Manual for

Servicing HFC Based Domestic and Commercial Refrigeration Appliances

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

- Manual for safe design and manufacturing of commercial refrigeration appliances using hydrocarbon refrigerants, May 1997.
- Refrigeration appliances using hydrocarbon refrigerants; Manual for safe design, manufacturing, servicing and drop-in conversion of domestic and commercial appliances, August 1997.
- Safe conversion and servicing practices for refrigeration appliances using hydrocarbon refrigerants; Manual for safe conversion and servicing of domestic and commercial appliances, April 1999.

This manual as well as the above mentioned earlier manuals can be obtained from, and comments may be sent to, the following addresses:

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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.

Contents

1. Introduction

Hydrofluorocarbon refrigerants (HFCs) are being extensively used in domestic and commercial appliances all over the world, mainly in developed countries. They are now being introduced into developing countries. HFC refrigerants are not toxic or flammable under normal circumstances. However, they require very careful handling to make sure the refrigeration system is reliable and to prevent poor performance. The compressor lubricants used with HFCs absorb more moisture than traditional oils, so greatest care must be taken to prevent moisture related faults developing after a system has been serviced. In practice this means the technician must work with greater care, and will usually need better tools and equipment. In addition, some other components are different for HFCs, such as the filter drier.

This manual covers:

- Background to HFC refrigerants and their use;
- Characteristics of HFC refrigerants;
- Precautions to be taken with HFC refrigerants for safety and reliability reasons;
- Tools and equipment needed for good servicing of HFC appliances;
- Service procedures for HFCs;
- Good handling practices for HFCs.

This manual should be used as a source of information for trainers of refrigeration technicians. Some of the sections and appendices can be used as a reference manual for technicians who have been trained to handle HFC refrigerants.

Throughout this manual …

This symbol is used to show important information – you must read this. The information is usually related to system performance and reliability, or to safety.

Note to Trainers …

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

The main part of this manual contains information about HFC refrigerants, the service procedures and the tools needed. Detailed technical information is included in the appendices.

Some parts of this manual have been designed to be copied directly for use in technician training manuals. These include the summaries of good practice in chapters 3 and 5.

It is important that trainers always demonstrate best and safest practice when training refrigeration technicians. Ensure that you have the correct tools and equipment, that they are used correctly, and that safe working practices are applied.

Why are CFCs to be replaced?

CFCs (chlorofluorocarbons) such as R12 and R502 deplete ozone in the stratosphere. Their production was phased out in developed countries in 1996 under international legislation (the Montreal Protocol). Production of CFCs in developing countries must stop by the year 2010, although many 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 2040 in developing countries.

Ozone depletion is serious because it increases the amount of ultra violet (UV) light that reaches the earth's surface. This increases the incidence of skin cancer and eye cataracts for humans and reduces crop yields. More information about ozone depletion is given in the United Nations Environment Programme (UNEP) training manual "Good Practices in Refrigeration". Internet users can also visit *http://www.unepie.org/ozonaction.html* or *http://www.atm.ch.cam.ac.uk/tour/* for additional information.

CFCs (R12, R502 etc.) and HCFCs (R22 etc.) deplete ozone if they are vented into the air. This happens during servicing and when systems leak.

Background to the use of HFC refrigerants

There are several refrigerants that can be used to replace CFCs as refrigerants. These fall into three main categories:

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

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 currently used mineral oil. However, HCs are flammable and this limits their safe application, although they are safely used in many domestic and commercial appliances. More information about HCs is covered in the ECOFRIG manual "Safe Conversion and Servicing Practices for Refrigeration Appliances using Hydrocarbon Refrigerants"[1].

HCFC based blends (e.g. R401A) are not long term alternatives to CFCs, but are used in many developed countries as an interim 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. They are not widely available in developing countries.

HFCs are non flammable in most circumstances and they have zero ozone depletion potential. But they are more difficult to use than CFCs because they cannot operate with the mineral oils used with CFC, HCFC and HC refrigerants. The new oil is a polyol ester type - it is more expensive and more readily absorbs moisture than mineral oil (i.e. it is very hygroscopic).

HFC refrigerants cannot easily be used to convert CFC or HCFC appliances because the oil would need to be changed. HC refrigerants are well suited for conversion of CFC systems, but you must follow the guidelines outlined in the manual "Safe Conversion and Service Procedures for Refrigeration Appliances using Hydrocarbon Refrigerants" to prevent safety problems.

[1] The HC manual can be obtained from IIT Delhi or INFRAS – see information at the beginning of this manual for contact details. It also can be downloaded from www.infras.ch .

Summary of main issues for HFC refrigerants and appliances

Servicing procedures for HFC refrigerants must be more stringent to avoid problems associated with moisture and other contamination in the system, as well as material incompatibilities. If servicing is not to the required high standard, 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.

In practice the differences in service procedures are therefore related to the greater absorption of moisture by the polyol ester oil:

- The evacuation process will take longer than for CFCs;
- Vacuum pumps must be high quality and effective;
- Systems must not be opened for longer than absolutely necessary;

Larger liquid line filter driers are used in the refrigeration circuit. In addition, some other components in the appliance are usually different for HFC refrigerants. This includes the compressor and the capillary tube (or expansion valve).

These issues are covered in more detail in the following chapters and appendices.

2. HFC Refrigerants

HFC refrigerants were developed in the 1980's as replacements for CFC refrigerants. Their use increased as the production of CFCs was phased out in developed countries. They are now also replacing HCFCs as the production of these refrigerants is reduced. This section covers:

- Characteristics of HFC refrigerants;
- Range of HFCs available as refrigerants;
- Lubricant issues;
- Differences in refrigeration circuit design for HFCs compared to CFCs;
- Conversion of CFC appliances to HFC refrigerants;
- Typical operating conditions for HFCs;
- Legislation and trends in use of HFC refrigerants.

Characteristics of HFC refrigerants

HFC refrigerants are chemicals which comprise hydrogen (H), fluorine (F) and carbon (C) atoms in various compositions. Unlike CFCs they do not contain the chlorine (Cl) atoms which cause the damage to the ozone layer.

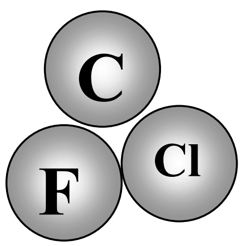


Figure 2-1, simplified CFC molecule

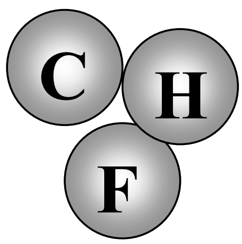


Figure 2-2, simplified HFC molecule

A range of HFC refrigerants has been developed to match the capacities and operating conditions of the CFCs they replace.

However, **HFCs are not miscible with the mineral oils** that are used to lubricate compressors operating with CFC or HCFC refrigerants. This has led to the development of polyol ester lubricants for refrigeration.

HFC refrigerants have no ozone depletion potential, but they do have a high global warming potential (GWP, the potential impact on adverse climate change). The global warming potentials of HFCs are not as high as for CFCs, but they are significantly higher than for the natural refrigerants such as hydrocarbons and ammonia. For this environmental reason some major European appliance manufacturers have already switched entirely from HFC refrigerants to hydrocarbon refrigerants.

Range of HFC refrigerants available

The table below summarises the commonly used HFC refrigerants, and shows the CFC refrigerants they replace.

