Proklima International

Operation of split air conditioning systems with hydrocarbon refrigerant

A conversion guide for technicians, trainers and engineers

On behalf of

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PROKLIMA is a programme of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Since 2008 Proklima has been working successfully on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under its International Climate Initiative (ICI) to disseminate ozone-and climate-friendly technologies.
PROKLIMA has been providing technical and financial support for developing countries since 1996, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) to implement the provisions of the Montreal Protocol on Substances that Deplete the Ozone Layer.

Disclaimer

Whilst GIZ does not condone the conversion of existing equipment using non-flammable refrigerant to use flammable refrigerants that they were not initially intended for, we do recognise that such conversion do and will continue to take place, regardless of recommendations to the contrary. Therefore, in order to try to help that it is done in the safest manner this booklet was developed.

However, in doing this, GIZ does not assume liability for any statements or any actions taken by its readers or users, which may cause unintended damage or injury as a result of any recommendations or inferences made within this handbook. Although all statements and information contained herein are believed to be accurate and reliable, they are presented without guarantee or warranty of any kind, expressed or implied. Information provided herein does not relieve reader or user from their responsibility of carrying out its own evaluation and analysis of the situation, and readers or users assume all risks and liability for use of the information, actions and events obtained. Readers or users should not assume that all safety data, measures and guidance are indicated herein or that other measures may not be required.

Here only general recommendations are made, which do not compensate for individual guidance and instructions.

National laws and guidelines must be consulted and adhered to under all circumstances. The handling of flammable refrigerants and its associated systems and equipment is to be done by qualified and trained technicians only.

INTRODUCTION

There are currently about 1 billion hydrochlorofluorocarbons (HCFCs) room air conditioners in operation worldwide, more than 100 million units are added annually (still with double digit growth rates due to higher demand). Each unit contains on average 1.6 kg of refrigerant, mainly R22. The Global Warming Potential (GWP) of R22 is 1810, amounting to almost 3,000 MT CO_2 equivalent of emissions. Servicing needs amount to annually 800,000 T R22, equal to about 1450 MT CO_2 equivalent per year.

In response to the environmental impacts – primarily ozone depletion and global warming associated – arising from the release of HCFC and hydrofluorocarbons (HFCs), the use of natural refrigerants as alternatives to these is becoming more widespread. Amongst these natural refrigerants, hydrocarbons are being used widely in new air conditioning systems.

Under certain circumstances, there may be a desire to convert a refrigeration and air conditioning (RAC) system from a non-flammable refrigerant to use hydrocarbons (HCs). This approach may be considered for a number of reasons, such as:

- An intention to improve the efficiency of a system
- To minimise the environmental impact
- Because it may be more cost-effective than using other refrigerant options
- There are no other refrigerant replacements available

Refrigerants that may be used for such purposes could include R290 (propane) or R1290 (propylene), where, for example, the system was previously charged with R22 or R407C.

Of course, if the existing refrigeration system is working correctly, then there is normally no need to convert the system to use any alternative refrigerant.

These guidelines are intended to assist with the safe conversion of air conditioning systems to use flammable HC refrigerants. Converting a system from an HCFC to an HFC normally requires basic changes. However, converting a system from a non-flammable to a flammable refrigerant requires special considerations, which are summarised here.

BASIC PRINCIPLES AND WARNINGS

When applying a flammable refrigerant to a system that ordinarily uses a non-flammable refrigerant, the term "conversion" is applied. This is important as it distinguishes from other phrases such as "re-fill", "drop-in" and "retrofit". The reason for this is that when a non-flammable refrigerant (such as R12) is replaced by another non-flammable refrigerant (such as R134a), if any changes are required to the system, then they relate to performance (e.g., change of capillary tube length) or compatibility (e.g., change in oil type). However, when changing from a non-flammable refrigerant (such as R22) to a HC refrigerant (such as R290), additional considerations must be taken into account. These include identifying whether or not the HC can be applied given the particular circumstances from a safety perspective, and if so, carrying out the required changes to the equipment that are related to mitigating the flammability risk. A switch from a non-flammable to a flammable refrigerant should be considered in terms of an entire conversion of the equipment, not just a change of refrigerant.

It must be emphasised that carrying out a system conversion to use flammable refrigerant necessitates careful consideration of the implications and it is essential to weigh up the risks and benefits. If a conversion is to take place, then it should be done comprehensively, with care and with attention to detail.

Given that a conversion to a flammable refrigerant represents a significant change in the purpose of the system, it must be understood that the conversion can only take place provided that the final product meets the requirements of the relevant safety standards and national regulations.

SPECIAL INSTRUCTIONS

- Any technician involved with conversion must be fully trained, competent and certified to use this flammable refrigerant
- Only convert with permission of building owner
- Only use proper service equipment suitable for use with HC refrigerants
- Multi-split and ducted systems which use large refrigerant charges are not suitable for conversion to HC refrigerants
- Refrigeration systems with extensive pipe work and multiple evaporators, such as compound plants, are not suitable for conversions
- If the situation permits, it is recommended that the equipment is removed from its existing position to a controlled workshop environment where work can usually be conducted in a more controlled and safer manner

CONSIDERATIONS AFFECTING CONVERSIONS

When approaching the choice of converting a particular system, it is important to follow a logical sequence of safety-related considerations to help make the correct decision. Such considerations include the following issues:

- The type and complexity of the equipment to be modified
- The environment and location within which the equipment is installed
- The quantities of refrigerant involved (in relation to the system location)
- The ease or possibility of modifying parts of the system
- The ease or possibility of handling the potential sources of ignition
- The necessity to develop specific awareness for the system operation by the owner

A decision chart to assist with evaluating the suitability of the equipment (predominantly with respect to the requirements of the safety standards) is shown in Table 1. This may be used to provide a good indication as to whether a system can be converted to use an HC refrigerant, although other specific aspects may need to be considered in addition; i.e., the requirements elsewhere within this guidebook (for new systems) and the relevant safety standards.

Since the refrigerant charge and the location of the refrigerant-containing parts of the system have such a strong influence on whether or not a conversion is viable (from a safety point-of-view), the suitability can be approximated according to typical system types. Table 1 provides an indicative overview of the types of systems that have been found to be acceptable for conversion. The viability is indicated as follows:

✔✔ often suitable
✔ sometimes suitable
✘ normally unsuitable
✘✘ nearly always unsuitable

As previously explained, each situation is unique in terms of the combination of system design and installation location and therefore each must be evaluated independently.

Table 1: Typical suitability for conversion of systems to use hydrocarbons

Sector	Equipment type	System type	Suitability
Domestic air conditioners, dehumidifiers and heat pumps	Portable units	Integral	✔✔
	Window units	Integral	✔✔
	Through-wall units	Integral	✔
	Split units	Remote	✔✔
Commercial air conditioning and heat pumps	Split units	Remote	✔✔
	Multi-split/VRV	Distributed	✘✘
	Packaged ducted	Remote	✘
	Central packaged	Remote	✘✘
	Positive displace chillers	Integral/Indirect	✔✔
	Centrifugal chillers	Integral/Indirect	✘✘

Two other issues should be considered with respect to carrying out a conversion.

