Safe Conversion and Servicing Practices for Refrigeration Appliances using Hydrocarbon Refrigerants

Manual for

Safe Conversion and Servicing of Domestic and Commercial Appliances

PREPARED BY

Cool Concerns
Newbury, UK

in collaboration with

Indian Institute of Technology
New Delhi, India

INFRAS
Zürich, Switzerland

An ECOFRIG publication

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Cool Concerns

18 Newbury Lane
Compton
Newbury
Berks., RG20 0PB
United Kingdom

in collaboration with

Indian Institute of Technology

Department of Mechanical Engineering
Hauz Khas
110 016 New Delhi
India

INFRAS

Gerechtigkeitsgasse 20
CH-8002 Zürich
Switzerland

ECOFRIG is a joint collaboration of

Ministry of Environment and Forests, Government of India
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The manual was written by
Jane Gartshore, Cool Concerns

in collaboration with
Prof. R. S. Agarwal, IITD and S. Kessler, INFRAS.

Valuable inputs have been received from:

Dr. S Devotta, National Chemical Laboratories (NCL), Pune, India
A. K. Gupta, RCurtis, Rockwell Industries Ltd., Hyderabad, India
P. Blacklock, Calor Gas, Slough, UK
Liebherr Hausgeräte GmbH, Ochsenhausen, Germany
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O. Schwank, INFRAS, Zürich, Switzerland

This manual has been completely new developed. The following manuals have been published earlier under the ECOFRIG project:

- Manual for Safe Design and Manufacturing of Commercial Refrigeration Appliances using Hydrocarbon, May 1997.
- Refrigeration Appliances using Hydrocarbon Refrigerants; Manual for safe Design, Manufacturing, Servicing and Drop-in Conversion of Domestic and Commercial Appliances, August 1997

This manual can be obtained from and comments may be sent to the following addresses:

IIT Delhi

Prof. R. S. Agarwal
Department of Mechanical Engineering
Hauz Khas
110 016 New Delhi
India
Tel. +91 -11 -686 19 77 Ext. 3112
Tel./Fax. +91-11- 652 66 45
e-mail: rsarwal@mech.iitd.ernet.in

INFRAS AG

Consulting Group for Policy Analysis and Implementation
Gerechtigkeitsgasse 20
CH-8002 Zürich
Switzerland
Tel. +41 -1 -205 95 95
Fax. +41 -1 -205 95 99
e-mail: “ECOFRIG”<zuerich@infras.ch>
homepage: www.infras.ch

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The manual is planned to be updated and complemented on a regular basis to integrate suggestions received and to keep pace with the evolving body of experience.

Foreword

Since 1993, the ECOFRIG project provides the Indian refrigeration industry with information and technical assistance for the phase out of ozone depleting substances by promoting the environmentally friendly hydrocarbon technology. From first activities in the field of domestic refrigeration, the focus has been widened and has now expanded to smaller commercial refrigeration appliances, conversion of small appliances which were originally charged with CFC12 and servicing. After more than 6 years of operation the ECOFRIG project has established a large number of international contacts. The Swiss Agency for the Environment, Forests and Landscape has been instrumental in facilitating these international contacts.

The commercial refrigeration sector in many Article 5 countries consumes a significant part of the ODS (Ozone Depleting Substances) attributed to the Refrigeration and Air Conditioning sector. At the same time, the phase out of CFCs appears to be more difficult in the commercial refrigeration and servicing sector due to the prevailing working practices (appropriate for CFC 12) and the low level of industrialisation in the production process.

Hydrocarbon refrigerants are seen as a viable and low cost alternative for domestic and small commercial refrigeration appliances to phase out CFCs. At the same time they are the most environmentally friendly technology option commercially available today. As blends of hydrocarbon refrigerants can be used as true drop-in solutions for CFC 12, the present working practices in production and servicing are to be improved under safety aspects only. The key change is that the appliance design and manufacturing facilities as well as the servicing procedures have to take due precaution with respect to the flammability of the hydrocarbon refrigerant.

This manual is already the third and completely revised edition in a series of ECOFRIG manuals on hydrocarbon appliances. Whereas the former editions provided information mainly for the manufacturer and engineer level, the present publication was developed for trainers in the refrigeration sector as well as for the on the job service technicians working in developing countries. It provides the necessary information to work safely on domestic and commercial refrigeration appliances. This includes information on what changes are needed to cover the safety requirements for the appliance design when using hydrocarbon refrigerants as well as detailed guidelines on how to handle hydrocarbon based appliances safely in servicing and conversion. A main focus is dedicated to how failed CFC 12 or HFC 134a based appliances can be converted to hydrocarbon blend refrigerants.

Even though the information provided is by large of a general nature and is believed to be useful for the Refrigeration and Air Conditioning sector of most developing countries, this manual has been developed with an Indian focus with respect to the reviewed appliances' designs and working practices.

We hope that the present manual provides the demanded assistance in contributing to an early, cost effective and sustainable phase out of ODS in the domestic and commercial refrigeration sector, in Article 5 countries.

Dr. Urs Heierli
Counsellor and Head
Swiss Agency for Development and Co-operation
110 021 New Delhi, India

Blaise Horisberger
Swiss Agency for the Environment,
Forests & Landscape
3003 Bern, Switzerland

Contents

1. Introduction

Hydrocarbon refrigerants (HCs) such as Isobutane, or blends of Isobutane and Propane are now being used in some domestic and small commercial appliances. HCs can also be used to convert existing CFC (chlorofluorocarbon) or HFC (hydrofluorocarbon) appliances to reduce CFC and HFC emissions. HCs are good refrigerants, but are flammable, so there are some differences in servicing procedures which are covered in this manual.

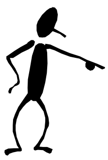
The foundation for this manual is sound, basic safety principles for the use of hydrocarbon refrigerants. The information has also been developed from practical experience gained in India in the safe application and handling of hydrocarbon refrigerants.

This manual covers:

- General good servicing practice;
- Servicing of domestic and small commercial refrigeration appliances using hydrocarbon refrigerants (less than 250g, equivalent to 600g CFC12);
- Conversion of R12 and R134a appliances to hydrocarbon refrigerants.

It is to be used as a source of information for trainers of refrigeration technicians. Some of the sections and appendices can be used as a short reference manual for service technicians who have been trained to handle hydrocarbon refrigerants.

Throughout this manual:



This symbol is used to show important information – you must read this. The information is usually related to safety.

☺ This symbol is used to highlight the benefits of using hydrocarbon refrigerants.

Note to Trainers …

This manual contains all the information you need to be able to present a training course for refrigeration service technicians, covering service of HC appliances and conversion of appliances to HCs. It is assumed that you have a good basic knowledge of refrigeration theory and practice. This information builds on your existing skills.

The main part of this manual contains information about HC refrigerants and the servicing and conversion procedures. More detailed information about HCs and necessary tools and equipment are included in the appendices.

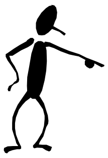
The appendices also include information that will help you prepare a training course, and a basic handout for the technicians you have trained. You can copy this handout as it is printed, or you can translate it into a local language.

Why are CFCs to be replaced?

CFCs (chlorofluorocarbons) such as R12 and R502 deplete ozone in the stratosphere and their production / consumption will be phased out under international legislation. Production of CFCs in developing countries must stop by the year 2010, although developing countries have pledged to reduce and cease production / consumption before that date.

HCFCs (hydrogenated chlorofluorocarbons) such as R22 also deplete ozone, but are less harmful – they will be phased out by 2030.

Ozone depletion is serious because it increases the amount of ultra violet (UV) light that reaches us. This increases the incidence of skin cancer and eye cataracts and reduces crop yields. More information about ozone depletion is given in the United Nations Environment Programme (UNEP) training manual “Good Practices in Refrigeration”.



CFCs and HCFCs deplete ozone if they are vented into the air. This happens during servicing and when systems leak.

Why are hydrocarbon refrigerants used?

There are several refrigerants that can be used to replace CFCs in both new and existing systems. These fall into three main categories:

- HCs (Hydrocarbons);
- HCFC based blends;
- HFCs (Hydrofluorocarbons).

HCs are environmentally friendly. They perform at least as well as CFCs, and in many cases running costs from electricity consumption will be lower. HCs do not react with system materials and work well with the existing compressor oil.

HCFC based blends are not long term alternatives to CFCs, but are used in many developed countries as an intermediary solution to convert existing CFC systems. They do have a small but nevertheless significant ozone depletion potential and will therefore be phased out in the future.

HFCs are more difficult to use because they cannot operate with the mineral oils used with CFC, HCFC and HC refrigerant. The new oil is a polyol ester type. It is more expensive and more readily absorbs moisture (i.e. it is very hygroscopic). Servicing procedures are more stringent to avoid problems associated with moisture and other contamination in the system. HFC systems are more likely to fail and to perform badly. This is especially the case where the climate is hot and humid, as in most developing countries.

Servicing procedures for HC refrigerants are very similar to those for CFCs, except that care is needed to prevent the flammability of HCs becoming a hazard. When converting systems to HC refrigerants, refrigeration circuit changes are not necessary, but electrical components may need to be changed.

When and why should I convert CFC systems to HCs?

It is not necessary to convert existing CFC systems that are working reliably and well. The CFCs that are contained in the system are not damaging the ozone layer. You can convert a system to HCs when it needs to be serviced.

Do not covert appliances unless:

- They are leaking;
- You need to open the circuit to replace a component such as the compressor or drier.

The advantage of using hydrocarbons to convert CFC systems is that they are environmentally friendly and you need to make very few changes to the appliance. You can also use HCs to convert HFC appliances (e.g. those using R134a).

Will the converted system be as reliable as before?

Provided the conversion is carried out correctly and the system is evacuated and charged with the correct amount of HC refrigerant, it will be as reliable as the CFC system.

When hydrocarbons are used to convert systems, the running costs often reduce because HCs are more efficient refrigerants. In comparison to HFCs, appliances using HCs will generally run more reliably, especially after servicing under field conditions in developing countries.

How will this benefit the service man's business?

☺

CFCs will become more difficult to obtain and more costly as their production / consumption is reduced. HC refrigerants cost no more than the CFCs they replace. In many places HC refrigerants will be even cheaper. The service man will be able to offer his customers appliances converted to HC refrigerant that will have a longer life and will cost less to run.

2. Hydrocarbons as Refrigerants

Hydrocarbons have been used as refrigerants for decades in refrigeration systems. Their use has increased in the last five years as they are now being used in place of CFCs, HCFCs and HFCs. This section covers:

- The hydrocarbon refrigerants;
- Properties of hydrocarbons as refrigerants;
- Refrigerant purity.

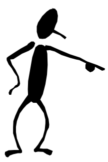
The hydrocarbon refrigerants

There are two HC refrigerants that are commonly used in new appliances and to convert R12 (and R134a) appliances:

- ***R600a*** is pure iso-butane and has a boiling point of -12°C at atmospheric pressure;
- ***Propane / iso-butane blend*** (e.g. Care 30, ER12, Ecool PIB[1]) has a boiling point of about –31°C at atmospheric pressure.

R600a is widely used in domestic refrigerators in Europe, and is starting to be used in developing countries. Its refrigerating capacity is very low (about 60% of that of R12). Compressors used with R600a must have a much higher displacement, but have the same size motor as for R-12 appliances. The compressor is therefore a new model with a different displacement / motor combination. R600a is generally only used for domestic appliances but sometimes also for very small commercial appliances. It is never used for conversion of existing R12 or R134a systems.

The ***propane / iso-butane blend*** has very similar properties to R12 – it gives the same capacity and operates at similar pressures. It is being used in some new appliances (e.g. ice cream freezers, water coolers), and is the refrigerant to use when converting R12 and R134a systems.



The propane / iso-butane mixture is a zeotropic blend[2] and it behaves differently to single substances or azeotropic blends[3]. **Zeotropic blends must be taken from a cylinder as a liquid to maintain the correct composition.** If refrigerant is removed

[1] Care 30, ER12 and Ecool-PIB are trade names of HC blend refrigerants consisting of approximately 50% iso-butane and 50% propane by weight.
[2] Zeotropic blends consist of two or more components. These blends boil / condense through a range of temperatures at a particular pressure
[3] Azeotropic blends consist of two or more components. These blends behave like a single substance.

from a cylinder as a gas, the composition will not be correct, and the system will not have the right cooling capacity. This is shown in the diagram below.

