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# Good Servicing Practices: Phasing out HCFCs in the Refrigeration and Air-Conditioning Servicing Sector


United Nations Environment Programme

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# Executive Summary

Hydrochlorofluorocarbons (HCFCs) are widely used in the refrigeration and air-conditioning servicing sector. While they do less damage to the ozone layer than CFCs, HCFCs are in the process of being phased out under the Montreal Protocol due to their potential ozone depleting properties. In Article 5 countries, refrigeration and air-conditioning systems account for some seventy-five[1] percent of HCFC consumption. Consequently, focusing HCFC phase-out efforts on the servicing sector will contribute significantly to ozone layer protection.

Promoting good practices in the refrigeration servicing sector has proved to be a successful tool for phasing-out HCFCs, and is one of the most important components of HCFC Phase-out Management Plans (HPMPs). The purpose of this guide is to help NOUs in Article 5 countries in their efforts to train refrigeration servicing technicians in good practices so they can contribute to HCFC phase-out. Not only does this training help HCFC control and phase-out, but it also contributes to climate change mitigation efforts. These guidelines focus on six areas that are key to reducing HCFCs consumption in the servicing sector and achieving phase-out. Each chapter either details necessary skills and procedures, or provides background information so that technicians can better understand good practices and incorporate them into their daily work. These guidelines can be used for both train-the-trainer workshops and technician training workshops, depending on local conditions.

The six key focus areas are:

**1.** Reducing the amount of HCFCs used in the servicing sector by improving good servicing practices (GSPs)

In the servicing sector, HCFCs are mostly used recharge leaky systems. Air-conditioning systems are designed to operate adequately with a fixed charge of refrigerant. Refrigerant leaks may be caused by many factors, including vibration, frictional wear, incorrect material selection, poor quality control, or poor connections, such as brazed joints, flare connections, or faulty valve caps. This guide will explain how to reduce system leakage by using tools and equipment properly and improving brazing skills.

**2.** Refrigerant management: reducing emissions during refrigerant charge and transfer

Many technicians purge HCFCs when transferring refrigerant from one cylinder to another or from cylinder to air-conditioner, and in the process, some of the refrigerant is released into the air. This guide offers technicians with in-depth information on using the right tools and equipment for properly charging and transferring refrigerants, which will ultimately reduce emissions.

**3.** Using alternative refrigerants and technologies that do not require Ozone Depleting Substances (ODS).

The ultimate goal in the servicing sector is to move towards using alternatives to ODSs. Currently available alternative technologies use zero-ODP, low-GWP refrigerants such as hydrocarbon, ammonia, carbon dioxide and HFCs. Technicians must learn how to use these alternate technologies correctly, as most pose safety and health problems if they are not handled properly.

**4.** Promoting recovery, recycling and reclamation to save the ozone layer

Recovery, recycling and reclamation of refrigerants are essential good practices and should be adopted by service technicians for environmental as well as economic reasons. Various types of recovery and recycling machines are currently available for different needs. It is also possible to make a simple recovery machine with used components in the service shop. Provided the components are in good condition, this can be an attractive and convenient option. Technicians can also purify contaminated refrigerants at reclamation centers, which have been established through various projects in several countries. Reclamation centers cannot, however, separate mixed refrigerants.

**5.** Maximising climate benefits through the servicing sector

Good practices can not only reduce the demand for HCFCs, but also reduce GHG emissions and benefit climate change mitigation efforts. As HCFCs have a high GWP, reducing demand can also directly reduce equivalent $CO_2$ emissions at a national level. Good practices also encourage energy efficiency in refrigeration and air-conditioning (RAC) equipment, thereby reducing energy consumption and electricity costs, and indirectly benefiting the climate. These guidelines explore the link between good practices and climate change mitigation.

**6.** Maintenance of refrigeration and air-conditioning servicing equipment

In order to maintain good practices in the refrigeration and air-conditioning service sector, it is essential to have good tools and equipment, such as vacuum pumps, recovery machines and double-stage nitrogen and oxygen regulators. It is equally important that technicians always keep these tools and equipment in good condition. These guidelines provide detailed information on how to conduct regular maintenance. Keeping equipment breakdowns to a minimum will lead to higher profits, quality workmanship and environmental protection.



[1] In 2006 global HCFC production was 34,400 ODP tones. Approximately 75% of global HCFC use is in the air-conditioning and refrigeration sectors. The main HCFC used is HCFC-22 or chlorodifluoromethane. (UNEP)

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# Foreword

At the 19th Meeting of the Parties of the Montreal Protocol in 2007, decision XIX/6 accelerated the phase-out schedule for HCFCs. Article 5 countries are now obliged to freeze their baseline consumption (2009–2010 average) by 1 January 2013 and achieve a 10% reduction in consumption by 1 January 2015. Considering the limited time frame, Article 5 countries must gear up now to take action.

Most Article 5 countries have started implementing their HCFC Phase-out Management Plans (HPMPs) and are initiating training programmes for refrigeration and air-conditioning service technicians. These training programmes need to address both how to rapidly phase out HCFCs consumption in the servicing sector, and how to safely use new alternative refrigerants, which are often flammable and pose a health threat if improperly handled.

Technicians in many Article 5 countries may also be unaware that good servicing practices can not only help reduce HCFC consumption, but also contribute to mitigating climate change. Using improved, energy efficient equipment and avoiding leaks both reduces the demand for energy (and the related carbon emissions) and lowers emissions of high-GWP refrigerant gases.

This guide was developed to help National Ozone Units and training institutions create HCFC phase-out training sessions for refrigeration servicing technicians. Countries can adapt and develop these guidelines further to suit their specific needs. A few key features:
• An emphasis on illustrating how good servicing practices in the RAC sector not only help countries meet their HCFC phase-out obligations under the Montreal Protocol, but also benefit the climate by reducing emissions and increasing energy efficiency;
• Details on how to address safety concerns when installing small air-conditioners that use flammable alternative refrigerants; and
• A harmonised approach to training methodologies for technician workshops, developed using the first-hand experiences of RAC trainers in the Asia-Pacific region.

We thank authors Dr. Anshu Kumar and Dr. Prakob Surawattanawan for their dedication and concerted efforts in creating a comprehensive, detailed guide to good practices for installing, servicing and maintaining refrigeration and air-conditioning equipment that benefits both end-users and the environment.

Our very special thanks to Prof. (Dr.) Radhey Shyam Agarwal, Prof. (Dr.) Jiangping Chen and Mr. Michael Moller, who graciously reviewed the document and gave valuable input at very short notice. I would also like to commend Mr. Atul Bagai and Mr. Shaofeng Hu, who directly supervised this project and provided detailed guidance to the authors in developing this material.

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# Introduction

## Guide for Trainers

## Good Servicing Practices: Phasing out HCFCs in the Refrigeration and Air-Conditioning Servicing Sector

### Introduction

This guide for trainers is designed for organisations and institutes that conduct training workshops for servicing technicians involved in the maintenance of refrigeration and air-conditioning (RAC) equipment. Its target audience includes:

- Trainers of HCFC-22 phase-out projects in Article 5 countries
- Trainers at vocational training institutes
- Educational establishments and RAC course developers
- Service and maintenance technicians
- Technician trainers at private companies
- Service and maintenance managers at private companies
- Managers who develop service and maintenance policies in private companies
- National Ozone Units (NOUs) responsible for developing policies for servicing and maintenance programmes related to the Montreal Protocol.

### Why you need this guide

In recent years, ozone depletion efforts have primarily focused on the obligatory phasing out of ozone depleting substances (ODS). However, in 2013, Decision XIX/6 at the 19th Meeting of the Parties highlighted the importance of climate and energy-efficiency as related to HCFC phase-out. In order to achieve reduction of both ODS and GHG emissions, attention must be paid to activities at a micro-level. This includes reducing leakage rates, adopting good service practices, improving energy-efficiency and preventing adverse environmental impacts during equipment servicing and maintenance.
With the aim of contributing to efforts to reach these goals, this guide offers trainers up-to-date information on new technologies and refrigerants, as well as other issues related to their use and application. The guide was written for trainers and others who already have a relatively comprehensive level of knowledge and understanding of RAC systems and associated technology, and can be used for both developing training programmes as well as general guidance and information.

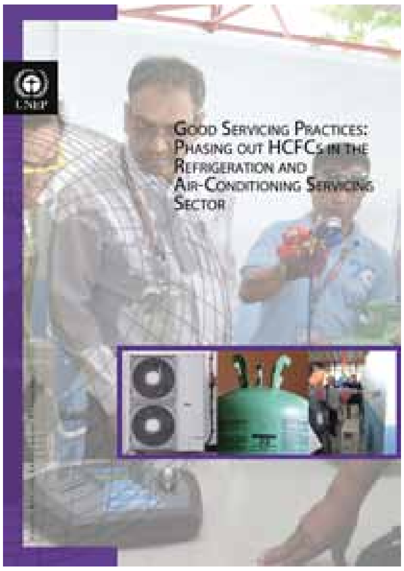
A wide range of RAC system topics are covered below, from ozone science, to good service practices, to air-conditioner installation. There is also a section on contaminated refrigerants, which may be useful for those who encounter counterfeit refrigerants.

### How to use this training package:

This training package is web-based on OzonAction website (www.unep.org/ozonaction)

The training package contains:
**Section A** the guidebook
**Section B** slide presentations, including some slides linked to animated demonstrations
**Section C** animated demonstrations and interactive exercices

## Section A: Guidebook




Section A contains the guidebook in PDF format with all the necessary images and slides for presentations, as well as notes to help trainers give presentations. The book is divided into seventeen chapters:

| **Chapter** | **Topic** |
|---|---|
| 1. | Environmental and Human Health Impacts of ODS Refrigerants |
| 2. | Alternatives to HCFCs and their Characteristics |
| 3. | Handling HCFC and HFC Refrigerants |
| 4. | Servicing HCFC and HFC-based Air Conditioners |
| 5. | Tools and Equipment for Servicing and Repair |
| 6. | Do's and Don'ts in Refrigeration and Air-Conditioning Servicing |
| 7. | Handling Hydrocarbon (HC) Refrigerants and Safety Issues |
| 8. | Servicing HC-Based Air Conditioners |
| 9. | Installation Procedures for Window and Split Air Conditioners |
| 10. | Refrigerant Recovery, Recycling and Cylinders |
| 11. | Economics of Refrigerant Reclamation and Best Service Practices |
| 12. | Contaminated Refrigerant and Refrigerant Identifier |
| 13. | Selection and Safe Use of Cleaning Solvents |
| 14. | Maximising Climate Benefits Through the Servicing Sector |
| 15. | Evacuation and Charging Unit Maintenance |
| 16. | Recovery Machine Maintenance |
| 17. | Single-Stage Versus Double-Stage Nitrogen Pressure Regulator and Maintenance |

The first page of every chapter provides the following details:

a) Training material reference
b) Target group
c) Duration of the session
d) Purpose of the session
e) Terminal performance objectives
f) Key messages
f) Required tools and equipment, if any
Next, you will find the chapter title, slide images and accompanying explanations.

## Section B: Slide Presentations

Section B contains a series of slide presentations in Microsoft PowerPoint format to be used in training sessions. Section A (the guidebook) should be carefully studied before using the presentations in Section B.

## Section C: Animated Demonstrations and Interactive Exercise

This section contains both the animated demonstrations linked to the presentations in Section B, and an Interactive Exercise on Good Servicing Practices.

After completing Section B, the trainers may wish to use the interactive exercise to test how well the trainees have understood the lessons they have just completed. This interactive exercise should be done before the trainees begin the hands-on session, "Best Practices for HFC based Air-Conditioners" (which falls on the second day when following recommended agenda).

# Acronyms and Abreviations

The main objectives of this guide are to provide trainers and technicians with the relevant knowledge, skills and step-wise procedures for good servicing practices in the RAC sector, and to help countries comply with HCFC control measures under the Montreal Protocol.

| | |
|---|---|
| AC | Air Conditioning |
| BCM | Bromochloromethane |
| CFC | Chlorofluorocarbon |
| CFM | Cubic Feet per Minute |
| $CO_2$ | Carbon Dioxide |
| CP | Copper Phosphorus |
| CPR | Constant Pressure Regulator |
| DC | Direct Current |
| DOT | Department of Transportation (USA) |
| EN | European Norm |
| FCU | Fan Coil Unit (indoor) |
| GWP | Global Warming Potential |
| HC | Hydrocarbon |
| HBFC | Hydrobromofluorocarbon |
| HCFC | Hydrochlorofluorocarbon |
| HFC | Hydrofluorocarbon |
| HP | High Pressure |
| ID | Inside diameter |
| IDU | Indoor Unit |
| LP | Low Pressure |
| MLF | Multilateral Fund for the implementation of the Montreal Protocol |
| NCG | Non-Condensable Gas |
| NPT | National Pipe Thread |
| OD | Outside Diameter |
| ODP | Ozone Depleting Potential |
| ODS | Ozone-Depleting Substances |
| OFP | Overfill Protection |
| ODU | Outdoor Condensing Unit |
| PAG | Polyalkylene Glycol |
| POE | Polyol Ester |
| PVC | Poly Vinyl Chloride |
| RAC | Refrigeration and Air Conditioning |
| R&R | Recovery and Recycling |
| RRR | Recovery, Recycling and Reclamation |
| RTK | Retrofit Test Kit |
| TEV | Thermostatic Expansion Valve |
| TT | Tubing Tools |
| UV | Ultraviolet |
| UNEP | United Nations Environment Programme |

# Glossary

**Absolute pressure**
Pressure measured in relation to a perfect vacuum (the zero value), and atmospheric pressure (approximately 1.013 bar).

**Air conditioning**
The process of controlling temperature, humidity, composition and distribution of air for the purpose of human comfort or for special technical needs in an industrial process (pharmaceutical, textile, etc.) or other application.

**Article 2 countries**
Parties to the Montreal Protocol that do not operate under Article 5 (see below). "Article 2 countries" generally refers to developed countries.

**Article 5 countries**
Developing country parties to the Montreal Protocol whose annual per capita consumption and production of ozone depleting substances (ODS) is less than 0.3 kg. Currently, 147 of the 196 parties to the Montreal Protocol meet these criteria. Article 5 countries are eligible to receive technical and financial assistance from the Multilateral Fund Secretariat, as per Article 10 of the Protocol.

**Atmospheric lifetime**
A measure of the average time that a molecule remains intact once released into the atmosphere.

**Atmospheric pressure**
Also known as barometric pressure, this refers to the pressure exerted by the atmosphere above the surface of the Earth. Standard sea level pressure equals 1atmosphere (atm) or 101.35 kPa.

**Azeotrope**
A blend consisting of one or more refrigerants of different volatilities that does not appreciably change in composition or temperature as it evaporates (boils) or condenses (liquefies) under constant pressure. Refrigerant blends assigned an R5xx series number designation by ISO 817 are azeotropes.

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

**Blends (mixtures)**
A mixture of two or more pure fluids. Blends are used to achieve properties that fit many refrigeration purposes. For example, a high pressure and a low pressure substance might be mixed to match the pressure of another substance. Blends can be divided into two categories: azeotropic and zeotropic.

**Boiling point**
The temperature of a liquid at the point it starts to vaporise (see NBP).

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

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

**Bubble point**
The liquid saturation temperature of a refrigerant at a specified pressure; the temperature at which a liquid refrigerant first begins to boil.

**Cascade system**
Two or more independent refrigeration circuits where the condenser of one system rejects heat directly to the evaporator of another.

**Charging**
Transferring a refrigerant from the refrigerant source (a new or recycled refrigerant cylinder) into a system, usually according to a specified weight, amount of sub-cooling, or evaporating pressure. Charging is normally carried out using a dedicated charging machine (e.g. in a production area) or using a cylinder connected to the system via a manifold or hoses. The cylinder is disconnected from the refrigeration system after the refrigeration system has been completely charged with the new refrigerant.

**Chlorofluorocarbons (CFCs)**
Halocarbons containing only chlorine, fluorine and carbon atoms. CFCs are both ozone depleting substances and greenhouse gases.

**Climate change**
Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that Article 1 of the Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability, observed over comparable time periods." The UNFCCC thus makes a distinction between "climate change," attributable to human activities altering the atmospheric composition, and "climate variability," attributable to natural causes.

**Coefficient of Performance (COP)**
A measure of the energy efficiency of a refrigerating system, also defined as the ratio of useful effect (heat) to the work supplied. The useful effect is the cooling rate in the case of RAC systems, and it is the heating rate in the case of heat pumps. The COP is primarily dependant on the working cycle and temperature levels (evaporating or condensing temperature), as well as on the properties of the refrigerant system design and size.

**Coil**
A part of the refrigerating system constructed from bent or straight pipes or tubes and serving as a heat exchanger (evaporator or condenser).

**Competence**
The ability to satisfactorily perform the activities of a given occupation.

**Compressor**
A device for mechanically increasing the pressure of a refrigerant vapour.

**Condenser**
A heat exchanger in which vaporised refrigerant is liquefied by removing heat.

**Condensing unit**
A combination of one or more compressors, condensers, liquid receivers (if needed) and appropriate accessories.

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

**Controlled substance**
Under the Montreal Protocol, any ozone depleting substance that is subject to control measures, such as a phase-out requirement.

**Destruction**
Destruction of ozone depleting substances or their mixtures by approved destruction plants.

**Dew point**
The temperature at which a vapour refrigerant first begins to condense; also defined as the temperature at which a vapour refrigerant saturates under the specified pressure.

**Disposal**
Conveying a product to another party, usually for destruction.

**Drop-in replacement**
The procedure for replacing CFC refrigerants with non-CFC refrigerants in existing refrigeration, air-conditioning and heat pump plants without any plant modifications. However, drop-in procedures are often referred to as retrofitting because plants need to make minor modifications, such as changing lubricant, replacing the expansion device and replacing desiccant material.

**Emissions**
The release of gases or aerosols into the atmosphere over a specified area and period of time.

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

**Evaporator**
A heat exchanger in which liquid refrigerant is vaporised by absorbing heat from the substance to be cooled.

**Expansion device**
A device such as an expansion valve, expansion orifice, turbine or capillary tube used to control the mass flow of a refrigerant from the high-pressure side to the low-pressure side of a refrigeration system.

**Fluorocarbons**
Halocarbons containing fluorine atoms, including chlorofluorocarbons, hydro chlorofluorocarbons, hydro fluorocarbons and perfluorocarbons.

**Fossil fuels**
Carbon-based fuels derived from geological (fossil) carbon deposits. Examples include coal, oil and natural gas.

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

**Fractionation**
The change in composition of a refrigerant mixture by evaporation of the more volatile component(s) or condensation of the less volatile component(s).

**Gauge pressure**
Pressure equal to the difference between the absolute pressure and atmospheric pressure.

**Global warming potential (GWP)**
An index comparing the climate impact of an emission of a greenhouse gas relative to that of emitting the same amount of carbon dioxide. GWP is determined as the ratio of the time integrated radiative forcing arising from a pulse emission of 1 kg of a substance relative to that of 1 kg of carbon dioxide, over a fixed time horizon.

**Greenhouse effect**
Greenhouse gases in the atmosphere effectively absorb the thermal infrared radiation that is emitted by the Earth's surface, by the atmosphere itself, and by clouds. The atmosphere emits radiation in all directions, including downward to the Earth's surface. Greenhouse gases trap heat within the surface troposphere system and raise the temperature of the Earth's surface. This is called the natural greenhouse effect. An increase in the concentration of greenhouse gases leads to increased absorption of infrared radiation and causes a radiative forcing, or energy imbalance, that is compensated for by an increase in the temperature of the surface-troposphere system. This is the enhanced greenhouse effect.

**Greenhouse gases (GHGs)**
The gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation within the spectrum of the thermal infrared radiation that is emitted by the Earth's surface, by the atmosphere and by clouds. This property causes the greenhouse effect. The primary greenhouse gases in the Earth's atmosphere are water vapour, carbon dioxide, nitrous oxide, methane and ozone. Moreover, there are a number of entirely anthropogenic greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances that are covered by the Montreal Protocol. Some other trace gases, such as sulphur hexafluoride, hydrofluorocarbons, and perfluorocarbons, are also greenhouse gases.

**Halocarbons**
Chemical compounds containing carbon atoms, and one or more atoms of the halogens chlorine, fluorine, bromine or iodine. Fully halogenated halocarbons contain only carbon and halogen atoms, whereas partially halogenated halocarbons also contain hydrogen atoms. Halocarbons that release chlorine, bromine or iodine into the stratosphere cause ozone depletion. Halocarbons are also greenhouse gases. Halocarbons include chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons and halons.

**Halogens**
A family of chemical elements with similar chemical properties that includes fluorine, chlorine, bromine and iodine.

**Heat**
A transfer of energy from one site to another owing to a temperature difference between the two sites. Heat can be transferred from one form of energy to another.

**Heat exchanger**
A part of the refrigerating system used for transferring heat across a boundary, including the condenser, evaporator, and intercoolers.

**Hermetic**
An airtight sealed system.

**Hermetic compressor**
A combination of a compressor and electrical motor operating in a mixture of oil and refrigerant vapour, both of which are enclosed in the same housing. There no external shaft or shaft seals.

**High pressure side**
The part of a refrigerating system operating at the pressure level of the condenser or gas cooler.

**Hydrocarbons (HCs)**
Chemical compounds consisting of one or more carbon atoms surrounded only by hydrogen atoms.

**Hydrochlorofluorocarbons (HCFCs)**
Halocarbons containing only hydrogen, chlorine, fluorine and carbon atoms. Because HCFCs contain chlorine, they contribute to ozone depletion. They are also greenhouse gases.

**Hydrofluorocarbons (HFCs)**
Halocarbons containing only carbon, hydrogen and fluorine atoms. Because HFCs contain no chlorine, bromine or iodine, they do not deplete the ozone layer. Like other halocarbons they are potent greenhouse gases.

**Isolating valve**
A valve that prevents flow in either direction when closed.

**Joint**
A connection made between two parts.

**Kyoto Protocol**
The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the Third Session of the Conference of the Parties (COP) to the UNFCCC in 1997 in Kyoto, Japan. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol agreed to reduce their anthropogenic greenhouse-gas emissions (specifically carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by at least 5% below 1990 levels in the commitment period 2008 to 2012. The Kyoto Protocol entered into force on 16 February 2005.

**Latent heat**
It is the amount of heat needed to change the phase of a pure substance where temperature remains constant.

**Liquid receiver**
A vessel permanently connected to a system by inlet and outlet pipes for accumulation of liquid refrigerant.

**Low pressure side**
The part of a refrigerating system operating at around the same pressure as the evaporator.

**Machinery room**
A completely enclosed room or space, vented by mechanical ventilation and only accessible to authorised persons, intended for the installation of refrigeration systems or their components. Other equipment may also be installed, provided they are compatible with safety requirements for the refrigerating system.

**Maintenance**
All kinds of work that may be performed by a maintenance technician, primarily related to ensuring the continued good operation and working of refrigeration systems, as well as record-keeping.

**Materials safety data sheet (MSDS)**
A safety advisory bulletin prepared by chemical producers for a specific refrigerant or compound.

**Maximum allowable pressure**
The maximum pressure for which the equipment is designed, as specified by the manufacturer.

**Maximum working pressure**
The maximum pressure for which the equipment is designed, as specified by the manufacturer.

**Mobile system**
A refrigerating system that is normally in transit during operation.

**Montreal Protocol**
The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in September 1987. Following the discovery of the Antarctic ozone hole in late 1985, governments recognised the need for firm measures to reduce the production and consumption of a number of CFCs (CFC-11,-12, -113, -114, and -115) and several Halons (1211, 1301, 2402). The Protocol was designed so that the phase-out schedules could be revised on the basis of periodic scientific and technological assessments. Following such assessments, the Protocol was adjusted to accelerate the phase-out schedules in 1990 (London), 1992 (Copenhagen), 1995 (Vienna), 1997(Montreal),1999 (Beijing) and again in 2007 in Montreal.

**Multilateral Fund**
Part of the financial mechanism under the Montreal Protocol. The Multilateral Fund was established by a decision of the Second Meeting of the Parties to the Montreal Protocol (London, June 1990) and began its operation in 1991. The main objective of the Multilateral Fund is to help Article 5 parties to the Montreal Protocol (whose annual per capita consumption and production of ODS is less than 0.3 kg) to comply with the control measures of the Protocol.

**Natural Refrigerants**
Natural refrigerants are naturally occurring substances, such as hydrocarbons (e.g. propane, iso-butane), carbon dioxide and ammonia. These substances can be used (amongst others) as refrigerants in various kinds of refrigeration and air-conditioning systems. The key characteristics of these refrigerants are that they do not contribute to depletion of the ozone layer and have no or only a negligible global warming impact.

**Non-condensable gases**
Gases with very low temperature boiling points, which are not easily condensed. Nitrogen and oxygen are the most common ones.

**Normal boiling point (NBP)**
The boiling point of a compound at atmospheric pressure (1.013 bar).

**Occupied space**
A completely enclosed space that is occupied for a significant period by people. The occupied space may be accessible to the public (for example supermarket) or only to trained persons (for example cutting up of meat). A complete refrigerating system or parts of one may be installed In an occupied space.

**OFP (Overfill Protection)**
Overfill protection is a safety switch installed in a refrigerant recovery unit or recovery cylinder meant for transferring and storing refrigerants. In general, these switches simply turn off the recovery machine. OFP devices do not provide any recovery machine with a "walk away" feature; refrigerant transfer must be monitored by a technician. Under certain

circumstances, this transfer can be hazardous even when the device is used. Hazards can occur in following situations:
1. During push-pull procedures, once a siphon is started, merely powering off the recovery machine does not prevent the recovery cylinder from overfilling.
2. When using a cylinder with a large amount of cold refrigerant to recover from a system at higher temperature, turning the recovery machine off will not stop the refrigerant from migration to the coldest point (in this case the recovery cylinder), and eventually overfilling the tank even when the machine is off.

**Ozone depletion**
Accelerated chemical destruction of the stratospheric ozone layer by the presence of substances produced by human activities.

**Ozone depleting potential (ODP)**
A relative index indicating the extent to which a chemical product may cause ozone depletion compared with the depletion caused by refrigerant R11. Specifically, the ODP of an ozone depleting substance is defined as the integrated change in total ozone per unit mass emission of that substance relative to the integrated change in total ozone per unit mass emission of R11.

**Ozone layer**
The layer in the stratosphere where the concentration of ozone is greatest. The layer extends from about 12 to 40 km. This layer is being depleted by anthropogenic emissions of chlorine and bromine compounds. Every year, during the Southern Hemisphere spring, a very strong depletion of the ozone layer takes place over the Antarctic region. This depletion is caused by anthropogenic chlorine and bromine compounds in combination with the specific meteorological conditions of that region. This phenomenon is called the Antarctic ozone hole.

**Ozone**
The triatomic form of oxygen ($O_3$), which is a gaseous atmospheric constituent. In the troposphere it is created by photochemical reactions involving gases occurring naturally and resulting from anthropogenic activities ("smog"). Tropospheric ozone acts as a greenhouse gas. In the stratosphere ozone is created by the interaction between solar ultraviolet radiation and molecular oxygen ($O_2$). Stratospheric ozone plays a major role in the stratospheric radiative balance. Its concentration is highest in the ozone layer.

**Ozone depleting substances (ODS)**
Substances known to deplete the stratospheric ozone layer. ODS controlled under the Montreal Protocol and its Amendments are chlorofluorocarbons, hydrochlorofluorocarbons, halons, methyl bromide, carbon tetrachloride, methyl chloroform, hydrobromofluorocarbons and bromochloromethane.

**Perfluorocarbons (PFCs)**
Synthetically produced halocarbons containing only carbon and fluorine atoms. They are characterised by extreme stability, non-flammability, low toxicity, zero ozone depleting potential and high global warming potential.

**Phase-out**
The ending of all production and consumption of a chemical controlled under the Montreal Protocol.

**Piping**
All pipes or tubes (including hoses, bellows, fittings, or flexible pipes) for interconnecting the various parts of a refrigeration system.

**Power**
The rate at which work is done or energy is transferred by a circuit.

**Pressure relief valve**
A pressure-actuated valve held shut by a spring or other means and designed to relieve excessive pressure automatically by starting to open at a set pressure and re-closing after the pressure has fallen below the set pressure.

**Push-pull method**
A method for recovering and recycling refrigerant from a system using a negative pressure (suction) on one side to pull the old refrigerant out and pumping recycled refrigerant vapour to the other side to push the old refrigerant through the system.

**Reclaim**
Processing used refrigerants to new product specifications. Chemical analysis of the refrigerant determines that appropriate specifications are met. The identification of contaminants and required chemical analysis are specified in both national and international standards for new products.

**Reclamation**
Reprocessing and upgrading of a recovered controlled substance through mechanisms such as filtering, drying, distillation and chemical treatment in order to restore the substance to a specified standard of performance. Chemical analysis is required to determine that appropriate product specifications are met. Reclamation often involves processing off-site at a central facility.

**Recovery**
The collection and storage of controlled substances from machinery, equipment, containment vessels, etc., during servicing or prior to disposal without necessarily testing or processing it in any way.

**Recycling**
Restoring and reusing recovered refrigerant. Used refrigerants are processed to reduce contaminants by separating oil, removing noncondensables and using devices such as filters, driers or filter-driers to reduce moisture, acidity and particulate matter. The recycling process, which often occurs on-site, normally involves recharging the recycled refrigerant back into equipment.

**Refrigerant**
A fluid used for heat transfer in a refrigerating system. This fluid absorbs heat at a low temperature and a low pressure and rejects heat at a higher temperature and a higher pressure, a process that usually involves changes of the state of the fluid.

**Refrigerant detector**
A sensing device that responds to a pre-set concentration of refrigerant gas in the environment.

**Refrigerating system**
A combination of interconnected refrigerant-containing parts, including one closed circuit in which the refrigerant is circulated for the purpose of extracting and rejecting heat (i.e. cooling, heating).

**Refrigeration**
The process of lowering the temperature of substance or a space to a desired temperature.

**Retrofit**
The upgrading or adjustment of equipment so that it can be used under altered conditions. For example, refrigeration equipment being adapted so that it can use an alternative refrigerant in place of a CFC, HCFC or HFC.

**Saturated vapour pressure**
The maximum vapour pressure of a substance at a given temperature when accumulated in its liquid state in a confined space.

**Sealed system**
A refrigerating system in which all refrigerant-containing parts are made tight by welding, brazing or a similar permanent connection. A sealed system contains no non-permanent connections.

**Secondary (or indirect) cooling system**
A system employing a fluid that transfers heat from a product or space, or from another cooling or heating system, to a refrigerating system, without fluid compression and expansion.

**Semi-hermetic compressor**
A unit containing a compressor and electrical motor operating in a mixture of oil and refrigerant vapour. The compressor and electrical motor are enclosed in the same housing, and has a removable cover for access, but there is no external shaft or shaft seals.

**Sensible heat**
It is the amount of heat that causes a change in the temperature of substance without changing its phase. It can be evaluated by means of temperature reading device.

**Servicing**
All kinds of work that may be performed by a service technician, from installation, operations, inspection, repair, retrofitting, redesign and decommissioning of refrigeration systems to handling, storage, recovery and recycling of refrigerants, as well as record-keeping.

**Shut-off device**
A device to shut off the flow of a fluid, such as refrigerant or brine.

**Soft-soldered joint**
A joint obtained by joining of metal parts with metallic mixtures or alloys which melt below 200 °C.

**Soldered joint**
A joint obtained by the joining of metal parts with metallic mixtures or alloys which melt at temperatures less than 450°C.

**Specific heat**
The quantity of heat needed to raise a unit mass of substance by 1°C. It is measured in joules per Kelvin per kilogram.

**Strength test pressure**
The pressure that is applied to test the strength of a refrigerating system or any part of it.

**Tightness test**
The pressurisation of a refrigeration system, or any part of it, in order to test for its tightness against leaks.

**Ton Refrigeration (TR)**
The common used unit for refrigeration or air-conditioning system capacity. It is defined as the rate of energy required to melt a ton of ice at 0 °C in 24 hours. 1 ton of refrigeration (TR) = 3.517 kW = 12,000 Btu/h.

**Total Equivalent Warming Impact (TEWI)**
A measure of the overall global-warming impact of equipment based on the total related emissions of greenhouse gases during the lifetime of the equipment, including its manufacture and the disposal of operating fluids and hardware at end-of-life. TEWI takes into account both direct emissions and energy-related emissions produced by the energy consumed in operating the equipment. TEWI is measured in units of mass of $CO_2$ equivalent.

**Trans-critical cycle**
A refrigerating cycle whose compressor discharges refrigerant at a pressure above the critical point.

**Transitional substance**
Under the Montreal Protocol, a chemical whose use is permitted as a replacement for ozone depleting substances, but only temporarily because the substance's ozone depleting potential is above zero.

**Ultraviolet radiation (UV)**
Radiation from the sun with wavelengths between visible light and X-rays. UV-B (280–320 nm), one of three bands of UV radiation, is harmful to life on the Earth's surface and is mostly absorbed by the ozone layer.

**United Nations Environment Programme (UNEP)**
Established in 1972, UNEP is the specialised agency of the United Nations for environmental protection.

**Venting**
A service practice where the refrigerant is allowed to escape into the atmosphere, and is usually a short-cut to avoid recovery.

**Vapour compression refrigeration cycle - vapour compression technology**
The most widely used refrigeration cycle. In this cycle, refrigerant is vaporized and condensed alternately; during the vapour phase the refrigerant is compressed. Basic components include a compressor, condenser, expansion device, and evaporator.

**Welded joint**
A joint obtained by the joining of metal parts in the plastic or molten state.

**Zeotrope**
A refrigerant blend consisting of two or more substances of different volatilities that appreciably changes in composition or temperature as it evaporates (boils) or condenses (liquefies) at a given pressure. A zeotropic refrigerant blend assigned an R4xx series number designation in ISO 817.

# 1. ENVIRONMENTAL AND HUMAN HEALTH IMPACTS OF REFRIGERATION AND AIR-CONDITIONING

**Training Material Reference:** Environmental and Human Health Impacts of ODS Refrigerants - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
a) To enhance target audience's awareness of effects of ozone layer depletion;
b) To enhance awareness of global warming and how refrigerant use can contribute to environmental problems;
c) To understand the need to replace ozone-depleting HCFC chemicals with alternatives; and
d) To inform participants about HCFC control measures under the Montreal Protocol.

**Final Performance Objectives**
At the end of the session, the participants should know:
a) What is the ozone layer and how is it formed?
b) How is the ozone layer damaged by HCFC refrigerants and other ozone depleting substances?
c) What are the harmful effects of ozone layer depletion?
d) What is meant by global warming and how is our climate affected by HCFCs?

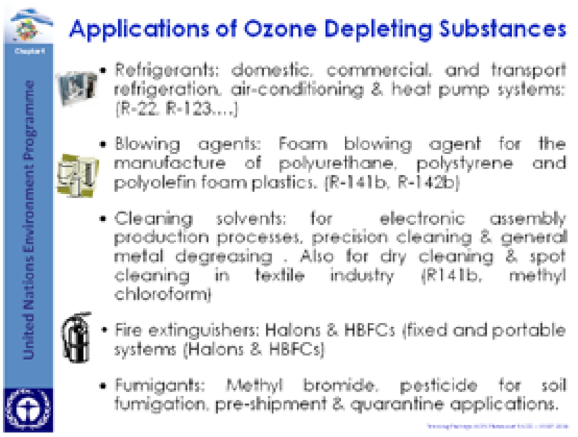
**Key Message Delivered in this Session**
While HCFCs have been widely used as refrigerants for several years, they have harmful impacts on the environment – including damage to both the ozone layer and the global climate. For the sake of future generations, it is very important that we stop production and consumption of HCFCs.

**Tools and Equipment Required for the Session:**
None. A video on ozone depletion and its harmful effects may be shown before or after the session.


**Slide 1: Environmental and Human Health Impacts of ODS - Refrigerants**

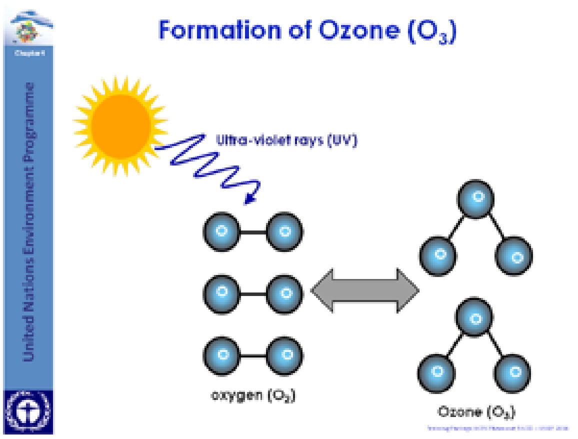
This is the title slide. The slide shows an image of the earth and the ozone hole.

The trainer can start with an overview of the programme outline, and then approach the slide topic. The trainer can then explain how the environmental impact of existing hydrochloroflourocarbon (HCFC) refrigerants has prompted the changeover to non-HCFC refrigerants, and how that effects the development and approval of the country's HCFC Phase-out Management Plan (HPMP).




**Slide 2: Applications of Ozone Depleting Substances**

Ozone Depleting Substances (ODSs) have a variety of applications. HCFCs are used as refrigerants in refrigerators, air-conditioners and other cooling appliances. ODSs are also commonly used as foam blowing agents in the process of manufacturing foam, and as solvents in industrial cleaning operations. Another important ODS application (in this case, halons) is in fire extinguishing systems. Lastly, the ODS methyl bromide is used as a fumigant for soil and grain storage, as well as quarantine and pre-shipment applications.

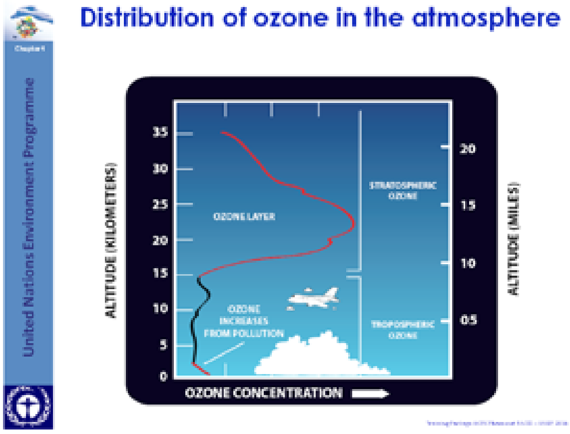



**Slide 3: Formation of Ozone($O_3$)**

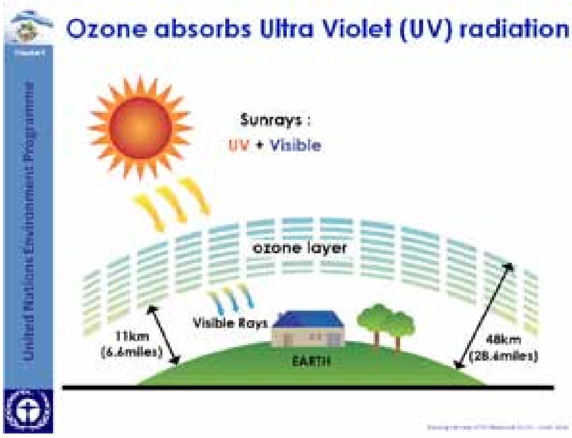
This slide explains how the ozone layer is formed. The most prevalent form of oxygen is created when two oxygen atoms of join together to form an oxygen molecule ($O_2$). Ozone, on the other hand, consists of three oxygen atoms ($O_3$).

In the stratosphere, the layer of the atmosphere that contains the ozone layer, UV rays from the sun react with the existing oxygen molecules, and break them down into oxygen atoms. In the reaction that follows, three oxygen atoms join together to form ozone molecules. Thus, oxygen is continually converted into ozone.

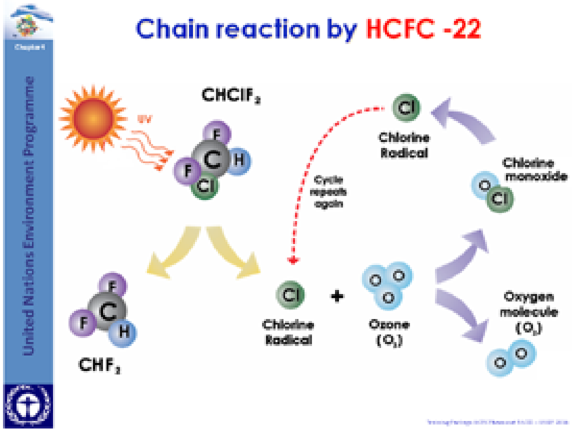
The reverse is also true: some ozone is also decomposed into three oxygen atoms, which join together in twos to become oxygen molecules. In this way, a continuous equilibrium is maintained between ozone and oxygen in the stratosphere.



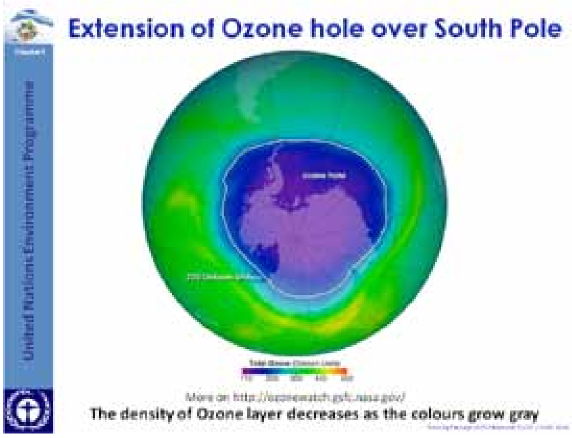

**Slide 4: Distribution of Ozone in the Atmosphere**
As the sun's radiation approaches the planet's surface it can be scattered, reflected, or absorbed, intercepted and re-emitted. This is where the ozone layer comes into its own by scattering and reflecting harmful high energy ultraviolet radiation. Variations in temperature and pressure divide the Earth's atmosphere into layers and the mixing of gases between the layers happens very slowly. That is why this 90% of the ozone stays in the upper atmosphere. This stratospheric ozone contains 90% of all ozone gas on the Earth but it is spread thinly and unevenly.
Life on earth has been safeguarded because of a protective layer in the atmosphere. This layer, composed of ozone, acts as a shield to protect the earth against the harmful ultraviolet radiation from the sun. Ozone is a form of oxygen with three atoms ($O_3$) instead of two ($O_2$). Through natural atmospheric processes, ozone molecules are created and destroyed continuously. Ultraviolet radiation from the sun breaks up oxygen molecules into atoms which then combine with other oxygen molecules to form ozone. Ozone is not a stable gas and is particularly vulnerable to destruction by natural compounds containing hydrogen, nitrogen and chlorine.
Near the Earth's surface (the troposphere) ozone is an increasingly troublesome pollutant, a constituent of photochemical smog and acid rain. But safely up in the stratosphere, 11 to 48 km above the earth's surface, the blue, pungent-smelling gas is as important to life as oxygen itself. Ozone forms a fragile shield, curiously insubstantial but remarkably effective. (courtesy: UNEP Ref Manual Servicing Technician 2010)



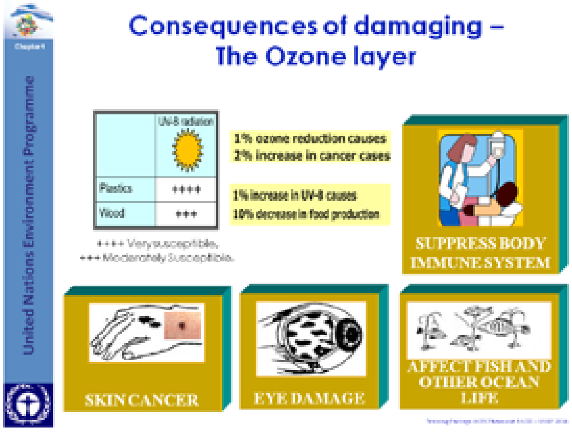

**Slide 5: Ozone Absorbs Ultraviolet (UV) Radiation**
This slide explains the role of the ozone layer. While the sun's rays help sustain life on Earth, they also contain harmful ultraviolet (UV) rays. Located in the stratosphere, the ozone layer efficiently screens out almost all the sun's harmful UV rays, absorbing them and preventing them from causing damage on the earth's surface.
Ozone molecules are spread over 37 kilometres , from 11km to 48 km above the Earth's surface. That said, the actual ozone content is rather small. In fact, if all of the ozone were to be compressed around the earth's surface at atmospheric level, it would barely have a thickness of 3 mm, no thicker than the sole of a shoe.




**Slide 6: Chain Reaction by HCFC-22**
This slide shows how UV rays cause HCFCs to release chlorine radicals and the subsequent reactions between chlorine and oxygen atoms from ozone molecules. These reactions cause of ozone depletion.
When HCFC molecules comes close to the ozone layer, they trigger a chain reaction. An HCFC molecule decomposes and releases a chlorine radical when it comes into contact with the sun's UV rays. This chlorine radical reacts with an oxygen atom from an ozone molecule, yielding an oxygen and a chloromono-oxide molecule. The chloromono-oxide molecule is unstable and breaks again, releasing a free chlorine radical. This chlorine radical now starts a similar reaction with another ozone molecule. These repetitive cycles deplete the ozone layer.
The presence of chlorine atoms in ODSs is the cause of ozone depletion. Reactions by manmade, ozone-depleting chemicals upset the natural ozone balance in the stratosphere, raising serious concerns.