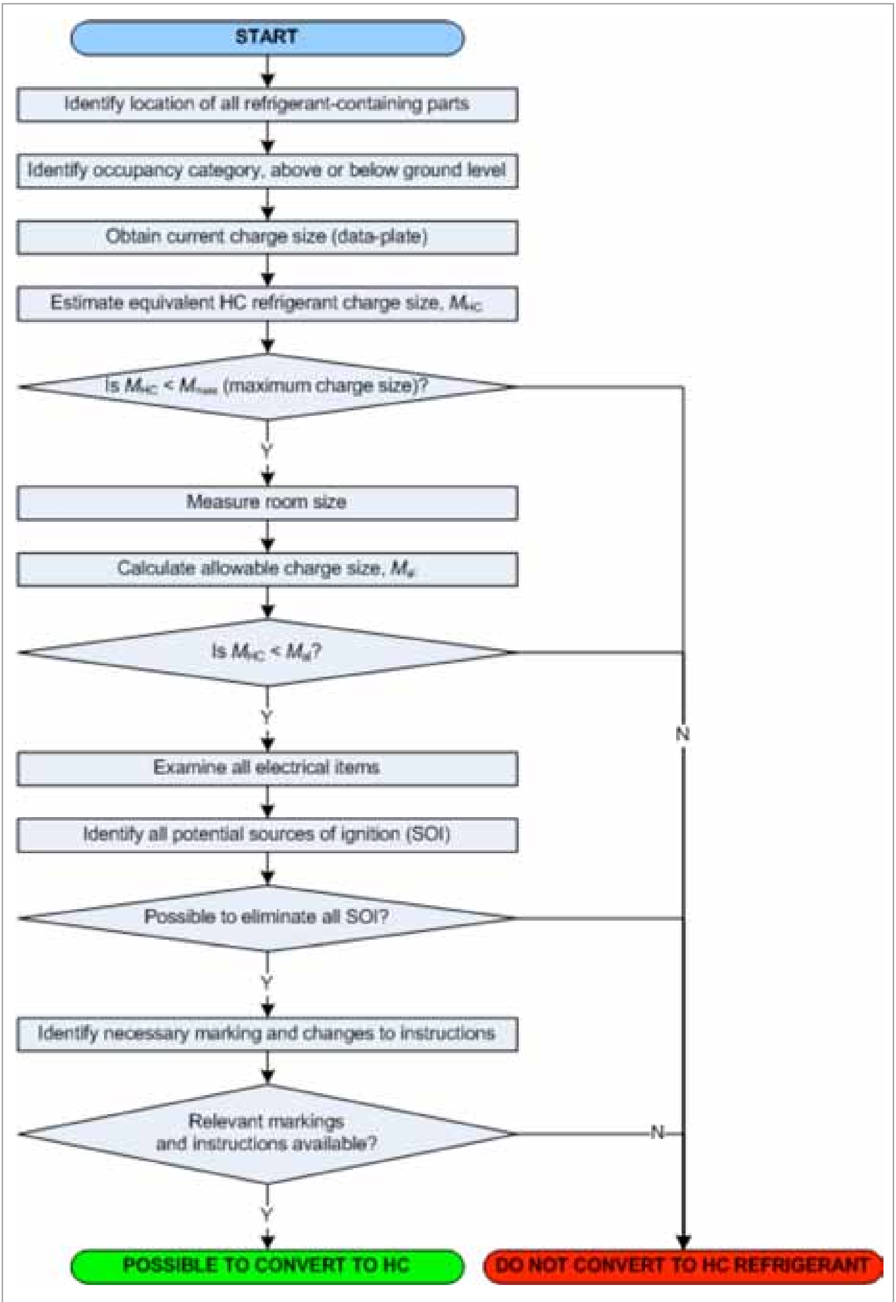
Firstly, it is strongly recommended that companies set up special conversion workshops, policies and upgrades of tools and equipment at their facilities. Thereby, systems can be removed from the site to the dedicated workshop in order to carry out conversions. There are significant advantages to this:

- Access to proper tooling and equipment is more likely
- The working area can be set up to handle the use of flammable refrigerants
- Preparation activities for commissioning with HC will minimise handling at installation site
- Expert technicians that specialise on HCs are more likely to be present
- There will be better and more immediate access to the required parts and components

Whilst it is understood that certain types of equipment may not be portable, this approach should be taken if it is possible.

Secondly, companies involved in frequent conversions of a particular type of system should prepare "conversion kits" for their technicians, where each kit is dedicated to a particular type of RAC system. When approaching the choice of converting a particular system, it is important to follow a logical sequence of safety-related considerations to help make the correct decision as to whether it is possible to convert the system or not. The decision chart in Figure 1 must be used to assist with evaluating the suitability of the equipment to use HCs.

Figure 1: Decision chart for determining whether it is possible to convert a system to HC refrigerant



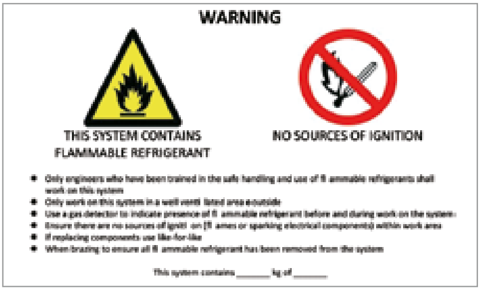
CONVERSION KITS

If enterprises are involved with carrying out conversions of existing systems, it is recommended that "conversion kits" are used. The reason for this is that it can be "inconvenient" for technicians – once at a site and already working on a system – to avoid using unsuitable methods for the conversion to HC refrigerants, which of course should be avoided. One way of helping to implement appropriate conversion methods is to issue technicians with a comprehensive conversion kit that contains all the necessary tools and parts. For example, such kits shall contain data sheets (with conversion factors, room size/charge size estimations, etc.), risk assessment forms, working instructions, sealed and solid-state electrical components, flammable gas stickers, valves, special fittings, and so on. If enterprises typically deal with a range of different systems, then it is sensible to have conversion kits that are better suited to each different type of system. Besides specific (if requested) fan motors, pressure switches, capacitor, overload protectors, etcetera, are needed. An example of a conversion kit is shown in Table 2.

Table 2: Example of a standard conversion kit collection for small AC systems

Set of blade connectors, ring and spade terminals etc. Specific tools for connectors fixing	
Sealed box, size depending the components to be inserted (usually the mains contactor) together with fastening screws	

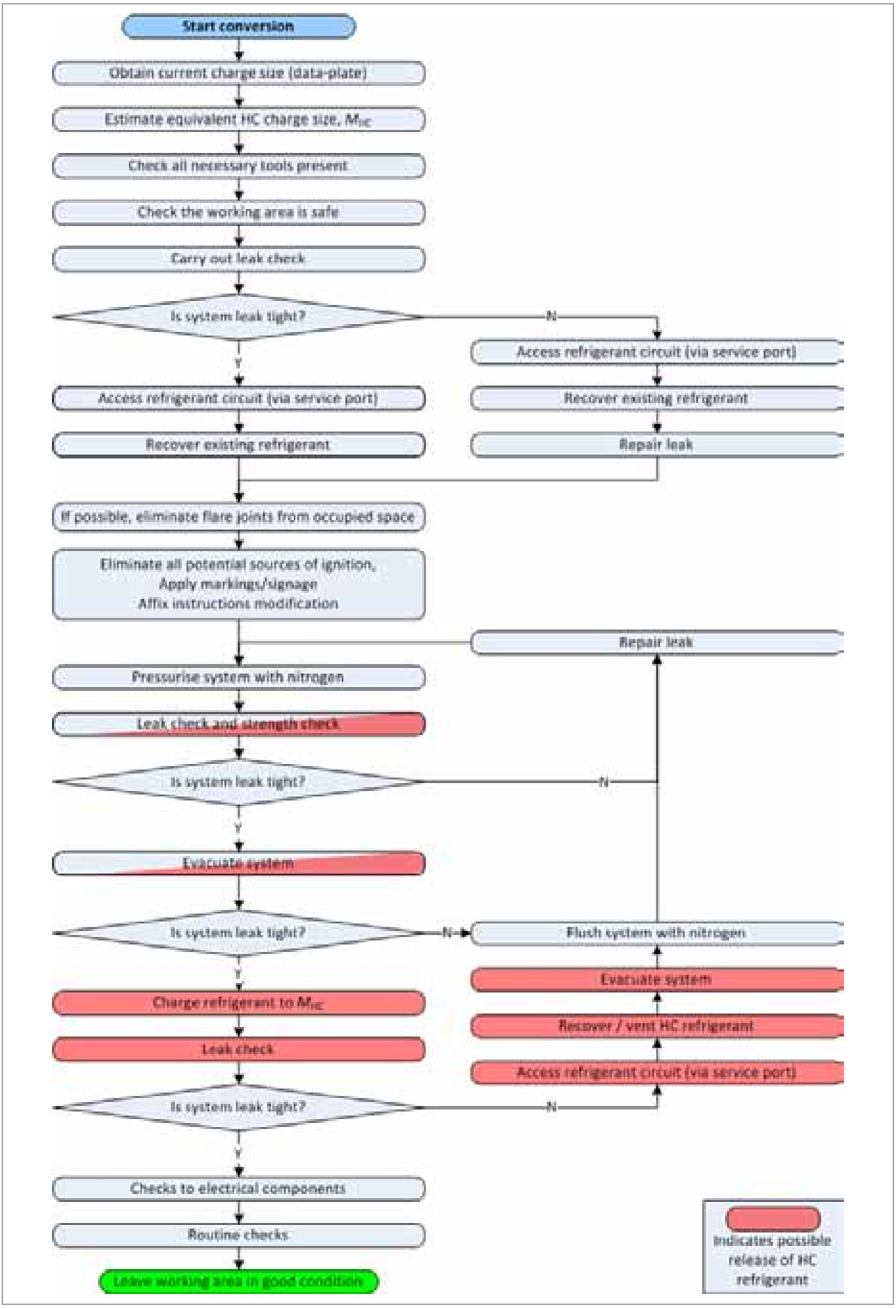
Different type of screwed cable glands	
Mains contactor according to the capacity required if replacement of existing device is indicated	
Flexible electric cable (wiring diameter according capacity of the system)	
Different cable straps for the fixation of wires and cables and not intended for tubes fixing	

Electrical tape	
Commissioning report, conversion label and warning sign stickers (see also annex of this document)	

CONDUCTING CONVERSIONS

When carrying out a conversion, the correct sequence of activities must be done in a way that both the safety of the workplace is maintained as well as ensuring the safety of the equipment. A process is provided in the flow chart in Figure 2.

