Republic of Macedonia
Ministry of Environment and Physical Planning
Ozone Unit

MANUAL

for refrigeration service technicians

Skopje, 2006
The manual is intended for training of the refrigeration service technicians. It is developed by the Ministry of Environment and Physical Planning of the Republic of Macedonia/Ozone Unit, within the frameworks of the project Terminal Phase-out Management Plan of CFCs.

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In the preparation of this Manual, as resource documents were used:
1. Training Manual on Good Practices in Refrigeration, UNEP DTIE;
2. Training Manual on Chillers and Refrigerant Management, UNEP DTIE;
3. UNEP Customs Training Manual;
4. Publications in refrigeration technique

Number of copies - 500
Table of contents
1. The Ozone layer and the ozone depletion
2. Controlled substances under the Montreal Protocol
3. Basic elements of the refrigeration technique
4. Good service practices
5. Recovery, recycling and reclaim
6. Alternative refrigerants and technologies
7. Legislation
8. Annexes
1. The Ozone layer and the ozone depletion

Ozone
Ozone is a gas composed of three oxygen atoms (O₃). The regular oxygen molecules (O₂) contained in the air we are breathing consists of only two atoms of oxygen. Ozone molecules are created by a photochemical reaction:

\[
3 \text{O}_3 \leftrightarrow 2\text{O}_2 + 2 \text{O}^- \leftrightarrow 2 \text{O}_3
\]

Reaction in the stratosphere
Oxygen molecules react to form ozone molecules and at the same time ozone molecules react to form oxygen molecules. If the number of ozone molecules being created is the same as the number of ozone molecules being broken down, the reaction is in dynamic equilibrium.

The ozone layer
The ozone layer is a term used to describe the presence of ozone molecules in the stratosphere. The layer stretches around the entire globe of the Earth like a bubble and acts as a filter for the harmful ultraviolet radiation (UV-B). UV-B radiation is a highly energetic light that originates from the Sun and which has severe impacts on human health and the environment.

The stratosphere is that part of atmosphere, which follows the troposphere. It starts at 10-20 km above ground level and continues up to 40-50 km height. Figure 1 shows the different layers of the atmosphere of the earth.

![Figure 1. Ozone in the atmosphere](image)

Stratospheric ozone is different from ground level (tropospheric) ozone.
Ground level ozone results from industry and traffic emissions in combination with specific weather conditions. It is part of photochemical smog and as an irritating gas it may cause respiratory health problems especially for older people and young children as well as plant damage.
Importance of the ozone layer

Filter for UV-B radiation
The ozone layer is vital to life on the surface of the planet. It acts as a filter and prevents the harmful ultraviolet radiation (UV-B) from reaching the Earth.

UV-B exposure
If ozone molecules are depleted, faster than they can be replaced by new ones that nature produces the result is what could be called an ozone deficit. The depletion of the ozone layer will lead to a reduction of its protecting capacity and thus an increased exposure to UV-B radiation.

Types of UV radiation
Scientists classify UV radiation into three types or bands-UV-A (wavelength 315-400\(\times 10^{-9}\) m), UV-B (280-315\(\times 10^{-9}\) m) and UV-C (<280 \(\times 10^{-9}\) m). UV-C does not reach the Earth’s surface. UV-B is partially filtered by the ozone layer. UV-A is not filtered at all by the ozone layer. However, it is the UV-B radiation which is mainly responsible for health damages and adverse impacts on the environment.

Effects of ozone layer depletion on human health and the environment

Human health
UV-B radiation is known to cause skin cancers—both non-melanoma (the less dangerous) and the virulent cutaneous malignant melanoma. Increased UV-B also causes damage to the eyes including eye cataracts, which in many countries is major reason for blindness. Suppression of the immune system by damaging the DNA (DeoxyriboNucleicAcid) results in increased incidents and occurrence of infectious diseases.

Plants
Ozone layer depletion causes serious adverse effects on agricultural crops and forests. The ultraviolet radiation causes changes in the chemical composition of several species of plants. Experiments on crops have shown that the ones most vulnerable to UV-B include melons, mustard and cabbage. Increased UV-B radiation also reduces the quality of certain types of tomatoes, potatoes, sugar beets and soybeans. Tests have also shown that seeds of conifers are also adversely affected.

Aquatic organisms
Damage of aquatic organisms, in particular the small organisms such as plankton, aquatic plants and fish larvae, shrimp and crabs—all of which from the essential base of the aquatic and marine food chain.

Materials
Materials used in buildings, paints, rubbers, wood and plastics are degraded by UV-B radiation, particularly plastics and rubbers used outdoors. Damage would be severe in the tropical regions where the effects are enhanced by high temperatures and levels of radiation. Such damages could cost billions of dollars each year.
Ground level smog
UV-B radiation results in increased ground level smog, especially in the cities where vehicle and industry emissions provide a basis for photochemical reactions. This has its own adverse effects on human health and environment.

Concentration of ozone molecules
The ozone molecules are dispersed in the stratosphere and therefore the physical thickness of ozone layer is spread on tens of kilometers. However, the pressure and thus the concentration of molecules in the stratosphere are already very low compared to those at the ground level.
Accordingly, the concentration of stratospheric ozone molecules is so low that if all ozone molecules were extracted from the stratosphere and spread around the Earth at ground level, they would form a layer of ozone gas of couple of millimeters thickness.

Dobson Unit
This theoretical thickness of the ozone layer at ground level is used as a measure for the amount of ozone molecules in the stratosphere and measured in Dobson Units (DU). Each Dobson Unit corresponds to 0.01 millimeter, therefore 300 Dobson Units correspond with a calculated thickness of the ozone layer of 3 millimeters.

Ozone hole
Antarctic ozone hole
In the 1970s scientists discovered that the released ODS (Ozone Depleting Substances) damage the ozone layer. The ozone concentration over Antarctica diminished between the 1970s and the 1990s by up to 70% of the concentration normally found over Antarctica. This large-scale phenomenon is usually referred to as the ozone hole. Scientist have observed declining ozone concentrations over the whole globe.

Arctic ozone hole
Recent observations show that the upper atmospheric conditions in the Northern Hemisphere are becoming similar to those of the Antarctic. The loss of ozone and the greenhouse effect are causing the upper atmosphere to become colder, which facilitates ozone destruction. The result of this could be formation of an “Arctic Ozone Hole” or “low ozone event” within the next 20 years.

The alarming difference is that there are millions of people that live in the area that will be exposed to the resulting increased UV-B radiation. An Arctic “low ozone event” could easily be blown south by high-altitude winds, and appear over populated areas of the United States, Canada, Europe and Asia. Figure 2 shows the area that may be affected by the formation of the Antarctic ozone hole.

Climate change and global warming
Ozone depletion is different issue from climate change and global warming. Global warming and climate change are caused by the emission of greenhouse gases, which trap the outgoing heat from the Earth causing the atmosphere to become warmer. Greenhouse gases include carbon dioxide, methane, CFCs, HFCs, HCFCs and halons. The global warming potential (GWP) is the contribution of each greenhouse gas to global warming relative to carbon dioxide whose GWP is defined as 1. It usually refers to a time span of 100 years (GWP 100).
The impacts of global climate change may include sea level rise resulting in loss of valuable coastal areas and intrusion of seawater further inland as well as unpredictable effects on eco-systems and natural disasters.

**Figure 2.** Antarctic ozone hole

**Ozone depletion**

*Dynamic equilibrium*

The dynamic equilibrium between creating and breaking down ozone molecules depends on temperature, pressure, energetic conditions and molecule concentrations. Other molecules reacting with the ozone molecules, and thereby destroying them can disturb the equilibrium, for instance. If this destruction process is fast and the creation of new ozone molecules is too slow to replace the destroyed ozone molecules, the equilibrium will get out of balance. Consequently, the concentration of ozone molecules will decrease.

*Destruction mechanism*

Under the Montreal Protocol, a number of ozone depleting substances (ODSs) have been identified and their production and use controlled. Their destructive potential is high because they react in a photochemical chain reaction with ozone molecules. After one ozone molecule has been destroyed, the ODS is available to destroy further ozone molecules.

*Atmospheric life time of ODS*

The destructive lifetime of ODS may range between 100-400 years depending on the ODS properties. Therefore, one molecule of ODS may destroy hundred of thousands of ozone molecules. The process through which CFCs deplete ozone layer or molecule is illustrated in Figure 3.
Ozone depleting substances (ODS)

Ozone depleting substances are chemical substances that have the potential to react with ozone molecules in the stratosphere. ODS are basically chlorinated, fluorinated or brominated hydrocarbons and include:

- chlorofluorocarbons (CFCs)
- hydrochlorofluorocarbons (HCFCs)
- halons
- hydrobromofluorocarbons (HBFCs)
- bromochloromethane
- methyl chloroform
- carbon tetrachloride, and
- methyl bromide.

Ozone depleting potential

The ability of these chemicals to deplete the ozone layer is referred to as the ozone depletion potential (ODP). Each substance is assigned an ODP relative to CFC-11 whose ODP is defined as 1.

Common uses of ODS

In most developing countries, the largest remaining sector in which ODS are still used is the refrigeration and air-conditioning servicing sector, where CFCs and HCFCs are used as refrigerants for the cooling circuits. ODS are also used as blowing agents for foam applications, as cleaning solvents in the electronics industry, as propellants in aerosol applications, as sterilants, as fire fighting agents, as fumigants for pest and disease control, and for feedstock applications.
**ODS application**

**Refrigerants**
ODSs are used as refrigerants in refrigeration and air-conditioning and heat pump systems. CFC refrigerants are gradually being replaced by the less ozone damaging HCFC refrigerants (ODP and GWP>0), HFC refrigerants (ODP=0 but GWP>0) and hydrocarbon refrigerants (ODP and GWP=0).

Many household refrigerators use CFC-12. Commercial refrigeration systems used for display and storage of fresh and frozen food may use CFC-12, R-502 (blend of CFC-115 and HCFC-22) or HCFC-22 as refrigerant. Transport refrigeration and air-conditioning systems used in road and rail transport containers and cargo and passenger ships may contain CFC-11, CFC-12, CFC-114, HCFC-22 or CFC containing mixtures R-500 (mixture of CFC-12 and HFC-152a) and R-502 (mixture of CFC-115 and HCFC-22).

Air-conditioning and heat pump systems for buildings may contain large amounts of HCFC-22, CFC-11, CFC-12 or CFC-114 as refrigerants. The most of the old vehicles often use CFC refrigerants in their air-conditioning systems. Many drop-in substitutes for CFC-12 refrigerants are based on mixtures containing HCFC.

**Use as blowing agent**
Before regulatory controls, CFC-11 was the most common foam-blowing agent for the manufacture of polyurethane, phenolic, polystyrene, and polyolefin foam plastics. Foams are used in a wide variety of products and for insulation purposes. CFC-11 was progressively replaced by HCFC-141b or non-ODS alternatives.

**Use as cleaning solvent**
CFC-113 has been widely used as cleaning solvent in electronic assembly production processes, precision cleaning and general metal degreasing during manufacture. It is also used for dry-cleaning and spot cleaning in the textile industry. Other ozone depleting solvents include methyl chloroform and carbon tetrachloride.

**Propellants**
CFC-11 and CFC-12 were widely used as aerosol propellants because they are non-flammable, non-explosive and non-toxic. CFC-114 was used as propellant in products containing alcohol. CFC-113 is and has been used in aerosols for cleaning purposes. They could be produced in highly pure form and they are good solvents. CFC-11 and CFC-12 are ingredients of the lacquers, deodorants, shaving foams, perfumes, insecticides, window cleaners, oven cleaners, pharmaceutical products, veterinary products, paints, glues, lubricants and oils.

By the end of the 1970s, countries started to ban or restrict the use of CFCs in aerosol products.

**Sterilants**
Mixtures of CFC-12 and ethylene oxide are used for sterilization in medical purposes. The CFC-compounds reduce the flammability and explosive risk caused by ethylene oxide presence. The most common mixture contains 88% CFC-12 by weight and is commonly known as 12/88. Ethylene oxide is particularly useful for sterilizing objects that are sensitive to heat and moisture, such as catheters and medical equipment using fiber optics.

**Fire extinguishers**
Halons and HBFU were largely used as fire extinguishers and in many cases are replaced by foams or carbon dioxide.
Fumigants
Methyl bromide was widely used as a pesticide for soil fumigation in order to protect crops and to prevent from pests. It is also used for quarantine and pre-shipment applications.

Feedstock
HCFC and carbon tetrachloride are commonly used as feedstock in chemical synthesis. Carbon tetrachloride is also used as a process agent. ODS used for feedstock applications are usually not released into the atmosphere and therefore do not contribute to ozone layer depletion.

Releasing of ODSs into the stratosphere
ODSs are released to the atmosphere in a variety of ways, including:
- Traditional use of cleaning solvents, paint, fire extinguishing equipment and spray cans;
- Venting and purging during servicing of refrigeration and air-conditioning systems;
- Use of methyl bromide in soil fumigation and for quarantine and pre-shipment applications;
- Disposal of ODS-containing products and equipment such as foams or refrigerators, and
- Leaking refrigerant circuits.
Once released into the atmosphere the ODSs are diluted into the ambient air and can reach the stratosphere through air currents, thermodynamic effects and diffusion. Because of their long lifetime, most ODS will reach the stratosphere at some point.

Ozone layer recovery
There is no exact prediction when the ozone layer will recover. Scientists assume that the concentration of ozone molecules in the stratosphere will reach “normal” levels by middle of this century, if all Parties of the Montreal Protocol comply with their phase-out schedule. This is partly due to the long lifetime of ODS and the chain reaction contributing the ozone molecules destruction.
Incidences of skin cancer and eye cataracts are expected to decline towards “normal” levels with a delay of 20-50 years by the end of the century.
It is possible that the effects of global warming will slow down the recovery process of the ozone layer. Therefore, attention should also be given to greenhouse gas emissions. Recent research suggests that the melting ice in Antarctica will release significant amounts of ODSs and greenhouse gases.
2. Controlled substances under the Montreal Protocol

Twenty-five years ago, the world community was not aware of stratospheric ozone layer depletion and its negative effects on human health and the environment. Today the importance of ozone layer protection is recognized in developed as well in developing countries worldwide and 189 countries have ratified the Montreal Protocol as of March 2006.

In 1987, governments adopted the Montreal Protocol to reduce and eventually eliminate the emissions of man-made ozone depleting substances. The Protocol contains a list of controlled ODSs - 5 CFCs (Annex A Group I: CFC-11, CFC-12, CFC-113, CFC-114, CFC-115) and 3 Halons (Annex A Group II: Halon-1211, Halon-1301 and Halon-2402) and defined the control measures to reduce production and consumption of these ODSs. Blends containing these substances (e.g. R-500 and R-502) are also affected. The Protocol entered into force on 1 January 1989 and as of today 189 countries world-wide have committed themselves under the Protocol to phase-out the consumption and production of ODSs.

In the dynamic history of the Montreal Protocol, four amendments and five adjustments have been agreed to ensure that the Protocol continues to reflect improved scientific and technical understanding. Adjustments of the Montreal Protocol itself may modify the phase-out schedules of already controlled substances as well as ODP values of controlled substances based on new research results. Amendments to the Montreal Protocol may introduce control measures for new ODS.

**Obligations for the Parties to the Montreal Protocol and its amendments**

The two main obligations of the Parties are complying with the ODS freeze and phase-out schedules and banning trade with non-Parties to the Protocol. The freeze and phase-out obligations for Article 5 countries (including the Republic of Macedonia), take into account that developing countries usually do not have easy access to alternative technologies, know-how and capital investment. Therefore, Article 5 countries are granted with grace period to fulfill MP obligations. This should allow sufficient time to provide smooth transition to non-ODS technologies. Developing countries still use most ODS, in particular CFCs and halons.