HFC	CFC replaced	Common applications
R134a	R12	Domestic refrigerators and freezers Commercial appliances Small sized, medium and high temperature refrigeration and air conditioning systems Centrifugal air conditioning systems
R404A	R502	Low temperature refrigeration systems
R407C	R22	Air conditioning applications Medium / high temperature refrigeration applications

At present R134a is the most common HFC being used in developing countries and its main applications are in imported domestic and commercial refrigeration appliances. This manual concentrates on the use and handling of R134a although most of the guidelines also relate to the other HFCs.

The table below indicates the differences in capacity, efficiency and operating conditions between R134a and R12.

	R134a	R12
Boiling point at atmospheric pressure, °C	-26	-30
Capacity relative to R12 at 1.7°C/54°C	99.7	100
COP * relative to R12 at 1.7°C/54°C	96	100
Pressure at 60°C, bar gauge	15.82	14.25
Pressure at 40°C, bar gauge	9.16	8.60
Pressure at –10°C, bar gauge	1.00	1.19
Pressure at –30°C, bar gauge	-0.16	0.00

* COP = coefficient of performance.

The following are the main issues arising form the characteristics in the above table:

The capacity and COP of R134a are lower than for R12, so these systems will cost more to run. The comparison in the table is for a high temperature application such as a bottle cooler. For lower temperature applications such as ice cream cabinets the difference is greater (i.e. the capacity and COP are even lower compared to R12), so these systems often have larger compressors than their R12 equivalents.

The evaporating pressure is lower than for R12 and the condensing pressure higher. The systems will therefore work at a higher compression ratio unless the condenser and / or evaporator are larger than for R12. A more detailed pressure temperature relationship is given in Appendix 1.

R134a low temperature systems are more likely to operate on a vacuum on the low side because of the higher boiling point.

More detailed technical information about R134a is given in Appendix 1.

Polyol ester lubricant issues

Mineral oils are not used with HFC refrigerants due to poor solubility - the oil will not be transported around the system and back to the compressor. Various oil types have been tested with HFCs – the most suitable are the polyol esters. (Poly alkaline glycols are used in some systems such as car air conditioning, but they are not generally used in refrigerated appliances.)

Do not use mineral oil with HFC refrigerants. The oil will not return reliably to the compressor.

The polyol ester lubricants which must be used with HFCs are more hygroscopic than the mineral oils used with CFCs and HCFCs. This means the oil more readily absorbs moisture, e.g. from the air when its container is opened. Polyol ester oils need careful handling to prevent moisture problems – see chapter 5 for more details.

Polyol ester oils are more harmful than mineral oils, so care should be taken to avoid contact with skin. Gloves should be worn when handling polyol ester oils.

Different makes of polyol ester oil are not necessarily compatible with each other because not all manufacturers use the same additives. Oils from different manufacturers should therefore not be mixed. If you need to add oil to a compressor or appliance, check it is the correct type.

Polyol ester oils are in general more expensive than mineral types.

Differences in refrigeration circuit design compared to R12

To ensure a refrigeration system operates with optimum performance and reliability with HFC refrigerants, some design changes are necessary. The following are the most common differences between R12 and R134a appliances:

- The compressor is specially designed for optimum performance and reliability for R134a (in general the motor and lubricant are different and the compressor's displacement may be slightly larger. In addition, plastic materials inside the compressor are compatible with HFC refrigerant);

- The liquid line filter drier is usually a molecular sieve type (XH-7, XH-9, MS592 or MS594) which has a greater moisture capacity than the types used with R12 and mineral oils;

- The capillary tube is usually between 10% and 20% longer for R134a compared to R12;

- The R134a charge is generally 90% to 95% of the R12 charge;

- The condenser may be larger than for R12 to increase capacity and efficiency to the levels for R12, especially for low temperature applications such as an ice cream freezer. Typically the condenser is 15% larger than for R12.

Retrofit of CFC appliances to HFCs

It is not recommended that CFC appliances are converted to HFCs.

The necessary retrofit procedure takes considerable time and resources because:

- the compressor lubricant (a proportion of which will be in the system rather than the compressor) will need to be changed ;

- the compressor may need to be changed.

In all cases the compressor oil must be changed several times to reduce the concentration of (old) mineral oil in (new) polyol ester oil to 5%. This usually takes at least two oil changes because a high proportion of the oil is in the system pipe work and components rather than the compressor. Changing oil is difficult in a hermetic compressor and requires forward planning. The appliance cannot be converted during a service operation to repair a fault, it must be carried out on a working appliance because the system must be run between oil changes.

In many cases the compressor would also need to be changed as some of its components may not be compatible with R134a.

In both of the above cases the cost of conversion (lubricant and possibly a new compressor, as well as labour) is very expensive compared to the value of the appliance.

A simpler alternative refrigerant to use is the hydrocarbon blend of propane and iso-butane. This conversion can be carried out during a service operation. Some changes may be needed to electrical devices on the appliance to prevent a hazard in the event of HC refrigerant leakage. Full information is given in the manual "Safe Conversion and Servicing Practices for Refrigerating Appliances using Hydrocarbon Refrigerants" referred to earlier.

Typical operating conditions for HFCs

Typical operating conditions for some common applications with R134a are given in the table below.

Appliance (Cabinet Temperature)	**Evaporator Temperature and Pressure**	**Condenser Temperature and Pressure**
Bottle Cooler (2°C to 4°C)	-10°C 2 bar abs, (14 psig)	55°C 15 bar abs (200 psig)
Ice Cream Freezer (-20°C)	-30°C 0.84 bar abs (-3 psig)	55°C 15 bar abs (200 psig)
Visi-cooler (2°C to 4°C)	-10°C 2 bar abs (14 psig)	55°C 15 bar abs (200 psig)
Display Cabinets (2°C to 4°C)	-10°C 2 bar abs (14 psig)	55°C 15 bar abs (200 psig)
Refrigerators (-7°C to +5°C)	-23.3°C 1.15 bar abs (2 psig)	55°C 15 bar abs (200 psig)

Legislation and trends in use of HFC refrigerants

The environmental impact of HFCs such as R134a is less than that for CFCs such as R12, as shown in the table below.

	R134a	R12	HC
GWP (100 year time horizon, GWP of CO_2 = 1)	1300	8500	3
ODP (ODP of R11 = 1)	0	1.0	0

Although the Global Warming Potential (GWP) of HFCs is lower than for CFCs international pressure is growing for HFC phase out. Some end users and manufacturers are replacing HFCs with natural refrigerants for this reason (and because of their poorer performance and reliability).

There is an agreement between industrialised nations (the Kyoto Protocol) to reduce emissions of carbon dioxide and other greenhouse gases, including HFCs. Many countries have committed to reducing emissions beyond these targets. For example, the UK government has agreed to a target of a 12.5% cut below 1990 levels in the basket of six greenhouse gases[1] by 2010. This effectively means that if HFCs are not carefully used and contained within refrigeration systems, their future availability is in doubt.

In addition, the Danish government has decided to phase out the use of HFCs in applications where natural refrigerants such as hydrocarbons could be used.

Controls have also been introduced in some areas to reduce emissions of HFCs. For example, the European Union is proposing regulations which would make recovery of HFC mandatory.

[1] Carbon dioxide, methane, nitrous oxide, HFCs, perfluorocarbons, sulphur hexafluoride.