Figure 2: Flow chart indicating the sequence of activities for converting a system to use HC refrigerant

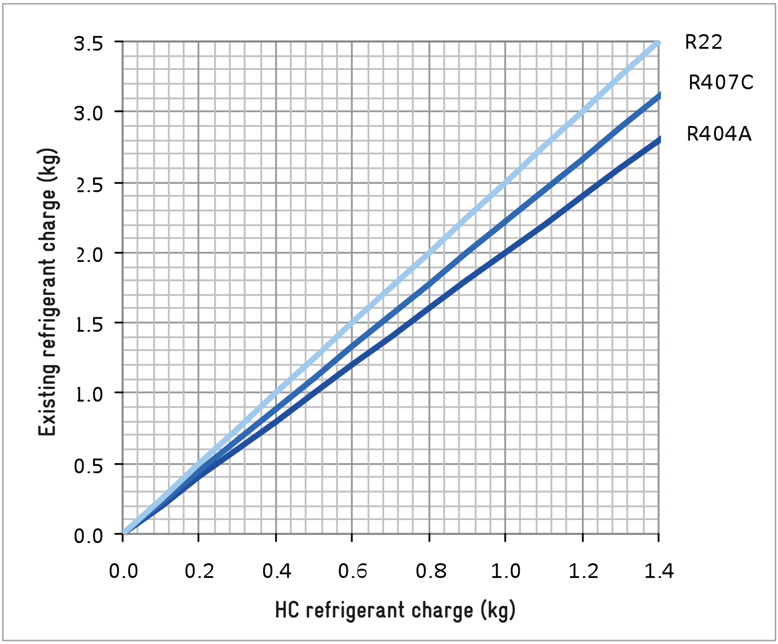


The following steps describe the process in Figure 2 and describe the important stages in evaluating and carrying out those conversions.

Estimate the required HC refrigerant charge size

This can be done using the existing refrigerant charge. Obtain the current refrigerant type and charge size from the equipment data-plate and / or verifying the existing amount of "old" refrigerant during the recovery process. Using the chart in Figure 3, estimate the equivalent mass of HC refrigerant.

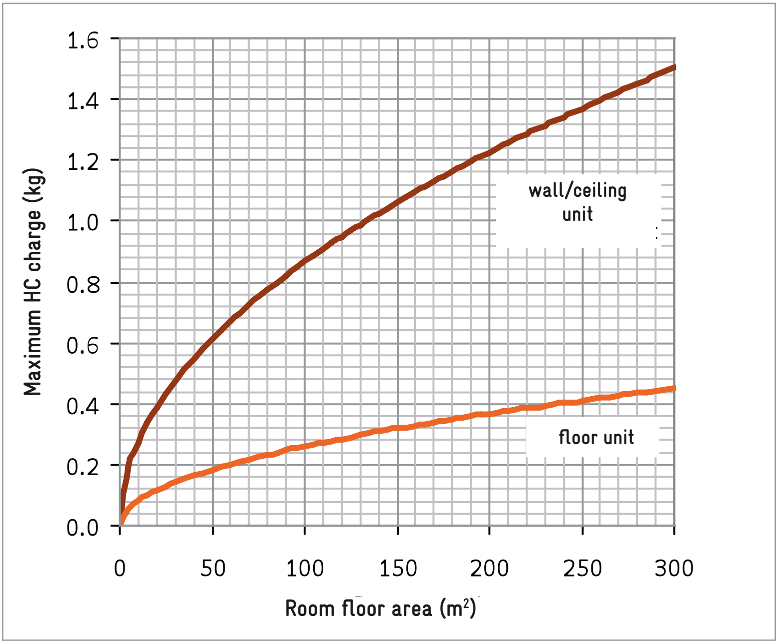
Figure 3: Conversion to estimate equivalent HC charge size

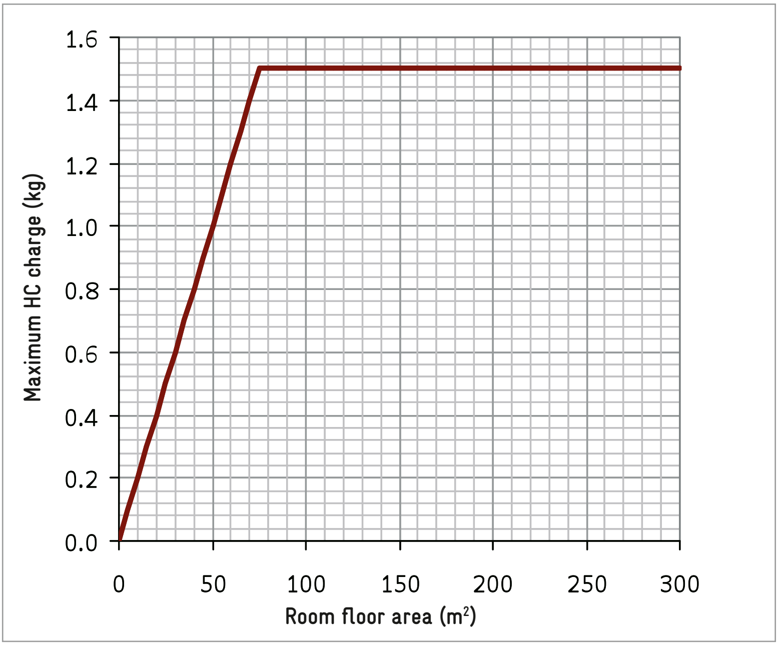


Check the refrigerant charge will be permissible

Ensure that the quantity of HC refrigerant to be used is permitted within the given room size. Calculate the occupied room area for the indoor unit and compare it with the HC charge size (Figure 4). For further information refer to GIZ-Proklima publication "Guidelines for the safe use of hydrocarbon refrigerants", Section 5.3 "Refrigerant charge size limits".

Figure 4: Minimum room sizes for a given refrigerant charge for air conditioners for human comfort (above) and air conditioning not for human comfort (below)





Check all necessary tools present

Prior to carrying out any work, it is essential to ensure all the tools, equipment, instrument and spare parts required for the work are on hands. In particular, this includes:

- General hand-tools appropriate for the use at refrigerant circuit components and electrics
- Refrigerant recovery machine (suitable for use with flammable refrigerants)
- Refrigerant recovery cylinder (two valves) HCFC
- Refrigerant recovery cylinder (two valves) HC (if it is decided to recover the HC refrigerant)
- Lubricant recovery cylinder (two valves)
- Refrigerant venting hose
- Comparator/pressure-temperature tables for HC refrigerant
- Vacuum pump
- Vacuum gauge (electronic) refrigerant balance (accuracy of at least ±3% full-scale)
- Handheld HC refrigerant gas detector
- Nitrogen service cylinder set
- Brazing set (oxygen/propane, oxygen/acetylene)
- Flammable gas (yellow triangle) stickers
- Flammable refrigerant warning signs
- Work area warning signs
- Safety gloves and goggles
- Fire extinguisher

The list comprises of both, equipment for work on HCFC and HC refrigerants.