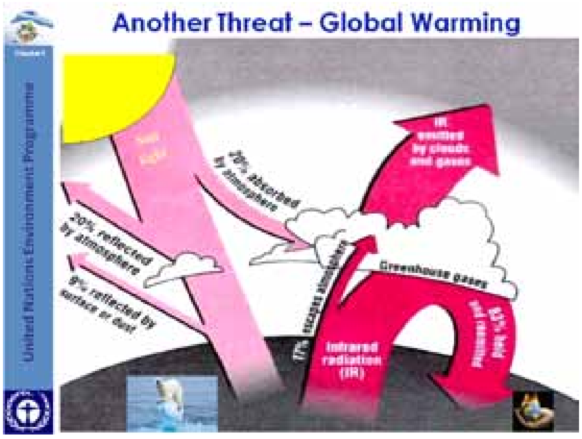

**Slide 7: Extension of Ozone Hole over the South Pole**
Here is an image of the Earth showing the thinning of the ozone layer (ozone hole) over the South Pole. The image is colour-coded to depict the decrease in ozone molecule concentration.
The ozone hole is not technically a "hole" where no ozone is present, but a region of the stratosphere over the South Pole that is exceptionally ozone-depleted. This depleted area appears at the beginning of spring in the southern hemisphere (which lasts from August to October). Satellite instruments provide daily images of ozone levels over the Antarctic region. The image on this slide shows very low values (blue and purple colour area) centred over Antarctica. From the historical record, we know that total column ozone values of less than 220 Dobson Units were not observed prior to 1979. After a series of double- and triple-check tests, Joseph Farman and his colleagues Jonathan Shanklin and Brian Gardiner published a paper in the journal Nature in May 1985 showing that ozone levels over Antarctica had fallen by about 40 percent from 1975 to 1984. An aircraft field mission over Antarctica has shown that a total column ozone level of less than 220 Dobson Units is the result of catalysed ozone loss from chlorinated and brominated compounds. This is why we use 220 Dobson Units as the boundary of the ozone loss region. Using the daily snapshots of total column ozone, we can calculate the approximate area of the ozone hole (the white line in the figure in slide).




**Slide 8: Consequences of Damaging The Ozone Layer**

Ultra Violet radiation (UV) is classified in three ranges: UV-A, UV-B, UV-C. Of these, UV-A is the least energetic and harmful. The component of UV-C in the solar spectrum itself is small, and that reaching the earth is practically nil. UV-B, however is energetic enough to cause biological interactions. With the loss of the natural ozone shield, the Earth's living organisms are exposed to the harmful effects of UV-B radiation. Among other effects, UV-B radiation can increase in the probability of skin cancer among human beings. It can also induce eye injury, damaging the cornea and lens of the eye, which can lead to cataracts. UV radiation can also suppress the human immune system, making it prone to a number of infectious diseases. Fish and other ocean animals are affected by this radiation, since it adversely influences aquatic life, leading to decreased reproductive capacity and impaired development. Materials are also harmed by increased UV radiation, which has adverse effects on synthetic polymers, naturally occurring biopolymers and other materials of commercial interest. Material used in buildings, paints, packaging and countless other substances can be degraded by UV-B rays, which accelerate photo-degradation rates. Typical damage ranges from discoloration to loss of mechanical integrity. Increased UV-B radiation may also cause decreased crop yields and damage to forests, as well as increased cancer rates in humans.

*(Trainers Guide – NCCoPP, India)*




**Slide 9: Another Threat - Global Warming**

Another important environmental impact of refrigerants relates to the phenomenon of global warming. This slide illustrates this phenomenon, also known as the "Greenhouse Effect".

a) Solar radiation interacts with Earth's surface in several ways. Out of the total solar radiation, nearly 20% is reflected from the earth's atmosphere, 20% is dispersed into the atmosphere, and 9% is reflected from earth's surface or dust. The remaining 51% penetrates the atmosphere and reaches the Earth's surface.

b) Most of the solar radiation reaching reaches the Earth's surface is reradiated to the atmosphere.

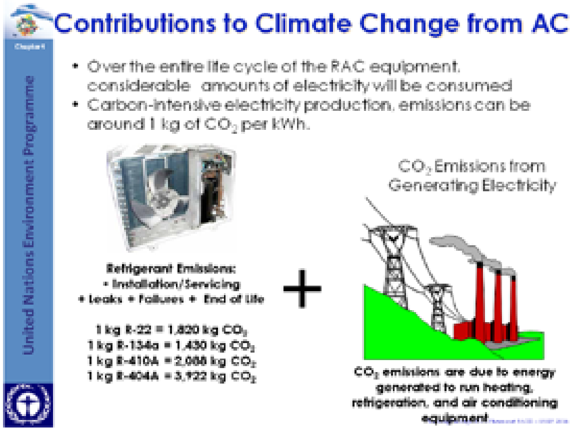
c) As the reradiated radiation leaves the earth, it once again interacts with the atmosphere. Some of this energy manages to escape (about 17%), but majority of this radiation is pushed back to the Earth's surface by the presence of greenhouse gases. This reflected energy further warms the surface of the earth, leading to global warming, or the "Greenhouse Effect."

A limited amount of global warming is necessary to sustain life on Earth. The complete absence of global warming would render the Earth's temperatures so low that human life would not be possible. However, some greenhouse gases emitted through human activities, such as carbon dioxide (CO2), methane (CH4), nitrous oxide (NO), sulphur hexafluorides (SF6), Hydrofluorocarbon (HFCs), and perfluorocarbons (PFCs), increase global warming beyond the natural levels, posing a threat to the environment and mankind.

In the last hundred years, the mean global temperature has increased by 0.3 to 0.6°C. This is causing seawater to thermally expand and the icecaps to melt, leading to rising sea levels. An increase in global sea levels of 4 to 10 inches has been observed over the last 100 years. The Earth's rainfall patterns have also been affected, leading to climate changes and impacting biodiversity. These changes also have a negative effect on human health.

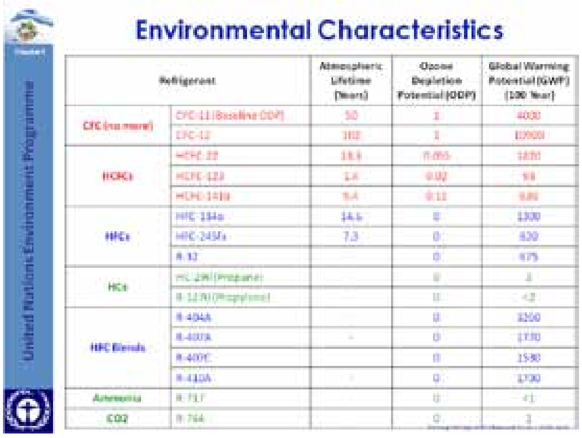
According to experts, the world will feel the impact of global warming in the next few decades. Increased global temperatures, combined with rising population rates, will make society more vulnerable to climate change. Higher temperatures will lead to climatic disorders, droughts, famine, floods and longer heat waves in new areas. Tropical islands and low-lying coastal areas will face the threat of being submerged by rising sea levels.

*(Trainers Guide – NCCoPP, India)*




**Slide 10: Contributions to Climate Change from Air Conditioners**

The main energy-related contribution of air conditioners to climate change comes from GHG emissions (mainly $CO_2$) from the production of electricity. This particularly true if the electricity was generated by fossil fuels, which is the case in most countries. The life cycle of refrigeration and air-conditioning equipment consumes a considerable amount of electricity. If the electricity production is carbon-intensive, the resulting indirect emissions can be around 1 kg of $CO_2$ per kWh. Studies have shown that the indirect contribution of thermodynamic systems to the greenhouse effect is significantly higher than the direct contribution associated with HCFC leakage and emissions. Direct and indirect contributions are both taken into account in a coefficient called TEWI (Total Equivalent Warming Impact).



Environmental Characteristics

| Refrigerant | | Atmospheric Lifetime (Years) | Ozone Depletion Potential (ODP) | Global Warming Potential (GWP) (100 Year) |
|---|---|---|---|---|
| CFC (no more) | CFC-11 (Baseline ODP) | 50 | 1 | 4000 |
| | CFC-12 | 102 | 1 | 10900 |
| HCFCs | HCFC-22 | 13.3 | 0.055 | 1810 |
| | HCFC-123 | 1.4 | 0.02 | 93 |
| | HCFC-141b | 9.4 | 0.11 | 630 |
| HFCs | HFC-134a | 14.6 | 0 | 1300 |
| | HFC-245fa | 7.3 | 0 | 820 |
| | R-32 | | 0 | 675 |
| HCs | HC-290 (Propane) | | 0 | 3 |
| | R-1270 (Propylene) | | 0 | <3 |
| HFC Blends | R-404A | | 0 | 3260 |
| | R-407A | - | 0 | 1770 |
| | R-407C | | 0 | 1530 |
| | R-410A | | 0 | 1730 |
| Ammonia | R-717 | | 0 | <1 |
| CO2 | R-744 | | 0 | 1 |

**Slide 11: Environmental Characteristics**

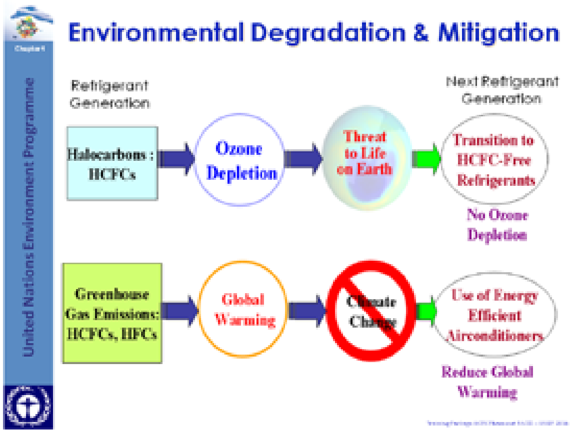
This slide compares the Ozone Depleting Potential (ODP) and the Global Warming Potential (GWP) of some of the most common refrigerants. The table also provides the atmospheric life of each of these refrigerants in years.

ODP and GWP Refrigerants are evaluated for their environment friendliness on the basis of their ODP and GWP. At this point, it is important that the trainer explains what ODP=1 and GWP=1 mean.

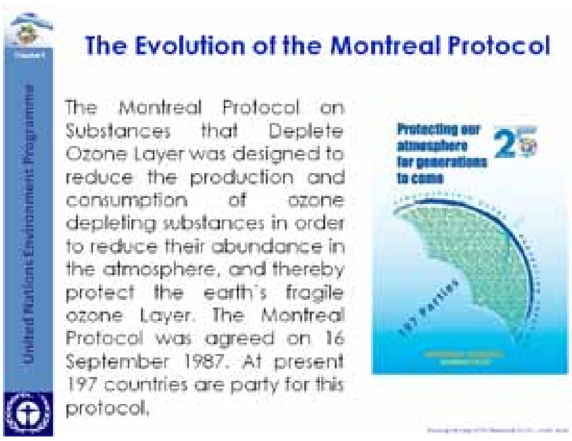
ODP is the measure of the ozone depleting capability of a refrigerant compared to that of CFC-11, which has been given an ODP of 1.0 (baseline). In the table, the ODP values have been colour-coded to visually distinguish the increasing values. As can be seen, the ODP baseline reference value is 1.0 for CFC-11. For HCFC-22 (commonly known as R-22), which is used as an air-conditioner refrigerant, the ODP value is 0.055, and for HFC-134a and hydrocarbons (both propane and butane), the ODP is zero.

GWP is an index that compares the warming effect of different gases over time, relative to equal emissions of $CO_2$ by weight.The highest value is 10,900 for CFC-12, and the lowest is <1 for ammonia. For HFC-134a, the GWP value is quite high: 1,300. This indicates that though HFC-134a is environmentally-friendly as far as ozone depletion is concerned, it is not environmentally friendly when its global warming impact is considered.

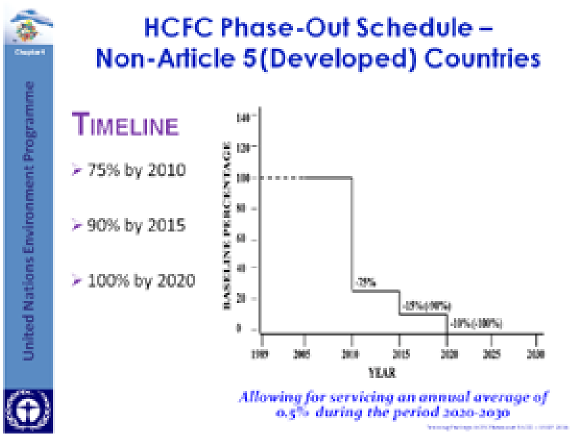
The table also gives ODP and GWP values for various other refrigerants. As mentioned earlier, ideally, ODP should be zero and GWP should be relatively low. GWP is also proportional to the atmospheric lifetime. The longer the atmospheric lifetime, the higher the GWP. HCFCs have high GWP compared to their alternatives (i.e., HFCs and HCs). HFCs have very high GWP compared to ammonia, $CO_2$ and HCs. HCs are close to ideal, having zero ODP and negligible GWP, but there are safety issues associated with their use.



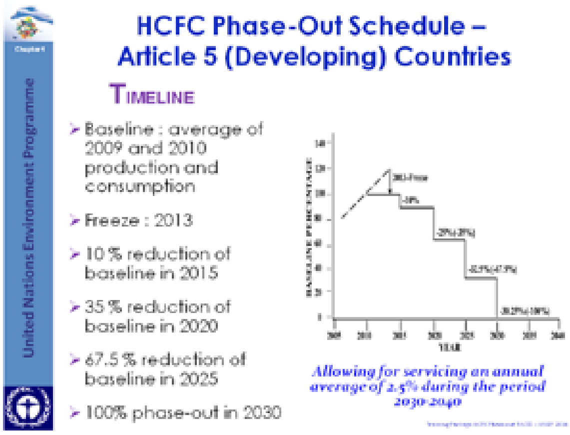

**Slide 12: Environmental Degradation and Mitigation**
This flow chart summarises the key environmental impacts of refrigerants. HCFC refrigerants are a source of ozone depletion, as they contain chlorine atoms. HCFC and HFC refrigerants are a source of global warming, as are other greenhouse gases such as carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide (NO), sulphur hexafluorides ($SF_6$),hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). Use of these refrigerants is a legacy from previous generations. Their continued use contributes to environmental degradation and climate change, and poses a threat to generations to come. In order to help save our environment and our future, we must switch over to HCFC-free, energy-efficient appliances.




**Slide No. 13: The Evolution of the Montreal Protocol**
The Montreal Protocol on Substances that Deplete the Ozone Layer was designed to reduce the production and consumption of ozone depleting substances in order to reduce their abundance in the atmosphere, and thereby protect the Earth's fragile ozone Layer. The original Montreal Protocol was agreed on 16 September 1987. At present, 197 countries are parties to this protocol.




**Slide 14: HCFC Phase-out schedule – Non-Article 5 (Developed) Countries**
At the 20th anniversary meeting of the Montreal Protocol on Substances that Deplete the Ozone Layer, an agreement was reached to adjust the Protocol's schedule to accelerate the phase-out of the production and consumption of HCFCs. This decision will result in early recovery of the ozone layer, with the intention of simultaneously reducing the global warming impact. In addition to the HCFC accelerated phase-out schedules, the 2007 Meeting of the Parties of the Montreal Protocol approved a decision to encourage Parties to promote the selection of alternatives to HCFCs that minimise environmental impacts, in particular impacts on climate, as well as meeting other health, safety and economic considerations. The developed countries will follow the schedule of phasing out 75% of their baseline production and consumption by 2010 and 90% (another 15% of the baseline level from 2010) by 2015. By 2020 they will phase out 100% (another 10% of the baseline level from 2015) except 0.5% that will be allowed to service of HCFC based equipment up to 2030.




**Slide 15: HCFC Phase-Out Schedule – Article 5 (Developing) Countries**
This slide shows the different phase-out schedules for developing countries. The developing countries will follow the schedule and freeze baseline levels of 2009-2010 in 2013. Reduction of 10% from the baseline level will take place in 2015 including 35% reduction in 2020, 67.5% reduction in 2025 and 100% phase-out by 2030. From 2030 onwards, only 2.5% of the baseline level will be allowed to service HCFC-based equipment up to 2040.


**Slide 16: Save Mother Earth**
In this slide, Trainers' role is to summarise important points of ozone depletion and its negative effects, and help the technician appreciate his or her role in the big picture. Trainers must make the technicians aware of their moral and social responsibility not to release refrigerants and other chemicals into the environment, but to recover and reuse the same.

## Evaluation Questions

1. What are the ODP values of:
1) Hydrocarbons
2) CFC-11 / CFC 12
3) HFC-134a
4) HCFC-22

2. Looking at the ODP values in slide, please state whether the following statements are true or false:
a) The refrigerant with highest ODP is CFC-11
b) Hydrocarbons have no ODP
c) HCFC-22 refrigerant has more potential to deplete ozone than HFC-134a

3. Which refrigerant appears to be most desirable from the point of view of both GWP and ODP? Why?

4. Why is global warming harmful to human life?

5. Which element in HCFCs triggers the formation of ozone hole? How?

6. Please state whether the following are ozone depleting substances:
a) CFC-11
b) HFC-134a
c) HCFC-22
d) Isobutane
e) Propane
f) Ammonia
g) $CO_2$

7. How does the use of more energy-efficient air-conditioners help reduce global warming?

8. Compared to carbon dioxide, what is the global warming impact of HCFC-22?

9. What are the harmful health impacts of ozone depletion?

# 2. ALTERNATIVES OF HCFCs AND THEIR CHARACTERISTICS

**Training Material Reference:** Alternatives to HCFCs and their Characteristics – 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 45 minutes

**Purpose of the Session**
To make the participants aware of the various available alternatives to HCFCs, their properties, advantages and disadvantages. The emphasis is on alternatives to HCFC-22 used in domestic and commercial refrigeration and air-conditioning. Issues relating to servicing and retrofitting, compatibility, safety and performance are also covered.

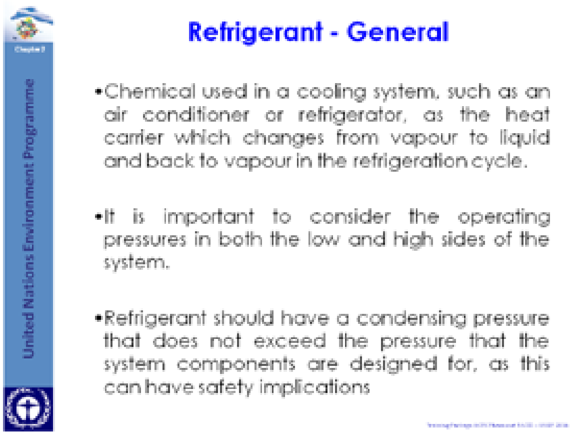
**Final Performance Objectives**
At the end of the session, the participants should know:
(a) What are the alternative refrigerants to HCFC-22
(b) What are the characteristics (properties) of each alternative, such as HFC group, HC group, $CO_2$ and ammonia.
(c) What are the advantages and disadvantages of each alternative.

**Key Message Delivered in this Session**
Under Montreal Protocol the impending phase-out of HCFCs is making way for new ozone-friendly alternatives. These are primarily hydrofluorocarbons (HFCs), hydrocarbons (HCs), ammonia and $CO_2$.

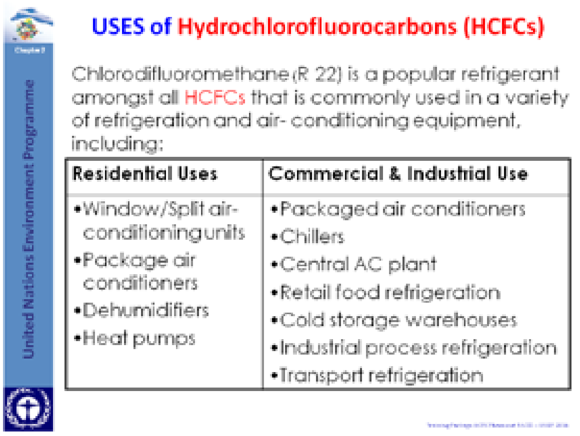
Each of these alternatives has distinct characteristics and properties. In the emerging market scenario, it is important for RAC service technicians to be aware of these alternatives and their characteristics in order to use correct servicing practices.

**Tools and Equipment Required for the Session:**
None.

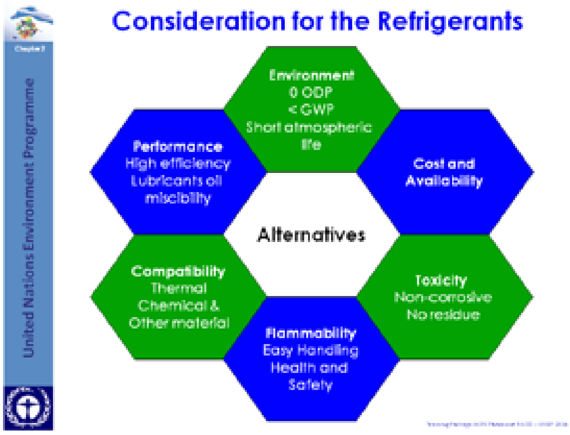

**Slide 1: Alternatives to HCFCs and their Characteristics**
HCFCs like HCFC-22 (popularly known as R-22), HCFC-123 and R-141b can be replaced by non-ODS alternatives. This session will discuss alternatives to HCFCs, and more specifically, the characteristics of alternatives to HCFC-22.




**Slide 2: Refrigerant – General**
A refrigerant is the fluid in refrigeration, air-conditioning and heat pump systems that alternately vaporises and condenses as it absorbs and gives off heat. Refrigerant absorbs heat from one area, such as an air-conditioned space (heat source), and rejects it into another, such as outdoors (heat sink). Ideally, the critical temperature and pressure of the refrigerant must be above the maximum temperature and pressure that will be encountered in the system. Likewise the freezing point of the refrigerant must be safely below the minimum temperature obtained in the cycle. For safe operation, the refrigerant must have a condensing pressure lower than the system's maximum pressure allowance.
It is always preferable that under normal operating conditions, the refrigerant has an evaporating pressure above atmospheric pressure, so that air, moisture and other contaminants will not be drawn into the system in the event of a leak.



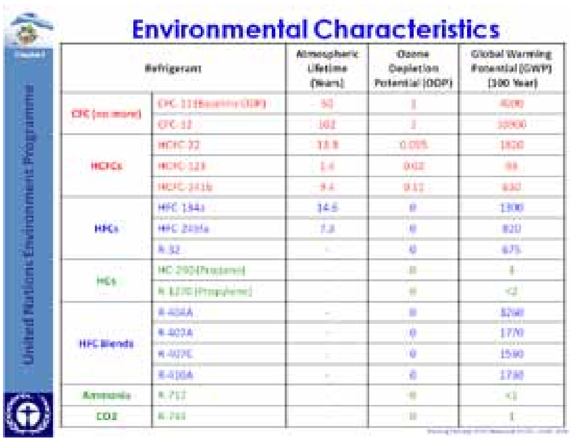

**Slide 3: Uses of Hydrochlorflourocarbons (HCFCs)**
This slide explains the use of HCFC as a refrigerant. HCFC contains hydrogen, chlorine, fluorine and carbon and is not a naturally occurring gas, but a man-made chemical. Commonly known as R-22, HCFC-22 is a commonly used refrigerant that can be found throughout the air-conditioning industry in a variety of applications, including window units, central AC systems and transport refrigeration units.
At this point, participants must be given fact sheet number 25 - Applications of HCFCs and Blends Containing HCFCs. Download the fact sheet at: http://www.unep.fr/ozonaction/information/mmcfiles/4766-e-25ApplicationsBlendsHCFCs.pdf




**Slide 4: Consideration for the Refrigerants**

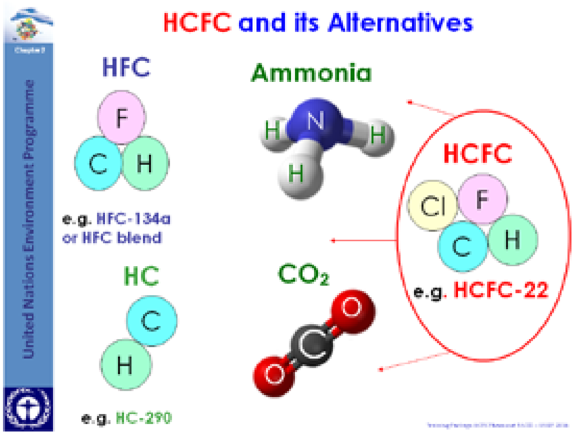
When we switch from HCFCs to more environmentally-friendly refrigerants, we must consider several issues, including whether the alternative has zero-ODP and low-GWP, and how the new fluid performs. The alternative refrigerant should be readily available and affordable. It should be suitably non-toxic and non-flammable. It must be compatible with the air-conditioning system, and not react with, or act as a solvent on, any of the materials found in the system. These include metals in pipes and other components, compressor oils and associated additives, plastic motor materials, elastomers such as seals, o-rings in valves and fittings, and desiccants within filter dryers. The refrigerant should also not react adversely with small quantities of contaminants such as moisture and air.

We note here that a single refrigerant cannot meet all the above-mentioned criteria. Certain HFC blends such as R-407C and R410A may have high GWP. R-290 and R-1270, are environmentally-friendly from an ozone and climate perspective, but also have flammability issues. One should always try to choose refrigerants that are suitable to a given working environment.




**Slide 5: Environmental Characteristics**

This slide is identical to slide 11 of Chapter 1, so there is no need to re-explain, but the trainer should convey the message that it is very important to consider ODP and GWP when choosing alternate refrigerants. (Refer to explanation of slide number 11 of chapter 1).




**Slide 6: HCFCs and its Alternatives**

A simplified figure explains the molecular structure of each family of refrigerants.

• HCFCs (e.g., HCFC-22) contain hydrogen, chlorine, fluorine and carbon.

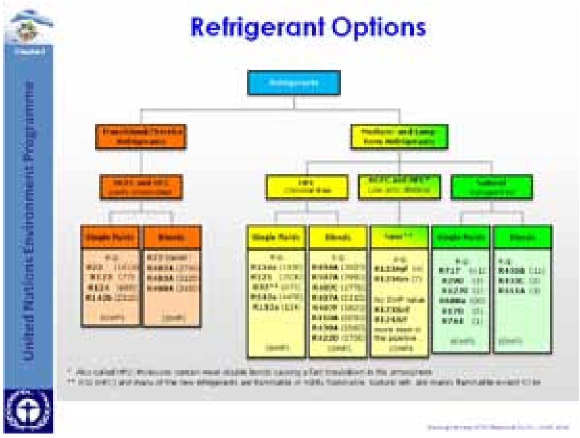
• HFCs (e.g., HFC-134a) contain fluorine, hydrogen and carbon.

• HCs (e.g., HC-290, HC-600a) contain hydrogen and carbon.

• $CO_2$ contains one atom of carbon and two of oxygen

• Ammonia contains one atom of nitrogen and three atoms of hydrogen

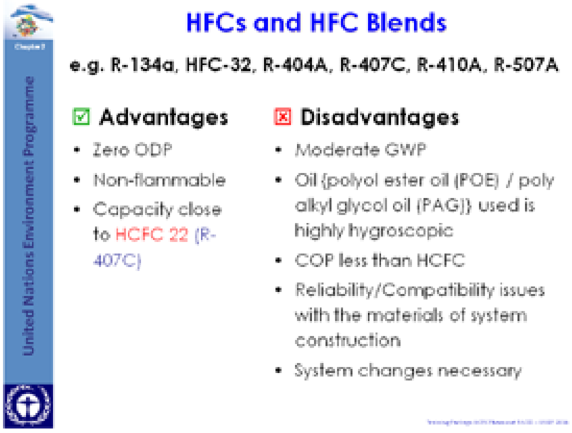
Refrigerants containing chlorine must be phased out from the RAC sector. The trainer can now emphasize the importance of switching over to non-chlorine refrigerants like ammonia, $CO_2$, HFCs and HCs, which are widely available. While low-GWP refrigerants like HCs and HFCs are appropriate for many RAC systems, $CO_2$ and ammonia are mostly used in large-capacity plants, and special training is required in order to use them correctly.




**Slide 7: Refrigerant Options**

In this chart, a shift from the colour red to the colour green indicates the right path to take to ensure environmentally-benevolent RAC systems. As we come increasingly aware of the need to address both ozone depletion and climate change, there is a stronger push towards adopting alternative refrigerants with zero-ODP and low or zero-GWP. Continued interest in replacement refrigerants, coupled with the ever-growing market for RAC has produced several hundred refrigerants and blends that are currently commercially available. This wide diversity of refrigerants, each with its own set of characteristics, can create difficulties for RAC technicians when it comes to handling and servicing practices.

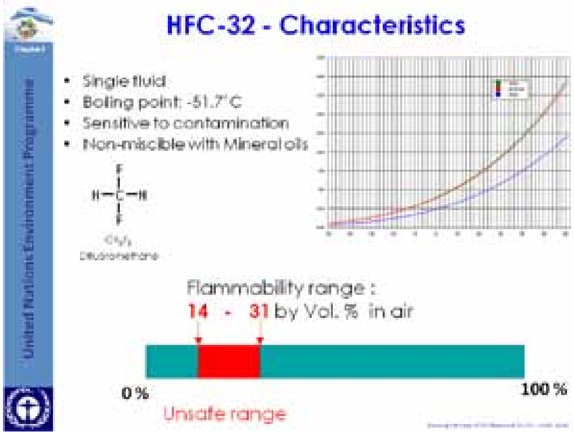
As mentioned earlier, since the 1930s HCFCs have been in widespread use in a variety of applications, including commercial refrigeration, cold storage, transport refrigeration, stationary air-conditioning and chillers. The time has come to permanently phase out HCFCs in order to protect the global environment.




**Slide 8: HFCs and HFC Blends**

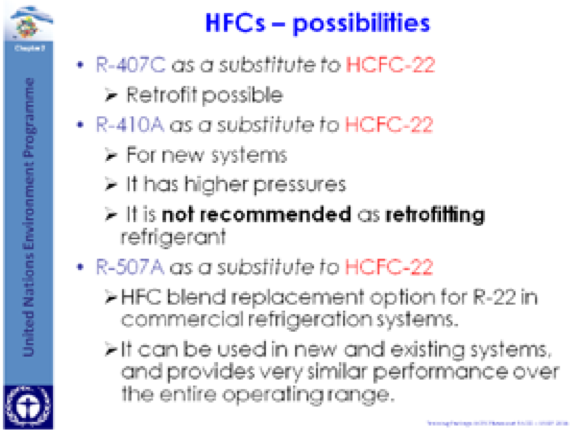
HFCs consist of hydrogen, fluorine, and carbon. The most common refrigerants in this group are R-134a, R-32, R-125 and R-143a (mostly within blends, such as R-404A, R-407C and R-410A). They have been used on a large scale since the 1990s in nearly all applications that have traditionally used CFCs and HCFCs, including domestic and commercial refrigeration, cold storage, vehicle air-conditioning, transport refrigeration, stationary air-conditioning and chillers. HFCs are chemically very stable. However, they are not miscible with traditional lubricants, so other types of synthetic oils must be used. Across the range of HFCs, there are a variety of pressure-temperature characteristics. This slide explains the advantages and disadvantages of HFCs.

The advantages: HFCs are non-flammable and have zero-ODP. The capacity of R-407C is close to HCFC-22. The disadvantages: HFCs have relatively high-GWP and are included in the group of six greenhouse gases defined under the Kyoto Protocol. There are reliability and compatibility issues with construction materials and lubricating oils when HFCs are used as a retrofit option in an existing HCFC system. As HFCs are not miscible with mineral oils, special synthetic oils have been developed for them: Polyol Ester Oils (POE) and Poly Alkyl Glycol (PAG).




**Slide 9: HFC-32 Characteristics**

HFC-32 (Difluoromethane), or R-32, is an organic compound of the dihalogenoalkane variety. It is based on methane, except that two of the four hydrogen atoms have been replaced by fluorine atoms. Hence the formula is $CH_2F_2$ instead of $CH_4$ for normal methane. R-32 is a refrigerant that has zero ozone depletion potential (ODP). As a refrigerant R-32 is classified as A2L: slightly flammable according to ASHRAE 2009. Although it has zero-ODP, it has a GWP of 675. The refrigerant R-32 is primarily seen as a possible alternative to R-410A. As the working pressure is 50% higher than R-22, R-32 is not a drop-in alternative for R-22. The main advantage of R-32 is its relatively low GWP. HFC-32 is a single-component refrigerant, and there is no temperature glide. However, as R-32 has a 20°C higher discharge temperature than R-410A, maintaining safe compressor temperature is important.




**Slide 10: HFCs - Possibilities**

This slide lists other HFC alternatives to HCFCs. These are: R-407C R-410A and R-507A. All three are HFC blends.

• R-407C is a substitute for HCFC-22; retrofitting is possible with certain changes in the system.

• R-410A is a substitute for HCFC-22. It is recommended for new systems but not for retrofitting, as the pressure is too high.

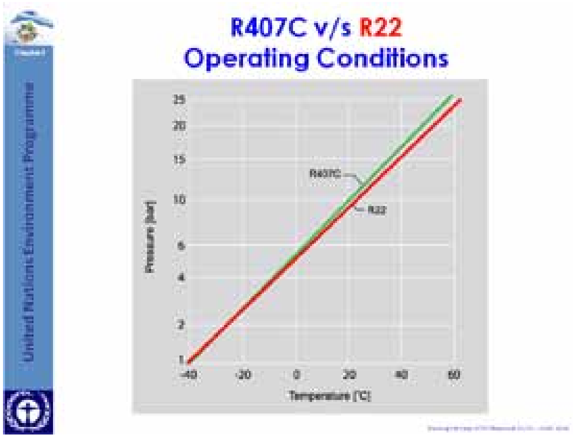
• R-507A is a substitute for HCFC-22 in a low-temperature system; it can be used in existing and new systems.

As all three are blends of HFCs, all of them require POE as a lubricant.

R-407C is a mixture of HFC-32, HFC-125 and HFC-134a in the ratio of 23%, 25% and 52% respectively.

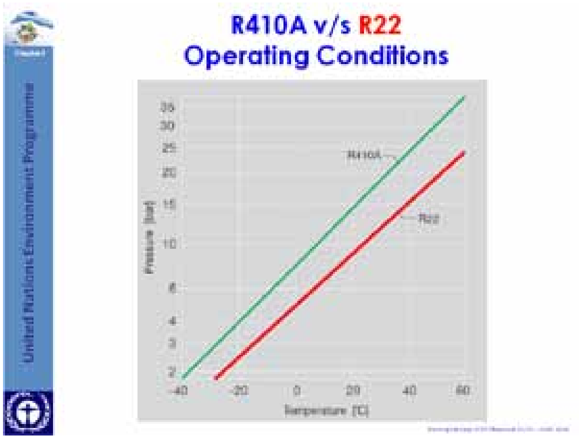
Similarly, R-410A is a mixture of HFC-32 and HFC-125 in a ratio of 50/50. R-410A has much higher pressure than HCFC-22.

R-507 is a mixture of R-125 and R-143a in a ratio of 50/50.

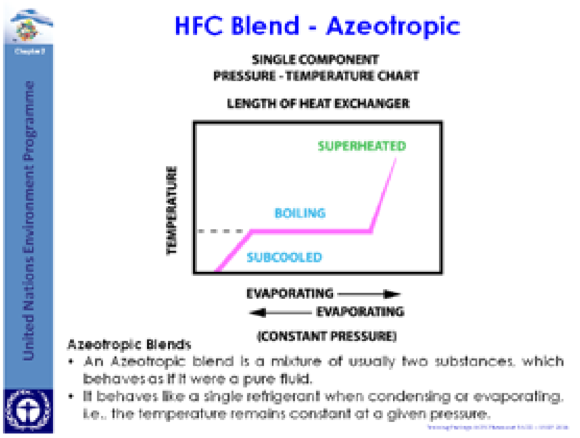



**Slide 11: R-407C v/s R-22 Operating Conditions s**

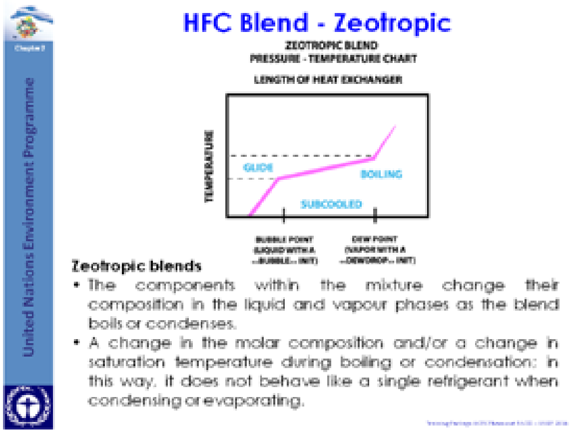
The favoured candidates for R-22 substitution is a blend of the HFC refrigerants R-32, R-125 and R-134a. The performance and efficiency is very similar, making R407C a good candidate for retrofitting. R407C corresponds well with R-22 in terms of pressure levels, mass flow, vapour density and volumetric refrigeration capacity.




**Slide 12: R-410A v/s R-22 Operating Conditions**
In addition to R-407C, an azeotropic blend is available, called R-410A. It is already widely used, mainly in air-conditioning applications. One of its most prominent features is that it has nearly 50% higher cooling capacity than R-22, but with a proportional rise in system pressure. At high condensing temperatures, energy consumption/COP initially seems to be less favourable than R-22. This is mainly due to its thermodynamic properties. R-410A is recommended only for new systems and not at all advisable for retrofitting. With an optimised design, it is quite possible for the system to achieve equal or better overall efficiency than with HCFC-22. Because of the negligible temperature glide (< 0.2 K), the general usability can be seen similar to a pure refrigerant. R-410A's material compatibility is comparable to the previously discussed blends, and the same applies for the lubricants. The fundamental criteria for HFC blends also apply to the system technology with R-410A, however the extreme high-pressure levels have to be considered (43°C condensing temperature already corresponds to 26 bar abs.)




**Slide 13: HFC blend – Azeotropics**
Azeotropic Blends: An azeotropic blend is a mixture, usually of two substances, which behaves as if it were a pure fluid. When heat is added to or removed from an azeotropic refrigerant blend, the composition (mole fraction) of the vapour and the liquid remain essentially unchanged throughout the complete process. In other words, in a blend of 50% of fluid A and 50% of fluid B, for every molecule of fluid A that vaporises or condenses, a molecule of fluid B does the same. Historically, the commonly used ODS blends were R-500 (mixture of R-12 and R-152a) and R-502 (mixture of R-22 and R-115). More recently, an azeotropic blend using only HFCs has been found, R-507A (mixture of R-125 and R-143a). An azeotropic blend behaves like a single refrigerant when condensing or evaporating, i.e., the temperature remains constant at a given pressure.

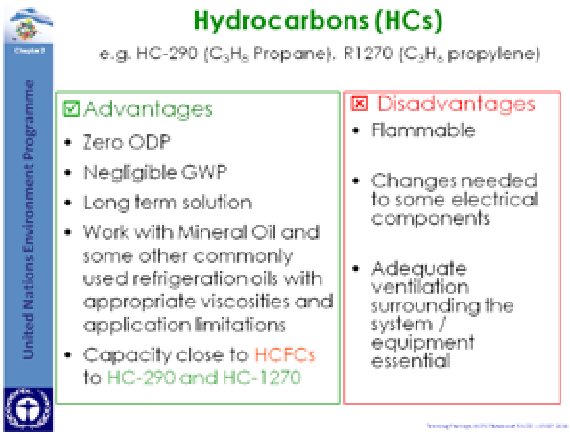



**Slide 14: HFC blend – Zeotropics**

Zeotropic blends: A zeotropic blend is a mixture of refrigerants whose different volatilities are seen when observing the performance of a refrigeration cycle. For example, in a change in the molar composition and/ or a change in saturation temperature during boiling or condensation the blend does not behave like a single refrigerant when condensing or evaporating. Two different situations arise, depending upon the type of system.

The slide shows a zeotropic mixture of refrigerant components, fluid A and fluid B, as it flows through a heat exchanger tube. In the case of a pure fluid, the temperature of the refrigerant remains the same as the liquid vaporises or condenses. However, with a zeotropic blend, as the refrigerant vaporises, the saturation temperature rises, or as the vapour condenses, the saturation temperature falls. The refrigerant is at the bubble temperature when it is just a pure liquid (e.g., when it is just evaporating) and is at the dew temperature when it is just a pure gas (e.g., when it is just condensing).

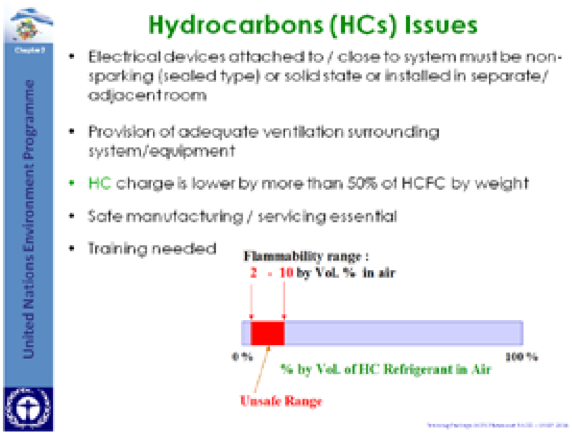
Temperature glide: The characteristic called "temperature glide" occurs when the refrigerant blend changes temperature as it evaporates or condenses under a single given pressure. R-407C has a 7.8°C temperature glide, so there is no way to know which compounds have leaked when leakage is found.



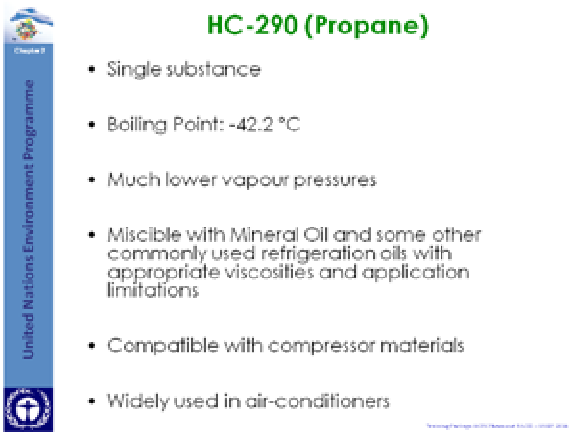

**Slide 15: Hydrocarbons (HCs)**

This slide covers the advantages and disadvantages using HCs as an alternate to HCFCs.

HCs are long-term solutions due to their zero-ODPs and negligible GWPs. They are miscible with mineral oil and some other commonly used refrigeration oils with appropriate viscosities. HCs can be used in existing or new systems, with few changes. The system capacities of HCs are close to HCFCs. The main disadvantage of HCs is that they are flammable. This safety issue needs to be addressed by changes in some electrical components and providing adequate ventilation surrounding the system and equipment.

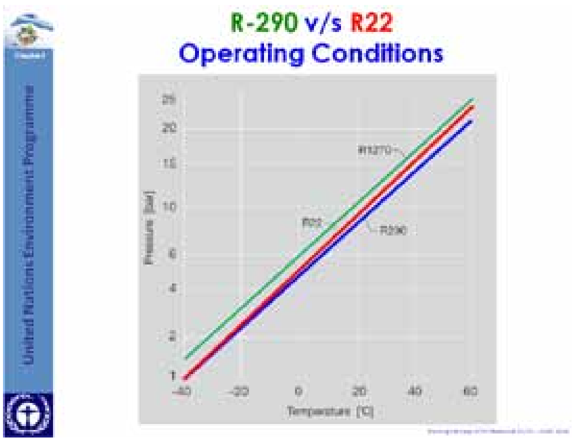



**Slide 16: Hydrocarbon (HCs) issues**
Flammability is the main concern when using hydrocarbon refrigerants. Therefore, safe design and manufacturing processes need to be followed. Care has also to be taken while servicing such appliances.
Due to the flammability of HCs, the electrical components attached close to the system must be non-sparking.
The liquid density of HCs is much lower than HCFCs. Therefore, the charge of HCs required by weight is much lower than the HCFC charge.
As explained earlier, HCs are also fully miscible with the traditionally used mineral oil. Hence, retrofitting is possible, but safety concerns must be addressed properly. This is one of the greatest advantages of using HCs for use in retrofitting.
Safe manufacturing and good servicing practices are essential when using HCs. This requires special training.

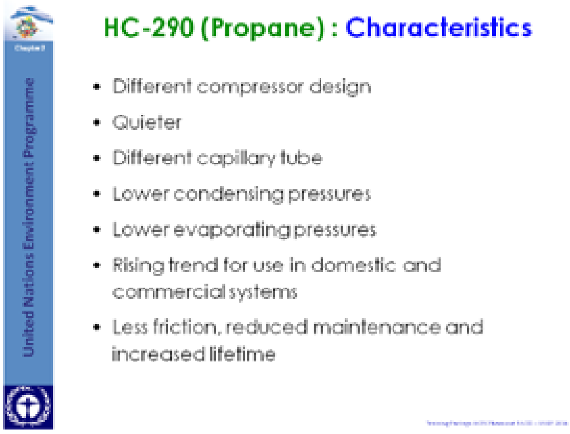



**Slide 17: HC-290 (Propane)**
HC-290, otherwise known as propane, produces a cooling capacity close to HCFC-22 with a same size compressor. HC-290 is a single-component refrigerant. The coefficient of performance (COP) of HC-290 is very near to that of HCFC-22. It can also offer the advantage of lower running costs, if the system is properly balanced and charged.

HC-290 has a normal boiling point of –42.2°C. The vapour pressure is much lower than other refrigerants. It is widely used in domestic air-conditioning and chillers. It is increasingly used in commercial refrigeration systems and chillers.



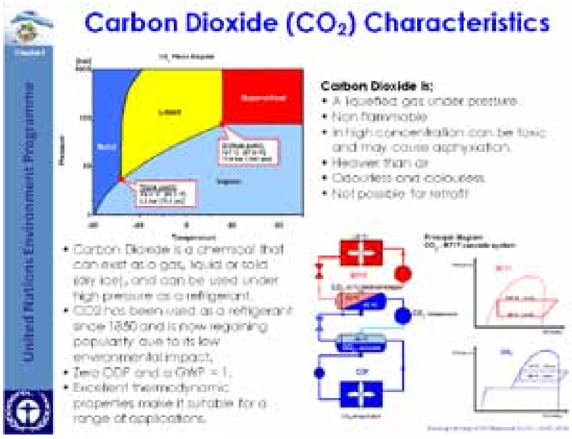

**Slide18: R-290 v/s R-22 – Operating Conditions**
This pressure versus temperature graph is plotted for HCFC-22, R-1270 and R-290. The vapour pressure curves for HCFC-22 and R-290 are very similar. However, for R-290, the pressures are lower than for the other two refrigerants.




**Slide 19: HC-290 (Propane): Characteristics**

HC-290 has lower condensing and evaporating pressures. The machine operates more quietly than when it is run with other refrigerants. The charge quantity amount is much less than HCFC 22 (approximately 44-50% by weight, as per the application).