3. Precautions When Handling HFC Refrigerant

HFCs have the same hazards as CFC refrigerants, so similar safety precautions must be taken when handling them. In addition they can, under some circumstances, be flammable, so care must be taken to ensure the conditions required for flammability do not develop.

Great care is needed when handling HFCs and polyol ester oil to prevent moisture contaminating the refrigeration system. The polyol ester oil also needs careful handling because it is more hazardous than mineral oils.

These topics are covered in more details in this section:

- General safe HFC handling;
- Potential flammability hazard;
- Polyol ester oil safe handling;
- Precautions to minimise moisture contamination in the refrigeration system;
- Summary of safe handling for HFC refrigerants.

General safe HFC handling

HFC refrigerants are non flammable under most circumstances and non toxic. But they have the following hazards, mostly similar to CFCs and HCFCs:

Contact with liquid refrigerant will cause a freeze burn (similar to frost bite). You must wear gloves, goggles and clothing which covers your body when handling all refrigerants (e.g. when charging or recovering refrigerant). A freeze burn should be treated by bathing the area with cold water. 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 – you will suffocate if you breath 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.

HFC refrigerant will decompose if it is heated. The products of decomposition are acidic and are very hazardous. These harmful break down products occur if HFC refrigerant is heated by a flame, (e.g. a brazing torch, a match / cigarette lighter, a halide torch leak lamp), or if HFC refrigerant is inhaled through a cigarette. Do not use naked flames or smoke if HFC refrigerant has leaked into the air. Ventilate work areas before lighting a brazing torch.

HFCs are stored in cylinders as liquefied gases, in the same way as CFCs are stored. They should be handled as follows:

- Store cylinders in dry, well ventilated areas out of direct sunlight and away from sources of heat.
- Do not modify cylinder or valves.
- Do not re-fill disposable cylinders.

Full safety information for R134a is given in the material safety data sheet in Appendix 2.

Potential flammability hazard

HFCs are non flammable at ambient temperature and atmospheric pressure. However, R134a is combustible at certain conditions, e.g. 0.4 bar and 177°C when mixed with air at concentrations greater than 60% (volume in air). At lower concentrations higher temperatures are needed for combustion. There is a possibility that a combustible mixture can occur if R134a is charged into a system or a cylinder which contains air at greater than atmospheric pressure. To prevent this:

Do not leak test appliances with air or a pressurised mixture of air and R134a. Appliances can be pressure tested using dry nitrogen. If the system is to be leak tested with an electronic HFC detector, the pressure of a small amount of R134a in a system (0.5 bar g) can be boosted with dry nitrogen.

Before evacuating a cylinder or a refrigeration system, any remaining refrigerant should be removed by a recovery machine. If a discharge line is fitted to the vacuum pump it should be free of restrictions that could increase the discharge pressure above 1 bar (and therefore result in the formation of a combustible mixture).

Refrigeration systems and cylinders must be evacuated before being filled / charged with refrigerant. They should never be filled if they contain air.

Final pressures in a cylinder or system should not exceed 20.6 bar gauge (this is equivalent to 76°C saturation temperature, so should not occur in a standard system or in a cylinder). Cylinders of R134a (especially recovery cylinders) should be checked regularly for air.

The practical application of these guidelines to servicing procedures is given in chapter 5.

Polyol ester oil handling

Your skin can develop problems if it is in contact with polyol ester oil. To prevent this you should wear gloves when handling polyol ester oil, or any component which is, or has been, in contact with polyol ester oil, such as a compressor. Oil from a system where the compressor has burnt out will be even more hazardous as it will probably be contaminated with acids.

Precautions to minimise moisture and other contamination in the refrigeration system

Moisture is a contaminant in a refrigeration system, and is more likely to be present in HFC systems because of the hygroscopicity of the polyol ester oils. Too much moisture results in:

- Formation of acids which may lead to copper plating in the compressor and / or to compressor motor failure;

- Partial or total blocking of the capillary tube or expansion valve, causing a high pressure drop and consequent loss of performance.

Care is needed during handling of components (in particular the oil and the compressor) and when servicing a system to minimise moisture presence.

Oil containers (or any component such as a compressor which contains oil) must not be opened to atmosphere unless absolutely necessary. The time such containers or components are opened should be minimised. Oil should not be poured from a container as this increases the amount of moisture it absorbs from the air. It should be pumped from the container into a compressor / system.

Filter driers should be replaced if a system has been opened to atmosphere. The correct type of filter drier (i.e. one suitable for use with HFCs) must be used. The filter drier should not be unsealed until it is to be installed in the system.

Systems must be evacuated using a good quality vacuum pump to a sufficient vacuum before HFC refrigerant is charged.

All replacement components and pipe work must be clean and should remain sealed until fitted into the refrigeration circuit.

More detailed information about service procedures and tools needed to reduce moisture and other contamination is given in chapters 4 and 5.

Summary of safe handling for HFC refrigerants

The following guidelines should be followed to ensure work is carried out safely.

- Ensure the appliance is disconnected from the mains electricity before carrying out any work on it.
- Liquid refrigerant will give you frost bite if it comes into contact with your skin. Wear gloves, goggles and clothing which covers your body when working on the refrigeration circuit.
- The pressure inside the refrigeration circuit is high. Even when the appliance is not working the pressure can be as high as 7 bar . Take care when opening the circuit – a sudden escape of refrigerant under pressure is dangerous.
- A high concentration of refrigerant in the air can asphyxiate you. Work in a well ventilated area when working on the refrigeration circuit to ensure that any refrigerant which leaks out is safely dispersed.
- The refrigerant in an appliance may be contaminated with acids. Take care when opening a system and when recovering refrigerant to ensure it does not come into contact with your skin. The compressor oil may also be acidic, so wear gloves and goggles when removing and / or repairing a faulty compressor.
- HFC refrigerants form toxic products of decomposition when they are burnt. Do not smoke when handling HFCs and do not allow them to come into contact with flames (e.g. from a brazing torch) or sparks (e.g. from a switch).
- Always recover HFC refrigerant from a system – do not vent it into the atmosphere. When recovering refrigerant into a cylinder do not exceed the safe fill weight of the cylinder (this is 80% of the maximum fill weight).
- Make sure cylinder valves are in good condition and are capped when not in use.
- Store refrigerant cylinders in a well ventilated area, away from heat sources and risk of fire.

4. Servicing Equipment, Tools and Facilities for HFC Refrigerant

In general the same tools and equipment can be used for CFCs and HFCs. However, in some cases better equipment is needed for HFCs, in particular vacuum pumps. Service facilities often need to be upgraded to reduce the possibility of contamination entering systems which are being serviced. The following topics are covered in this section:

- Recovery equipment;
- Charging equipment;
- Other tools and equipment, including vacuum pumps;
- Avoiding cross contamination in tools / equipment for HFCs;
- Upgrading service facilities for HFCs.

Recovery equipment

Do not vent R134a and other HFCs into the atmosphere because they are powerful greenhouse gasses which contribute to adverse climate change. R134a must be recovered from a system into a suitable recovery cylinder.

In most cases the recovered refrigerant will be contaminated, e.g. following a motor burn out or because of moisture in the system. The recovered refrigerant can be reclaimed (cleaned to the standard of new refrigerant) for re-use using an appropriate recycling machine. If the refrigerant is not contaminated it can be re-used in the system it was removed from without cleaning it.