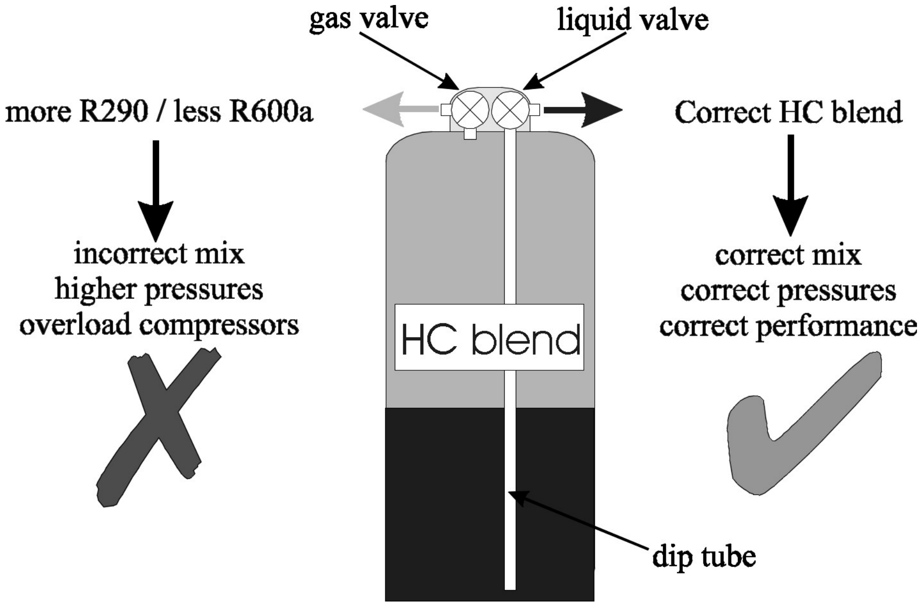


Figure 2-1: Always remove HC blend refrigerant as a liquid

More details about the characteristics of the HC zeotropic blend is given in Appendix 1.

Other HCs are available as refrigerants such as pure propane and a propane / ethane blend, but these are not suitable as replacements for R12 or R134a. The safety information in this manual applies to all HC refrigerants but the performance and operating characteristics apply to R600a and the propane / iso-butane blend only. Further information about the other HC refrigerants can be obtained from the suppliers, listed in Appendix 4.

Properties of hydrocarbons as refrigerants

Hydrocarbons are very good refrigerants, but have different properties to CFCs and HFCs (halocarbons) as shown below.

The **latent heat of hydrocarbons is much higher** than that of the halocarbons – i.e. the amount of heat absorbed during evaporation is much higher per kg of circulating refrigerant, as shown in figure 2-2.

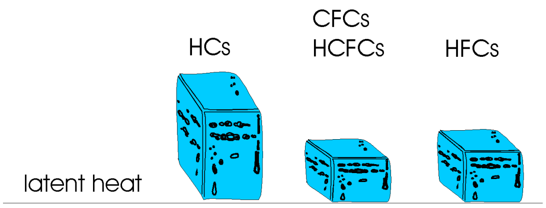


Figure 2-2

The **density of hydrocarbons is much lower** than that of halocarbons, as shown in figure 2-3. In a system designed for R12, the same volume of HC would be used, but it would weigh only about 40% of the R12 charge.

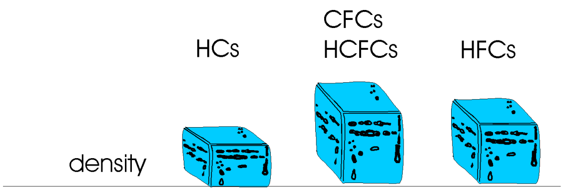


Figure 2-3

The density difference is important when charging systems:

- When charging hydrocarbons **by weight, 40 to 45% of the halocarbon charge is used**, as shown in figure 2-4.

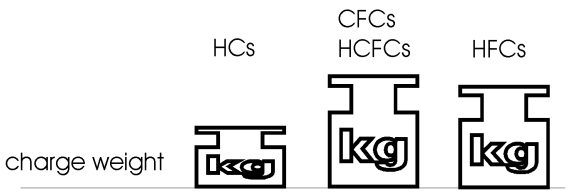


Figure 2-4

- When charging hydrocarbons **by volume, the same volume as for the halocarbon is used** as shown in figure 2-5.

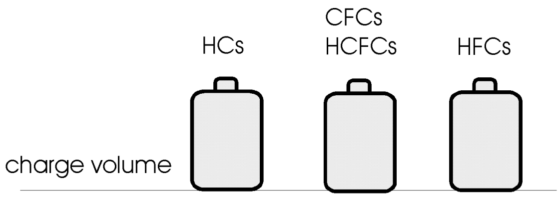


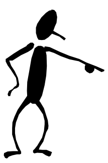
Figure 2-5

More detailed technical information on HC refrigerants is given in Appendix 1.

Purity

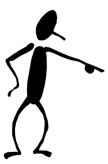
Refrigerants must be very pure – they must have extremely low levels of moisture and other contaminants, and must be unstenched. The use of impure HCs will cause the following problems:

- A high level of moisture will saturate the filter drier, freeze in the capillary tube and can lead to compressor damage and failure;
- A stenching agent (as used in LPG) can damage compressor motors and block filter driers.



If you can smell the hydrocarbon, don't use it in refrigeration systems.

In addition, the type of HC is important. HC used as a fuel for example, is not the right composition for a refrigerant. It will not give the correct refrigeration capacity, and its use may result in higher running costs and poor reliability.



Only use refrigerant grade HCs which have low levels of contamination and are of the correct composition.

3. Safety Information for Hydrocarbon Refrigerants

In many respects the hazards of HC refrigerants are similar to those for R12. In addition to this, HCs are flammable. This section covers:

- General safe refrigerant handling;
- Flammability;
- Simple workplace precautions;
- Handling HC cylinders;
- Design of HC appliances.

General safe refrigerant handling

All refrigerants are hazardous. The following safe handling guidelines apply to all refrigerants, including CFCs (e.g. R12), HFCs (e.g. R134a) and HCs.

Contact with liquid refrigerant will cause a freeze burn (similar to frost bite). You must wear gloves and goggles and clothing which covers your body when handling all refrigerants (e.g. when charging or recovering refrigerant). Bathing the area with cold water should treat a freeze burn. Medical attention may be necessary.

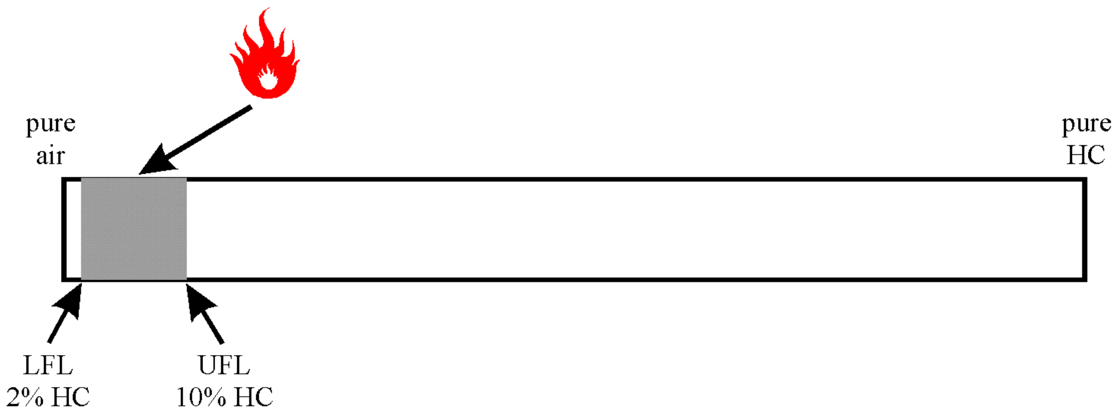
Refrigerants do not smell and are heavier than air and will therefore tend to collect in chest freezers / chillers, pits, trenches and basements. You should ventilate these areas to disperse leaking refrigerant.

Refrigerants displace air and are asphyxiants – they will suffocate you if you breathe in high concentrations. An affected person should be removed to an uncontaminated area (e.g. outside a building) and kept warm and still. Artificial respiration or oxygen may be needed. Medical attention may be necessary.

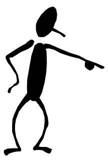
Most refrigerants, including CFCs, HCFCs, HFCs and HCs (i.e. those which include propane, iso-butane and / or ethane) are not toxic.

Flammability

Hydrocarbons are flammable when mixed with air and ignited. The concentration of the HC in air must be between the lower and upper flammable levels as shown below.



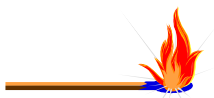
If the concentration is below the lower flammability level (LFL) of approximately 2%, there is not enough HC for combustion. If the concentration is above the upper flammability level (UFL) of approximately 10% there is insufficient oxygen for combustion.



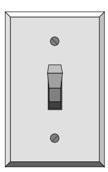
The LFL is approximately equal to 35 g/m^3 of HC refrigerant in air. **For safety reasons a practical limit of 8 g/m^3 of HC in air should not be exceeded in a closed space.**

For example, in a room 3m by 3 m by 2.5 m high the **practical** limit for an HC charge is 180 g. If the total charge of 180 g is released into the room, it will not be enough to produce a flammable mixture. The resulting concentration will be about 20% of the lower flammability level if the refrigerant was evenly dispersed in the entire room. But this may not be the case, and therefore the practical limit should never be exceeded.

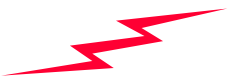
For combustion there must be an ignition source. The ignition source must be hotter than 460°C to ignite the HCs commonly used as refrigerants. The following are potential ignition sources:



A flame, e.g. from a brazing torch, halide torch leak lamp, match or cigarette lighter;

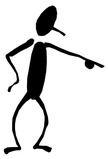


A spark from an electrical component such as a switch, relay, overload protector, loose wiring connection;



Static electricity.

Combustion will not occur inside the system as there will not be enough air. Even if a system is not evacuated before charging, there will not be enough air for combustion.

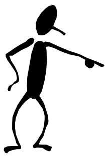


However, combustion can occur if a leak of HC results in a flammable mixture and there is an ignition source.

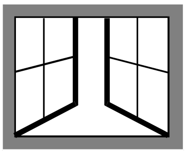
Refrigerant leakage can be dangerous if:

- **Refrigerant leaks into a closed cabinet (or other sealed space) and there are sparking electrical components inside the cabinet;**
- **Refrigerant leaks into the air around the system and there are sparking electrical components on the system;**
- **Refrigerant is lost during servicing (e.g. when venting, flushing or charging a system), and there are sparking electrical switches and / or flames.**

Simple workplace precautions



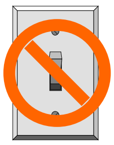
You must take these simple precautions when working with HC refrigerants:



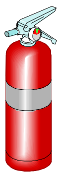
Work in a well ventilated area, or outside.

No smoking

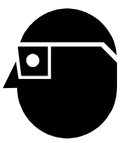
No flames within 2 m of the charging / venting area.

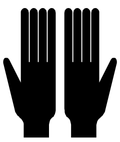


Do not use switches within 2 m of the charging / venting area.



Have a fire extinguisher (dry powder type).





Wear gloves, goggles and clothing which covers you.

Do not store HCs inside

HCs can accumulate, e.g in chest cabinets and basements

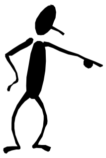
Handling HC cylinders

Cylinders containing HC refrigerants should be clearly labelled to show the type of refrigerant and that it is flammable. This label should not be removed.

The guidelines below are recommended good practice when handling HC cylinders – they are very similar to the guidelines for any refrigerant cylinder (e.g. CFCs):

- The valve cap should be fitted when the cylinder is not being used;
- The cylinder should not be heated. Refrigerants cylinders can usually withstand temperatures up to 45 to 50°C. If a cylinder needs to be heated (e.g. to remove refrigerant more easily) it should be placed in a container of water no hotter than 45 to 50°C;
- The cylinder and its valve should not be modified;
- The cylinder should not be re-filled unless it is designed for recovered refrigerant.

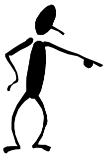
Some HC refrigerants are supplied in cylinders fitted with an excess flow valve as an additional safety device (e.g. CARE refrigerants in 3.5 kg cylinders and larger). This valve closes if the flow of refrigerant suddenly increases, e.g. if the charging hose is removed before the cylinder valve is closed. The excess flow valve is re-set by closing the valve and opening it again slowly. The excess flow valve sometimes closes if the cylinder valve is opened too quickly.



HCs should not be decanted into smaller cylinders unless absolutely necessary. In some countries law prohibits this.

If HCs are required to be decanted

- This should be done outside or in a well-ventilated area.



- The cylinder that is being filled must be weighed. Note that **the weight of the same volume of HC refrigerant is 40% of the weight of other refrigerants –** the same volume of refrigerant will weigh 60% less (e.g. a cylinder which can safely contain 14 kg of R12, will only be able to contain 5.6 kg of HC);
- The transfer hose used should be as short as possible to minimise loss and risk;
- The transfer hose should be evacuated or carefully purged before transferring refrigerant;
- When decanting a blend, it must be removed from the supply cylinder as a liquid;

- Aerosol can type cylinders (sometimes used for servicing) should never be re-filled.

Some cylinders (especially those that HC refrigerants are supplied in) have a non-return valve – you must not re-fill these cylinders.

When you need to purge lines, e.g. before charging with HC refrigerant, you must take care. In many cases you will have to purge with liquid refrigerant, which can be dangerous. To do this safely:

1. Make sure the area is well ventilated;
2. Open, then close the cylinder valve;
3. Purge each line for a short time – 1 second should be long enough.

Transport of HCs

Follow local regulations for the transport of flammable gases (e.g. LPG).

Storage of HCs

Follow local regulations for the storage of flammable gases. The diagram in figure 3-1 shows an ideal storage area in a locked cage outside a building.