Table 1 summarizes control measures and the phase-out schedule for the different ODSs, applicable to developing and developed countries.
<table>
<thead>
<tr>
<th>Montreal Protocol</th>
<th>Controlled substances (ODSs)</th>
<th>Obligation of the countries classified according to the Article 5 of the Montreal Protocol (developing countries)*</th>
<th>Obligation of the countries classified according to the Article 2 of the Montreal Protocol (developed countries)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annex/Group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CFC-12</td>
<td>Freeze: July 1, 1999</td>
<td>Freeze: July 1, 1989</td>
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<tr>
<td></td>
<td>CFC-113</td>
<td>50% reduction: January 1, 2005</td>
<td>75% reduction: January 1, 2005</td>
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<td></td>
<td>CFC-114</td>
<td>85% reduction: January 1, 2007</td>
<td>100% reduction: January 1, 2010</td>
</tr>
<tr>
<td></td>
<td>CFC-115</td>
<td>100% reduction: January 1, 2010</td>
<td></td>
</tr>
<tr>
<td><strong>A II</strong></td>
<td>Halon-1211</td>
<td>Base level: Average of 1995-1997</td>
<td>Base level: 1986</td>
</tr>
<tr>
<td></td>
<td>Halon-1301</td>
<td>Freeze: January 1, 2002</td>
<td>20% reduction: January 1, 1992</td>
</tr>
<tr>
<td></td>
<td>Halon-2402</td>
<td>50% reduction: January 1, 2002</td>
<td>100% reduction: January 1, 1994</td>
</tr>
<tr>
<td></td>
<td>CFC-111</td>
<td>20% reduction: January 1, 2003</td>
<td>20% reduction: January 1, 1993</td>
</tr>
<tr>
<td></td>
<td>CFC-112</td>
<td>85% reduction: January 1, 2007</td>
<td>75% reduction: January 1, 1994</td>
</tr>
<tr>
<td></td>
<td>CFC-211</td>
<td>100% reduction: January 1, 2010</td>
<td>100% reduction: January 1, 1996</td>
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<tr>
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<td>CFC-212</td>
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<td>CFC-213</td>
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<td>CFC-214</td>
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<td>CFC-215</td>
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<td>CFC-216</td>
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<td>CFC-217</td>
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<td></td>
<td></td>
<td>85% reduction: January 1, 2005</td>
<td>85% reduction: January 1, 1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% reduction: January 1, 2010</td>
<td>100% reduction: January 1, 1996</td>
</tr>
<tr>
<td><strong>B III</strong></td>
<td>1,1,1,-trichloroethane</td>
<td>Base level: Average of 1998-2000</td>
<td>Base level: 1989</td>
</tr>
<tr>
<td></td>
<td>(methyl chloroform)</td>
<td>Freeze: January 1, 2003</td>
<td>Freeze: January 1, 1993</td>
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<td></td>
<td></td>
<td>30% reduction: January 1, 2005</td>
<td>50% reduction: January 1, 1994</td>
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<td>70% reduction: January 1, 2005</td>
<td>100% reduction: January 1, 1996</td>
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<td></td>
<td></td>
<td>100% reduction: January 1, 2015</td>
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<tr>
<td><strong>C I</strong></td>
<td>HCFCs</td>
<td>Base level: 2015 consumption</td>
<td>Base level: HCFC consumption in 1989 + 2.8% of CFC consumption in 1989</td>
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<td></td>
<td></td>
<td>Freeze: January 1, 2016</td>
<td>Freeze: 1996</td>
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<td>35% reduction: January 1, 2004</td>
<td>65% reduction: January 1, 2015</td>
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<td></td>
<td></td>
<td>65% reduction: January 1, 2015</td>
<td>99.5% reduction: January 1, 2020</td>
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<td></td>
<td></td>
<td>70% reduction: January 1, 2015</td>
<td>100% reduction: January 1, 2030</td>
</tr>
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<td><strong>C II</strong></td>
<td>HBFCs</td>
<td>100% reduction: January 1, 1996</td>
<td>100% reduction: January 1, 1996</td>
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<td><strong>C III</strong></td>
<td>Bromochloromethane</td>
<td>100% reduction: January 1, 2002</td>
<td>100% reduction: January 1, 2002</td>
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<td></td>
<td></td>
<td>Freeze: January 1, 2002</td>
<td>Freeze: January 1, 1995</td>
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<tr>
<td></td>
<td></td>
<td>20% reduction: January 1, 2005</td>
<td>25% reduction: January 1, 1999</td>
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<td>100% reduction: January 1, 2015</td>
<td>50% reduction: January 1, 2001</td>
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<td></td>
<td>70% reduction: January 1, 2003</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>100% reduction: January 1, 2005</td>
</tr>
</tbody>
</table>

* Republic of Macedonia is classified in the Article 5, as developing country
3. Basic elements of the refrigeration technique

History of refrigeration
Before mechanical and thermal systems were introduced, people cooled their food with ice transported from mountains. Wealthy families used ice cellars, which were pits dug into the ground and insulated with wood and straw, to store the ice. In this manner, packed snow and ice could be preserved for months. Ice was the principal means of refrigeration until the beginning of the 20th century, and it is still used in some countries. People who did not have ice available salted or smoked food products to preserve them.
The American physician John Corrie to cool sickrooms in a Florida hospital invented the first practical mechanical refrigeration system in 1884. The system used an air-cycle method of cooling. The American business man Alexander C Twinning is generally credited with initiating commercial refrigeration in 1956. Shortly afterward, an Australian, James Harrison, introduced vapor-compression refrigeration to the brewing and meat-packing industries.
Ferdinand Carre in France then developed a thermally powered ammonia absorption refrigerating system in 1859. Carre’s refrigerators were widely used in industry.
However, the cost, size, and complexity of refrigerating system of the time prevented the general use of refrigerants in the home. Most households used iceboxes that were supplied almost daily with blocks of ice from a local refrigeration plant.

Introduction in refrigeration
The job of a refrigeration plant is to cool articles or substances down to and maintains them at a temperature lower than the ambient temperature. Refrigeration can be defined as a process that removes heat.

Vapor compression mechanical refrigeration
The vapor compression refrigeration operating principles is simplified from can be divided into four operations: evaporation, compression, condensation and expansion. During evaporation, heat is absorbed from the air or process to be cooled from the refrigerant and is vaporized. This vaporized refrigerant is then sucked into the compressor, which derived its energy from an electric motor or other mechanical means like engine. The compressor raises the gas pressure and thereby compresses it. The high-pressure refrigerant gas goes to the condenser where it can now be returned to a liquid state by a high temperature cooling source like ambient air or cooling tower water. The high-pressure liquid then returns to the evaporator through an expansion device where its pressure is lowered and part of the liquid is vaporized to provide cooling to the liquid refrigerant. At this point, we have a cold liquid refrigerant ready to begin the cycle all over again.

Absorption refrigeration system
A system in which compression of the refrigerant is secured by a thermal means. This is usually accomplished by an absorbent fluid capturing the vaporized refrigerant, reducing its volume by phase change, utilizing a small pump to raise the combined fluids to condensing pressure, distilling the refrigerant from the absorbent fluid with heat and sending the refrigerant vapor off the condenser and returning the absorbent fluid to the absorber.
A refrigerant is a liquid or gas which transfers heat away from one point to another. In a typical vapor compression system, the refrigerant changes phase. This is, it changes from a liquid to a gas when it absorbs heat and changes back to a liquid when it gives up heat. Most chemicals have ability to change from a liquid to a gas, but only a few chemicals do so in a manner that makes them good refrigerants. First chemical used as refrigerant is ethyl ether in the piston compressors (1856) and methyl ether (1864), that was more suitable, but the negative side of these fluids is the fact they are toxic and flammable.

With development of the technique, new refrigerants have found their applications: Ammonia (NH₃) – since 1874, sulfur dioxide (SO₂) – since 1874, methyl chloride (C₂H₅Cl) – since 1878, carbon dioxide (CO₂) – since 1881, which are rightfully called classic refrigerants. Ammonia still finds its application.

For lower temperature (−110°C) new refrigerants have been discovered: methane (CH₄), ethylene (C₂H₄), ethane (C₂H₆), propane (C₃H₈), butane (C₄H₁₀) and propylene (C₃H₆). These materials have certain disadvantages: they are burning and in contact with air form explosive blend. Because of their low molecule mass, there is a need of larger facilities for cooling.

Later 1930s, through halogening of the saturated hydrocarbons with chlorine and fluorine were produced derivates, called freons or CFC-compounds, which are satisfying technical requests for refrigeration application. All of these saturated hydrocarbons CₙHₙ can from chlorofluorocarbons (CₙHₙFₓClz, 2ₙ+2=n+x+y+z).

The formula for determination of the number of possible basic compounds is (n+1)(n+2)/2. For instance, the methane forms 15 compounds, ethane together with its isomers forms 55 compounds, propane forms 332 compounds, and butane forms over 1000 compounds.

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**Figure 4. Vapor Compression Refrigeration Cycle**
Criteria for election of compounds suitable for refrigerant are: larger number of fluorine atoms (those compounds are less toxic and have lower chemical activity to the metals), if the number of hydrogen atoms is lower, the flammability gets lower. Not all halogen carbons (without hydrogen) burn and in touch with air, they are not flammable and traces of toxic gas phosgene appear. It is recommended to not smoke in the premises where this gas is released.
### Table 2. Ozone depleting refrigerants – most commonly used

<table>
<thead>
<tr>
<th>Refrigerant number</th>
<th>Chemical Formula</th>
<th>Common name</th>
<th>Properties</th>
<th>Lubricant</th>
<th>Applications</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Molecular mass</td>
<td>NBP °C</td>
<td>t_c °C</td>
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<tr>
<td>CFC-11</td>
<td>CCl_3F</td>
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<td>137,37</td>
<td>23,7</td>
<td>198,0</td>
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<td>BFC-12B1</td>
<td>CBrCl_2</td>
<td>halon 1211</td>
<td>165,36</td>
<td>-4,0</td>
<td>154,0</td>
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<td>CFC-12</td>
<td>CCl_2F_2</td>
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<td>-29,8</td>
<td>112,0</td>
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<td>BFC-13B1</td>
<td>CBrF_3</td>
<td>halon 1301</td>
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<td>-57,7</td>
<td>67,1</td>
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<td>CClF_3</td>
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<td>CFC-113</td>
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<td>214,1</td>
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<td>CFC-114</td>
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MO - Mineral oil  
AB – Alkylbenzene  
POE – Polyester  
NBP – Normal Boiling Point  
ODP – Ozone Depleting Potential  
ALT - Atmospheric Life Time  
t_c - critical temperature  
p_c - critical pressure  
GWP – Global Warming Potential
Thermodynamics and expressions within refrigeration

Heat
Heat always flows from warmer to cooler substance. What happens is that the faster moving atoms give up their energy to slower moving atoms. Therefore, the faster atom slows down a little and the slower one moves a little faster. Heat causes some solids to become liquid, or gases, or liquids to become gases. Cooling will reverse the process. This happens because the atoms making up the molecules of these substances act in a different way to temperature. Instead of moving faster or slower, one or more of the atoms in the molecule shift their positions.

Cold
Cold means low temperature or lack of heat. Cold is the result of removing heat. A refrigerator produces “cold) by drawing heat from the inside of the refrigerator. The refrigerator does not destroy the heat, but pumps it from the inside of the cabinet to the outside. Heat always travels from a substance at a higher temperature to a substance at a lower temperature. Heat cannot travel spontaneously from a cold body to a hot body.

Methods of heat transfer
Three methods by which heat can be transferred:
- Conduction;
- Convection;
- Radiation.

Conduction
Heat travels along the material from the warm and to the cold. Most metals are good conductors of heat. This explains why most unheated metals feel cold: when they are touched, the heat of the hand is conducted always quickly. Poor conductors of heat are called insulators; also very important to the refrigeration engineer for walls of cold rooms and insulation of pipes, etc. The rate at which heat flows by conduction also affects producing cooling. For example, in the chilling of beef it may take three days for the heat at the centre of the deep round of a side of beef to flow out to give the temperature of 7°C.

Convection
Can only occur in fluids, that is liquid and gases. Convection occurs when a fluid is heated and expands and so become lighter than the surrounding fluid and rises to float above its surroundings, its place being taken by a colder fluid. Rising smoke from a fire is a good example, or the turbulence in a pan of boiling water.
In a cold room or air-conditioning the air is cooled at high level so that it becomes heavier than its surroundings and falls to the lower level, its place being taken by warmer air which rises.
An interesting situation occurs when a cold store door is opened. The cold air in the room being heavier than the ambient tends to flow out at the ground level. Its place is taken by warm air flowing at a high level.

Radiation
The prime example of this is the heat of the sun radiated over 150 million km. This is not used for heat transfer by the refrigeration engineer, although, solar radiation onto buildings and through windows figures in the heat load calculations of the air conditioning engine. Note that heat is only radiated from a hot object to its cooler surroundings. There is no such thing as a “cold” radiator.
Definitions

**Absolute Pressure**
Pressure above that of an absolute or perfect vacuum. Numerically, it is gauge pressure plus the barometric pressure (atmospheric pressure) expressed in bar.

**Absolute Temperature**
Temperature above the thermodynamic zero, which is the temperature at which all heat energy is absent. Numerically, it is Celsius temperature above –273.15°C. Absolute temperature is normally expressed in Kelvin (K). 0°K=–273.15°C.

**Absorption**
The extraction of one or more components from a mixture of gases when gases and liquid are brought into contact. The process is characterized by a change in physical or chemical state of the components.

**Absorption Refrigerating System**
A system in which compression of the refrigerant is secured by thermal means. This is usually accomplished by an absorbent fluid capturing the vaporized refrigerant, reducing its volume by phase change, utilizing a small pump to raise the combined fluids to condensing pressure, distilling the refrigerant from the absorbent fluid with heat and sending the refrigerant vapor off the condenser and returning the absorbent fluid to the absorber.

**Air Conditioning**
Simultaneous control of temperature, humidity, composition, motion and distribution of air for the purpose of human comfort or for industrial utilization.

**Azeotrope**
Mixture whose liquid and vapor phases have the same composition at a specific temperature. A mixture can only be an azeotrope at one temperature. For practical (refrigeration) purposes, if the change in composition of the azeotrope with temperature is small then it can be treated as a single fluid.

**Blends**
Used to describe mixtures which are zeotropes or near azeotropes. Blends are mixtures and not pure compounds. Thus, two or three molecules are present versus one molecule present in a pure compound.

**Brine**
A water solution of salts, having a freezing point lower than of pure water. Also any liquid which is used in the refrigeration system for the transfer of heat.

**Brine Cooler**
An evaporator for cooling brine by means of the evaporation of a primary refrigerant.

**SI – Thermal Unit**
The heat energy necessary to rise the temperature of one kilogram of liquid water by one degree Celsius is a unit, which is sufficiently accurate for normal engineering computations.
Capacity, Thermal
The amount of heat energy required rising the temperature of a mass of material one-degree.

Change of State
The process of changing from one state of aggregation to another, such at the change from the solid state to the liquid state to the gas or vapor state.

Coefficient of Performance
The measure of efficiency of a refrigeration system. Numerically, the amount of heat removed from the refrigerator divided by the work expended.

Compression Refrigerating System
A system in which the refrigerant gases or vapor is compressed by a mechanical device.

Condenser
A vessel or arrangement or tubes in which warm vapor is cooled and liquefied by the removal of heat.

Conductivity, Thermal
When temperature differences are present in any matter, heat flows from the hot to the cold regions until the temperatures are equalized. Thermal conductivity is expressed in \[\lambda = \text{W/mK}.\] E.g. polyurethane insulation from 0,017-0,027 W/mK.

Conduction
The process of heat transmission from molecule to molecule through a body of material.

Convection
The process of transferring heat by the movement of heated gas, vapor or liquid.

Counter flow
Heat exchange between two fluids which flow in opposite directions so that the warmest portion of one liquid meets warmest portion of the other.

Critical Point
A state point at which liquid and vapor has identical properties.

Critical Pressure
The pressure observed at the critical point of a substance.

Critical Temperature
The temperature observed at the critical point of a substance.

Cycle
A closed path in a thermodynamic system by which the working fluid is brought back after a series of changes to the original conditions of temperature, pressure and enthalpy.

Dalton's Law
The total pressure of a mixture of gases in a closed vessel is the sum of the pressures that each separate gas would exert if the others were not present.
Degree of Superheat
The difference between the temperature of a vapor at a given pressure and the temperature corresponding to saturation at this pressure.

Density
Weight or mass per unit volume; usually expressed in kg/m³.

Evaporative Condenser
A condenser which is cooled by the continued evaporation of water upon the condensing surfaces.

Energy
The capacity to do work. The engineering unit of heat energy is Joule, J, kcal or kWh for electrical energy.

Enthalpy
(Also known as heat content and total heat). The sum of the internal energy plus the product of pressure and volume. Its particular utility is that the energy (heat or other forms) gained or lost by working fluid in passing through a piece of apparatus is the change of enthalpy of the liquid. The engineering unit of enthalpy is kJ/kg (Kilo Joule/kilogram) with “I” or normally used “H”.

Eutectic Brine
A solution composed of one or more substances dissolved in water such proportions that the lowest possible freezing point is secured. Eutectic Salt Brine contains 23.3% of dry sodium chloride and freezes at –25°C. Eutectic Calcium Chloride brines contains 29.6% of anhydrous calcium chloride and freezes at –51°C.

Evaporator
The component in a refrigerating system in which liquid refrigerant absorbs heat and is changed to vapor.

Flash Gas
The vapor formed as a result of a reduction in pressure of a volatile liquid, which has no subcooling.

Flooded Evaporator
An evaporator in whom the heat transfer surfaces are always wetted by evaporating liquid refrigerant.

Heat
A basic form for energy, which is characterized by its ability to pass from a body at one temperature only to a body at a lower temperature. It may appear as sensible heat or as latent heat. The engineering units are the Joule, J.

Heat capacity
The heat energy required to cause unit change in temperature of unit mass of material.

Heat of Condensation
Or Liquefaction – Heat energy given up by pure vapor or gas during the process of changing to a liquid at constant temperature and pressure.
Heat Exchanger
A device in which heat is transferred from a liquid at one temperature to another fluid at lower temperature.

Heat, Latent
The heat energy liberated or absorbed in change of state at constant temperature and pressure of pure substance. It is not perceptible to human senses and is thus latent, or hidden.

Heat, Sensible
Heat energy, which is characterized by change of temperature and is thus perceptible to human senses.

Heat Transfer coefficient
Quantity of heat transferred through a body of unit length and unit cross-sectional area in unit time when the temperature gradient along the length dimension is one unit. Usually expressed in $\text{W/m}^2\text{K}$ and letters often used are K-value or U-value.

High Side
The part of a refrigerating system which is under the condenser pressure.

Horsepower
A unit of power, which is 1 hp=745.7 W

Humidity, Absolute
The weight of water vapor in a mixture with a unit weight of air. Usually expressed in $\text{kg of vapor/kg of dry air}$.

Humidity, Relative
The ratio between the partial pressure of water in air at a given temperature and the saturation pressure of water vapor at the same temperature. This ratio is not dependent upon the atmospheric pressure.

Internal Energy
Energy possessed by a body or a system of bodies by virtue of the motions and potential energy of the molecules.

Low Side
The portion of a refrigerating system under the evaporator pressure.

Melting Point
The temperature at which a solid substance changes to a liquid state at a given pressure.

Partial Pressure
The fraction of the total pressure of gas mixture which is awarded by one particular component.

Phase
In a physical sense, it is applied to one of the states of matter, such as the solid, liquid or gas phase.
**Polyester (POE)**
A synthetic lubricant formed from one or more ester chains. Polyester lubricants are typically more miscible with HFC refrigerants than mineral oils.

**Power**
The time of doing work, engineering units, hp, kilowatt, kW.

**Pressure**
The force exerted by a fluid upon a unit area of the wall of container. Engineering units: Bar, Pa, and torr (mm Hg).

**Primary Refrigerant**
The fluid which is used in a thermodynamic cycle to remove heat from a low temperature region and convey it to a high temperature region.

**Purge system**
A device used to expel air and other non-condensables from the circulating refrigerant.

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

**Replacement**
The conversion of an air-conditioning or refrigeration system to an alternative refrigerant which requires the removal of the existing installation of a completely new.

**Retrofit**
The conversion of an air-conditioning or refrigeration system to an alternative refrigerant. Unlike a replacement; only parts of components of the existing system may need to be replaced.