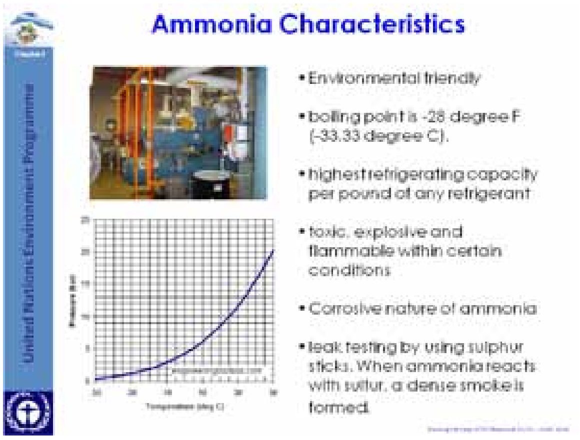
Note: At this stage retrofitting with HC is not encouraged as R&D is still ongoing.




**Slide 20: Carbon Dioxide ($CO_2$) Characteristics**

Carbon dioxide ($CO_2$) or R-744, contains carbon and oxygen, and is widely used in many industries. Since late 1990s, its use is increasing in industrial refrigeration, cold storage, commercial refrigeration and hot-water heat pumps, among other applications. R-744 is chemically stable, and does not react under most conditions, and is compatible with most materials. R-744 has zero ODP, a negligible GWP (GWP = 1), is chemically inactive, non-flammable and mildly toxic in the classical sense. This is the reason that $CO_2$ is not subjected to as stringent of containment regulations as for HFCs (F-Gas Regulation), and flammable or toxic refrigerants.

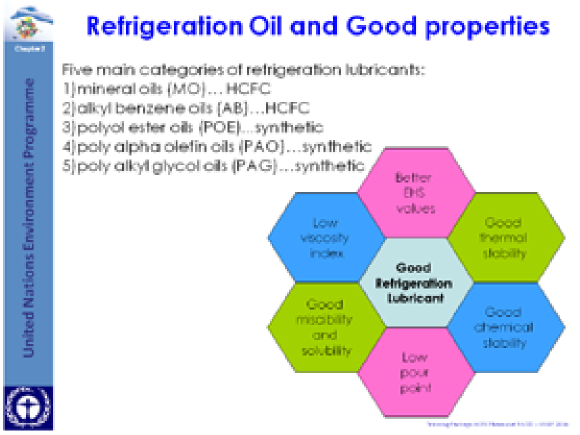
Unlike most conventional refrigerants, R-744 operates at high pressure, (approximately seven times higher than R-22, for example), which means that the RAC system must be designed for high pressure. In addition, it has a low critical temperature, such that when ambient temperatures exceed about +25°C, a special system design is required. Due to its lower toxicity and non-flammability, it has an A1 safety classification. R-744 is very cheap and widely available from specialist retailers.




**Slide 21: Ammonia Characteristics**
NH3 (ammonia) has been used for more than a century in industrial and large refrigeration plants. It has no ozone depleting potential and no direct global warming potential. It is very efficient in system using R-22. In addition, it is very low in price. It has the highest refrigerating capacity per pound of any refrigerant.

While ammonia is a very good refrigerant that is well suited to large installations, it has several drawbacks, including toxicity, mild flammability and incompatibility with copper. Due to its corrosive nature, it is not compatible with some metals. Special care must be taken when designing and servicing ammonia-based equipment.

In an ammonia plant, leaks can be identified with the help of a sulphur stick. Ammonia reacts with sulphur and produces dense smoke, making it possible to find the leakage very quickly.




**Slide 22: Refrigeration Oil and Good Properties**
Compressor manufacturers always specify oil type, and fill each model of compressor accordingly. One of the most common servicing mistakes is not checking which is the appropriate lubricant for the serviced system. Using the wrong lubricant can cause damage to the system due to non-compatibility with refrigerant and system components. In hermetic systems, the lubricant is in intimate contact with the electrical motor windings. The oil must therefore provide good, material compatibility and have high thermal stability properties. Although most of the lubricant remains in the compressor, a small amount will be circulated into the rest of the refrigerant circuit. The lubricant must be able to resist both the high temperatures at the compressor discharge valves and the low temperatures at the expansion device. The lubricant must be miscible with the refrigerant itself in order for it to be returned back to the compressor. Otherwise, over time, the compressor becomes starved of oil, which can lead to mechanical failure. There are five major categories of lubrication oil: mineral oils (MO), alkyl benzene oils (AB), polyol ester oils (POE), poly alpha olefin oils (PAO) and poly alkyl glycol oils (PAG). The first two are mineral oils and the next three are synthetics.

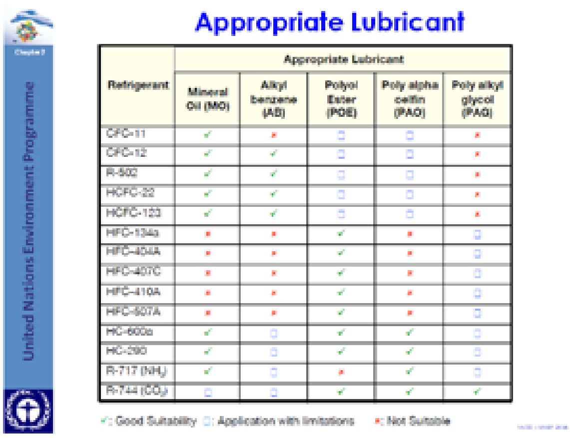
The properties of a good refrigeration lubricant are:
• Low wax content. Separation of wax from the refrigeration oil mixture may plug refrigerant control orifices.
• Good thermal stability. It should not form hard carbon deposits and spots in the compressor, such as in the valves of the discharge port.
• Good chemical stability. There should be little or no chemical reaction with the refrigerant or materials normally

found in systems.

• Low pour point. This is the ability of the oil to remain in a fluid state at the lowest temperature in the system.

• Good miscibility and solubility. Good miscibility ensures that the oil will be returned to the compressor, although a too high solubility may result in lubricant being washed off the moving parts.

• Low viscosity index. This is the ability of the lubricant to maintain good oiling properties at high temperatures and good fluidity at low temperatures and to provide a good lubricating film at all times.

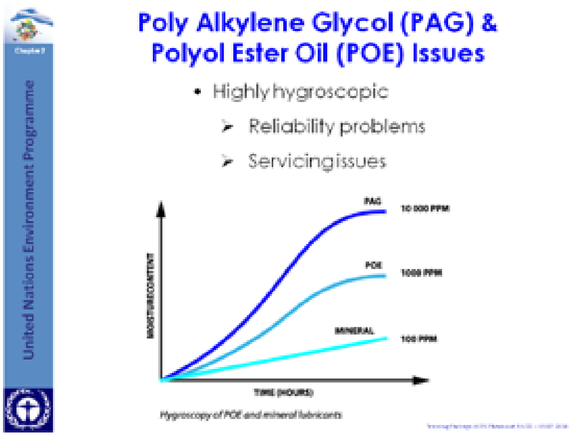



| Refrigerant | Appropriate Lubricant | | | | |
|---|---|---|---|---|---|
| | Mineral Oil (MO) | Alkyl benzene (AB) | Polyol Ester (POE) | Poly alpha olefin (PAO) | Poly alkyl glycol (PAG) |
| CFC-11 | ✓ | ✗ | □ | □ | ✗ |
| CFC-12 | ✓ | ✓ | □ | □ | ✗ |
| R-502 | ✓ | ✓ | □ | □ | ✗ |
| HCFC-22 | ✓ | ✓ | □ | □ | ✗ |
| HCFC-123 | ✓ | ✓ | □ | □ | ✗ |
| HFC-134a | ✗ | ✗ | ✓ | ✗ | □ |
| HFC-404A | ✗ | ✗ | ✓ | ✗ | □ |
| HFC-407C | ✗ | ✗ | ✓ | ✗ | □ |
| HFC-410A | ✗ | ✗ | ✓ | ✗ | □ |
| HFC-507A | ✗ | ✗ | ✓ | ✗ | □ |
| HC-600a | ✓ | □ | ✓ | ✓ | □ |
| HC-290 | ✓ | □ | ✓ | ✓ | □ |
| R-717 ($NH_3$) | ✓ | □ | ✗ | ✓ | □ |
| R-744 ($CO_2$) | □ | □ | ✓ | ✓ | ✓ |

✓: Good Suitability □: Application with limitations ✗: Not Suitable

**Slide 23: Appropriate Lubricant**

In this slide a table shows which lubricants are appropriate for each refrigerant. It has been divided into three groups based on the following criteria: good suitability, with limitation and not suitable.




**Slide 24: Poly Alkylene Glycol (PAG) and Polyol Ester (POE) Oil Issues**

The use of POE and PAG lubricants with HFCs is a key concern. PAG and POE oils are highly hygroscopic and thus can easily absorb moisture from the air. PAG oils are many times more hygroscopic than POE oils. To remove moisture, which is very likely to enter during servicing, the technician needs to evacuate properly using a good two-stage vacuum pump. The system should not be left open for a long time. Due to this issue, manufacturing and servicing practices need to be changed and improved significantly. Additional training to avoid contamination is required.

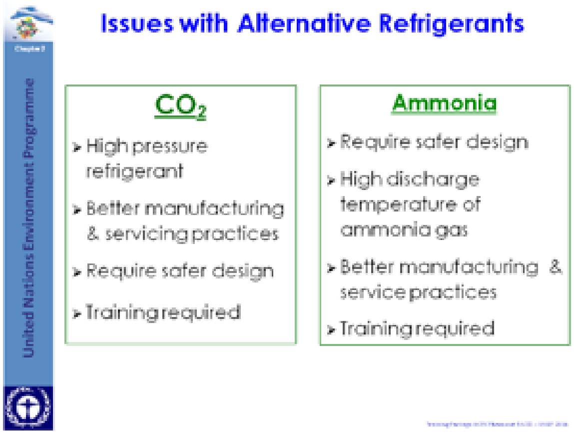
[Some new generation oils, which are less hygroscopic, are under trial].


**Slide 25: Issue with Alternative Refrigerants (HFC Blends and HC)**

Issues relating to refrigerant blends are:

- HFC-based blends are an interim replacement solution for HCFCs.
- Due to their non-azeotropic and possibly flammable characteristics, the servicing procedure, especially charging, is complicated, and technicians should be trained to follow proper handling procedures.
- It is more difficult to estimate the amount of superheating and sub-cooling when commissioning or servicing a system.
- Leakage from heat exchangers and subsequent re-filling will lead to a gradual change in composition, thereby resulting in a change in performance and operating characteristics over time.

This part deals with issues related to hydrocarbons. Due to their flammability issues, technicians need to know how to handle HCs safely, and be familiar with their country's HC standards. While manufacturers should incorporate design safety features, technicians also must follow good servicing practices.




**Slide 26: Issue with Alternative Refrigerants ($CO_2$ and Ammonia)**

$CO_2$ has a very high operating pressure and requires special training for service technicians.

Ammonia also has a similar disadvantage with a high discharge temperature, so extreme care must be taken while handling refrigerant and specific training is required.

Ammonia is a very good refrigerant suited for large installations; toxicity, mild flammability and incompatibility with copper are the main drawbacks.

## Evaluation Questions

1. Name the different alternatives to HCFC-22 (R-22).
2. What precautions should be taken while servicing HFC appliances?
3. What are the major issues with regard to HCs?
4. In what state must blends be removed from a cylinder and why?
5. Does R-290 require a bigger or smaller compressor than HCFC-22?
6. When we opt for lubricant oil, what precautions should be taken?


INVERTER
New Refrigerant
R410A
Model
CIEDC

# 3. HANDLING OF HFCs REFRIGERANTS

**Training Material Reference:** Handling of HCFCs/ HFCs refrigerants – 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 20 minutes

**Purpose of the Session**
To make the participants aware of critical characteristics of HFC-based refrigerants, the precautions to be taken while handling HFC cylinders and cans and general safety issues regarding HFC use.

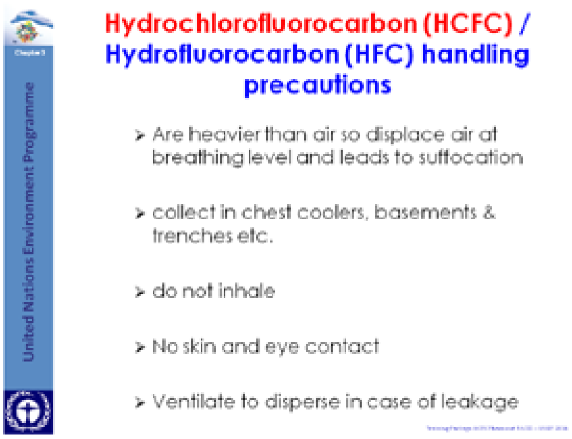
**Final Performance Objectives**
At the end of the session, the participants should know:
(a) The important characteristics of HFCs
(b) General safety issues
(c) What precautions should be taken when handling and storing HFC cylinders
(d) That they should not refill disposable/non-refillable cylinders, overfill refillable/recovery cylinders or change valves on any type of cylinder
(e) How to handle related issues arising out of the use of polyester oils

**Key Message Delivered in this Session**
With the increased use of alternative refrigerants, there will be a growing need for training on how to handle and store cylinders filled with these new alternatives.

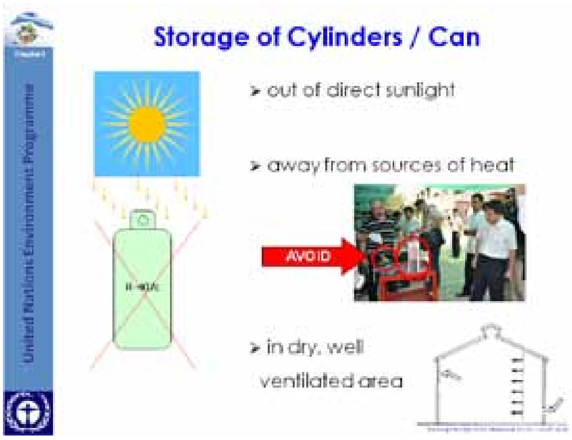
Along with HFCs and HFC-based blends, it is important to address POE oil handling issues. Proper safety precautions must be taken to avoid accidents due to refrigerant and lubricant mishandling or storage.

**Tools and Equipment Required for the Session:**
None.


**Slide 1: Handling HCFC/HFs Refrigerants**
This is the title slide. The trainer can initiate discussion on pure HFCs like R-134a and blends like R-407C, R-410A, R-404A.

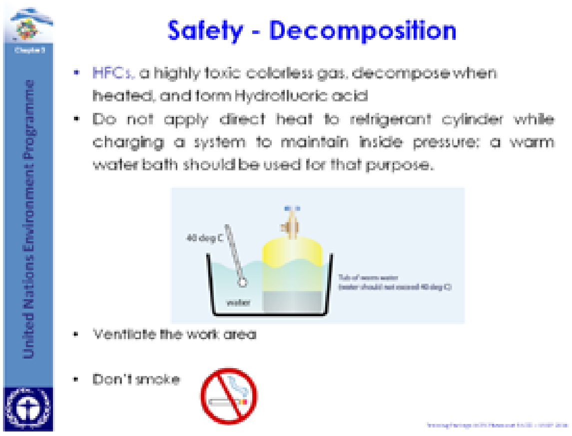



**Slide 2: Hydrochloroflourocarbons (HCFC) Hydroflourocarbons (HFC) Handling Precautions**
The following points need to be emphasised for the safe handling of HFCs
a) HFCs are heavier than air, so they displace air and
b) HFCs have no smell.
c) Since they are heavier than air, HFCs collect in lower positions like the bottom of an appliance or the basement of a building.
d) HFCs can be toxic; a person may suffocate if a high concentration of HFC is inhaled.




**Slide 3: Storage of Cylinder / Can**
HFC cylinders should be stored in dry, well-ventilated areas, away from direct sunlight. Make sure there are no sources of direct heat near the storage. It must be well explained here that no flame or torch must be ignited near the cylinder (see example in the picture). The best practice is to work in a well-ventilated area.


**Slide 4: Cylinder Valve**
Never modify the cylinder and cylinder valves, as they are specifically designed for HFC use.
It is advised never to refill disposable cylinders, as they are not designed for refilling.




**Slide 5: Safety: Decomposition**
HFCs decompose on heating and form hydrofluoric acid. It is therefore advised that appliances should not be heated by flame, electrical heating elements, or smoke. The work area must be well ventilated. If the cylinder becomes cold or some frost forms on the outside of the cylinder while charging, do not heat it with a flame, just put the cylinder in hot water (40°C) and then charge the refrigerant.
In case of any decomposition, ventilate the work area and make sure no one smokes.

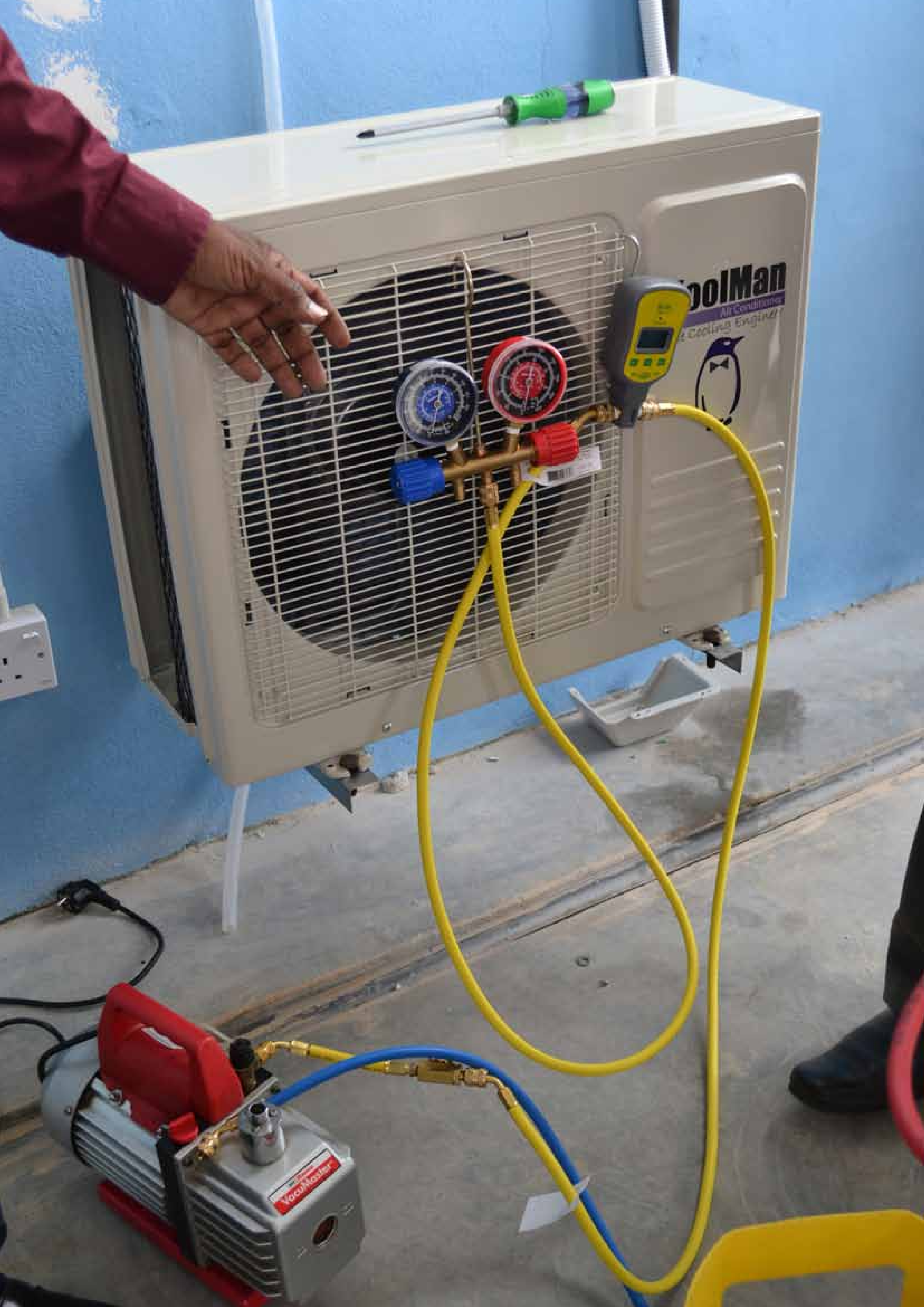

**Slide 6: Safety - Do not overfill cylinder**
This slide emphasises the importance of not overfilling a cylinder. A refillable or recovery cylinder should not be refilled more than 75% of volume and at a temperature of 21°C, as the temperature is directly proportional to the space covered by the refrigerant. When we refill the cylinder to 85% of its volume and expose it to direct sunlight, and if the temperature reaches 54°C, the cylinder can explode. This is because if atmospheric temperature increases, the refrigerant volume also increases. This can lead to explosion.


**Slide 7: Safely - POE Oils**

Polyol ester oils (POE), Poly alpha olefin oils (PAO) and Poly alkyl glycol oils (PAG) are used with HFCs. The oils cause skin problems. Technicians should wear gloves when handling the oil or oil-filled components. Technicians must take special precautions when handling burnt-out systems, as burnt-out compressors form undesirable gases, specifically acids. The best option is to wear personal protective equipment (PPE) while handling burnt out systems and when working with mineral oils.

## Evaluation Questions

1. What are safety issues related to handling and using HFCs?
2. How should HFC cylinders be stored?
3. Why should the refillable or recovery cylinder not be filled above 75%?
4. What are the precautions to be taken in handling POE oil?


Air Conditioner
VacuMaster

# 4. SERVICING OF HCFC/ HFC-BASED AIR-CONDITIONERS

**Training Material Reference:** Servicing of HCFC/ HFC-based Air-conditioners - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
To train participants on systematic servicing practices for HFC-based air conditioners.

**Final Performance Objectives**
At the end of session the participants should understand the following:
(a) How to recover HCFC/HFC-refrigerants
(b) The steps in servicing HCFC/HFC-based air conditioners
(c) Why leakages happen in RAC systems
(d) The importance of drawing proper vacuum
(e) The charging procedure for HCFC/HFC refrigerants

**Key Message Delivered in this Session**
Since HFCs contribute to climate change, and HCFCs have both high GWP and deplete the ozone layer, these refrigerants should be recovered and not vented. HCFC 22 and HFCs (such as R-410A) are the most commonly used refrigerants in air conditioners. Mineral oils are not compatible with HFCs, and so POE oils are used. POE oils are hygroscopic in nature. The HFC systems are also very sensitive to contamination. Thus, servicing procedure and facilities for handling HFCs should be upgraded. Good servicing practices for HCFCs are also necessary to save ozone layer.

**Tools and Equipment Required for the Session:**
During the practical session, some special tools and equipment will be explained and used.


**Slide 1: Servicing of HCFC/HFC-based Air Conditioners**
In domestic and commercial air-conditioning appliances, HFCs are the most commonly used replacement for HCFC refrigerant. This session will discuss step-by-step procedures for good servicing practices for both HCFC and HFC-based appliances.


*In this slide, Trainer may quickly read out each bullet, or use explanations in the following slides.

**Slide 2: Steps of Servicing***
The following step-by-step procedures should be followed for good servicing of HCFC or HFC-based appliances. Each step is described in detail in the slide presentation as well as during the practical sessions.

| Step | HFC Servicing Steps |
|---|---|
| 1 | Recover the HCFC or HFC into a cylinder using a recovery machine as well as a piercing valve for window air-conditioners, or a core removal tool for split air-conditioners. |
| 2 | De-braze the filter and the old process tube. Braze a new “T” process tube and also braze a six-inch (15.25 cm) copper charging pipe. Flush and clean the refrigeration system with nitrogen. |
| 3 | Do the necessary repair work on the appliance, as required. The system should stay open for as little time as possible. In case of medium-sized commercial HCFC/HFC-based appliances, change the filter drier (always use an activated alumina drier for HCFCs and molecular sieve drier for HFCs ) |
| 4 | Choke testing: Flush using oxygen-free dry nitrogen to ensure that nitrogen flows freely from the suction process tube and the “T” process tube or the filter drier process tube. |
| 5 | Leak test with dry nitrogen and soap solution, or an electronic leak detector. Release nitrogen into atmosphere (charge a small quantity of refrigerant and remaining nitrogen into the system, while using electronic leak detector). |
| 6 | Evacuate to lowest pressure, check if vacuum holds. |
| 7 | Charge HCFC/HFC or HFC blend. |
| 8 | Pinch and seal both process tubes. |
| 9 | Run unit and check its performance. |


**Slide 3: Recovery of HCFC/HFC Refrigerant**

Both HCFCs and HFCs are greenhouse gases, and HCFC have ODP as well. It is recommended to recover the pure or azeotropic refrigerant in a cylinder rather than venting it out in the atmosphere. This gas can be reused later for recycling or reclamation.

To recover the HCFC or HFC, the following tools are needed:

• Piercing valves or piercing pliers

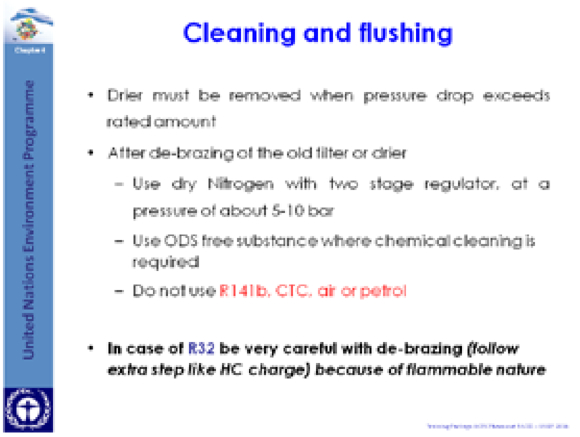
• A good recovery machine (preferably an oil-less compressor) and

• A recovery cylinder

The photograph shows the fixing of piercing pliers on a copper tube. Make sure that the pliers are fixed tightly enough so that there is no leakage of refrigerant.

For subsequent steps, as described in the practical procedures, the piercing pliers and valve are removed and an extension tube with a hand shut-off valve is brazed at the other end.

⇨Run the animation on Section C.




**Slide 4: Cleaning and Flushing**

Cleaning and flushing are important steps in proper servicing practice. Synthetic and hygroscopic oils must not be exposed to ambient conditions for extended periods of time. The HFC and POE combination is very sensitive to contamination, therefore, proper cleaning and flushing of system is required. Once the old filter is removed, the system needs to be properly flushed and cleaned of micro particles.

The following good practices are advised for cleaning and flushing the system:

• Always use dry nitrogen at about 5-10 bar (72-145 psig). The nitrogen cylinder must be fitted with a two-stage regulator. It must have a proper regulator.

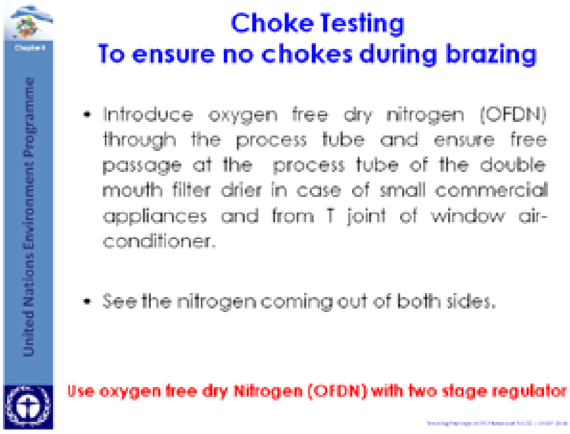
• As R141b is also an ODS, it should not be used. Use ODS-free substances when chemical cleaning is required. There should be no traces of liquid chemical after the cleaning is done. Technicians must be aware that exposure to any of the chemicals by inhalation, eye and skin contact or ingestion is toxic to humans. Technicians must wear personal protective equipment (PPE) while handling chemicals.

• Atmospheric air contains moisture, which is detrimental to the RAC system. Use of air should be totally avoided, especially with HCs, HFCs or HCFCs.

• Petrol contains impurities that can contaminate the system. Never use petrol for cleaning.

If the system is based on R-32 refrigerant, the same precautions must be taken for de-brazing as for HC de-brazing.


**Slide 5: Repair the System**
Carry out all necessary repairs. In the case of small commercial HCFC- or CFC-based machines, use an activated alumina drier for HCFC and a molecular sieve drier for HFC appliances, as each of these filter driers contain the appropriate grade of molecular sieves desiccants for each refrigerant. Also, fix with a “T” copper tube in front of the air conditioner filter. Also braze a process tube with a hand shut-off valve to the “T” joint.

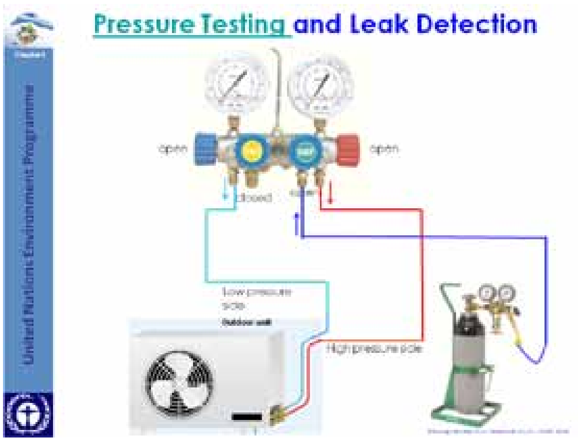



**Slide 6: Choke testing**
After the required repairs, it is necessary to flush the system and ensure that no choking has taken place due to improper filter brazing, particularly at the capillary end.
To do this, introduce nitrogen at 5 bar through the hand shut-off valve on the filter process tube and see if nitrogen flows freely from the suction process tube. This will ensure that there are no chokes due to brazing at the capillary-filter joint.

Next, introduce oxygen-free dry nitrogen at 5 bar through the suction process tube and see if nitrogen flows freely through the filter process tube. This ensures that the filter and condenser joints are not choked.

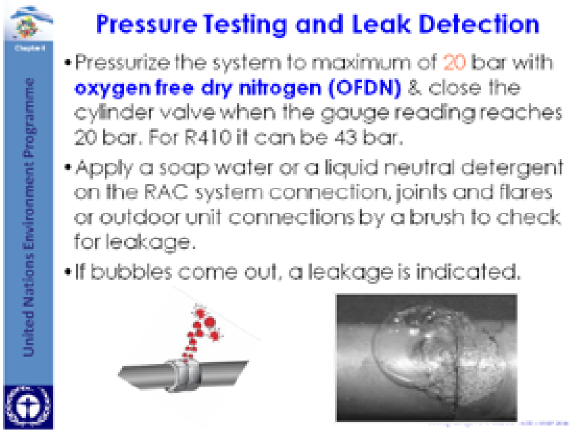

**Slide 7: Why does leakage occur?**
Refrigerant leaks are caused by material failure. The material failure is normally attributable to one or more of the following factors:
1. Vibration – Vibration is a significant factor in material failure and is responsible for “work hardening” of copper, misalignment of seals, loosening of securing bolts to flanges, etc.
2. Frictional wear – There are many cases of frictional wear causing material failure, and they vary from poorly-fixed pipe work to malfunctioning shaft seals.
3. Incorrect material selection – In a number of cases, the use of inappropriate materials leads to leaks. For example, certain types of flexible hoses are known to leak, while other materials cannot hold up to vibration, transient pressure and/or temperature changes.
4. Poor quality control – Unless the materials used in the refrigeration system are of a high and consistent standard, changes in vibration, pressure and temperature will cause failure.
5. Poor connections – Poorly made connections, such as brazed joints, flare connections, or valves without caps, can allow refrigerant to escape.
6. Corrosion – Exposure to a variety of chemicals or harsh weather can result in a variety of different types of corrosion, which decay the construction material and result in pitting on pipes.
7. Accidental damage – Accidental mechanical impacts to refrigerant-containing parts can happen under many circumstances, therefore it is important to ensure that all parts of the system are protected against external impacts.

Refrigeration systems are designed to operate correctly with a fixed charge of refrigerant. If it has been determined that a system has insufficient refrigerant, the system must be checked for leaks, then repaired and recharged.




**Slide 8: Pressure Testing and Leak Detection**
This slide shows the line connection to fill the nitrogen pressure to check the leakage in the circuit. Pressure testing should be done after repairs using oxygen free dry nitrogen (OFDN).

➩Run the animation of Pressure Leak on Section C.




**Slide 9: Pressure Testing and Leak Detection**

The test pressure can be 1.5 times the working pressure. In case of air conditioners, it may be about 20 bars. Test pressure varies depending on the refrigerant. For instance, R-410 around 43 bars for test pressure. The procedure for testing for leaks for HFC refrigerant is similar to that for HCFCs. Apply soap solution on each joint with a brush and look for leakage, if any. Be sure to wipe off all the joints with dry cloth before the next step (i.e., evacuation). The given pressure is to be monitored over a period of time (may be 15 to 20 minutes) in order to check for a fall in pressure.


**Slide10: Different Methods – Leak detection**

*Leak Detection with Fluorescent Dyes*

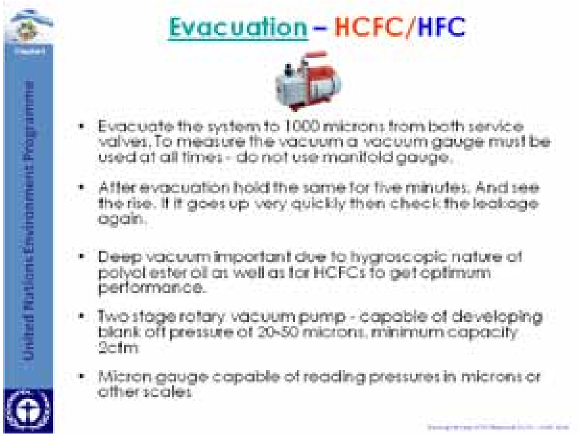
An RAC system can be examined visually for leaks with fluorescent dye. Place a small concentration of fluorescent dye in the refrigerant and allow it to disperse throughout the system, then use an ultraviolet light to check for leaks. The dye in the refrigerant will make the leak glow yellow-green when the ultra-violet lamp passes over it. This method will only be effective on high pressure points in the systems. The ultraviolet lamp method is commonly used in large systems where accessing all joints and connections by soap solution or electronic detectors is difficult.

*Leak Detection by Oil Stains*

A trained service technician can identify a leaking refrigeration system by observing the presence of oil stains on the outside of the equipment. If refrigerant leaks out, lubricant oil leaks out as well, but it does not evaporate rapidly and remains on the outside of the equipment and pipes, indicating the leak area.

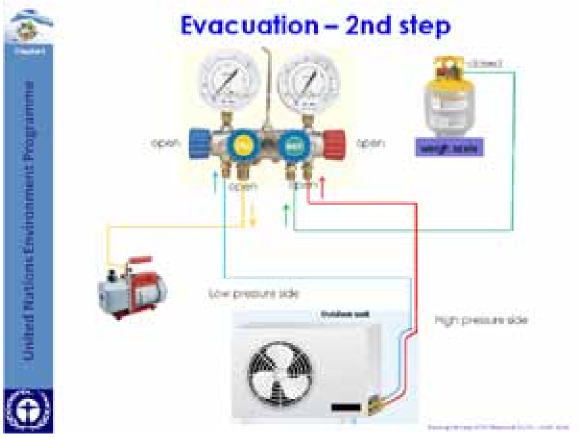
*Leak detection with Electronic Leak Detector*

Electronic refrigerant detectors contain an element sensitive to a particular chemical component in a refrigerant. The device may be battery or AC-powered and often has a pump to suck in the gas and air mixture. Often, an audible “ticking” signal, and/or flashing indicator lamp increases in frequency and intensity as the sensor finds higher concentrations of refrigerant, which in turn leads to the source of the leak. Many refrigerant detection devices also have varying sensitivity ranges that can be adjusted. Many modern refrigerant detectors have selector switches for switching between refrigerant types, e.g., HCFCs, HFCs, or HCs. When using electronic refrigerant detectors in a workshop, always ensure good ventilation since sometimes it gives false signals due to other refrigerants being present in the surrounding area.

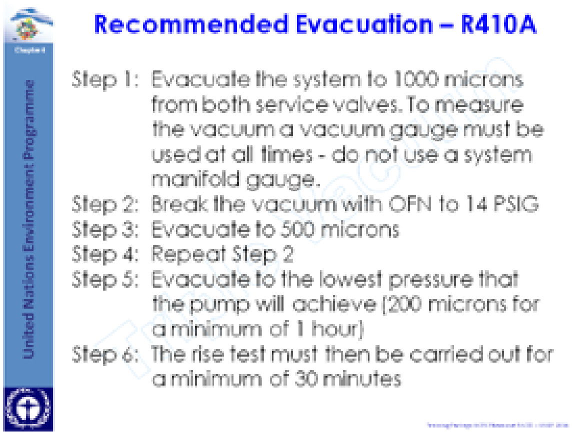



**Slide 11: Evacuation – HCFC/HFC**
Evacuation is very important to remove non-condensable gases and moisture from HCFC/HFC refrigerants. HFC systems need more deep vacuum than HCFCs (500 microns or lower) because of hygroscopic nature of polyol ester oil. A two-stage vacuum pump, capable of pulling vacuum between 20 to 50 microns at blank off is required. A micron gauge capable of reading between 5 to 5000 microns is required to make accurate measurement of the vacuum.
⇨Run the animation of Evacuation on Section C.


**Slide 12: Evacuation – 1st step**
First make proper connection to the vacuum pump (or the manifold) connecting an appropriate hose to the process tube or suction and discharge valves (according to air-conditioner design). Then switch on the vacuum pump and open the valves. Run the pump and evacuate till the gauge shows the lowest vacuum at which it holds steady. This level should be around 500 microns or preferably lower.
Next, close the valve to isolate the vacuum pump from the manifold and observe the rise in pressure (vacuum holding). The pressure should not rise beyond 1,500 microns (the lower the better) in 5 to 10 minutes. This is an indication that most of the moisture is expelled. Of course, lower readings like 500 microns or so are even better and welcome. In case the pressure increase is greater, the system should be evacuated once again and the vacuum holding repeated. In the absence of a micron vacuum gauge, the vacuum pump should be run for at least half an hour after the Bourdon type vacuum gauge reading shows -30"/ -760 mm/ 0 millibar (this value is for locations at sea level; please correct for altitude at other locations above sea level).




**Slide 13: Evacuation – 2nd step**
After the vacuum gauge shows the vacuum, close the valve as shown in the figure and remove the micron gauge. Then attach the charging cylinder with valve in close position. Again run the vacuum pump for two minutes with high side valve in open position to remove the non-condensable gases from the charging hose. By doing this there will be no need to purge the refrigerant from the charging hose.




**Slide 14: Recommended Evacuation – R-410A**

As R-410A is a new refrigerant on the market, technicians need to follow good practices, including deep vacuum. The following is the methodology for performing a vacuum for R-410A air conditioners:

Step 1: Evacuate the system to 1,000 microns from both service valves. To measure the vacuum, a vacuum gauge must be used at all times—do not use a system manifold gauge.

Step 2: Break the vacuum with oxygen free dry nitrogen (OFDN) to 14 PSIG.

Step 3: Evacuate to 500 microns.

Step 4: Repeat Step 2.

Step 5: Evacuate to the lowest pressure that the pump will achieve (200 microns for a minimum of 1 hour).

Step 6: The rise test must then be carried out for a minimum of 5 to 10 minutes.


**Slide 15: Charging by weight**

Following charging method should be followed:

• Charge always in a well-evacuated system.

• Charging should be done slowly and gradually, so that no liquid goes into the compressor.

• Charging should be done by weighing accurate mass of charge; this is essential for good appliance performance.

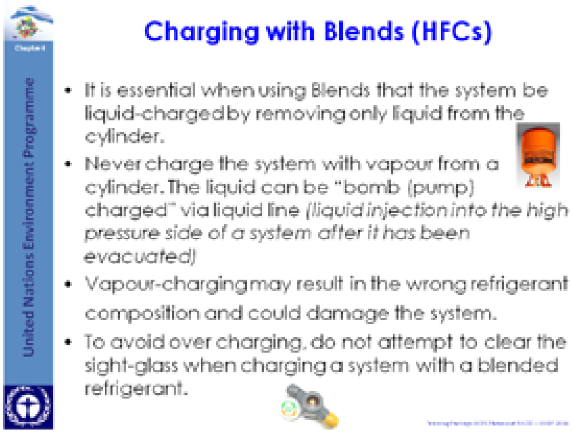
• In case excess refrigerant is charged by mistake, the excess refrigerant charge should not be vented out. It is better to release the full refrigerant and recharge the recommended weight after evacuation.

• Charge the exact same weight of refrigerant in the system as recommended by the appliance manufacturer instead of charging by feel (To ensure good cooling performance and low energy consumption).

➪Run the animation of Charging on Section C.


**Slide 16: Charging by volume**

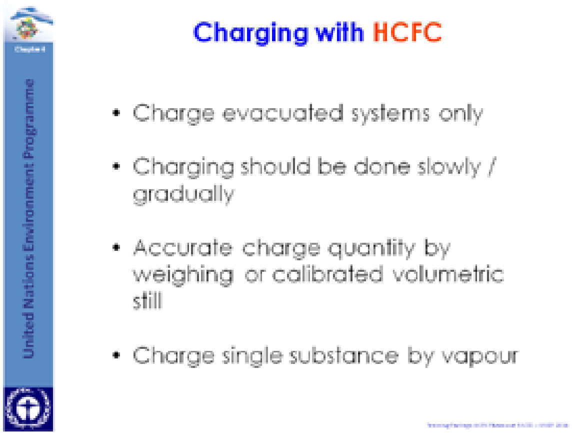
This process uses a glass tube liquid level indicator, which allows a technician to transfer the refrigerant into a system and measure the amount on a scale. Some cylinders are electrically heated to speed up the evaporation and maintain pressure in the cylinder. This process of electrically heating cylinder is usually done with an electrical insert. It is extremely important that a pressure control relief valve and thermostat be used to provide the required temperature and pressure safety controls. The system has a pressure gauge and hand valve on the bottom for filling the charging cylinder liquid refrigerant into the system. It also has valve at the top of the cylinder. This valve is used for charging refrigerant vapour into the system.




**Slide 17: Charging with HFC Blends**

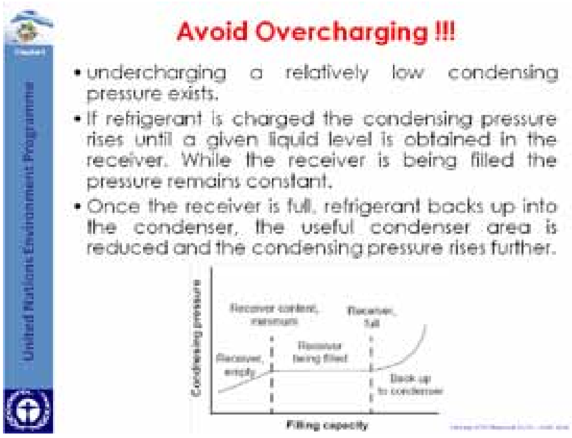
Refrigerant blends are simply a mixture of different refrigerant components. If the blend is a zeotropic mixture (i.e. R-4xx) and it is charged as vapour, the refrigerant with the highest vapour pressure will be charged at a higher proportion than the other component(s). Charging as a liquid is the only way to guarantee that the blend is charged within its intended composition. Refrigerant can be "bomb" charged into the liquid line.

Fractionation of a refrigerant blend (separation of the individual components) can occur by removing the refrigerant from the cylinder as a vapour instead of a liquid. This can potentially lead to both safety and performance issues. As such, it is recommended to charge all blends in their liquid phase only. Care must be taken that the machine is not started immediately after the charge. Give some time for the refrigerant to settle in the system. Watch the glass site to make sure not to overcharge HFC blends. Technicians usually think that clear glass means the charge is full and final. But in the case of blends, small bubbles can appear, which does not necessarily mean that refrigerant is less or under charge. Hence, it is better to charge the refrigerant by weight.



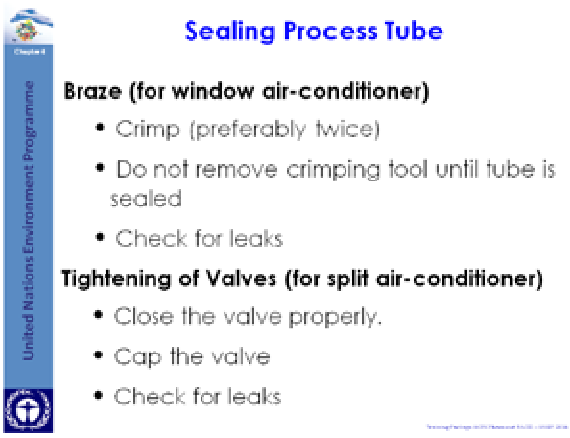

**Slide 18: Charging with HCFC**

Charge the system when it under a perfect vacuum. Charging must be done very slowly and no liquid refrigerant should come from the charging line. The best method is to charge the machine is by weight. If a weighing machine is not available then one can charge by calibrated volumetric still, which requires more accuracy. For a vapour charge, HCFC 22 must be charged only from the charging line. For a liquid charge it must be charged from high side time must be allowed for the liquid to settle down.




**Slide 19: Avoid Overcharging!**

Undercharging an air-conditioner results in a relatively low condensing pressure. But when a technician charges by feel, once the refrigerant is charged, the condensing pressure rises until a given liquid level is obtained in the condenser/receiver. While the condenser/receiver is being filled, the pressure remains constant. Once the condenser/receiver is full, refrigerant backs up into the condenser, the useable condenser area is reduced and the condensing pressure rises further. The caution is "Avoid Overcharging."




**Slide 20: Sealing Process Tube**

After the charging is completed, the process tube should be sealed. It is recommended that crimping be done twice in a perpendicular direction and the crimping tool should remain on the line till the process tube is sealed by brazing. Brazing may be done using either oxyacetylene gas or LPG gas.

Once again, test for leaks using a soap solution or an electronic leak detector before operating the system. If the system is running during the leak test, and there is a leak, the soap solution will enter the system due to low pressure on the suction side.

In case of split air-conditioners, where there is no process tube but there are service valves, after a complete charge close the valve properly and put on the valve cap. After closing the cap, check for leakages.


**Slide 21: Checking Proper Operation**

As a final step, the air-conditioner should be switched on and the following parameters verified to ensure that it is operating correctly:

• Grill temperature—the return air temperature and grill temperature difference must be between 10°C to 15°C, depending upon wet bulb temperature;

• Compressor current; and

• Extraneous vibrations. If there are vibrations, remove them with anti-vibration pads.