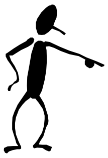
Figure 3-1

Design of HC appliances

HC appliances usually have electrical components that are either:

- Sealed;
- Solid state;
- Enclosed in a sealed box;
- Located remote from the refrigeration circuit.

This avoids the risk of combustion if HC refrigerant leaks from the circuit.



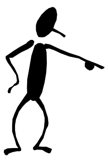
When replacing these components you must use the same type, and fit them in the same position. If you need to open a sealed enclosure, make sure you re-seal it correctly.

4. Servicing Procedures with Hydrocarbon Refrigerants

This section only covers the servicing of an appliance **that already has been charged with HC refrigerant**. Conversion of R12 or R134a appliances to HC blend refrigerant is covered in section 5.

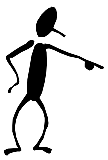
Servicing procedures for HC refrigerants are similar to those for R12, except for the additional precautions needed for working with flammable refrigerants. This section covers:

- Safe venting of HC refrigerants from systems;
- Removal of remaining HC refrigerant;
- Replacing system components;
- Pressure testing;
- Leak testing
- Evacuation;
- Charging;
- Sealing the process tube;
- Leak testing of process tube.



Follow the precautions in Section 3 when servicing HC appliances. Remember that HC + air is flammable and can be ignited by flames and sparks.

Safe venting of HC refrigerants from systems



The HC refrigerant should be vented to an area away from ignition sources (flames and sparks), preferably outside.

The best tool to open the system is piercing pliers with a long hose connected as shown in the photo in figure 4.1. Piercing pliers are not necessary if the process tube already has a connection on it.

To vent the HC safely, follow the procedure outlined below:

Run the compressor, if possible, before venting refrigerant - this heats up the compressor oil so that less refrigerant will be dissolved in it.

1. Do not open the system in an enclosed area - work in a well-ventilated area (with windows and doors open and / or fan running) or outside.

2. Before you use the piercing pliers to open the system, put the other end of the hose outside or in a very well ventilated area. The area where you are releasing the refrigerant must:

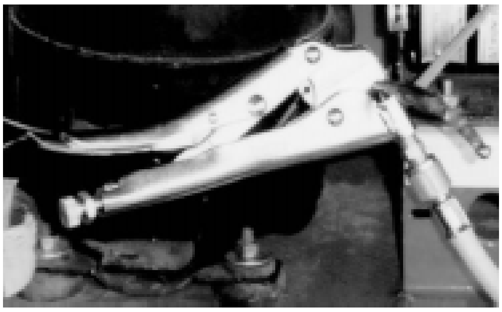


Figure 4-1

- not contain ignition sources (flames and sparking electrical components),
- not be underground.

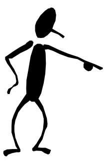
The vented refrigerant must not be drawn into a building or underground area.

4. Pierce the process tube as shown in the photograph. Take care to ensure that pliers are adjusted so that they clamp firmly onto the process tube so that refrigerant does not leak from this connection.

It can take up to 15 minutes for the refrigerant to be vented from an appliance in this way. Check that no more the refrigerant is coming out of the hose before proceeding further (for example by putting the end of the hose in a container of water and looking for bubbles).

Most of the refrigerant will be vented by this procedure, but some will remain in the oil and the system. You will need to remove this refrigerant. The piercing pliers do not give a good enough seal for evacuation and charging, so they must be replaced by a tube adapter, flare or similar.

Take care if you have to braze an extension onto the process tube - there will still be some HC in the system. Never stand in front of the tube opening while brazing and always make sure you could not ignite any flammable materials.



Do not try to ignite the refrigerant being vented from the appliance.

Removal of remaining HC refrigerant

You must evacuate the remaining HC refrigerant using a proper vacuum pump.

Your vacuum pump probably has an on / off switch which can spark when used. Do not use this switch when you use the pump to evacuate an HC system. Switch it on and off at the mains socket. You do not need to use a different vacuum pump for HCs.

When you evacuate the system work in a very well ventilated area or outside.

Replacing system components

The HC system can be serviced in a similar way as for CFCs. You may need to un-braze old components (e.g. a failed compressor) and braze in the replacement.

It is essential that the system has been evacuated and that you braze in a well-ventilated area or outside.

Make sure there is no HC in the air before lighting your brazing torch, e.g. by forced venting of the area or by checking with a simple HC / LPG gas alarm.

The electrical components on an HC appliance may be:

- Sealed or solid state;
- Enclosed in a sealed box;
- Located remote from the refrigeration circuit.

This prevents a hazard from sparks if HC refrigerant leaks from the circuit.

You must use the correct electrical components if you need to replace these items, and you must replace them in the correct way.

In most HC appliances:

- The compressor relay is solid state and the overload protector is a sealed device (to prevent sparking).
- The thermostat is either located in a sealed electrical box or a solid state / sealed type is used (to prevent sparking).
- On / off and door switches are sealed types (although usually they are not fitted).

Standard capacitors and induction type fan motors are safe to use with HCs as they do not spark.

If you need to replace a sealed or solid state device, use the correct safe type.

If you need to replace devices which are mounted inside a sealed enclosure make sure you put them again inside the electrical box and seal it properly, including the cable entries.

Make sure any wiring connections cannot work loose - loose wires can cause sparks

Pressure testing

The HC Systems can be pressure tested similar to R12 (or R134a) systems. It is preferable to use dry, oxygen free nitrogen for pressure testing.

Testing pressure should be 1.3 times the working pressure as used in R12 or R134a systems.

Leak Testing

The refrigeration system is to be tested for leakage before charging the system. The safest and most accurate method for leak testing of HC refrigerants in appliances is soapy water. This finds very small leaks and poses no hazard with a flammable refrigerant.

Each joint should be checked with the system at the highest practical pressure.

Evacuation

The system must be evacuated to remove moisture and non-condensable gases such as air. If a system is not evacuated properly the system will not give required performance.

With HC refrigerants there is no need to evacuate the system for any longer then you would do for R12.

When you evacuate the system work in a very well ventilated area or outside.

Charging

Refrigerant should only be charged into a clean, dry, leak free system, so you must evacuate the system before charging with refrigerant.

When charging HC refrigerant make sure:

- **the charging area is very well-ventilated (or outside);**
- **the charging equipment is suitable for use with HC refrigerants (i.e. it is safe and accurate);**
- **you vent as little refrigerant as possible into the air;**
- **you have a dry powder type fire extinguisher in the charging area;**
- **you take the HC blend from the cylinder in the liquid form (pure R600a can be removed as a gas).**

Each of these points is covered in more detail below.

The charging area

The area where you charge refrigerant into an appliance should be very well ventilated or outside.

To be safe the charging area must:

- be a no smoking area;
- be at least 2 m from flames and sparking electrical components;
- never be below ground.

Store as little refrigerant as possible in this area, the remainder should be stored outside (i.e. as LPG is stored).

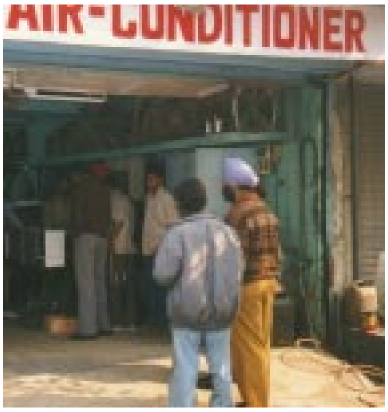


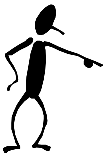
Figure 4-2

The photographs in figure 4-2 show good charging areas at service companies. One area (on the left) is outside, but under cover. There are no ignition sources within the charging area. The other is an open fronted workshop with good natural ventilation.

Charging equipment

There are different methods of measuring the amount of refrigerant charged into a system:

- By weight (i.e. using a balance);
- By volume (i.e. using a calibrated still);
- To known suction and / or discharge pressures;
- To a frost line (where this is known for an appliance).



The amount of refrigerant charged into a system affects its performance. If too much or too little refrigerant is charged, the capacity of the system will be lower than expected and the power consumption may be higher. This applies to all refrigerants – CFCs, HCFCs, HFCs and HCs.

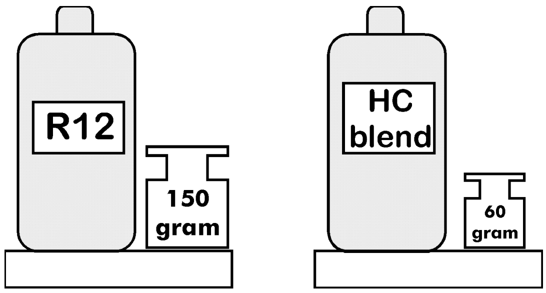
Weighing the refrigerant is the most accurate method, and should be used for all refrigerants where possible. If you do not know the weight of refrigerant, then charging to the correct suction pressure is the next best method.

Whichever method is used make sure that, if your charging equipment is also used with another refrigerant, e.g. R12, you do not contaminate the HC – evacuate or purge the equipment (hoses etc) before using it on a different refrigerant.

Charging by weight

The amount of HC refrigerant should be marked on the appliance. **It is only 40% of the equivalent R12 charge weight** - the lower weight means that greater care is needed with the accuracy of the weighing procedure.

Use an electronic balance with an accuracy of ±1 g when charging systems with less than 100 g of refrigerant. For greater charge weights less accuracy is acceptable.



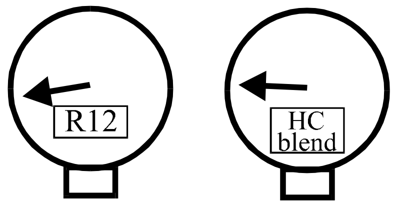
Electronic balances are safe to use with HC refrigerants – you do not need to make any changes.

Charging to the correct suction pressure

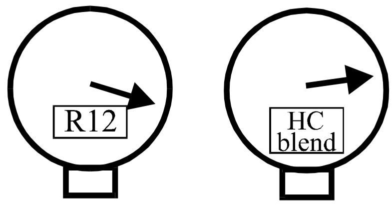
Appliances are often charged with refrigerant whilst they are running, and the refrigerant slowly charged in until the correct suction pressure has been reached. The equipment used for this procedure is usually just hoses and a gauge and is therefore is not hazardous and does not need to be changed.

The pressures that a hydrocarbon system will operate at are as follows:

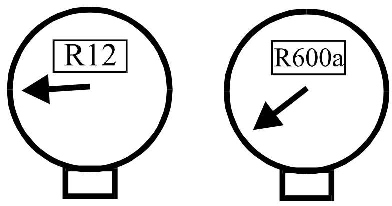
- The **suction pressure** with the HC blend will be almost the same as the R12 suction pressure;



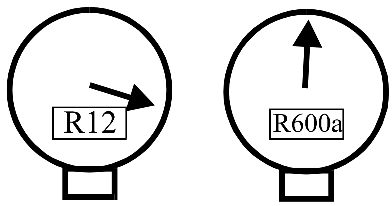
- The **discharge pressure** in case of HC blend will be between 1 and 2 bar (15 to 30 psi) lower than with R12;



- The **suction pressure for R600a** will be close to atmospheric pressure for a chilled food appliance, and will be lower than atmospheric pressure for a frozen food appliance (about 1 bar (14 psi) lower than for R12);



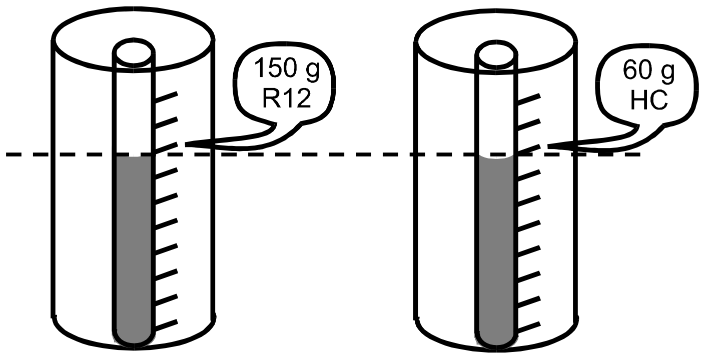
- The **discharge pressure with R600a** will be much lower than for R12. For example, in an ambient of 32°C (90°F) the discharge pressure will be about 5 bar (70 psi) lower than for R12.



Charging by volume

A charging still measures the volume of refrigerant to be charged into an appliance. The scale on the still is usually in ounces (oz) or grams (g), and is given for different conditions. If the charging still is not calibrated for different conditions (i.e. ambient temperature or refrigerant pressure) it cannot accurately measure any refrigerant.

The scale has been calibrated from the density of refrigerant, usually R12, at different temperatures or pressures.



The <u>same volume</u> of HC refrigerant as R12 must be used, but it will weigh less.

If the appliance has the weight of HC refrigerant marked on it, but your still is calibrated for R12 use the following calculation to find the equivalent R12 amount:

R12 weight = 2.5 x HC weight.

For example, if the cabinet needs 60 g of Care 30, this is equivalent to 150 g of R12 (60 x 2.5 = 150). The charging still should be filled with Care 30 to the level marked 150 g for R12, and all of this charged into the system. It will weigh 60 grams, but has the same volume as 150 grams of R12.

