (52.5/47.5)	0	2,300	A1
HFC Blend	R-424A	R-125/134a/600a/600/601a (50.5/47.0/ 0.9/	0	2,400	A1
HFC Blend	R-425A	R-32/134a/227ea (18.5/69.5/12.0)	0	1,500	A1
HFC Blend	R-426A	R-125/134a/600/601a (5.1/93.0/1.3/0.6)	0	1,500	A1
HFC Blend	R-427A	R-32/125/143a/134a (15.0/25.0/10.0/50.0)	0	2,100	A1
HFC Blend	R-428A	R-125/143a/290/600a (77.5/20.0/0.6/1.9)	0	3,600	A1
HFC Blend	R-429A	R-E170/152a/600a (60.0/10.0/30.0)	0		
HFC Blend	R-430A	R-152a/600a (76.0/24.0)	0		A3
HFC Blend	R-431A	R-290/152a (71.0/29.0)	0		A3
HFC Blend	R-434A	R-125/143a/134a/600a (63.28/18.0/16.0/2.8)	0		
HFC Blend	R-434A	R-125/143a/134a/600a (63.2/18.0/16.0/2.8)	0		
HFC Blend	R-435A	R- E170/152a (80.0/20.0)	0		
HFC Blend	R-437A	R-125/134a/600/601 (19.5/78.5/1.4/0.6)	0		
HFC Blend	R-507A	R-125/143a (50.0/50.0)	0	4,000	A1
HFC Blend	R-508A	R-23/116 (39.0/61.0)	0	13,000	A1
HFC Blend	R-508B	R-23/116 (46.0/54.0)	0	13,000	A1

Hydrocarbons (local safety regulations apply)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
HC	R-1150	CH2=CH2 - ethylene	0		A3
HC	R-1270	CH3CH=CH2 - propylene	0		A3
HC	R-170	CH3CH3 - ethane	0		A3
HC	R-290	CH3CH2CH3 - propane	0	3	A3
HC	R-600	CH3-CH2-CH2-CH3 - butane	0	3	A3
HC	R-600a	CH(CH3)2-CH3 - isobutane	0	3	A3

Hydrocarbon Blends (local safety regulations apply)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
HC Blend	R-432A	R-1270/E170 (80.0/20.0)			A3
HC Blend	R-433A	R-1270/290 (30.0/70.0)			A3
HC Blend	R-436A	R-290/600a (56.0/44.0)			A3
HC Blend	R-436B	R-290/600a (52.0/48.0)			A3
HC Blend	R-510A	R-E170/600a (88.0/12.0)			A3

Natural Refrigerants (local safety regulations apply)

Type	R-Number	Chemical formula / common name	ODP	GWP 100yr	Safety group
Natural	R-702	H_2 - normal hydrogen	0		A3
Natural	R-704	He - helium	0		A1
Natural	R-717	NH_3 - ammonia	0	0	B2
Natural	R-718	H_2O - water	0	0	A1
Natural	R-729	air - 78% N_2, 21% O_2, 1% Ar, +	0	-	A1
Natural	R-744	CO_2 - carbon dioxide	0	1	A1
Natural	R-764	SO_2 - sulfur dioxide	0	300	B1

Chapter 14: Safety

Preface

Work with or on refrigeration and AC equipment (RAC), machineries or material and substances is always in different ways associated with high risks to personal health.

The following chapter gives an overview of important signs and work clothing concerning the safety of personnel working in this field.

Work must only be performed by properly trained personnel equipped with safety equipment, machineries and tools in good condition and of good quality.

Warnings

Danger! Harmful skin/eye contact with refrigerant and oil

Danger! Flammable refrigerant

Danger! Electricity

Danger! Inhalation of harmful gases

Danger! Hazard area

Danger! Compressed gas and vessel

Danger! Suspended heavy objects

Danger! Hot surfaces

Figure 1: Warning signs

Bans

Smoking ban

No open fire

Only authorized persons
No bystanders

Use of machineries not in
wet areas

Figure 2: Ban signs

Rescue

Notice escape way

Provide First Aid material

Provide eye shower fluid

Notice nearest Medical Help
contact information

Figure 3: Rescue signs

Commandment

Wear suitable work clothes

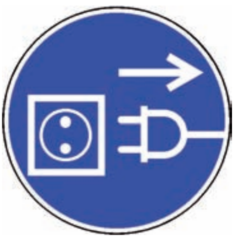
Wear protective gloves

Wear ear defender

Wear safety glasses

Wear safety helmet

Wear safety shoes



Plug out equipment for service

Disconnect machineries for service

Figure 4: Commandment signs

Work Clothing

Normal work gloves
with rubber knobs

Normal work gloves,
inside palm rubber covered

Protection grade depends on work task

Figure 5: Work gloves (example 1)