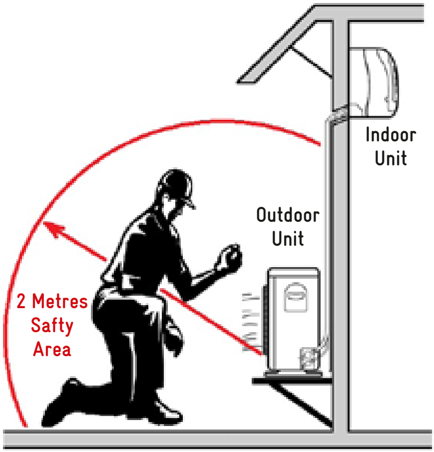
Check the working area and system

Ensure both the working area and the system is safe. This includes:

- All staff, maintenance staff and others working in the local area must be instructed that flammable refrigerants are being handled
- The area around the workspace must be sectioned off
- Working within confined spaces should be avoided
- No flammable materials are stored in the work area
- No ignition sources are present within a minimum of two metres anywhere in the work area
- Suitable fire extinguishing equipment (CO_2 or dry-powder type) is available within the immediate area
- The work area is properly ventilated; ventilation should safely disperse any released refrigerant
- HC gas detectors are present and operating to warn workers of a dangerous concentration
- Erect appropriate signage, including “flammable gas”, “no naked flames” and “do not enter the area”

- All appropriate and necessary tools and equipment are available
- The equipment should, whenever possible, be isolated from the electricity supply

Figure 5: Designated work area where potential Sources of Ignition (SOI) must not be present during service works



Initial leak check

Before removing the existing refrigerant, a leak check must be carried out. Search for leakage on the high-side of the system (whilst the system is operating) and on the low side (when the system is off). Use electronic gas detector and soapy water, where appropriate. If any leak is found, this must be repaired before conversion.

Access refrigerant circuit

Connect the refrigerant hose to service valve. The system must not be broken into, by means of cutting, breaking or brazing pipework, if it contains any flammable refrigerant or any other gas under pressure.

If it is necessary to break into a system, especially to change parts or to carry out brazing, all of the refrigerant must be recovered from the system and then flushed with nitrogen.

Recovery

Any remaining refrigerant within the system must be recovered, particularly since the refrigerant is CFC, HCFC or HFC and therefore if released will be harmful to the environment. Furthermore, there are also safety implications associated with releasing non-flammable refrigerants. Therefore a recovery machine should be used to recover the existing refrigerant, and stored in a recovery cylinder approved for that refrigerant. Identify the existing refrigerant type and quality in order to decide to recover for recycling or destruction purpose. Identification may take place, taking the type of refrigerant from the data plate, comparing with temperature / pressure method or with the use of a quality identifier. Particular attention must be paid to prevent mixing refrigerants and to avoid overfilling the cylinder. Lastly, mark the cylinder appropriately after use.

Figure 6: Example testing the "old" existing HCFC R22 refrigerant quality

If recovering HC refrigerant, the recovery machine should be suitable for use with flammable refrigerants.

Repairs to the system

It may be necessary to carry out repairs to the system. In this case, all repairs must be completed before charging with HC refrigerant. If repairs to the refrigerant circuit have been made, it is necessary to carry out a thorough leak check using pressurised nitrogen before proceeding.

At this point, it may also be beneficial to take the opportunity to conduct other, less critical repairs, such as oil changes, replacing filter driers, internal cleaning of the circuits, replacing damaged parts, and so on.

Design changes

The design changes that are made to the RAC system are critical to ensure that the safety requirements are met. It is essential that, based on the system type, location, occupancy and HC refrigerant charge size, the appropriate safety features are integrated into the equipment. Failure to do this properly may result in a serious flammability hazard. The major considerations are usually:

- Elimination of all mechanical joints from occupied space and minimisation of the possibility for leakage
- Elimination of all potential sources of ignition
- Setting up of emergency detection/ventilation/alarm system, where applicable
- Application of relevant markings and modifications to instructions

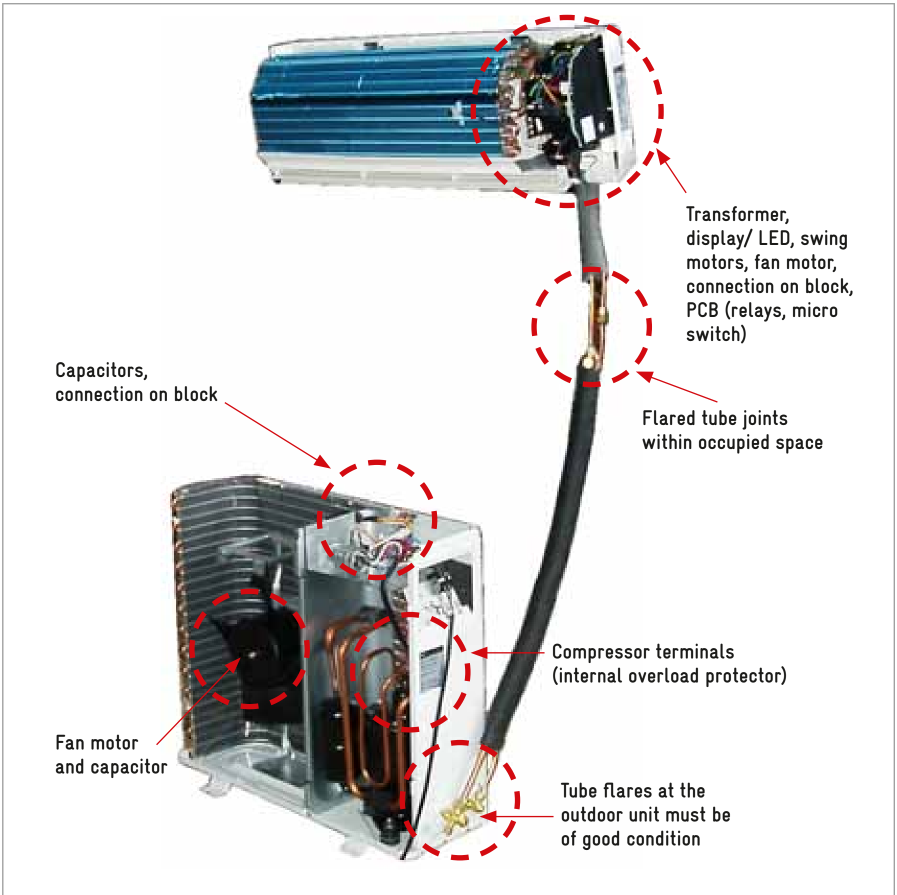
It is re-emphasised that particular attention must be paid to addressing the potential sources of ignition. In all cases the following assessment must be carried out:

- Inspect the system and associated equipment, noting down all electrical components
- Determine which of the components could act as a potential source of ignition
- Decide how each of those potential sources of ignition will be handled, for example:
  - by replacing with sealed components
  - using solid state devices or types
  - placing within a fully sealed enclosure
  - re-positioning outside the unit away from leaked refrigerant

- Consider also that electrical terminals and wiring connections must be adequately secured and sufficient insulation is provided to avoid shorting of parts
- Carry out the modifications accordingly

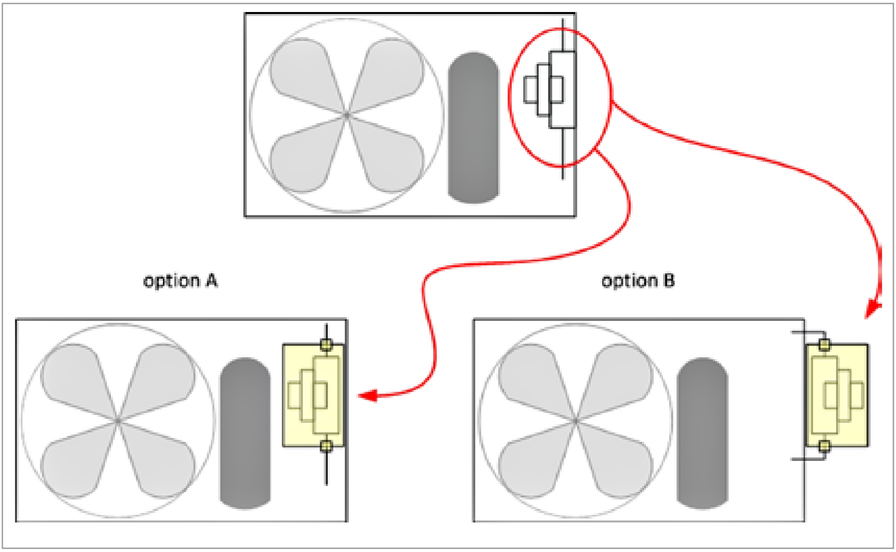
An example of aspects to look at is indicated in Figure 7.

Figure 7: Check for potential SOI sources and design changes, areas where interventions can be necessary



An example of options for modifying a potential source of ignition is provided in Figure 8.