To recover refrigerant you need:

- A recovery machine that is suitable for use with HFC refrigerant;
- A recovery cylinder or recovery bag for storing the HFC in;
- A balance to check the weight of the recovery cylinder as it is being filled with refrigerant.

Recovery machines are available in developing countries, but they are usually imported and therefore expensive.

There are three basic types of recovery machine:

1. A simple machine with a compressor, which pumps refrigerant gas into an external cylinder. The gas condenses in the cylinder;

2. A machine with a compressor and condenser, which pumps refrigerant liquid into a cylinder;

3. A machine with on board storage for liquid refrigerant, which does not need an external cylinder during the recovery procedure. The recovered liquid in the machine will need to be pumped out when the recovery machine is full. The machines are usually designed to hold refrigerant from several appliances.

Figure 4-1, simple recovery machine of first type described above

Figure 4-2, recovery machine with an oil free compressor

Some refrigerant will remain in the recovery machine after the refrigerant has been recovered from the system. For types 2 and 3 described above this will be a significant amount of liquid refrigerant. It is therefore recommended that these machines are only used for one refrigerant. If they are used with different refrigerants, they need to be evacuated between each type, and a significant amount of refrigerant will be vented into the atmosphere.

If you buy a recovery machine make sure it is suitable for HFC refrigerant, i.e. the compressor is charged with polyol ester oil, or is a oil free type (as shown in figure 4-2).

Figure 4.3, Recovery Machine made for HIDECOR workshop

You can make your own recovery machine. Details are given in Appendix 3, with instructions for operating the machine. Figure 4.3 shows a recovery machine made for the HIDECOR workshop in Delhi in November 1999.

The recovery cylinder should be a proper cylinder for storing refrigerant – do not use disposable or "aerosol" type cylinders for storing recovered refrigerant. The cylinder should be weighed as you are filling it so that you can check you are not over-filling it. Cylinders should not be filled to more than 80% of their maximum fill weight. The fill weight and the weight of the empty cylinder (the tare weight) should be marked on the cylinder. Cylinders of recovered refrigerant should be stored in the same way as new refrigerant (i.e. in a well ventilated area away from heat sources and risk of fire).

Refrigerant can also be recovered into special bags. These are used by mobile technicians servicing small systems such as domestic refrigerators. They are designed to hold a small amount of refrigerant, which is then pumped into recovery cylinders at a central location.

Charging equipment

HFC refrigerant can be charged into a system in the same way as CFC is charged and generally the same equipment can be used. Refer to the section below on avoiding cross contamination in equipment.

Charging hoses

The same charging hoses can be used for HFCs and CFCs.

Gauges

The same gauges can be used for HFCs and CFCs, but the temperature scales are only accurate for the marked refrigerants (usually R12, R22 and R502). Read the pressure from the gauge and refer to pressure / temperature charts for accurate saturation temperatures for R134a and other HFCs.

Charging cylinder (still)

The same charging cylinder (a graduated cylinder for accurate metering of a small amount of refrigerant) can be used for HFCs and CFCs, but the cylinder must be evacuated before it is used on a different refrigerant to avoid cross contamination. An older charging cylinder will be calibrated for CFCs only. The scale will be marked in ounces or grams, although the cylinder is actually measuring a volume.

The density of HFCs is about 94% the density of CFCs. This means a given weight of HFC will have a volume of 106% that of CFC. To use a scale calibrated for R12 with R134a, you must fill the cylinder to 106% of the R12 level and use all this refrigerant.

R12 weight = 1.06 x R134a weight.

R134a weight = 0.94 x R12 weight

For example, if the cabinet needs 150 g R134a, this is equivalent to 159 g R12 (150 x 1.06 = 159), The charging cylinder should be filled with R134a to the level marked 159 g for R12, and all of this charged into the system. It will weigh 150 g, but has the same volume as 159 g of R12.

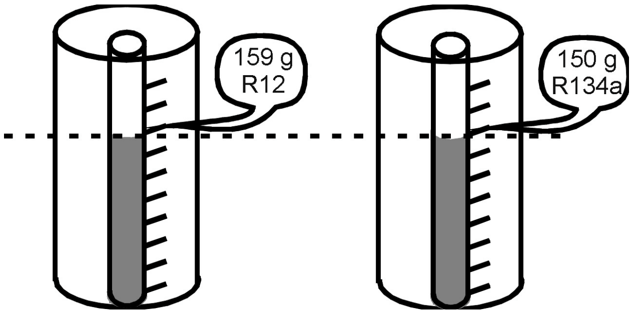


Figure 4-4, Charging cylinder calibration

Other tools and equipment

Other tools and equipment can be used as follows:

Vacuum pump

The vacuum pump must be a two stage type, capable of evacuating the whole system to a level of 100 microns. The same vacuum pump can be used for other refrigerants.

Leak detector

Soapy water can be used to find HFC leaks. Soapy water is a good, safe, accurate method of leak detection.

Most electronic leak detectors for CFCs and HCFCs will not detect HFC leaks. There are electronic leak detectors available for HFCs. Some models can now detect CFCs, HCFCs and HFCs. Make sure you use one which is suitable for HFCs, and where you use multi refrigerant types, make sure it is set to detect the refrigerant you are using.

A halide torch must not be used to detect HFC leaks as toxic fumes will be produced.

All other tools and equipment are standard for CFCs and HFCs. A complete tool / equipment list is given in appendix 4.

Avoiding cross contamination in tools / equipment for HFCs

R134a and R12 are chemically compatible with each other but, when mixed, they form an azeotrope. In certain proportions the resulting azeotrope will work at higher pressures than either R12 or R134a. In general compressor discharge pressures will be undesirably high if systems contain a mixture of R134a and R12.

Care must therefore be taken not to mix R12 and R134a when tools and equipment are used with both refrigerants.

- Evacuate or purge hoses and gauge manifold sets before using them with a different refrigerant. A large service organisation will find it is more practical to have different equipment for CFCs and HFCs.

- Evacuate charging cylinders and recovery machines before using with a different refrigerant.

Note – if your recovery machine is the type which contains liquid after recovery (i.e. it has a condenser and / or on board refrigerant storage) it is better to have a different recovery machine for each refrigerant. If this is not the case, significant amounts of refrigerant will be lost when you switch to using another refrigerant because you will have to evacuate your machine.

Upgrading service facilities for HFC system repair

It is very important that HFC appliances are serviced in an area which is clean and dry. HFC appliances should not be serviced outside. The service area should be kept clean of dust and dirt.

5. Servicing Procedures for HFC Refrigerants

The main difference when servicing an HFC appliance compared to a CFC one is that greater care must be taken to prevent moisture and other contaminants entering the refrigeration system. The full service procedure is covered in this section:

- Steps for servicing an HFC appliance;
- Recovery of HFC refrigerant;
- Replacing components;
- Cleaning the system;
- Pressure and leak testing;
- Evacuation;
- Charging, sealing, leak testing and checking operation;
- Compressor replacement;
- Summary of good practice for HFC refrigerant servicing.

Steps for servicing an HFC appliance

The following procedure is recommended when servicing the refrigeration circuit of an HFC appliance. If you use this procedure you will minimise the amount of moisture and other contaminants in the refrigeration circuit.