Some charging stills include a heater to speed up the charging process. This is not normally hot enough to ignite hydrocarbon refrigerants, but the contacts must be spark proof. Loose connections can spark and may ignite a flammable mixture. Some charging stills are combined with vacuum pumps. Make sure the pump does not have electrical components that can spark - usually the on / off switch is the only part which can spark.

Charging to a frost line

It is not recommended that you use this method unless you are familiar with the operation of the appliance on the HC refrigerant. The frost line may be different for the HC blend, R600a and R12.

Procedure for charging an HC refrigerant

The procedure outlined below must be followed for safe and accurate charging. The steps are outlined in the box below, and are then explained in more detail. The steps are very similar to those for R12, and are good refrigeration practice.

Step 1, ensure the area is well ventilated.

Step 2, connect the charging hose(s).

Step 3, remove air from the hoses(s).

Step 4, charge the HC refrigerant.

Step 1. Ensure the area is ventilated or work outside.

This will ensure that any HC refrigerant which leaks will be safely dispersed. There must be no flames within 2 m of the charging area. Switches within 2 m of the charging area should not be used.

Step 2. Connect the charging hose(s).

The hoses should be as short as possible to reduce the amount of refrigerant vented, e.g. if there is a problem during charging.

Connect the hose(s) to the charging equipment and system, but remember that the HC blend must be taken from the cylinder as a liquid.

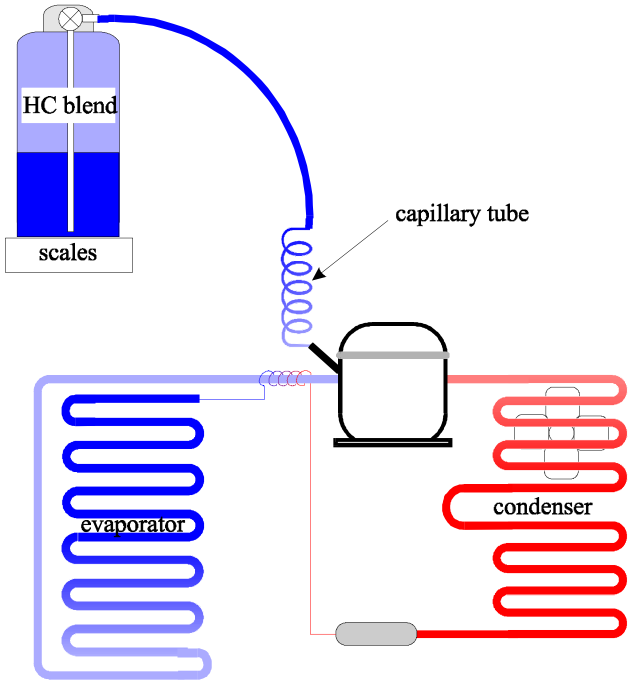
Step 3. Eliminate air from the hose(s).

If there is air in the hoses (or any other gas that is not HC) you must remove it. Avoid purging the hoses if possible - evacuate them using your vacuum pump. If you do purge the hoses, do this carefully using refrigerant from the cylinder. Purging is more hazardous when flammable liquid refrigerant is used, so minimise the loss of refrigerant by:

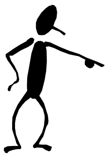
1. opening then immediately closing the cylinder valve to limit the quantity of refrigerant in the charging line;
2. venting a very small amount of refrigerant at the connection to the system - purging for 1 second is enough to push air out of the lines.

Step 4. Charging the HC refrigerant.

Accurately meter in the HC refrigerant - make sure you take it from the cylinder as a liquid if you are charging the HC blend, to ensure the correct blend composition is charged into the appliance. Refrigerant is charged into the process tube of the compressor so any liquid must be evaporated before it enters the compressor. To do this, put an expansion device (such as a short length of capillary tube) between the hose and the system, as shown in the diagram. This will evaporate the liquid refrigerant.



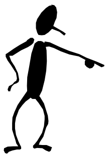
Remove the charging hose(s) carefully to minimise the amount refrigerant lost. Do this by closing the cylinder valve and running the system to draw in as much liquid as possible from the charging hoses. Seal the process tube as described in the next section.



Do not remove the label (showing refrigerant type) from the cabinet. If it has already been removed or is difficult to read, replace it.

Sealing the process tube

The charging connection can be brazed, but care must be taken. It is not possible to ignite the HC refrigerant in the system because it has no air mixed with it.



Ventilate the area before you light your brazing torch and while you braze. This will ensure any HC refrigerant that has leaked into the air has been safely dispersed.

To seal the process tube by brazing:

1. Pinch the process tube using pinching pliers or a pinch off tool;

2. Leave the pinching pliers or tool in place and use soapy water to check for leaks at the end of the tube (see next section for information on leak detection);

3. Braze the connection as normal.

4. Remove the pinching pliers or tool and test for leaks again. A sealing compound can be used on the area where the pipe has been pinched to prevent bending and later leakage at this point.

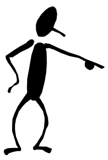
Check the process tube for leaks as described in the next section.

The process tube can also be sealed using methods which do not require brazing such as the Lokring system.

Leak testing

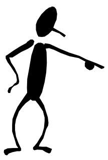
When the system has been charged and sealed, the process tube should be checked for leaks. (You may also need to check the whole system.) The safest and most accurate method for HC refrigerants in appliances is soapy water. This finds very small leaks and poses no hazard with a flammable refrigerant.

Other leak detection methods are available which may not be suitable with HC refrigerants. Most electronic leak detectors are not sensitive to HC refrigerants and may not be safe to use. Only special models suitable for HC refrigerants may be used (for example Tiff type 8800) but sensitivity and therefore reliability may deteriorate when used in dusty or CFC / HFC / HCFC contaminated areas.



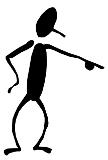
Never use a halide torch or lighted match to find hydrocarbon refrigerant leaks.

Each joint should be checked with the system at the highest practical pressure. Ideally the high side of the system should be checked when working, and the low side when the system is off.



Do not check the low side of an R600a system while it is running – the water will be drawn into the system if there is a leak.

If a leak is found the refrigerant should be safely removed and the system evacuated as described earlier before the leak is repaired.



Never braze a leaking joint with refrigerant in the system.

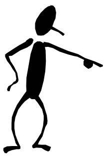
5. Conversion Procedures Using Hydrocarbon Refrigerants

It is possible, in most cases, to convert an appliance using R12 or R134a to the hydrocarbon blend. This can be done at the time when appliance needs servicing. The conversion is a simple procedure and is covered in this section:

- Assessment of necessary electrical component changes;
- How to assess if an appliance is suitable for conversion;
- Which hydrocarbon refrigerant to use;
- Conversion procedure;
- Example of conversion.

Appliances can be converted to HC refrigerants using a simple procedure. In most cases no changes are needed to the refrigeration circuit, but only to the electrical components.

It is simpler than the conversion procedure that is needed to convert CFC appliances to HFC refrigerants such as R134a. During this procedure the compressor oil is changed. This must be done several times, usually over a period of days or weeks. This conversion procedure must be planned in advance and can only be carried out properly on a working system.



You should not convert properly working CFC/HFC appliances to an alternative refrigerant. If the refrigeration circuit is working correctly it does not need to be converted. However, appliances can be converted if they need servicing.

The drop-in conversion procedure is simple and it should not add much time to the normal service / repair. You will need to:

1. Recover the R12 (or R134a);
2. Make the necessary repairs to the system;
3. Pressure and leak test the system;
4. Replace, re-position or enclose electrical components as necessary to make the system safe;
5. Evacuate the system;

6. Charge with the HC blend refrigerant;

7. Seal the process tube.

Step 4 is the only addition to the usual repair procedure. The procedure is covered in more detail later in this section.

Assessment of necessary electrical component changes

You need to examine an appliance to find out which electrical devices would need changing to make it safe to work with HC refrigerant. You should list all the electrical devices and use this section to determine:

- If they are unsafe to use with HC refrigerant;

- How they can be most easily made safe.

Unsafe devices are those which spark when they operate. Where such devices are attached to, or are close to the refrigeration circuit, they could ignite leaking HC refrigerant. The electrical devices which you need to examine are usually the compressor relay, compressor overload protector, thermostat, door switch, on / off switch and light.

These devices must be:

- Replaced with sealed or solid state types (that do not spark); or

- Enclosed in a sealed box; or

- Moved away from the refrigeration circuit to a safe place where leaked refrigerant cannot reach.

The table below shows the type of device and how you can make it safe. The method in bold type is the recommended option, and usually the simplest.

Ignition source	**Options for making safe – you need to use only one of these for each ignition source**
Compressor relay	**Replace with a solid state relay e.g. PTC (= Positive Temperature Coefficient) of the correct type.** Enclose the standard relay in a sealed box, if it can be removed from the compressor. If you replace the compressor, use a special HC blend compressor.
Compressor overload protector	**Use a sealed overload protector which is approved for use with HC refrigerant by the manufacturer of the compressor.** If you replace the compressor, use a special HC blend compressor.

Thermostat (for cooling and possibly heating)	**Replace with a sealed type.** Enclose in a sealed box that also has sealed cable entries. Re-locate remote from the refrigeration circuit and preferably above it.
Wiring connections	Ensure connections cannot work loose – use **ring** or spade types with a plastic sleeve.
Door switch	**Disconnect the light switch if internal light is not essential**. Replace by a sealed switch that is approved for use with HC systems.
On / off switch	**Replace with a sealed type.** Eliminate if not essential. Re-locate remote from, and preferably above, the refrigeration circuit.
Internal light	**Eliminate if not essential.** Seal the lamp holder if possible (e.g. using part of a bicycle inner tube). Replace lamp holder with a sealed type.
Starter / ballast for light	**Eliminate if not essential.** Move to outside of cabinet, remote from refrigeration circuit.



The photographs in figure 5-1 show (from left to right) a sealed relay/OLP combination, sealed overload protector and sealed thermostat.

Special HC blend compressors will be supplied by the manufacturers with safe relay (PTC type) and overload protector (sealed).

The fan motors and capacitors used in appliances are not ignition sources.

A sealed box can be used to house the relay and / or thermostat. This is in addition to the terminal box mounted on the compressor. The box should meet the following conditions:

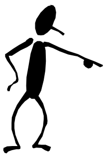
- It should be sealed to at least IP54 (dust proof and splash proof, e.g. according to BS 5345 part 1:1976). This is considered by European specifiers to be adequate to significantly reduce the probability of combustion in the event of a leak;

- The sealing gasket in the lid should be permanently fixed to the lid so that it cannot be removed during service and then not correctly re-fitted. A label should be fixed to the lid showing the importance of replacing the lid to maintain the seal after servicing;

- The cable entries should be via terminals permanently fixed to the electrical box. This is in place of sealed but removable entries such as glands and is recommended to eliminate the possibility of other methods of entry being left unsealed after service.

How to assess if an appliance is suitable for conversion

Not all appliances can be safely and practically converted to HC refrigerant. In some cases the cost of the conversion is too high. In others, it may not be possible to eliminate all the ignition sources. To determine whether it is possible and practical to convert an appliance you must examine the appliance. The flow chart below shows you how to do this.

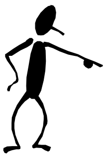


Do not try to reduce the cost of conversion by not making the necessary changes to electrical devices.

In general, the most practical appliances to convert are:

- Those with no electrical components in the food compartment, such as chest coolers and freezers;

- Those where the refrigerant cannot leak into the food compartment, such as some domestic refrigerators with foamed in evaporators (this depends on the design of the appliance, you may not always be able to identify the leakage paths).