Work gloves for refrigerant
and oil handling

Thick work gloves for
welding and brazing

Protection grade depends on work task

Figure 6: Work gloves (example 2)

Normal safety glasses
with side protection

Normal safety glasses
with full cover protection

Protection grade depends on work task

Figure 7: Safety glasses

Ear defender

Respirator (dust and dirt)

Safety helmet

Protection grade depends on work task

Figure 8: Safety devices

Safety shoes (high and low shaft)

Protection grade depends on work task

Figure 9: Safety shoes

Overalls | Normal work trousers | Work jacket

Protection grade depends on work task

Figure 10: Safety clothes

Glossary

Bending

Because a copper tube is so readily formable, it is often bent to adapt to the needs of a piping system at the job site. This is a relatively simple matter to do by hand if a wide, sweeping radius is involved, but for tighter bends, it is often desirable to use a special piece of equipment to avoid kinking the line, which would restrict flow. Such tools can range from a simple spring-like device that prevents the collapsing of tube walls, to more sophisticated devices that involve lever or gear arrangements.

Brazing

Brazing is a joining process whereby a filler metal or alloy is heated to a melting temperature above 450°C (840°F) and distributed between two or more close-fitting parts by capillary action. At its liquid temperature, the molten filler metal and flux interact with a thin layer of the base metal, cooling to form a strong, sealed joint. In order to attain the highest strengths for brazed joints, parts must be closely fitted and the base metals must be exceptionally clean and free of oxides.

Brazed joint: A joint obtained by the joining of metal parts with alloys which melt at temperatures in general higher than 450°C, but less than the melting temperatures of the joined parts.

Charging

This is transferring a refrigerant from the refrigerant source (refrigerant cylinder for virgin refrigerants or recycled refrigerant cylinder) into a system, normally according to a specified weight, a specified amount of subcooling or evaporating pressure. Charging is normally carried out using a dedicated charging machine (e.g. in a production area) or using a cylinder connected to the system via manifold/hoses. The cylinder is disconnected from the refrigeration system after the refrigeration system has been completely charged with the new refrigerant.

Containment

The application of service techniques or special equipment designed to preclude or reduce loss of refrigerant from equipment during installation, operation, service or disposal of refrigeration and air-conditioning equipment.

Evacuation

Evacuation of a refrigeration system means the ultimate removal of rests of moisture or non-condensable gases in the system. This means the removal of all refrigerant and volatile contaminants such as moisture and air, thus leaving a near-vacuum. Evacuation is normally carried out by a specific vacuum pump, after refrigerant recovery has been completed (if applicable), and is ideally drawn to an absolute pressure of 0.5 mbar (50 Pa, 375 micron) or lower.

Flared joint

Whereas brazing is a thermal bonding process, flared joints provide a mechanical connection between copper tubing and fittings. This is a metal-to-metal compression joint in which a conical spread is made on the end of the tube. This is a mechanical joint and is prone to leakage.

Global Warming Potential

Global Warming Potential (GWP) is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the contribution to global warming of the gas in question to that of the same mass of Carbon Dioxide (whose GWP is by definition 1) over a defined time horizon. For instance, Methane is a significant contributor to the greenhouse effect and has a GWP of 21 (100-yr time horizon). This means Methane is approximately 21 times more heat-absorptive than Carbon Dioxide per unit of weight.

GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit GmbH/German Technical Cooperation Agency)

As an international cooperation enterprise for sustainable development with worldwide operations, the federally owned 'Deutsche Gesellschaft für Technische Zusammenarbeit' (GTZ) GmbH supports the German government in achieving its development policy objectives. It provides viable, forward-looking solutions for political, economic, ecological and social development in a globalised world. Working under difficult conditions, GTZ promotes complex reforms and change processes. Its corporate objective is to improve people's living conditions on a sustainable basis.