- Work in a clean, dry area.
- Any HFC remaining in the system should be recovered using a suitable recovery machine and cylinder.
- Components should be repaired / replaced as necessary. The filter drier must be changed if the system is opened to atmosphere, or has been contaminated, e.g. due to a compressor burn out. Components must be suitable for HFCs and must be clean and remain sealed until fitted into the system. The duration a system is opened to atmosphere must be minimised. For example, if the system is opened for only one minute, the moisture absorbed by the oil will impair system operation.
- The system should be pressure and leak tested using dry (oxygen free) nitrogen.

- The system should be evacuated using a two stage vacuum pump, to a vacuum of 100 microns.
- The system should be charged with the correct amount of refrigerant.
- The charging point should be sealed, e.g. by brazing, and then leak tested.
- The system should be correctly labeled and its operation checked.

This procedure is covered in more detail in the following sections of this chapter.

HFC recovery

HFC refrigerant must not be vented into the air because it is a powerful greenhouse gas. Any refrigerant remaining in the system must be recovered into a cylinder using a recovery machine suitable for HFCs. The recovered refrigerant can be reclaimed for re-use using an appropriate recycling machine.

The recovery procedure varies depending on the type of machine used, but in general the procedure will be as follows:

1. Evacuate the recovery machine for between 15 and 30 minutes if it was not previously used with the refrigerant you are about to recover. With some types of recovery machine this results in a significant amount of refrigerant being vented into the atmosphere - see the section on recovery machines in chapter 4 for more information about this.
2. Connect inlet of recovery machine to a piercing valve or piercing pliers on the process tube of the appliance, as shown in figure 5-1.
3. Weigh recovery cylinder to ensure it can safely contain refrigerant from appliance. Do not fill the cylinder to more than 80% of its volume. The safe filling weight of the refrigerant (e.g. R134a) should be marked on the recovery cylinder. The safe filling weight should be added to the tare (empty) weight of the cylinder to find its maximum gross (overall) weight. Do not mix different refrigerants in a cylinder as the mixture cannot be re-used. Do not pump HFC into a cylinder containing air.

Figure 5-1, connection of recovery machine to system and cylinder

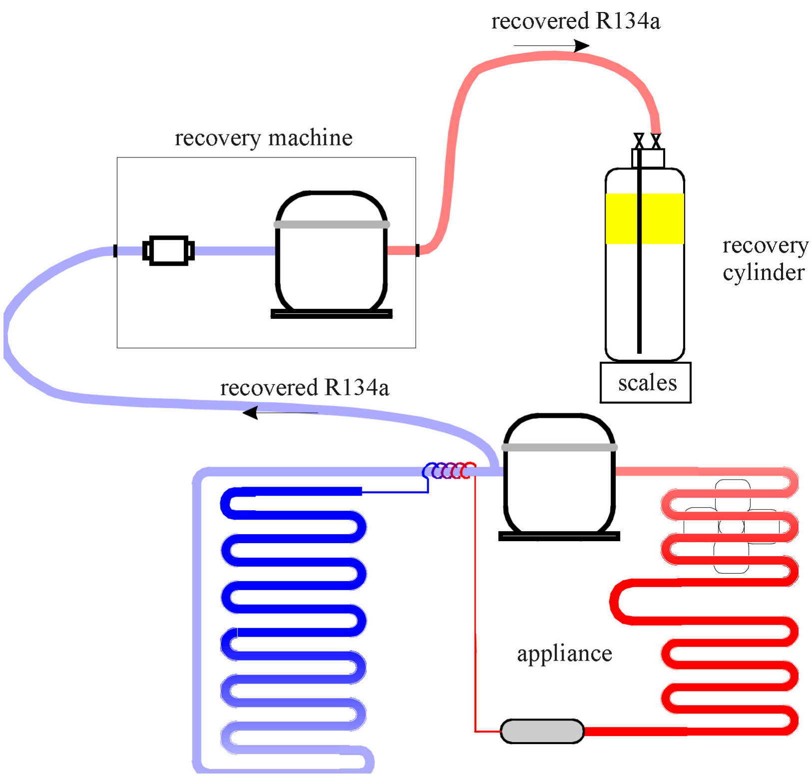


Figure 5-2, Connection of recovery machine to refrigeration circuit

4. Connect outlet of recovery machine to gas port of recovery cylinder, as shown in figures 5-1 and 5-2.

5. Carefully purge lines using refrigerant from the cylinder or the appliance.

6. Open all valves and start the recovery machine. Note – the actual valve opening and starting sequence may be different for different recovery machines. Some machines will be damaged if liquid refrigerant is drawn from the appliance.

7. Allow the machine to draw as much refrigerant as possible from the appliance.

8. Close all the valves and disconnect the recovery machine and cylinder.

9. Weigh the recovery cylinder and label it with the refrigerant type and weight.

10. Label the recovery machine to show the refrigerant you have just used it with.

11. Label the appliance to show its refrigerant has been recovered, unless you will work on it immediately.

The appliance is now ready for repair.

Replacing components

When you replace components make sure you use the correct type (i.e. they are compatible with HFC refrigerant). Do not unseal them until you are ready to install them in the system.

Make sure the compressor you use is an HFC type – CFC compressors usually include materials (e.g. paraffin based materials) which are not compatible with polyol ester oils and HFCs.

Make sure the filter drier you use is the correct type for HFC refrigerant (types XH-7, XH-9, MS592, MS594). Filter driers used with CFCs are not good enough for HFC appliances where there will probably be a greater moisture level.

Make sure the capillary tube is the correct length for the HFC circuit – in most cases capillary sizes have been optimised for HFCs – using a CFC capillary size will reduce the performance of the appliance .

If you need to un-braze or braze joints, make sure all the HFC has been recovered from the refrigeration circuit. Don't forget that the brazing torch flame will break down the HFC into very toxic products. It is good practice to pass dry (oxygen free) nitrogen through pipes while you are brazing to eliminate refrigerant and prevent build up of oxides which contaminate the system.

Cleaning the system

A system which has been contaminated or opened to atmosphere must be correctly cleaned before charging with the HFC refrigerant. This can be done in a number of ways, but the most practical is to flush the system with dry nitrogen at a pressure of approximately 2.5 bar.

Pressure and leak testing

When repairs have been made, the refrigeration circuit must be pressure and leak tested. A similar procedure to that which should be used for CFCs can be followed.

Dry nitrogen should be used to pressurise the system – you must not use compressed air as this may result in a combustible mixture if mixed with HFC refrigerant. Note – dry nitrogen is 99.998% nitrogen.

As with CFCs, the circuit should be pressure and leak tested at a pressure above the maximum pressure it will work at, but generally no higher than 30% above the maximum working pressure. For example, if an appliance is designed to operate at a maximum condensing temperature of 55°C, it should be pressure tested at between 14.0 and 18.2 bar gauge. (For R12 the test pressure would be between 12.7 and 16.5 bar gauge.)

Leak testing can be carried out using a soap solution on each joint. Bubbles in the soap solution indicate there is a leak.

The leak test could be carried out using an electronic leak tester. Such testers can detect a leak of HFC equivalent to a leak of less than 10g/yr. To use such a tester a small amount of HFC must be charged into the evacuated system, to a pressure of 0.5 bar g. The pressure is then boosted to the test pressure with dry nitrogen and each joint checked with the electronic tester. An electronic leak tester suitable for HFC must be used, and it must be properly maintained. These testers can give false alarms, and are not reliable if used in a windy / draughty conditions.