**Quality**
Percent (%) by weight of vapor in a mixture of liquid and vapor.

**Saturated Vapor**
A vapor which is in equilibrium with its liquid phase at the specified temperature and pressure.

**Saturated Temperature**
The temperature at which the liquid phase is at the specified temperature and pressure.

**Secondary Refrigerant**
Any liquid, which is used to convey heat from what, has to be cooled to the evaporator.

**Sub-cooling**
The process of cooling a liquid below its condensing or saturation temperature.
Sublimation
The change of state of solid directly to vapor without phasing through the liquid state.

Superheated Vapor
A vapor whose temperature is higher than saturation temperature for the specified pressure.

Thermodynamic Properties
The relationship between the temperature, pressure, specific volume, enthalpy and entropy of a liquid under various conditions.

Valve, Expansion
Valve which controls the flow of high pressure refrigerant to the evaporator.

Vapor
This term is applied to a gas which is near its saturation temperature and pressure. In general, it is usually employed for gases below the critical temperature.

Zeotrope/Non Azeotropic Mixture
A mixture which shows significant changes in vapor and liquid compositions with temperature. Evaporates and condenses over range. Calculations and unit design must take this into account. It also called a “wide boiling mixture”.
Refrigeration cycle on the Mollier chart

*Mollier Chart*

The conditions of the refrigerant at any thermodynamic state can be represented as a point in “Pressure-enthalpy diagram” (Mollier chart). The horizontal line on Figure 5 are lines of constant pressure and the vertical lines are lines of constant enthalpy, in others worlds the amount of heat presented in one kilogram of refrigerant.

![Mollier Chart Diagram](image)

**Figure 5.** Mollier chart

The chart is divided into three main areas which are separated from each other by the saturated liquid line and the saturated vapor line. The area and the left side of the saturated liquid line are called “subcooled region”. At any point in the subcooled region, the refrigerant is in the liquid state and its temperature is below the saturation temperature corresponding to its pressure.

The area on the right side of the saturated vapor line is the “superheated region” and the refrigerant in this region is in the form if superheated vapor. The centre section of the chart, between the saturated liquid and saturated vapor lines, is called the “region of phase change”, which represents the change in phase of the refrigerant between liquid and vapor states. At any point between the two lines the refrigerant is in the form of liquid-vapor mixture.

The joint point of the saturated liquid line and the saturated vapor line is called the “critical point”. The temperature and pressure at this point are called the “critical temperature” and “critical pressure” respectively.

Temperature of the refrigerant can be given by reading the lines of constant temperature. The lines of the constant temperature in the subcooled region are almost vertical on the chart and parallel to the lines of constant enthalpy. In the centre section, since the refrigerant changes in state at a constant temperature and pressure, the lines of constant temperature run horizontally across the chart and parallel to the lines of constant pressure. At the saturated vapor line the lines of constant temperature change direction again, and fall off sharply toward the bottom of chart in the superheated vapor region.
Refrigeration cycle
The simple vapor compression refrigeration cycle consist of four main processes such as vaporization, compression, condensation and expansion, as shown in on the Figure 6.

Figure 6. Scheme of refrigeration system

Figure 7. Refrigeration cycle in Mollier chart

Vaporization
As the refrigerant vaporizes at the lower constant pressure, it passes horizontally from A to B (Figure 7). This lines indicates the vaporization of refrigerant from liquid into vapor in the evaporator. The distance from B to C represents the heating process of this vapor through the end of evaporator and the suction line. The simplify the discussion, the pressure drop between B and C is ignored.
**Compression**

Point C is the condition of the vapor when it moves into the compressors and is compressed. When it is compressed to D, note low its pressure increases rapidly and how a few kgJ (kiloJoule) of heat are added to the vapor while the compressor is considerably superheated, and D represents the condition of the vapor leaving the exhaust valve of the compressor.

**Condensation**

The distance between D and E represents the cooling process of this superheated vapor to the point at which it starts condenses. At E, the vapor has not superheat and is 100 percent saturated vapor. The line from E to F represents the condensation process of the refrigerant in the condenser from vapor into liquid. The point F represents the amount of heat the in the liquid and the pressure imposed on the liquid as it forms in the condenser. From F to G, heat is reduced from the liquid while passing along the line to the refrigerant control.

**Expansion**

Line from G to A represents the throttling of the liquid while passing through the refrigerant control orifice. The cycle is now ready to be repeated.

**Typical design of vapor compression mechanical refrigeration system**

A refrigeration system consists principally of high-pressure side and low-pressure side.

**High-pressure side**
- Compressor (hermetic, semihermetic etc.), often with an oil separator;
- Condenser (air-cooled, water-cooled, evaporative);
- Liquid receiver – when a thermostatic expansion valve or automatic expansion valve is used;
- High pressure safety motor control;
- Liquid line – with drier, sight glass a shut off valves. Current system designs are different in their use of shut off valves, because it is required that sections are available to be closed in cases of system failure.

The refrigerant control is at the division point between the low side and high side of the system. It will consist an automatic thermostatic expansion valve or capillary tube.

**Low pressure side**
- Evaporator;
- Low pressure or temperature motor control;
- Suction line – some with filter-dryers and surge tanks. When system piping is short, it is recommended that a suction accumulator be installed.

**Classification of applications**

Refrigeration applications may grouped into six general categories: Domestic refrigeration, Commercial refrigeration, Industrial refrigeration, Marine and Transport refrigeration, Comfort air-conditioning and Industrial air-conditioning.

**Domestic Refrigeration**

Domestic refrigeration is being concerning primarily with household refrigerators and home freezers. Because the number of units in service is quite large, domestic refrigeration represents a significant portion of the refrigeration industry.
Domestic units are usually small in size, having power input ratings of between 35 W and 375 W and are of the hermetically sealed type. Millions of refrigerators running on CFC are installed in people’s homes. Owing the concern about depletion of the earth’s protective stratospheric ozone layer, the CFC refrigerants are being phased out. Today’s new refrigerators are mostly manufactured with alternative refrigerants, one which is HFC-134a or HC-600a. Due to the chemical differences between CFC and alternatives, traditional mineral oils cannot be used in most cases and would ultimately sacrifice performance and system reliability. That means that with domestic refrigerators with hermetic compressors it almost impossible to replace the CFC with alternatives without major high cost repairs.

The basic fresh food refrigerator has many variations, and convenience accessories, such as auto defrosts, icemakers, drink dispensers, etc.

Commercial Refrigeration
Commercial refrigeration is concerned with the designing, installation and maintenance of refrigerant features of type used by retail stores, restaurants, hotels and institutions for the storing, displaying, processing and dispensing of perishable commodities of all types.

The unit operating capacities broadly cover the range less than 1 kW up to several hundred kW. This category includes self-stand alone equipment, remotely supplied display cases, and pre-fabricated walk-in cold storage rooms. Most of this equipment is factory assembled, to be later field-installed by interconnecting piping and wiring at the job site. Refrigeration equipment ranges from single compressor units through to multi-compressor parallel system using reciprocating, rotary or screws compressors.

Air-conditioning
Air-conditioning is concerned with the condition of the air in some designated area or space. This usually involves control not only of the space temperature but also of space humidity and air motion, along with the filtering and cleaning of the air.

Air-conditioning applications are two types, comfort and industrial.

Typical installations of comfort air conditioning are in homes, schools, offices, hotels, retail stores, public buildings, factories, automobiles, buses, trains, plains ships etc.

Any air-conditioning which does not haven as primarily purpose the conditioning of air for human comfort is called industrial air-conditioning. This does not necessarily mean that industrial air-conditioning systems cannot serve also as comfort air-conditioning coincidentally with their primary function.

The applications of industrial air-conditioning are almost without both in number and variety.

The functions of industrial air conditioning systems are to:
- Control the moisture content of hydroscopic materials;
- Govern the rate of chemical and biochemical reactions;
- Limit the variations in the seize of precision manufactured articles because of thermal expansion and contraction;
- Provide clean, filtrated air which is often essential to troublefree operation and to the production of quality products.

Mobile air-conditioning (MAC)
Automobile air-conditioning involves heating, cooling and dehumidification. The heat required to warm the passenger compartment is usually provided by circulating warm coolant from the engine through a heater core. When a cooling effect is
desired, a refrigerating system is brought into operation, causing an evaporator in the plenum chamber of the system to cool the air is to be circulated through the passenger compartment.

**Parts of Domestic Refrigerators and freezers**

**Domestic Refrigerators**
The domestic fresh food refrigerator or food freezer consists primarily of three parts:
- Cabinet;
- Refrigeration system (evaporator, compressor, condensing unit and expansion device);
- Electrical circuit.

The cabinet contains and supports the evaporator and condensing unit, it also supplies shelving and storage space for the foods and beverages.

**Evaporator**
The evaporator is located in the cabinet. The liquid refrigerant entering the evaporator from the refrigerant flow control (usually capillary tube) is reduced to evaporator pressure. The remaining liquid then absorbs heat from the cabinet and is vaporized. The vapor moves on into suction line. If the entire liquid refrigerant has not vaporized in the evaporator, there is usually a cylinder (Figure 8, Accumulator), to prevent liquid refrigerant from flowing into the compressor suction line. In some cases, a motor driven fan forces air over the necessary refrigeration temperatures for the compartments.

![Accumulator](https://example.com/accumulate.png)

**Figure 8. Refrigerator evaporator**
**Compressor**
The suction line from the evaporator extends down the wall of the cabinet to the inlet side of the compressor, which is located in the base of the cabinet. In domestic applications, the hermetic compressor is used, where compressor and motor are build together as a complete hermetic unit.
To lubricate the compressor, the return suction gas is fed into a shallow disk mounted on the motor compressor shaft. Centrifugal force throws the oil and a liquid refrigerant to outer rim of the disk and flows over the motor windings. Only the vapor refrigerant remains at the centre and is drawn into cylinders of the compressor.

**Condenser**
The condenser is usually placed in the back of the refrigerator and removes the condensation heat from the refrigerant vapor. Refrigerators commonly use the four following types of condensers:
- Finned - static (natural convection) (Figure 10);
- Finned - forced convection;
- Wire - static;
- Plate - static.

Most commonly used in domestic refrigerators is a finned type static condenser. Static means that air circulation through the condenser tubing and fins is by natural convection; that is warm air tends to rise. As the air in contact with the fins and tubes becomes heated, it rises and cooler air takes place. The tubes and fins are usually made of copper or steel.
Figure 10. Condenser with natural convection

**Capillary tube**
Refrigerant is condensed in the condenser; it flows through a high-side filter-drier into a capillary tube attached to a section of the suction line. This provides a heat exchange between the capillary tube and the suction line. The refrigerant from the capillary tube flows into the evaporator and the cooling cycle is completed. The capillary tube is the most common refrigerant flow control for domestic refrigerators. The capillary tube is a long length of small diameter tubing. It reduces pressure, by reducing the flow of refrigerant through its length. The tubes inside diameter may vary, depending upon the refrigerant, capacity of the unit, and the length of the line. The tube is placed between the liquid line and the evaporator. Just enough liquid passes through it to make up for the amount that is vaporized in the evaporator as the compressor operates. It reduces the liquid refrigerant from its condensing pressure to its evaporating pressure. There is no change in to liquid except a slight drop in pressure for about the first two-thirds of the length of the capillary tube. Then some of the liquid starts to change in to vapor. By the time the refrigerant reaches the end of the tube, from 10 to 20 percent of it has vaporized. The increased volume of the vapor causes most of the pressure drop to take place in the end of the tube nearest the liquid line.

**Liquid line filter-drier**
It is common practice to install a filter drier in the liquid line. This tank-like accessory keeps moisture, dirt, metal, and chips from entering the refrigerant flow control.
What is more, the drying element in the filter (usually silicagel) removes moisture, which might otherwise freeze in the refrigerant flow control.

**Motor control**

All automatic electric refrigerators are designed with more cooling capacity than needed. Therefore, under normal use, they do not run all of the time. To get the correct refrigeration temperature, the motor must be turned off when the desired low temperature is reached and turned on again when evaporator has warmed up again to a certain temperature.

Two principal types of motor controls are used to turn the motor on and off:
- Temperature motor control (Thermostatic);
- Pressure motor control (low-side pressure).

**Thermostatic temperature control**

This motor control type has a sensing bulb connected by a capillary tube to a diaphragm or bellows. This element is charged with a volatile fluid, which expands to increase the pressure as the bulb become warmer, and will contact again to decrease the pressure as the bulb cools. As bulb cools pressure increase, the diaphragm moves. Since it is connected to a toggle or snap action switch, it will turn this switch on (close circuit). Then, as the bulb cools and the diaphragm or bellows moves the other way, the toggle switch will move (to open circuit).

These controls have adjustments that permit differences in operation temperatures. Many controls have manual switch to permit shutting off or turning on or off the refrigeration system. They also may include an overload protector which will open the switch if the unit draws too much current. A hermetic motor compressor usually requires an outside electrical relay starting mechanism.

Thermostats may also be electrically connected to timers for automatic defrosting of the evaporator.

For refrigerator with frozen food compartment recommended operating temperatures are:
- Evaporator inlet Ti= -25°C -26°C;
- Evaporator outlet To= -26°C;

The capillary tube is in contact with suction line and provides superheat at the compressor inlet.

**Freezers**

The outer and inner shells of the chest-type freezer are metal. The evaporator surrounds the inner liner and is attached to it. The condenser is attached to the outer shell.

The hermetic compressor is located at the lower right end. The liquid refrigerant flows through the capillary tube and into the evaporator. There, evaporation of the refrigerant and cooling take place. The compressor draws the vaporized refrigerant through the compressor and pumps it into the precooler condenser on the back wall of the freezer. Here, it releases part of its latent heat of vaporization and sensible heat of compression.

From the precooler condenser, the refrigerant passes to the machine compartment and through the oil cooling coil in the compressor dome. The compressed vapor then flows back to the main condenser where the heat is released to the atmosphere.

The refrigerant condenses from a high-pressure vapor to high-pressure liquid. The liquefied refrigerant collects in the bottom of the condenser tubing, flows into the filter-drier, moves into capillary tube, on into the evaporator, an the cycle repeats.

Since chest-type freezers are manually defrosted, condensate (water) is usually drained out through the bottom of the cabinet.
**Piercing valve**
A way to gain access to a hermetic system is to mount service piercing valves on suction tubing, on the discharge tubing (tubing to condenser), on both or on the process tube. A piercing valve is shown in the Figure 11. Many designs of tubing mounted piercing valve have been developed and are available from most well known refrigeration equipment manufacturers.

![Piercing valve mounted on tubing](image)

**Figure 11.** Piercing valve mounted on tubing

**Commercial Refrigeration Systems**
The majority of commercial refrigeration systems are used in food merchandising and food service applications such as supermarkets, food stores, restaurants, commercial and institutional kitchens, etc. Other applications are small systems supplying vending machines for beverages and foods.
Operation fundamentals of domestic refrigeration systems also apply to commercial systems. But many commercial systems using mechanical cycle mechanisms differ in some way from the domestic mechanism, i.e. more complex controls and piping connection etc.
Figure 12 shows a typical open display cabinet system coming under the commercial category.

![Open display cabinet](image)

**Figure 12.** Open display cabinet
Usually, the products need different temperatures of storage. Because of that multi evaporator systems are in use. These systems consists a few evaporating units and common compressor-condenser. Figure 13 shows a multi evaporator system.

![Multi evaporator system](image)

**Figure 13.** Multi evaporator system  
A - Water valve, B - Suction line shutoff, C - Liquid line shutoff valve, D - Low-high-pressure motor control, E - Thermostatic expansion valves, G - Liquid line solenoid valves, H - Two-temperatures valves, J - Check valve, K - Drier, L - Sight glass, M - Distributor

**Evaporators**

In commercial refrigeration, because of customers demand great variety, special evaporator designs are required for many installations. These evaporators vary from coils of tubing immersed in a sweet water bath to forced-circulation evaporators which have the air blown them or by a motor driven fan. Evaporators may be divided into two main groups:
- Those submerged in a liquid such as brine or beverage;
- Those used for cooling air; in run, the air cools contents of the cabinet.

Evaporators for cooling air are of two principal types:
- Natural convection;
- Forced convection.

In natural air convection evaporators, air circulated depends on gravitational (warm air rises, cool air descends) or thermal circulation. Natural convection, air-cooling evaporators fall into three classes:
- Frosting;
- Defrosting;
- No frosting

The condition under an evaporator must work determines its classification. The governing conditions are desired temperature range of the cabinet and the temperature difference between the evaporator and the cabinet.
**Compressors**

Small commercial and air-conditioning plants have a hermetic compressor but some large commercial systems have semihermetic compressors. Refrigerant-cooler motor compressors have an oil pressure lubricating system. This system supplied by a positive displacement oil pump, working in either direction. The compressors are usually equipped with an oil sight glass through which the oil quantity and its suction and discharge shut-off valves with gauge connections. Excessive discharge temperatures can lead to a number of failures, e.g. due to loss oil lubricating properties or forming of acid and thus damage to motor and bearings. Some compressor manufacturers have installed a sensor into the cylinder head, which senses the temperature of the discharge gas next to the valve reed. If the permissible discharge temperatures are being exceeded, the compressor motor will be switched off automatically.

*Reciprocating open drive compressor*

Another commercial system compressor used is the open drive compressor. The original energy source is usually an electric motor. Its rotary motion must be changed to reciprocating motion. A crank and a rod connecting the crank to the piston usually make this change. The complete mechanism is housed in a leakproof container called a crankcase.

**Figure 14. Evaporator**

**Figure 15. Semihermetic compressor**
**Condensers**

The compression process adds heat to the vapor for exactly the same reason that a bicycle pump gets warm in use. The compressor may rise the pressure of the vapor to a level at which it easily condenses at atmospheric temperature, but the compression process adds much heat so that the compressed vapor leaving the compressor is highly superheated.

The pressure at which the vapor condenses is determined by combination of how much vapor is delivered by the compressor, how much heat is extracted by the condenser and the temperature of the condensing medium. Heat will flow out of condenser into the condenser cooling medium; condensation must occur at temperature higher that of the cooling medium. This usually in the range 5-6 °C higher than the cooling medium, depending on whether air or water is used for condensing. Before condensation can occur the superheated must be removed and this is the first function of the condenser, followed by condensation to liquid and then a few degrees of subcooling of the liquid.