Do not convert:

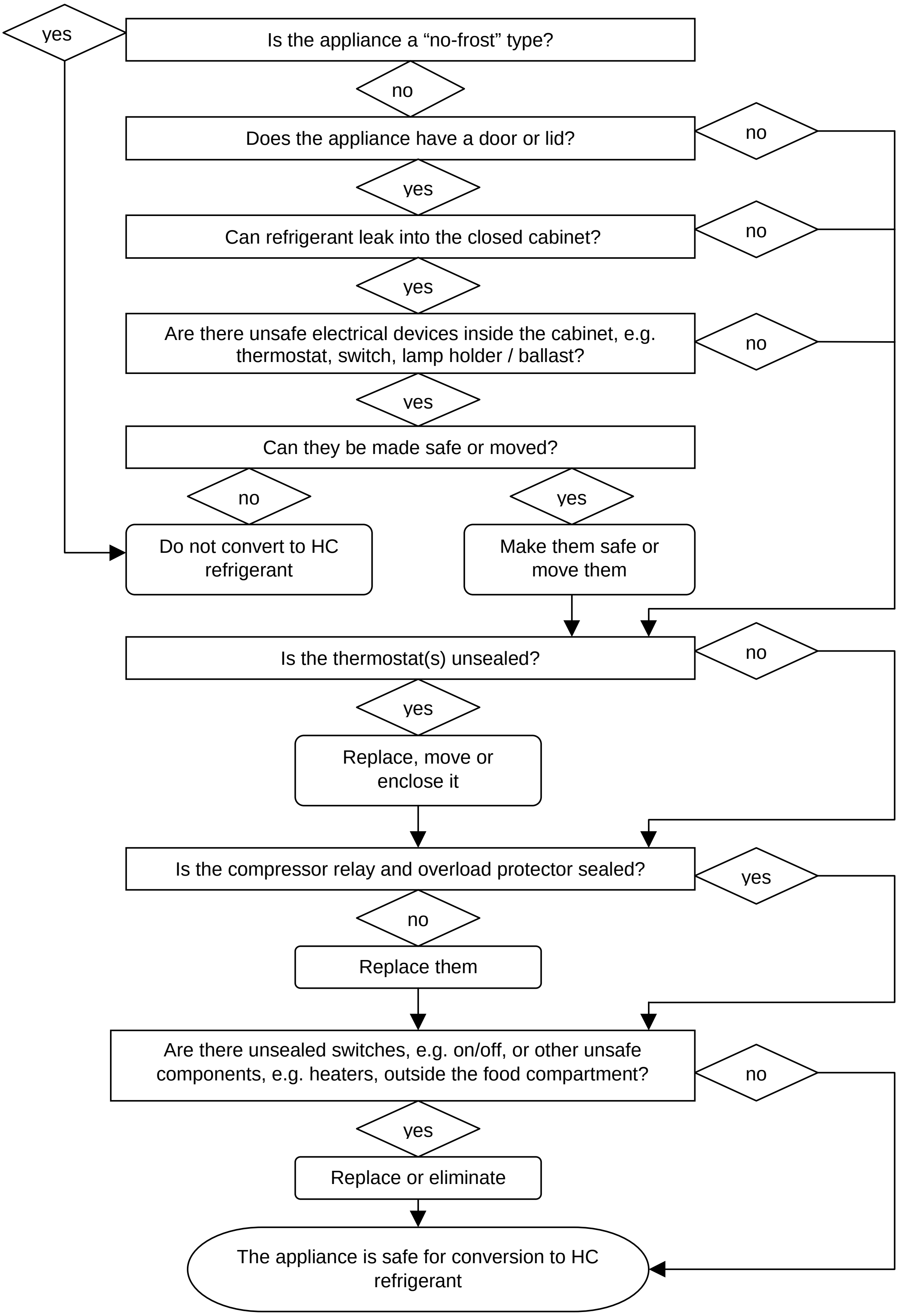
- Domestic appliances where the HC refrigerant charge will be more than 150 g;

- Commercial appliances where the HC refrigerant charge will be more than 250 g;

- No-frost refrigerators.

These recommended maximum charges are based on European standards for domestic and commercial systems using HC refrigerants.

Flow chart for assessing appliance conversion



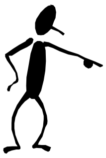
Which hydrocarbon refrigerant to use

The hydrocarbon blend of propane and iso-butane (approximately 50% propane / 50% iso-butane by weight, e.g. CARE 30, Ecool-PIB, ER12) should be used to replace R12 or R134a.   When this blend is used:

- The capacity and energy consumption of the system will be similar to R12;
- The condensing pressure will be up to 2 bar lower than for R12;
- The refrigeration circuit components (compressor, condenser, expansion device, drier, evaporator) do not need to be changed;
- The compressor lubricant (usually a mineral oil) does not need to be changed.

The compressor lubricant (usually a mineral oil) will remain the same.

The HC blend also works with the polyol ester oils used with R134a, and so can be used to replace R134a without changing the compressor oil.   However, you will need to evacuate the system for longer because the compressor oil used with R134a absorbs more moisture.



Do not use pure R600a (iso-butane) or pure R290 (propane) to replace R12 or R134a – the system will not perform properly.   Also, make sure the HC blend you use proper refrigerant quality and is specified as a possible replacement for R12 (i.e. has the right composition of approx. 50% R600a and 50% R290 by weight).

Conversion procedure

The conversion procedure uses common, good refrigeration practice and equipment, which you should already have, or can easily obtain. The steps are described below.

Step 1, assess the appliance

Follow the flow chart on page 5-5 to assess the appliance to ensure:

- It can be converted to an HC blend safely and practically;
- You have the necessary electrical components.

Step 2, recover the R12

Do **NOT** vent the R12 remaining in the system into atmosphere because of the environmental damage it does. Remember vented CFCs deplete ozone, which causes an increase in eye cataracts and skin cancers. Instead, recover the R12 from the appliance and store it in cylinders. It can later be recycled (cleaned) and re-used.

Appendix 7 gives more information about recovering refrigerant and shows how you can make your own recovery machine.

Step 3, repair the appliance as necessary

The appliance will probably need some repair work. Do the necessary repair / replacement of the system components and the system in the same way as you do for R12 systems.

If the system is opened to atmosphere or if the compressor has burnt out, or if the system has been contaminated with moisture you should change the filter.

It is **not** necessary to fit a different type of filter drier.

Step 4, Pressure testing and leak detection

Carry out pressure testing and leak detection in the system similar to R-12 systems as discussed in section 4.

Step 5, replace, re-position or enclose electrical components as necessary

You will need to replace, re-position or enclose sparking electrical components that are close to the refrigeration circuit (as described in the previous section).

Step 6, evacuate the system

You should evacuate the appliance as usual, as shown in section 4.

If you are converting an R134a system the evacuation procedure would be longer than for a CFC / HC system because the polyol ester oil absorbs moisture more readily.

Step 7, charge with the hydrocarbon blend

Follow the procedure in section 4, which describes how you should safely charge a hydrocarbon blend into an appliance.

If you are going to charge by weight you will need to calculate the amount of hydrocarbon blend needed as follows:

weight of hydrocarbon blend = 0.4 x weight of R12.

Example, if the charge of R12 in the appliance was 260 g, the weight of the HC blend needed is:

0.4 x 260 g = 104 g.

If you are going to charge the refrigerant in until the correct pressures are reached remember that the suction pressure with the hydrocarbon blend will be the same as for R12, but the discharge pressure will be between 1 bar and 2 bar lower.

You must clearly label the appliance after it has been charged with the hydrocarbon blend to show that the refrigerant is flammable. Figure 5-2 gives an example of such a label.

The label should be fixed to the compressor so that a service technician can see it if the appliance needs repairing.

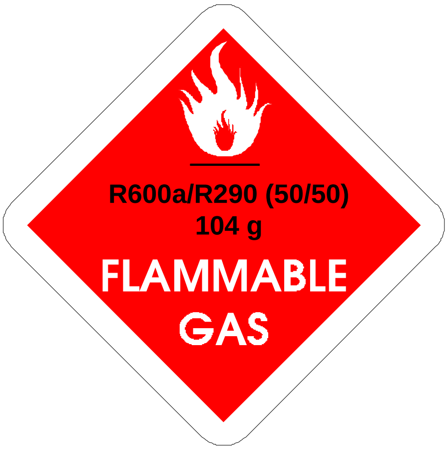


Figure 5-2

Step 8, seal the process tube and leak test

Seal the process tube as described in section 4. Leak test the system using soapy water as described in section 4.

Examples of conversion

Chest bottle coolers were converted to HC refrigerants at Hyderabad. An example is given below. The assessment showed that:

- The cabinet had a lid, but there were no electrical components inside it;
- The thermostat was unsealed and close to the refrigeration circuit – it would have to be replaced with a sealed type;
- The compressor already had a combined, sealed relay and overload protector;
- There were no switches;
- The system used 240g of R12.

The following procedure was used to convert the cabinet:

1. A sealed thermostat was sourced with suitable specifications;
2. The R12 was recovered using piercing pliers and a recovery machine produced by a local company for the training workshop;
3. An extension tube was brazed on with a flare nut at the end. This connection was used for the vacuum pump and the charging hose;
4. The system was evacuated;
5. The thermostat was changed to the sealed type;
6. 96g of hydrocarbon blend refrigerant (R290/R600a) was charged in, using an electronic balance;
7. The process tube was crimped and brazed;
8. The tube was leak tested;
9. The appliance was labelled to show the refrigerant type and amount;
10. A warning label was put on the compressor to indicate that flammable refrigerant was used.
11. The appliance was run to check that it would pull down the temperature.

Appendix 1, Refrigerant Properties and Chemical Data Safety Sheet for Hydrocarbon Refrigerants

This appendix includes:

- Hydrocarbon refrigerant properties
- Hydrocarbon blend characteristics.

The following table gives data for R600a and a typical commercially available propane / iso-butane blend (Care 30). Data for R12 is included as a comparison.

Property, metric unit, weight basis	R600a	HC blend	R12
Boiling point at 1 atmosphere, °C	-11.8	-31.5	-29.8
Specific heat of liquid at 30°C, kJ/kg K	2.49	2.54	0.99
Specific heat of vapour at constant pressure at 30°C, MJ/kg K	1.86	1.7	0.62
Ratio of specific heats (C_p/C_v) at 1 atmosphere, 30°C	1.10	1.116	1.136
Density of liquid at 30°C, Mg/m^3	0.545	0.517	1.292
Density of saturated vapour at boiling point, kg/m^3	2.81	2.6	6.3
Latent heat of vaporisation at boiling point, kJ/kg	362	405	165
Thermal conductivity of liquid at 20°C, W/m°C	0.098	0.1	0.07
Thermal conductivity of vapour at 30°C, 1 atmosphere, W/m°C	0.017	0.018	0.010
Surface tension at 25°C, mN/m	9.55	8.6	8.5
Viscosity of liquid at 30°C, centipoise	0.14	0.11	0.19

Hydrocarbon blends

The propane / iso-butane blend is a zeotropic blend which behaves differently in the evaporator and the condenser to single substances and azeotropic blends.

A zeotropic blend evaporates (and condenses) at a range of temperatures instead of a single temperature, as shown in the diagram below.

The refrigerant is at the bubble temperature when it is just a pure liquid (e.g. when it has just condensed), and is at the dew temperature when it is just a pure gas (e.g. when it has just evaporated).

The range of temperatures between the dew and bubble is called the temperature glide. For the propane / iso-butane blend, the temperature glide as approximately 8°C, as shown in figure A1-1.

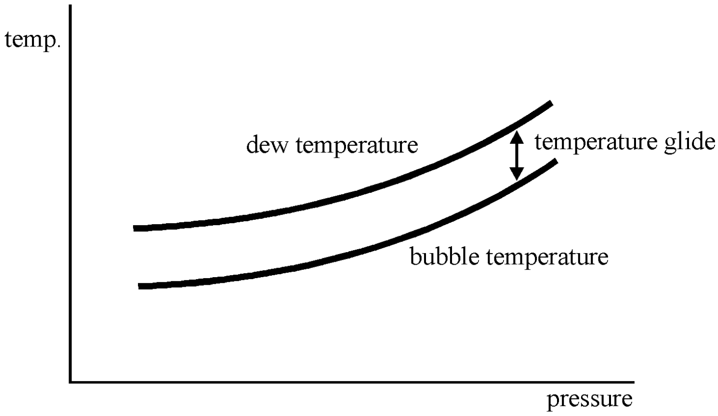


Figure A1-1. Pressure / temperature relationship for the HC blend

The refrigerant behaves differently in the evaporator and the condenser. The evaporating temperature rises as more refrigerant changes from liquid into gas, as shown in the diagram below.

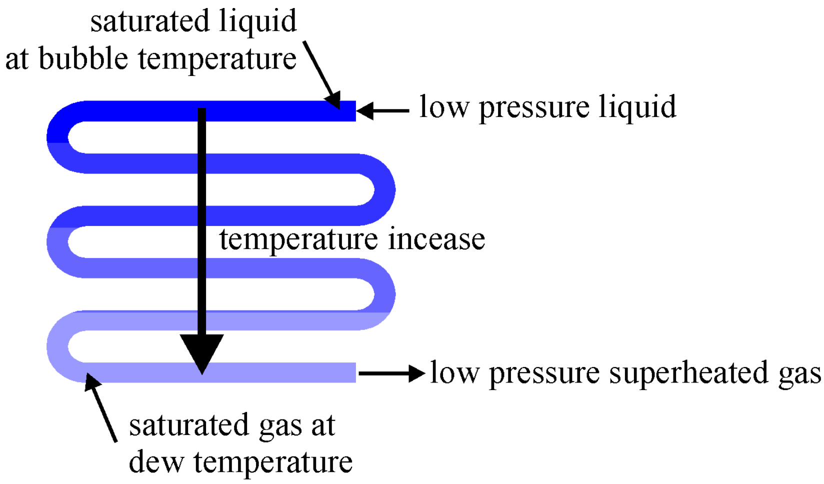
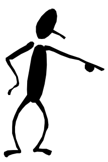


Figure A1-2. Temperature glide in an evaporator

In the condenser the condensing temperature drops as gas changes to liquid.

The changing evaporating temperature may result in uneven ice build up inside an appliance. This is not usually a problem.



When zeotropic blends are used, they must be removed from the cylinder as a liquid.

A gas taken from a cylinder has the wrong composition, as shown in the example for a typical commercially available HC blend refrigerant (Care 30). This will effect the reliability and performance of the system.