HFC refrigerant must not be mixed with air or compressed air for leak testing as this could be dangerous.

Evacuation

The evacuation process is critical for HFC systems. Appliances must be properly evacuated before they are charged with refrigerant. You cannot just purge the refrigeration circuit before charging – this is not adequate and will not remove moisture contamination. Don't forget that moisture is more likely to be a problem with HFC systems because of the hygroscopicity of the polyester oils used with HFCs.

The photo in figure 5.3 is of a piston, connecting rod and shaft assembly from a compressor which has failed as a result of the presence of moisture and other contamination in the system. This type of failure is much less likely in a system which has been correctly evacuated.

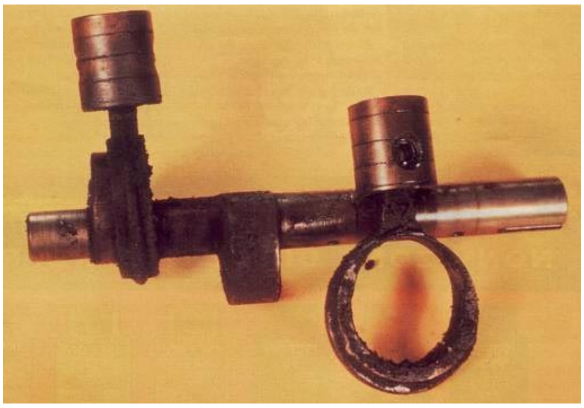


Figure 5-3, components from a failed compressor

A proper two stage vacuum pump should be used, with a gauge which can measure vacuum accurately. Do not use a refrigeration compressor to evacuate a refrigeration system. It will not be able to evacuate to the level required for HFC refrigerants.

The evacuation procedure is as follows:

1. Remove the piercing pliers or piercing valve and replace with a tube adapter or braze in a valve. The piercing pliers / valve will not seal well enough for you to be able to evacuate the system properly.

2. If possible, make a similar connection to the high side of the system – on many appliances there is a process tube at the filter drier. Evacuating from both the high and low side of the refrigeration circuit gives a faster, better evacuation.

3. Connect the vacuum pump to the system. A manifold set will be needed if you are able to connect to the high and low side of the circuit. Figure 5-4 shows a vacuum pump connected to the process tube of the compressor, with a proper vacuum gauge. If the vacuum pump does not have a non return valve at the inlet, then you should fit one in the line between the pump and the system. When the pump is switched off, or in the event of a power cut, this will prevent the vacuum pump oil being drawn into the appliance.

4. Evacuate the system until a vacuum of 100 microns has been reached. This should take about 30 minutes with a good vacuum pump, connected to both sides of the circuit, if the system has not been badly contaminated with moisture. It will take longer if you are only evacuating from the compressor process tube and / or the system is badly contaminated with moisture. You will not be able to reach the required vacuum with a poor vacuum pump.

   100 microns is:
   - 0.1 mm HG = 0.1 Torr
   - 0.0019 psia
   - 0.0039 in Hg
   - 0.000133 bar abs
   - 0.133 mbar abs
   - 0.054 in H_2O

Figure 5-4, vacuum pump and gauge connected to appliance

5. When the system is down to the required vacuum, close the valves and stop the vacuum pump. Check that the pressure does not rise for 5 minutes. If it rises quickly there is probably a leak in the circuit – check and repair leaks (check the connections of your pump to the system as well as the circuit) and start the evacuation process again. If it rises slowly there is still moisture in the system – continue to evacuate the system.

6. Remove the pump (with all valves closed) when the evacuation is completed.

Note – make sure you regularly change the oil in the vacuum pump to maintain its reliability and its ability to evacuate to the vacuum required for HFCs. Change the oil immediately after you have used the pump – it will be easier.

The system is now ready to be charged.

Charging, sealing, leak testing and checking operation

HFC refrigerants are more sensitive to charge size than CFCs. Appliance performance will change more significantly if the system is over or under charged. The charge can be accurately metered in by:

- Weight, using an accurate balance (this is the most accurate and simplest option);

- Volume, using a charging cylinder / still, with an accurate calibration for the refrigerant, or using a conversion factor applied to the CFC scale, as discussed in chapter 4;

- Operating conditions, by measuring appropriate pressures and temperatures.

The charging procedure is the same as for CFCs and depends on the method used, but great care must be taken to ensure moisture does not enter the system when charging:

- Eliminate air from charging hoses by carefully purging them, or by evacuating them;

- Eliminate air from a charging cylinder / still by purging or evacuating it;

- Use good quality HFC refrigerant from a reputable supplier;

- Charge refrigerant into a properly evacuated system which has been pressure and leak tested.

When the system has been charged, remove the charging equipment and seal the process tube in the normal way. Check the process tube for leakage while the system is off – do not check it while the system is running because if there is a leak water and air may be drawn into the system.

Label the system to show what refrigerant has been charged, and the amount, if known. Check that the appliance is running correctly, i.e. that it is pulling down the temperature and not drawing excessive power.

Compressor replacement

Compressors for HFC refrigerants should preferably be repaired in a repair center authorised by the compressor manufacturer.

Other repair centers will not be able to repair the compressor to the necessary high standard of cleanliness, and may not have the correct parts. HFC compressors repaired in road side centers will be much less reliable than those repaired in an authorised center.

When removing a burnt out compressor from a system make sure you wear gloves – the oil in the compressor will be acidic after a burn out.

Do not test a compressor by running it open, i.e. compressing air. This is dangerous and will usually lead to premature compressor failure.

Summary of good practice for HFC refrigerant servicing

The following guidelines should be followed to ensure that appliances will work reliably and as efficiently as possible after service.

- Evacuate systems to a vacuum of 100 microns – you will need a good quality vacuum pump – do not use a compressor for this job. Maintain the vacuum pump properly.
- Do not charge HFC refrigerant into a system unless it has been properly evacuated and leak tested.
- Replace filter driers if the system has been opened to atmosphere or the compressor motor has burnt out. Make sure you use the correct type of filter drier for HFC refrigerant.
- Make sure you use the correct type of compressor for HFC refrigerant, and when using a repaired compressor, make sure it has been repaired by an authorised repair center.
- Keep systems and components sealed for as long as possible
- HFC refrigerants do not perform as well as the CFCs, especially if the evaporating pressure is low and / or the condensing pressure is high. Make sure evaporators and condensers are clean.