# Evaluation Questions

1. What are the steps to be followed in servicing HCFC/HFC-based appliances?
2. Why should the HFC refrigerants be recovered?
3. What are the precautions to be taken while servicing HCFC/HFC-based appliances?
4. What are the advantages of using oxygen-free dry nitrogen (OFDN) for flushing and pressure testing?
5. If you notice extra vibrations, what is the remedial measure?

# 5. TOOLS AND EQUIPMENT FOR SERVICING AND REPAIR

**Training Material Reference:** Tools and Equipment for Servicing and Repair – 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 45 minutes

**Purpose of the Session**
To familiarise participants with the tools and equipments required for quality servicing that will lead to customer satisfaction; adopting Good Servicing Practices (GSP) in the RAC servicing sector.

**Final Performance Objectives**
At the end of the session, the participants should know:
1. What kind of tools and equipment are used for inspection, measuring, testing, servicing and repairing RAC appliances
2. What precautions must be taken while using these tools and equipment

**Key Message Delivered in this Session**
Facilities' tools and equipment need to be upgraded in order to deliver quality servicing and to handle new refrigerants. The use of proper tools and equipment will improve accuracy, reliability, responsiveness and credibility, which are key elements of high quality service. Many tools and equipment are available on the open market, but their accuracy and quality may be questionable. The range of options makes it difficult to choose. For example a vacuum gauge may cost anywhere from USD$ 20 to USD$1,000, and each product may have a different level of accuracy and reliability. Another example: a capillary tube can be cut in many ways, but the use of a capillary cutter ensures that no burr is left at the end. In order to have a good set of appropriate tools and equipment, technicians must be familiar with the available products and the importance and benefits of each.
As HCFC refrigerants are replaced with alternatives, this understanding is even more essential, as these alternatives generally require a high level of accuracy.

**Tools and Equipment Required for the Session:**
One complete RAC tool kit. Special tools must be shown to the trainees.


**Slide 1: Tools and Equipment for Servicing and Repair**
This is the title slide. The trainer may initiate a short discussion on the importance of having proper tools and equipment. The trainer can highlight the fact that even though a technician or business may pay more initially for good tools and equipment, the rewards will be greater too. Profits will be higher in the long run because customers will appreciate the high quality servicing resulting from a combination of good equipment and lessons learned during the workshop on Good Servicing Practices. Good tools lead to higher earnings.


**Slide 2: Tools**

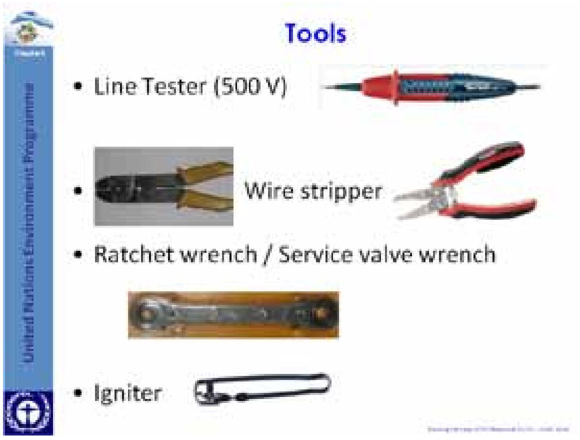
This slide illustrates the following tools and items needed for electrical measurements and servicing:

*Quick Test Board*
This is a special portable test board suitable for safe inspection of any appliance or compressor. It consists of a bell push, piano type switches and LED's to check the continuity of appliance or compressor wiring (using a series test). It is also useful for testing plug points (neutral, phase wire position, earthing, or neutral wire condition). Two-pin sockets are provided for connecting ampermeters and voltmeters. A special green lead wire is used for ground testing. All of these functions are provided in this safe, compact board.

*Dummy Relays or Test Terminals*
Test terminals are used for safely checking a compressor directly without risking errors due to an incorrect terminal sequence, loose contact, or other problem. A push button and/or two terminals can be added for fixing capacitors.

*Digital Clamp Meter (Multifunction)*
A digital clamp meter can measure resistance 0-200kΩ, DC voltage up to 1000 V, AC voltage up to 750 V, or AC current 0 to 30 Amperes without breaking a wire or switching off the appliance. It is also has an audible beep that sounds when used as a continuity or diode tester. The display is very easy to read and if necessary, one can hold the data on the screen by pressing the hold button.

*Digital Thermometer with Puncture Probe*
This instrument has an electronic display and a long probe that can measure both indoor and outdoor temperatures between -50 to +70°C. The probe can be directly inserted into a grill read its temperature, and also has a Fahrenheit / Centigrade conversion switch.




**Slide 3: Tools**

The items showed in this slide are:

*Line Tester (500 V)*

One must purchase a good brand and not be tempted to try a cheaper product.

*Wire stripper*

In the past, technicians often used their teeth to peel off the wire insulation instead of using the correct tool. A wire stripper is a much better option that removes insulation without cutting the individual filaments of the wire, or damaging the technician's teeth.

*Ratchet Wrench*

This is also one of a technician's key tools. A ratchet wrench can be rotated both clockwise and counter clockwise to open or close a service cylinder valve. Many field technicians use the wrong tool, usually a screw spanner. After being opened a few times with a screw spanner, the cylinder valve loses its form and the edges become rounded, so that the spindle slips when it is turned with any device. One can also use valve keys for operating the cylinder valve.

*Igniter*

An igniter is used to light the brazing torch and is a safe alternative to matchsticks, which can be dangerous.


**Slide 4: Tools**

*Pinch-Off Pliers*

Pinch-off pliers are used for crimping or pinching a tube before sealing. Various styles of pinch-off pliers are available; two are shown in the slide. The gap between the jaws of the pliers can be adjusted by turning a screw bolt at the end of the handle. This type of pliers is handy and easy to use with tubes of different sizes. The most common mistake that technicians make with this pliers is to use it too close to a flame, or to use it to hold something that needs to be heated in a flame. If the bit or the spring becomes too hot, the tool can be damaged. The trainer should explain how to avoid this during the training.

*Piercing Pliers or Valve*

Piercing pliers or valves are among the best tools for refrigerant recovery, but should not be used with a vacuum. During a vacuum use the hand shut off valve. Also, they must not be clamped on a brazed portion or mild steel (MS) pipe, otherwise the needle will get damaged. They also must not be over-tightened, as the rubber seal will press in the tool and may cause leakage when the refrigerant is released.

*Core Removal Tool*

This tool is very important for split air-conditioner service, and can be used during pin valve leakage (in the case of a two-way or three-way service valve), recovery or vacuum. It saves the time during vacuum operation. To operate this valve, first tighten it clockwise and hook it into the core or pin valve. Next, rotate it counter clockwise, making sure that the charging hose pipe and valve are attached to it. Due to system pressure, core removal tools' spindle will drag out the spindle along with valve. Then close the ball valve and start the recovery procedure.


**Slide 5: Tools**

*Tube Cutter*

Tube cutters are available in different design and sizes. A tube cutter is usually used on smaller, annealed (soft) copper tubing, while hacksaws are preferred for cutting larger hard copper tubing. The tubing should be straight and cut squarely (at a 90-degree angle) to eliminate an off canter flare. If a saw is used, a wave set blade of 32 teeth per inch will do the best job. Care must be taken while using tube cutter. Adjust the tube between roller and blade with little pressure. Rotate the tube cutter. After one 360-degree round, tighten the knob one-quarter turn. Rotate the cutter with a full turn. Again, tighten the knob. Repeat this until the pipe is cut. To avoid tube kinking and to keep the blade safe, do not put extra pressure on the knob.

*Deburring Tool*

After the tubing has been cut, its ends must be scraped or reamed with a tool. Many tube cutters have a reamer. This important tool is important is also one of the most neglected. Technicians often use a nose pliers or the back of a file for taking off burrs on the inside of a pipe. This makes the copper pipe thin inside, leading to poor swage, or poor flare. A deburring tool allows you to clean the inside as well as outside burr, and to keep the wall thickness intact. It is also important to keep the tool on the lower end of the tube and other part of tube on the upper end, so that all the burrs fall into in the deburring tool, which keeps them from entering the system.

*Capillary Tube Cutter*

This is a very important tool for RAC technicians. Not only can it cut the capillary at an angle with no burrs, but it also saves time. Taper cutting is also possible with capillary cutters. Trainers must remind technicians not to use wire cutters as a substitute for capillary cutters, as the wire cutter does not have angle inside the cutter. A capillary cutter must not be left on or near brazing material, or the blade will get damaged.

(Note: Trainer should demonstrate how to cut the capillary.)


**Slide 6: Tools**

*Tube Bender (lever type)*

It takes practice to become good at bending tubing. For smaller-sized tubes used in domestic RAC models, it is not necessary to use special bending tools. That said, these tools can do a much neater and more satisfactory job. The tubing should be bent so that it does not place any strain on the fitting after it is installed. At the bend, the tubing should not be reduced (kinked) in the cross-section area. Be very careful when bending the tubing to keep it round; do not allow it to flatten or buckle. The minimum radius for a tubing bend is 5 to 10 times the diameter of the tubing. Do not try to make the complete bend in one operation, but bend the tubing gradually. Technicians can also use internal and external spring benders, as the situation requires. Use the spring bender externally in the middle of long lengths of tubing. The lever type bending tool is preferable however, as it produces accurate bends and reduces the danger of flattening or buckling the tube during the bending process.

*Flaring Tool with Swaging Kit*

Swaging tool is used to make the copper pipe of same size available for brazing and permanent joints. This tool is important in making quality brazing joints. Different types and size of swaging tools are available. Technicians should use them as per manufacturer instructions.

⇨Flaring blocks currently available on the market can be used. However, new flare blocks specifically designed for higher pressures have a torque adjustment and provide a more consistent, smoother flare face. R-410A flare blocks also have a clutch to avoid over tensioning which results in a weakened flare face.

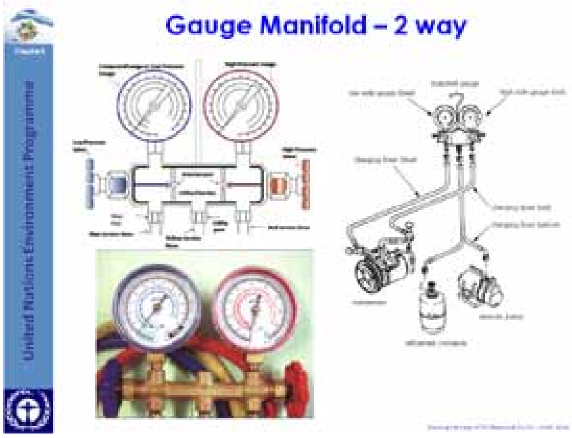
A flare is prepared on the copper pipe with the help of flaring tool. These joints are not permanent joints and are made with the help of flare nuts and union. These flare nuts are available in different sizes.

*Expander*

A hand expander can be used to expand pipes, and is a useful tool for a RAC technician.

*Scrubber or Wire Brush*

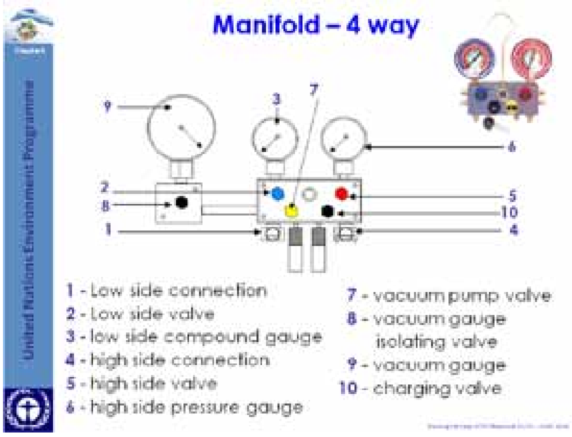
Wherever external flux is used for brazing, that joint must be scraped all around with a scrubber or wire brush to remove sticky flux. The joint should then be cleaned with a wet cloth to avoid corrosion formation on the tube.




**Slide 7: Gauge Manifold – 2 Way**

Many types of refrigerant gauge manifolds are available on the market. A two-way gauge manifold functions as follows:

1. The hand knob on the right (high pressure valve, painted red) controls the flow from the high side ports to the centre port when the hand knob on the right (high-pressure valve, painted blue) is in the open position.
2. Similarly the hand knob on the left (low pressure valve, painted blue) controls the flow from the low side ports to the centre port when the hand knob on the left (low-pressure valve, painted blue) is in the open position.
3. Should flow be needed only through the centre port (yellow line), close the low pressure (blue) hand knob.
4. The low pressure (blue) side operates in the same manner as the high pressure  (red) side.
5. Pressure gauges and compound gauges are colour-coded.
6. The gauges indicate either vacuum or pressure according to which hand-knobs are in the open or closed position.




**Slide 8: Gauge Manifold – 4 way**

A four-way manifold has few external joints connecting the vacuum pump, charging cylinder or weighing scale and the vacuum gauge, and is therefore more compact and leak-proof.

A four-way manifold also saves time because there is no need to reconnect hoses for different processes. The low and high sides, the vacuum pump and the charging device can be hooked up right at the beginning of the job. The manifold is a central control for service. One needs to just operate the appropriate valve.

The slide illustrates the manifold with the legends for the different components. This type of manifold can be fitted to several gas charging stations.


**Slide 9: Brazing Equipment**

For proper brazing at adequate temperature, a technician needs to have at the minimum, an LPG brazing kit.  If possible, try to use other technology based torches like swirl jet or spit fire that can reach higher temperatures than ordinary LPG torches.

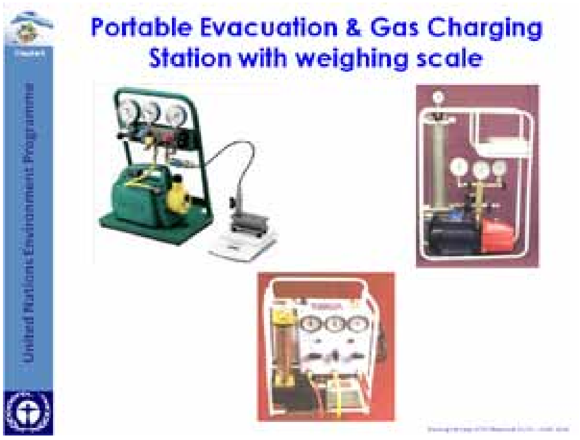
The best option is an oxy-acetylene brazing torch, but it is also more expensive. Also, due to its bulky size, this type of torch is difficult to carry to the site.

Currently available, lighter weight oxy-LPG brazing torches are easier to carry to and from the site.

Tongs and asbestos-lined heat deflectors are used to handle the heated components and assist during brazing.


**Slide 10: Refrigerant Recovery Machine with a Recovery Cylinder**
In order to recover ozone-depleting, climate-damaging HCFCs and HFCs, and not allow them to escape into the atmosphere, a special recovery machine is required.
The image shows a recovery machine with an oil-less compressor and a drier at the refrigerant entry port. The refrigerant flows through a mesh filter is fitted inside the inlet valve before it passes onto the system. Oil-less recovery machines do not risk adding oil from the compressor into the cylinder as few of the recovery machines are fitted with oil separators.
Separate recovery cylinders should be used for recovery of different refrigerants.

*Note: More details on these items are given in the session on Recovery of Refrigerant.*




**Slide 11: Portable Evacuation and Gas Charging Station with weighing scale**
The common features of Evacuation and Charging (E & C) units are a vacuum pump connected to a manifold through an electromechanical or electronic anti-suck-back valve. The manifold has several inlet and outlet ports connected to high pressure, compound or vacuum gauges. Within these common features, there are two possible variants:
1. E&C units with volumetric charging and a calibrated correction dial to take care of change in refrigerant volume due to temperature change (dial-a-charge)
2. E&C units with an electronic weighing scale and a hose to connect the refrigerant can or cylinder to the manifold
While buying the vacuum pump one must keep in mind the specifications of vacuum pump: double stage, rotary van type, with blast facility and blank off facility to 50 microns.


**Slide 12: Important Equipment**

*Electronic Leak Detector*

Electronic leak detectors sense refrigerant components. They beep and give off a light signal in case of any leakage. Audio/visual indications, sensitivity up to 0.5 g /Year, lockout and clear facility (switches) are also provided. Every manufacturer has different specification for different models. Separate leak detectors are required for HC refrigerants.

*Sound Level Meter (dB meter)*

This equipment, housed in a lightweight ABS plastic case, is used to measure the noise and vibrations produced by compressors or appliances. 'A' frequency and fast time weighing have been incorporated to meet IEC 651 standards. It has a built-in adjustment for calibration. Its condenser microphone is very accurate and has long-term stability. The hold function helps to freeze the display values. A warning indicator shows over and under values. The surrounding noise level must be at least 12 dB levels lower than that of object under test, or the reading will be incorrect.

*Anemometer*

An anemometer is an apparatus for measuring the speed of air. The most common kind of anemometer has fan blades fixed in a plastic ring. When its back is to the air, the pressure on the inside of a fan blade overcomes the pressure on the angular blades, and the blades start rotating with the air speed. The air speed is easily calculated by timing a given number of revolutions, and then indicated on the LCD screen.

*Fire Extinguisher*

It is essential to remember to have a powder type fire extinguisher on hand, as only a powder fire extinguisher can be used on any type of fire (oil, electric wires, papers etc.). The extinguisher should be placed in a safe, but rapidly-accessible location so it can be used when needed. It is best to keep it either near the entrance of the workshop or close to brazing kit. The extinguisher should be checked regularly to be sure it is in working order.


**Slide 13: Important Equipment**

*Thermocouple or Pirani Vacuum Gauge*
A precision instrument used to measure vacuums and pressure, a micron vacuum gauge is capable of measuring 5-5000 microns. Both analogous and digital micron gauge are available on the market.

*Nitrogen Cylinder with Two-Stage Regulator and Hose*
Nitrogen gas, being inert and non-oxidizing, is recommended for flushing and leak-testing a refrigeration system. However, when in a cylinder, nitrogen pressure is above 2000 psi, and such pressure can cause serious accidents if mishandled. To avoid accidents, a two-stage regulator must be used to regulate output pressure so it is within safe working limits (about 15 to 20 bar, or 220-294 psig).
*Note: A separate presentation for Trainers explains how this regulator works and why it is better than a single-stage. After reading these slides explain the technology to technicians.*


**Slide 14: Test Kit for Oil**

*TKO:*
This test kit is designed to give a visual indication as to the acid content of both mineral and alkylbenzene lubricants. Simply place a sample of oil in the bottle, shake and look at the colour. If it remains purple, the oil is safe. If it turns orange, the oil is marginal and steps may need to be taken. If it turns yellow, the oil is acidic and needs to be changed or other steps need to be taken.

*ETK:*
This test kit is designed to give visual indication as to the acid content of polyol ester (POE) lubricants. Simply place a sample of oil in the bottle, shake and look at the colour. If it remains purple, the oil is safe. If it turns orange, the oil is marginal and steps may need to be taken. If it turns yellow, the oil is acidic and needs to be changed or other steps need to be taken.

*Note: Always read the manufacturer's instructions before use.*


**Slide 15: Test Kit for Oil**

The retrofit process requires the removal of mineral-based oil and replacement with polyol-ester-based lubricants. Mineral oil residues must be kept to an acceptable level to assure proper system operation. The RTK (retrofit test kit) provides a simple method of determining the level of residual mineral oil in a system. It is ideal for field use as it provides a visual indication of three levels of mineral oil concentration: Greater than 5%, between 1% and 5% and equal to or less than 1%.

*Note: Always read the manufacturer's instructions before use.*

## Evaluation Questions

1) Why is it important to have good tools?
2) At what angle we must keep the capillary tube cutter?
3) Why is the deburring tool better than normal reamer?
4) Why is the four-way manifold better than the two- way?

# 6. DO'S AND DON'TS IN REFRIGERATION AND AIR-CONDITIONING SERVICING

**Training Material Reference:** Do's and Don'ts in Refrigeration and Air-Conditioning Servicing - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 45 minutes

**Purpose of the Session**
The purpose of this session is to draw the attention of technicians to certain critical areas in servicing air-conditioning and refrigeration appliances. If overlooked, bad practices can result in serious problems in the air-conditioning system, including poor cooling performance, recurring failures and reduced operating life. Apart from defining good practices, the session also examines existing servicing practices: what works, what needs to be changed and why. Many current practices are detrimental to existing HCFC-based appliances and can be even worse for HCFC substitutes, which are even more sensitive to moisture, dirt and other contaminants. The areas of focus are: tools, flare fitting, swaging, bending, brazing, cleaning and flushing, leak testing, evacuation, measuring and maintaining vacuum, charging refrigerant and cross-contamination.

**Final Performance Objectives**
At the end of this session, the participants should be able to:
a) Understand the need for adopting the good practices described in the sessions.
b) Compare good practices with the practices they currently follow.
c) Realise the difference in their own practices and what is prescribed, and how their current practices might have negative effects.
d) Analyse what they need to do in order to change over to the prescribed methods. Was the problem a lack of information and awareness? Has the session provided them with the knowledge they were missing and they now understand the reasons for following the prescribed methods? Or was the problem more a lack of the right type of tools, instruments, gauges and equipment?
The participants, having been convinced of the need for change, should put down in writing what is possible for them to change immediately (taking into account practical limitations and costs), and what will require a larger investment and how that might be achieved.

**Tools and Equipment Required for the Session:**
None.


**Slide 1: Do's and Don'ts in Refrigeration and Air-Conditioning Servicing**

The trainer will introduce the subject of good practices, go over some of the current practices followed by technicians in the field, and the reasons why certain of these practices need to be changed.


**Slide 2: Who is better?**

In this slide trainer asks the participants which technician they would like to be, A or B. In the upper image for technician A, the tools are organised and all are placed in a single cabinet. In the picture below, the technician is brazing following safety precautions by wearing goggles. The upper image for technician B shows the tools scattered on the ground, increasing the risk of the technician getting injured and the possibility of damaging to the tools. In the lower image B, the technician is holding his goggles but not wearing them. The trainer should encourage technicians to follow the example of technician A.


**Slide 3: Common Practices that are damaging to Refrigeration and Air-conditioning Systems**

This slide provides a non-exhaustive list of incorrect practices by refrigeration and air-conditioning technicians. The trainer can go over them one by one, briefly discussing the negative outcomes of these practices with the trainees.


**Slide 4: Areas of Focus**

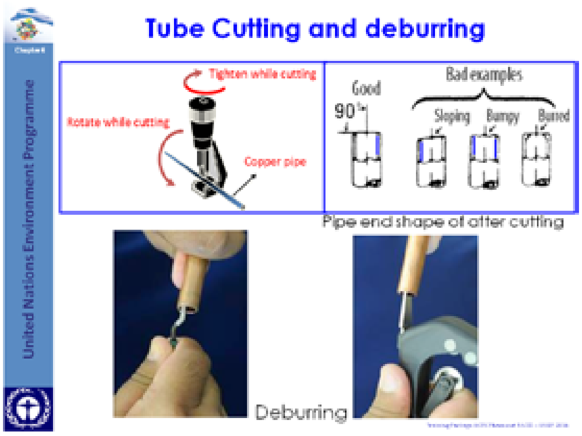
There is no need to discuss at length each item in this list. The trainer might simply say that the items in the list are the topics that will be discussed in detail in the coming slides.


**Slide 5: Good Tools**

Using proper tools and equipment leads to accuracy, reliability, responsiveness and credibility—the essential elements of quality service. In order for a refrigeration and air-conditioning system to be properly evacuated and dried, a technician needs to use the correct vacuum pump. Tools like flaring tools and torque wrenches are required for more recently developed refrigerants, and these need to be of good quality. In order to properly handle and service these new refrigerants, facilities need to be upgraded in terms of tools and equipment.

Many cheap tools and equipment are available on the open market, but their they are not always accurate and their quality is uncertain. It is essential to have the right tools for the right job.

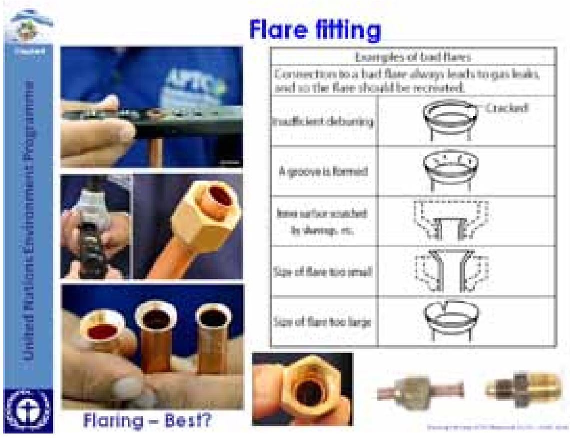
In order to have a good set of tools and equipment, technicians must understand the importance and benefits derived from each of them. Since HCFC refrigerants are being phased-out, many alternatives are being commercialised. The level of accuracy required by these new alternatives is relatively high, making it that much more important to understand the use of each tool and equipment.




**Slide 6: Tube Cutting and Deburring**

Tube cutting, a basic technical operation, is a good place to start with good practices. In the same way that if the base of a building is strong, you can construct a multi-storey building, proper tube cutting is an essential first step for a strong RAC system. The technician must cut the tube by slowly rotating the wheel, adding pressure on every two rounds to cut the tube perfectly. After cutting, the pipe should be from the inside and outside.

The trainer can ask the trainees which of the pictures on the slide is the better way of tube cutting.

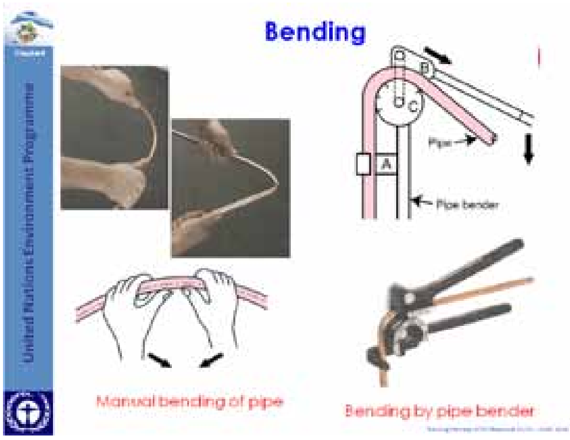



**Slide 7: Flare Fitting**

As new refrigerants enter the market and technicians need to work on increasingly high pressures, they need to be able to prepare the right kind of flare fittings to tolerate these pressures. A suitable flaring tool needs to be used so that the integrity of the copper is not compropmised when it is flared. The trainer can ask which picture on the slide is the best flare.

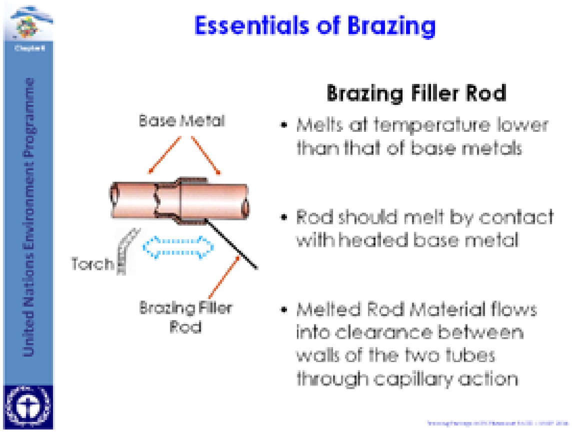

**Slide 8: Swaging**

After the tube is properly cut and cleaned, it is ready to be swaged. Many technicians use the hammer and swaging tool shown in the slide. After insertion, they try to give the tool a soft blow to enhance the gap of the swage. This method results in a lot of play in both the pipes, which ultimately leads to poor brazing. This slide also shows the new tool available on the market. It is like a flaring tool, but the technician changes the flaring cone with the swaging bit, which comes in a set of different sizes. Remember to rotate the handle twice to loosen it, and then rotate and tighten again. Repeat the process until the desired swaging is reached.




**Slide 9: Bending**

Often, when a tube is small, technicians bend it by hand. The problem with this practice is that it is impossible to see any wrinkles on the inside of the tube with the naked eye, and if there is a wrinkle, it will restrict the flow of refrigerant. Always use a pulley type tube bender so the tube will be correctly bent. In some countries there are still a few technicians who use a spring-type bender but they should be encouraged to change to the pulley type bender for greater accuracy.



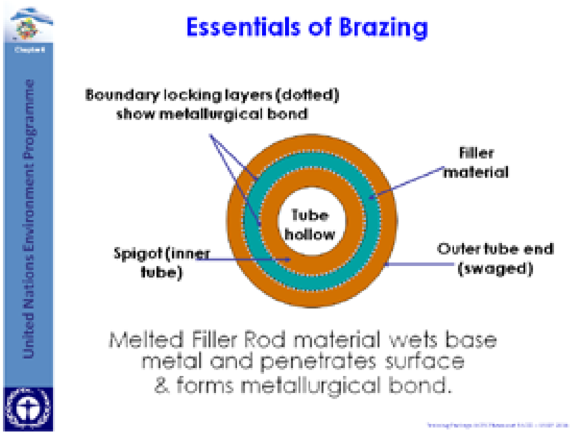

**Slide 10: Essentials of Brazing:**

This slide presents the key aspects of brazing:

a) In brazing, the base metals to be joined, copper (Cu) and iron (Fe) are never melted, but are heated to a temperature below their melting point (above 650°C but below the Cu melting point, 1,083°C). The filler rod, made of a special alloy, melts at these temperatures when it contacts the heated metals.

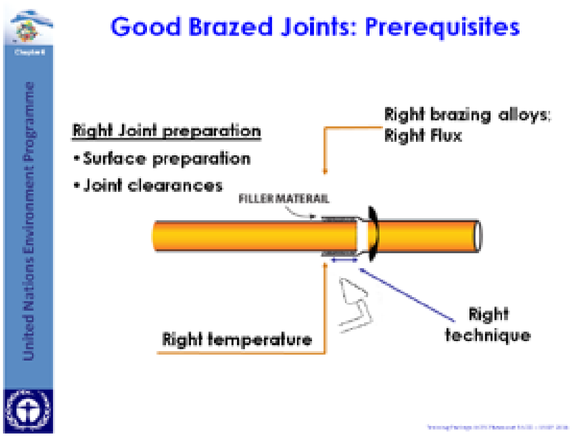
b) The brazing rod should melt on contact with the heated Cu tubes and should never be heated directly by the torch flame and melted onto the joint. This can happen only if the Cu tubes have been heated to the appropriate temperatures.

c) The filler rod that has melted on contacting the heated base metals (Cu tubes) flows into the clearance between the overlapping Cu tubes by capillary action. This capillary action will take place only when the clearances are maintained within certain limits.




**Slide 11: Essentials of Brazing**

This slide shows a cross-section of the inner and outer tubes being brazed, along with the molten filler material. The melted filler rod, now liquid, coats the surface of the Cu tubes and penetrates superficially into their surface. This process forms a strong metallurgical bond between the outer surface of one tube and the inner surface of the other tube where this overlap is formed. The boundary-locking layers in the diagram show the metallurgical bond.



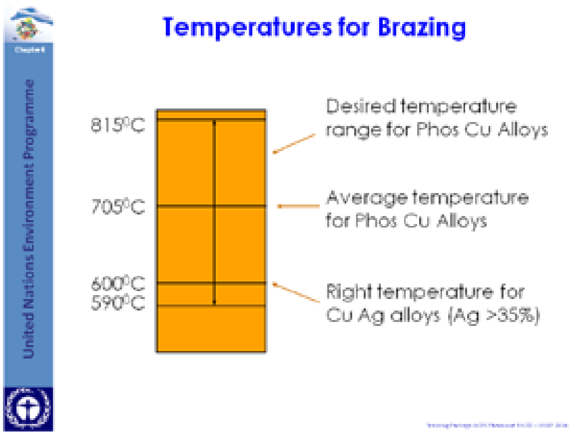

**Slide 12: Good Brazed Joints: Prerequisites**

a) The first thing to be done before starting to braze is to ensure that the joints are correctly prepared. This involves a thorough cleaning of the surfaces to be joined, using emery or wire brush to leave a clean and bright surface. This will ensure removal of all dirt, grease, oil and other impurities that might be present on the surfaces and can prevent proper coating of the surfaces. The second thing is to ensure that the clearances between the two tubes to be joined are maintained correctly. The ideal clearance would be between 0.05 mm to 0.200 mm. If the tubes are the same diameter, this can be achieved using good swaging tools.

b) The next important aspect is the brazing temperature, which is a result of the right combination of fuel, torch and flame. The best results can be had using oxy- acetylene or oxy-LPG torches, though air-LPG torches can also be used.

c) It is also essential to use the right brazing filler rods. For Cu to Cu brazing, filler rods consisting of 7.5% phosphorus and the rest Cu (known as Phos Cu) can be used without a flux, as phosphorus itself acts as a good flux. Brazing rods with 2% silver (Ag) can also be used, preferably with a flux, as Ag lowers the melting temperature. For brazing copper to a different metal (Cu to Fe), filler rods containing phosphorus must be strictly avoided. For Cu to Fe brazing, rods containing at least 35% Ag must be used with a flux, the balance composition of the rods being Cadmium and Zinc (Cd and Zn).

d) Finally, brazing operation with a torch must be done in a way that ensures that the base metals (the tubes) are heated in a manner that facilitates the flow of the molten filler rod into the clearances.




**Slide 13: Temperatures for Brazing**

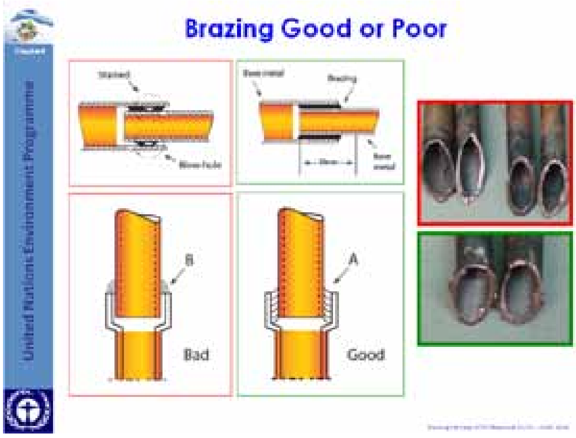
This refers to the temperature range at which Phos Cu brazing rods start melting. Taking into account all brazing alloys for Cu, the temperature should be in the range of 600°C to 815°C. The average temperature for such brazing rods is around 705°C.

The addition of Ag lowers the melting point of the rods; rods with 35% Ag start melting at around 600°C. Phos Cu rods with 2% Ag start melting at around 643°C. With experience, the technician can judge the temperature visually, because an infrared temperature reader will not always be available to take precise measurements.

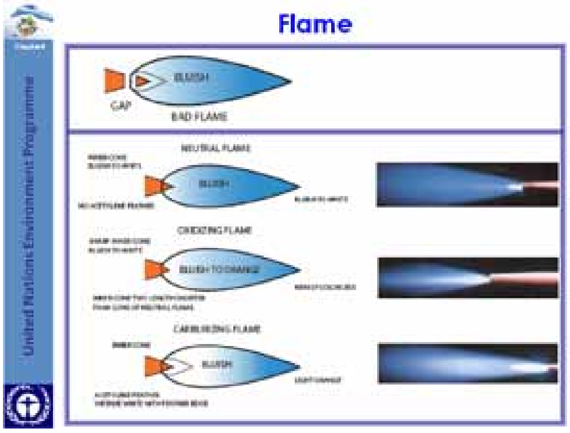

**Slide 14: Brazing by Passing Dry Nitrogen**

This slide shows a technician brazing with pass of dry nitrogen during brazing process. When we prepare the normal joint, one can see the carbon deposit. In the picture on the lower middle and right hand side, there are two sectional views of copper pipe. One pipe was done with normal brazing while the other was done with nitrogen introduction. The trainer may ask the trainees which tube looks better.

Technicians can insert the $N_2$ from one end of the copper tube and keep the other end open, so that all the contaminants be flushed out into open air.




**Slide 15: Brazing Good or Poor**
This slide also compares good versus poor brazing. As shown in image "B", stained brazing is an indication of bad brazing. In the practical session, technicians will practice brazing and cut the same sectional view to see if they done a good job or not.




**Slide 16: Flame**

There are three types of flames, namely neutral, oxidising and carbonising. The neutral flame is recommended for brazing Cu to Cu, or Cu to mild steel (MS) pipes. The oxidising flame is used for cutting material. Sometimes, when the oxygen pressure is released a blow-hole appears in the copper pipe. This is known as an oxidising flame. The third type of flame, mild carbonising, is also recommended for brazing RAC work.


**Slide 17: Caution!!**

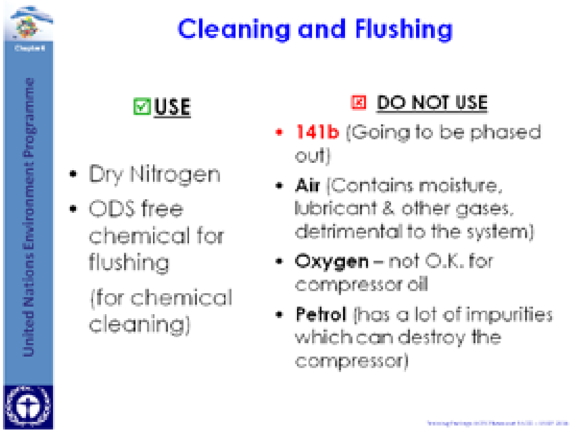
Keep away all types of refrigerant cylinders away from any flame while brazing. Stay at a minimum of two meters away from all flammable materials. Smoking must be avoided while servicing.


**Slide 18: Suitability of Brazing Equipment**

a) An oxy-acetylene flame can attain a temperature of 3,200°C, and heats tubes to the necessary temperature very fast, so the brazing operation is over very quickly. In fact, with an oxy-acetylene torch, one has to watch out for overheating.

b) The second best option is to use an oxygen-LPG combination, which also has the advantage of being an economical choice. As acetylene is not available in many cities, oxygen-LPG is a good substitute.

c) Using LPG cooking gas as fuel, the flame of an air-LPG torch fuel attains a temperature of 900°C (straight flame) to 1,030°C (swirl jet or cyclone). An air-LPG torch is a good choice for small tubing of 1/4" to 3/8" (6.35mm to 9.525mm), as it can heat the tubes to the temperature necessary to completely melt the rods.



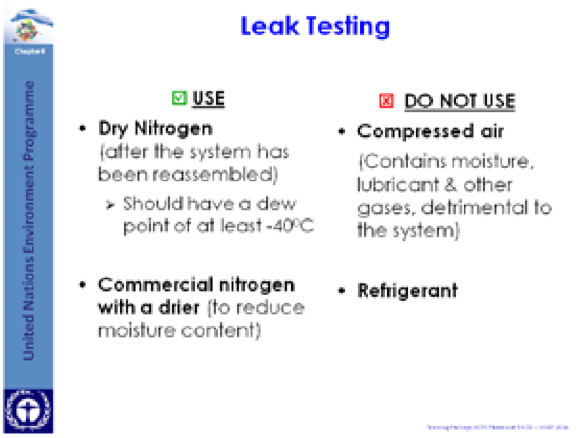

**Slide 19: Cleaning and Flushing:**

a) Compressed air should never be used for flushing, particularly when a hermetic compressor is used to generate the compressed air. This is because the compressed air contains moisture and other gases and the lubricant from the compressor will contaminate the system. Instead, use only dry nitrogen. It is inert and will also absorb some of the moisture in the system.

b) Oxygen in the air can react with the compressor oil, while moisture in the air can be absorbed by the compressor oil. This is particularly critical for compressors running on HFCs and POE lubricants.

c) Whenever chemical cleaning is needed to clean contaminated systems and use ODS-free alternatives, technicians must be aware of the toxic effects of these chemicals on human health (technicians should read the Material Safety Data Sheet on each chemical before use). These effects can occur after inhalation, eye or skin contact, or ingestion. Technicians must wear personal protective equipment (PPE) while handling these chemicals. Any chemical poured inside the RAC system for cleaning must be vaporised out of the system.

d) Though not at all recommended, petrol is sometimes used as a cleaning agent. This is not a good idea since commercial petrol contains all sorts of impurities that will contaminate the system.




**Slide 20: Leak Testing**

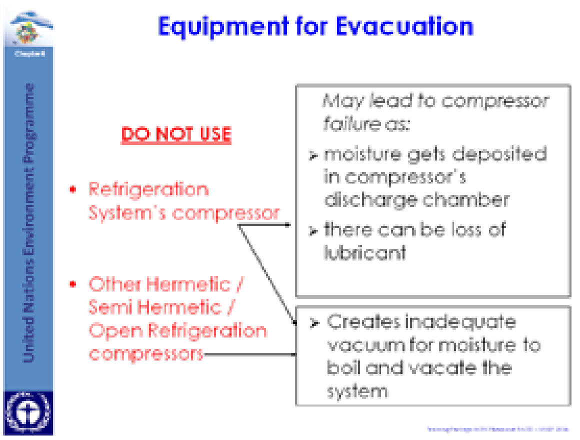
a) Leak testing should always be done using dry nitrogen because it is inert. Dry nitrogen also absorbs moisture inside the system. Compressed air or oxygen should never be used for this purpose.

b) The same reasons that prohibit using air for flushing, mentioned in an earlier slide, hold for leak testing. It may be worth going through the reasons again with the trainees.

a) If commercial nitrogen is used, use a silica gel or other desiccant drier at the outlet of nitrogen cylinder to ensure that the nitrogen is indeed dry.

b) The advantage of dry nitrogen is that it absorbs a good bit of the moisture present in the system and reduces the moisture removal load of the vacuum pump during the next step of evacuation.

c) When using an electronic leak detector, a small quantity of the refrigerant is introduced as a tracer gas and mixed with nitrogen, since the electronic leak detector never senses Nitrogen.




**Slide 21: Equipment for Evacuation**

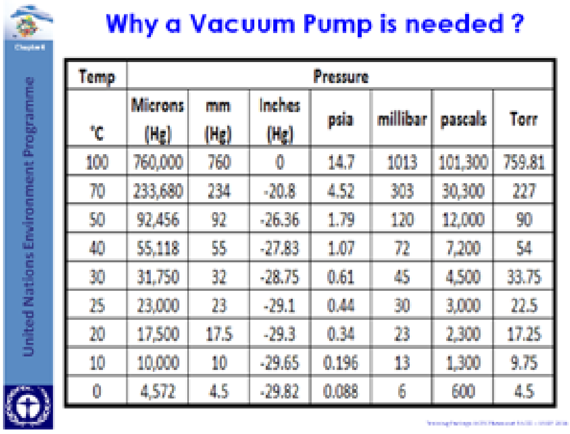
a) Using the appliance's compressor for evacuation ('self-vacuuming') is a common practice in the field. It is a bad practice, as not only does not evacuate all the moisture and other gases out of the system, but it also damages the compressor.

b) Reciprocating refrigeration compressors cannot produce the vacuum necessary to evacuate all the moisture. Further, using the appliance compressor as a vacuum pump can deposit moisture in the discharge chamber and valves, resulting in compressor deterioration. It can also pump out lubricant oil, which can lead to compressor failure.

c) The same reasons hold for separate reciprocating compressors being used as vacuum pumps. The vacuum created will be just as inadequate to boil out all the moisture in the system.

d) Moisture is present in the system as tiny droplets of condensed liquid, usually water. It can be removed only by boiling, which can be done either by heating or by creating a deep vacuum. On site, the most practical way to remove moisture is create a vacuum in the system deep enough to boil off the water. Water boils at 25°C at a vacuum of about 1" Hg or 25,000 microns. To ensure complete and rapid boiling off, a vacuum of at least 500 microns has to be reached.

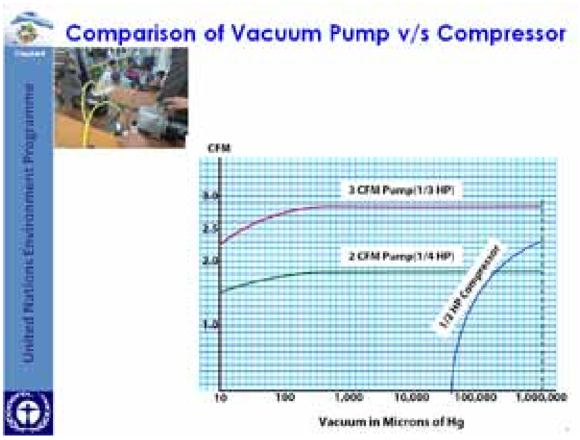
e) Reciprocating refrigeration compressors generate vacuum of about 76,000 microns. Single stage rotary vacuum pumps are normally used for vacuum levels of about 76,000 microns. It is therefore essential to use a two-stage rotary vacuum pump to reach levels of 100 to 200 microns at a fairly good speed of pumping, particularly for refrigerants like HFCs and HCs. This will ensure that most of the water in the system will have boiled off.




| Temp | Pressure | | | | | | |
|---|---|---|---|---|---|---|---|
| °C | Microns (Hg) | mm (Hg) | Inches (Hg) | psia | millibar | pascals | Torr |
| 100 | 760,000 | 760 | 0 | 14.7 | 1013 | 101,300 | 759.81 |
| 70 | 233,680 | 234 | -20.8 | 4.52 | 303 | 30,300 | 227 |
| 50 | 92,456 | 92 | -26.36 | 1.79 | 120 | 12,000 | 90 |
| 40 | 55,118 | 55 | -27.83 | 1.07 | 72 | 7,200 | 54 |
| 30 | 31,750 | 32 | -28.75 | 0.61 | 45 | 4,500 | 33.75 |
| 25 | 23,000 | 23 | -29.1 | 0.44 | 30 | 3,000 | 22.5 |
| 20 | 17,500 | 17.5 | -29.3 | 0.34 | 23 | 2,300 | 17.25 |
| 10 | 10,000 | 10 | -29.65 | 0.196 | 13 | 1,300 | 9.75 |
| 0 | 4,572 | 4.5 | -29.82 | 0.088 | 6 | 600 | 4.5 |

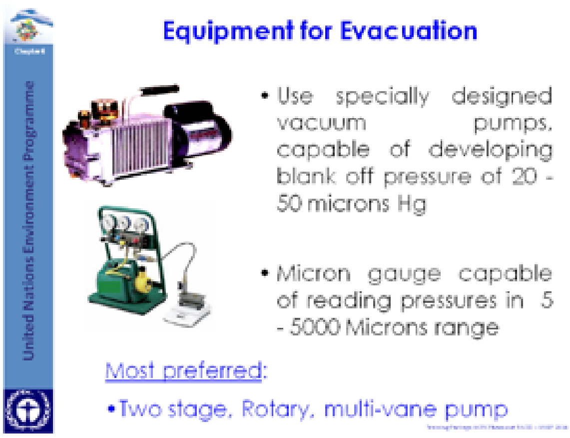
**Slide 22: Why is a vacuum pump needed?**

As can be seen in this table, at an ambient temperature of 25°C, a vacuum of 23,000 microns is required for the water to boil off as a vapour. As the water boils off, the temperature of the water is also reduced, as latent heat required for boiling is also drawn from the water. As the water temperature falls, a lower vacuum is needed to boil, as can be seen in the table at 10 and 0°C. <u>A vacuum pump is necessary because a reciprocating compressor is unable to generate vacuum at 10,000 microns.</u>




**Slide 23: Comparison of Vacuum Pump v/s Compressor**

This slide shows a graph of the vacuum drawn by two-stage vacuum pumps and a typical system compressor. As the graph indicates, the compressor produces a blank-off vacuum of around 50,000 microns and therefore cannot be used to remove water vapour below 40°C. A demonstration can be conducted here on the difference between reciprocating compressor and double-stage vacuum pump.