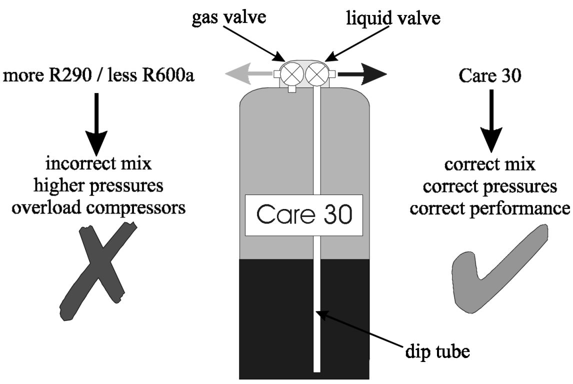
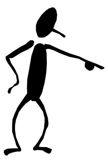


Figure A1-3. Charging a zeotropic blend

The system will run at higher pressures than expected (and therefore may leak), and the compressor may be overloaded.

Zeotropic blends are usually supplied in cylinders with a liquid off-take valve. Where there is only a gas off-take, the cylinder must be inverted (carefully) to remove the refrigerant as liquid.



The composition of the blend is important – if it is not right the appliance will not operate correctly.

Many blends are available with the correct composition. Make sure you use the correct blend – it makes a difference to the performance and the pressures. Do not try to make the blend yourself. See appendix 4 for details of HC blend suppliers.

Appendix 2, Training Information

This appendix includes the following information to be used to put together a training programme for technicians:

- Suggested training programme for a 2 day course;
- General hints for a the training course;
- Trainee's manual.

Suggested training programme

The suggested training programme below covers the knowledge and skills needed by a service technician to safely handle HC refrigerants. The times specified are suggested as a guideline – the actual time needed will depend on how many technicians are trained at one time.

Topics covered	**How**	**Time needed, hours**	**Equipment, tools needed**
Hydrocarbon refrigerants			
CFC / HCFC phase out; HC refrigerants available; HC refrigerant properties; HC blends; Purity of HCs as refrigerants.	Theory	1	Overhead transparencies
Safe HC refrigerant handling			
Flammability; Other safety hazards; Precautions; Handling HC cylinders; Storage and transport of HC cylinders.	Theory	1	Overhead transparencies
Servicing with HC refrigerants			
Removing HC from a system; Evacuation of HC systems; Brazing HC systems; Charging with HCs; Sealing the process tube; Leak testing; Charging components.	Theory intro-duction, practical	4	Appliance, hoses, vacuum pump, charging equipment, brazing equipment, HC refrigerant, leak tester, example components.

Conversion to HC refrigerant			
When to convert systems; What systems to convert; Component changes needed; Which HC to use; Conversion procedure.	Theory intro-duction, practical	4	Appliance, hoses, vacuum pump, charging equipment, brazing equipment, HC refrigerant, leak tester, components.
Making a recovery machine			
Principle of a recovery machine; Components needed; How to assemble a recovery machine; Operation of the recovery machine.	Theory intro-duction, practical	2	Old condensing unit, drier, copper pipe, material for frame, valves, fittings.

General hints for a training course

Practical demonstration / participation is the best way to convey safe HC refrigerant handling. The sessions should emphasise how HC refrigerant can be handled using simple basic tools and equipment (which most service companies should already have).

It is helpful if the tools and equipment used are all available locally. The appliances used in demonstrations should also be locally produced and widely used where possible.

You must make sure the training workshop is a suitable and safe area for working with HC refrigerants. If it is a closed workshop then adequate ventilation must be provided (e.g. by extraction fans).

You can use the information in Appendix 3 (basic tool / equipment list) to check that you have the necessary tools and equipment to carry out the training course.

Manual for trainees

This manual can be used for trainees if you omit this appendix. If you prefer, a more concise manual can be prepared using the following sections / appendices:

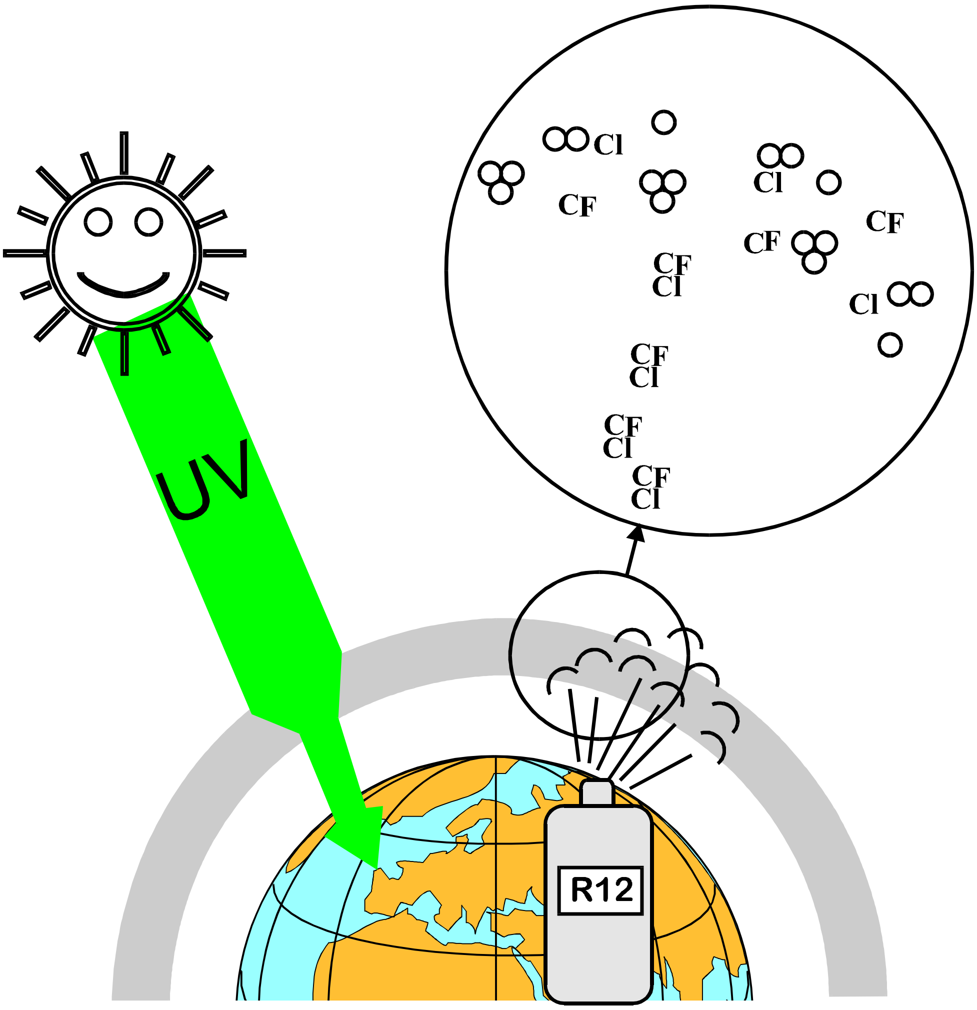
- Section 1, Introduction;
- Summary of environmental issues (page 4 of this appendix);
- Summary of HC refrigerant information (page 5 of this appendix);
- Simple workplace precautions (page 3.4);
- Section 4, Service Procedures;
- Section 5, Conversion procedure;

- Appendix 3, Basic tool / equipment list;
- Appendix 6, Check list for a service company;
- Appendix 7, Making a recovery machine.

You can also include information about local suppliers of HCs, components, tools and equipment, similar to that given in Appendix 4.

The summaries referred to above are given in the following pages.

Summary of environmental issues of refrigerants

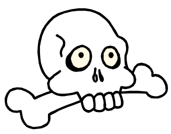


⇒ CFCs and HCFCs (e.g. R12, R502, R22) deplete ozone in the upper atmosphere.

⇒ The ozone layer protects us from too much UV (ultra violet) radiation.

⇒ When CFCs and HCFCs are vented, more UV radiation reaches us.

⇒ This causes an increase in eye cataracts and skin cancers and reduces crop yields.

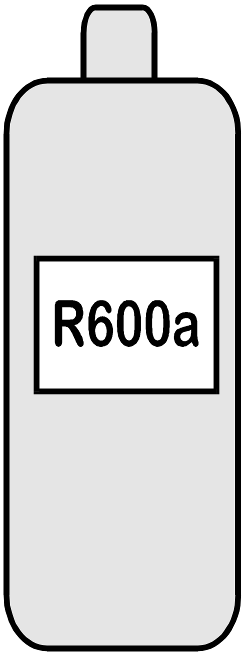


You can reduce this harm by:

- **not venting CFCs and HCFCs when you are servicing refrigeration and air conditioning equipment, and**

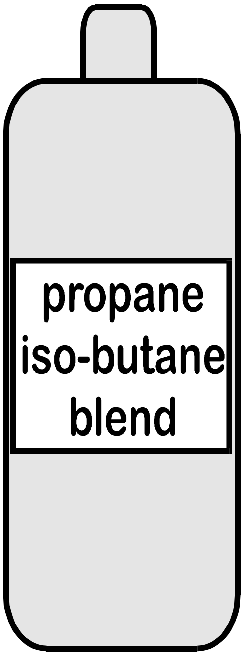
- **by converting CFC appliances to HCs when you service them.**

Summary of HC Refrigerant Information



R600a is iso-butane and is used in some domestic fridges.

- Pressures are lower than R12 – about 1 bar (15 psi) lower on the suction side, and 7 bar (100 psi) lower on the discharge side.
- Refrigerating capacity is lower, so a compressor with a larger displacement is needed. If you need to replace a compressor, make sure you use an R600a model.
- Do not re-charge an R600a system with any other refrigerant.



Propane / iso-butane blend is used in some domestic fridges and small commercial appliances.

- Suction pressure is similar to R12, the discharge pressure is between 1 and 2 bar lower than for R12.
- Capacity is the same as for R12, so you can use the same size compressor.
- This is a zeotropic blend and must be taken from the cylinder as a liquid.
- This blend can be used to replace R12 or R134a in an existing system – changes to electrical components may be necessary.

Appendix 3, Basic Tool / Equipment List

The tools listed in this appendix are those needed for basic servicing of HC systems. They are very similar to those that should be used with other refrigerants. The table below shows when you will need each item.

Tool	**Service of HC systems**	**Conversion of CFC / HFC systems to HCs**
Piercing pliers	✔	✔
Tube adapter / schreader valve	✔	✔
Vacuum pump, 2 stage type	✔	✔
Brazing equipment (do not use soft solder)	✔	✔
Balance or still or manifold set	✔	✔
Hoses	✔	✔
Crimping (pinching) pliers or tool	✔	✔
Soapy water and brush or electronic leak detector which is safe and sensitive for HC detection.	✔	✔
Fire extinguisher	✔	✔
Recovery machine		✔
Recovery cylinder and balance		✔

Appendix 4, Suppliers of Tools, Equipment and Hydrocarbon Refrigerant

Category	Address	Product
Hydrocarbon Refrigerant Suppliers	Calor Gas Refrigeration Athena Drive, Tachbrook Park, Warwick, CV34 6RL. United Kingdom Mrs. Loretta Powell Tel. +44-1926 330088 Fax. +44-1926 318706 http://www.calorgas.co.uk	Isobutane (R600a), Propane (R290), CARE 30 Blend (R600a/R290)
	ECOZONE Frans Halsplein 8 NL-2021 DL-Haarlem The Netherlands Mrs. Marja Tummers Tel. +31-23-525 95 57 Fax. +31-23-525 95 26 http://www.ecozone.nl	Isobutane (R600a), Propane (R290), Blend (R600a/R290)
	ELGAS Ltd 10 – 18 Cliff Road, Milson's Point NSW 2061, Australia Phone + 61 2 957 3422 Fax + 61 2 925 0454	Isobutane (R600a), Propane (R290), CARE 30 Blend (R600a/R290)
	ESANTY Refrigerants Suite 9, 602 Whitehorse Road Mitcham, Victoria Australia 3132. Tel. +61 3 9872 3043 Fax. +61 3 9873 5925 http://www.esanty.com.au	Blend ER12 (R600a / R290)
	LINDE AG Werksgruppe Technische Gase Seitnerstr. 70 D-82048 Hollriegelskreuth Germany Tel. +49-89-7446 1360 Fax. +49-89-7446 1490 http://www.linde.de/linde-gas/	Isobutane (R600a), Propane (R290), Blends (R600a/R290)
	REFCO Manufacturing Ltd. Industriestr. 11 CH-6285 Hitzkirch Switzerland Tel. +41-41-919 72 82 Fax. +41-41-919 72 83 http://www.refco.ch	Isobutane (R600a) in aerosol cans
	SHV Energy India Pvt. Ltd. Block no. 39, Plot no. 4 East Patel Nagar New Delhi – 110 008. India. Mr. Jagdeesh Bhatia Tel. +91-22-64 58 301 Fax. +91-22-64 58 094	Isobutane (R600a), Propane (R290), CARE 30 Blend (R600a/R290)

Category	Address	Product
Industrial charging stations / recovery units	Galileo Vacuum Tec. S.P.A. Via delle Fonti 432 50047 Prato Firenze – Italy Mr. M. Ingilesi Tel. +39-574-564 329 Direkt 564 340 Fax. +39-574-564 300	Production scale charging equipment
	A'Gramkow Augustenborg Landevej 19 DK-6400 Sønderborg Denmark Tel. +45 74123636 Fax. +45 74433646 http://www.agramkow.dk	Production scale charging equipment
	RDA Refrigeration Engineering Riverway Industrial Estate Newport Isle of Wight PO30 5UX United Kingdom Tel. +44-1983-821 189 Fax. +44-1983-821 149	Portable recovery units for hydrocarbon refrigerants
	VES (Vacuum Engineering Systems) St. Modwen Road Stretford Manchester M32 0ZE United Kingdom Tel. +44-161-866 8860 Fax. +44-161-866 8861	Production scale charging and helium leak detection equipment (medium size)