Figure 8: Example of how to prevent electrical contactor acting as a source of ignition; "option A" is fitting the contactor within an sealed enclosure in its existing location and "option B" is relocating the contactor outside the housing within a separate enclosure



The marking of all equipment that contains HC refrigerant is also re-emphasised here. The appropriate "flammable gas" stickers must be placed on equipment housing entries and refrigerant access points, as well as on exposed piping (Figure 9). This should also be supplemented by a comprehensive warning sign applied to an access panel to provide advice to other technicians.

Figure 9: Appropriate warning sticker (left) and comprehensive warning sign (right) for use of system access panels

Sealing the system

Upon completion of the work to the system, the circuit must be sealed according to the guidelines. This means through either:

- Using compression (e.g., Lokring) connectors explain
- Brazing the service port (process tube) using pinch-off pliers
- Closing service valves

NOTE: The use of Schrader valves or line-tap valves should be generally avoided. Schrader valves can leak if not properly sealed and caps can be easily removed. Line-tap valves are for temporary use only (e.g. refrigerant recovery) but must not be left on the system.

Testing the integrity of the system

If the refrigerant circuit has been broken into, it is necessary to carry out leak tightness tests and strength pressure tests.

These may be carried out simultaneously by pressurising the system with oxygen-free dry nitrogen to the maximum working pressure of the system (plus 10%) and then check every single joint, connection and component for bubbles using soapy water or other such fluids.

If a leak is identified, follow the appropriate procedures to repair it.

Evacuation
The system must be evacuated.

This requires a use of a suitable vacuum pump and electronic vacuum pressure gauges; the system should maintain a vacuum of 200 microns, held for at least 15 minutes (without the pressure changing).

Refrigerant charging[1]
Provided that the system is proved to be leak free, charge the quantity as determined above. Charging must be carried out by mass using an electronic balance (accuracy of at least ±3% full-scale). Avoid charging to system pressure/temperatures only.

Consider the following:

- Ensure there are no sources of ignition nearby
- Place an HC gas detector at floor level to warn of any inadvertent release
- When connecting hoses between the refrigeration system, manifold gauges and refrigerant cylinder, ensure that the connections are secure
- Ensure that the refrigeration system is earthed prior to charging
- Extreme care must be taken not to overfill the refrigeration system
- After charging, carefully disconnect the hoses so to minimise the quantity of refrigerant emitted
- The mass of refrigerant charged into the system should be noted in a log-book and marked on a nameplate

When charging be aware that HC refrigerant have a lower density than most other refrigerants; only 40 – 50% of the charge expected with HFC/HCFC is needed. Remember that HC refrigerant blends must be charged in liquid state.

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1 A note on refrigerant purity: Refrigerant grade product should be used for all RAC systems. Commercial grade HCs (e.g. liquefied petroleum gas, LPG) contains significant quantities of sulphur, water, and other impurities and could contribute to oil degradation, shorten compressor life and invalidate warranties. The composition of commercial LPG is variable so the thermodynamic properties of the fluid may vary significantly from cylinder to cylinder. Also, unlike commercial LPG, HC refrigerants are not odorised.

Final leak check

After charging with refrigerant, carry out leak tightness checks, using a combination of:

- HC gas detectors – check every single joint, connection and component for the presence of refrigerant
- Bubble test – check every single joint, connection and component is checked for bubbles using soapy water or other such fluids

Search for leakage on the high-side of the system (whilst the system is operating) and on the low side (when the system is off).

If a leak is identified, follow the appropriate procedures to repair it.

Systems may have more than one leak, so the system should be repeatedly checked (including positions of recently repaired leaks).

Final checks

After charging and leak checking is complete, carry out final checks to ensure a safety and reliability of the system:

- Repeat checks to electrical components (i.e., there are no potential sources of ignition)
- Initiate the operation of the refrigeration machine and run the unit for a period of about 15 – 30 minutes
- Check for correct operating pressures, temperatures and current
- Ensure sealing caps have been replaced

CONVERSION EXAMPLE FOR SPLIT AIR CONDITIONER

The following pictures provide an example of the various steps one may take to convert a split air conditioner from R22 to R290.

Identify problem with air conditioner

Proper operating RAC equipment generally should not be converted to any other refrigerant (do not touch a good running system). Systems which may bear major problems, such of corrosion of heat exchanger and main frame or the system is overaged, should not be subject for a conversion to HC refrigerant.

Figure 10: Example of AC system that is unsuitable for conversion

If the (R)AC system is in a generally good condition and subject to any repair or service where a breaking into the refrigerant circuit is necessary (e.g. damaged compressor, leaking system) considerations should be taken to convert the system to a HC refrigerant if safety considerations permit.

Assumption:
A fully functional system does not need to be converted. The only time when a system may be converted is when there is a problem with the equipment that at least requires handling of refrigerant and/or breaking into the system.

AC split system conversion activities from HCFC R22 to HC R290

This example explains the conversion of an HCFC R22 based AC Split system (2.8 kW / 9000 BTU – cooling only) after repairing a leaky suction line coupler between indoor and outdoor unit, identified during system fault finding procedure within the operational HCFC R22 system.

Step 1)
Obtain current charge size -> 0.68 kg of R22

The charge size is generally indicated with the data plate.
If there is no information available at the outdoor-unit (e.g. weather-beaten) check if there is information available at the indoor-unit.
Finally, the charge amount can also be estimated from the amount of recovered (old) HCFC refrigerant charge amount (assuming there was no leak prevailing).

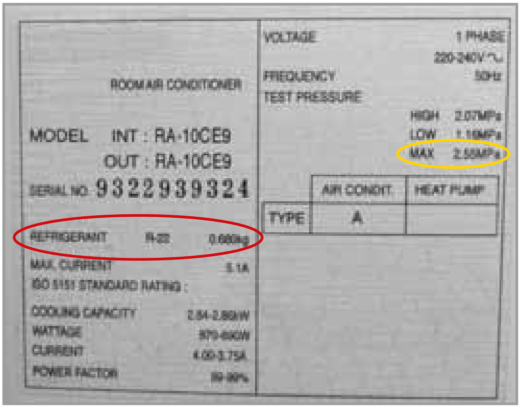


Figure 11: Split AC system data plate

Step 2)
Estimate equivalent HC charge
-> Conversion to R290, R22 charge is 0.68 kg and equivalent HC charge according diagram (Figure 12) is 0.28 kg of HC R290

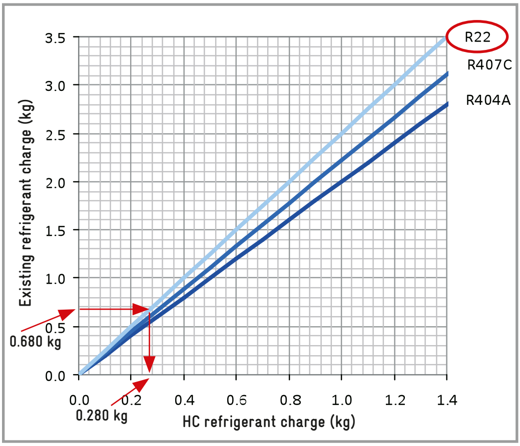


Figure 12: Refrigerant charge calculation diagram

Step 3)
Identify occupancies
-> Outdoor unit is in well ventilated area, and general occupancy (category A) is above ground level

-> Indoor unit within office for human comfort

Figure 13: Example AC system installation

Step 4)
Check charge size limits
-> Charge size is below maximum limit of 1.5 kg (0.28 kg < 1.5 kg)
-> Room size is 6 m × 5 m = 30 m², so below allowable charge (0.28 kg < 0.48 kg)

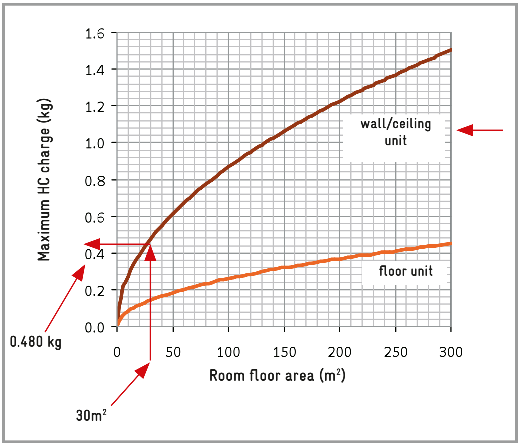
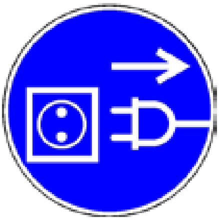