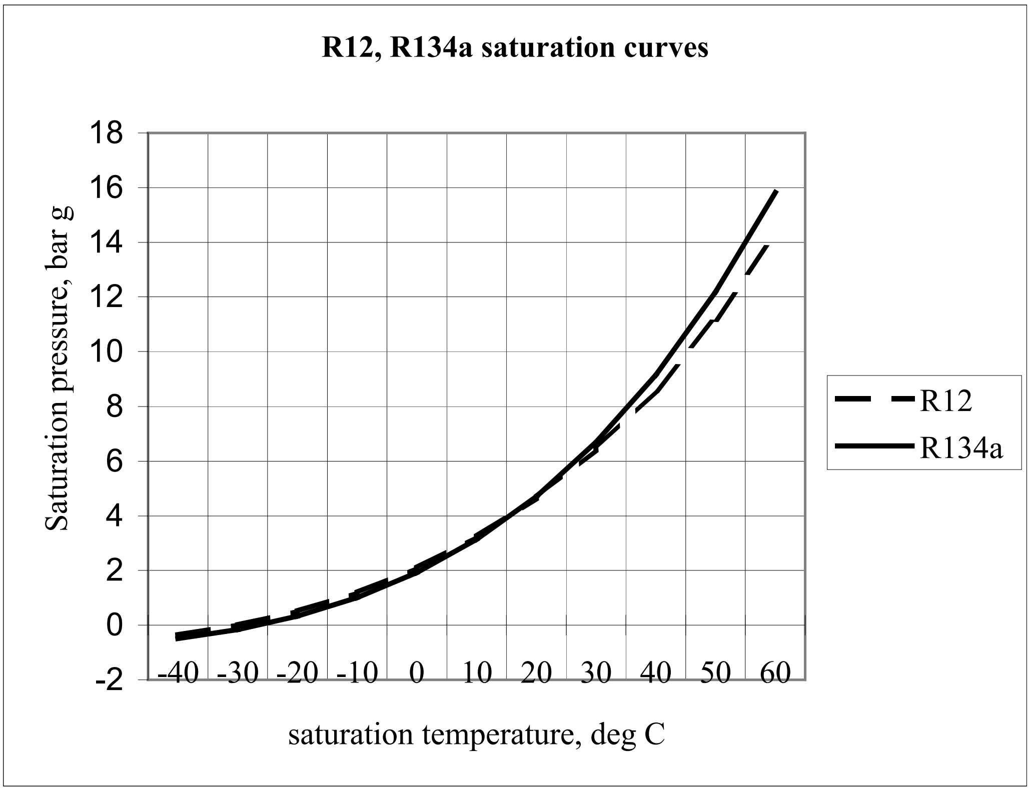
Appendix 1, R134a Data

Table of physical properties

Property, weight basis	R134a	R12
Boiling point at 1 atmosphere, °C	-26.1	-29.8
Specific heat of liquid at 30°C, kJ/kg K	1.45	0.99
Specific heat of vapour at constant pressure at 30°C, kJ/kg K	0.86	0.62
Ratio of specific heats (C_p/C_v) at 1 atmosphere., 30°C	1.118	1.136
Density of liquid at 30°C, Mg/m^3	1.187	1.292
Density of saturated vapour at boiling point, kg/m^3	5.3	6.3
Latent heat of vaporisation at boiling point, kJ/kg	217	165
Thermal conductivity of liquid at 30°C, W/m°C	0.08	0.07
Thermal conductivity of vapour at 30°C, 1 atm., W/m°C	0.015	0.010
Surface tension at 25°C, mN/m	8.4	8.5
Viscosity of liquid at 30°C, centipoise	0.20	0.19

Table of saturation pressures and temperatures

Temperature	Pressure, R134a, bar g	Pressure, R12, bar g
-40	-0.488	-0.359
-30	-0.156	0.003
-20	0.327	0.508
-10	1.004	1.190
0	1.925	2.084
10	3.141	3.231
20	4.710	4.670
30	6.695	6.446
40	9.159	8.603
50	12.176	11.189
60	15.820	14.254



More detailed information about R134a and other HFC refrigerants can be obtained from your local refrigerant supplier, or e.g. from the web site of Du Pont, a large manufacturer of HFCs at http://www.dupont.com/suva/emea/index.html.

Appendix 2, R134a Safety Data

786 BOC GASES

Safety Data Sheet

Suva 134a (1, 1, 1, 2- Tetrafluoroethane, R134a)

1 IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY

Product name	Suva 134a (1, 1, 1, 2-Tetrafluoroethane, R134a)
Company identification	See heading and/or footer
Emergency phone numbers	See heading and/or footer

2 COMPOSITION/INFORMATION ON INGREDIENTS

Substance/Preparation	Substance.
Components/Impurities	Contains no other components or impurities which will influence the classification of the product.
CAS Nr	00811-97-2
EEC Nr (from EINECS)	2123770

3 HAZARDS IDENTIFICATION

Hazards identification	In high concentrations may cause asphyxiation. Liquefied gas.

4 FIRST AID MEASURES

Inhalation	In low concentrations may cause narcotic effects. Symptoms may include dizziness, headache, nausea and loss of co-ordination. In high concentrations may cause asphyxiation. Symptoms may include loss of mobility/consciousness. Victim may not be aware of asphyxiation. Remove victim to uncontaminated area wearing self contained breathing apparatus. Keep victim warm and rested. Call a doctor. Apply artificial respiration if breathing stopped.
Skin/eye contact	In case of frostbite spray with water for at least 15 minutes. Apply a sterile dressing. Obtain medical assistance Immediately flush eyes thoroughly with water for at least 15 minutes.
Ingestion	Ingestion is not considered a potential route of exposure.

5 FIRE FIGHTING MEASURES

Specific hazards	Exposure to fire may cause containers to rupture/explode. Non flammable
Hazardous combustion products	If involved in a fire the following toxic and/or corrosive fumes may be produced by thermal decomposition: Carbonyl fluoride Hydrogen fluoride Carbon monoxide
Suitable extinguishing media	All known extinguishants can be used.
Specific methods	If possible, stop flow of product. Move container away or cool with water from a protected position.
Special protective equipment for fire fighters	Use self-contained breathing apparatus and chemically protective clothing.

6 ACCIDENTAL RELEASE MEASURES

Personal precautions	Evacuate area. Wear self-contained breathing apparatus when entering area unless atmosphere is proved to be safe. Ensure adequate air ventilation.
Environmental precautions	Try to stop release. Prevent from entering sewers, basements and workpits, or any place where its accumulation can be dangerous.
Clean up methods	Ventilate area.

7 HANDLING AND STORAGE

Handling and storage	Suck back of water into the container must be prevented. Do not allow backfeed into the container. Use only properly specified equipment which is suitable for this product, its supply pressure and temperature. Contact your gas supplier if in doubt. Refer to supplier's container handling instructions. Keep container below 50°C in a well ventilated place.

8 EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure limit value for country	Great Britain: LTEL:1000ppm (EH 40/97)
Personal protection	Ensure adequate ventilation. Do not smoke while handling product.

9 PHYSICAL AND CHEMICAL PROPERTIES

Molecular weight	102
Melting point	-101 °C
Boiling point	-26.5 °C
Relative density, gas	3.5 (air=1)
Relative density, liquid	1.2 (water=1)
Vapour Pressure 20°C	4.7 bar.
Solubility mg/l water	No reliable data available.
Appearance/Colour	Colourless gas.
Odour	Ethereal. Poor warning properties at low concentrations.
Other data	Gas/vapour heavier than air. May accumulate in confined spaces, particularly at or below ground level.

10 STABILITY AND REACTIVITY

Stability and reactivity	Stable under normal conditions. Thermal decomposition yields toxic products which can be corrosive in the presence of moisture.

11 TOXICOLOGICAL INFORMATION

General	May produce irregular heart beat and nervous symptoms.

12 ECOLOGICAL INFORMATION

General	Not covered by the 'Montreal Protocol'.
Ozone depletion factor	0
Global warming factor	0.28 (R11=1)

13 DISPOSAL CONSIDERATIONS

General	Must not be discharged to atmosphere. Do not discharge into any place where its accumulation could be dangerous. Refer to supplier's waste gas recovery programme. Contact supplier if guidance is required.