Hermetisation

Hermetisation is to maintain a 'sealed system' of the refrigerant cycle in refrigeration. A sealed system is a refrigeration system in which all refrigerant containing parts are made tight by welding, brazing or a similar permanent connection.

MLF (Multilateral Fund) of the Montreal Protocol

The Multilateral Fund was established in 1990 as a financial mechanism for the implementation of the Montreal Protocol. By financing technology transfer and cooperation, the Fund assists developing (so called Article-5) countries to meet their commitments under the Montreal Protocol, that means to enable these countries to phase out and replace ODS within an agreed time frame. Industrialised countries agreed to contribute to the Fund in order to help Article-5 countries achieve the Protocol's goals. Financial and technical assistance (closure of ODS production plants and industrial conversion, technical assistance, information dissemination, training and capacity building) is provided in the form of grants or concessional loans and is delivered primarily through four implementing agencies (UNEP, UNDP, UNIDO, World Bank).

Montreal Protocol
The international treaty 'Montreal Protocol on Substances that Deplete the Ozone Layer' was agreed in 1987 after scientists discovered that certain man-made substances, such as CFCs, were contributing to the depletion of the Earth's ozone layer. The ozone layer protects life below from harmful UV radiation. So far it has been ratified by all countries worldwide (November 2009 – universal ratification). The Protocol aims at protecting the ozone layer and therefore regulates the successive phase-out of substances that could harm the ozone layer through the restriction of production, import und use of such substances according to a specific timetable. The phase-out of ODS will enable the ozone layer to repair itself.

Natural Refrigerants
Natural refrigerants are naturally occurring substances, such as Hydrocarbons (e.g. Propane, Iso-Butane), Carbon Dioxide and Ammonia. These substances can be used (amongst others) as refrigerants in various kinds of refrigeration and air-conditioning systems. The key characteristics of these refrigerants are that they don't contribute to depletion of the ozone layer and have no or only a negligible global warming impact.

ODS (Ozone-Depleting Substances)
These are substances that damage the ozone layer in the upper atmosphere. They are widely used in refrigerators, air-conditioners, foam extrusion, fire extinguishers, dry cleaning, industrial cleaning, as solvents for cleaning, electronic equipment and as agricultural fumigants. They are defined in Annex A of the Montreal Protocol. Ozone-depleting substances include:

- Chlorofluorocarbons (CFCs),
- Halon,
- Carbon Tetrachloride, Methyl Chloroform,
- Hydrobromofluorocarbons (HBFCs),
- Hydrochlorofluorocarbons (HCFCs),
- Refrigerant blends containing HCFCs,
- Methyl Bromide,
- Bromochloromethane (BCM).

ODP (Ozone Depletion Potential)
This is a relative value that indicates the potential of a substance to destroy ozone gas (and thereby damage the Earth's ozone layer) as compared with the impact of a similar mass of chlorofluorocarbon-11 (CFC-11), which is assigned a reference value of 1. Thus, for example, a substance with an ODP of 2 is twice as harmful as CFC-11.

OFP (Overfill Protection)

Overfill protection is a device (switch) installed to a refrigerant recovery unit and recovery cylinder originally intended to be a safety feature whilst transferring and storing refrigerants into a cylinder. On most machines, these switches simply turn off the recovery machine. OFP devices do not provide any recovery machine with a 'walk away' feature. Any refrigerant transfer into systems or special cylinders must be monitored by measuring the weight of the refrigerant by the technician. Due to specific circumstances hazards can occur in following situations:

1. During push-pull procedures, once a siphon is started, merely powering off the recovery machine does not prevent the recovery cylinder from overfilling.

2. When using a cylinder with a large amount of cold refrigerant and recovering from a system at higher temperature, turning the recovery machine off will not stop the refrigerant from migration to the coldest point (in this case the recovery cylinder) eventually overfilling the tank even when the machine is off.

Phase-Out of Ozone-Depleting Substances

In this context, phase-out means a successive limitation and production ban on substances that deplete the ozone layer according to a defined schedule for different groups of countries as regulated under the Montreal Protocol.