Figure 14: Maximum charge amount for existing room size

Step 5)
Check all necessary tools are present and the working area is safe
-> Okay

i) General hand-tools appropriate for the use at refrigerant circuit components and electrics
ii) Refrigerant recovery machine intended firstly for the HCFC R22 charge but suitable for use with flammable refrigerants (if subsequent service/repair with HC R290 is necessary)
iii) Refrigerant venting hose (only for venting of small amounts of HC during service or repair) and minimum of ½" OD
iv) Refrigerant recovery cylinder (two valves) for the existing R22
v) Lubricant recovery cylinder (two valves) utilised in series between recovery unit inlet and AC unit service port (oil-separator)
vi) Comparator/pressure-temperature tables for HC refrigerant (provided with the annex of this document)
vii) Vacuum pump with connector of the venting hose at the exhaust port

Step 5)	viii) Vacuum gauge (electronic), to check the 200 micron vacuum level ix) Electronic refrigerant balance (accuracy of at least ±3% full-scale) x) Handheld HC refrigerant gas detector xi) Nitrogen service cylinder with pressure regulator xii) Brazing set (oxygen/propane) xiii) Flammable gas (yellow triangle) stickers xiv) Flammable refrigerant warning signs xv) Work area warning signs xvi) Safety gloves and goggles xvii) Fire extinguisher Further required the spare parts and HC R290 refrigerant.



NOTE!

Whenever possible the system must be disconnected from power-supply!

Secure unintentional restarting of the system!

Step 6)
Eliminate all mechanical joints from occupied space!

In this specific case the identified leaking coupler within the suction line was removed and therewith the leak was repaired.

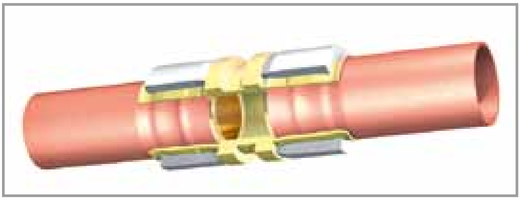
Figure 15: Mechanical connections in occupied space

Before repair: Arrow indicates leaky flared coupler within the suction line.

Figure 16: Removal of mechanical connections by joining tubes with brazing

After repair: Both mechanical joints are removed within the occupied space and doing so, the identified leak (suction line coupler) was repaired.

Figure 17: Joining tubes with Lokring couplers

Step 6) **-> Okay**	**Alternative repair:** There where brazing is not possible or as general alternative tube joining method, pressing connection (Lokring) can be used.  Figure 18: Lokring coupler for refrigerant transfer tubes
Step 7) Reset pressure device **-> Okay**	Not applicable

Step 8)
Eliminate all potential sources of ignition

-> Inside unit: transformer, display/ LED, swing motors, fan motor, connection block, PCB (relays, micro switch) – all non-SOIs
-> Okay

-> Outdoor unit: – fan motor, capacitors, connection block, compressor terminals (internal overload) – all non-SOIs,

Figure 19: Checking for SOI at the indoor unit

In general, wire connection screws must be fastened and wires have to be in good condition. All electrical connections should be subject to quality and functional checks. Loose connection will, sooner or later, create sparks and components damage. Dirt and humidity will create short cuts.

Use blade connectors, ring and spade terminals and appropriate cable end sleeves. Ensure insulation of each single connection and between the different terminals. Loose flexible wires connected to terminals will cause arcing and sparks!

Figure 20: Appropriate wire connectors

Step 8)

Compressor terminal sealing caps must be tight and the wire connection screws be fastened.

Wire connections should be in good condition and properly isolated to avoid arcing.

Figure 21: Appropriate cable end sleeves

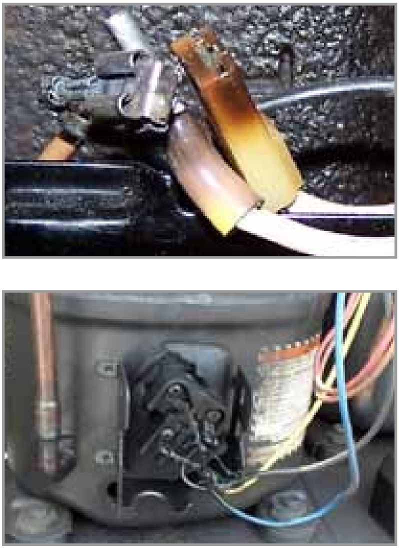


Figure 22: Loose connection causes arcing and short-cut

Figure 23: Not acceptable capacitor may cause short-cut and sparks

Step 8)

Mains contactors (either the existing or new one) must be fitted into a sealed enclosure.

The clearance between fan blade and housing must be sufficient to avoid any impact.

Compressor rubber grommets and sleeves must be in good condition to avoid vibration.

The level of vibration associated with the system must be within normal, acceptable limits; too much vibration implies that there is a greater possibility of leakage therefore compromising safety.

Refrigerant transfer tubes most have enough space in-between to avoid rubbing on each other, so that chafing is avoided.

Figure 24: Replace contactor into isolated box!

Step 8)

Capacitor connections should be either sealed with a cap and factory assembled cable, or the wires connected via an isolated spade type connector.

-> Okay

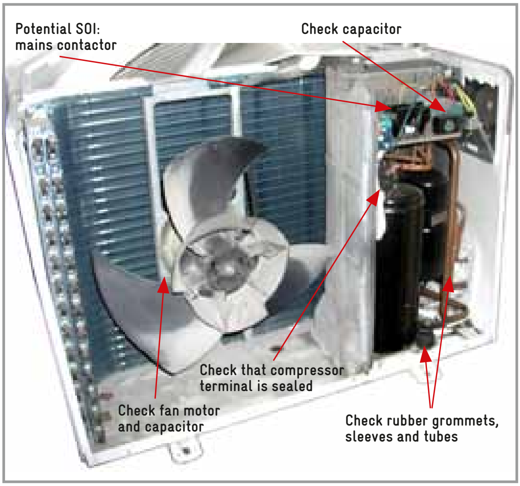


Figure 25: Checking the outdoor unit

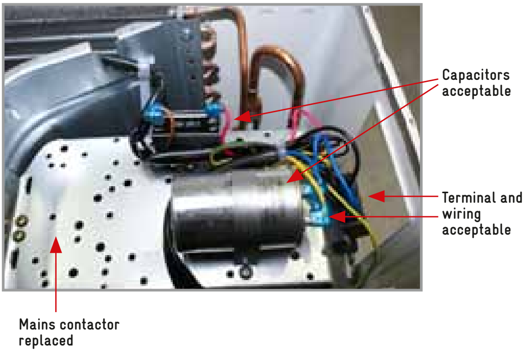


Figure 26: Replacing mains contactor and checking capacitors

Step 9)

Set-up emergency ventilation/detection and alarm system

-> Okay

Not applicable

Step 10)

Integrity test (pressure test / strength test

Since the refrigerant circuit has been broken into by replacing the flared tube couplers / suction and liquid line and the filter-drier, it is necessary to carry out leak tightness tests and strength pressure tests.

This is carried out simultaneously by pressurising the system with oxygen-free dry nitrogen (OFDN) to the maximum working pressure (PS) of the system or system sections (as stated on the data plate) plus 10% (according to EN 378-2).

Pressure Test Value =
1.1 × PS (2.55 × 1,1) = 2.80 MPa (28 bar)

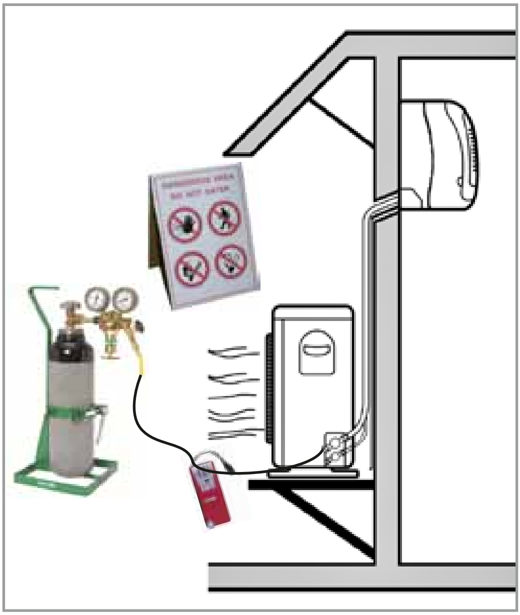


Figure 27: Pressure / strength test with OFDN

Step 10)

i) Nitrogen cylinder is connected with a common but reliable transfer hose to the service port of the outdoor unit. For safety reason, with starting of the test procedure, the pressure adjusting handle of the pressure regulator is back-seated (pressure regulator discharged).

ii) Nitrogen is now transferred to the system by slowly adjusting and opening the pressure regulator (pressure adjusting handle) and carefully applied at a pressure of 28 bar (2.8 MPa) to the system.

iii) Check every single joint, connection and component for bubbles using soapy water or other such fluids.

iv) If a leak is identified, follow the appropriate procedures to repair it.

v) If the system is found to be free of leaks, release the OFDN from the system slowly and carefully to the ambient.