Category	Address	Product
Safe electric components for compressors and appliances	Annapurna Electornics and Services Pvt. Ltd. Plot No. 41, Phase V, Jeedimelta Hyderabad- 500018 Tel: 91-40 371 2950 Fax: 91-40 309 6492	Sealed thermostats, Solid states, Compressor, starting devices (PTC), Sealed OLP's and combination type relays Sealed switches and sealed lamp sockets
	ELECTRICA s.r.l. Mr. Salami Via privata della Torre 24 20127 Milano, Italia Tel. +39-2-289 2641 Fax. +39-2-282 7511	Solid state compressor starting devices (PTC), sealed OLP's and combination type relays according to IEC 79-15
	ELTEK S.p.A. Strada Valenza 5-A 15033 Casale Monf. Italy Tel. +39-142-76 451 Fax. +39-142-782 263 http://www.eltek.it	Sealed door switches Sealed lamp sockets for domestic refrigeration according to IEC 79-15
	GENERAL ELECTRIC Mr. Gian Barbieri Tel. +39-2-8950 4755 Fax. +39-2-8953 1652	Sealed thermostats according to IEC 79-15
	IRCA S.p.a. Mrs. Alfare Viale Venezia 31 31020 San Vendemiano (TV) Italy Tel. +39-438-49 02 09 Fax. +39-438-40 00 45	Electrical defrost heater according to IEC 79-15
	Procond Elettronica spa Marino Mancini Zona Industriale 6 32013 Longarone (BL) Italy Tel. +39-437-577 302 Fax. +39-437-772 220	Spark Proof Thermostats according IEC 79-15
	Rexnord Electronics LTD. 92-D Govt. Indl. Estate Charkop. Kandivli (W) Bombay – 400 067 India Mr. Josy Cardoz Tel. +91-22-805 6275;801 0715 Fax. +91-22-626 9466; 862 7784	AC Axial Fan (e.g. for Visi-Cooler, Bottle coolers)
	Sealed Unit Parts Co., Inc. 2230 Landmark Place P.O. Box 21 Allenwood, NJ 08720 Tel. +1-908-223 6644 Fax. +1-908-223 1617	Solid state compressor starting devices (PTC), OLP's and combination type relays according to IEC 79-15
	TEXAS INSTRUMENTS Product Information Centre Japan Tel. +81-3-3457 0972 Fax. +81-3-3457 1259	Solid state compressor starting devices (PTC) according IEC 79-15

Category	Address	Product
Gas Sensors and Leak Detection for servicing and industrial	ALTRONIC Di Allodi F. Mana L. & C. SEDE LEGALE: Via Roma 60 STABILIMENTO: Via Torino 84 12041 BENE VAGIENNA (CN) Allodi Francesco Tel. +39-172-654445 Fax. +39-172-654105	Leak detectors for production / servicing and gas warning systems
	Anglo Nordic 12/14 Island Farm Avenue West Molesey Surrey KT8 2UZ Mr. Colin Beaumont Tel. +44-181-979 0988 Fax. +44-181-979 6961	Leak detectors for production / servicing and gas warning systems
	Dräger Germany Hrn. Günther Bendisch Moisshinger Allee 53/55 P.O. Box 1339 23451 Lübeck 1 Germany Tel. +49-451-882 2094 Fax. +49-451-882 2080 http://www.draeger.de	HC Gas sensors and gas warning systems for industrial use
	ION SCIENCE LTD. The Way, Fowlmere Cambridgeshire SG8 7QP England Tel. +44-1763-208 503 Fax. +44-1763-208 814	Leak detectors for production / servicing and gas warning systems
	Joseph Leslie Dräger Ltd. Leslico House, 4th Floor 87-c Bhavani Shankar Road Dadar Bombay 400 00 28 India Mr. Chowhan / Mr. Joshi Tel. +91-22-4 22 75 87 Fax. +91-22-4 30 60 44 http://www.draeger.de	HC Gas sensors and gas warning systems for industrial use
	TIF Instruments, Inc. 9101 NW 7th Avenue Miami, Florida 33150 Tel. +1-305-757 8811 Fax. +1-305-757 3105	Leak detectors for production / servicing
	VES (Vacuum Eng. Systems) St. Modwen Road Stretford Manchester M32 0ZE United Kingdom Tel. +44-161-866 8860 Fax. +44-161-866 8861	Production scale charging and helium leak detection equipment (medium size)

Category	Address	Product
Digital balances for HC refrigerant charging in small to medium scale production / servicing	Essae-DIGI Gala 61, First Floor Raj Industries Complex Military Road Andheri Bombay-400059 Tel. +91-22-8389577 Fax. +91-22-8371509	Digital balances (for servicing / 2kg ±1g and small scale production / 15kg ±2g) Semi-automatic charging station (with solenoid valve)
	Essae-DIGI 51-A/1, 1st Floor Green Park Extn. Yusuf Sarai New Delhi-110016 Mr. Mohan Bhatt Tel. +91-11-6855232	Digital balances (for servicing / 2kg ±1g and small scale production / 15kg ±2g) Semi-automatic charging station (with solenoid valve)
	Essae-DIGI H-No. 54, Paigha Colony Secunderabad-500 003 Tel. +91-40-811 701	Digital balances (for servicing / 2kg ±1g and small scale production / 15kg ±2g) Semi-automatic charging station (with solenoid valve)

Category	Address	Product
Servicing Equipment	REFCO Manufacturing Ltd. Industriestr. 11 CH-6285 Hitzkirch Switzerland Tel. +41-41-919 72 82 Fax. +41-41-919 72 83 http://www.refco.ch	Servicing equipment for hydrocarbon refrigerants
	Robinair PO Box 51, London Road Daventry, Northamptonshire NN11 4YU. Tel. +44 1327 714461 Fax. +44 1327 706632 http://www.robinair.com	Vacuum pumps and charging equipment.
	VULKAN TECHNOLOGIES (S) PTE LTD Ang Mo Kio Industrial Park 2 # 01-1162 Block 5089 Singapore 569592 Tel. +65-4 81 80 38 Fax. +65-2 24 26 56	Servicing equipment for hydrocarbon refrigerants Lockring connectors
	VULKAN LOKRING GmbH & Co. KG Heerstr. 66 D-44653 Herne Tel. +49-2325-922 0 Fax. +49-2325-5 12 22	Servicing equipment for hydrocarbon refrigerants Lockring connectors

Appendix 5, Costs of Conversion

The cost of conversion of a CFC based appliance includes the cost of electrical components to be replaced, HC refrigerant and cost of labour. As suggested in section 5 of this manual, you should only convert an appliance that is not functioning and therefore needs some servicing. In this case the cost of refrigerant and servicing are not additional but common for normal repair and conversion. However there will be some additional labour cost for replacement of components in case of a conversion.

Estimated cost of electrical components that are compatible with HC refrigerants along with additional labour cost are listed in the table below. The cost estimates are based on retail prices for the components as they are available in the Indian market. If some of the original components are already suitable for use with HC refrigerant (i.e. if there is already a PTC and sealed OLP as for many modern compressors) replacement is not necessary and therefore conversion costs will reduce accordingly.

Item	Cost of Components in Indian Rupees	Cost of Components in US$
Sealed Thermostat	170	4.2
Sealed Lamp Holder	70	1.6
Sealed Door Switch	60	1.5
Sealed PTCR from 1/8 HP to 1/4 HP	90	2.2
Sealed OLPs	70	1.7
Additional Cost of Labour for replacement of Components	200	5.0
Subtotal conversion costs (maximum)	***approx. 600 ... 700***	***approx. 15... 17***
*Cost of Refrigerant	60-150	1.5 ... 6.
*Normal Cost of Servicing of Application	800 ... 1600	20 ... 40
Total repair costs including conversion	***1600 ... 2200***	***36 ... 63***

*Cost of servicing of application is not an additional cost in case of conversion as it is assumed that the unit is not functioning and therefore needs some servicing anyhow.

Appendix 6, Check List for Service Company

You can use this tick sheet to make sure you have the correct equipment etc for handling HC refrigerants.

Check …	**Yes / no**
Have technicians been trained in HC safe handling, service, conversion?	
Are the technicians aware of the safety procedures to be used?	
Is there a training / reference manual available?	
Have you identified a suitable area for venting and charging HC refrigerant?	
Do you have at least one fire extinguisher (preferably 1 kg dry powder type)?	
Have you identified all potential ignition sources (flames and sparking electrical components within 2 m) and made sure they are not a hazard when charging or venting HC?	
Do you have safe and suitable charging equipment?	
Have you refrigerant grade hydrocarbon?	
Have you a suitable storage place for HC refrigerant?	
Do you have safe electrical components if necessary?	
Do you have the correct, permanent labels to show HC refrigerant has been charged?	

Appendix 7, Recovering Refrigerant and Making a Recovery Machine

CFC, HCFC and HFC refrigerants should not be vented into the atmosphere when you service a refrigeration / air conditioning system. You can recover the refrigerant using a simple recovery machine and cylinder. It is recommended that you use a high quality recovery machine – they are widely available. However, if you cannot afford to buy this type of machine, or if they are not available locally, then you can make your own – this is better that venting the refrigerant.

This appendix covers:

- Basic recovery procedure;
- Components needed to make a recovery machine;
- Checking the components;
- Assembly of the machine;
- Operation and maintenance;
- Reliability.

Basic recovery procedure

A recovery machine and recovery cylinder is used to recover the R12. The machine is very simple - usually comprising a hermetic compressor, air cooled condenser and filters. The refrigerant from the appliance is drawn through the filters by the compressor and then discharged into the recovery cylinder. The recovery cylinder should just be used for recovered (and therefore contaminated) refrigerant. Do not mix different refrigerants in a recovery machine or cylinder as the resulting mixture cannot be recycled and re-used.

You should weigh the recovery cylinder while filling it - it is dangerous to overfill a cylinder. Do not fill the cylinder to more than 80% of its volume. The safe filling weight of R12 should be marked on the recovery cylinder.

The diagram in figure A7-1 shows how a recovery machine is to be connected to the system.

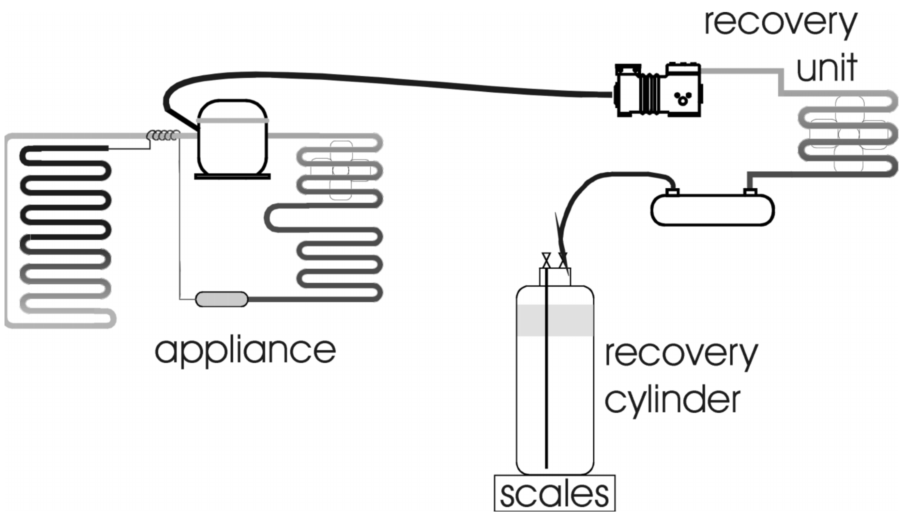
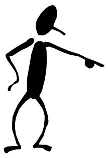


Figure A7-1. Diagram of the recovery setup



You can build your own recovery machine. The simplest and most practical machines use a small hermetic compressor (the larger the compressor the quicker the recovery process will be).

The compressor must be protected from the contamination in the recovered refrigerant. Therefore a good filter drier must be incorporated into the suction side of the machine. The machine must be protected against excess pressure - a high pressure switch, set to no more than 17 bar, must be fitted at the compressor discharge. Many commercially available machines also include devices which protect the compressor from liquid refrigerant, and oil separators.

Do not recover hydrocarbon refrigerants with a recovery machine unless all the recovery machine electrical devices - incl. compressor electrics - are solid state or sealed.

Figure A7-2 shows an example of a portable recovery unit. Similar models are available which can handle all kind of refrigerants, including hydrocarbons.

Figure A7-2. Example of portable recovery unit. Special models are available that can handle all refrigerants, including hydrocarbons

Components required to build a recovery machine

These can be old parts unless stated otherwise.