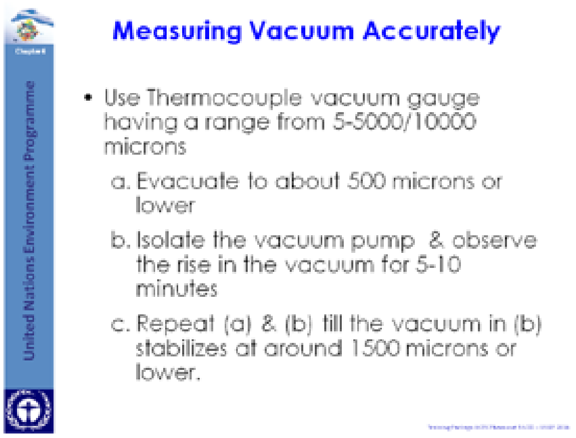



**Slide 24: Equipment for Evacuation**

a) The reasons for using two-stage rotary vacuum pumps have been outlined in a previous slide. Evacuation is necessary for all HFC refrigerants, which, along with their lubricating oils, are highly hygroscopic. Moisture, if present, leads to other problems like sludge formation and capillary choking.

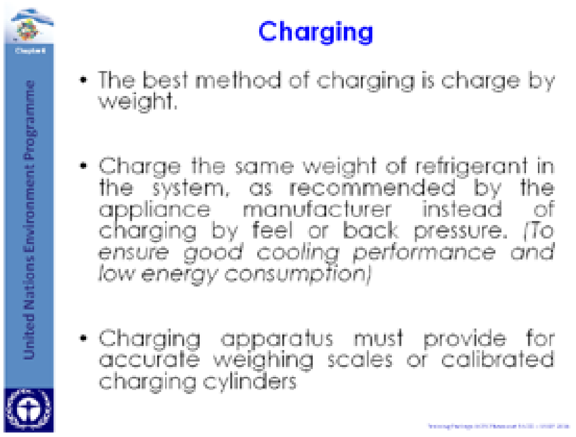
b) The two-stage rotary vacuum pumps are able to pull vacuum to about 100 microns because of their construction (a rotary multi-vane pump) and the excellent sealing done by the vacuum pump oil, which serves as both lubricant and sealant.

c) Reciprocating refrigeration compressors cannot produce such deep levels of vacuum because of the clearance volume in the pumping chamber or cylinder, and also because the sealing is not as good as in rotary vacuum pumps.




**Slide 25: Measuring Vacuum accurately**

a) In order to acertain a vacuum level, it is helpful to use a micron level vacuum gauge (usually Pirani or Thermocouple vacuum gauges) that has a 1-9999 micron range.
b) The micron gauge can be used to check the vacuum. For best results, the gauge should read 500 microns or lower. The vacuum pump is isolated to check the true vacuum in the system.
c) If the vacuum rises too rapidly and goes beyond 10,000 microns, it means there is a leak. If it rises slowly and stabilises at a particular value in 5-10 minutes, it means moisture is still present.
d) Repeat steps b) and c) till the vacuum stabilises at a value lower than 1,500 microns. The lower the level, the better the quality of evacuation.




**Slide 26: Charging**

a) The performance of capillary-fitted refrigeration and air-conditioning systems, both in terms of cooling as well as energy consumption, is optimum at a particular charge weight, which is normally defined by the appliance manufacturer on the nameplate.

b) It has been shown that energy consumption (kWh/day) increases sharply if the charge is lower or higher than the optimum weight.

c) The most sensitive appliances are those fitted with HCs, where the charge weight is less than 50% of the equivalent HCFC-22 system.

d) Thus, after carrying out any air-conditioning system repair or servicing, it is best to recharge the system with the amount of refrigerant specified by the manufacturer.

e) Charging by observing suction and head pressures or suction line temperature, or charging to a frost line will not give accurate results. The best way is to charge by weight using scales. The next best practice is by using volumetric charging cylinders corrected for ambient temperatures.

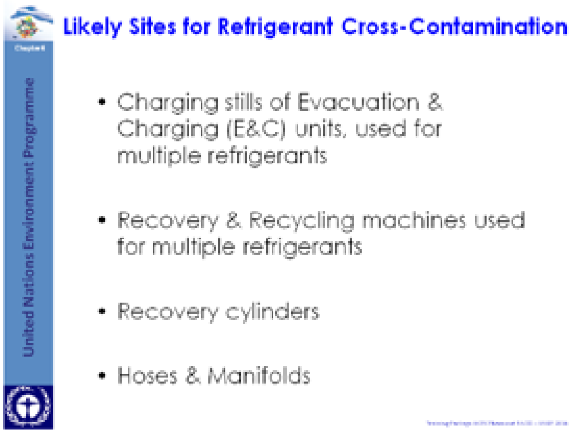

**Slide 27: Contamination and Cross-Contamination**

Contaminants: If sufficient care is not taken during servicing, refrigerant systems can be contaminated by moisture, non-condensable air (particularly if evacuation is not done thoroughly), chemical residues, dirt or dust.

Cross-Contamination: In addition to the above sources of contamination, there is also the risk of cross-contamination, which is the introduction or contaminants into a RAC system from another system or equipment used during servicing.

• This can happen when the same refrigerants cylinders are used for refilling different refrigerants.

• This will seriously affect appliance performance




**Slide 28: Likely Sites for Refrigerant Cross-Contamination**

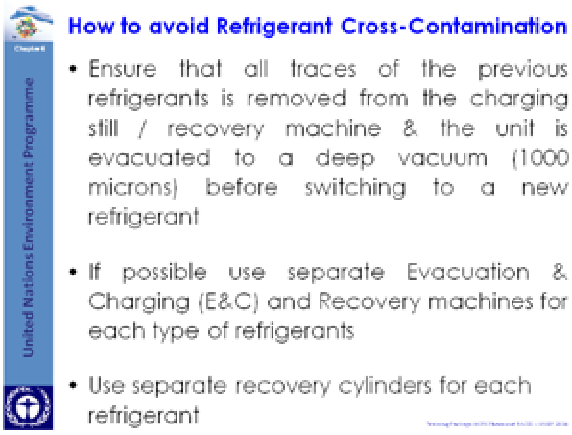
1. The most common sites for substantial refrigerant residues are the evacuation & charging (E&C) units and the recovery and recycling (R&R) machine condensors. In both of these cases, where a E&C unit or a R&R machine is used for more than one refrigerant, there is the potential for cross-contamination. In order to avoid this, the following action is recommended:

    a. Empty out the residual refrigerant completely before using a different refrigerant and evacuate the E&C unit or R&R machine, preferably to 1,000 microns, before reuse. This ensures removal of almost all traces of residual refrigerant.

    b. It is better however, if separate machines are used for separate refrigerants.

2. Other potential sources of contamination are recovery cylinders. It is absolutely essential to use a separate cylinder for each and every type of refrigerant.

3. When retrofitting old systems with substitute refrigerants, it is necessary to remove all traces of old refrigerant through deep evacuation.




**Slide 29: How to Avoid Cross-Contamination**

Perform a deep vacuum up to 1,000 microns or less before switching to a new refrigerant. And if possible, use separate E&C and recovery machines for each type of refrigerant. Make sure that separate recovery cylinders are used for each refrigerant.

## Evaluation Questions

1. What are the essentials of brazing?
2. Why do brazing joints carry less carbon deposit when we use dry nitrogen during the brazing process?
3. Which kind of flame is recommended for brazing?
4. Why we must avoid the use of air or oxygen for flushing systems?
5. What is the reason that we should use dry nitrogen for leakage testing?
6. Why must we not use a reciprocating compressor to create a vacuum?
7. Why is the vacuum pump necessary to perform proper vacuuming?
8. What is implication of charging refrigerant lower or higher than the optimum amount? What is the best practice to ensure accurate charging of refrigerant?


CAUTION

# 7. HANDLING AND SAFETY ISSUES OF HYDROCARBON (HC) REFRIGERANTS

**Training Material Reference:** Handling and Safety issues of Hydrocarbon (HC) refrigerants - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
To make participants aware of the critical characteristics of hydrocarbons, hydrocarbon issues, and precautions to be taken while handling and storing HC cylinders, as well as general safety precautions for technicians.

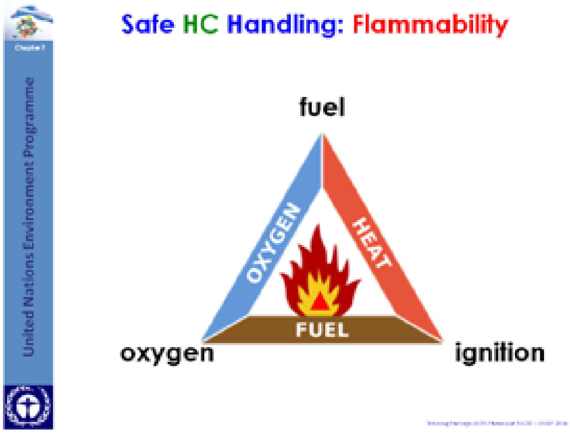
**Final Performance Objectives**
At the end of the session, the participants should know:
(a) Important characteristics of HCs
(b) Flammability aspects of HCs, like flammability limits, practical limits and classification
(c) General safety issues
(d) Precautions to be taken while handling cylinders and storage

**Key Message Delivered in this Session:**
Hydrocarbons are quickly emerging as appropriate substitutes to HCFCs in the RAC sector. As a result, their share in this sector is likely to increase. Service technicians will be increasingly obliged to handle HCs when they repair and service appliances. Therefore, it is essential for these technicians to be fully aware of the characteristics, flammability limits, safety issues and other precautionary measures associated with handling these refrigerants. Being familiar with all these issues is of paramount importance to those who deal directly with HC refrigerants.

**Tools and Equipment Required for the Session:**
None.


**Slide 1: Handling and Safety Issues for Hydrocarbon (HC) Refrigerants**

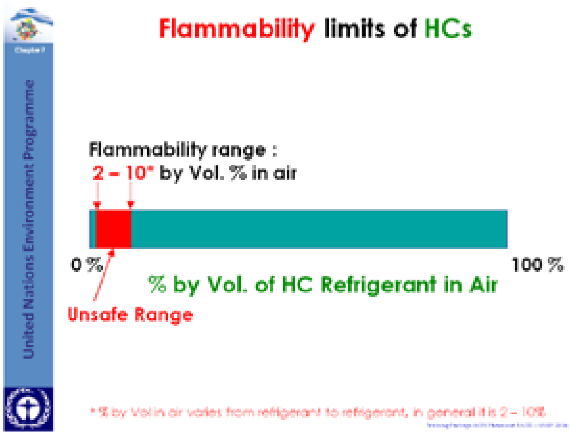
The trainer should emphasize the issue of f HC refrigerant flammability during handling. Technicians must know the pros and cons of using HC refrigerants.




**Slide 2: Safe HC Handling - Flammability**

There are three essential requirements for the combustion of any substance. These are fuel, oxygen and an ignition source. All the three factors are interrelated. Flammability is an issue only when all these factors are simultaneously present in the right proportion.

For example, a brazing torch does not ignite even when there is a spark from the igniter. The quantities of fuel and oxygen are not in the right proportion to create combustion so there is no flame even when the torch is ignited.



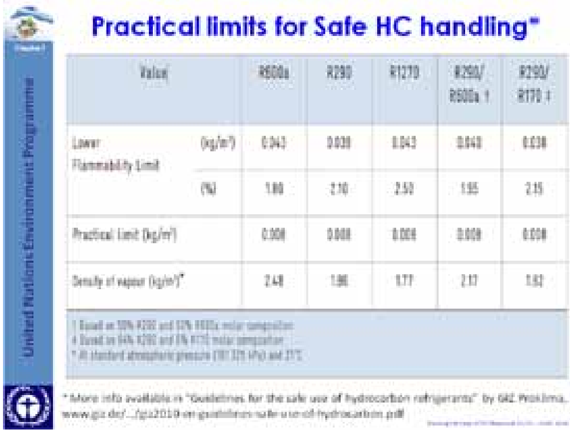

**Slide 3: Flammability Limits of HCs**

HCs are flammable when they are mixed with air and ignited.

The lowest concentration of a vapour capable of producing fire when ignited is the fluid hydrocarbon's Lower Flammability Limit (LFL). When the concentration of HCs is lower than its LFL, it can not produce a flame. Conversely, the highest concentration of the vapours capable of producing fire when ignited is the Upper Explosive Limit or Upper Flammability Limit (UFL).

The intermediate range is the flammable range; within these limits any mixture of fluid and air can burn. A vapour or gas with relatively wide limits of flammability is more hazardous; the flammability ranges are 2.2 to 9.5% for propane, 1.9 to 8.5% for butane, 2% to 11.1% for propylene, 2.5 to 81% for acetylene, 16 to 25% for ammonia and 1.5 to 7.8% for pentane. Therefore, acetylene is the most dangerous of these gases.

<u>Generally, the LFL for airborne HCs is around 2% and the UFL is about 10%.</u>

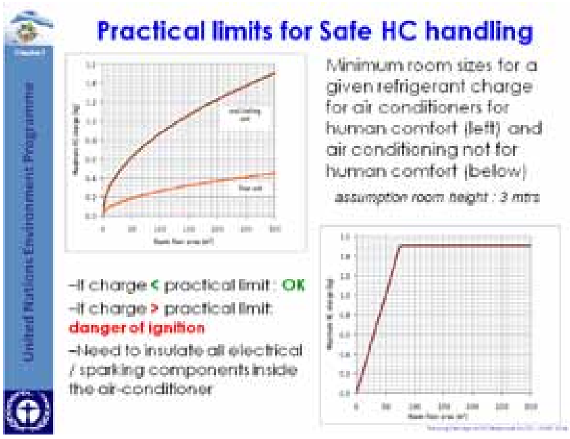



**Slide 4: Practical Limits for Safe HC handling***

The allowable charge sizes are typically based on the assumption that under the worse case scenario, the entire refrigerant charge from a circuit will leak into space almost instantaneously. Since the vapour is denser than air, it will partially stratify. The allowable charge normally accounts for this by including a 20% safety margin (in certain cases, this safety margin is extended to factors approaching less than 5%). On the other hand, the values for maximum charge size have been chosen on a broadly arbitrary basis, having little or no technical basis, although it can be seen that there is a general correspondence between lower charge sizes and the number and vulnerability of the occupants. In the case of systems located below ground level, a common value is applied throughout on the basis that it is difficult for a denser-than-air vapour to disperse upwards.

In general, HC refrigerants should be used only in sealed systems with a restricted charge, in occupancy categories where only competent members of staff are present. In any case, the refrigerant charge in a system with any refrigerant-containing part situated below ground level is restricted to no more than 1.0 kg. Sealed systems with refrigerant charge of 4 × LFL (for example, 4 × 0.038 = 0.15 kg for R290) or less may be sited in any location or category of occupancy provided there are no sources of ignition associated with the refrigerating system.

* More info available in "Guidelines for the safe use of hydrocarbon refrigerants" by GIZ Proklima, www.giz.de/.../giz2010-en-guidelines-safe-use-of-hydrocarbon




**Slide 5: Practical Limits for Safe HC handling**

For HCs, LFL corresponds to approximately 35g of HCs per m³ of air. For safety reasons, a practical limit of 8g of HCs per m³ of air should not be exceeded in a closed space. This means that there should be no problem if the charge used is within this practical limit. If the amount of HC goes beyond this limit, precautions must be taken to monitor sealed space and ignition sources, or appropriately safer systems must be used.

For example, the current charge size from the air conditioner's data plate > 0.68 kg of R22.

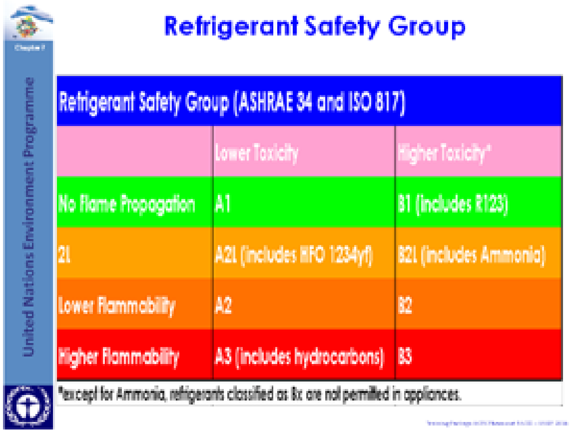
The charge size is generally indicated on the data plate on the RAC system. If the unit is outdoors, and the data plate is weather beaten and unreadable, check if the information is readable on the indoor unit. Finally, the charge amount can also be estimated from the amount of recovered (old) HCFC refrigerant charge (assuming there was no leak). Estimate equivalent HC charge -> Conversion to R-290, R-22 charge is 0.68 kg and equivalent HC charge is 0.28 kg of HC R-290.

For calculation purposes,  follow the procedure below:

a) Maximum charge amount for existing room size (room area in sq meter and maximum charge limit);

b) Check charge size limits> Charge size is below maximum limit of 1.5 kg (0.28 kg < 1.5 kg);

c) Room size is 6 m × 5 m = 30 m2, so below allowable charge (0.28 kg < 0.48 kg).




**Slide 6: Refrigerant Safety Group**

Refrigerants are classified into different safety groups on the basis of toxicity and flammability. The classification scheme is adopted by standards such as ISO 817 and EN 378. An overview is given in the slide.

The classification is based on the toxicity of the refrigerant at concentrations of less than 400 ppm by volume. Based on the data, we determine the threshold limit value, time weighted average (TLV-TWA), or consistent indices. There are two toxicity classes:

• Class A refrigerants are those where no toxicity has been observed below 400 ppm

• Class B refrigerants are those where toxicity has been observed below 400 ppm

The flammability classification depends upon whether or not the substances can be ignited in standardised tests, and if so, what the lower flammability limit (LFL) and the heat produced during combustion. There are three flammability classes (currently, the introduction of a new "lower" lower flammability class ("Class 2L") is being considered for certain safety standards on an international level):

• Class 1 refrigerants are those that do not show flame propagation when tested in air at 60°C and standard atmospheric pressure

• Class 2 refrigerants are those that exhibit flame propagation when tested at 60°C and atmospheric pressure, but have a LFL higher than 3.5% by volume, and have a heat of combustion of less than 19,000 kJ/kg

• Class 3 refrigerants are also those that exhibit flame propagation when tested at 60°C and atmospheric pressure, but have an LFL at or less than 3.5% by volume, or have a heat of combustion that is equal to or greater than 19,000 kJ/kg

Since the common HC refrigerants (R-290, R-600a, R-1270) have a TLV-TWA of 1,000 ppm or higher, they have a Class A toxicity classification. However, these refrigerants exhibit flame propagation under standard atmospheric conditions, and the LFL is typically around 2% with the heat of combustion around 50,000 kJ/kg. Thus, the flammability classification is Class 3. Overall, this renders them with an A3 safety classification according to the relevant standards.

By comparison, most common CFC, HCFC and HFC refrigerants, as well as R-744 (carbon dioxide) have an A1 classification, although some HFCs have an A2 classification. A few HCFCs and HFCs have a B1 classification, whilst R-717 (ammonia) has a B2 classification. There are no B3 refrigerants (although this may be possible with certain mixtures).

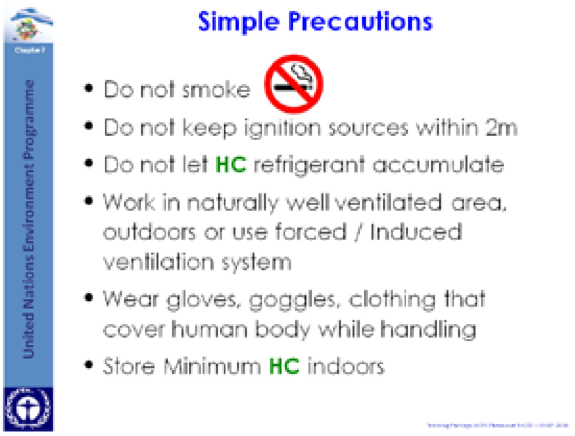
Typically, a "higher" classification (that is, toxicity Class B over Class A, and flammability Class 3 over Class 1) means that the refrigerating system has more onerous design requirements in order to handle the higher risk presented by the refrigerant.


**Slide 7: Ignition sources**

This slide illustrates different possible sources of ignition during system servicing. These include brazing torches, matches or cigarette lighters, or sparks from unsealed electrical components such as relays, over load protectors (OLPs), loose capacitor wires and even static electricity.

The basic safety rule is that in order to have an explosion, there must be a combustible mixture of gas and air (oxygen) within the flammable limits, and simultaneously, there should be an ignition source with sufficient intensity to create the combustion of the mixture.

The first step is to avoid the possibility of any leak. Even if there is a leak, make sure that a combustible mixture is not formed. In addition, the working area should be well ventilated and maintained in such a way that sources of ignition are eliminated.





**Slide: 8 and 9 – Simple precautions**

Taking into consideration the safety issues, the following simple precautions must be implemented.

a) Smoking while working can have dangerous consequences and should be strictly prohibited in the work area.

b) Do not work within two meters of any ignition source.

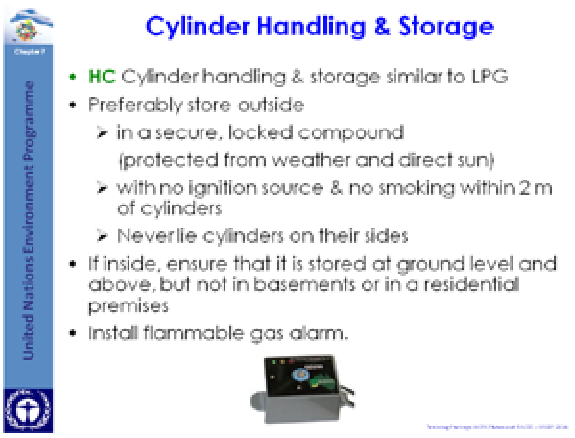
c) Any kind of repair or servicing work must be carried out in a well-ventilated area so as to prevent accumulation of refrigerant, if leaked out.

d) As a precautionary measure, always wear protective items like goggles, gloves and clothing that cover the body.

e) Keep a minimum amount of HCs in the work or storage area so that there is no possibility of HC accumulation.

f) Use dry powder fire extinguishers only.

g) A suitable ventilation fan should be used when working inside if there is insufficient natural ventilation. Electrical repairs should always be done outside the work area, so that if there is a refrigerant leak it will not be ignited by a spark from switching on the ventilation fan. Always fix the electrical outside the work area so that in case of leakage of refrigerant there should be not be no spark during switching on the ventilation fan.




**Slide 10: Cylinder Handling and Storage**

This slide explains the proper way to handle and store HC refrigerants. HC refrigerants should be handled and stored in the same way as LPG or any other flammable gases. Cylinders should be stored in dry and ventilated areas away from fire. Any build-up of static electricity should be avoided. Ideally, cylinders should be stored outside in a secure and locked compound, protected from weather and direct sunlight. The cylinders should be kept upright with valves closed and capped. There should be no ignition sources in the proximity of the storage area.

Cylinders can also be kept inside, provided safety measures are implemented. However, they should not be stored in residential buildings. In refrigeration workshops, store the smallest possible HC cylinder (or 14 kg of HCs) inside. A flammable gas alarm should be fitted in the bulk storage area. Cylinders should preferably be stored at ground level and never stored in basements. If stored in a basement, any leakage of HCs will accumulate and will not be easily dispersed. This can eventually lead to an explosion if there is a spark in the room. HC cylinders should not be stored with other flammable substances, particularly flammable gases. Storage of empty cylinders should be separated from that of the filled-up cylinders.

If it is necessary to warm the cylinder, use only water or air (with temperature not exceeding 40°C). No naked flames or radiant heaters should be used.


**Slide 11: Safety Precautions – Cylinder Safety**

Always transport and store the cylinders in an upright and secured position, no more than four rows deep, for easy access to the valve in case of any leak. The storage yard or vehicle should have adequate ventilation to avoid the build up of flammable mixture in case of a leak. Never leave cylinders in a closed van unattended or for longer than necessary. Never allow smoking or naked flames near the vehicle.

Code of Practice for Liquefied Petroleum Gas Cylinder Installation must be taken care of with respect to the country law.

In general, guidelines for HCFC cylinders and HC cylinders do not vary significantly. Most regulations applicable to local LPG (cooking gas) are also applicable to hydrocarbons. Always weigh the cylinder to check if it is empty; its pressure is not an accurate indication of the amount of refrigerant remaining in the cylinder.

During the transport of cylinders charged with HC refrigerants, it is recommended to carry two dry chemical powder (sodium bicarbonate) fire extinguishers of at least 1 kg capacity each, one in the driver's cabin and the other in the load compartment. The driver and the helper should be trained in the practical use of the fire extinguisher. The cylinders may be gently off-loaded on a thick and heavy rubber mat, taking care that the cylinders do not bump against each other.

If a cylinder is burning, water can be used to cool the other cylinders and the surrounding area. If the valve is not closed, the burning cylinder should be rolled on its foot ring, keeping it upright, to a safe and open area to let the gas burn off.

Cylinders should always be labelled and should also indicate the amount of gas inside.

Never puncture the cylinder with a sharp-edge tool as it can cause a spark and risk fire. It is better to remove 100% of the refrigerant from the cylinder, then remove the valve, crush it and put it to scrap.


**Slide 12: Safety Check of Working Area**

As discussed earlier, when a technician is working with HCs, he or she must avoid confined spaces and work in a well-ventilated area. To avoid any untoward incident, the area must be cordoned off by a two meters “safe” area. An HC refrigerant leak detector must be placed in the work area; it will give a signal if ever there is a leak.


**Slide 13: Safety Precaution – Eye Protection**

As we all know, when refrigerants operate at extreme pressure and temperature changes, high speed discharges may occur that can cause eye irritation and even frostbite. Direct skin contact with liquefied product or cold vapor may cause freeze burns and frostbite. If inhaled, HCs are non-toxic, but high concentrations may cause central nervous system events such as dizziness, drowsiness, headache, and similar narcotic symptoms, though not long-term effects. Avoid inhaling HCs, and always try to wear PPEs like hand gloves, goggles and eye masks.

# Evaluation Questions

1. What are the main safety issues when handling HCs?
2. Which are the three important factors associated with flammability?
3. What is the flammability limit of HCs? What is the significance of this limit?
4. What are the possible ignition sources for HCs?
5. Can a switch be regarded as an ignition source?
6. How should HC cylinders be stored?

# 8. SERVICING OF HC BASED AIR-CONDITIONERS

**Training Material Reference:** Servicing of HC Based Air-conditioners- 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
To train the participants in systematic servicing of hydrocarbon based air-conditioning appliances.

**Final Performance Objectives**
At the end of session the participants should know the following:

1. The basic steps for servicing HC-based appliances
2. Charging procedures and HC charge quantity
3. Sealing procedure for process tube and label

**Key Message Delivered in this Session:**
Hydrocarbons are emerging as eco-friendly alternatives to HCFC-22 refrigerants for domestic and commercial air-conditioning appliances. HC-based appliances are increasingly available on the market. Over time, these appliances will require servicing by servicing technicians. As hydrocarbon technology is relatively new to the industry, technicians need to learn systematic servicing procedures for HC-based appliances, while assuring both safety and good service practices.

**Tools and Equipment Required for the Session:**
None.


**Slide 1: Servicing HC-based Air Conditioners***
This title slide can be linked to the earlier sessions on good practices. Hydrocarbons are emerging as eco-friendly alternatives to HCFC-22 refrigerants. These are being used as refrigerant for some refrigeration and air-conditioning appliances. This session will deal with the servicing of HC based appliances.
* This text refers to equipment specifically designed by for hydrocarbons, not retrofitted equipment.


**Slide 2: Safety Rules that MUST be followed**

This slide is a reminder to all trainers and technicians that they MUST NOT SMOKE on the job and/or in the working or storage area. The technician must keep the fire extinguisher well within reach while working, ensure that there are no ignitions during the HC charge, keep the HC leak detector on during HC charge, wear PPE during service, and cordon off a two-meter distance from the air conditioner while working with HCs. These safety precautions are meant for not only the technician's well-being, but also for the equipment and the global environment.


**Slide 3: Servicing Procedure**

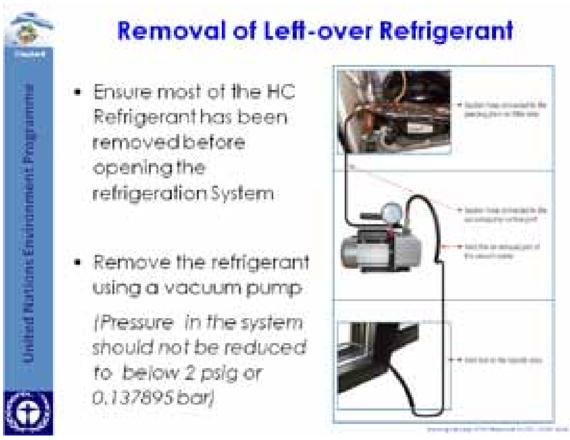
A systematic procedure is required when servicing HC-based appliances, which is described step-by-step below. These steps will be described in detail and demonstrated during the practical session:

| Step | HC Servicing |
|---|---|
| 1 | Analyse the electrical components and recover HC. |
| 2 | Remove residual HC from the system. |
| 3 | Debraze the filter and add a "T" joint before the filter. Braze a new process tube with valve. Flush and clean refrigeration system with nitrogen. |
| 4 | Use filter, braze with capillary and condenser liquid line adding "T". |
| 5 | Flush the system and carry out choke testing. |
| 6 | Carry out leak testing by first filling with nitrogen and then testing with soap solution |
| 7 | Evacuate to lowest pressure. Check if the vacuum holds. |
| 8 | Charge HC blend. |
| 9 | Pinch and seal both process tubes. |
| 10 | Run the unit, check that it is functioning properly and label it. |

*In this slide, trainer may quickly read out each bullet; explanations of each can be done in the following slides.


**Slide 4: Removal of HCs from the System**

Hydrocarbon refrigerants are eco-friendly as they do not deplete the ozone layer, nor do they contribute significantly to global warming. Moreover, the quantity of refrigerant in the appliance is very small. However, it is recommended that technicians recover HC refrigerant before starting the repair job. Due to HC's flammability, the technician must recover the refrigerant with a specially designed HC recovery machine. Do not use a compressor for refrigerant recovery, as it may ignite a flame. The recovered refrigerant may be reused in the same air-conditioner. If compressor is burnt out then check the oil for acid and re-use the refrigerant only if the acidic value is within permissible limits).




### Slide 5: Removal of Leftover Refrigerant

Some refrigerant, often mixed with lubricating oil, may remain in the appliance after removal. Use a vacuum pump to remove the leftover refrigerant.
Make sure that the system does not go in vacuum; otherwise air, moisture and dust particles may get into the system when it is opened. If the system goes into a vacuum by mistake, add a small quantity of dry nitrogen to get positive pressure.


### Slide 6: Cleaning and Flushing

This step is necessary after the old filter is de-brazed during the repair.

The following are guidelines that technicians should keep in mind while cleaning and flushing the system:

• Always use dry nitrogen at about 5 bar (75 psig). The nitrogen cylinder must be fitted with a two-stage regulator. It must have a proper regulator.

• When chemical cleaning is required, use ODS-free chemicals. R-141b is an ODS, and will soon be phased-out. There should be no traces of liquid chemical after the cleaning is done.

• Atmospheric air contains moisture and dust, which are detrimental to the system. Never use air, especially when working with HCs and HFCs.

• Petrol contains impurities that can destroy the compressor. Never use petrol when working with HCs and HFCs.


### Slide 7: Precautions While Repairing

Repair of HC-based appliances is not very different from repairing non-HC appliances. However, similar components may be found in different locations or be solid state.

Other precautions:

• Make sure that refrigerant is removed from the system.

• Make use of a tube cutter to avoid any metal chips going into the system.

• Make sure there is no HC refrigerant in or around the system while brazing.

• All brazing should be done in a well-ventilated area.

• To avoid contamination, always use clean components and tubes.

• Wear gloves and goggles for safety, which is essential while servicing any appliance, including HCFC-22.

• Do not smoke during appliance servicing.

As described in the practical procedures, also braze a process tube with a hand shut-off valve to the "T" joint.


**Slide 8: Choke Testing**

After repairs, it is essential to ensure that no choking has taken place due to improper filter brazing, particularly at the capillary end.

To check for choking, introduce nitrogen at 5 bar through the hand shut-off valve on the filter process tube and see if nitrogen flows freely out from the suction process tube. This will ensure that there are no chokes due to brazing at the capillary-filter joint.

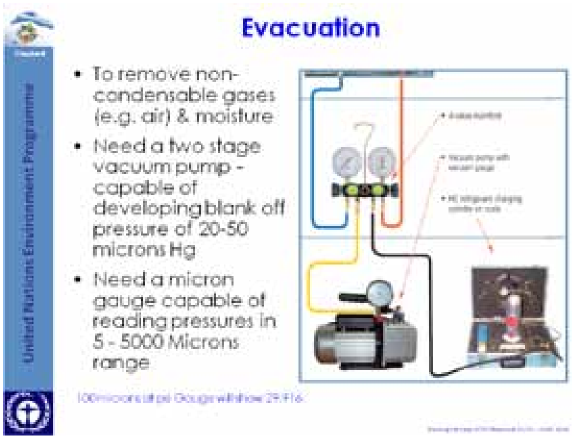
Next, introduce nitrogen at 5 bar through the suction process tube and see if nitrogen flows freely through the filter process tube. This ensures that the filter or condenser joint is not choked.

Always use a double-stage nitrogen regulator.


**Slide 9: Pressure Testing and Leak Detection**

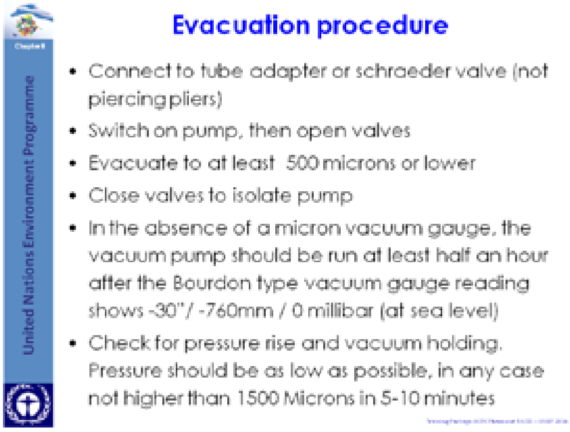
Pressure testing should be conducted after repairs using dry nitrogen. The test pressure should be 1.5 times the working pressure. For air conditioners, it may be about 15-20 bar. The procedure for leak testing HCs is similar to that for HCFCs and HFCs. Use a soap solution for leak testing. Apply soap solution on each joint with the help of a brush and look for leakage.

As described in the practical procedures, also braze a process tube with a hand shut-off valve to the "T" joint.

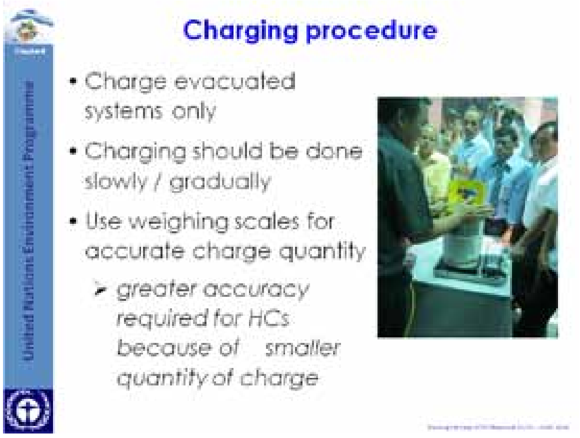



**Slide 10: Evacuation**

In order to remove non-condensable gases and moisture, it is very important to run an evacuation. HC systems need a deep vacuum (500 microns or lower), so a two-stage vacuum pump, capable of pulling vacuum between 20-50 microns at blank off, is required. A micron gauge capable of reading between 5 to 5,000 microns is also necessary to make an accurate vacuum measurement.



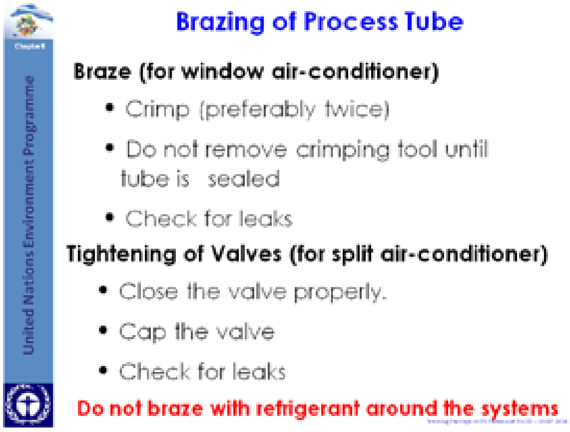

**Slide 11: Evacuation Procedure**
This slide describes how to do an evacuation. First make a proper connection to the vacuum pump (or the manifold) connecting an appropriate hose to the process tube. Then switch on the vacuum pump and open the valves. Run the pump and evacuate till the gauge shows the lowest vacuum at which it holds steady. This level should be around 500 microns, or if possible, lower.
Next, close the valve to isolate the vacuum pump from the manifold and observe the pressure rise and vacuum holding. Repeat this twice or thrice. The pressure should not rise beyond 1,500 microns (the lower the better) in 5 to 10 minutes. This is an indication that most of the moisture has been expelled. Of course, lower readings, like a stabilisation at 500 microns or so, are even better and welcome. In case the pressure rises above 1,500 microns, the system should be evacuated once again and the vacuum holding repeated. In the absence of a micron vacuum gauge, the vacuum pump should be run for at least a half an hour after the Bourdon type vacuum gauge reading shows -30"/ -760mm/ 0 millibar. (This value is for locations at sea level; please correct for altitude at locations above sea level.)




**Slide 12: Charging Procedure**

HC-based appliances require high accuracy when charging. As mentioned earlier, it is best to use a weight scale for accurate charging. The system should be charged after proper evacuation. Us the correct charging equipment, which consists of a weighing scale and a manifold. To charge the system, connect the hoses to the cylinder and then purge or evacuate the charging line, depending on the available equipment. Open the valve and charge the exact prescribed charge amount. Close the cylinder valve and start the system. This will circulate the refrigerant in all parts of the system and also draw out the remaining refrigerant in the charging lines, etc.

Finally, close the remaining valves of the charging equipment and disconnect the equipment from the system.




**Slide 13: Brazing the Process Tube**

Process tube brazing can be done in the same manner as with HCFC-22 appliances. It is recommended that technicians crimp the process tube twice, and leave the crimping (pinching) tool on the process tube until it is sealed. After the copper pipe cools down, check for leaks. Once again, make sure there is no HC refrigerant around the system.

In split air-conditioners, there is a service valve, and therefore the crimping may not be required. Check for leakage after closing the service valve


**Slide 14: Checking Proper Operation**

Finally, the air conditioner should be switched on and the following parameters monitored to ensure that it is operating properly:

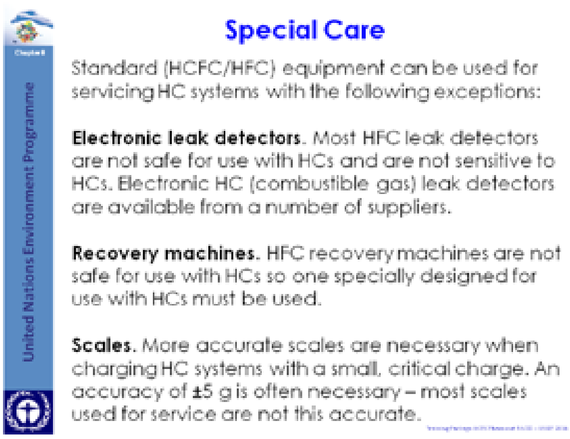
• Time needed to reach the recommended temperature

• Compressor current

• Vibrations. If there are any unwanted vibrations, find the cause and fix the problem.

• The label should be intact and readable. If it has been torn off, attach a new one.

If everything on this list checks out correctly, than the appliance should be operating properly.




**Slide 15: Special care**

When servicing HC-based air conditioners, the following steps must be taken:

An electronic leak detector, capable of detecting HCs, must be used in workshop. HFC-based electronic leak detectors will not sense the presence of HCs.

Do not use a recovery machine designed for HFCs or HCFCs. If recovery is required, use special recovery machines designed for HCs.

During charging, you must use a digital weighing scale, otherwise you will not be able to charge the exact amount of refrigerant.

## Evaluation Questions

1. What are the steps to be followed when servicing HC-based air conditioners?
2. What are the precautions to be taken while servicing HC-based air conditioners?
3. Can HFC-based electronic leak detectors be used to detect the presence of HCs? If not, why?
4. Can a recovery machine for HFCs or HCFCs be used for recovering HC? If not, why?

# 9. INSTALLATION PROCEDURE OF AIR-CONDITIONER WINDOW AND SPLIT

**Training Material Reference:** Installation Procedure for Window and Split Air Conditioners - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 45 minutes

**Purpose of the Session**
To make the participants aware of the correct air conditioner installation procedures. This will lead to enhanced system life and optimum performance.

**Final Performance Objectives**
At the end of the session, the participants should know:
a) What is a quality installation?
b) What are the procedures for choosing the installation location for indoor and outdoor units?
c) What are different thicknesses of copper tubes used in air conditioners?
d) How does one lay out the piping?
e) How does one adapt installation procedures?

**Key Message Delivered in this Session:**
Proper air conditioner installation plays a very important role in terms of machine life, energy consumption and aesthetics. The technician must wisely decide where the appliance will be installed, what direction to place the condensing unit and other issues. He or she must also know the right techniques for unrolling the copper tube, swaging, flaring and brazing so that there will not be refrigerant leaks and customer complaints.

**Tools and Equipment Required for the Session:**
None.


**Slide 1: Installation Procedure for Window and Split Air Conditioners**

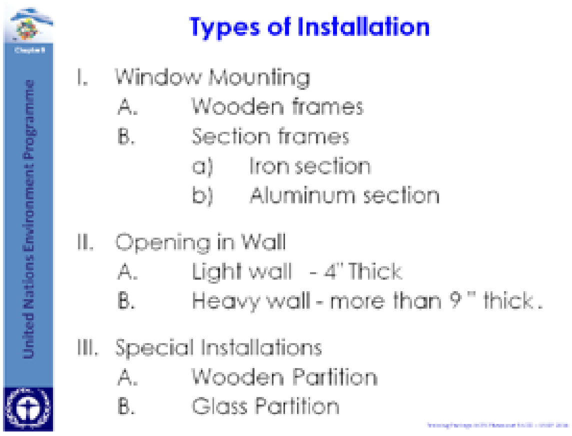
This title slide can be used to start a general discussion. The trainer may explain that before installing any air-conditioner, it is better to think twice about location. Normally, the customer already has a preferred location, but technicians may need to explain the technical reasons why the customer's location is not the best choice in terms of energy consumption, service and other factors.


**Slide 2: Quality Installation**

As mentioned in the slide, quality installation prevents the majority of complaints. But what is quality installation? It includes considering site selection, indoor unit airflow, slope, condensing unit direction, piping layout and ultimately, customer education. All this will be discussed in the coming slides.


**Slide 3: Use Personal Protective Equipment (PPE) During Installation**

Every service technician's first safety concern is him or herself, then the customer and the machine. Many accidents happens because technicians neglect to use safety equipment. When you are ready to install the air conditioner, always wear appropriate safety gear. Complete PPE gear is recommended especially for work in high-rise buildings.




**Slide 4: Types of Installation**

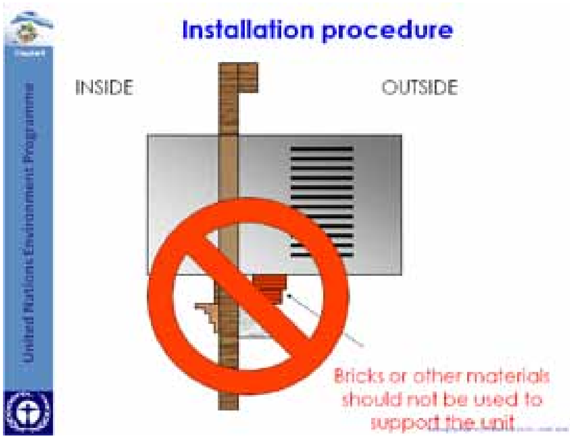
During the technician's visit before installing a window air conditioner, he or she must discuss with the customer what type of mounting is to be used. The mounting could be a wooden frame or a section frame of iron or aluminium, for example. If the wall does not have any window opening, then an opening must be made to install the air-conditioner. Check the thickness of the wall and order the same width of wooden frame.