14 TRANSPORT INFORMATION

UN Number	3159
Class/Div	2.2 (Non flammable, non toxic gases)
ADR/RID Item Nr	2, 2°A
ADR/RID Hazard Nr	20
CEFIC Groupcard Nr	20G39
Labelling ADR	Label 2: non flammable non toxic gas
Other transport information	Avoid transport on vehicles where the load space is not separated from the driver's compartment. Ensure vehicle driver is aware of the potential hazards of the load and knows what to do in the event of an accident or an emergency. Before transporting product containers ensure that they are firmly secured and: - cylinder valve is closed and not leaking - valve outlet cap nut or plug (where provided) is correctly fitted - valve protection device (where provided) is correctly fitted - there is adequate ventilation. - compliance with applicable regulations.

15 REGULATORY INFORMATION

Labelling of cylinders	
-Symbols	Label 2: non flammable non toxic gas
-Risk phrases	RAs Asphyxiant in high concentrations.
-Safety phrases	S9 Keep container in well ventilated place. S23 Do not breathe the gas.

16 OTHER INFORMATION

Ensure all national/local regulations are observed.
Contact with liquid may cause cold burns/frost bite.
The hazard of asphyxiation is often overlooked and must be stressed during operator training.
Before using this product in any new process or experiment, a thorough material compatibility and safety study should be carried out.
Details given in this document are believed to be correct at the time of going to press. Whilst proper care has been taken in the preparation of this document, no liability for injury or damage resulting from its use can be accepted.

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Appendix 3, Recovery Machine Information

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:

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

Components required to build a recovery machine

A recovery machine and recovery cylinder are used to recover HFCs (and CFCs and HCFCs). 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 only 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 reclaimed and re-used.

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 18 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.

You need the following components to build your own 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 R134a, then you should use an R134a 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 and suitable for use with HFC refrigerants);

- 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. Close the suction valve and 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.

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.

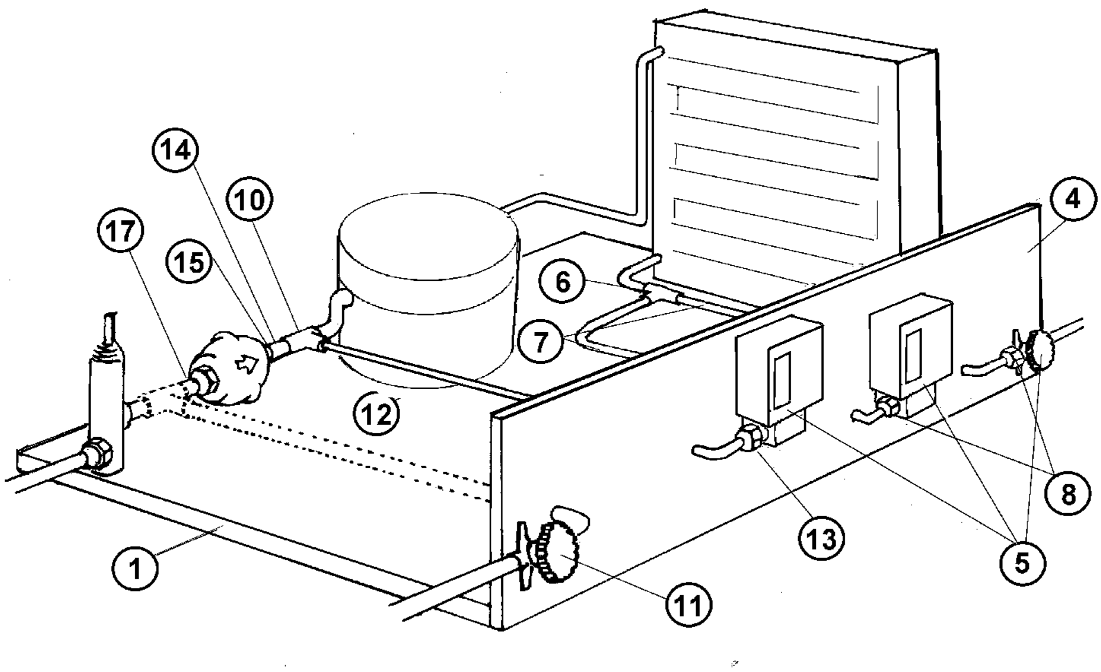

Figure A3-1, diagram of recovery machine. Numbers relate to the instructions for assembling the machine.

8. Fit flare nuts and flare the ends of the two pipes to fit the HP switch and the shut off valve.

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).

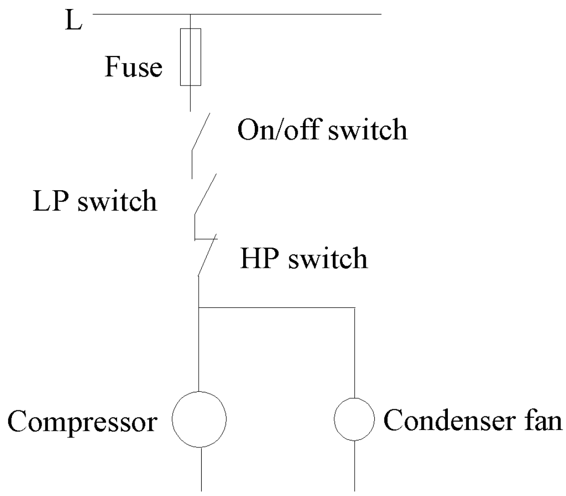

Figure A3-2, typical wiring diagram

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 A3-3 "Home made" recovery machine

The photo in figure 3.3 shows a recovery machine made for a training workshop in Hyderabad, India from mostly scrap 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. Pump out as much refrigerant as possible into a suitable cylinder.

   II. 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;

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

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

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

   VI. Close the valves on the recovery machine.

3. Connect the inlet of the recovery machine to the process tube of the compressor, using piercing pliers / valve on the process tube.

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

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

6. Purge the air from the hose by slightly opening the hose connection to the suction valve of the recovery machine.

7. Purge the hose for about 1 second and then retighten the hose.

8. Open the suction valve on the recovery machine.

9. Open the discharge valve on the recovery machine.

10. Purge the air out of the hoses.

11. Open the valve on the recovery cylinder.

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

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

14. 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.

15. Switch off the recovery machine.

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

17. Remove all the hoses.

18. Note the weight of the cylinder.

19. 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.

Appendix 4, Full Tool / Equipment List

The following refrigeration tools, equipment and consumables are needed to carry out good service work on an HFC appliance.

Tools	Equipment	Consumables
Valve key Flaring / swaging kit Tube cutter Piercing pliers / valve Tube adapter Pipe benders Hand shut off valves or couplers Charging hoses Mirror	Two stage vacuum pump * Vacuum gauge Balance Manifold and gauge set Brazing set Labeled cylinders for recovered refrigerant Thermometer Gloves and goggles Recovery machine * (Charging cylinder/still*) (Leak detector *)	Refrigerant Copper tube Brazing rod and flux Soap solution Flare nuts and fittings M seal Oil ** Driers **

Most of the tools and equipment listed above can be used with any refrigerant. However, if you already have the items marked * they may not be suitable for use with HFCs, and new equipment may be needed. In most cases new equipment is available which can be used with a variety of refrigerants.

Equipment in ( ) is not always needed.

The consumables marked ** do need to be suitable for HFC refrigerant.