**Air-cooled condenser**

Air-cooled condensers are quite common in commercial and air-conditioning systems. Cooling water may be too expensive or corrosive. Longer condensers may be cooled by a big fan built onto the motor or into the compressor flywheel on external drive units. Larger hermetic units use separate motors to drive the fans. Placing a metal shroud around it may increase the efficiency of the fan on an air-cooled condenser. Air fan can be drawn, inducted (led into), or forced through the condensers. These condensers have fins and frequently use a double or treble row of tubes.

**Figure 16. Air-cooled condenser**

Water cooled condensers
Some commercial refrigerating units use water cooled type condenser. This condenser is built in three styles:
- Shell and tube;
- Shell and coil;
- Tube-within-a-tube.
In the shell and tube type, the refrigerant vapor goes directly from the compressor into a tank or shell while the water travels through the tank or shell in straight tubes. The second type also uses a shell but the water travels through the shall in coils of tubing. The third type uses two pipes or tubes: one inside the other. The refrigerant passes one way through the outer pipe, while the condenser water flows in the opposite direction through the inner tube.

![Diagram of a water-cooled condenser](image)

**Figure 17.** Water cooled condenser

**Expansion valves**

An expansion valve is refrigerant control operated by the low-side pressure of the system. Its purpose is to throttle the liquid refrigerant in the liquid line down to a constant pressure on the low-pressure side while the compressor is running. The valves act like a spray nozzle. While the compressor is running, the liquid refrigerant is sprayed into the evaporator. A system using an automatic expansion valve is sometimes called a “dry” system. This is because the evaporator is never filled with liquid refrigerant, but with a mist or fog.

**Operation of Thermostatic expansion valve**

The operation is influenced by three pressure acting on the control element. The bulb pressure \( p_1 \) effects the valve opening modulating movement. The bulb pressures vary with temperature of the vaporized refrigerant and bulb charge. In the closing direction of the valve evaporation pressure \( p_0 \) and regulating spring (nominal value) \( p_3 \) are working.

While these three pressures are balancing, the opening position and thus the unrestricted passage area of the valve remain uncharged. If the evaporator is supplied with too little refrigerant, the bulb warms up and the bulb pressure \( p_1 \) raises the effecting further opening of the valve and thus widening of the cross section of passage. Falling of the evaporator pressure, however, move the valve into closing directions. If the compressor in the off cycle mode is disconnected, \( p_0 \)
will rise since there is no compressor in operation and the valve closes (as long as the bulb pressure $p_1$ does not exceed the closing pressure $p_0$ and $p_1$).

![Thermostatic expansion valve with evaporator](image)

**Figure 18.** Thermostatic expansion valve with evaporator

- $p_0$ – Evaporator pressure, $p_1$ – Bulb pressure, $p_3$ – Pressure equivalent of the regulating spring

**Superheat**

The thermostatic expansion valve is a proportional control. Its control size represents the refrigerant superheat over the saturated evaporator temperature (suction line close to evaporator).

The liquid-vapor-mixture of the refrigerant enters the evaporator in A and should be vaporized completely in E. Between E and the mounting place of the bulb F, the refrigerant vapor is superheated – that means it is heated above its saturation temperature (increase of temperature at constant pressure). This superheat distance reduces evaporator capacity but it is necessary for stable operation of the control valve.

The pressure $p_3$ of the regulating spring determines at what difference between bulb and evaporator temperature the valve will open. This value is called “static superheat”.

**Liquid filter-drier**

The efficient operation of a commercial system depends, largely, on the internal cleanliness of the unit. Only clean, dry refrigerant and clean, dry oil should circulate in the system. These devices (filters and water absorbents) may be in separate units or may build into a single unit. A common method of removing moisture is with a liquid line drier.

**Sight glass - moisture indicator**

The acceptable limit of the safe moisture levels, according to the most authorities, is: for CFC-12 is 50 ppm, for CFC-22 is 60 ppm and for R-502 is 30 ppm. The moisture indication for either of the refrigerants has a two-color indication. The dark green indicates dry and a bright yellow indicates wet.
**Solenoid valves**
The solenoid valves are basically servo controlled. These valves are designed to be fitted into liquid line, before expansion device to prevent flow of refrigerant into evaporator, when the system is shut off. When power is active, the opening force lifts the diaphragm valve plate from the valve seat and holds the valve open until current is cut off.

![Solenoid valve](image)

**Figure 19.** Solenoid valve

**Shut off valves**
These hand valves and service valves must be studied and designed to undertake frequent opening and closing without leaking. Valve stems and packing must be handled with care. The valve should be tight hard when in closing position, because this will damage the mounting flange.

**Heat exchanger**
Liquid line heat exchanger is never used with HCFC-22 but only with CFC-12 or R-502 system and is mounted in the suction and liquid line. There are three advantages:
- It sub cools the liquid refrigerant and increases operating efficiency;
- It reduces flash gas in the liquid line;
- It reduces liquid refrigerant in the suction line.

A heat exchanger provides for a heat transfer for warmer liquid in the liquid line to the cool vapor coming from the evaporator.

If the liquid is cooled 5 to 10\(^\circ\)C at the prevailing heat pressure, it can absorb more latent heat as it changes to vapor in the evaporator. The reduction of flash gas vapor (sometime called flash gas) is important. Refrigerant flash gas is that portion of refrigerant liquid that changes to vapor when pressure is reduced (e.g. when pressure is reduced through a thermo-expansion valve or capillary tube). The flash gas cools the remaining liquid to the lower pressure saturation temperature. This reduces the valve capacity, increases low-side pressure drop and reduces amount of heat each kilogram of refrigerant can absorb as it evaporates. The heat exchanger also helps prevent sweat backs or frost backs on the suction line. If there is low temperature liquid refrigerant present in the returning suction vapor, it will evaporate in the heat exchanger as it absorbs heat from the liquid line.
The liquid receiver is a tank, mounted after the condenser, which is usually equipped with two service valves. One is a liquid receiver service valve mounted between the liquid receiver and the condenser. The other located between the receiver and the liquid line.

Receivers should have safety devices. A thermal release plug provides minimal safety to release gas in case of fire or pressure relief valve. These safety releases should never release refrigerant direct out to the air. A special line should be installed a safety relief valve to the evaporator.

Some receivers are provided with a device sight-glass, magnet floats or valves for determining the level of liquid refrigerant. The receiver should be large enough to hold all refrigerant in the system.

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**Figure 20.** Heat exchanger

**Liquid receiver**

**Figure 21.** Liquid receiver installed with as compressor-condensate unit
**Oil separators**
Refrigeration system works better when the oil is kept in the compressor. Oil in the condenser and evaporator will reduce efficiency of the unit. It is important to keep the oil from circulating in low-temperature installations. It thickens in very low temperatures and becomes difficult to move out of the evaporator.
Oil separators remove the oil from the hot compressed vapor as the vapor leaves the compressor. The oil will separate because the vapor flow slows down as it arrives in the separator. The oil will collect in the separator until a certain level is reached in the oil separator crankcase.

![Figure 22. Oil separator installed in the system](image)

**Refrigerant lines**
Hard drawn copper is usually used to carry the refrigerant around the system. Larger systems are usually designed to use steel pipe. Streamline brazed connections are used to connect the fittings to the pipe. Because of the worldwide environmental focus on refrigerating systems, flare fittings will be used less in the piping and welded or brazed connections will be required.
**Transport Refrigeration**

The food transportation is performed by special vehicles, truck-refrigerators. The area for food storage is an insulated cold room situated within the vehicle. Outside the cold room is fixed a air-cooled compressor-condensing unit. These mobile refrigeration systems are different then commercial ones in view of the original energy source. There are several ways of performance:

- Compressor driven by the vehicle engine. The cooling operation takes place only during the while vehicle engine works;
- Compressor driven by an electric motor. The refrigeration system works only during the vehicle is in state of rest and is supplied by the regular electricity net;
- Compressor driven by combined energy source. This system is applied in big truck-refrigerators and transport by containers. The compressor is directly driven by the electric motor. The power supply is provided by the generator with internal combustion engine. The alternative solution is the electric motor to be connect directly to electricity net (during the vehicle is in state of rest).

![Truck-refrigerator](image)

**Figure 23. Truck-refrigerator**

**Air-conditioning systems**

Several types of comfort systems are in common use. They can be classified by arrangement of the mechanism:

- Self-contained or unit coolers;
- Remote (controlled from distance).

The self-contained system includes:

- Window units;
- Through-the-wall unit;
- Cabinet units.

Remote units are of two types:

- Condensing unit: The evaporator is installed in the room to be conditioned or in the main duct;
- The central air-conditioning plant.
**Self-contained systems (unit coolers)**

**Window units**
Window respectively wall units may be installed on a windowsill or in special wall openings.
The condenser is located in the section of the cabinet that is outside the building. Outside air forced over the condenser by a fan. Inside the room, another fan draws air in through a filter and forces it over the evaporator. The two airflow fans may be driven by same motor.
Windows units are available in several types. One type cools and filters the air and has a fresh air intake. Another type has these same devices, but, in addition, has an electrical resistance heating unit to furnish heat. A third type uses a reverse cycle system (heat pump) to permit the use of the refrigerating units both for comfort cooling and heating.
The condensate (water) from the surface of evaporator is often drained to the base of the motor compressor. A capillary tube or an automatic expansion valve refrigerant control is usually used.
Thermostats control the system. The sensitive bulb is usually mounted at the inlet of the evaporator. A differential of about 3°C is normal.

**Cabinet-package units**
In package air-conditioning, the whole system is mounted in a cabinet. They vary in capacity from 6 - 30 kW or more. Such units are often used in small commercial establishments such a restaurants, stores, and banks.
Package models may have either water-cooled or air-cooled condensing units. Air-cooled models, needed in some localities because of water restrictions, must have air ducts to the outdoors for condenser cooling.

![Cabinet-package unit](image-url)

**Figure 24.** Cabinet-package unit
**Split air-conditioning units**

Split systems are units with air-cooled outdoor condensing unit. Split system consists two main parts: indoor and outdoor unit, connected with insulated cooper pipes. The outdoor condensing unit consists of hermetic compressor (reciprocating or scroll type), air-cooled condenser, filter-drier, package valves, motor and fan. The indoor unit consists of evaporator, thermo-expansion device, air-filter, motors and fans.

Several types of indoor units are in use: floor; wall; ceiling; duct etc. Operating conditions are monitored, and automatically displayed on the indoor unit indicator panel. The governing of the system is usually by a remote controller.

**Figure 25.** Split air-conditioning plant


**Central air-conditioning plant**

In the central air-conditioning plant the evaporator are installed away from the place being conditioned. Cooled brine or water is circulated to the heat exchangers in the various spaces to be conditioned. Refrigeration device which cools water, which is used in an industrial process or in air-conditioning plant, is called chiller.

**Chillers**

There are four basic types of chillers: centrifugal; screw; reciprocating, and absorption.

Compressor-driven chillers can be divided into two types:
- Aerodynamic (e.g. centrifugal compressors);
- Positive displacement compressors (screw, reciprocating).
The refrigeration cycle is similar for each, only the compression device differs. While these compressors can be powered in a number ways including gas engines, by far the most common source of power is an electric motor.

**Centrifugal turbo-compressor chillers**

The centrifugal chillers can be divided into two categories:
- Negative pressure (low-pressure centrifugal chillers);
- Positive pressure (high-pressure centrifugal chillers).

Negative (low) pressure chillers use CFC-11 or HCFC-123, both low-pressure refrigerants. In a negative chiller, the evaporator is at a pressure lower than the surroundings. Hence, all evaporator lakes are leaking into system. These leaks are for the most part air and moisture, which will interfere with the efficient operation of chiller and result in internal corrosion if not removed.

Refrigerant in the condenser portion is generally at a pressure slightly greater than the surroundings; therefore, leaks in the condenser will go outward.

Positive (high) pressure centrifugal chillers use CFC-12, R-500, HCFC-22 or HFC-134a, all medium and high-pressure refrigerants. These systems have pressures that are higher than the surroundings. All system leaks are refrigerants out of the system.

The basic chiller cycle is similar of any vapour compression refrigeration cycle. The gas flows into the compressor impeller and spun around at a very high velocity. The high velocity gas exits the impeller into a diffuser where the high velocity gas becomes a low velocity, high pressure gas. The compressor has been designed to operate efficiently at a given input and output pressure. The difference between the high pressure and low pressure gas is sometimes described as the compressor “head” or “lift”. It is important that substitute refrigerants used in an any compressor operate at pressures similar to the original refrigerant.

The high pressure refrigerant then goes to the condenser, where gives up heat. Heat may be transferred to the air or to cooling water. In this process, the refrigerant condenses into a liquid. In order for the chiller to be economical, it is desirable for the refrigerant to give up as much heat as possible in as small a condenser as possible.

The liquid refrigerant passes through a pressure reduction device. The low pressure liquid enters the chiller evaporator. In the evaporation process the refrigerant again becomes a gas, absorbs heat and cools surfaces around it. In turn, the chiller water is cooled.

The gas leaving the evaporator goes to the compressor where the cycle repeats.

**Chillers with positive displacement compressors**

The most common for chiller applications are reciprocating and screw compressors. Reciprocating compressors draw the low pressure refrigerant into a cylinder. A piston in the cylinder moves to squeeze or compress the gas into a smaller volume, thus increasing its pressure. This high pressure refrigerant gas is then discharged. It travels to the condenser and through the same cycle described above.

**Chillers with screw compressors**

There are two types of screw compressors:
- Single screw;
- Twin screw.
The single screw compressor uses a single cylindrical main rotor that works with a pair of gate rotors. The twin screws compressor uses two interlocking rotors to reduce the volume and increase the refrigerant pressure.

Figure 26. Water cooled screw chiller

Mobile air-conditioning (MAC)

Function
The automobile air conditioning uses a refrigerant system driven by the car's engine (some cars have direct driven compressor) to furnish the cooling action desired. In most cases, warm water from the engine cooling system is used for heating purpose.

The mechanism and controls of a factory installed air conditioning system are designed to ease the task of selecting and controlling car temperature. When operating the air conditioning, the humidity of the air inside the car is reduced. In addition, moisture (condensate) formed on the evaporator surfaces collects much of the dust and pollen. These entrapped particles are carried away by the condensate as it drains from the evaporator underneath the car.

Operation
A cooling unit for automobiles is the compressor mounted on the engine and is driven by a belt. The condenser is mounted ahead of the car radiator. In operation, liquid refrigerant flows from the condenser to the liquid receiver, which driers and filters it. The liquid refrigerant travels through a refrigerant control to the evaporator where it is vaporized and heat is absorbed. The vaporized refrigerant flows back through the suction line to the compressor.

Most mobile air conditioners are driven directly from the vehicle’s engine by means of a belt drive mechanism. The compressor is disengaged from the engine when it is not required by means of a clutch mechanism that is typically electronically engaged.
**Compressor**
There are two types of compressors in use:
- Conventional reciprocating type with crankshaft, connecting rod, piston and cylinder and
- Swash plate type, which use a different reciprocating piston and cylinder arrangement.
The swash plate compressor has a straight shaft and a “swash plate” mounted at an angle to the shaft. Double acting pistons are fitted over the swash plate. As the shaft and swash late revolve, the pistons are caused to reciprocate in the cylinders.

![Swash plate compressor](image)

**Figure 27.** Swash plate compressor

**Refrigerant lines**
Special flexible refrigerant lines are used in automobile air-conditioning applications. Their purpose is:
- To carry liquid refrigerant from receiver-drier to the evaporator expansion valve;
- To carry vapor refrigerant from the receiver-drier to the evaporator to compressor;
- To carry hot compressed vapor from the compressor to the condenser;
- To carry liquid refrigerant from the condenser to the liquid receiver-drier (on some units).
The hoses are commonly covered with a braid to protect them against injury. These hoses are constructed to be flexible and vibration proof and made of steel and cooper. Hoses are fastened to the system parts in various ways:
- Flared fitting;
- O-ring fitting;
- Hose clamp fitting.
Figure 28. Mobile air-conditioning installation

Figure 29. Scheme of mobile air-conditioning installation
4. Good service practices

The intent of the improvement of service practices is to reduce the amount of refrigerant lost to the atmosphere. Reducing emissions of refrigerants should be a goal for all service technicians.

If refrigerant emissions are reduced, a related benefit is that equipment operators will drastically reduce the cost of replacing expensive refrigerant. Additional savings will probably also occur since a well-maintained refrigerant system will run more efficiently and is less likely to require costly repairs.

All service technicians have an obligation to protect the environment against CFC emissions. Every effort must be made to prevent the emissions of CFCs that are presently held in refrigeration systems. A reduction in CFC consumption can only be achieved by reducing refrigerant loses from existing systems, and the main refrigerant losses may be split in to 3 categories:

- Intrinsic leaks;
- Accidental leaks;
- Emissions due to transfer (emptying, filling or purging cycles), because of poor service procedures.

Refrigeration systems must be inspected and maintained regularly. To minimize emissions, the refrigerant and oil must be transferred with as little loss as possible. Any leakage detected must be repaired immediately. To eliminate leaks, the corresponding system section must be isolated, and refrigerant contained in the latter must be transferred either within the system, or into a service container for refrigerant.

**Refrigerant leaks**

The refrigerant in a refrigerating system is never used up. If it is has been determined that a system is low on refrigerant, the system must be tested for leaks, then repaired and recharged. It is a not environmentally sound solution to add refrigerant without first locating and repairing leakage. Adding refrigerant will not permanently correct the difficulty. Attempt to pinpoint the leak before recovering the refrigerant, to avoid contaminating the surrounding air with refrigerant from a newly open system.

The presence of **oil around tubing joint** usually indicates leaks, but does not let this be the determining factor. Always checks area with a leak detector.

**The causes of leakage**

All refrigerant leakages are caused by material failure. The mechanism that creates the material failure is normally attributable to one or more the following factors:

**Vibration**

Vibration is a significant factor in material failure and is responsible for “work hardening” of cooper, misalignment of seals, loosening of securing bolts to flanges etc.;

**Pressure changes**

Refrigerating systems depend on the changes in pressure for their operation. The rate of change of pressure has different effects on the various components in the systems, which results in material stress, and differential expansion and contraction;
Temperature changes
Refrigeration systems frequently consist of different materials, differing materials, and different thickness. Rapid changes in temperature result in material stress and differential expansion and contraction;

Friction wear
There are many cases of frictional wear causing material failure, and they vary from poorly fixed pipework to shaft seals;

Incorrect material selection
In a number of cases, materials are selected that are inappropriate e.g. certain types of flexible hoses have a known leakage rate, and materials that are known to fail under conditions of vibration and transient pressure and temperature changes are used;

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;

Accidental damage
These are rare occasions and care should always be taken to protect pressurized systems from accidental damage.