**Slide 5: Installation Procedure**

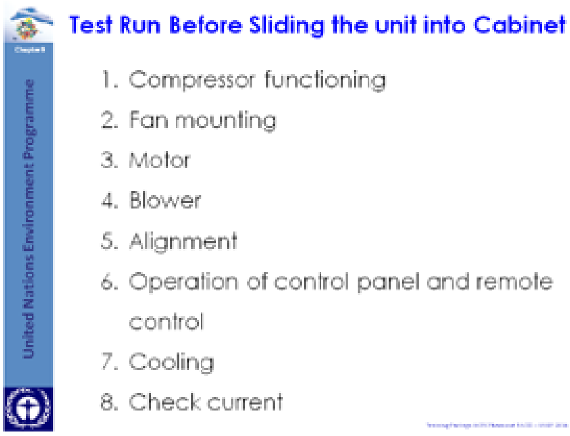
This slide enumerates the eight steps of installation. Each step will be explained in detail in the following slides.


**Slide 6: Get to Know the Air Conditioner**

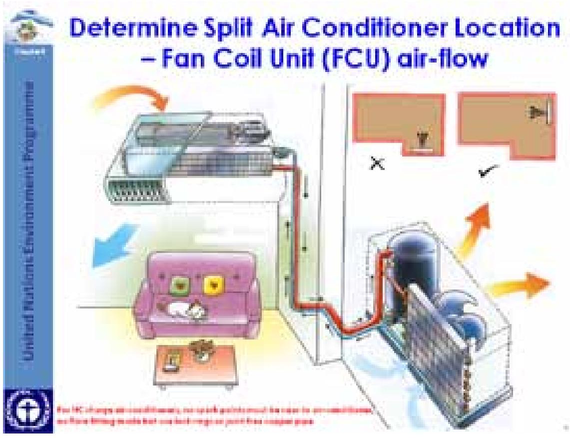
Before installation, the technician should know the dimensions of the air conditioner, including width, depth and height. He or she must also find out how the grill is fixed—by lock or by screw—and if the air flow is from the right or left side. Also, the technician must become familiar with the remote control so they can educate the customer, as not all remote control devices are the same.




**Slide 10: Installation procedure**
Insufficient bracing and or framing may result in the air-conditioner unit falling down, which can cause machine damage and accidents. Do not use a temporary object, like bricks or wooden planks, to hold the weight of the air conditioner. Make an appropriate frame and/or brace.




**Slide 11: Test Run Before Sliding the Unit into the Window**
The technician must check the air conditioner before installing it to make sure there are no transit locks, such as a strip on the compressor or base bolts. If there are, they must be removed. The unit should then be tested before sliding it into the frame. Check the compressor function, fan motor noise and blade balance. The technician should also be ready to explain to the customer how the remote control works. Most importantly, he or she should check the manufactuer's recommended grill temperature and current.




**Slide 12: Determine Split Air Conditioner Location - FCU Airflow**
The fan coil (FCU) indoor unit must be installed at a place that meets the following conditions:

• A place that provides good air circulation into the room. Normally, that would be 6 to 7.5 feet (183cm to 229cm ) above the floor;

• A place with an easy connection to the outdoor unit;

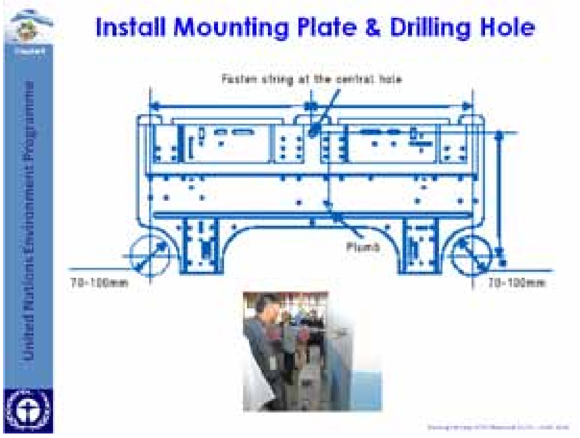
• A place with an easy connection for the condensate drain;

• Air inlet and outlet kept at a far distance from the blockage;

• Mounted on a place solid enough to bear the weight of the FCU unit and not cause any vibration;

• A place that is at least 1m away from the electronic gadgets.

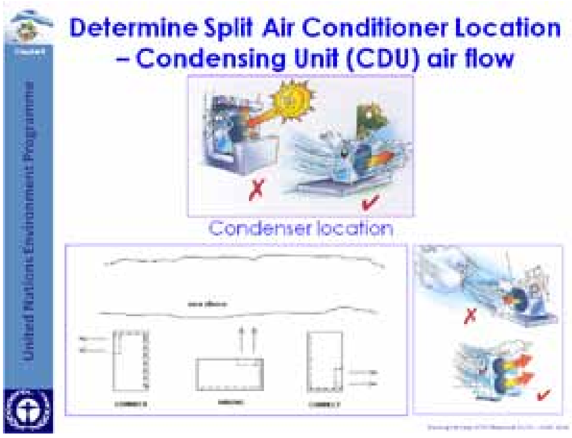
• When installing an HC-charged air conditioner, be sure that there are no nearby spark points.




**Slide 13: Installing Mounting Plate and Drilling Hole:**
Find a suitable location for the indoor unit on the wall. Mark the distance from roof top. place the plate and mark the centre point. Drill the hole, insert rowel plug and tighten the screw (but don't fully tighten). Place the water level meter and check that the plate is level. After levelling, mark the remaining points for drilling. Next, mark the centre point where the piping will exit through wall. It can vary from 70-100 mm diameter. Drill the hole for the piping.


**Slide 14: Determine the Split Air Conditioner Location - Placing Electronic Gadgets**

An indoor unit must not be installed very close to a microwave, TV, radio or other electronic device as it can malfunction from to noise or Harmon's generation due to high voltage. Electronic devices must be approximately 1 m or more from the indoor unit.




**Slide 15: Determine Split Air Conditioner Location - CDU Airflow**

The condensing unit (CDU) or outdoor unit should be installed at a place that meets as many of the following conditions as possible:

• A well-ventilated site with good heat dissipation;

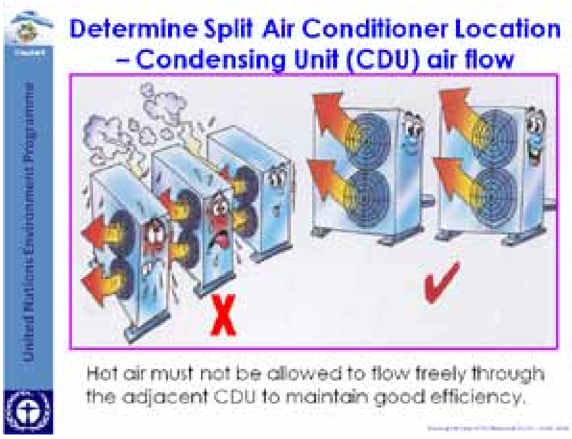
• A CDU must not be exposed to rain or direct sunlight;

• A place that does not increase the operating noise or vibration of the CDU unit; and

• A place where the discharge air does not counter flow with the wind direction. This is very important when air-conditioners are installed on buildings by the seashore.


**Slide 16: Determine Split Air Conditioner Location - CDU Airflow**

Rain on the outdoor chassis will effect the air conditioner; the CDU must be placed under a canopy of some sort. If it gets wet, rust formation can ultimately lead to a shorter operating life. As shown in this slide, the airflow absolutely must not be restricted. Making sure the airflow is not restricted is even more important than having a canopy over the unit.



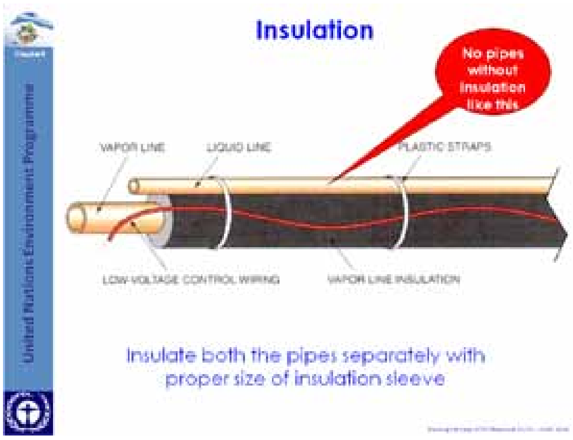

**Slide 17: Determining CDU Airflow**

Never install condensing units right next to each other in a series, as it will lead to one air conditioner's hot air entering into the second CDU's inlet and so on. This will result in high head pressure and ultimately more energy consumption. The exhaust of one air conditioner must not be allowed to flow through the adjacent CDU unit.


**Slide 18: Determine Split Air Conditioner Location in Relation to a Wall**

• The location must be free from obstacles near the CDU's air inlets outlets.

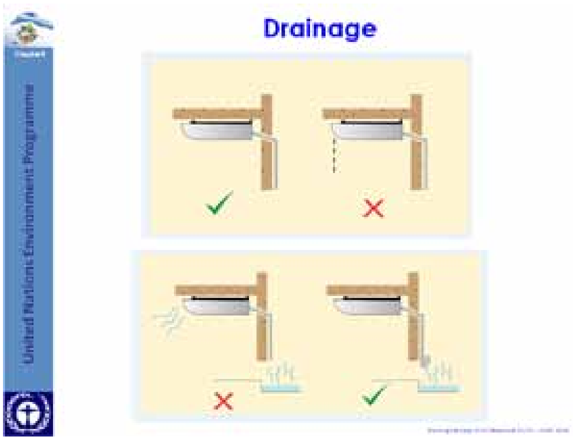
• Keep a distance of 12"  (30.5cm) between any wall and the CDU and 1.5 feet (36cm) or more on sides between the CDU unit and the wall surface. The distance from the outlet of the condenser fan to the wall must be at least six feet (183cm).




**Slide 19: Insulation**

The slide shows how to insulate the copper tube when the metering device (capillary tube) is installed at the inlet of evaporator (in the FCU indoor unit). Only the vapor line or the larger copper tube must be insulated; the liquid line or smaller copper tube does not require insulation because at this stage the refrigerant needs to dissipate heat from the system.

1. If the metering device (capillary tube) is installed at the outlet of condenser (in the CDU outdoor unit), both the vapor line or the larger copper tube and the liquid line or smaller copper tube need to be insulated separately in order to save energy and prevent condensation on the tube's surface.




**Slide 20: Drainage**

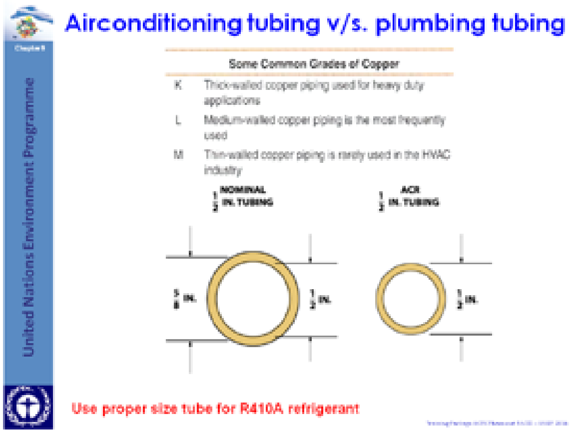
Condensate drain pans must be installed in a tilted position that allows the water to flow out from FCU unit. To drain the condensate water easily, the drain hose should be inclined downwards. If the end of drain pipe is near a waste water sump, unpleasant odours could transfer to the air-conditioned room due to the draw force from the evaporator fan.

This problem can be prevented by making a u-bend at the end of the drain pipe. The u-bend collects the condensate water and blocks the undesirable odours.

1. Do the clamping after every 3 feet (approx. 1 m) or less;
2. Do not run piping in air. Use the wall for support;
3. Make a proper joint to avoid leakage;
4. Make the drain pipe as short as possible;
5. Maintain a slope of 1 inch (approx. 25 mm) for every 3 feet (approx. 1 m).


**Slide 21: Indoor Test for Water Flow**

The simplest way to test for correct flow is by pouring the water into the condensate drain pan after the FCU unit is installed and looking at how the water drains. If the water falls inside the room, this means that slope of the drain is not correct. If all the water flows outside from the drain pipe, this means that the slope is well-maintained.



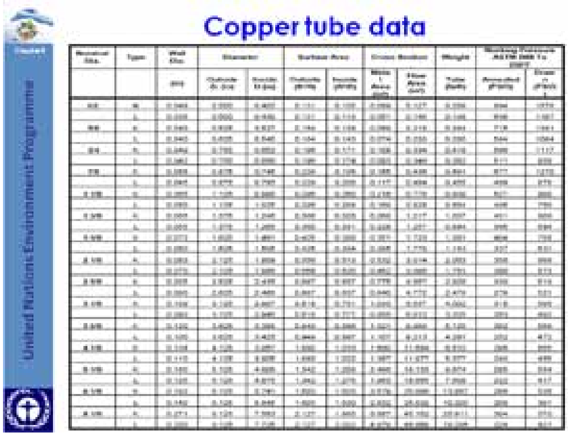

**Slide 22: Air Conditioning Tubing Versus Plumbing Tubing**

The most common tube fitting you will find in refrigeration systems is made of copper. It is sized by the actual outside diameter and comes in lengths of 16 to 20 feet (5 to 6 m) in hard copper and coils of 50 to 165 feet (15 to 50 m) in soft copper. There are two common types of copper tubes:

Hard Copper: A hard copper tube is rigid and is identified by size and name. This type of tube makes a neater installation, but is time consuming and difficult to install. It needs very little mechanical support to keep it in position, compared to soft copper tubes. There are three types of hard copper tubes (Type K, Type L and Type M). Type K has the thickest wall section, while Type L and Type M have a thinner pipe walls, respectively.

Soft Copper: Soft, flexible copper tubing is much more versatile than a hard copper tube. It comes in much longer lengths and requires fewer joints, reducing leak potential. Since it is easy to bend, it saves time during installation.

The major difference between plumbing and RAC tubes has to do with how they are sized. When you will ask for a ½" RAC tube it will be measured by inner diameter, but if you ask for a ½" air-conditioning copper ACR tube (ACR), you will get the outer diameter. There are specially designed copper pipes that can withstand high pressure for use in refrigeration. They arrive from the producer sealed at both ends to prevent contamination by moisture or dust.




**Slide 23: Copper Tube Data**

This is overloaded chart with data on different kind of tubes, showing the diameter and the pressure tolerance. The technician can choose the size according to working pressures.


**Slide 24: Unrolling Copper Tube Rolls**

It is very important to keep both ends of the roll closed until technician decides to use it. Once the tube is unrolled, it must be laid down on a flat surface. Hold one end of the tube and try to unroll it slowly and softly, moving keeping one hand close to the roll. There should be no kinks formed in the copper tube during the unrolling process.

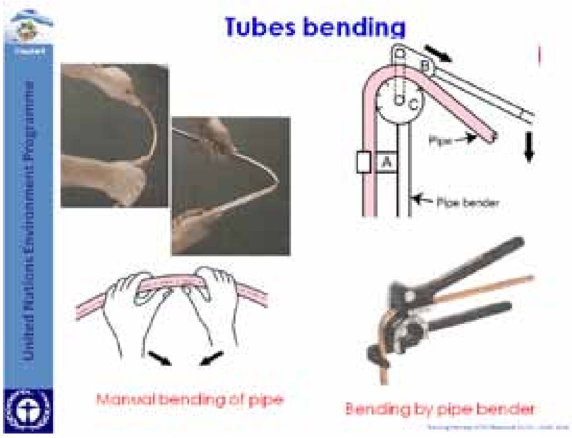

**Slide 25: Tube cutting, Swaging and Flaring**

Because of its exceptional flexibility, copper can be shaped as desired at the job site. While a copper tube is usually joined by soldering and brazing, flaring is a mechanical way of joining copper tubes. A mechanical joint may be required or preferred at times. Flared fittings are an alternative when the use of an open flame is either dangerous or impractical. Flared joints (and screwed connections) should be kept as minimal as possible. In order to prevent leaks, create a system that is well sealed.

Check the availability of 'brazed in' components and use them wherever possible.

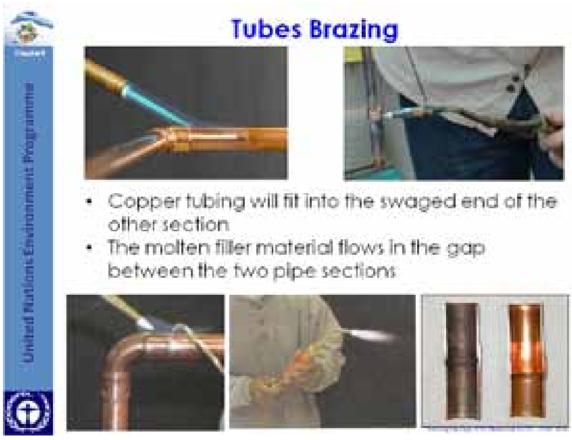
| Copper Pipe Outer Diameter (mm) | Tightening Force N.m (Kgf.cm) |
|---|---|
| Dia 6.35 | 14 to 18 ( 140 to 180) |
| Dia 9.52 | 34 to 42 (340 to 420) |
| Dia 12.70 | 49 to 61 (490 to 610) |
| Dia 15.88 | 68 to 82 (680 to 820) |
| Dia 19.05 | 100 to 120 (1000 to 1200) |

*(Also see more in Chapter 6 - Best Service Practices Dos and Don'ts)*




**Slide 26: Tube Bending**

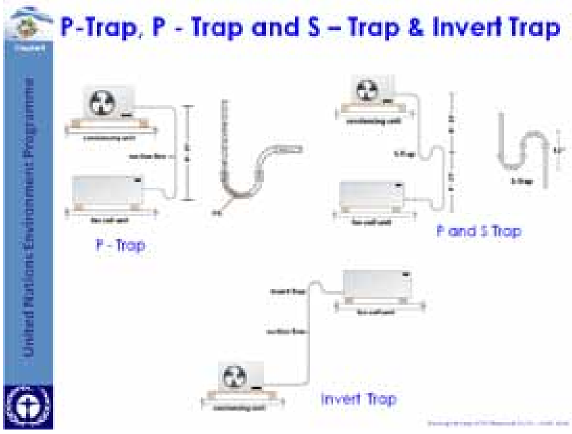
It is much easier to install the system correctly than to rectify problems later. There is no excuse for allowing an unnecessary pressure drop, which can affect a system for its operational life. Technicians must plan the piping layout around the optimum route for the suction line, as it is very important to minimise any pressure drop. If while manually bending soft copper the technician accidentally kinks the pipe, he or she must cut and discard the kinked section and try again. When properly bent, copper tubing will not kink on the outside of the bend and will not buckle on the inside of the bend. Because copper is easy to shape, with the proper tools and methods, expansion loops and other necessary bends are quickly and simply made. Each tube side requires a properly-sized bender. Benders as small as 22 mm can be carried in a tool kit. *The minimum radius for a tubing bends is between 5-10 times diameter of the tubing.*




**Slide 27: Tubes brazing**

Brazing and soldering are the most common methods of joining copper tubes and fittings. Good brazing joints are strong, durable and stay tight. Brazing is necessary for joints that can withstand vibration, temperature and thermal cycling stress. The basic soldering and brazing techniques are the same for all diameters of copper tubes. The only variables are the filler metal and the amount of time and heat required to complete a given joint. Soldering is the joining process that takes place below 450°C (840°F) and brazing as a process that takes place above 450°C (840°F), but below the melting point of the base metals. Most brazing is done at temperatures ranging from 600°C to 815°C (1,100°F to 1,500°F). For making non-detachable joints, it is best to braze with copper-phosphorus filler metals. No flux is needed as the vaporised phosphorus will remove the copper oxide film. Flux is used with silver mixed brazing rods.

When heat is applied to copper in the presence of air (oxygen), oxides form on the surfaces of the tube. This is very harmful for a durable functioning of the refrigeration system in general, but mostly for the compressor's lubricating system. Oxide scale on the inside of refrigerant pipelines can lead to problems once the refrigerant and the lubricant are circulating in the system. Refrigerants have a scouring effect that will lift the scale from the tubing, and this can carry throughout the system and lead to sludge formation. The oxide formation during brazing can be easily prevented: just slowly pass nitrogen through the pipe-work while the heat is being applied. This method, which uses nitrogen as a protective gas (very low flow rate inside the pipe assembly during brazing process) is a common way of avoiding oxidation.




**Slide 28: P-Trap, P and S Trap and Invert Trap**

*P-Trap*

The suction pipe is the most critical site for oil return. A P-trap should be used at the base of any suction riser greater than 8 ft (244cm) in length. A suction riser is any vertical line that has an upward refrigerant flow.

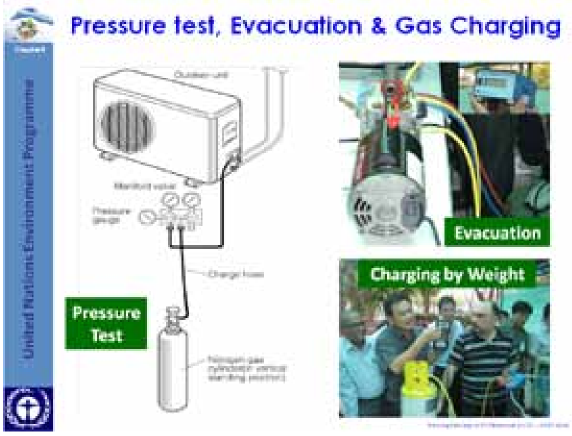
*P - Trap and S - Trap*

In long suction risers, P-traps should be used for every 25 ft (about 7.5m) of vertical rise. In addition, it is good practice to install a P-trap at the outlet of the evaporator if the suction line rises above the bottom of the evaporator. This trap will ensure that oil can flow freely out of the evaporator. The reason for the suction P-trap is to help the return of oil to the compressor. The refrigerant gas returning from the evaporator will contain drops of oil that can collect and mix in the turbulence of the trap. This turbulent action breaks up the larger drops of oil into smaller droplets carried up to the riser pipe by the gas velocity.

Be careful of piping installations where the pipe is being routed over, around, or under obstacles. This can inadvertently create unwanted traps in the return line and collect oil. If possible, the refrigerant line should travel a direct and straight course between the evaporator and compressor.

*Invert Trap*

While operating, the suction line is filled with superheated refrigerant vapour and oil. The oil flows on the bottom of the pipe and is moved along by the refrigerant gas flowing above it. When the system stops, the refrigerant may condense in the pipe depending on the ambient conditions. This may result in slugging if the liquid refrigerant is drawn into the compressor when the system restarts. To promote good oil return, suction lines should be inclined 1/8 inch per foot (10.4 mm/m) in the direction of refrigerant flow. To minimise slugging of condensed refrigerant, the evaporators should be isolated from the suction line with an inverted trap. The trap should extend above the top of the evaporator before leading to the compressor.




**Slide 29: Pressure Test, Evacuation and Gas Charging**

Here, there is need for the trainer to explain the complete details of the process of leak testing, evacuation and gas charging again. He can summarise what trainees have learned in the section on best servicing practices.


**Slide 30: Leak test with Electronic Leak Detector**
The technician charges small amount of refrigerant into the system, balanced with dry nitrogen to raise the pressure to the desired level. Now the system is ready to be tested with the electronic leak detector.

A soap solution is an equally good method for checking leakage.

The technician must hold the pressure at least for three hours.


**Slide 31: Measure Recommended Current of OEM**
During the test run, the working electrical current should be equal to the rating current indicated on the manufacturer's name plate.


**Slide 32: Customer Education**
Technicians are generally given lessons on technical subjects in workshops. The following slides have been introduced to help them inform the customer how to avoid bad practices and how to deal with customers in general. These tips can help save energy and keep the equipment working longer.


**Slide 33: Customer Education**

To help save energy and keep the machine running well, the customer needs to know how to use the air conditioner correctly.

If the customer is not familiar with air conditioners, they need to be told not to block the cooling coil or condenser exhaust with unwanted items. Never water plants in the air conditioned room as it makes it harder for the machine to cool the air and makes it necessary to run AC longer. Never hang wet clothes to dry in a room, as it will take longer for the appliance to cool the room and require higher energy consumption.


**Slide 34: Customer Education**

Customers must never cook food in a room when the air-conditioner is ON. The air-conditioner will run higher due to the extra heat consume more energy.


**Slide 35: Dealing with complaints**

A technician must be a good listener. He or she must listen to the customer very carefully and then offer a response. Even if the customer is wrong, the technician must explain politely why something has happened. Customer queries must never be ingored. Always be polite with the customer.

## Evaluation Questions

1) Why is it necessary to have a gap behind the condenser of a window air conditioner?
2) What are the basics for piping layout?
3) Should we install the air conditioner's condensing unit parallel to each other or one behind another?
4) How does one unroll a copper tube?
5) Is customer education necessary? What are the key steps in customer education?


RECOVER
VAC
SENSOR
SELECT
OPEN
PURGE
CLOSED
OUT
RG5410A

# 10. REFRIGERANT, RECOVERY, RECYCLING AND CYLINDERS

**Training Material Reference:** Refrigerant Recovery, Recycling and Cylinders - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
To make trainees aware of the importance of recovering refrigerants, and how to effectively accomplish the task. Subjects include which refrigerants should be recovered, active and passive methods of recovery, and how to assemble simple recovery and single-pass recovery machines, as well as recycling (R&R) units.

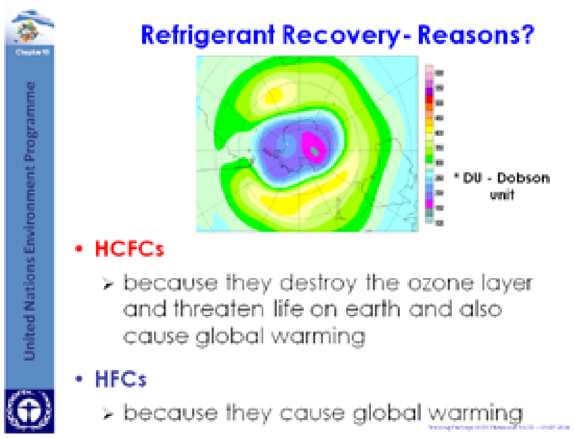
**Final Performance Objectives**
At the end of the session, participants should know:
a) The reasons for recovering various refrigerants, including not only HCFCs (HCFC-22), but also HFCs (HFC-134a, HFC blends);
b) The differences between recovery, recycling and reclamation;
c) What are the different types of recovery operations, as well as their main components and circuit diagrams;
d) How to assemble a simple recovery machine; and
e) The development and design and single-pass R&R machines.

**Key Message Delivered in this Session:**
Refrigerant recovery is a good practice that should be adopted by service technicians for both environmental and economic reasons. Various types of recovery and recycling machines can be purchased for different needs. However, it is also possible to make a simple recovery machine oneself with used components that can be found at the service shop. This can be an attractive option, provided the components are in good conditions.

**Tools and Equipment Required for the Session:**
It is best to have a recovery machine close by.


**Slide 1: Refrigerant Recovery, Recycling and Cylinders:**
Recovering refrigerants such as HCFCs and HFCs reduces damaging atmospheric emissions. The following issues will be discussed in this chapter:

- Why refrigerant recovery is necessary
- Recovery principles and terminology
- Passive and active recovery procedures
- How technicians can create a simple recovery machine
- Different types of cylinders




**Slide 2: Refrigerant Recovery - Reasons?**

HCFCs (e.g. HCFC-22) must be recovered. If released into the atmosphere, not only will they deplete the ozone layer, but they also will contribute to global warming.

However, from an environmental point of view, it is not enough to recover just HCFCs. HFCs, such as HFC-134a and R-401A must also be recovered. Even if they do not damage the ozone layer, the still have a moderately high GWP, and should not be released into the atmosphere.

There are also economic reasons for recovering these gases. Due to phase-out regulations, the price of HCFCs may rise dramatically over the next few years.


**Slide 3: Recovery, Recycling, Reclamation**

According to ISO 11650, these terms are defined as follows:

<u>Recovered Refrigerant:</u> Refrigerant that has been removed from a refrigeration system for the purpose of storage, recycling, reclamation, or transportation.

<u>Recovery:</u> The process of removing a refrigerant in any condition from a refrigeration system and storing it in an external container without any type of testing or processing.

*Technicians must avoid reusing refrigerant recovered from burnt-out compressor systems or from damaged or neglected appliances. It is usually possible to determine if the gas or oil is unrecoverable by checking to see if it has a blackish colour or smells acidic. The lubricant will have a similar odour. If the recovered refrigerant is in good condition, it can be reused, for example, to repair a leak or to replace a valve. If the contaminants level is excessive, the refrigerant should be stored in a safe place to be sent for destruction. In some countries, test kits are available to verify the quality of recovered refrigerant.*

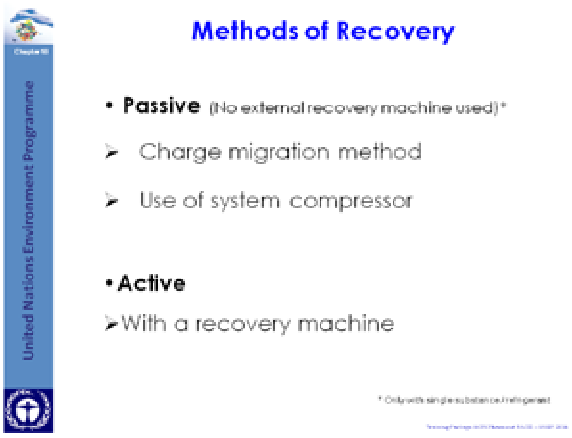
Recycling: The process of reducing contaminants in used refrigerant by separating the oil, removing non-condensable gases, or using core filter driers to reduce moisture, acidity and particulate matter.

*Inexpensive single-pass recycling machines can reduce the level of contaminants, but they are not very effective. Multiple-pass machines are more effective, but they are also more expensive. In order to keep recycling equipment in good condition, filter systems need to be changed or cleaned regularly. In most cases, the recycled refrigerant is reused in the same system it was removed from, or charged into compatible equipment at the same site.*

Reclamation: This process transforms used refrigerant into a new product through various methods, including distillation. Chemical analysis is necessary to determine whether the reclaimed refrigerant meets product specifications. There are mini reclamation centres where technicians can go to reclaim refrigerant.

Disposal: In several countries, licensed disposal firms destroy refrigerants that cannot be recycled or reclaimed. Such destruction facilities, which may include incinerators, are not yet available in most developing countries.

It is important to clearly explain the three different processes.




**Slide 4: Methods of Recovery**

There are two primary recovery methods. The first is passive: refrigerant is recovered without using any external equipment.

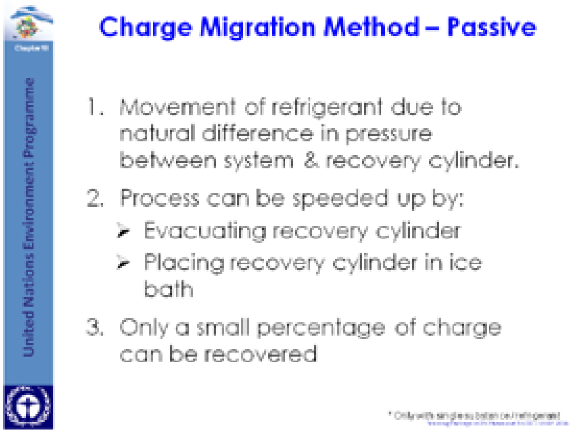
The two most common passive recovery techniques are:

1. Charge migration

2. Using the system compressor to accelerate the recovery process

The second method is active: refrigerant is recovered with external machines.

In each method, both the refrigerant and its oil are recovered.




**Slide 5: Charge Migration Method: Passive**

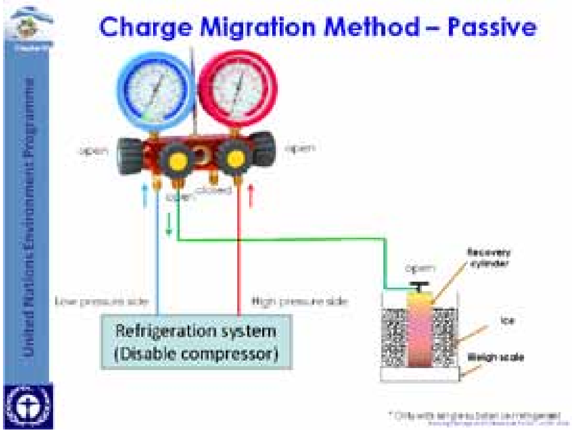
Recovering In this technique, the refrigerant flows from the system to the recovery cylinder due to the pressure difference between the two. The greater the pressure differential between the system and the cylinder, the faster and larger the quantity of refrigerant that will be recovered. The process can be speeded up by creating a greater pressure differential by:

a) evacuating the recovery cylinder; or

b) placing the recovery cylinder in an ice bath; or

c) a combination of the above.

Basically, only a small percentage of the charge can be recovered using this technique.




**Slide 6: Charge Migration Method: Passive**

This slide shows the scheme of the recovery arrangement.


**Slide 7: Accelerated Passive Recovery Using a System Compressor**

In this case, the system's own compressor is used to create the pressure differential, thus accelerating the pumping of the refrigerant into the recovery cylinder. As noted on the slide, the important points to remember are:

1. The system compressor can pump out refrigerant either as vapour (if the service valve used), or as liquid (is the condenser exit is used);

2. The system compressor should not run below "0" PSIG; and

3. A higher percentage of refrigerant can be recovered using this method.

Still, a significant amount of refrigerant will be left in the system, and an external recovery machine will be necessary.

This slide presents the scheme of the recovery process, along with the names of the components.


**Slide 8: Active Methods of Recovery**

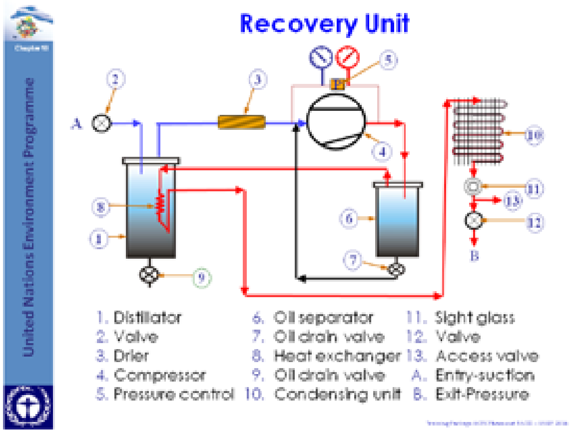
Active methods use external recovery machines.

One compact option that is easy to transport is a simple system using a compressor to liquefy the vapour in the condenser before it enters into the recovery cylinder. However, this method does not separate the oil contained in the refrigerant.

A more advanced method separates the system oil from the refrigerant during the recovery process. Moreover, it also separates the recovery machine compressor oil and returns it back to the compressor.

Currently, many recovery machines function with an oil-less compressor. Special recovery machines have been developed for HCs.

The same recovery machine can be used to recover different refrigerants, after vacuuming the recovery machine up to 500 microns or below.



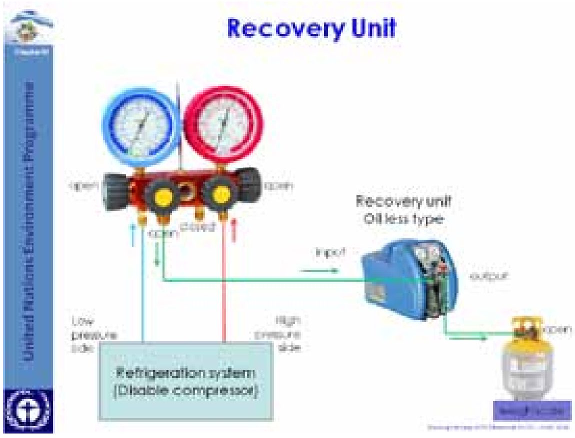

**Slide 9: Recovery Unit**

This slide explains how oil is separated from refrigerant during the recovery process, using an active, single-pass system with oil separation. Unlike a simple recovery machine, which allows oil to get into the recovery compressor and damage it, a single-pass system separates the oil and keeps it out of the compressor.

In this scheme, the refrigerant is recovered (as vapour) from the system and passed through an oil separator.

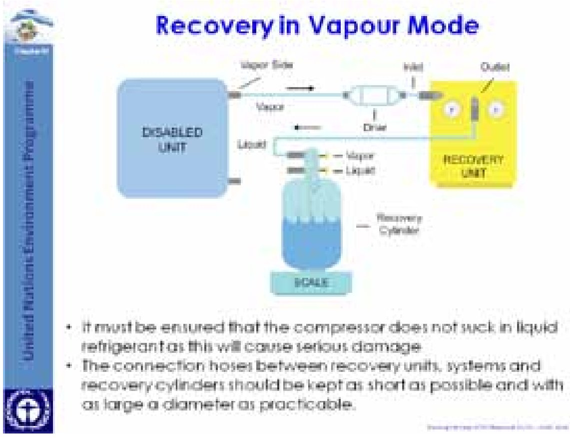
During the recovery process, the refrigerant soaks up oil from machine's compressor. This oil is separated in a second oil separator and returned to the compressor. This step is essential to keep the compressor from running out of oil and burning out.

The refrigerant is then liquefied in the condenser and collected in the recovery cylinder.



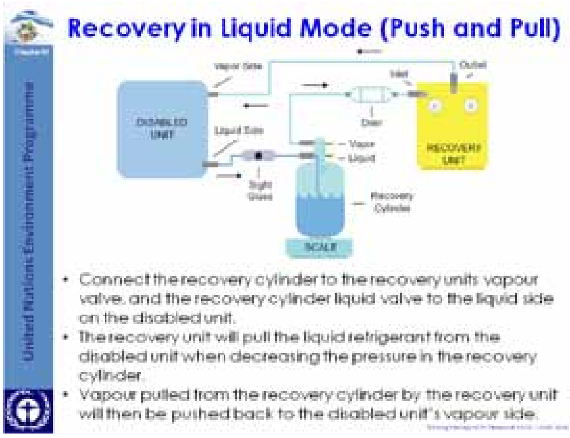

**Slide 10: Recovery Unit**

This slide shows the schematic connection between an oil-less recovery machine and a recovery cylinder with a weighing scale.



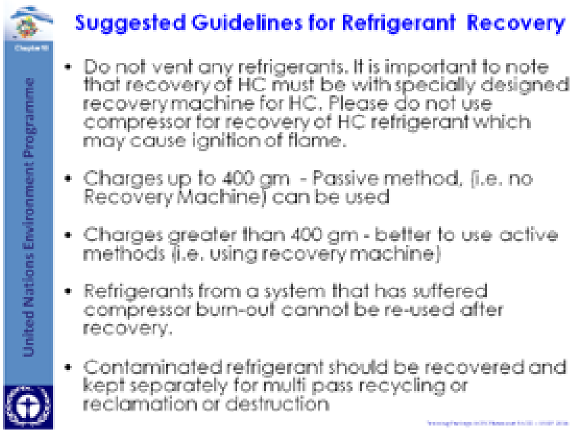

**Slide 11: Recovery in Vapour mode**

As shown in this diagram, the refrigerant charge can be recovered in vapour recovery mode. In larger refrigeration systems, this mode will take more time than transferring liquid. The technician must be sure that the compressor does not suck in liquid refrigerant even if it is taken out of the receiver, as this will cause serious damage. The connection hoses between recovery units, systems and recovery cylinders should be kept as short as possible and with as large a diameter as practicable.




**Slide 12: Recovery in Liquid Mode (Push and Pull)**

Another liquid recovery method is called the "push and pull" method. As shown in the diagram, the technician must connect the recovery cylinder to the disabled unit's vapour side, and the recovery cylinder's liquid valve to the unit's liquid side. The recovery unit will pull the liquid refrigerant from the disabled unit when the pressure decreases in the recovery cylinder. Vapour pulled from the recovery cylinder will then be pushed back to the disabled unit's vapour side.





**Slide 13 and 14: Suggested Guidelines for Refrigerant Recovery**

In the absence of clear guidelines, trainers are unable to answer questions like how to discriminate between reusable and non-reusable recovered refrigerants, or what is to be done with recovered refrigerant. For project purposes, the following guidelines are recommended:

1. Do not vent any refrigerants. It is important to note that HC recovery must be done with specially designed recovery machines. Important: do not use compressors for recovering HC refrigerant as it may ignite a fire.
2. Use passive or active recovery methods for recovering refrigerant from the appliance;
3. If the refrigeration and air-conditioning system has suffered a compressor motor burn-out, the refrigerant should be recovered but not reused, as it will have to be reclaimed;
4. Recovered refrigerants can be reused after testing the oil extracted from the recovery machine for acidity with an acid test kit and for moisture with a moisture test kit. The acceptable limit for acidity is 0.2 TAN and the limit for moisture is 100 ppm. Recovered refrigerant with readings above these limits must be stored separately, such as refrigerant from burnt out compressors;
5. If the acid test indicates acid and moisture limits within the above-mentioned limits, the refrigerant can be reused.

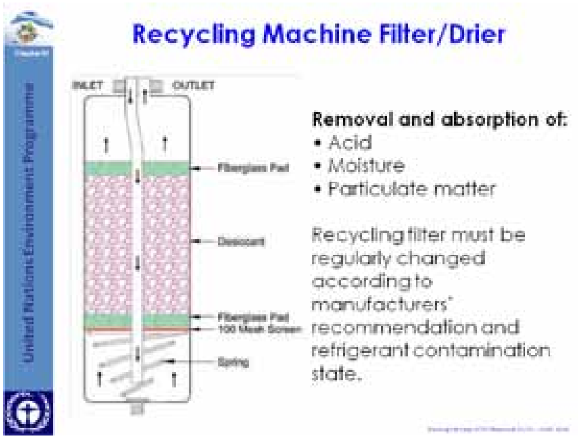
The above guidelines do not purport to be a substitute for national policies and frameworks, but they should at least make it possible to discriminate between useable and unusable refrigerants.


**Slide 15: Recycling Machine**

A recycling machine recovers and recycles refrigerants without releasing them into the atmosphere, and at the same time purges the refrigeration and air-conditioning system of humidity and deposits contained in refrigerant oil. The machine is equipped with a built-in evaporator and separator that removes oil and other impurities from the recovered refrigerant. The fluid is then filtered, recycled and returned to the tank installed in the machine. The machine also permits running certain operational and leak tests on the refrigeration and air-conditioning system.

Some of these units are assessed for quality and performance as per Air-conditioning and Refrigeration Institute (AHRI) standard 740. (Standard file soft copy available in CD)

http://www.ahrinet.org/site/686/Standards/HVACR-Industry-Standards/Search-Standards




**Slide 16: Recycling Machine Filter/Drier:**
A recycling filter must be installed in the recycling system to absorb and remove acid, moisture and particulate matter from the refrigerant. This filter must be changed regularly according to the manufacturers' recommendations.


**Slide 17: Safe Refrigerant Capacity**

During recovery, the technician must only use the appropriate cylinders and label them to indicate what kind of refrigerant is stored inside. To calculate the exact capacity of the cylinder, use the formula below:

Water contents x 0.8 = safe refrigerant capacity

<u>It is important to know the recommended HCFC charge size</u> for the system. If it is not clear what the charge size is, weigh the entire amount of refrigerant removed. This amount can be used as a guide for charging replacement refrigerant into the system.


**Slide 18: Type of Refrigerant Cylinders**

Refrigerants are packed in both disposable and returnable (refillable) shipping containers, commonly called "cylinders". They are considered pressure vessels, and therefore subject to regulations in most countries. Cylinders are designed for either pressurised and liquefied gases and are labelled accordingly. Two types of refrigerant cylinders are currently available on the market:

a) Disposable/non-refillable cylinders and cans in different sizes.

b) Recovery/refillable cylinders


**Slide 19: Disposable / non-refillable cylinders**

"Non-refillable" or "disposable" cylinders are sometimes used when the supply infrastructure is not comprehensive, and are a less expensive solution for refrigerant suppliers who expect their cylinders to be lost. From both an environmental and safety perspective, the use of disposable cylinders is a bad practice. These containers are generally discharged after use, releasing refrigerant into the atmosphere. Furthermore, despite regulations prohibiting reuse of these cylinders, people often attempt to use them again (for example, through brazing new valves to enable re-filling). Also, they tend to be manufactured from thinner metal than the conventional, re-usable cylinders, rendering them more susceptible to rusting and mechanical damage over time. For these reasons, the re-use of non-refillable, disposable cylinders is not recommended under any circumstances.

If a disposable cylinder has been used, it should be properly emptied. This means the remaining refrigerant should be recovered until the pressure has been reduced to approximately 0.3 bar (absolute). The container should then be marked empty. At this point, the cylinder is ready to be disposed. However, it is also recommended that the technician then open the cylinder valve to allow air to enter, and render the cylinder useless by breaking off the valve or puncturing the container. This will keep the container from being misused by untrained individuals. Used cylinders can be recycled with other scrap metal. Never leave used cylinders with residual refrigerant outdoors where the cylinder can rust. An abandoned cylinder will eventually deteriorate and could potentially explode.


**Slide 20: Recovery / Refillable Cylinders**

Recovery cylinders are specifically designed to hold refrigerant that has been removed from refrigeration systems. The recovered refrigerant can then be re-used or sent for reclamation or disposal. The cylinder valve has an open refrigerant filling port so that refrigerant can be easily fed into the cylinder. It is important to ensure that the recovery cylinder is only used for one type of refrigerant. There are two reasons for this rule: first, if different refrigerants are mixed, it may not be possible to separate them again for re-use, and second, mixing two or more refrigerants can result in a higher pressure than either of the refrigerants, creating a potentially dangerous situation.

Refillable cylinders are available in every country in a variety of sizes. They are used to transport new refrigerant from one site to another.

The following guidelines must be followed by technicians:

• Use only clean cylinders, free from oil, acid and moisture and other contaminants. Only certified cylinders should be used, and they should be checked visually before filling;

• Do not fill beyond 80% of the cylinder's rated capacity;

• Never mix different refrigerants or recover one refrigerant into a cylinder meant for another refrigerant;

• Always label the recovery cylinder with the refrigerant number and name, as well as the weight of the cylinder, the total weight, and the date; and

• Use only approved cylinders that are exclusively reserved for recovery.


**Slide 21: Cylinder Inspections and Re-testing**

Both the cylinder and the valve are usually subject to national regulations regarding their design, fabrication and testing. As previously discussed, keeping the various refrigerants from escaping into the environment is a serious concern. Although the interior of these cylinders must be void of moisture, it is impossible to keep moisture away from the exterior. Corrosion can and does occur, as well as mechanical damage due to mishandling.