- Hermetic condensing unit with working compressor (max. 1hp), or a separate condenser and compressor. If you are only going to recover R12, then you can use an R12 compressor. If you will need to recover high pressure refrigerants such as R22 or R502, then you should use a compressor suitable for use with R22 or R502. These compressors can also be used with R12;
- Wooden or metal base possibly fitted with wheels and/or handles for ease of movement (the base is not necessary if you use a condensing unit which already has a base frame);
- High and low pressure switches (or dual pressure switch);
- 3/8in. filter/drier (this must be new);
- One 3/8in. hand shut off valve (if a valve is not fitted to the condensing unit);
- One ¼in. hand shut off valve (if a valve is not fitted to the condensing unit or on the liquid receiver);
- ¼in. & 3/8in. copper pipe;
- ¼in. & 3/8in. copper T connector;
- ¼in. & 3/8in. flare nuts;

- ¼in. to 3/8in. copper connector;
- On/off switch with fuse.

Initial checks

1. Check that the compressor is in good condition and is pumping efficiently:

    I. Fit a pressure gauge to the inlet valve, or to the suction pipe using a line tap valve if an isolating valve is not fitted to the condensing unit;

    II. Open the discharge shut of valve (if fitted);

    III. Switch on the mains supply to the unit;

    IV. Check the suction pressure gauge. If the compressor is in good condition it should quickly pull down to a vacuum.

2. Check that the condenser fan is working.
3. Switch off the electrical supply.

Do not leave the compressor running for more than about 10 seconds during this test.

Assembly

1 Fit the compressor and condenser to a base if necessary. Wheels and handles will make the unit easier to move.

2. Cut the discharge pipe between the outlet of the condenser and the liquid receiver.
3. Remove the liquid receiver. Is it necessary in every unit even if they have compressor, condenser separately and no liquid receiver.
4. Fit a wooden side panel to the base – this is to mount the pressure switches, electrical components and shut off valves.
5. Mount the ¼in. shut off valve and pressure switches onto the side panel.
6. Insert the ¼in. copper T piece into the discharge line from the condenser.
7. Cut and bend two pieces of ¼in. pipe to connect the T piece to both the HP switch and the ¼in. shut off valve.
8. Fit a flare nut and flare the ends of the two pipes to fit the HP switch and the shut off valve.

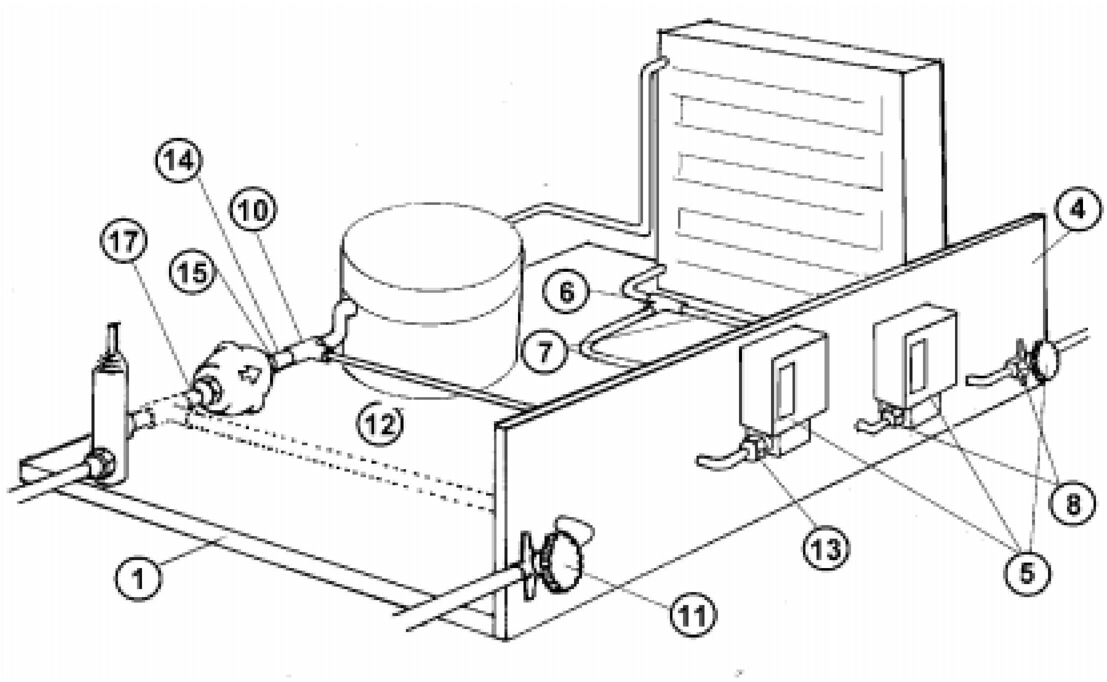


Figure A7-3, diagram of recovery machine. Numbers relate to the instructions for assembling the machine.

9. Braze all the pipes to the T piece and tighten the flare connections.

10. Cut the suction pipe to the compressor and insert the 3/8in. copper T piece.

11. If a new suction shut off valve is needed, mount it on the side panel.

12. Cut and bend a piece of ¼in pipe to connect the LP switch to the T piece – use the ¼in. to 3/8in. connector to fit the pipe to the T piece.

13. Fit a flare nut and flare the end of the pipe to fit the LP switch.

14. Cut and bend a piece of 3/8in. copper pipe to connect the filter/drier to the T piece – ensure that the filter/drier is fitted with the arrow showing the gas flow towards the compressor. It is advisable to use an old filter/drier during the assembly stage replacing it with a new drier once the unit is ready for commissioning.

15. Fit a 3/8in. flare nut and flare the end of the pipe to fit the filter/drier.

16. Braze all three pipes to the T piece.

17. Cut and bend a piece of 3/8in. pipe to connect the filter/drier to the suction shut off valve.

18. Fit flare nuts and flare both ends of the pipe.

19. Connect the pipe and tighten all of the flare connections.

20. Connect the fused on/off switch, the HP and LP switches and the compressor with 3 core single phase wire as shown in the wiring diagram. Ensure that you have a continuous earth connection between all of the components.

21. Set the HP switch to the pressure shown below and the LP switch to cut out at –0.3 bar (10 ins Hg) with a differential of about 1.0 bar (15 psi).

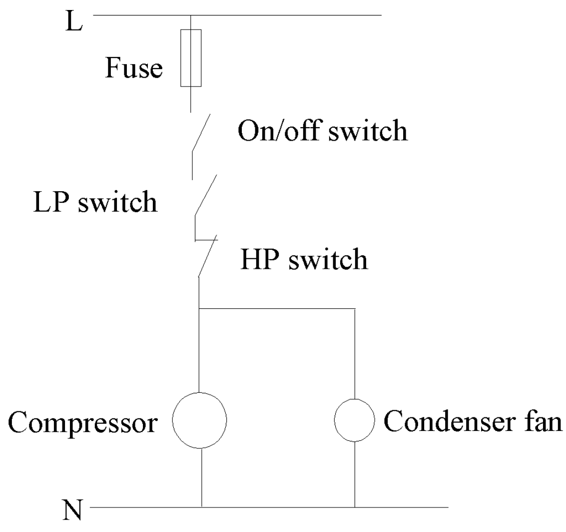


Figure A7-4, typical wiring diagram

HP switch settings:

For condensing units designed for use with R22 set the cut out at 20barg (280psig).
For condensing units designed for use with R12 or R134a set the cut out at 15barg (220psig).

Operation of unit

If liquid refrigerant enters this machine the compressor will probably fail. Therefore, this machine can only be used to remove refrigerant gas. **Do not connect it to the liquid line or liquid receiver.**

If a condensing unit for R12 or R134a has been used to make the recovery machine it must not be used to recover R22, R502, or any other similar high pressure refrigerant.

This machine should not be used to recover HC refrigerants unless the electrical components are either non sparking or enclosed.

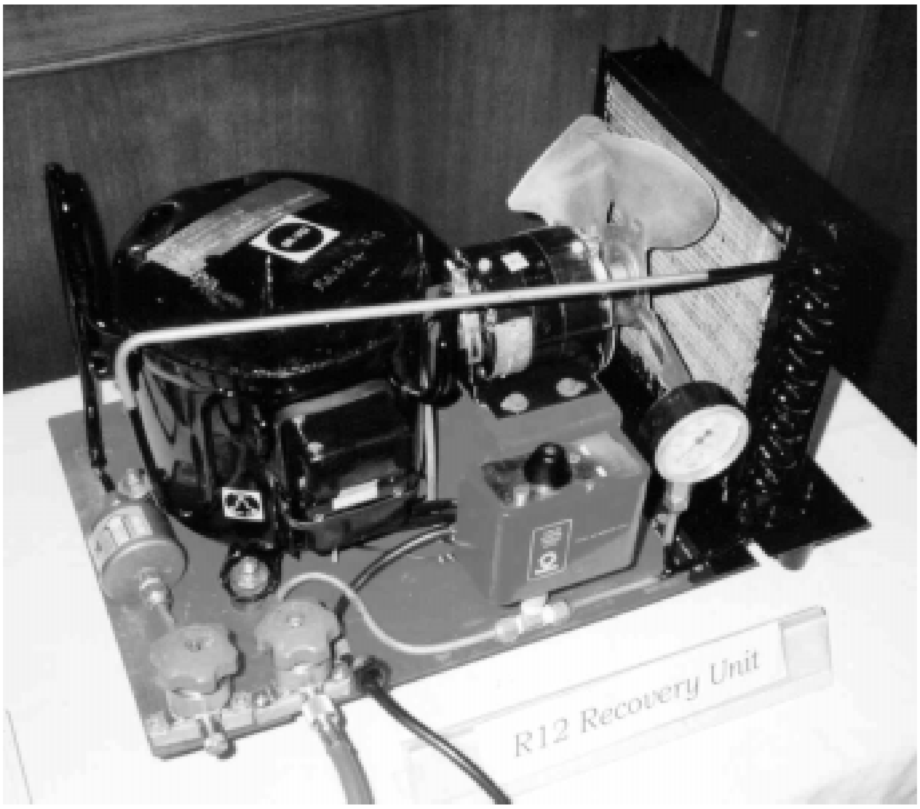


Figure A7-5, recovery machine

The photo in figure A7.5 shows a recovery machine made for a training workshop in Hyderabad, India from mostly used components.

Recovering refrigerant

Follow these instructions to recover refrigerant from a system.

1. Check the label on the recovery machine to confirm which refrigerant it was used with last time.

2. If this is different to the refrigerant to be recovered:

    I. Take the recovery unit into a well ventilated area, preferably outside, and open the suction and discharge valves to release as much refrigerant from the machine as possible;

    II. Connect a gauge manifold to the suction and discharge valves of the machine;

    III. Connect a vacuum gauge between the common connection of the gauge manifold and a vacuum pump;

IV. Switch on the vacuum pump and pull a vacuum on the recovery machine of at least 200 microns;

V. Close the valves on the recovery machine.

3. First check that the valves on a gauge manifold are closed and then connect the low pressure hose to an access port on the suction valve of the refrigeration system’s compressor, or to a pair of piercing pliers clamped onto the process tube of a hermetic compressor.

4. Connect the high pressure hose of the gauge manifold to an access port on the compressor’s discharge valve if one is fitted.

5. Connect the common hose from the manifold to the inlet valve of the recovery machine.

6. If the low pressure hose is connected to the compressor’s suction valve, open the access port.

7. If the high pressure hose has been fitted, open the valve on the compressor.

8. Connect the outlet of the recovery machine to the gas port of a suitable recovery cylinder. Do not mix different refrigerants in a cylinder.

9. Weigh the recovery cylinder to check that the cylinder is not already full.

10. Open the low pressure valve on the gauge manifold and purge the air from the low pressure hoses by slightly opening the hose connection to the suction valve of the recovery machine.

11. Purge the hoses for about 1 second and then retighten the hose.

12. Purge the air from the high pressure hose by slightly opening the connection to the gauge manifold for about 1 second and then retighten it.

13. Open the high pressure valve on the gauge manifold.

14. Open the suction valve on the recovery machine.

15. Open the discharge valve on the recovery machine.

16. Purge the air out of the hoses.

17. Open the valve on the recovery cylinder.

18. Start up the recovery machine and remove the refrigerant from the system.

19. Monitor the weight of the cylinder to ensure that it is not overfilled.

20. If the system is being scrapped, allow the recovery machine to cycle twice on its low pressure switch. If work is to being done on the system, stop the recovery machine while there is a small positive pressure in the system, about 0.3barg (5psig). This will minimise the possibility of contamination entering the system.

21. Switch off the recovery machine.

22. Close all the valves on the refrigeration system, the recovery machine and the recovery cylinder.

23. Remove all the hoses.

24. Note the weight of the cylinder.

25. Label the following items:

- The recovery machine indicating when it was used and the type of refrigerant.
- The recovery cylinder with the type of refrigerant and its weight.
- The refrigeration system to show that it no longer contains any refrigerant and the date that it was removed.

Maintenance

After about 100 hours operation, or earlier if refrigerant has been removed from a badly contaminated system, replace the 3/8in. filter/drier.

Reliability of the recovery machine

The recovery machine will not be as reliable as a commercially manufactured unit. It is possible that the compressor will fail and will need to be changed if the machine is used on a regular basis. Therefore, it is recommended that if a spare compressor becomes available it is kept ready for this purpose.