Mechanical joints
The most likely source of leakage is at mechanical joint, where invariably materials form a junction.

Leak detection
When a system is through to have a leak the whole system should be checked, with leaks found being marked for restriction. It should be noted that traditional “Halon lamps” could not be used with HFCs such as R-134a as they require the presence of chlorine to produce a colored flame. Detection can be made electronically. The sensors have been tuned to measure chlorine or fluorine. Special electronic leak detectors available can be used.

Equipment to prevent refrigerant loss
Many products have been developed to help reduce refrigerant emissions. Many of these are inexpensive when compared to the value of the refrigerant, which can save.

Leak methods and detection equipment
It is important to use the most accurate leak detection method available to locate any system leaks.

Electronic halide detectors
Electronic leak detectors are widely available and accepted. They are relatively easy to use a can detect very small leaks of CFCs, HCFCs or HFCs. They are able to measure refrigerant vapors in the atmosphere at very low concentrations. They are accurate to leak rates as small as 15 grams per year. Because of extremely sensitivity, electronic detectors can only be used in clean atmosphere not contaminated by a refrigerant vapor, smoke, vapor from carbon tetrachloride or other solvents which may give a false reaction.
**Ultrasonic leak detectors**
Ultrasonic leak detectors use sophisticated sensors to “listen” for the high frequency sounds made by a leaking gas. They require a low level of background noise and some experience on the part of the service technician to interpret the results correctly.

**Fluorescent dyes**
If small concentrations of fluorescent dye is placed in the refrigerant and allowed to disperse throughout the system, then the system can be examined visually with an ultraviolet light for any evidence of leaks. This method will only be effective on high pressure lines (points) of the systems.
**Refrigerant monitor**
If the equipment room where the system is located has a refrigerant monitor, this can be used to detect lakes. Refrigerant monitors today are very sensitive and can detect very low levels of refrigerant in the atmosphere. They are more useful as a safety device, but if a leak is large enough to detect, they can point out the existence, but not its location. It is very important to have a refrigerant monitor present in the equipment room for safety and code reasons.

**Soap solution**
Soap solutions work well in leak testing specific areas of the system. The soap bubble method will not detect very small leaks or leaks located in inaccessible areas. The soap solution will indicate a leak when it is placed directly on an area, which is leaking refrigerant vapor. The vapor leaking past the soap causes bubbles to form in the area of the leak.

![Detection by soap solution](image)

**Halide torch**
A halide torch can also be used as a leak testing option. However, it has poor sensitivity. The flame of this propane powered torch changes color when refrigerant gas is passing through it (small amount of refrigerant has a bright green color, large amount – violet). The torch must not be used in the presence of explosive fumes or gases. Much experience may be needed to develop the skill necessary to find small lakes with halide torch.

**Oil stains**
A trained service technician can identify a badly leaking refrigeration system by the presence of oil stains on the outside of the equipment. If refrigerant leaks out, lubricant oil leaks out as well, but it doesn’t evaporate rapidly and remains on the outside of the equipment and pipes, identifying the leaks area.
Contaminants in the refrigeration systems
The main problem areas in vapor compression refrigerant or air conditioning systems are presence of moisture and dirt (contaminants) in the system, problems with the lubricant and leak of refrigerant.

Moisture and acid
Moisture is the cause of several operating problems in vapor compression systems. Moisture can be classified as a visible and invisible. “Visible” moisture is high concentration of water, can be seen with the eye, and is in liquid form. Liquid water is found in systems but this is rather unusual.
“Invisible” moisture is low concentration water and cannot be seen with the eye (vapor). Its content in the air is expressed in term’s relative humidity.
Moisture can get to a system easily but is hard to get out.

Moisture in the system
The moisture within a system can freeze-up and stop refrigerant flow. Moisture will generally be picked up by the refrigerant flow and can become entrained in the liquid line near the expansion device and freeze causing a restriction or even block flow. As the expansion valve warms, due to the lack of refrigerant, the ice melts and moisture returns to the expansion valve and once more generates an intermittent cooling.

Corrosion
Moisture can also induce corrosion. Moisture in form of water alone can cause rust after a period. However, moisture plus the refrigerant creates much more corrosions problems. Refrigerant such as CFC-12 containing chlorine will slowly hydrolyze with water and form hydro-choleric acids. This acid greatly increases the corrosion of metals.
Heat increases the rate of corrosion due to acids because at higher temperatures the acid-forming process is accelerated. This acid attacks all the materials it contacts the rate of corrosion of the individual materials being determinate by their corrosion-resistant qualities. Steel will generally corrode at lower moisture levels than cooper or brass. Refrigeration lubricant presents another caused by moisture. Polyol ester (POE) refrigerant lubricant is an exemption to the rule that “oil and water don’t mix”. This type of refrigerant lubricant has a hygrooscope affinity for moisture and will absorb it rapidly if left open to the atmosphere. Mineral lubricants do not mix with water in the same range as POE lubricants.
Water changed into acid emulsifies with refrigerant lubricants, the two forming an intimate mixture of exceedingly fine globules. This effect is called “slugging” of the oil and greatly reduces its lubricating ability.
Corrosion becomes troublesome from the operating standpoint when the metallic surface is eaten and a solid, detachable product is formed. This formation is commonly known as “sludge”. Sludge exists as slimy liquids, fine powders, granular solids or strictly solids and causes a variety of problems. They can plug fine strainers, expansion valves and capillary tubes. In addition, because they usually contain acids they corrode whatever they ceiling to, accelerating damage.
To eliminate moisture problems it is necessary to take precautions and actions which will ensure a moisture-free system. The most effective way to eliminate moisture from a system is through the use of a high vacuum pump and the key point is the level of vacuum.
The recommended level of evacuation is of 1 milibar absolute (100 Pa) to achieve the evacuation of moisture. This level of vacuum must be maintained for 10 minutes without the help of a vacuum pump.
Another method is changing filter dryers.
**Symptoms when moisture is present**

Moisture in the refrigerating system will affect the oil and could cause the unit to malfunction and a hermetic compressor to burn out. The main sources for moisture to enter the system are when there is leakage to the ambient, or during service and repair, when filters or lubricant is changed.

The moisture forms ice in the refrigerant control device. Icing closes the opening, blocking flow into the evaporator.

This condition can be recognized by several observations:

- The system will completely defrost. Then, since the icing, which caused the blockage, has disappeared, the unit will work properly again. But only for a while until ice again forms at the refrigerant control;
- Another symptom is decreasing pressure. The suction pressure gauge shows a steady decrease even to a vacuum. After while time, when the blockage has disappeared, pressure becomes normal again. This abnormal cycle will keep repeating;
- If, during system shutdown, one warms the refrigerant control device with a safe resistance heater, the ice will melt. Should the system then begin to work properly, there is definitely moisture in the refrigerant.

**Dirt**

A danger to the system is also particles of dirt, which means any solid matter allowed to enter open pipes, valves and other parts. Again this possibility exists particularly where renovations are taken place or when new premises are being built. The dust seen to accumulate on outer surfaces in evidence of that can be taking place inside if permitted to do so. The quick plugging of open lines is necessary for the prevention of this danger as well as the elimination of air.

**Foreign matter**

Another risk is the introduction of foreign matter through carelessness. For example, fill-ins may be allowed to enter copper tubing when cleaning the tube ends before flaring. Obviously precautions must be taken to prevent this happening, either by filling with tube and facing downwards or where is not practicable, by plugging the tube with clean rag. Another possibility is that of solder used excessively following through the join into the tube, where it may solidify into mobile particles of varying sizes. If this occurs on the compressor suction theirs is a real danger of these particles causing serious damage. In any case, obstruction filter may result.

**Internal scaling**

During the process of brazing, internal scaling may take place which will become dissolved when refrigerant passes through, again causing possible obstruction. To prevent this, a wisp of oxygen-free dry nitrogen (white spot) should be introduced within the piping whilst brazing; this removes the oxygen and prevents scaling. Even with every precaution having been taken, it is still good practice to insert cloth filters into the compressor suction to collect any debris remaining before it can enter the compressor. These filters must not be left permanently since they restrict refrigerant flow, and should be removed after a day or so of operation.

**Purging**

Purging is term used to describe the process of removing unwanted air, vapors, dirt’s or moisture from the system. A neutral gas such as Nitrogen is allowed to flow through the refrigerator part or tubing, forcing unwanted air and vapors out.
**Non condensables**

Gases other than refrigerant are contaminants that are frequently found in the air conditioning and refrigeration systems. These gases infiltrate sealed systems in the following manner:

- Non-condensable gases are present during manufacture and remain due to incomplete evacuation;
- Non-condensable gases are disrobed from various system materials or formed by decomposition of gases at elevated temperatures during system operation;
- Non-condensable gases enter through low side (below atmospheric pressure – low pressure chillers etc.) leaks;
- Non-condensable gases are formed from chemical reactions between refrigerants, lubricants and other materials during operation.

Chemically reactive gases, such as hydrogen chloride, attack other components in the refrigerant system.

Chemically inert gases in the system, which do not liquefy in the condenser, reduce the cooling efficiency. The quantity of inert non-condensable gas that is harmful depends on the design and size of the refrigerating system and nature of the refrigerant. Its presence contributes to higher the normal head pressures and resultant higher discharge temperature.

Gases found in hermetic refrigeration units include nitrogen, oxygen, carbon dioxide, carbon monoxide, methane and hydrogen.

**Oil in the system**

Special oils are used for lubricating the refrigerant compressors. The brand of oil originally supplied is often specified on an oil data plate and is suitable for the relevant operation conditions. If has been added, the same brand should be used. Avoid mixing different brands of oil. Motor oils cannot be used in system with CFC-12 or HCFC-22 compressors, nor can used oil be applied even when it is reclaimed. Used oil absorbs moisture from the air.

The oil should be stored in a closed air-tight container in dry surrounding, and only dry vessels may be used for filling.

**Refrigerant oil**

When 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 the majority of the lubricant remains in the compressor pump, a small amount will be circulated into the rest of the refrigerant circuit. The lubricant must be able to withstand both the high temperatures at the compressor discharge valves and the low temperatures at the expansion device.

Transport properties are essential to ensure minimal system hold up and lubricant return to the compressor, thereby avoiding the extreme condition of compressor oil starvation. The combined properties of viscosity, surface wetting characteristics and refrigerant solubility (to keep oil fluid at a low temperature) not only contribute to lubricant circulation, but also affect film characteristics on heat transfer surfaces and subsequently energy efficiency performance. 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 valves of 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.** Ability of the oil to remain in a fluid state at the lowest temperature in the system;
• **Low viscosity.** This is the ability of the lubricant to maintain good oiling properties at high temperatures and good fluidity at low temperatures; to provide a good lubricating film at all times.

**Miscibility with HFC refrigerants**
Lubricant manufacturers have developed a wide range of new polyol ester (POE) lubricants that have been specifically synthesized to provide miscibility (ability of two liquids or gases to uniformly dissolve into each other) with HFCs and HFC-134a. The lubricants have been tested with many refrigerant gases and found miscible with most CFCs, HCFCs and HFC-134a.

**Hygroscopy**
The POE lubricants are more hygroscopic than naphthenic mineral oils. They saturate at approximately 1000 ppm from atmospheric moisture, compare to about 100 ppm for mineral oils. The POE lubricants are considerably less hygroscopic than polyalkylene glycol lubricants (the first generation of oil dissolved for use with HFC-134a) which saturate in excess of 1% water (10,000 ppm) condition.
Service practices

Review of safety
The term safety, as applied to any refrigerating or air conditioning activity, may have three different applications. It may apply to:

Safety of the operator
When refrigerant and air conditioning equipment is properly handled, there is relatively little danger to the operator. Always pull on a wrench (instead of pushing), to prevent possible slippage of the wrench, which could cause rounded corners on nuts and bolts and possible injury to hands. A hoist is recommended for fitting anything weighing over 13 kg.
Always use leg muscles when lifting anything objects, never the back muscles. Make certain there is no oil or water on the floor. Always wear safety goggles when working with refrigerants.
Most refrigerating mechanisms are electrically driven and controlled. When working on electrical circuits, make sure that the circuit is disconnected from the power source. This can usually be accomplished by opening the switch at the power panel.
Machinery room ventilation should be switched on when operators are working in such room.

Safety of the equipment
Many parts of refrigeration and air conditioning equipment are quite fragile. Parts may be ruined by over tightening nuts and bolts, not tightening them in the correct order, or using wrong size wrench. Make certain that all connections are tightened before operating a compressor. Before operating open compressors, be sure the flywheel and pulley are in alignment that guards are in place.

Safety of the contents
Safety of the contents of the refrigerant space depends entirely on the accuracy and care given the installation and adjustment of the various parts of the system. Observe the operation temperatures to provide safe conditions.

Refrigeration hand tools
In service refrigeration jobs, some specific tools are needed to do the job professionally. Cutters, reamers, flaring, benders etc, are general tools, which a service technician should have the necessary knowledge to use to prevent system leakage because of bad flaring and connections.

Cutter for hard and soft copper, brass, aluminium, thin wall steel, Monel, stainless steel titanium and other tubing. This design is for use tight quarters where other cutters will not fit. Perfect for instrument panels, control cabinets, freezers, refrigeration units etc. Designed for cutting sizes from 1/8” to 1 1/8”. On top of the cutters, there is also a reamer, which should be used whenever cutting pipes.
Figure 29. Cutters

*Flaring tool rolls* out 45° flares above die block then automatically burnishes flare face. Flaring tools will be used when new connections are needed or old pipes connections are damaged or leaking.

Figure 30. Flaring tool

*Reamers* for use both inside and outside edges of tubes. Must be used whenever cutting pipe at installation or flaring. To prevent copper or other piping material remaining loose in the pipe or blocking the pipe opening.
Figure 31. Reamer

*Tube benders* for bending soft copper, brass, aluminium, steel, stainless steel and other materials. Bend to 180°. Makes piping and installation look better and gives better refrigerant flow inside the tubing.

Figure 32. Benders
Evacuation of the systems

Vacuum
The refrigerant is sensitive to moisture in the system. To understand how water behaves and how to dry out a system, the following natural low must be understood.

The boiling point of water varies depending on pressure. In SI units, pressures are expressed in kPa (kilopascals). Normal atmospheric pressure is 101.3 kPa (760 mm Hg column). However, for practical purposes, gauges are often calibrated at 100 kPa for atmospheric pressure. Pressures lower than atmospheric are called partial vacuums. Zero on the absolute pressure scale is at a pressure, which cannot be further reduced. A perfect vacuum is zero Pa. The Pascal, rather than kilopascal, is used for measuring high vacuums. The relationship between absolute and gauge pressure is also important to understand when performing a vacuum procedure. Gauges are normally calibrated to read zero at the atmospheric pressure (but not always).

Vacuum pump
To be able to properly evacuate a system a good vacuum pump is needed. Vacuum pump should:
- have a flow rate suitable for the system to be evacuated;
- be a two stage design;
- have high pumping efficiency;
- have gas ballast eliminating condensation of vapor within the pump intake and exhaust filter.

![Figure 33. Vacuum pump](image)

Evacuation
A refrigerating system must contain only the refrigerant in liquid or vapor state along with dry oil. All other vapors, gases, and liquids must be removed. These substances can be removed best by connecting the system to vacuum pump to run continuously from some time while a deep vacuum is drawn on the system. It some times necessary to warm the parts to 49°C while under a high vacuum, in order to remove all unwanted moisture, heat the parts using warm air, heat lamps or water. **Never use a torch.**
Always evacuate the system when:
- Replacing a compressor, condenser, drier, evaporator etc;
- The system has no refrigerant;
- The refrigerant is contaminated;
- The refrigerant lubricant is charged.

**Charging Manifold**

Using an evacuating and charging manifold is good practice when performing system evacuating or charging. When system uses tire valve access fitting (if refrigerant compressor type have not assembled with inlet/outlet valves) connect end of hoses to access fittings, according the Figure 34 below.

![Charging Manifold Diagram](image)

**Figure 34. 4-valve manifold**

**Table 3. Instructions for service manifold**

<table>
<thead>
<tr>
<th>To purge hoses</th>
<th>To evacuate and charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>A,C,D Open</td>
<td>A,B Closed</td>
</tr>
<tr>
<td>B Closed</td>
<td>C,D Open</td>
</tr>
<tr>
<td>1,3,4 Connect as shown but not tightened at and opposite manifold</td>
<td>1,3 Connect as shown</td>
</tr>
<tr>
<td>2 Connect as shown</td>
<td>H,L Crack open off back seat</td>
</tr>
<tr>
<td>B Open to begin purge</td>
<td>If gauge shows pressure, complete Purge System before proceeding</td>
</tr>
</tbody>
</table>

**To charge refrigerant into suction side**

<table>
<thead>
<tr>
<th>A,B,D Closed</th>
<th>A Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>C Open</td>
<td>H,L Open to mid position</td>
</tr>
<tr>
<td>1,2,3 Open</td>
<td>2,4 Connect as shown</td>
</tr>
<tr>
<td>H Crack open off back seat</td>
<td>Start pump and complete evacuation</td>
</tr>
<tr>
<td>L Open to mid position</td>
<td>A Close and stop pump</td>
</tr>
<tr>
<td>B Open and regulate flow</td>
<td>H Crack open back seat</td>
</tr>
</tbody>
</table>
To purge system

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A,B</td>
<td>Closed</td>
<td>B</td>
</tr>
<tr>
<td>C,D</td>
<td>Open</td>
<td></td>
</tr>
</tbody>
</table>

To observe operation pressure

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1,3</td>
<td>Connect as shown</td>
<td>C,D</td>
</tr>
<tr>
<td>4</td>
<td>Connect to manifold and direct opposite end to vent</td>
<td>1,3</td>
</tr>
<tr>
<td>H,L</td>
<td>Crack open off back seat</td>
<td>H,L</td>
</tr>
<tr>
<td>A</td>
<td>Open to begin purge</td>
<td></td>
</tr>
</tbody>
</table>

Evacuate and charging
To evacuate and dehydrate a system, before filling with refrigerant.