These are a few of the reasons why cylinders must be inspected and re-tested at regular intervals. The required intervals differ by country, but the date for the next inspection or testing is usually indicated on the cylinder. Once the cylinder has reached its expiry date, it should cylinder be returned to the refrigerant supplier. Similarly, the valves should be periodically examined, especially the relief valve. Check to be sure that nothing is obstructing the relief valve and that no visual deterioration or damage has occurred. If any damage is visible, empty the cylinder and have the tank repaired. Never use a cylinder with a faulty pressure-relief valve or with obvious structural impairments.

http://www.asme.org/about-asme

## Evaluation Questions

1. Is it necessary to recover HFC refrigerants for environmental reasons?
2. Can you make a recovery unit without a condenser?
3. What are the components required to make a basic recovery unit?
4. What is the maximum capacity of the recovery cylinder? How much recovered refrigerant should be stored in it?
5. What is the difference between recovery, recycling and reclamation?
6. Can the same recovery machine be used for different refrigerants?


AIR

# 11. ECONOMICS OF REFRIGERANT RECLAMATION AND BEST SERVICE PRACTICES

**Training Material Reference:** Economics of Refrigerant Reclamation and Best Service Practices - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
To show trainees how recovered refrigerant can be purified to the extent that it is almost the equivalent of virgin refrigerant, and then reused. Purifying and reusing recovered refrigerant helps lower costs to consumers and benefits the global environment.

**Final Performance Objectives**
At the end of the session, participants should know
a) How recovered refrigerant can be purified to almost the equivalent of virgin refrigerant
b) How to change refrigerants in a reclamation machine
c) How refrigerant recovery can help the technician save money
d) How best service practices can reduce breakdown time and increase profits

**Key Message Delivered in this Session:**
At a reclamation centre, technicians can either dispose of recovered refrigerant, or have it purified for reuse. Recovering refrigerant both helps reduce GHG emissions and save technicians money. Technicians need to adopt the habit of recovering refrigerant instead of throwing it away. Small reclamation centres have been set up by different projects under the Montreal Protocol in many developing countries. These centres can be operated by a qualified technician.

**Tools and Equipment Required for the Session:**
If there is a mini-reclamation centre is in the institution providing the training, then it must be used for the demonstration.


**Slide 1: Economics of Refrigerant Reclamation and Best Service Practices**

The trainer can give an overview of how refrigerant recovery can boost business while also helping to save the environment. An all-in-one machine, called a mini-reclamation centre, is currently available in many developing countries. Good servicing practices lead to customer satisfaction, increased profits for technicians and cost savings for customer.


**Slide 2: What is Reclamation?**

Reclamation means processing used refrigerant to new product specification, using a variety of methods, including distillation. Chemical analysis of the refrigerant is required to determine if appropriate product specifications have been met.

Reclaiming usually requires processes available only at a manufacturing facility and involves expensive equipment. Mini-reclamation centres offer an inexpensive way of reclaiming small quantities of refrigerant (i.e., 84 kg per hour).




**Slide 3-8: Components of a Mini-Reclamation Centre**

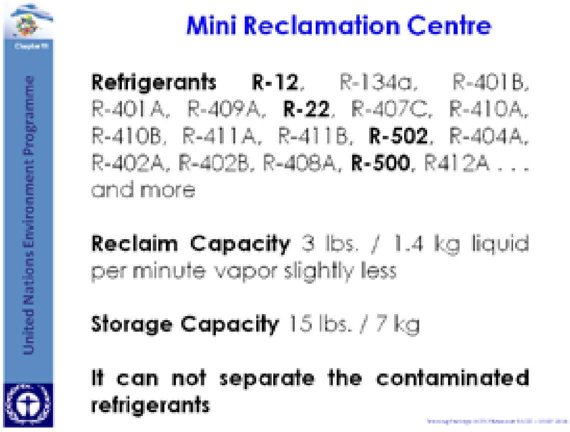
The pictures in these six slides show the components of a mini-reclamation centre, including an oil separator, a chill chamber and a suction line accumulator. The trainer must explain how this machine works:

1. The centre can process refrigerant in EITHER vapour or liquid form.
2. The centre creates high temperatures and centrifuges the refrigerant at high velocity using the heat of the compressor and its discharge.
3. The refrigerant then enters a large separation chamber where velocity is reduced to near zero. During this phase, copper chips, carbon, oil, acid, water and all other contaminants drop to the bottom of the chamber where they can be removed during the “oil out” operation (This process also allows you to accurately determine the amount of oil removed from a reclaimed system since all of it remains in the bottom of the separation chamber).
4. At high temperature, the distilled refrigerant vaporises and passes from the separation chamber to the compressor, then to the tube heat exchanger, then to the air-cooled condenser where it is converted to liquid.
5. The liquid passes into the on-board storage chamber. Within this chamber, an evaporator assembly, including thermal expansion valves that correspond to the type of refrigerant, sub-cools the liquid. Depending on several variables, the liquid is sub-cooled to 20 to 40°F (-6.7 to 4.4°C) during the chill operation.
6. A pair of replaceable filter/driers in this circuit removes any remaining moisture while finalizing the cleaning process.
7. Chilling the refrigerant also facilitates transferring refrigerant to external cylinders or systems at ambient temperature.


Mini Reclamation Centre
United Nations Environment Programme

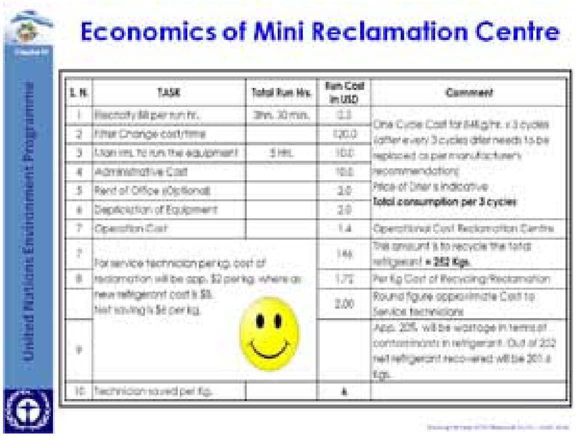

Mini Reclamation Centre
United Nations Environment Programme


Mini Reclamation Centre
United Nations Environment Programme
Air out port controlled
by Solenoid Valve
Pressure sensing device
and feedback to
Reclamation centre




**Slide 9: Mini-Reclamation Centre**

This mini-reclamation centre can reclaim refrigerants like R-12, R-134a, R-401B, R-401A, R-409A, R-22, R-407C, R-410A, R-410B, R-411A, R-411B, R-502, R-404A, R-402A, R-402B, R-408A, R-500, R412A, and many others. Volume is different for various models, but in general, mini-reclamation centres reclaim about 3 lbs (1.4 kg) of liquid per minute, although with vapour input, the quantity may be less. The machine's storage capacity is 3 to 7 kg, depending upon the model. While it can reclaim contaminated refrigerant, the machine cannot separate two or more mixed refrigerants.




**Slide 10: Economics of Mini-Reclamation Centres**

If the total cost of reclaiming one kilogram of refrigerant is compared to the price of one kilogram of new refrigerant, it becomes clear that reclaiming saves the technician a lot of money. This calculation is made on the basis of three cycles, for a total of 252 reclaimed kg (84 kgs per cycle). When calculating cost, it is important to keep the following factors in mind:

a) The electricity used to run the centre for three hours and thirty minutes;

b) After every three cycles (almost 252 kg of purified refrigerant), the filter/drier needs to be changed.

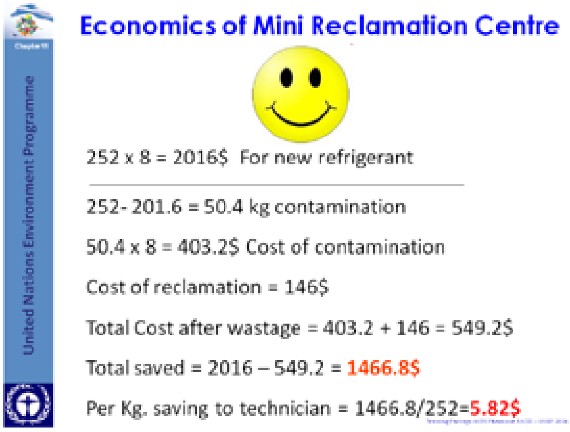
c) The cost of an employee to run the mini-reclamation centre machine;

d) Office rental, office management and other administrative costs;

e) Depreciation cost of the equipment

f) Reclamation centre profits

Based on the above, the total cost for reclaiming 252 kgs is $145, and the cost of reclamation per kg is 145/252 = $0.58. While the input of refrigerant is 252 kgs, the outcome is 15 to 20% less. This is due to the presence of contaminants like chips, oil and air in the refrigerant. Hence, the actual outcome of pure refrigerant will be 252 – 50.4 (20%) = 201.6 kilograms. Thus, in order to calculate the saving per kilogram, you subtract the cost of reclamation plus profits from the cost of virgin refrigerant.




**Slide 11: Economics of Mini-Reclamation Centres**
Now let us compute the savings from this process, assuming that the price of virgin refrigerant is about $8 per kilogram*. If one buys 252 kilograms of virgin refrigerant, the total is 252 x $8 = $2,016. We would then calculate the cost of contamination, which is 50.4 kgs x $8 = $403.20 (the cost of buying virgin refrigerant to compensate the amount of contamination) plus a reclamation fee of about $145. The total cost after wastage is $403.2 + $145 = $548.2. Therefore, the net saving is of $2,016 – 548.2 = $1,467.8. Per kilogram, the saving is $1,467.8 / 252 kilograms. = $5.82. When technicians vent refrigerant out into the air instead of recovering it, this savings is lost and the dispersed refrigerant contributes to ozone layer depletion and climate change.
The simple economic message is this: reclamation saves money and protects the environment.

**The cost of refrigerant will vary in different countries and figures should be recalculated accordingly.*


**Slide 12: Economics of Good Service Practices**

Here, the trainer should explain that good servicing practices allow the technician to save and earn more money. When a technician works on a machine that requires refrigerant, and that machine is sent back due to minor leakage, the technician usually only calculates the cost of the refrigerant needed to re-charge the system. These slides show what else the technician is going to lose.


**Slide 13: Economics of Good Servicing Practice**

Here, the trainer will explain the effects of bad servicing practices.

Usually, when repairing a machine under warranty, technicians only calculate the cost of re-charging refrigerant. However, this is not the only cost to consider. Other related costs include:

• The amount of time the technician spends repairing the machine, which could have been spent working on other jobs and earning money;

• The cost of the refrigerant;

• The cost of the electricity used to repair the machine;

• Damage to the technician's reputation for not delivering quality work; and

• Environmental damage due to poor skills or poor workmanship.

This is why it is always better to use proper tools, proper raw materials and pure refrigerants. Technicians who do can save almost 20% in raw materials, fuel and man power hours.


**Slide 14: We Only Live Once, So Protect Your Life by Protecting the Environment**

The trainer gives a summary and closing message, highlighting the need for technicians to identify their bad servicing practices and replace them with good practices – not releasing refrigerants into the atmosphere and recovering them for reuse, recycling or reclamation.

## Evaluation Questions

1. What is “reclamation”?
2. Why is reclamation necessary?
3. Describe how technicians can save money through reclamation of refrigerants.
4. What are potential implications of not following good practices in servicing?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# 12. CONTAMINATED REFRIGERANT AND REFRIGERANT IDENTIFIER

**Training Material Reference:** Contaminated Refrigerant and Refrigerant Identifier – 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

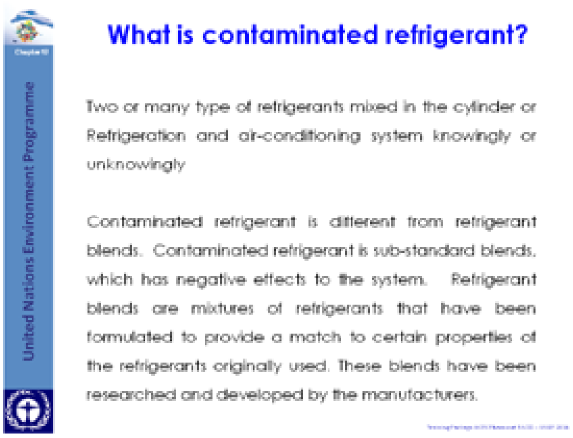
**Purpose of the Session**
To make trainees aware of the problem of contaminated refrigerants. Refrigerants that are not 100% pure are currently rampant on the market. Technicians must be very careful when buying new refrigerants, using a refrigerant gas identifier to make sure that they are purchasing a quality product.

**Final Performance Objectives**
At the end of the session, participants should know
a) What is a contaminated or fake refrigerant?
b) How does contaminated refrigerant affect the system?
c) Trends in counterfeit refrigerants across the globe
d) How a refrigerant identifier works

**Key Message Delivered in this Session:**
Fake refrigerants are a threat to a technician's business. Technicians must keep records of refrigerants purchased, and monitor their performance. Contaminated refrigerants cause accidents. In some cases, contaminated refrigerants have caused the death of technicians. When in doubt, technicians can do different kinds of tests to assess the purity of the refrigerant. He can also ask the seller to verify purity using a refrigerant identifier.

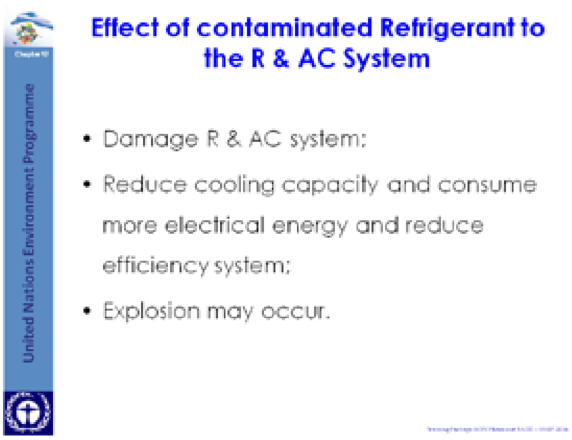
**Tools and Equipment Required for the Session:**
Refrigerant gas identifier.


**Slide 1: Contaminated Refrigerant and Refrigerant Identifier:**
While showing the cover slide, the trainer can give an overview of this topic.




**Slide 2: What is Contaminated Refrigerant?**
A refrigerant is contaminated when two or more types of refrigerants are mixed together, either in a cylinder or a refrigeration and air-conditioning system, with or without the knowledge of the product manufacturer.

Contaminated refrigerant is different from refrigerant blends. Contaminated refrigerant is a sub-standard blend that has negative effects on the system. Refrigerant blends are mixtures of refrigerants that have been researched and formulated by manufacturers to provide a match to certain properties of the original refrigerants. These blends have been researched and developed by the manufacturers.




**Slide 3: Effect of Contaminated Refrigerant to the RAC System:**
When the refrigerant is contaminated it will work at different temperatures and pressures than the pure refrigerant. The difference can damage the system, which is calibrated for use with pure refrigerant. The presence of contaminants reduces the system's cooling capacity and consequently, the system will consume more energy. Moreover, with flammable refrigerants, if the contamination level is high, it raises the chances of an explosion.


**Slide 4: Case of Counterfeit Refrigerant**
Contaminated refrigerants are widespread on the market. Often, the dealers or sellers themselves are not aware that they are selling fake refrigerants, as they also buy on the local market. The common composition of fake R-134a refrigerant is 60% of R-22 (Monochlorodiflouromethane) $CHClF_2$ and 40% of R-40 (methyl chloride). The fake product, which is sold in standard cylinders of 13.6 kgs, cannot be identified by the label, collar, or colour. For this reason, technicians should only buy refrigerant from authorised outlets, and should always ask for a receipt.


**Slide 5: Reefer Container Case in Vietnam**

The following three slides present real cases of contaminated refrigerants in different parts of the globe.

The slides show an accident caused by fake refrigerants in two different places in Viet Nam. The machinery was severely damaged and the technicians died on the spot.


**Slide 6: Case in North America**

This case happened in North America. The engineer found that the gas combusted upon contact with air and concluded that it must be alkyl metal halide. Ultimately, he succeeded in collecting a test sample to send a laboratory.


**Slide 7: Case in South America**

This case happened in South America. There was a catastrophic explosion during maintenance, and a large volume of sludge was found after the explosion. The residues were white powder and alumina smoke.


**Slide 8: Fake Refrigerant Cylinders**

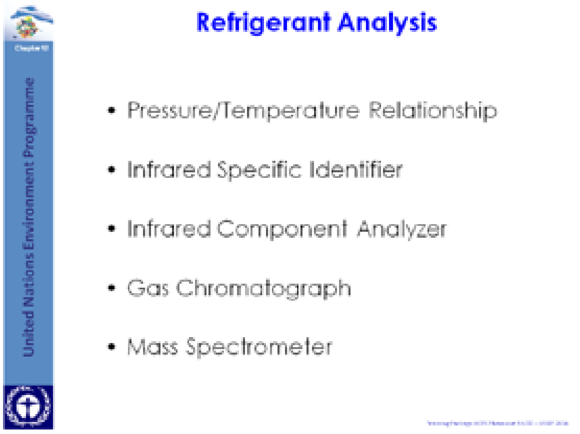
This slide show cylinders containing contaminated refrigerants. The label on the cylinder indicates a particular refrigerant but the contents are different from the label. If these contaminated refrigerants were charged into a system, they could damage the whole system and cause accidents.


**Slide 9: Reasons that R-40 Mixtures are on the Market?**

R-40 is commonly found in fake refrigerants. There are two reasons for this:

a) The rapid increase in the price of HFCs and the cheaper cost of R-40; and

b) The excessive quantity of HCFCs in the market, which can be mixed with R-40 to decrease refrigerant cost.

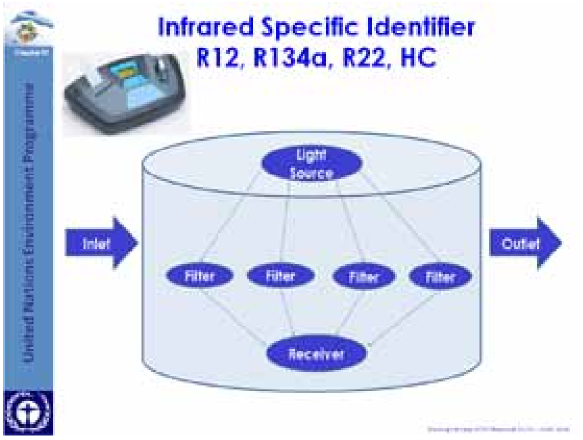



**Slide 10: Refrigerant Analysis**

There are many ways of identifying refrigerants, such as examining the pressure and temperature relationship, or using an infrared specific identifier. For example, to analyse R-22, you compare cylinder pressure and ambient temperature with a common chart. If the levels are higher than those specified in chart, you can use another test to determine the quality of refrigerant.

When the automotive industry replaced CFC-12 with HFC-134a, there was great concern about mixed or contaminated refrigerants, and technicians began to use infrared specific identifiers and infrared component analyzers to check refrigerant purity. This type of technology has advanced greatly over the past 17 years, and is still used today.

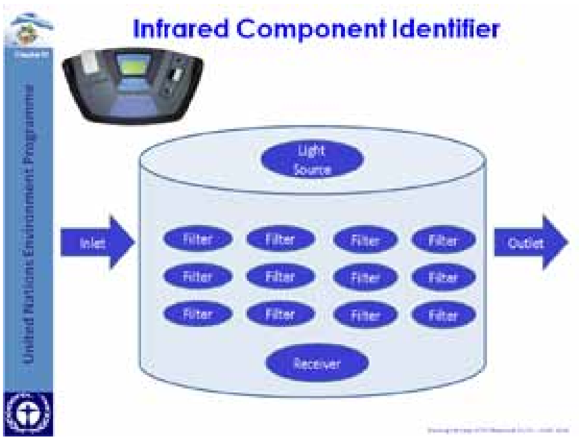
Gas chromatographs and mass spectrometers are high-end laboratory instruments with high accuracy, high cost and limited availability.




**Slide 11: Infrared Specific Identifier R-12, R-134A, R-22, HC**

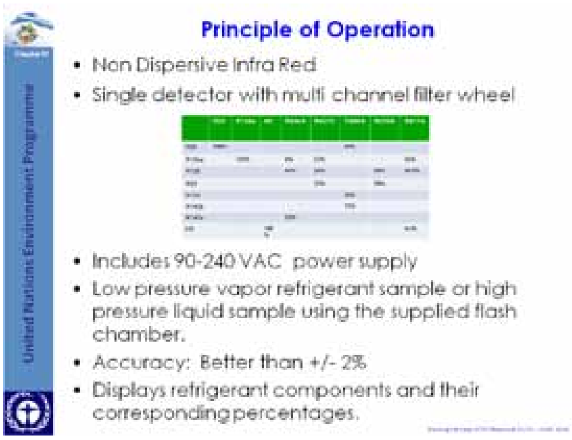
A refrigerant Identifier is a portable electronic device that allows reliable identification or detection of a percentage composition of CFCs, HCFCs, HFCs, hydrocarbons (HC) and air.

Single substance identification and infrared technology is used to check the refrigerant. Each identifier has four filters specifically optimised for detection of the desired refrigerant. An infrared specific identifier has a filter wavelength of between 2 and 30 microns and can detect R-12, R-134A, R-22 and HC. Vapour refrigerant is passed through the infrared bench and a known value light source is turned on. The light passes through the vapour and through the filters to a receiver. By measuring the amount of energy at the receiver, the refrigerant concentrations for each measured refrigerant is interpreted and displayed.




**Slide 12: Infrared Component Identifier**

A new refrigerant analyser has been developed to address the problem of multi-component refrigerants. This new analyser technology shares the same external physical characteristics and infrared operating principle as its predecessor, however that is where the similarities end. By increasing the number of filters to twelve and tuning each filter to measure a different component of the ODS sample, the new model has the potential to accurately identify some twenty-five common refrigerants with +/- 1% accuracy. In addition, the software can be updated by the user anywhere in the world if new refrigerants emerge or improvements are made.




**Slide 13: Principle of Operation**

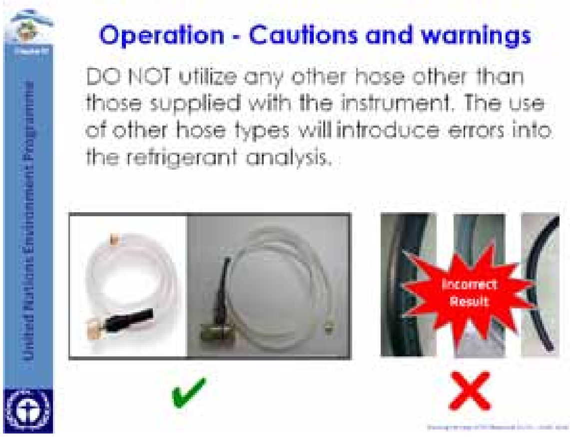
A refrigerant identifier identifies various refrigerants. There are two types of models: one for pure refrigerants and one for both pure and blended refrigerants. Refrigerant identifiers can identify refrigerants such as R-12, R-134A, HC, R-22, R-407, R-404, R-410 and many more, using the principle of non-dispersive infrared. Newer models have a single detector with a multi-channel filter wheel for testing blends. Earlier models use only low pressure vapour refrigerant samples. In the newer models, one can use either low-pressure vapour refrigerant samples or high-pressure liquid samples in the flash chamber. The refrigerant components and their corresponding percentages are displayed on a LCD screen.


**Slide 14: Operation - Caution**

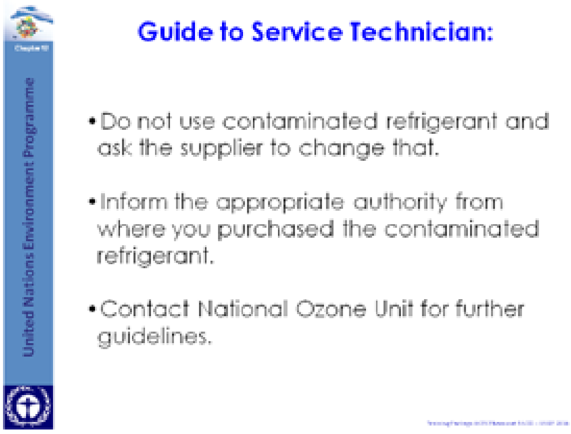
When using the identifier, never obstruct the instrument's air intake and sample exhaust port. Otherwise, the results will be inaccurate and the instrument may be damaged.


**Slide 15: Operation - Cautions**

Always make sure that you do not open the valve and pour liquid refrigerants directly into the instrument. Use VAPOR SAMPLES ONLY! The refrigerant must not contain excess amounts of oil. If so, the instrument can be damaged and will provide inaccurate results. Although the newer model can take high pressure liquid samples, it is essential to use the supplied flash chamber to transform the sample from liquid to vapour before pouring into the instrument.




**Slide 16: Operation - Caution**
DO NOT utilise any other hoses than those supplied with the instrument. The use of other hose types will introduce errors into the refrigerant analysis. The flow and the quantity of refrigerant will be in excess of the recommended amount, which can produce inaccurate results.




**Slide 17: Guide for service technicians**

Once technicians find that the refrigerants they have are contaminated, they must NOT use them. Instead, ask the supplier to replace them. They must also inform the appropriate authority in their country, and contact the National Ozone Unit (NOU) for further guidelines.

## Evaluation Questions

1. What are contaminated refrigerants?
2. What are the effects of contaminated refrigerants on the machine?
3. What are the various methods to check purity of refrigerants?

# 13. SELECTION AND SAFE USAGE OF CLEANING SOLVENTS

**Training Material Reference:** Selection and Safe Usage of Cleaning Solvents – 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

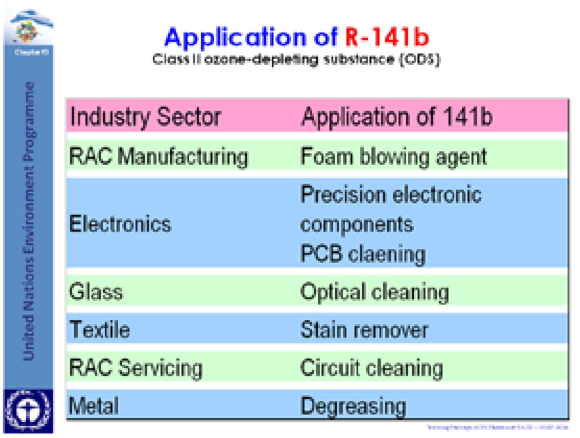
**Purpose of the Session**
To inform participants that R-141b is being phased out under the Montreal Protocol, like all HCFCs. At present, R-141b is used as cleaning and flushing agent. It is being replaced by ozone-friendly substances that are readily available. These are cost-efficient and equally effective in cleaning.

**Final Performance Objectives**
At the end of the session, participants should know
a) What are the uses and advantages of R-141b?
b) What are the reasons for sludge formation and the effects of contamination in air-conditioning systems?
c) What are the suitable alternatives to R-141b?
d) What are the good practices that technicians can adopt for using solvents?

**Key Message Delivered in this Session:**
Air conditioning systems sometimes need to be cleaned and flushed due to a major breakdown or poor servicing practices during maintenance. Alternatives to the cleaning solvent R-141b (an HCFC) are available, and this session will detail the properties of these alternative solvents. It is important to adopt good servicing practices when cleaning and flushing, like using oxygen-free dry nitrogen (OFDN) to flush and then vacuuming with a double-stage vacuum pump. Trainees must be made aware that when they purchase any solvent, they must read the Material Safety Data Sheet (MSDS) to safeguard their health.

**Tools and Equipment Required for the Session:**
A solvent bottle to show the colour of solvent and to explain the meaning of the different symbols on the bottle.

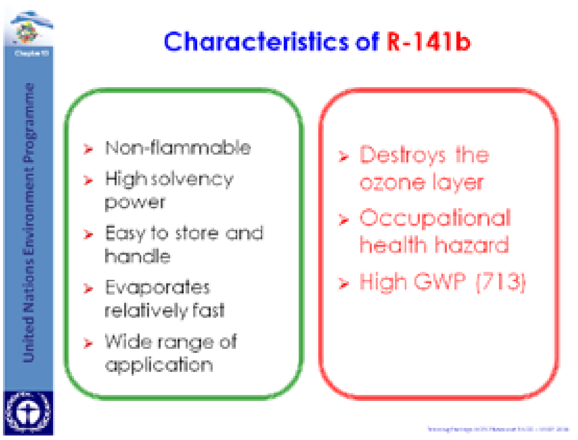

**Slide 1: Selection and Safe Usage of Cleaning Solvents:**
Solvents are chemicals that are used to dissolve or dilute other substances. In this case, we are talking about cleaning solvents used to dissolve dust particles and unwanted oils. Technicians must switch to environmentally-friendly solvents as soon as possible. Most importantly, technicians must know how to handle the solvent safely to prevent accidents.




| Industry Sector | Application of 141b |
|---|---|
| RAC Manufacturing | Foam blowing agent |
| Electronics | Precision electronic components<br>PCB claening |
| Glass | Optical cleaning |
| Textile | Stain remover |
| RAC Servicing | Circuit cleaning |
| Metal | Degreasing |

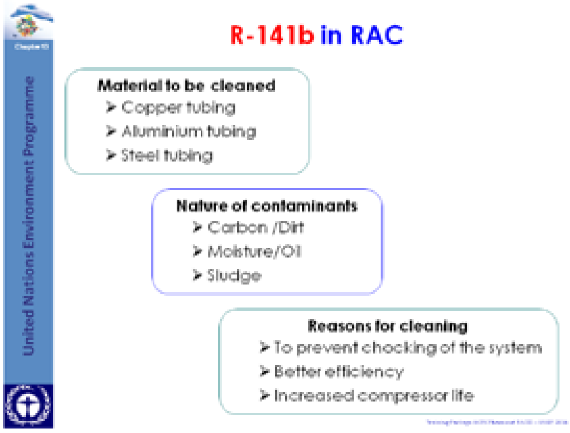
**Slide 2: Applications of R-141b**

R-141b is widely used in the RAC sector, as well as other sectors. It is used in the manufacturing sector as foam blowing agent, in electronics for cleaning precision components and printed circuit boards, in glass for optical cleaning and in the RAC service sector for circuit cleaning.




**Slide 3: Characteristics of R-141b**

Technicians prefer this solvent for cleaning because it is non-flammable and it has a high solvency power. (The capacity of a substance, usually a liquid, to disolve another substance is known as solvency power). R-141b evaporates relatively very fast (boiling point 32°C). However, R-141b is being phased out under the Montreal Protocol because it destroys the ozone layer. It also has a global warming potential (GWP) of 713. R-141b also poses occupational health hazards. In low concentrations, it may cause narcotic effects and in high concentrations, it may cause asphyxiation. Symptoms may include dizziness, headache, nausea and loss of coordination. Also, it may lead to irregular heart beats and can damage the nervous system.

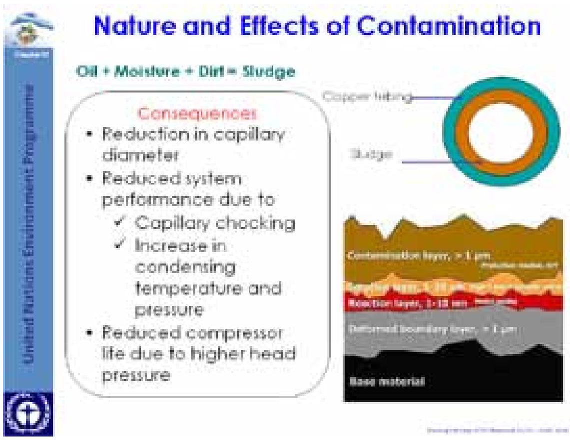



**Slide 4: R-141bin RAC**

Technicians often use R-141b to clean copper, aluminium and steel tubing, which collects carbon and dirt when there is oil and moisture in the RAC system. This dirt must be removed to prevent choking in the system. Choking can shorten the machine's life and limit its efficiency.

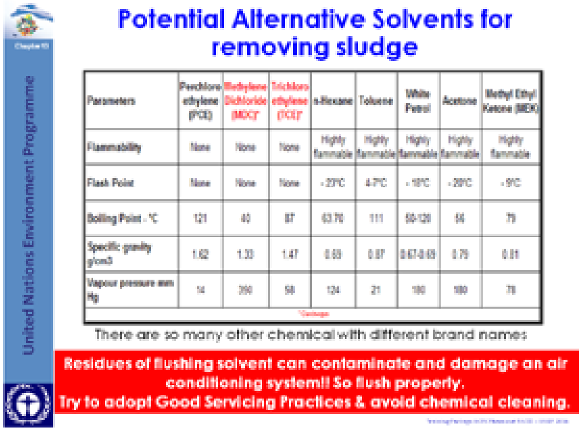

**Slide 5: Reasons for Sludge Formation**

Impurities and contaminants can enter a RAC system due to wrong practices and lack of knowledge. For example, when a technician uses air for flushing and leak testing, some contamination enters the system. Some technicians, on the other hand, use petrol for system cleaning, which ultimately leads to powder formation inside the system. Some technicians use the system compressor to do the vacuum and some use a compressor that has been removed or repaired for the same purpose. In addition, a few technicians charge the old, contaminated refrigerant, which leads to sludge formation. Sometimes, the compressor is seriously burnt out, which leads to the formation of a lot of sludge inside. The formation of sludge ultimately leads to equipment failure or a decrease in the machine's performance.




**Slide 6: Nature and Effects of Contamination**

When there is oil, moisture and dirt inside a tube, sludge forms and choking takes place. Choking reduces the diameter of the capillary from inside which ultimately leads to an increase in condensing pressure and temperature. Sometimes, a capillary chokes due to sludge. Due to higher head pressure, the life of the compressor also gets reduced. Technicians must adopt the proper methods to avoid contamination and further complications in the machine. This will increase the life and efficiency of the machine.



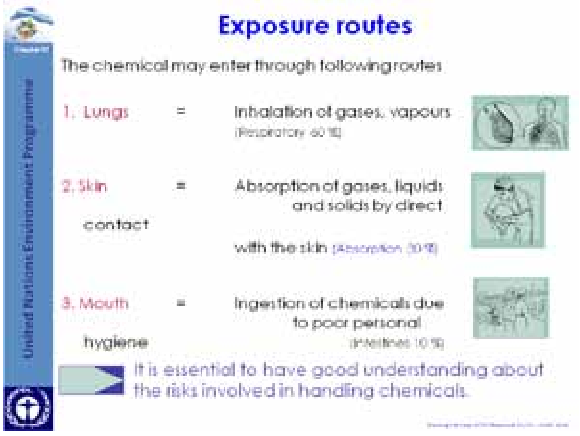

**Slide 7: Potential Alternative solvents to R-141b for Removing Sludge**

Using a set of five parameters including flammability, flash point, boiling point, specific gravity and vapour pressure, the table in the slide compares data on Perchloroethylene (PCE), Methylene Dichloride (MDC), Trichloroethylene (TCE), Hexane, Toulene, white petrol, acetone and Methyle Ethyle Ketone (MEK). All the solvents have their limitations, but TCE and MDC are carcinogenic in nature. Before using these solvents, one must read the Material Safety Data Sheet (MSDS).

Servicing technicians should adopt good servicing practices and avoid chemical cleaning.


**Slide 8: Recognizing Chemical Hazards**

First of all, a technician performing the task of RAC circuit cleaning must know the effects of the use of the solvent to the environment and health. The person using the solvent is at risk, since he inhales maximum vapours while performing his task. Direct contact with the solvent can cause serious health problems like itching and skin cancer (especially when used continuously without personal protective equipment (PPE)). As discussed earlier, no solvent is completely safe to human beings except water. Water is one of the best solvents but unfortunately cannot be used in RAC circuit cleaning. Technicians must use soap and water for hand-washing rather than solvent. To protect health and environment, technicians should minimise the use of cleaning solvents.




**Slide 9: Exposure Routes**

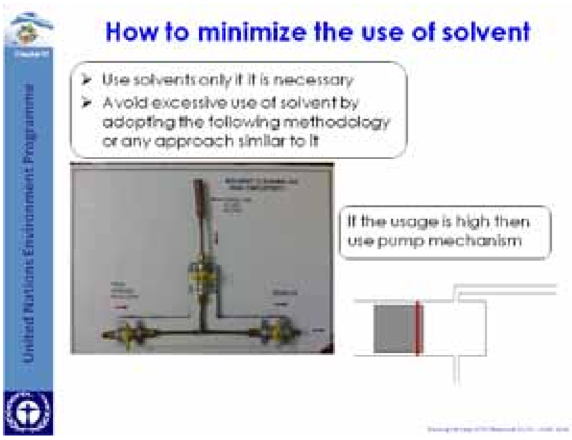
Technicians are exposed to solvents at the workplace that can enter the body through three major routes: inhalation, ingestion and dermal (lungs, digestive system and skin). If a technician eats, drinks or smokes at the workplace, he may be introducing hazardous chemicals into his digestive system because particles of solvent may coat and even enter the food or eating utensils. Solvent can even be absorbed through the eye, a vital organ. It is important to understand the risks involved in using solvents. When familiar with the risks, protective measures can be taken to minimise exposure.


**Slide 10: Current Practices**

Market surveys have shown that technicians use solvents in excessive quantities. Moreover, they use bad practices when using solvents to clean the RAC circuit. A lot of solvent is wasted when it is poured into the normal charging hose. This means a huge loss of money and increased health risks due to direct exposure with the solvent. It has been observed that technicians often have a very casual approach towards the usage of solvents. Most of them never ask for the Material Safety Data Sheet (MSDS) from the supplier of the solvent, which is why they are unable to read all the safety precautions. Training on the proper use of solvents is not very common.


**Slide 11: Follow Good Practices**

A technician's first and foremost task is to avoid or minimise the use of solvents by following good servicing practices. He must work in a well-ventilated area and must not inhale the solvent vapours. When using solvents, the technician must always wear personal protective equipment (PPE) to avoid inhalation or direct contact with the solvent. The appropriate cleaning method must be adopted. The next slide will show an example of how to safely use lesser quantities of solvent without direct contact. Whenever a technician uses solvents, he must wash his hands with water and soap, after finishing the job, and not with the solvent.




**Slide 12: How to Minimize the Use of Solvents**

The small circuits shown in the slide have been made in-house from available materials in the RAC technician's workshop. Any technician can make them at a very nominal cost. It is important to emphasise that technicians must use solvents only when necessary.

The following sequence shows how technicians can use this board for adding solvent into the system and flushing:

a) Open valve A

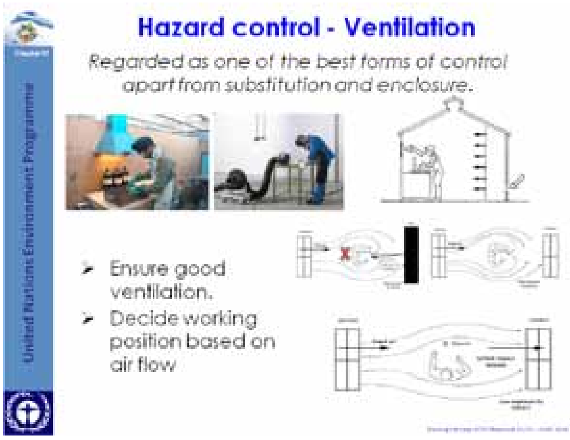
b) Pour in the solvent

c) Open valve B

d) Close valve A

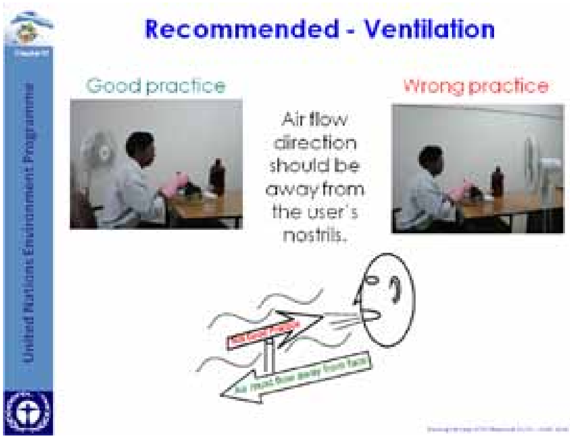
e) Open valve C

Technician may repeat the process, if required. If the process of cleaning is regular and continuous, then technician can make the pump arrangement with RAC circuit and re-circulate the solvent.




**Slide 13: Hazard Control - Ventilation**

This method can be adopted to remove dangerous solvent vapours from the workstation. The pictures in the slide clearly show the ideal flow of air in the workshop. When working with solvent, technicians must ensure good ventilation. If the workshop is not well-ventilated, it is necessary to install a chimney or hood to take in the vapours released after flushing.




**Slide 14: Recommended – Ventilation**

This slide shows good practice versus bad practice in ventilation. Technicians must never allow vapours to blow in his face. Electric fans should be placed in a location where the vapours will be pushed away from the technician.


**Slide 15: Protection (PPE)**

This very important slide addresses Personal Protective Equipment (PPE). Trainers must convince technicians that when using any solvent, they must always wear goggles, nose mask or face mask and hand gloves. The usage of PPE can save a person from lot of ailments acquired from using solvent. At this time, the trainer himself can demonstrate wearing the PPE. He must also explain that technicians must not feel ashamed when wearing the PPE. Instead, wearing the proper and complete PPE shows that the technician is serious about his health and job.

## Evaluation Questions

1. What is the reason and effects of sludge formation?
2. How can the technicians find information regarding the safe use of solvents?
3. What is the best air flow to avoid inhalation?
4. What is personal protective equipment?

# 14. MAXIMISING CLIMATE BENEFITS THROUGH THE SERVICING SECTOR

**Training Material Reference:** Maximising Climate Benefits through the Servicing Sector- 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
To explain to participants how they can help protect the environment by phasing-out HCFCs in the servicing sector.

**Final Performance Objectives**
At the end of session the participants should know the following:
1. How proper installation and good servicing practices can lead to energy savings
2. Why it is important to be careful during repair and servicing
3. What kind of recommendations to give to the customer

**Key Message Delivered in this Session:**
Good practices are an essential component of any HCFC Phase-out Management Plan (HPMP). It is important to realise, however, that they are more than simply helpful recommendations. Good practices are a vital link to HCFC phase-out:

- Good practices directly reduce HCFC consumption at the national level by reducing the need for new equipment and excess servicing, thus reducing HCFC refrigerant demand.
- Good practices reduce energy consumption by keeping refrigeration and air-conditioning (RAC) equipment energy-efficient. When equipment function optimally, it is energy-efficient and uses less electricity. This saves money and indirectly benefits the global climate.
- Good practices directly contribute to closing the hole in the ozone layer and mitigating of climate change by reducing damaging HCFC emissions.

**Tools and Equipment Required for the Session:**
None.


**Slide 1: Maximising Climate Benefits Through the Servicing Sector**

As an introduction, the trainer can explain that servicing RAC equipment presents many opportunities to help phase out HCFCs and fight climate change. The RAC service sector is vital to achieving HCFC phase-out because technicians help customers choose refrigerants, and thus can point them towards non-HCFC alternatives.


**Slide 2: Reducing Energy Consumption in RAC Systems Saves the World!!**

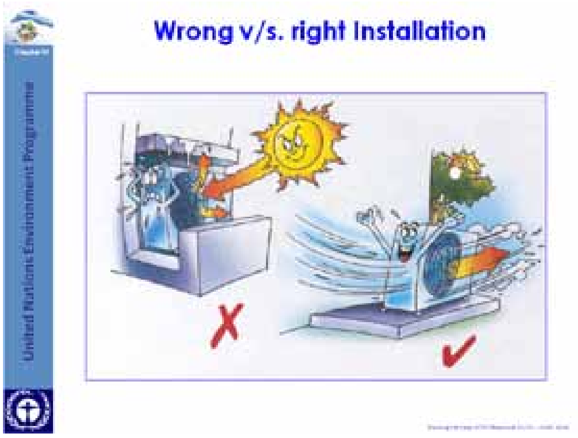
When technicians follow good servicing practices, they contribute to the protection of the ozone layer and reduction of greenhouse gas (GHG) emissions. By protecting the environment, technicians also protect the lives of future generations. Moreover, reduced energy consumption saves money.


**Slide 3: Being Careful Benefits the Climate**

Four servicing processes give technicians an opportunity to save energy: installation, repair, servicing and customer recommendations. If technicians follow good practices for all of these processes, the resulting energy savings can be huge.

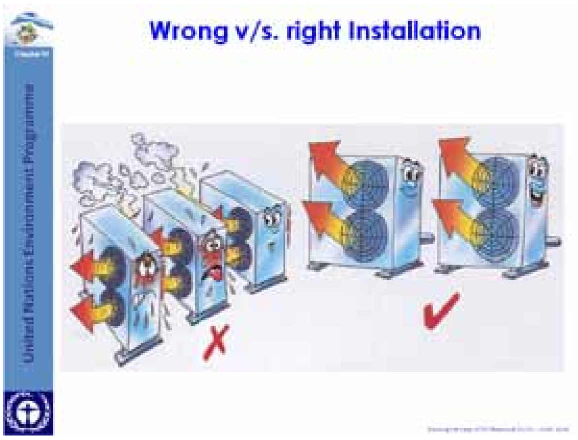

**Slide 4: Wrong v/s. Right Installation**
When a condensing unit is installed in such a way that it has restricted airflow, the unit will not function well and it will use more energy. There should always be a minimum of 200mm gap between the wall and condensing unit to ensure proper airflow.

In order to ensure optimum energy efficiency and condensation, the technician should make sure that there are no obstacles blocking the flow of air.




**Slide 5: Wrong v/s. Right Installation**
Condensing units should not be installed where they will receive direct sunlight, as this will cause poor condensation and lead to higher energy consumption.

The condensing unit should either be installed in a shaded area or a under a canopy of some sort that keeps it from getting too much sun.  This will ensure that the unit condenses properly and  is energy-efficient.

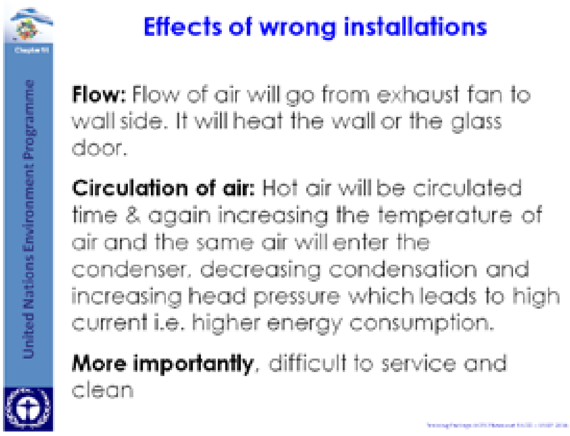



**Slide 6: Wrong v/s. Right Installation**
Putting condensers one behind the other leads to poor condensation and high head pressure, which makes the system consume more energy.