Flushing the system with OFDN will require the same work activities and equipment provisions but with applying lower pressure (max. 10 bar).

-> Okay

Step 11)
Temporary flammable zones

Place warning signs within the working area.

Make sure that the gas detector is operational and place it on the floor within the work area. This will give a clear indication if HC refrigerant is in the surrounding environment.

Strategically plan the work schedule in order to have tools and equipment direct available and to avoid having to change the equipment and refrigerant hose interconnections during servicing the AC unit with HC.

When working on systems using flammable refrigerants, the technician should consider certain locations as "temporary flammable zones". These are normally regions where at least some emission of refrigerant is anticipated to occur during the normal working procedures, such as recovery, charging, and so on; typically where hoses may be connected or disconnected.

In general, the work schedule for refrigerant handling during service and repair activities should be arranged in a manner that the release of refrigerant is not necessary (e.g. „pumping down" the system and moving the refrigerant charge to the high side of the system). In anticipation of the maximum quantity of refrigerant that may be released during such a procedure (such as disconnecting a hose whilst it is full of liquid refrigerant), the minimum distance in all directions and with respect of the occupied working area where the service equipment is placed, should be a minimum of two metres.

Step 11)

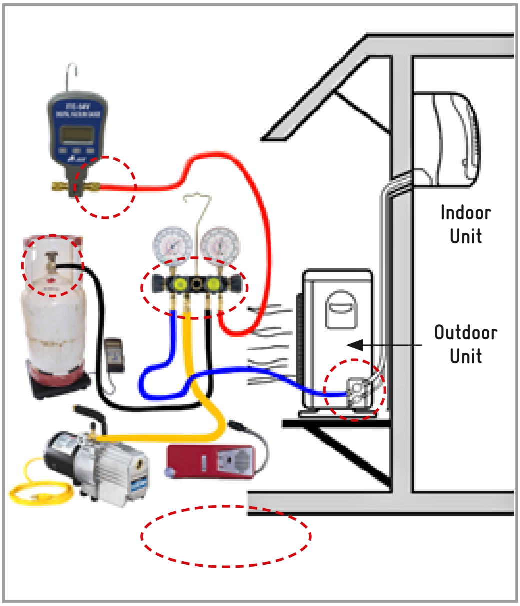


Figure 28: Temporary flammable zones

For any reason and under specific circumstances where service or repair activities have to be carried out at the indoor unit (breaking into the refrigerant caring system), the designated two (2) metres safety area will apply the same way as indicated for the outdoor unit!

-> Okay

Step 12)
System Evacuation and charging

The diagram below indicates the arrangement of equipment and tools and the interconnection with refrigerant hoses for drawing a vacuum at the system and finally charging with refrigerant. These are activities in general where flammable refrigerant can be present. It is important to respect the temporary flammable zones, as indicated before, for carrying out intended work activities and arrangement of the safety area.

The process of evacuation requires the use of a suitable vacuum pump and electronic vacuum pressure gauges; the system should maintain a vacuum of 200 microns (0.5 mbar, 50 Pa), held for at least 15 minutes (without the pressure changing).

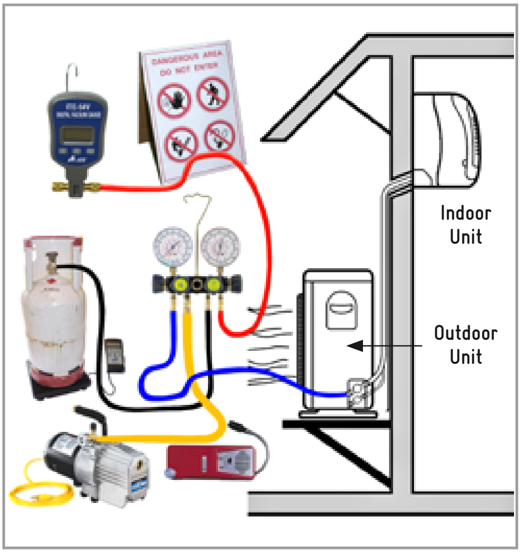


Figure 29: Equipment and tools arrangement for vacuuming and charging

Step 12) **-> Okay**	The process of charging the AC systems with HC refrigerants is similar to those using halocarbon (e.g. HCFC R22) refrigerants. Since R290 is a pure refrigerant the charging can take place in gaseous or liquid state. For small amounts of refrigerant (as for this example 0.280 kg) the charging of this system can be done by taking only vapour from the refrigerant cylinder and charging to the suction line of the compressor by measuring the weight of refrigerant. If charging the refrigerant in liquid form to the suction side of the system it must be evaporated before it reaches the system. Interconnect an expansion device (e.g. a short length of capillary tube) between the hose and the system, to enable the refrigerants evaporation. The charging amount should be monitored by the use of an accurate and sensitive scale. For safety reasons and to provide accurate charging, the smallest refrigerant cylinder sizes possible should be used.

Step 13)

Apply relevant documentation and system markings.

Figure 30: Warning sign at the compressor

-> Okay

Figure 31: Labelling of the outdoor unit

Step 14)

Final leak checking

With an HC gas detector – check every single joint, connection and component for the presence of refrigerant.

Using a bubble test – check every single joint, connection and component is checked for bubbles using soapy water or other such fluids.

-> Okay

End of AC system conversion

Figure 32: Bubble test

Figure 33: Leak check with electronic leak detector

Note:
For the use with Hydrocarbon refrigerants (here HC R290) it is important to make sure that the detector is safe and sensitive for this refrigerant. Regular used electronic gas detectors for CFCs, HCFCs or HFCs refrigerants are in most cases not designed for the use with HC R290, so check with the equipment provider and review the product manual if the gas detector is safe for a specific use.

Table 3: PT chart for R290 HC refrigerant

HC Refrigerant R-290							
Temperature		Absolute pressure			Gauge pressure		
°C	°F	kPa	bar	PSI	kPa(g)	bar(g)	PSI(g)
-40	-40	111,1	1,1	16,1	11,1	0,1	1,6
-39	-38,2	116,0	1,2	16,8	16,0	0,2	2,3
-38	-36,4	121,1	1,2	17,6	21,1	0,2	3,1
-37	-34,6	126,3	1,3	18,3	26,3	0,3	3,8
-36	-32,8	131,7	1,3	19,1	31,7	0,3	4,6
-35	-31	137,2	1,4	19,9	37,2	0,4	5,4
-34	-29,2	143,0	1,4	20,7	43,0	0,4	6,2
-33	-27,4	148,9	1,5	21,6	48,9	0,5	7,1
-32	-25,6	155,0	1,6	22,5	55,0	0,6	8,0
-31	-23,8	161,3	1,6	23,4	61,3	0,6	8,9
-30	-22	167,8	1,7	24,3	67,8	0,7	9,8
-29	-20,2	174,5	1,7	25,3	74,5	0,7	10,8
-28	-18,4	181,4	1,8	26,3	81,4	0,8	11,8
-27	-16,6	188,6	1,9	27,3	88,6	0,9	12,8
-26	-14,8	195,9	2,0	28,4	95,9	1,0	13,9
-25	-13	203,4	2,0	29,5	103,4	1,0	15,0
-24	-11,2	211,2	2,1	30,6	111,2	1,1	16,1
-23	-9,4	219,2	2,2	31,8	119,2	1,2	17,3
-22	-7,6	227,4	2,3	33,0	127,4	1,3	18,5
-21	-5,8	235,8	2,4	34,2	135,8	1,4	19,7
-20	-4	244,5	2,4	35,5	144,5	1,4	21,0
-19	-2,2	253,4	2,5	36,8	153,4	1,5	22,3
-18	-0,4	262,6	2,6	38,1	162,6	1,6	23,6
-17	1,4	272,0	2,7	39,5	172,0	1,7	25,0
-16	3,2	281,7	2,8	40,9	181,7	1,8	26,4
-15	5	291,6	2,9	42,3	191,6	1,9	27,8
-14	6,8	301,8	3,0	43,8	201,8	2,0	29,3
-13	8,6	312,3	3,1	45,3	212,3	2,1	30,8
-12	10,4	323,0	3,2	46,8	223,0	2,2	32,3
-11	12,2	334,0	3,3	48,4	234,0	2,3	33,9
-10	14	345,3	3,5	50,1	245,3	2,5	35,6
-9	15,8	356,8	3,6	51,8	256,8	2,6	37,3
-8	17,6	368,7	3,7	53,5	268,7	2,7	39,0
-7	19,4	380,8	3,8	55,2	280,8	2,8	40,7
-6	21,2	393,3	3,9	57,0	293,3	2,9	42,5
-5	23	406,0	4,1	58,9	306,0	3,1	44,4
-4	24,8	419,1	4,2	60,8	319,1	3,2	46,3
-3	26,6	432,5	4,3	62,7	332,5	3,3	48,2
-2	28,4	446,1	4,5	64,7	346,1	3,5	50,2
-1	30,2	460,1	4,6	66,7	360,1	3,6	52,2
0	32	474,5	4,7	68,8	374,5	3,7	54,3
1	33,8	489,1	4,9	70,9	389,1	3,9	56,4
2	35,6	504,1	5,0	73,1	404,1	4,0	58,6
3	37,4	519,4	5,2	75,3	419,4	4,2	60,8
4	39,2	535,1	5,4	77,6	435,1	4,4	63,1
5	41	551,1	5,5	79,9	451,1	4,5	65,4
6	42,8	567,5	5,7	82,3	467,5	4,7	67,8
7	44,6	584,2	5,8	84,7	484,2	4,8	70,2
8	46,4	601,3	6,0	87,2	501,3	5,0	72,7
9	48,2	618,8	6,2	89,7	518,8	5,2	75,2
10	50	636,6	6,4	92,3	536,6	5,4	77,8