- Pressurize the system with nitrogen (N₂). Leak tests, keep pressure over a period of time, and see if gauge changes.
- When the system is found free from leakage, blow out the N₂. Connect a proper vacuum pump to both suction side and discharge side of compressor. Open all valves, also solenoid valves. Use a service manifold with gauges. Allow time for diffusion of water vapor and air.
- When satisfactory vacuum has been reached (100 kPa) stops the pump and leaves it for a few hours to see if the gauge moves towards atmospheric pressure. If so happens there could be two reasons for it, there is either a leak or still moisture in the system. If the pressure (vacuum) remains substantially the same over a period, the circuit is correctly evacuated and dry, free of leakage.
- Charging of refrigerant can now begin, either direct to the high-pressure liquid side or charging into the suction side when the compressor is running.

Figure 35. Charging refrigerant with service manifold
Oil changing
Most welded hermetic compressors have no means of determining the oil. This type of compressor is primarily designed for installation in factory designed, assembled, and charged systems where the oil charge is accurately measured into the system at the time of original assembly. In case of leak, if the amount of oil lost is small and can be reasonably calculated, this amount is added to the compressor. If however, there is major loss of oil, the service technician must remove the compressor, drain the oil, and add the correct measured charge before replacing the compressor.

Semihermetic and open type compressors are normally equipped with crankcase sight-glasses; the oil level should be maintained at or slightly above the centre of the sight-glass while operating. An abnormally low oil level may result in a loss of lubrication; while excessively high oil level may result in oil slugging and possible damage of compressor valves or excessive oil circulation. The oil level may vary considerably on initial start-up if liquid refrigerant is present in the crankcase, and the oil level should be check with the compressor running after having reached a stabilized condition.

Some refrigerant will always be absorbed in the oil and to avoid emission of refrigerant, an alternative can be to install an oil heater or use a recovery unit before opening the oil connection. A possible procedure would then be:

- Operate the oil heater;
- Exhaust the gaseous refrigerant (recovery unit);
- Drain the oil into appropriate and marked vessels, if necessary with the help of nitrogen.

Recharge oil to a hermetic compressor
The recharge with a measured amount of oil, the compressor must be removed from the system, and the oil must be drained out from the suction line stub by tilting the compressor. The exact amount of oil must be clear before recharging is starting. Check the instruction manual for correct charge.

To avoid too much mixture of refrigerant in the oil and to avoid emission of refrigerant, an oil heater could be installed.

Adding oil to a semihermetic or open compressor

Open system method
If the compressor is equipped with an oil fill hole in the crankcase, the simplest means of adding oil is to isolate the compressor crankcase, and pour or pump the necessary oil in. If the system contains no refrigerant, or compressor is open for repairs, no special precautions are necessary other than the normal measures of keeping the oil clean and dry, since the system should be evacuated before start up.

If the compressor contains a charge of refrigerant, close the compressor suction valve and reduce the crankcase pressure to approximately 7 or 14 kPa. Stop the compressor and close the compressor discharges valve.

Oil pump method
Many service technicians have either made up or purchased a small oil pump for adding oil to compressors. The addition of oil to an operating compressor is through the service port if necessary; or it can be used to add oil directly to the crankcase where space may not permit a gravity feed. When the compressor is in operation, the pump check valve prevents the loss of refrigerant, while allowing the service technician to develop sufficient pressure to overcome the operating suction pressure and add oil as necessary.
In an emergency where an oil pump is not available and the compressor is inaccessible, oil may be drawn into the compressor through the suction service valve. Extreme care must be taken to insure that no air will be drawn into the compressor.

**Impact of the lubricant on recovery measures**

Since the advent of new non-ozone depleting HFC refrigerants, which are not compatible with normal oils, oil manufacturers have been develop a new series of HFC miscible lubricants. Use of a conventional immiscible lubricant in conjunction with HFC-134a adversely affects the efficiency of the refrigeration unit. In such case, the immiscible oil separates in congealed masses from the refrigerant within the condenser and thus impedes flow especially through expansion devices (capillary tubes or expansion valves) often causing “superheating”. Once through the expansion device, the immiscible oil will settle on the bottom of the evaporator tubes causing further degradation in flow and heat transfer. In some cases, lack of oil to the compressor can promote component wear and eventual failure through lubricant starvation.
Servicing

Servicing domestic refrigerators and freezers

Tools
When servicing a hermetic domestic system, the following tools are available to be able to perform a good service job without unnecessary release of refrigerant:
1. High vacuum pump;
2. 1 pc.3/8” dia. By 1,5 m vacuum hose;
3. Recovery/recycling unit;
4. Service cylinder for refrigerant;
5. 1 purging line 1/4” dia. by 1 m equipped with hand shut-off needle valve and check valve;
6. Capillary tube cleaner;
7. Capillary tube sizing kit;
8. Soldering-brazing torch, either LP fuel-air, oxyacetylene;
9. Hand vacuum cleaner
10. Gauge manifold
11. Process tube adapters;
12. Bending springs;
13. Leak detector.

Changing filter drier
When moisture or dirt is present in a system, it may be removed by fitting a drier in the liquid line. This is basic procedure to follow:
1. If no connection valve, install piercing valve;
2. Install gauge manifold;
3. Remove the refrigerant with a recovery unit to a recovery cylinder;
4. Dry and clean filter connections;
5. Apply flux;
6. Heat connections;
7. Braze connections;
8. Install new drier;
9. Pressurize and test for leaks;
10. Evacuate system;
11. Charge system with virgin or recycled refrigerant. Use a charging cylinder for correct charge;
12. Warm the control enough to melt ice. The drier will absorb this moisture as it circulates;
13. Install new drier after some hours running

Burn out filter
Special “Burn out” suction cleaning filter dryers are available for cleaning, decontaminating and thoroughly controlling pollution of liquid refrigerant circuits. Recommended for “Burn out” function and circuit cleaning operation after compressor burn out.
High head pressure is one of the most frequent reasons for motor burnout. This pressure creates very high temperatures as the gas passes the discharge valves of the compressor. The high temperature increases chemical action, adding to or creating new carbon and sludge. If the discharge line to the compressor reaches excessive temperatures, oil breakdown will take place.
**Clean up after motor burnout**

When a motor begins to burn out, it is overheated. The overheating will cause the refrigerant to break down, and if moisture is present, to form hydrochloric and hydrofluoric acid. Oil in this condition is said to be “acidic”. The acid will cause insulation on motor windings to deteriorate and increase the motor temperature. Eventually, the motor windings will short circuit and burn out. If system has a motor compressor burnout, refrigerant controls should be repaired or replaced. Flush the system with the same refrigerant used in the system.

Do not release the refrigerant to the atmosphere.

Do not touch the oil from a burnout compressor, as it will cause a severe acid burn. Wear goggles and rubber gloves.

**Charging with portable charging cylinder or digital scale**

A charging cylinder, with glass tube liquid level indicator, allows a technician to transfer 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. In some cases, the compressor itself is heated, using a heat gun so the refrigerant and oil will circulate and be purged more easily.

In both cases, 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 a system. It also has valve at the top of the cylinder. This valve is used for charging refrigerant vapor into the system.

The following steps are recommended for use of a portable-charging cylinder after evacuation. Wear goggles and follow these steps:

1. Attach a line from the charging cylinder to the centre of the gauge manifold and purge with the fitting loose at the centre part of the gauge manifold. See Figure 36. Tighten this connection;
2. Open the piercing valve or valve adapter and gauge manifold valve;
3. Crack the charging cylinder valve and allow the refrigerant to enter the system. Know what the new scale reading on the tube must be to put in the correct charge;
4. When the correct amount of refrigerant has entered the system, close the cylinder valve. The amount can be checked by reading the scale on the charging cylinder;
5. Close the piercing valve or the valve adapter and the gauge manifold valves;
6. Use the pinch-off tool and close off the process tube between the compressor and the adapter. Leave pinch-off on tube until tube end has been brazed;
7. Remove the piercing valve or the valve adapter;
8. If a piercing valve was used, cut off the part of tubing with hole in it. Use a pipe cutter.
9. Crimp the end of process tube;
10. Braze the end of the process tube;
11. Check the system for leaks.
Servicing commercial systems
To perform a quality service on commercial system some major tools are required. The tool list below covers mostly all service tasks, but we describe only how to charge a commercial system to avoid release of refrigerant.

Service equipment
Two major items of concern are:
1. Obtain and use a high quality tools;
2. Keeping complete records of each job.

Most companies provide a panel truck or pickup equipped with major items such as:
- Vacuum pump, recovery&recycling unit;
- Tubing and piping;
- Combination soldering, brazing, and welding outfit;
- Supply of replacement parts and materials
  - Controls
  - Fittings
  - Oil
  - Refrigerant
- Leak detectors (electronic tester);
- Electrical testing instrument.

Charging commercial system
When charging a system, the quantity of charged refrigerant must always be weighted, and refer to the manufacturers directions if they are available. The manufacturer has designed and tested the products under various operating conditions and has developed specific charging procedures.
In general, there are two basic methods used to charge a system:
1. Low-side method
2. High-side method

**Low-side**
In the low-side method, charging small quantities of refrigerant into commercial systems is similar to charging domestic machines. Charging into the low side (vapor method) usually does it. To charge a commercial external derive system equipped with service valves, the storage cylinder should be attached to the gauge manifold. Charging lines must be clean and evacuated to get the air and moisture. Connections must be tested for leaks prior to the actual charging operation.
In the low-side method, the principle of operation is to use the service cylinder as a temporary evaporator in the system.
As the compressor runs, it will remove refrigerant vapor from the cylinder as well as from the evaporator. Charging may be speeded up by partly closing the suction service valve to reduce flow from the regular evaporators and speed the evaporation from the service cylinder. Hot water may apply to the service cylinder to help speed the evaporation. The low-side pressure should be kept at normal levels. Too high a pressure may overwork the compressor. Pressures, which are too low, may cause oil pumping. A service cylinder must not be left connected into a system. It is very important that liquid refrigerant is not allowed to reach the compressor. The liquid is not compressible and the compressor valves, even the bearings and rods, be ruined if the compressor should pump liquid. Although it is not usually recommended, some service technicians do put liquid refrigerant into the high-pressure side of the system. The compressor should not run while this charging is being done.

![Diagram of a low-side commercial system charging](image)

**Figure 37.** Low-side commercial system charging

**High-side**
Larger systems are equipped with a liquid charging valve on the receiver. This is a dangerous practice because dynamic hydraulic pressures are possible, which may rupture the lines, causing considerable damage. However, this method can be used to put initial charge into a system, if done very carefully.
In one inverts a cylinder and it has a higher pressure than the system, liquid refrigerant will be forced into the system. One reason this practice is discouraged is that if the compressor exhaust valve is leaking, liquid may enter the compressor cylinder and damage the compressor when started. If the unit is water-cooled, the pressure in the liquid receiver, with the water flowing, will be sufficiently below that of the pressure in the cylinder to permit opening of the two valves after the charging line has been evacuated. The pressure difference will force refrigerant from the cylinder into the system.

If the unit is air-cooled, pressure in the refrigerant drum must be increased. This may be done using the compressor to pump vaporized refrigerant into the cylinder, increasing its pressure.

In detail, this method is follows:

1. Connect the refrigerant cylinder to gauge manifold with a flexible charging line. Never use a disposable container here. It may explode.
2. Run the compressor for a few revolutions with the discharge service valve turned all the way until a pressure of 242 to 311 kPa above the condenser pressure is built up in the cylinder.
3. Stop the compressor.
4. Invert the refrigerant cylinder (be careful not injure the line).
5. Turn the discharge service valve part way out. High pressure on the surface of the refrigerant in the cylinder will force liquid into the system. While the liquid is flowing into the high side, a gurgling sound may be heard. If this sound stops abruptly, it means that the cylinder has been emptied. Use this method only if all refrigerant has been removed from the system.

![Figure 38. High pressure side charging](image-url)
Servicing air-conditioning systems

Small air-conditioning systems

A number of conditions may cause the refrigerant oil inside the compressor to become hot. The presence of hot refrigerant oil in the refrigerant circuit will result in problems, which can only be corrected by changing the compressor (Burn out). If the hot refrigerant oil is left the circuit, the compressor motor cannot be used again.

Servicing package units

In servicing water-cooled package system, the difference to note is the water flow through condenser. When city water is applied, a water flow regulator should be installed to maintain a constant condensing pressure. The setting pressure should be no less approx. 12 kPa.

If new unit is installed, be aware of the shipping brackets. The compressor in the outdoor unit or inside the cabinet of the package unit is mounted on rubber isolators, and is rigidly held during the shipment by shipping bolts and brackets. Never operate the compressor with the shipping brackets still attached.

Panels must be removed to work on internal parts of the unit. Periodic maintenance duties include replacing the filter of cleaning it, cleaning the evaporator and fins, cleaning the fan motor and oiling it (unless it has sealed bearings), and cleaning the drain pan and drain tube. The inner lining of the cabinet sometimes gathers lint. This should be removed by vacuuming.

It is important to check the refrigerant charge, the operation of the thermostatic expansion valve, and the water flow. A regular maintenance schedule is necessary if the owner is so receive long and satisfactory service from the air conditioning system.

Maintenance and servicing split AC units

Maintenance

The unit should be periodically inspected in order to ensure dependable operation and long life. Should be given attention to:

1. Compressor: No maintenance work is required for the hermetic compressor, if the refrigerant cycle remains sealed. Only cleaning and discharge temperature should be done to avoid too high pressure;
2. Outdoor condenser: Inspect and remove any accumulated dirt from the coil at regular intervals. Other obstacles restricting airflow should be removed;
3. Outdoor fan: Inspect abnormal sound or any dent or crack and remove any accumulated dirt from the fan;
4. Air filter: The air filter cleaning work should be done by end user when filter indicator is turned on or (if no indicator) at regular intervals;
5. Indoor evaporator: Inspect and remove any accumulated dirt from the coil at regular intervals;
6. Indoor fan: Inspect and remove any dent or crack and remove any accumulated dirt from the fan;
7. Condensate drain pan and drain piping: Inspect and clean the condensate drain piping at least twice a year;
8. Electrical equipment: Inspect working voltage, input, amperage, power factor and phase balance. Check for faulty contact caused by loosened terminal connections, oxidized contacts, foreign matter and other items.
Evacuation and charging

1. Check to ensure that the stop valves for outdoor unit are completely closed;
2. Connect the indoor unit and outdoor unit with field-supplied refrigerating tubes;
3. Connect the gauge manifold by charging hoses with a vacuum pump, a refrigerant charging cylinder and nitrogen cylinder to the check joint of the liquid line stop valve;
4. Check for any gas leakage at the flare nut connection, by utilizing nitrogen gas to increase the pressure inside the tubes;
5. Operate the vacuum pump until the pressure decreases to less than pressure of 100 kPa in vacuum;
6. Fully open the gas line stop valve;
7. Slightly open the liquid line stop valve;
8. Charge the required refrigerant by setting the remote control switch at “Cool” and by operating the unit;
9. Ensure charging of correct volume by using the charging cylinder or a weight scale. Excess or a shortage of refrigerant is the main cause of trouble to the units. Check date plate on outside unit;
10. Fully open the liquid line stop valve after refrigerant charged;
11. Leak tests the system.

Servicing MAC system

Servicing an automobile air conditioner is about the same as servicing a standard air conditioning system and commercial systems.

Servicing usually starts with customer’s complaint or during an annual check of the system. Owner’s complaints received most commonly are:


Before servicing a MAC system, know what performance to expect from the unit. Always check the system thoroughly to find the correct cause. Shut off the engine and install a gauge. Attach a gauge manifold to the automobile air conditioning system before braying to service it. Fitting the gauge into the automobile system should be done as normal procedure as with any other refrigerating systems. Never use a manifold set which has been left open to the air after the manifold and lines have been cleaned and dried.

Some compressors are fitted with gauge openings at both the suction service valve and the discharge service valve.

Abnormal low side and/or high side pressures or noise will signal the need for service.

Adding oil to system

The compressor must have the correct amount and type of oil. For hot systems, 500-viscosity refrigerant oil is best. It must be clean and dry. Too much oil cause oil pumping, reducing the efficiency of the system and possibly causing damage to the compressor valves. Too little oil will cause rapid wear of the compressor bearings, piston rings, and valves. It will also cause scoring of the shaft seal. Therefore, it is important to check the oil level each time a unit is serviced.

The check system oil, install the gauge manifold. Evacuate the lines. Turn suction service valve in all the way. Run the compressor until the compound (low-side) gauge reads zero Pa. Then, turn the discharge service valve in all the way. Remove the oil level plug, and check the oil level. If the oil is too high, it will drain out. If too
low, add oil by siphoning it into the compressor with the compressor crankcase at a partial vacuum. Use either a vacuum pump or the compressor to create this vacuum.

Some compressors must be removed from the system to check the oil level. Others require a hand-made dipstick. The wire dipstick is inserted through a bolt hole in the compressor crankcase to check the oil level. Check service manual procedures if in doubt.

Specially prepared oil should be used in the refrigerating system because the oil circulates throughout the system with the refrigerant but most of it stays in the compressor. It must lubricate whether it is very cold or very hot and it must be dry.

**Vacuum drawing**

A common failure on MAC systems is caused by vibration, which causes leakage. To minimize the release of refrigerant, charge should always be carried out correctly. Residual air in the cooling cycle results in increased high pressure, corrosion to the metallic part, and clogged expansion valve. Remove air from the cooling cycle thoroughly whenever disconnecting the cooling cycle line. This operation is called vacuum drawing.