When fresh air is able to enter the condenser, the unit condenses efficiently and uses less energy.


**Slide 7: During Installation**

These photos show how technicians sometimes unnecessarily risk their lives, as well as the machine, when servicing. In the first two photos on the left, not only is the technician putting himself in a very dangerous position, but also the machine is poorly installed and could drop and break irreparably. The picture on the right, meanwhile, shows a haphazard piping installation that will cause a lot of vibration and ultimately, refrigerant leaks.




**Slide 8: Effects of Improper Installation**

Flow: If the airflow goes from the exhaust fan to a wall or glass door, it will heat that surface and contribute to heating the room instead of cooling it.

Circulation of air: If the air is not circulating properly, hot air will be circulated over and over, and the temperature of air will increase over time. The same air will enter the condenser, decreasing condensation and increasing head pressure, which leads to increased energy consumption.

More importantly, machines that are improperly installed are more difficult to service and clean.

Vibrations produced due to poorly installed or loose pipes can lead to frequent gas charging and servicing, which not only increases repair and maintenance costs for the customer, but also causes more refrigerant emissions, including ODSs and greenhouse gases.


**Slide 9: During Repair**

Using the system compressor to vacuum will not evacuate all non-condensable gases in the system.  This will lead to:

- High refrigerant charge
- High head pressure
- High current, which ultimately causes higher energy consumption

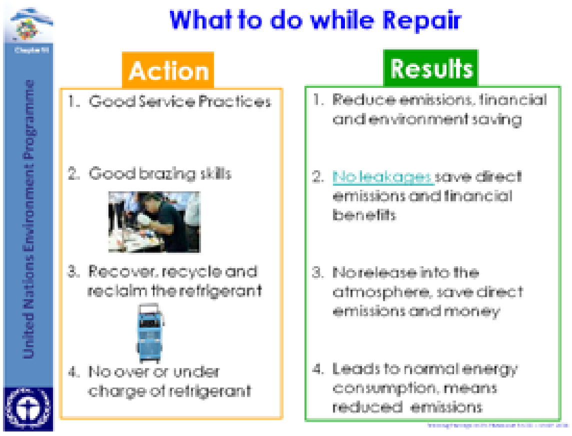
The machine must only be charged after the technician has ensured a proper vacuum. He must always use a two-stage vacuum pump to remove all non-condensable gases.  This will extend the life of the machine and encourange optimum performance.


**Slide 10: Result of Wrong Repairs**

Non-condensates left in the system can result in the following:

- High head pressure
- Reduced capacity and energy consumption
- The room will not be adequately cooled and user will be dissatisfied.

Technicians must follow Good Servicing Practices as discussed earlier.




**Slide11: What to do While Repairing**

This slide shows the proper practices and their results:

1. Good Service Practices will lead to reduced emissions, and financial and environment savings.

2. Good brazing skills will lead fewer leaks and hence, reduced refrigerant emissions and monetary savings.

3. Recovery, recycling and reclamation of refrigerants will help reduce refrigerant emissions and save money.

4. Not over- or under- charging refrigerants will lead to optimum energy consumption, which means energy savings and indirect climate benefits.

Find more info in: UNEP CAP *Fact Sheet 36: Maximising Climate Benefits of HCFC Phase-out in the Refrigeration Servicing Sector (2012)*

➪ *Run the animation on Section C.*


**Slide 12: Servicing Management**

If a technician manages to balance the airflow and reduce the condensing temperature, it can lead directly to energy saving.

Both proper design and proper servicing contribute to ensuring proper airflow.

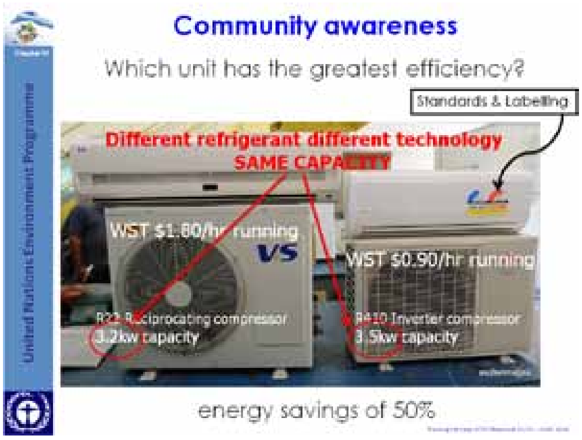

**Slide 13: No or Less Servicing**
This slide refers to a case study in India concerning a three-phase cold room compressor/cooling unit with an initial current of 2.4 amps. The photos show the dust accumulation in the condenser. If a technician does not regularly clean the condenser, dust accumulates, leading to higher energy consumption.

➪Run the video of dust from CD.


**Slide 14: No or Less Servicing**
This slide shows a photo of the same condenser after it has been serviced by a technician. The current has come down from 2.4 amps to 1.7 amps. Notice the cleanliness of the condenser coil. At the same time, the cooling coil was also serviced. A clean condenser reduces the running cost and leads to high efficiency.


**Slide 15: Good Maintenance Leads Net Exchequer Saving of US$ 6,458/year**
This is the mathematical calculation shown for the three-phase system. The cost of energy savings has been calculated by applying the three-phase power formula.

The results show that proper maintenance and regular servicing leads to monetary savings and reduced emissions.




**Slide 16: Community Awareness**

This slide shows two air conditioners of approximately same capacity, i.e. 3.2kw and 3.5kw. But there is a big difference in current and energy consumption. One unit uses almost half the amount of energy as the other. The unit on the right hand side consumes \$1.8/running and the other one consumes \$0.9/running. The difference is due to different technologies. Technicians must promote energy-efficient appliances that use less energy, and thus save signigicant indirect carbon emissions from thermal power plants.


**Slide 17: Community Awareness**

Many people set the air-conditioner temperature at 19°C and sleep with a blanket. However, it is better to set the temperature at 25°C.  Since the thermostat can vary ± 2°C, the nominal range will be between 23°C to 27°C, which should be quite comfortable at night. Setting the thermostat at 25°C will save a lot of energy and prolong the life of the air-conditioner.


**Slide 18: Best Investment: Training**

In this slide, the trainer must emphasise that training benefits technicians, and encourage the trainees to tell their fellow technicians about training courses. These training sessions will help their colleagues learn about best practices, which in turn will help them save money, protect their health, and will also indirectly benefit both themselves and their families by preserving the environment.


**Slide 19: Let Us Save Mother Earth**

This is the last slide of the training. The role of trainer is very important because it is his or her job to put the mindset of the trainees to the reality on the ground. The trainer has to emphasise the technicians' moral and social responsibility of protecting the environment by not releasing refrigerants and other chemicals into the atmosphere but by recovering and reusing them. At this point, the trainees should already be convinced that they must switch to natural or low-GWP refrigerants. This is the carry-home message to the technician and different methodologies may be adopted by the trainer to convey this message from "the brain to the heart" of the technicians.

## Evaluation Questions

1. What kinds of issues should a technician consider during installation?
2. In which direction should an air-conditioner be installed when the installation is near the seashore?
3. What are the key factors affecting a unit's energy efficiency?

# 15. EVACUATION AND CHARGING UNIT MAINTENANCE

**Training Material Reference:** Evacuation & Charging Unit - Maintenance - 2014.ppt

**Target Group:** Trainers and Technicians

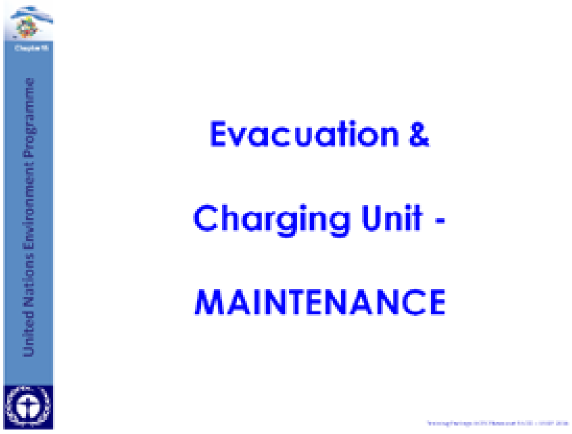
**Duration of the Session:** 30 minutes

**Purpose of the Session**
To teach trainers why it is necessary to maintain the evacuation and charging station, and how maintenance can extend the machine's life and enhance the image of the HCFC Phase-out Management Plan (HPMP). Trainers must be able to explain the importance of safety precautions when using the vacuum pump in chapter 4 "Servicing HCFC/HFC-based air-conditioners".

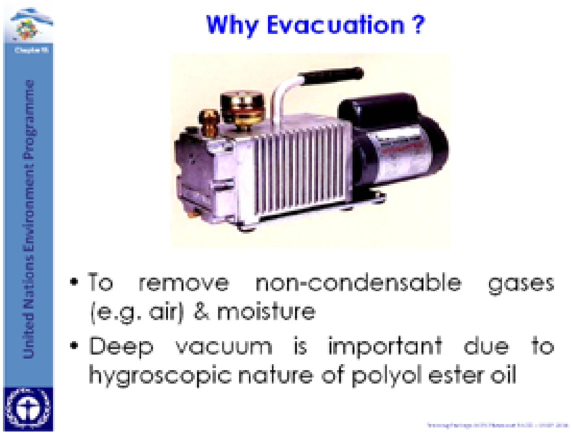
**Final Performance Objectives**
At the end of the session, participants should know
a) What is usual vacuum pump and charging station maintenance
b) How to maintain valves
c) What is usual pressure gauge maintenance
d) How to check the motor and pump

**Key Message Delivered in this Session:**
To clear the refrigeration system without non-condensable gases, you need a good vacuum pump. A vacuum pump will work perfectly only when the pump is regularly checked and maintained, including changing oil.

**Tools and Equipment Required for the Session:**
A vacuum pump.

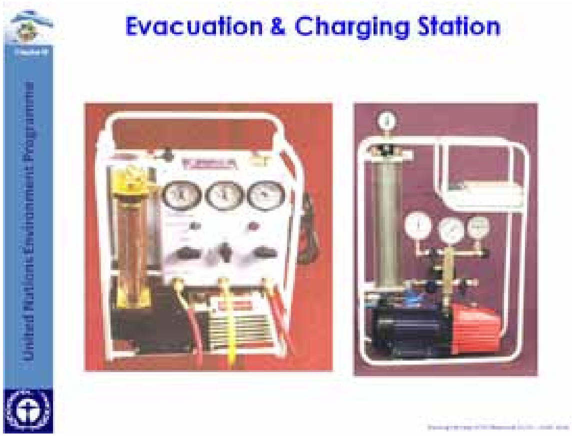



**Slide 1: Evacuation & Charging Unit - Maintenance**
The trainer must understand the importance of maintaining the evacuation and charging (E&C) station. If the E&C is not well maintained, the technician will not be able to achieve the desired vacuum.




**Slide 2: Why Evacuation?**

Evacuation is very important for removing non-condensable gases and moisture. HFC systems need a deep vacuum (500 microns or lower) because of the hygroscopic nature of polyolester oil. A deep vacuum requires a two-stage vacuum pump, capable of pulling vacuum between 20-50 microns at blank off.

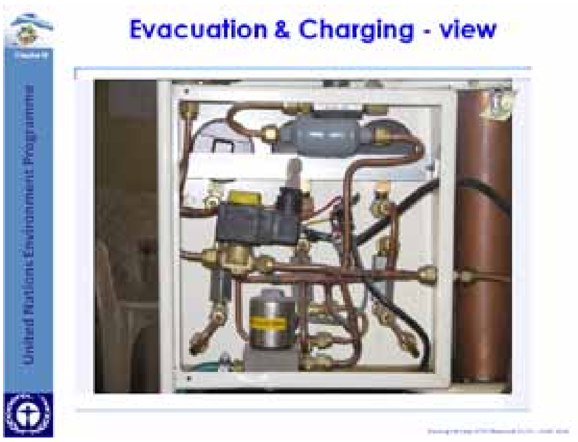



**Slide 3: Evacuation and charging station**

This slide shows different evacuation and charging stations available on the market.


**Slide 4: Evacuation and charging station**

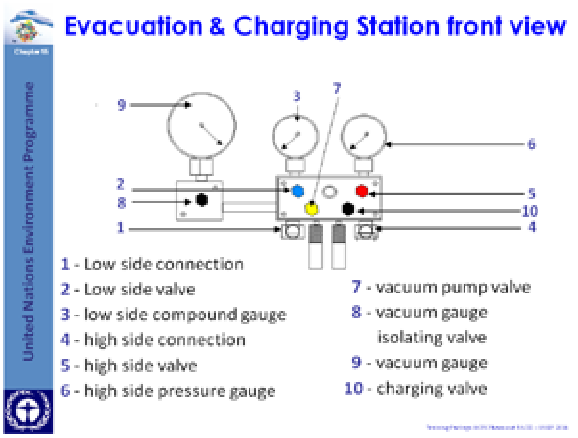
This slide also shows different evacuation and charging stations available on the market.




**Slide 5: Evacuation and Charging Station – view from behind**

This slide shows the back end of an evacuation and charging station. There are many flare joints and connectors that need to be checked regularly to ensure the proper level of vacuum. When there are traces of oil near flare fittings, the evacuation and charging station should be checked by filling the dry nitrogen pressure.

The filter drier is also visible. The filter drying should be changed as per the manufacturer's recommendations.



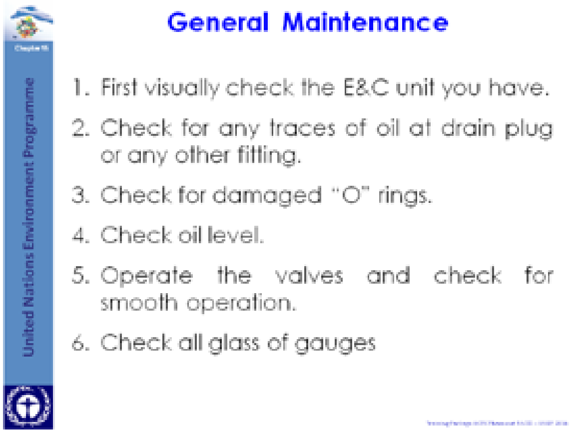

**Slide 6: Evacuation and Charging Station – front view**

This slide shows a four-way manifold. This kind of valve can be found in various configurations on the front panel of the evacuation and charging station. The maintenance of these kinds of arrangements will be discussed separately in the coming slides.


**Slide 7: Importance of Maintenance**

Every running machine has a life span. To increase the life span of an evacuation and charging station, technicians must first learn the importance of maintenance.

To achieve the optimum performance, technicians should follow the monthly check-up schedule or as recommended by the manufacturer. The trainer must understand that during the training, if all the equipments work well, the image of the HPMP project will be good. Any breakdown of the equipment can give a bad name to the HPMP project. Moreover, with regular maintenance schedule, technicians can increase the life of the equipment and can save both money and time.



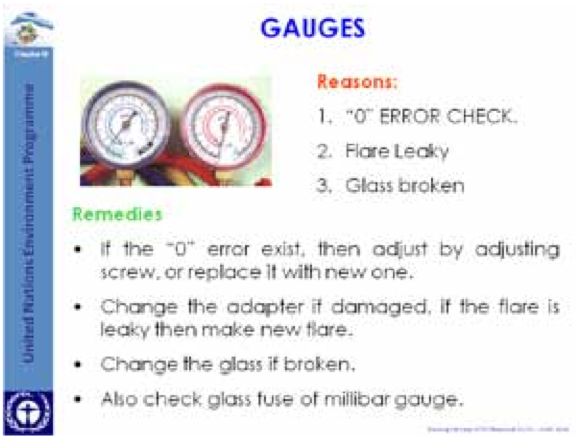

**Slide 8: General Maintenance**

This slide gives an insight into the general maintenance of the machine. Technicians can physically check the evacuation and charging station for any trace of oil on the vacuum pump cover, drain plug, etc. If the vacuum pump has been dismantled, the "O" rings must be changed. The oil level of the vacuum pump must always be checked before starting. Add oil if necessary, or reduce it if the level is too high. For smooth operation, open the hand shut off valve, if provided, at the suction port of the vacuum pump. If it tightens with a lot of pressure, then check the stem of valve and perform the required repair or replacement. Also, check if the glass of the gauges is dull or broken. If it is, replace the glass only.


**Slide 9: Valve's Maintenance**

This slide explains the reasons for valve maintenance. When the gland leaks, or there is leakage through valve seat, or the flare fitting is leaky, that means the valves need attention.

Trainers and Technicians can maintain the valves by cleaning, performing minor repairs, or changing the damaged "O" rings. If the seat is damaged, it is better to replace the valve or connector. If the spindle does not move freely inside, the spindle must be checked and if play exists, the spindle or complete valve must be replaced.

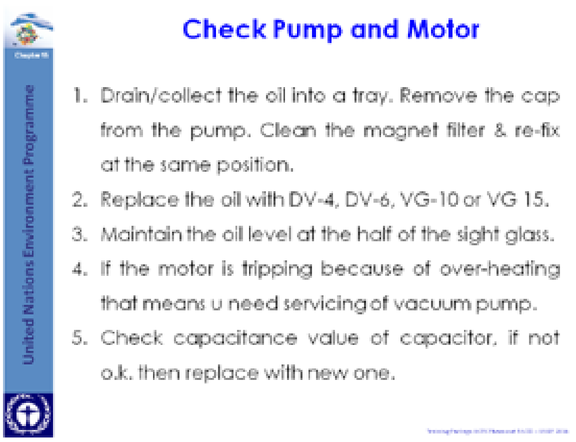



**Slide 10: Gauges**

This slide explains the reasons for checking for errors. The zero errors on gauge must always be checked for traces of oil on the gauge connector, and to see if the glass is broken. When there is gauge error, it is very important that the gauge needle is not removed, and that it is re-fixed to zero. The needle must be reset by rotating the screw clockwise or counter-clockwise. If traces of oil are present on gauge adapter, then the technician must and replace the adapter. If the glass of the gauge is broken, it must be replaced.


**Slide 11: Check Pump and the Motor**

Before starting any vacuum pump, technicians must check the oil level of the sight glass. If the oil has changed colour or has become dark brown, then the oil must be changed.




**Slide 12: Check Pump and the Motor**

The following guidelines must be followed when checking the pump and motor:

• Remove the cover of the vacuum pump only after the oil has been drained from it.

• Clean the magnetic filter and replace it in its original position.

• Replace the oil with recommended vacuum pump oil and NEVER use mineral or polyester oil as replacement.

• After replacing the oil, check to see if the pump runs properly.

• If while vacuuming the vacuum pump switches off, check the capacitance of the capacitor or the bush of the motor shaft. Replace bush or shaft if there are scratches on it. However, before removing shaft, drain the oil in new tray and keep it packed in an airtight container until it is poured back into the pump.


**Slide 13: Oil change in vacuum pump**

Trainers must follow the sequence below when changing vacuum pump oil:

a) Open the oil-in plug at the top and open the oil-out plug at bottom to collect the old oil in a drain tray.

b) Remove the cover of the vacuum pump and clean the magnetic filter.

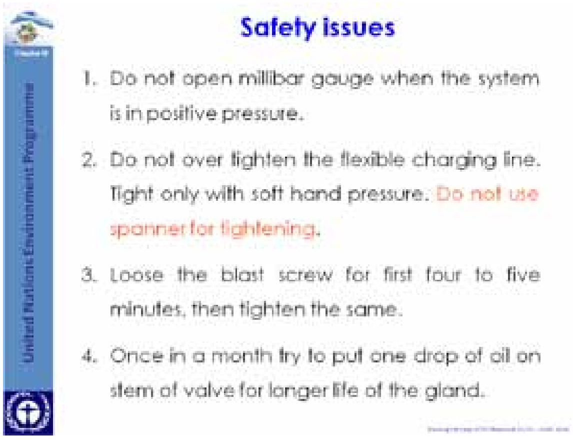
c) Refix the magnetic filter, then check the “O” ring between the wall of pump body and cover. If the new “O” ring is damaged or malformed due to heat, replace it.

d) Close the drain plug.

e) Pour the measured quantity of fresh oil as recommended by manufacturer via oil-in plug. Watch the oil level indicator.

f) Do not under charge or overfill the oil because it can lead to poor suction in the vacuum pump.

g) Always wear personal protective equipment during work.




**Slide 14: Safety Issues**

Important safety instructions have to be followed during the maintenance of equipment:

• Never open the valve of millibar gauge during the maintenance of vacuum pump as the pressure can damage the gauge.

• Never use a spanner while tightening the flexible hose pipe or charging line.

• When the vacuum pump is going to start, open the blast facility of the vacuum pump for four to five minutes. It will save the oil and make the pump run for a longer time without any major contamination.

# 16. RECOVERY MACHINE MAINTENANCE

**Training Material Reference:** Recovery Machine - Maintenance - 2014.ppt

**Target Group:** Trainers and Technicians

**Duration of the Session:** 30 minutes

**Purpose of the Session**
To explain to trainers why it is necessary to regularly maintain recovery machines and how maintenance can both extend the machine's life and enhance the image of the HCFC Phase-out Management Plan (HPMP). During Chapter 10, "Refrigerant Recovery, Recycling & Cylinders," trainers must be able to explain recovery machine maintenance during and after operation.

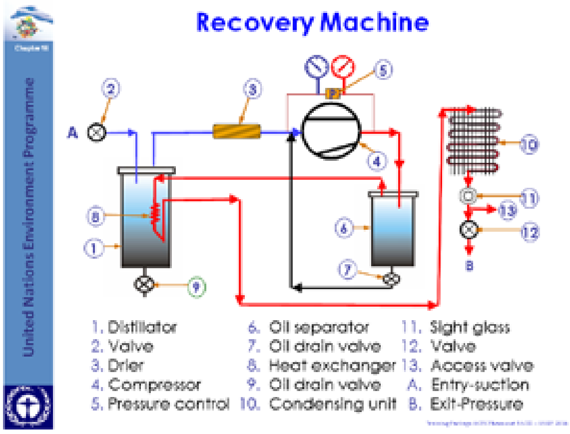
**Final Performance Objectives**
At the end of the session, participants should know
a) General maintenance of the recovery machine
b) How to maintain the valves
c) General maintenance of the pressure gauges

**Key Message Delivered in this Session:**
For complete recovery of refrigerant from a refrigeration system, a recovery machine in good working order is essential. The recovery machine will only work well when it is regularly checked and maintained by a qualified technician.

**Tools and Equipment Required for the Session:**
A recovery machine.


**Slide 1: Recovery Machine - Maintenance**

This is the title slide. What needs to be emphasised is what the word “maintenance” means. Maintenance can be preventive, scheduled or breakdown. The trainer or technician has to make sure that the recovery machine is working properly.




**Slide 2: Recovery Machine**

This slide shows the different components inside the recovery machine. One must keep in mind that recovery machines may have different designs, but the basic structure is the same.


**Slide 3: Recovery Machines**

Two kinds of recovery machines are shown in this slide. Guidelines for maintaining recovery machines are as follows:

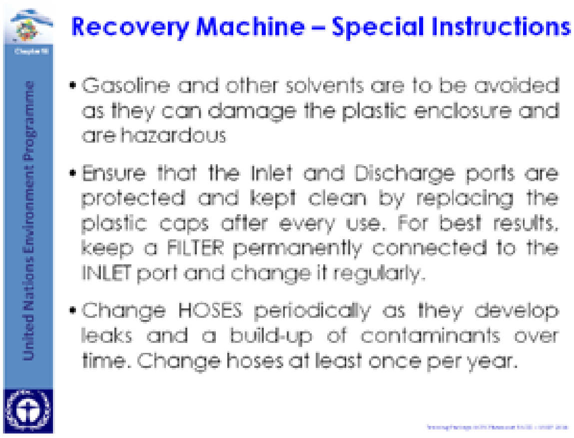
a) Clean the condenser regularly to avoid any dust accumulation.

b) Always keep the drier capped when not in use. However, after running the recovery operation 25 to 30 times, replace the input drier, as its absorption capacity may diminish.

c) Wash the internal filter screen at regular intervals to ensure that refrigerant suction is optimal.

d) Always check the zero error gauges. If these gauges need adjustment, rotate the screw clockwise or counter-clockwise. Never remove the needle. Refix the needle at zero.

e) Drain the oil from the oil separators regularly (if the machine has oil separators).




**Slide 4: Recovery Machines- Special Instructions**

There are special instructions that the trainer must follow when running maintenance on a recovery machine. They must remember the following:

• Gasoline and other solvents should be avoided as they can damage the plastic enclosure and are hazardous;

• The inlet and discharge ports must be protected and kept clean by replacing the plastic caps after every use. For best results, a FILTER must be kept permanently connected to the INLET port and changed regularly.

• HOSES must be changed periodically as they develop leaks and contaminant build-up over time. Hoses must be changed at least once every year.


**Slide 5: Recovery Machines- Special Instructions**

This slide is in continuation of the previous slide.

• When storing the recovery machine for long periods of time, the unit must be PURGED with an inert gas such as nitrogen.

• When performance falls off, it is likely that the compressor seals require replacing.

• Required replacement parts must be identified and kept in stock.


OZONE LAYER

# 17. SINGLE-STAGE VERSUS DOUBLE-STAGE NITROGEN PRESSURE REGULATOR AND MAINTENANCE

**Training Material Reference:** Single-Stage versus Double-Stage Nitrogen Pressure Regulator and Maintenance - 2014.ppt

**Target Group:** Trainers

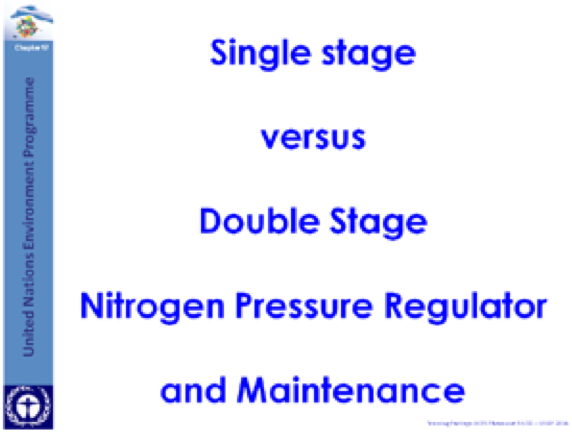
**Duration of the Session:** 30 minutes

**Purpose of the Session**
To ensure that trainers understand safety issues when working with high-pressure gases. In this session, trainers will learn the difference between the two types of nitrogen regulators and learn how to deliver this message to technicians.

**Final Performance Objectives**
At the end of the session, participants should know
a) The difference between single-stage and double-stage nitrogen pressure regulators
b) How to use a nitrogen regulator safely

**Key Message Delivered in this Session:**
In order to have a safe working environment, it is necessary to have good equipment. Single-stage nitrogen pressure regulators are not as safe as double-stage pressure regulators. It is important to stress to technicians that when changing an old nitrogen regulator, they should buy a double-stage regulator. Even though a single-stage regulator is cheaper, the double-stage is preferable due to its safety features.

**Tools and Equipment Required for the Session:**
Single-stage and double-stage nitrogen regulators




**Slide 1: Single-Stage versus Double-Stage Nitrogen Pressure Regulators and Maintenance**

The trainer gives an overview of the high-pressure nitrogen gas used to detect leakage. The trainer can also discuss the equipment to be purchased and the importance of maintaining that equipment. Choosing the right regulator for application is critical and often difficult. The required delivery pressure influences the selection of the regulator. Trainers must convince technicians that the regulator is a valuable tool that can make their working environment safer.

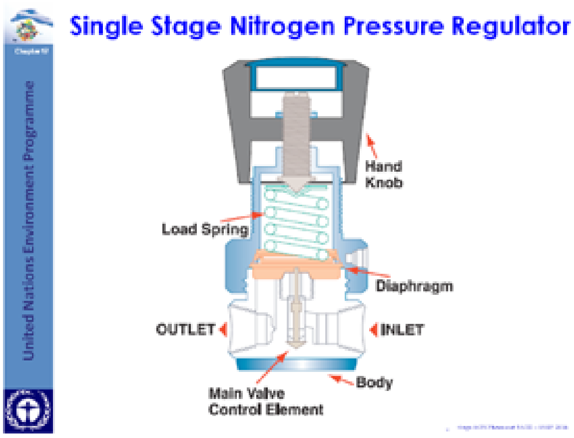

**Slide 2: Nitrogen Pressure Regulator**

There are three basic operating components in most regulators: a loading mechanism, a sensing element and a control element. These three components work together to produce pressure reduction.

The <u>Loading Mechanism</u> determines the setting of the regulator delivery pressure. Most regulators use a spring as the loading mechanism. When the regulator hand knob is turned, the spring is compressed. The force that is placed on the spring is communicated to the sensing element and the control element to achieve the outlet pressure.

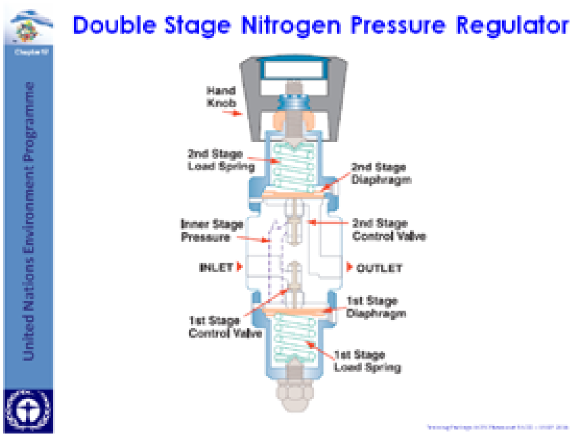
The Sensing Element senses the force placed on the spring to set the delivery pressure. Most regulators use a diaphragm as the sensing element. The diaphragms may be constructed of elastomers or metal. The sensing element communicates this change in force to the control element.

<u>The Control Element</u> is a valve that actually produces the reduction of inlet pressure to outlet pressure. When the regulator hand knob is turned, the spring (loading mechanism) is compressed. The spring displaces the diaphragm (sensing element). The diaphragm then pushes on the control element, causing it to move away from the regulator seat. The orifice becomes larger in order to provide the flow and pressure required.



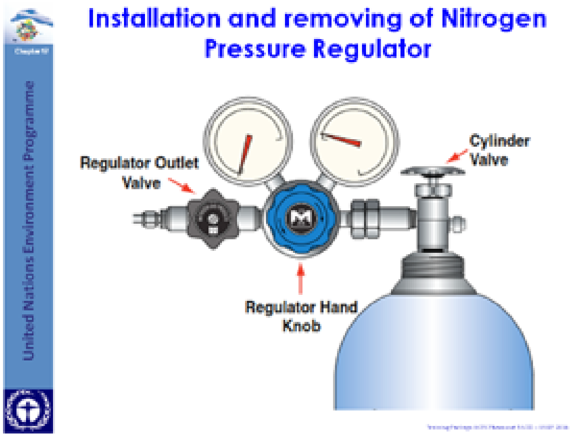

**Slide 3: Single-Stage Nitrogen Pressure Regulator**

Single Stage Regulators accomplish the pressure reduction in a single step. Delivery pressure cannot be as tightly controlled as with a double-stage regulator. Single-stage regulators should only be used where an operator can monitor and adjust pressure as needed, or where the regulator is supplied with a nearly constant source pressure.




**Slide 4: Double-Stage Nitrogen Pressure Regulator**

Double-Stage Regulators reduce the source pressure down to the desired delivery pressure in two steps. Each stage consists of a spring, diaphragm, and control valve. The first stage reduces the inlet pressure to about three times the maximum working pressure. The final pressure reduction occurs in the second stage. The advantage of a dual-stage regulator is its ability to deliver a constant pressure, even with a decrease in inlet pressure. For example, as a nitrogen cylinder of gas is depleted, the cylinder pressure drops. Under these conditions, single-stage regulators exhibit 'decaying inlet characteristic'; the delivery pressure increases as a result of the decrease in inlet pressure. In a double-stage regulator, the second stage compensates for this increase, providing a constant delivery pressure regardless of inlet pressure. The dual-stage regulator is recommended for applications such as gas supply to analytical instruments, where constant delivery pressure is critical.




**Slide 5: Installation and Removal of the Nitrogen Pressure Regulator(NPR)**

The guidelines below must be followed when installing and removing the NPR :

Installing:

1. Close the regulator by rotating the hand knob in a counter-clockwise direction.

2. Close the regulator outlet valve by rotating the valve knob in a clockwise direction.

3. Connect the regulator to the cylinder. The regulator should be attached to the cylinder without forcing the threads. If the inlet of the regulator does not fit the cylinder outlet, it is likely that the regulator is not intended for the gas service.

4. Slowly open the gas cylinder valve. Check the inlet pressure gauge to ensure that it registers the expected value.

5. Check all high-pressure connections for leaks using an approved soap solution or leak detection device.

6. Open the cylinder valve completely.

7. Adjust the regulator hand knob to raise the delivery pressure to the desired value. Do not exceed maximum delivery pressure indicated by the label on the regulator.

8. Open the outlet valve on the regulator to establish gas flow to the system. This valve is used to control the gas flow. The regulator itself should not be used as a flow controller by adjusting the pressure to obtain different flow rates. This practice defeats the purpose of the pressure regulator.

9. After flow is established, the set delivery pressure may decrease slightly. Check to see that the delivery pressure correct and make any necessary adjustments.

Removing:

For temporary shutdown (less than 30-minute duration), simply close the regulator outlet valve. For extended shutdown (beyond 30-minute duration), follow these steps:

1. Shut off the gas cylinder valve completely.

2. Shut down any additional gas supplies that may be supplying gas to the system.

3. Open the regulator and the outlet valve to drain the contents of the regulator through the system in use. Both regulator gauges should descend to zero.

4. When using a toxic or other hazardous gas, purge the regulator and system with an inert gas.

5. Close the regulator by rotating the hand knob counter clockwise. Close the outlet valve by rotating the valve knob clockwise.


**Slide 6: Safe Usage of Nitrogen Pressure Regulator**

The following guidelines must be remembered for safe use of the regulator:

• Before a regulator is removed from a cylinder, fully close the cylinder valve and release all gas from the regulator.
• Never interchange regulators, hoses, or other equipment with similar equipment intended for use with other gases.
• Pressure regulators and related fittings should never be handled with oily or greasy hands or gloves.
• Never hold hand over the outlet(s) to test for the presence of pressure.
• Do not stand in front of a regulator outlet when opening the cylinder valve in case foreign particles are present.
• Secure cylinders to wall, stand, or cart in accordance with local fire codes.
• The regulator is equipped with an internal safety, which is designed to protect the regulator.


**Slide 7: Safe Usage of Nitrogen Pressure Regulator**

• Do not use oil or grease on nitrogen regulators, cylinders, valves or other related equipment.

• Do not use or store nitrogen equipment near excessive heat (>125 °F or 51.5 °C) or open flame.

• CAUTION: Do not use organic-based threaded sealants on any portion of the regulator. Use only Teflon threaded – sealing tape or nitrogen service thread compound.

• Never leave pressurised nitrogen within a regulator. Always purge residual gases when not in use.

• The regulator must NOT be twisted or turned when it is tight on the cylinder valve and/or under pressure to prevent tip seal, or face washer abrasion.

• Never permit nitrogen to enter a regulator suddenly. Always open the cylinder valve slowly


**Slide 8: Safe usage of Nitrogen Pressure Regulator**

Flushing A/C System or Individual Components Using Nitrogen:

SAFETY PRECAUTION — When using an aluminium solvent flushing canister with nitrogen as the propellant for the solvent, DO NOT let the regulated pressure exceed 1000 kPa (150 psi). If this pressure is exceeded the canister will split and could cause serious personal injury. The manufacturers of these flushing canisters recommend using only filtered compressed air rather than the higher pressure nitrogen.

PREVENTIVE MAINTENANCE: All regulators should be tested and cleaned periodically to insure proper performance. The frequency of testing should be established according to usage, but it should be performed at least once per year to evaluate for damage, contamination, wear and performance.

# Further Information

The information within this guide was drawn from a variety of sources. Rather than providing a detailed reference list, each chapter is accompanied by a short list of publications for further reading. These publications offer detailed information on many topics addressed in this guide. The list below includes a selection of some of the many textbooks available on refrigeration engineering, with a focus on those that cover to servicing and maintenance practices:


Air Conditioning and Refrigeration,
by R Miller and M R Miller, 2006

Modern Refrigeration and Air Conditioning,
by A D Althouse, C H Turnquist, and A F Bracciano, 2004

Principles of Refrigeration,
by R J Dossat and T J Horan, 2001

Refrigeration and Air Conditioning Technology,
by B Whitman, B Johnson, J Tomczyk, E Silberstein, 2008

Refrigeration Equipment: A Servicing and Installation Handbook,
by A C Bryant, 1997

National CFC phase-out Project, India training material.
by Prof. R S Agarwal, IIT, Delhi and Team, Ozone Cell, India

Good Practices in Refrigeration
by GTZ Proklima, 2010

Hydrocarbon Refrigerants Guidelines Safety
by GTZ Proklima


Many organizations have websites offering extensive information and resources related to refrigeration and refrigerants.  Below is a short list of recommended websites:

- www.ashrae.org - American Society of Heating, Air-conditioning and Refrigeration Engineers
- www.hydrocarbons21.com - related to the hydrocarbon refrigeration industry
- www.iifiir.org - International Institute of Refrigeration
- www.refrigerantsnaturally.com - an organization of end-users involved in the adoption of natural refrigerants
- www.ozone.unep.org
- www.unep.org/ozonaction – website of the UNEP OzonAction, an implementing agency that also functions as an information clearinghouse


UNEP DTIE OzonAction
 – Refrigeration & Air-Conditioning
http://www.uneptie.org/ozonAction/topics/refrigerant.htm

UNEP DTIE OzonAction
 – Protecting the Ozone Layer, Volume 1, Refrigerants, UNEP, 2001
www.unep.fr/ozonaction/information/mmcfiles/2333-e.pdf

UNEP DTIE OzonAction
- Guidebook for Implementation of Codes of Good Practice Refrigeration Sector, 1998
www.unep.fr/ozonaction/information/mmcfiles/2174-e.pdf

US Environmental Protection Agency
- Significant New Alternatives Policy (SNAP) Program
www.epa.gov/ozone/snap/index.html

# Further Reading


Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Proklima
- Good Practices in Refrigeration GTZ Proklima, 2010
www.giz.de/expertise/.../giz2010-en-good-practices-in-refrigeration.pdf

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Proklima

- Guidelines for the safe use of hydrocarbon refrigerants - GIZ
www.giz.de/expertise/.../giz2010-en-guidelines-safe-use-of-hydrocarbon.p...

Ozone Secretariat, Refrigeration
– reports of the Air Conditioning and Heat Pumps Technical Options Committee (RTOC)
http://ozone.unep.org/new_site/en/assessment_docs.php

UK Institute of Refrigeration Service Engineers' Section
– Bulletin 24 on Refrigerant Handling and Registration Schemes, 2006
http://www.ior.org.uk/ior_/images/pdf/se/bulletin%2024%20refrigerant%20handling%20schemes.pdf

UK Institute of Refrigeration Service Engineers' Section
- Bulletin 28 on Leak checking and Record Keeping under the F Gas Regulations, 2007
www.ior.org.uk/ior_/images/pdf/se/bulletin%2028%20f%20gas%20leak.

UK Institute of Refrigeration Service Engineers' Section
– Technical Information on F Gas Refrigerant Handling Training, 2009
www.ior.org.uk/ior_/images/pdf/se/SMfgastraining12revised09.pdf

UK Institute of Refrigeration Service Engineers' Section
– Assessment for Safe Handling of Refrigerants, 2006
www.ior.org.uk/ior_/images/pdf/serv%20matters%209-%20ref%20assess..

UNEP DTIE OzonAction
- Training Guide on Good Practices in Refrigeration 1994

UNEP DTIE OzonAction
- Guide for Refrigeration Servicing Technicians 2010
www.unep.org/pdf/7443-e-Ref_manual_servicing_technicians.pdf

UNEP DTIE OzonAction –
- Ozone Protection, Climate Change & Energy Efficiency, Centro Studi Galileo / UNEP, 2007
www.unep.fr/.../6241-e-industria_formazione_special_issue_2.pdf

UNEP DTIE OzonAction
– Protecting the Ozone Layer, Volume 1, Refrigerants, UNEP, 2001
www.unep.fr/ozonaction/information/mmcfiles/2333-e.pdf

UNEP DTIE OzonAction
- Fact Sheet No. 16 on Refrigerant Blends
www.uneptie.org/ozonaction/information/mmcfiles/4766-e-16blends.pdf

UNEP DTIE OzonAction
- HCFC Help Centre: Refrigerant blends containing HCFCs, UNEP
www.uneptie.org/ozonaction/topics/hcfcblends.htm

UNEP DTIE OzonAction
– Refrigeration & Air-Conditioning
http://www.uneptie.org/ozonAction/topics/refrigerant.htm

UNEP DTIE OzonAction
– Protecting the Ozone Layer, Volume 1, Refrigerants, UNEP, 2001
www.unep.fr/ozonaction/information/mmcfiles/2333-e.pdf

UNEP DTIE OzonAction
- Guidebook for Implementation of Codes of Good Practice Refrigeration Sector, 1998
www.unep.fr/ozonaction/information/mmcfiles/2174-e.pdf

US Environmental Protection Agency
- Significant New Alternatives Policy (SNAP) Program
www.epa.gov/ozone/snap/index.html

# About the UNEP DTIE OzonAction Programme

Under the Montreal Protocol on Substances that Deplete the Ozone Layer, countries worldwide are taking specific, time-targeted actions to reduce and eliminate the production and consumption of man-made chemicals that destroy the stratospheric ozone layer, Earth's protective shield.

The objective of the Montreal Protocol is to phase out ozone depleting substances (ODS), which include CFCs, halons, methyl bromide, carbon tetrachloride, methyl chloroform, and HCFCs. One hundred ninety seven governments have joined this multilateral environmental agreement and are taking action.

The UNEP DTIE OzonAction Branch assists developing countries and countries with economies in transition (CEITs) to enable them to achieve and sustain compliance with the Montreal Protocol. With our programme's assistance, countries are able to make informed decisions about alternative technologies, ozone-friendly policies and enforcement activities.

OzonAction has two main areas of work:

- Assisting developing countries in UNEP's capacity as an Implementing Agency of the Multilateral Fund for the Implementation of the Montreal Protocol, through a Compliance Assistance Programme (CAP).
- Specific partnerships with bilateral agencies and Governments.

UNEP's partnerships under the Montreal Protocol contribute to the realisation of the Millennium Development Goals and implementation of the Bali Strategic Plan.

## For more information

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## About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

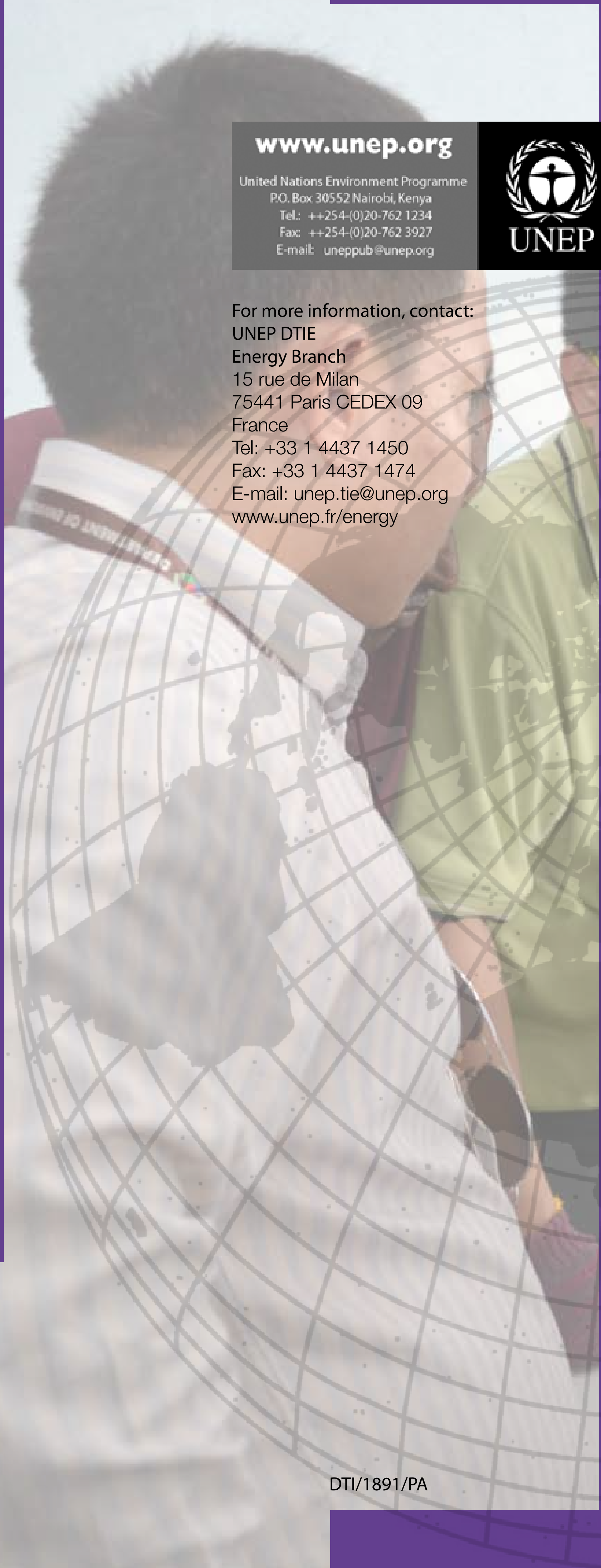
### The Office of the Director, located in Paris, coordinates activities through:

**> The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
**> Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns to contribute to human development through global markets.
**> Chemicals** (Geneva), which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemicals safety worldwide.
**> Energy** (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
**> OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
**> Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

***UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.***

For more information
see **www.unep.org**

The main purpose of this Guide on Good Practices: Phasing-out HCFCs in the Refrigeration and Air-conditioning Servicing Sector is to provide National Ozone Units and refrigeration and air-conditioning training institutes with a standardised module for delivering training programme under HCFC Phase-out Management Plan. It could be used together with web-based slides and interactive animated exercise. The publication can serve as a guide for other multilateral environmental agreements to also think globally and act locally.

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