Pressing

Pressing means a method of producing hermetically sealed metal-to-metal tube connections with the use of specific connectors, adapters and tools.

Reclamation

Reclamation is the (re-)processing of used refrigerants through mechanisms such as filtering, drying, distillation and chemical treatment to new product specifications. Note that chemical analysis of the refrigerant determines if appropriate specifications have been met. The identification of contaminants and required chemical analysis are both specified in national and international standards for new product specifications.

Recovery

Recovery means removing a refrigerant in any condition from a refrigeration system and storing it in an external container.

Recycling

This is the process of reducing contaminants in used refrigerants by separating oil, removing non-condensables and using devices such as filters, driers or filter-driers to reduce moisture, acidity and particulate matter. The aim of recycling is to reuse the recovered refrigerant following a basic cleaning process such as filtering and drying.

Refrigerant

A fluid used for heat transfer in a refrigerating system which absorbs heat at a low temperature and a low pressure and rejects heat at a higher temperature and a higher pressure usually involving changes of the state of the fluid.

Retrofit

This is where refrigeration equipment is subject to some modifications (upgrading or adjustment) so that it can be used with a refrigerant different to the original one. This may involve, for example, oil change, swapping of certain system components or modifications to electrical devices.

SAE (Society of Automotive Engineers)

SAE is an international non-profit organisation with more than 90,000 members (engineers, students, business executives, educators etc.) from all over the world who share information and exchange ideas for advancing the engineering of mobility systems.

TÜV (Technischer Überwachungs-Verein)

TÜV is a German testing and certification organisation. Its services comprise consultancy, testing, certification and training mainly in the field of engineering.

Acronyms and Abbreviations

AC	Air-Conditioning
AC	Alternating Current
BCM	Bromochloromethane
CFC	Chlorofluorocarbon
CFM	Cubic Feet per Minute
CO_2	Carbon Dioxide
CP	Copper Phosphorus
CPR	Constant Pressure Regulator
DC	Direct Current
DOT	Department of Transportation (USA)
EN	European Norm
EU	European Union
GTZ	Gesellschaft für Technische Zusammenarbeit GmbH (German Technical Cooperation Agency)
GWP	Global Warming Potential
HC	Hydrocarbon
HBFC	Hydrobromofluorocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HP	High Pressure
LP	Low Pressure
MAC	Mobile Air-Conditioning
MI	Measuring Instruments
MLF	Multilateral Fund (of the Montreal Protocol)
MMA	Ministério do Meio Ambiente do Brazil
NCG	Non-Condensable Gas
NPT	National Pipe Thread
OD	Outside Diameter
ODP	Ozone Depletion Potential
ODS	Ozone-Depleting Substances
OFP	Overfill Protection
PAG	Polyalkylene Glycol
POE	Polyol Ester
PVC	Poly Vinyl Chloride
RAC	Refrigeration and Air-Conditioning
RHC	Refrigerant Handling and Containment
R&R	Recovery & Recycling
RRRE	Recovery, Recycling, Reclamation and Evacuation
RTK	Retrofit Test Kit
SAE	Society of Automotive Engineers
SENAI	Brazilian 'Servico Nacional de Aprendizagem Industrial'
TEV	Thermostatic Expansion Valve
TT	Tubing Tools
TÜV	Technischer Überwachungs-Verein (German testing and certification organisation)
UNF	Unified Fine Thread
US	United States
UV	Ultra Violet

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The manual GOOD PRACTICES IN REFRIGERATION is the second edition of a booklet jointly published by the PROKLIMA Programme of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (since 2011 GIZ), the 'Brazilian Servico Nacional de Aprendizagem Industrial' (SENAI) and the 'Ministerio do Meio Ambiente do Brazil' (MMA) in 2004.

This manual has now been updated to provide professional guidance on how to service and maintain refrigeration systems operating with new technology, e.g. ozone- and climate-friendly alternative refrigerants to CFCs and HCFCs.

It addresses essential know-how on containment of HFC refrigerants which have a high Global Warming Potential (GWP) and provides information on the safe use of environmental-friendly natural refrigerants, such as CO_2, Ammonia or Hydrocarbons.

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