Vacuum drawing procedure:

1. Connect the gauge with one hose to the high-pressure side on compressor. Connect the charging hose to the air purge valve and refrigerant gas bottle. Open the high-pressure valve, low-pressure valve, and vacuum pump valve (or vacuum pump stop valve when the 2 – valve manifold gauge is connected). Operate the vacuum pump until the low pressure gauge indicates 700 mmHg or more.
2. Start drawing vacuum for 15 minutes.
3. Stop drawing and wait for 5 min.
4. Check the gauge.
   - If abnormal pressure:
     Check the pipes and missing O-rings. Tightening the pipes or replace them.
   - If normal pressure:
     Charge a small quantity refrigerant.
5. Leak test;
6. If gauge indicates normal pressure, charge accurate refrigerant quantity.
7. Leak test.

**Charging the system**

The system is charged by means of the service manifold. Connect the manifold to the system. Then connect the charging cylinder to the manifold and evacuate the hoses. If only a small amount of refrigerant is to be added, charge through the low side with cylinder upright. If the complete charge of the cylinder is to be put in the system and if the system is under vacuum, charge the refrigerant into the high side in liquid form.
Figure 39. Charging typical MAC system

Leak testing

Check for refrigerant leaks by using a trace chemical, electronic leak detector, soap solution, or pressure rise method.

Some technicians will put into the refrigerant collared with reddish dye. Then, red discoloration on the metal surfaces will reveal the source of the leak. Most frequently, leaks are found with the halide torch leak detector. If there is refrigerant vapour in the air sample, the flame will turn green.

When CF-12 is burned, very poisonous phosgene gas is produced. Avoid breathing fumes when leak testing a MAC system with a torch type tester.

The fluorescent leak detection system is used on residential, commercial, and automotive systems. It uses a high-intensity ultraviolet lamp; a mist infused tool, and specially formulated fluorescent additives to find the smallest possible leaks in the system. It can be used on any type of refrigerant. The technician inserts a premeasured amount of fluorescent additive, depend on type of refrigerant system, CFC-12 or HFC-134a, into the refrigerant or air-conditioning system with the mist infuser. Then the lamp is used to pinpoint the leaks in the fitting, tubing, coils or compressor, or whenever it may be. The additive remains in the system, allowing leak inspection with the ultraviolet lamp on a system.

With the vacuum pump running, shut off the vacuum valve on the manifold. If the vacuum gauge needle starts to creep back toward zero, there is a leak in the system. The leak must be located and corrected before completing the vacuum operation for drying out the system. Pressurizing the system and the using the leak detectors doe's detection.
**Service tips**

Always disconnect the negative cable from the battery whenever servicing air conditioner parts.

Keep moisture and dust out of the system. When disconnecting any lines, recover the refrigerant from the entire system, cap all open fittings, and plug any open pipes immediately, do not remove the caps or plugs until just before the lines are reconnected.

When tightening or loosening a fitting, use two wrenches to support the nuts of the lines. When discharging the system, do not let the refrigerant escape too fast, it will draw the compressor oil out of the system.

**MAC start up**

When vehicle equipped with an air conditioning system is stored for long period, the conditioner should be started very carefully. Sometimes the compressor binds during storage. It is best to raise the hood and watch the compressor and belt while turning on the air conditioning. If the belt starts slipping, stop the engine at once. This indicates that the compressor is turning with difficulty or is “frozen”. Try to “free” the compressor by slow and careful turning. If will not run, remove it at once for reconditioning.

**Servicing central air-conditioning plant**

**Chillers**

**Maintenance and service procedures**

Common source of refrigerant losses is during routine chiller maintenance and major service procedures. For instance, during oil filter changes, refrigerant vaporizes from exceeded oil, oil filters and open oil lines. Emissions can also occur when vent lines for purge and rupture disk are opened for any reason.

When servicing chiller, that means opening of the chiller tubes, compressor repair, and motor replacement or for any other reason, we have another source of refrigerant loss. If only liquid refrigerant is removed from the chiller before opening it for service, a large fraction of the charge will typically be lost. Common practice in the past was to simply vent the vapour, but today, the vapour must be recovered for both environmental and economic benefit.

**New service procedures**

Venting of any refrigerant should be strictly avoided. Service technicians must be even more diligent than in the past. Many practices, which were common just short time ago, should be avoided today.

Some examples are:

- In the past, systems were opened for service or repair without first recovering the refrigerant. Now refrigerants should be recovered from the system poor to repair;
- In used to be acceptable to pump the liquid refrigerant out of a chiller, and then open it to the atmosphere for service, venting the remaining vapour charge. This procedure results in as much as 10 percent of the refrigerant charge being lost. This is a substantial loss for the owner. Today, the vapour must be properly recovered for reuse in the system;
- Responsible practice dictates that refrigerant-contaminated components be disposed of in an environmentally acceptable manner, so they do not vent to the atmosphere;
• The casual opening of refrigerant drums should be stopped. New service tools are available to minimize emissions when doing this. These tools should be used. Nevertheless, refillable cylinders should be used for refrigerant recovery;
• Refrigerant has been used as common parts cleaner. This practice should be stopped;
• Service technician should not pressurize low-pressure chillers with nitrogen to leak test the chiller. This technique requires unnecessary purging cycles to remove the nitrogen;
• Nitrogen should not be used to push the charge from one location to another.

Chiller operating procedures, which used to be commonplace and have been followed for many years must now be changed. For example:

• Chillers should not run overcharged or undercharged with refrigerant. This is hard on the chiller and is not energy efficient;
• The technician should not change the oil and filter on a scheduled basis. Do this only if oil analysis dictates it to be necessary;
• If it leaks, fix it. Don’t let leaky chillers “get by” by popping off the charge;
• Perform leak tests on high-pressure chillers on a routine, scheduled basis at regular intervals. Leaks can be detected on low-pressure chillers by monitoring purge run-time.

**Chiller logs**

Complete and regular chiller log reports are an important tool to be used in diagnosing system conditions that may indicate or result in refrigerant loss. The presence of non-condensables, capacity loss, tube fouling or excessive purging is some of the possible indicators of refrigerant loss. Below is a list of the important elements, which should be recorded, in the chiller log:

• Refrigerant monitor reading
• Oil pump level and temperature
• Purge run time
• Condenser temperature
• Condenser pressure
• Chilled water entering temperature
• Chilled water leaving temperature

Leak detection (with an electronic leak detector) for high-pressure chillers must now be performed regularly on a schedule, not just, if leak is suspected.

**Purge operation**

Older purge systems on most existing low-pressure chillers provide no information on the amount of non-consensables which are actually purged. To prevent unnecessary refrigerant loss, allow the purge to operate only as long as absolutely required by the chiller. For manual purge units, a good rule-of-thumb is the following: operate the purge manually for one hour and monitor the purge pressure. If no air is purged during that period, limit the run time to only one-hour per week. Do this manually each week to minimize emissions. If the chiller needs more than one hour per week purge time, it is leaking excessively and should be repaired.

High efficiency purge units can be added on to existing chillers, greatly reducing emissions from the purging unit.
To facilitate purge maintenance, permanent access and isolation valves should be installed on the purge system if they are not already present.

**Servicing lubrication system**

Chiller lubrication systems require regular service such as oil changes, filter changes and oil sample analysis. One modification, which should be made to the system to keep emissions at minimum during oil system service, is the installation of permanent oil filter isolation valves and an oil sample port. The manufacturer should be contacted for the details on the best options for modifications.

Annual chiller oil changes are no longer recommended on direct drive (non-hermetic) chillers. Gear drive chillers may require yearly oil changes for reliability. Oil and filter changes should be made only when oil analysis results indicate that the change is needed. Contaminated oil should be pumped from the chiller sump into an evacuated tank, if possible. Otherwise, the oil should be disposed of to an airtight, re-sellable container. Waste oil should be disposed of properly. Any refrigerant vapour that outgases from the oil should be discharged back into the chiller.
5. Recovery, Recycling and Reclaim

Definitions
According ISO 11650 standard, these definitions are:

Recovered refrigerant:
A refrigerant that has been removed from a refrigeration system for purpose of storage, recycling, reclamation or transportation.

Recovery:
The process of removing a refrigerant in any condition from a refrigeration system and storing it in an external container without necessary testing or processing it in any way.

Recycling:
The process of reducing the contaminates in used refrigerant by oil separation, non-condensable removal and core filter-dryers which reduce moisture, acidity and particulate matter.

Reclaim:
To process used refrigerant to new product specification, by means which may include distillation. Chemical analysis of the refrigerant will be required to determine that appropriate product specifications are met.

The identification of used refrigerants requires chemical analyses, which are specified in national or international standards for new product specifications. This term usually implies the use of process or procedures available only at a re-processing or manufacturing facility.

Identification of refrigerants

Is very important to know which refrigerant is in a system in order that correct refrigerant can be used when work is carried out on the system. The manufacturers for re-processing will accept only unmixed refrigerants. Any mixed refrigerants have to be destroyed (do not vent to the atmosphere).

R-502 cannot be re-processed by manufacturers as it is a mixture but may cleaned using a reclaim rig for reuse.

Refrigerants may be identified by the following methods:
- Refrigerants stamped on unit data plate;
- Thermostatic expansion valve – for specific refrigerant;
- Standing pressure.

Test refrigerant for contamination

Refrigerants can be tested for water/oil contamination and acidity with an test kit.

With the change to alternative refrigerants, in many cases, has come need for new lubricants. Where retrofit procedures call for the removal of mineral-based oil and replacement with ester lubricants, it is necessary to reduce the mineral lubricant to minimal level. These test kits provides simple methods of determining the level of residual mineral oil in an ester lubricant mixture.
**Test oil contamination**

It is possible to test the oil in some systems for acidity. Acid in the oil indicates that a burnout or partial burnout has taken place, and/or that there is moisture in the system, which can cause a burnout.

To carry an oil test it is necessary to remove a sample of oil from the compressor without undue release of refrigerant. The procedure for this will vary depending on the arrangement of shutoff valves and access to the oil available on the unit.

The refrigeration oil acid test kit is one-bottle (one step) test, and is the fastest way of determining if compressor oil is safe or acidic. Simply by filling oil into line on bottleneck and shaking. If test remains purple, the oil is safe. If it turns yellow, it is acidic. Ultra-sensitive color change guarantees an accurate test.

**Recovery of refrigerants**

Decanting refrigerants into service cylinders is hazardous practice. It should always be carried out using the method prescribed by the refrigerant manufacturer. Special care should be taken:

- Not overfill the cylinder;
- Not to mix grades of refrigerant or put one grade in a cylinder labeled for another;
- To use only clean cylinders, free of contamination by oil, acid, moisture;
- To visually check each cylinder before use and make sure all cylinders are regularly pressured tested;
- Recovery cylinder has a specific indication depending on the country in order not to be confused with virgin refrigerant container;
- Cylinders should have separate liquid and gas valves and be fitted with a pressure relief device.

![Figure 40. Recovery cylinder](image-url)
Disposable and returnable refrigerant containers

Refrigerants are packed in both disposable and returnable shipping containers, commonly called “cylinders”. Disposables are manufactured in sizes from 0.5 to 25 kg capacities. They are considered pressure vessels, and in most countries therefore are subject to state law regulations. Disposable cylinders indicate very bad practice: those containers are generally discharged after usage and a lot of refrigerant is released in the atmosphere due to disposal cylinders. Their usage is not recommended and is forbidding their re-use (do not sold/braze adapter port valves).

Containers designed for pressurized gases are labeled to contain liquid refrigerants. CFCs shipped in ISO containers include liquids and compressed gases. IMO 1 containers contain liquid refrigerants such R-11 and R-113. IMO 5 containers hold compressed gases such as R-12 and R-114.

Some refrigerants are gases at room temperature, transported, and stored as liquefied compressed gases in pressurized cylinders. Other refrigerants are liquids at room temperature and contained in drums, barrels or other standard containers as they are used for all types of liquid chemicals. In the next Table 4, indicates examples of liquefied compressed gases which are liquid at room temperature. Their physical state at room temperature is indicated by their international Chemical Safety Cards or can be deducted from the temperature-pressure charts (see Annexes).

**Table 4. Examples of liquefied compressed and liquid refrigerants**

<table>
<thead>
<tr>
<th>Physical state</th>
<th>Temperature/pressure</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquefied compressed gas</td>
<td>At room temperature, the vapor pressure is above the standard atmospheric pressure at sea level</td>
<td>R-12, R-13, R-22, R-115, R-134a</td>
</tr>
<tr>
<td>Liquid</td>
<td>At room temperature, the vapor pressure is below the atmospheric pressure at sea level</td>
<td>R-11, R-113, R-123</td>
</tr>
</tbody>
</table>

**Flammability of refrigerants**

HC refrigerant cylinders should be marked flammable and CFC refrigerants not flammable. Any refrigerant cylinder labeled as HC refrigerant without a warning that may contains flammable gases. Refrigerant cylinders containing flammable gases are equipped with left-hand valves. Any cylinder labeled as HC refrigerants or flammable gases should be equipped with left-hand valves.

**Cylinder valves**

Mobile air-conditioning (MAC) systems have different access valves depending on the type of refrigerant used. There are no international standards and the valve types used may differ region to region. Pressure relief safety with realizing pressures pre-set to highest vapor pressure anticipated with R-502 is installed on every cylinder manufactured. They are the frangible (rupture) disc style, or spring-loaded relief integrated into the valve stem.
Neither of the types is adjustable or is to be tampered with. US manufacturers use standard access and the following Table 5 specifies which access valves are used for which type of refrigerant.

Table 5. Valve types used in the US

<table>
<thead>
<tr>
<th>Valve type for US cylinders</th>
<th>Refrigerants</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼” right hand flare fitting (clockwise)</td>
<td>CFC-12 HCFC</td>
</tr>
<tr>
<td>½” right hand flare fitting (clockwise)</td>
<td>HCFC HFC-134a</td>
</tr>
<tr>
<td>Quick fittings</td>
<td>HCFC Retrofitted</td>
</tr>
<tr>
<td>½” or other left hand flare fitting</td>
<td>Hydrocarbon</td>
</tr>
</tbody>
</table>

Labeling of refrigerant cylinders

Refrigerant cylinders as well as drums, tanks, cans and bottles are labeled with a company-specific label (or international standards) of the outer shield of the container, with necessary data for end user. This may include chemical name, trade name, weight of container (tare) and product. In the US and many other countries, US standards are used to label specifically refrigerants and refrigerant containers (ARI color assignments for refrigerant containers). ASHRAE (American Society of Heating Refrigerating and Air-conditioning Engineers) also provides a system of classifying refrigerants into different safety groups according to their flammability and toxicity.

Chemical names

Chemical names provide an indication of the molecular structure of a substance and type, number and position of the atoms contained. Often, it is more practical to use short formulas, which may still indicate the structure of a molecule, or formulas, which only indicate the type and number of atoms contained. In these short formulas, “C” stands for carbon atoms, “F” for fluorine atoms, “Br” for bromine atoms and “H” for hydrogen atoms. The subscript numbers indicate the number of each type of atom contained in the molecule.

The ASHRAE numbers

The ASHRAE number for refrigerants is defined in ASHRAE standard 34-1997 on “Number Designation and Safety Classification of Refrigerants”. The number designation of hydrocarbon and halocarbon refrigerants is systematic and allows the determination of the chemical composition of the compounds from the refrigerant numbers. Single component refrigerants have an “R-“ designation of two or three numbers, which reflect its chemical composition:

- The first digit (of refrigerant with three numbers) is one unit lower than the number of carbon atoms in the molecule. If the molecule contains only one carbon atom, the first digit is omitted.
• The second digit is one unit greater than the number of hydrogen atoms in the molecule.

• The third digit is equal to the number of fluorine atoms in the molecule.

For example: R-134a (C₂H₂F₄ – chemical formula)
  1 – One less than the number of carbon atoms (there are 2-1=1)
  3 – One more than the number of hydrogen atoms (there are 2+1=3)
  4 – Number of fluorine atoms (there are 4 fluorine atoms)
  a – Indicates an isomer (different arrangement of the same atoms)

Refrigerant mixtures

Some refrigerants however are comprised of two or more chemicals. R-500 and R-502 are two examples. R-502 is composed of 48,8% (by weight) of HCFC-22 and 51,2% CFC-115. When formulated in those proportions these refrigerants take on the characteristic of a single refrigerant. Combinations of chemicals that act as single refrigerant are called azeotropes. Azeotropes are designed by a three digit number beginning with the number “5”.

Combinations of chemicals that maintain some of their original characteristic are called zeotropes. For example, unlike single refrigerants and azeotropes, which boil at a single temperature, zeotropes boil over a range of temperatures determined by the boiling points of their individual components. A zeotrope is also sometimes referred to as a blend. Zeotropes are designated by the three digit number beginning with the number “4”. The designation ends with a letter to differentiate, between compositions of the same chemicals, such as in R-401A. (see Annex B).

Trade names

Trade names are the names that companies call their products. Example of trade names is Freon-12, Generon-11 and Algofrene-11. The ASHRAE number of a certain chemical often appears in the trade name like 11 or 12, this means that they are CFC-11 or CFC-12.

ASHRAE safety groups for refrigerants

The ASHRAE safety groups for refrigerants standard classifies commonly used refrigerants depending on their toxicity and flammability. The standard defines 6 safety groups – A1, A2, A3, B1, B2 and B3 where “A” signifies lower toxicity, “B” higher toxicity, “1” signifies no flame propagation, “2” lower flammability, and “3” higher flammability. Therefore, “B3” signifies a refrigerant with higher toxicity and higher flammability. ASHRAE safety groups for the most common ozone depleting refrigerants are included in Annex E.
**ARI color codes**

The ARI color assignments for refrigerant containers are described in more detail in ARI Guideline N. Examples of the color assignments can be found in Annex C in this Manual. ARI Guideline N is a voluntary US industry guideline for the uniform assignment of colors for containers used for new or reclaimed refrigerants that meet ARI Standard 700 purity specifications.

Containers used to store recovered refrigerants do not fall under the scope of ARI Guideline N. The color for all refrigerant recovery containers is grey with yellow top shoulder or cap as specified in ARI Guideline K.

Refrigerant container color assignment assist in quickly distinguishing refrigerants within containers. The same color may be assigned to different refrigerants provided those refrigerants are in different classes. As defined in ARI Guideline N (can be found in Annex D in the Manual), the refrigerant classes are:
- Class I – low pressure refrigerants
- Class II – medium pressure refrigerants,
- Class III - high pressure refrigerants, and
- Class IV – flammable refrigerants.

Containers used for storage of flammable refrigerants should also have a red colored band around its top shoulder or cap.