HC Refrigerant R-290							
Temperature		Absolute pressure			Gauge pressure		
°C	°F	kPa	bar	PSI	kPa(g)	bar(g)	PSI(g)
11	51,8	654,8	6,5	95,0	554,8	5,5	80,5
12	53,6	673,4	6,7	97,7	573,4	5,7	83,2
13	55,4	692,4	6,9	100,4	592,4	5,9	85,9
14	57,2	711,7	7,1	103,2	611,7	6,1	88,7
15	59	731,5	7,3	106,1	631,5	6,3	91,6
16	60,8	751,7	7,5	109,0	651,7	6,5	94,5
17	62,6	772,3	7,7	112,0	672,3	6,7	97,5
18	64,4	793,2	7,9	115,1	693,2	6,9	100,5
19	66,2	814,6	8,1	118,2	714,6	7,1	103,7
20	68	836,5	8,4	121,3	736,5	7,4	106,8
21	69,8	858,7	8,6	124,5	758,7	7,6	110,0
22	71,6	881,4	8,8	127,8	781,4	7,8	113,3
23	73,4	904,5	9,0	131,2	804,5	8,0	116,7
24	75,2	928,1	9,3	134,6	828,1	8,3	120,1
25	77	952,1	9,5	138,1	852,1	8,5	123,6
26	78,8	976,5	9,8	141,6	876,5	8,8	127,1
27	80,6	1001,4	10,0	145,3	901,4	9,0	130,7
28	82,4	1026,8	10,3	148,9	926,8	9,3	134,4
29	84,2	1052,7	10,5	152,7	952,7	9,5	138,2
30	86	1079,0	10,8	156,5	979,0	9,8	142,0
31	87,8	1105,8	11,1	160,4	1005,8	10,1	145,9
32	89,6	1133,1	11,3	164,3	1033,1	10,3	149,8
33	91,4	1160,8	11,6	168,4	1060,8	10,6	153,9
34	93,2	1189,1	11,9	172,5	1089,1	10,9	158,0
35	95	1217,9	12,2	176,6	1117,9	11,2	162,1
36	96,8	1247,2	12,5	180,9	1147,2	11,5	166,4
37	98,6	1276,9	12,8	185,2	1176,9	11,8	170,7
38	100,4	1307,2	13,1	189,6	1207,2	12,1	175,1
39	102,2	1338,1	13,4	194,1	1238,1	12,4	179,6
40	104	1369,4	13,7	198,6	1269,4	12,7	184,1
41	105,8	1401,3	14,0	203,2	1301,3	13,0	188,7
42	107,6	1433,7	14,3	207,9	1333,7	13,3	193,4
43	109,4	1466,7	14,7	212,7	1366,7	13,7	198,2
44	111,2	1500,2	15,0	217,6	1400,2	14,0	203,1
45	113	1534,3	15,3	222,5	1434,3	14,3	208,0
46	114,8	1569,0	15,7	227,6	1469,0	14,7	213,1
47	116,6	1604,2	16,0	232,7	1504,2	15,0	218,2
48	118,4	1640,0	16,4	237,9	1540,0	15,4	223,4
49	120,2	1676,3	16,8	243,1	1576,3	15,8	228,6
50	122	1713,3	17,1	248,5	1613,3	16,1	234,0
51	123,8	1750,9	17,5	253,9	1650,9	16,5	239,4
52	125,6	1789,0	17,9	259,5	1689,0	16,9	245,0
53	127,4	1827,8	18,3	265,1	1727,8	17,3	250,6
54	129,2	1867,2	18,7	270,8	1767,2	17,7	256,3
55	131	1907,2	19,1	276,6	1807,2	18,1	262,1
56	132,8	1947,8	19,5	282,5	1847,8	18,5	268,0
57	134,6	1989,1	19,9	288,5	1889,1	18,9	274,0
58	136,4	2031,0	20,3	294,6	1931,0	19,3	280,1
59	138,2	2073,5	20,7	300,7	1973,5	19,7	286,2
60	140	2116,8	21,2	307,0	2016,8	20,2	292,5
61	141,8	2160,6	21,6	313,4	2060,6	20,6	298,9

Table 4: Start-up Record – AC system conversion to HC R290

Start-Up Record – AC system conversion to HC R290 refrigerant Service Company	
Service Company	
Address	
Telephone & Fax	
Technician Name	
Registration No.	
Client / Company	
Contact Person / Telephone No.	

Installation / Appliance DATA	
Manufacturer and type	
Refrigeration capacity rating	
Date of Installation / year	
Initial refrigerant type and charge	
Amount of recovered refrigerant	
Comments / Repair	
Replaced parts and conversion activities	(1)
(2)	(3)
Pressure / strength test – OFDN pressure value	

Operating data after conversion – Cooling mode		
Refrigerant Type		**Flammable Refrigerant**
Refrigerant Name		
Refrigerant charge in kg		
Suction Pressure		
Suction Temp		
Air Temp. entering condenser		
Air Temp. leaving condenser		
Air Temp. entering evaporator		
Air Temp. leaving evaporator		

Electrical Data		
Power Supply		
Overall Ampere Reading		
Current draw Compressor		

Other executions for system commissioning - tick box for completion!	
Only use correct and reliable tools / equipment for system commissioning!	
All flared (mechanical) connections are removed from occupied space!	
There are no sources of ignition (SOI) left at the system (indoor & outoor)	
Check system function!	
Check the AC system for HC leakage (bubble test and with electronic leak detector)!	
Check that electrical connections are tight and proper insolated!	
Check that condensate drain is tight and with down-grade!	
Check condition of refrigerant transfer tubes insulation!	
Check free run of condenser and evaporator fans!	
Check system operation (indoor/outdoor) on abnormal operational noise!	
Clean system components including air filter (if indicated)	
Check function of remote controller!	
Execute briefing of the AC system user!	

Company signature and date:	Client signature and date:

Table 5: Service label to be place at the outdoor unit after conversion and service / repair.

Flammable Refrigerant R290 Service	
Company	
Name of Technician	
Address	
Telephone & Fax No.	
Registration No.	
 Flammable Refrigerant	This System is charged with the natural and environmental protective Refrigerant R290
Refrigerant Charge in kg	
Lubricant Type & Charge	
Date:	
Signature:	

This conversion guide is intended to assist with the safe conversion of air conditioning systems to use flammable hydrocarbon (HC) refrigerants. Converting an air conditioning system from a non-flammable to a flammable refrigerant requires special considerations, which are summarised here.

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