The color codes used for marking refrigerant containers vary from country to country. Color codes often vary within the country. For example, the military may have different color codes for refrigerants than industry.

**Recovery technologies**

Since a recovery unit wills remote more fluorocarbon refrigerant from a system than any other practicable method, their use should be regarded as the norm and not the exception.

As with vacuum pumps, recovery units will work much more efficiently if connection hoses are kept as short and large in diameter as possible. A 3/8” diameter hose should be the minimum size used and ½” is preferable. However, not being able to get a recovery unit close to a system is not an acceptable excuse for not using one. If long hoses have to be used all that will happen is that recovery will take longer. There is no longer any acceptable reason or excuse for releasing fluorocarbon refrigerants to the atmosphere.

**Using recovery units**

Recovery units are connected to the system by available service valves or line tap valves or line piercing pliers. Some of them can handle refrigerants in both liquid and vapor form and many have onboard storage vessels. Take care not to be let the compressor suck in liquid refrigerant, only vapor or it will break due to hydraulic lock.

There are three types of recovery apparatus available. These are self-contained, system dependent and passive. These are defined as follows:
Self-contained:
A self-contained recovery unit has its own compressor (or other transfer mechanism) to pump refrigerant out the system. It requires no assistance from any component in the system that is being recovered.

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

Passive:
Passive recovery refers to a deflated bag on an activated charcoal canister, which is used to store small amounts of refrigerant near or slightly above atmospheric pressure.

![Figure 41. Self-contained recovery unit](image)

Methods of refrigerant recovery

The methods of recovery depend upon the type of refrigerant being recovered. This is usually divided into two general groups, high pressure, where the boiling point of the refrigerant is between –50°C and 10°C at atmospheric pressure and low pressure where the boiling point is above 10°C at atmospheric pressure. High-pressure refrigerants include CFC-12, HCF-134a and HCFC-22, while low-pressure refrigerants are CFC-11, HCFC-113, HCFC-123 etc.
**Liquid transfer**
In the recovery unit does not have a built-in liquid pump (system depending) or is otherwise not designed to handle liquid, then liquid can be removed from a system using two recovery cylinders and recovery unit. The recovery cylinders must have two ports and two valves, one each for liquid and one each for vapor connections. Connect one cylinder liquid port directly to the refrigeration system at a point where liquid refrigerant can be decanted. Connect the same cylinder vapor port to the recovery unit inlet. Use the recovery unit to draw vapor from the cylinder, thereby reducing the cylinder pressure, which will cause liquid to flow from the refrigeration system into the cylinder. The care as this can happen quite quickly. The second cylinder is used to collect the refrigerant from the recovery unit as it draws it from the first cylinder. If the recovery unit has adequate onboard storage capacity (self-contained recovery unit), this may not be necessary. Once the entire liquid refrigerant has been recovered from the refrigeration system, the connections can be relocated and the remaining refrigerant recovered in vapor recovery mode. It may be found convenient to fit a liquid sight glass within the transfer line.

**Push-pull liquid recovery**
There is another method for liquid recovery, more common that described previously called “Push and Pull” method. If you have access to a recovery cylinder, the procedure will be successful if you connect the recovery cylinder to the recovery units vapor valve, and the recovery cylinder liquid valve to the liquid side on the disabled unit as shown in Figure 42. The recovery unit will pull the liquid refrigerant from the disabled unit when decreasing the pressure in the recovering cylinder. Vapor pulled from the recovery cylinder by the recovery unit will then be pushed back to disabled unit’s vapor side.

![Diagram of push-pull liquid transfer](image)

**Note:** Do not connect liquid line to transfer unit.
Compressor would be damaged

*Figure 42. Push-pull liquid transfer*
**Vapor transfer**

The refrigerant charge can also be recovered in vapor recovery mode as shown in Figure 43. On larger refrigeration systems, this will take appreciably longer than if liquid is transferred.

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

![Figure 43. Push-pull vapor transfer](image)

**Using the system’s own compressor**

If the refrigerant in system is to be moved and the system has a working compressor, it is possible to use the compressor to recover the refrigerant. It may be possible to pump the system down in the normal way and then decant the refrigerant into a cooled recovery cylinder, or it may only be possible to use the cooled recovery cylinder as both condenser and receiver by installing it at the compressor outlet.

**Reuse of refrigerant**

Recovered refrigerant may reused in the same system from which is was removed from the site and processed for use in another system, depending upon the reason for its removal and its condition, i.e. the level and types of contaminants it contains. Refrigerant from a unit with a burn-out hermetic compressor is reusable providing it has been recovered with a recovery unit incorporating an oil separator and filters. To check the acid content of any reclaimed oil is necessary to use a refrigeration oil test kit.

(Note: Used refrigerant put into a new system may void equipment warranties).
Recycling technologies
Recycling has always been a part of refrigeration service practice. Various methods range from pumping the refrigerant into a receiver for minimal loss, to cleaning burned out refrigerant with filter-dryers. Two types of equipment are on the market. The first is referred to a single pass. The other is a multiple pass.

**Single pass**
The single pass recycling machines process refrigerant through filter-dryers and/or distillation. It makes only one trip from the recycling process through the machine and then into the storage cylinder.

![Diagram of single pass filtering](image1)

**Multiple pass**
Multiple pass machines recirculate the recovered refrigerant many times through filter-dryers. After a certain period of time or number of cycles, the refrigerant is transferred into storage cylinder. Time is not reliable measure of how well the refrigerant has been reconditioned, because the moisture content varies. Figure 45 shows a typical multipass system.

![Diagram of multipass filtering](image2)
Reclaim technologies

Reclaiming is defined as the reprocessing of a refrigerant to the level of purity of virgin refrigerant specification as verified by chemical analysis. In order to accomplish this, the machine must meet the ARI 700-93 standards. That the complete set of analysis has to be done and the reclaim refrigerant must be reprocessed until specifications of virgin refrigerant are met.

Purpose of refrigerant recycling a reclaim is to reduce contaminants. These include:

- Water: Which can lead to corrosion, freeze up, and acids;
- Acid: Which promotes corrosion and further refrigerant degradation;
- Particulates: Which accelerate wear and plug small openings in the system;
- Chlorides: Indication of presence of acids;
- Other refrigerants: Which can affect the performance of the system;
- Non-condensables: Which will affect system pressures and general performance;
- High boiling residues (oil): Which inhibit heat transfer and can plug evaporators

Acceptable levels of contaminants (under the ARI 700-93) are shown in Annex F to the Manual.

Reclaim unit

This type of system can best be described as follows:

1. The refrigerant is accepted into the system as either vapor or liquid;
2. Refrigerant then enters a large unique separator chamber where the velocity is rapidly reduced. This allows the vapor, at high temperature, to rise. During this phase, contaminants drop to the bottom of the separator to be removed during the “oil out” operation.
3. The distilled vapor passes into the air-cooled condenser and is converted to liquid.
4. The liquid passes into the on-board storage chamber. Within the chamber, an evaporator assembly lowers the liquid approximately 56°C to a sub-cooled temperature 3°C – 4°C.
5. A replaceable filter-drier in this circuit removes the moisture while it continues the cleaning process to remove microscopic contaminants.
6. Chilling the refrigerant also facilitates the transfer to any external cylinders, which are at room temperature.

Safe handling of recovery refrigerant

1. Read the Manufacturer manual and apply all prescribed methods in instruction every time equipment is employed.
2. Liquid refrigerants can case severe frost bite, avoid the possibility of contact through use of adequate gloves and long sleeved shirts/cover.
3. The refrigerant being recovered could come from badly contaminated system. Acid is a product of decomposition; both hydrochloric and hydrofluoric acid can be produced. Extreme care must be taken to prevent oil spills of refrigerant vapors from making contact with skin and clothing surfaces when servicing contaminated equipment.
4. Wear protective gear, such as safety glasses and shoes, gloves, safety hat or hard hat, long pants, and shirts with long sleeves.
5. Refrigerant vapors can harmful if inhaled. Avoid ingestion and always provide low-level ventilation.
6. Ensure that all power is disconnected and disabled to any equipment requiring recovery. Disconnect and lock out any power supply with an approved locking device.

7. Never exceed the cylinder's safe liquid weight level, based upon net weight. Maximum capacity of any cylinder is 80% by maximum gross.

8. When moving a cylinder, use an appropriate wheeled device. Never roll a cylinder on its base or lay it down to roll it.

9. Use top quality hoses. Make sure they are properly firmly attached.

10. Label the cylinder or container as specified regulations.

11. Hoses and electrical extension cords can be trip hazard. Place hose sensibly, where risk is minimized.

12. Ensure that all cylinders are in safe condition, capped as necessary, with proper identification.
Recovery from a domestic refrigerator

It is possible to recover refrigerant from a hermetically sealed system, which has no service valves. A line-tap valve (piercing valve) should be fitted to the system, and a recovery unit used to remove the refrigerant from the unit via the line-tap as with the larger system. Line-tap valves should never be left permanently in place, but removed after use if placed on the process tube. Because of the small charge of refrigerant, only vapor recovery is needed. It has recommended to install tap-valves on both and low pressure side.

Recovery from commercial cold room system

Liquid transfer
Connect the recovery cylinder’s hose to the system’s outlet stop valve on the condenser/receiver. To control liquid flow, install a sight glass to the hose and cylinder. From the recovery cylinders vapor side (use a drier). Outlet/discharge side of the recovery unit goes to the system’s high-pressure side at inlet condenser or compressor high-pressure stop valve. All system’s stop valves have to be opened, including solenoid valves. Run the recovery unit and keep an eye on the sight glass.
When there is no more liquid transferred through the sight glass, this indicates there is no more refrigerant left in the system.

Vapor transfer
When liquid transfer is completed, connect the hoses from the recovery unit suction/inlet side to the compressor low or high-pressure side. For better recovery, connect hoses to both high and low pressure side (use service manifold). Recovery discharge/outlet side connected to the recovery cylinder’s vapor side. Be sure that all service/shut off valves are open to avoid “locking” refrigerant.

Recovery from air-conditioning system

Liquid transfer
Air-conditioning installations normally have service stop valves installed in the pipe lines. When recovering refrigerant from such a system, liquid should be transferred first because the quantity can be rather large. The push-pull method is recommended.
The system’s liquid pipe should be connected to the recovery cylinder’s liquid side. The cylinder’s vapor side should be connected to the recovery inlet (suction) side. Discharge side recovery unit should be connected to the suction pipe on the air-conditioning system. If there are available valves on the systems receiver (high-pressure side), the recovery unit discharge side could be connected here as well.
Liquid flows now from the liquid side of the air-conditioning system and into in the cylinder. The recovery unit will keep the pressure inside the cylinder lower than in the air-conditioning system and keep up the liquid flow.

Vapor transfer
When liquid transfer is completed there will still be some refrigerant vapor left in the system. To transfer all refrigerant to the recovery cylinder, connect the suction hose from recovery unit to the gas pipe on air-conditioning system. Connect the recovery unit discharge outlet hose to the recovery cylinder’s vapor side. Run recovery unit until the suction gauge reads –0,6 Bar or lower.
Recovery from the mobile air-conditioning system

Vapor transfer
Mobile air-conditioning systems are normally equipped with service valves on compressor’s high and low-pressure side. The refrigerant charge on such system is rather small and therefore only vapor transfer is required. Connect the hose from the recovery unit’s suction/inlet side to the air-conditioning system’s compressor low-pressure side and the discharge hose to the vapor valve on the recovery cylinders. Run the recovery unit for 3 – 5 min. Connect another hose to the system’s high-pressure side and complete the recovery. Run the recovery unit until pressure gauges read 0,6 bar.

Figure 46. Recovery from an MAC system
6. Alternative refrigerants and technologies

The Montreal Protocol requires the eventual cessation of all CFCs and HCFCs and therefore, the air conditioning and refrigeration industry has been engaged with the chemical community for more than two decades establishing refrigerant substitutes and alternative technologies. Several significant alternative refrigerants are examined.

CFCs refrigerants are a limited resource and have a steadily increasing value. The regulatory and record keeping requirements further emphasize the need for a focused approach to terminal refrigerant management plans.

After all the alternative refrigerant decisions have been made, the implementation a new refrigerant option is best accomplished in a methodical, organized manner. Every system has unique operating conditions. It is important to remember that all current practices for refrigeration system service still apply with alternative refrigerants. The basic refrigeration cycle still applies, and changes that accompany the alternative refrigerants involve additional service practices that must be followed.

**Alternative refrigerants**

Before any alternative refrigerant can be mass-produced, it must first pass exhaustive toxicity and environment acceptability tests. In addition, individual companies are researching other possible alternatives, new blends and combinations of existing chemicals.

There are three categories into which replacement fluids can fall. These are:

- **Drop-ins** - fluids that can be substituted into an existing system without any work being required apart from vary minor servicing such as the replacement of a refrigerant filter dryer.

- **Retrofittable fluid** – fluids that can be substituted into an existing plant but only after certain changes are made, such as substitution of a new type of lubricating oil or a modification of compressor speed.

- **Non-retrofittable fluid** – liquids that cannot be used in existing equipment even with major modifications, because of different operating pressures and materials incompatibility.

The changes of a “drop-in” being available with exactly the same properties as the refrigerant it replaces are fairly remote, and consequently some modifications to the system are likely to be necessary, and areas are:

- Drier
- Expansion valve
- Lubricant compatibility and miscibility
- Compressor swept volume and input power

Thus, retrofittable fluids are the more likely option.

In the following Table 6 below are given common use refrigerants, and their replacements (alternatives) and applications.
<table>
<thead>
<tr>
<th>ASHRAE #</th>
<th>Type</th>
<th>Lubricant</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-12 (CFC) replacements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-134a</td>
<td>HFC</td>
<td>POE</td>
<td>Domestic refrigeration; Commercial refrigeration, appliances, automotive AC; new and retrofit</td>
</tr>
<tr>
<td>R-401A</td>
<td>HCFC</td>
<td>MO or AB</td>
<td>Positive displacement refrigeration equipment, supermarket systems, medium temperature, walk-in coolers</td>
</tr>
<tr>
<td>R-409A</td>
<td>HCFC</td>
<td>MO or AB</td>
<td>Positive displacement refrigeration equipment, supermarket systems; Medium temperature, walk-in coolers</td>
</tr>
<tr>
<td>R-500 (CFC/HCF) replacements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-401B</td>
<td>HCFC</td>
<td>MO or AB</td>
<td>Closest performance match to R-500; Best retrofit choice for R-12 freezers; R-12 transport refrigeration equipment</td>
</tr>
<tr>
<td>R-502 (CFC/HCF) replacements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-404A</td>
<td>HFC</td>
<td>POE</td>
<td>New equipment and retrofit for commercial refrigeration, R-502 transport refrigeration</td>
</tr>
<tr>
<td>R-507</td>
<td>HFC</td>
<td>POE</td>
<td>New equipment and retrofit for commercial refrigeration, R-502 transport refrigeration</td>
</tr>
<tr>
<td>R-408A</td>
<td>HCFC</td>
<td>MO or AB</td>
<td>Existing commercial refrigeration equipment</td>
</tr>
<tr>
<td>R-402A</td>
<td>HCFC</td>
<td>MO or AB</td>
<td>Existing commercial refrigeration equipment</td>
</tr>
<tr>
<td>R-402B</td>
<td>HCFC</td>
<td>MO or AB</td>
<td>Ice machines and other selected applications</td>
</tr>
<tr>
<td>R-22 (HCFC)replacements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-407C</td>
<td>HFC</td>
<td>POE</td>
<td>Positive displacement AC equipment; New commercial and light commercial AC; Existing residential and commercial/light AC; Always consult OEM for guidance</td>
</tr>
<tr>
<td>R-410A</td>
<td>HFC</td>
<td>POE</td>
<td>Residential and commercial air conditioning and some very large centrifugal chillers for air conditioning and industrial process cooling</td>
</tr>
<tr>
<td>R-13 (CFC), R-23 (CFC), R-503 (CFC/HCF) replacements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-508B</td>
<td>HFC</td>
<td>POE</td>
<td>New and existing centrifugal (below –40°C) applications; Cascade refrigeration systems</td>
</tr>
<tr>
<td>R-11 (CFC) replacements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-123</td>
<td>HCFC</td>
<td>MO</td>
<td>New and existing centrifugal chillers Consult OEM</td>
</tr>
<tr>
<td>R-114 (CFC) replacement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-124</td>
<td>HCFC</td>
<td>AB</td>
<td>Industrial refrigeration and AC; Light ambient AC</td>
</tr>
</tbody>
</table>

MO – mineral oil  
AB – alkylbenzene  
POE – polyester  
OEM – Original Equipment Manufacturers
Existing alternative refrigerants

**Hydrocarbons (HC) – Isobutane and propane**
Both of the se gases have sound thermodynamic properties. Their main disadvantage is their flammability. A good option for domestic and commercial applications such as shop display cases, canteen fridge’s etc. For these refrigerants are developed new service procedures, tools and safety measures when servicing refrigerators.
R-600a (C₄H₁₀ - isobutane) and R-290 (C₃H₈ - propane) are ozone friendly (ODP=0, GWP=0).

![Image of HC charging tools](image)

**Figure 47. HC charging tools**

**Ammonia –NH₃**
R-717 – has been used as a refrigerant for many years. At the present time, it is mainly used in industrial applications. It use could be extended to encompass R-12 uses in cold stores. However, because of its toxicity and flammability, it has not been considered a viable long term alternative in the commercial field. Ammonia is ozone friendly, and increasing attention is being focused in as an environmentally begin substance that could yet be explored in a number of applications.

**Absorption**
Absorption cycles have been used since the mid 1800s. Absorption cycles have been successfully applied to refrigerator, residential air conditioners and large water chillers. Absorption chillers replace the compressor and its driver with an absorber chamber, absorbent fluid, a small pump and a generator. The refrigerant vapor migrates from the evaporator, changes state as it absorbed into an absorbent, pumped to the generator and separate from the absorbent fluid by adding heat. The refrigerant then goes to the condenser where it is liquefied and returned to the evaporator to begin the cycle again. The absorbent fluid goes from the generator back to absorber. The driving force is the heat added at the generator, which may
come from direct firing with natural gas, steam, hot water or waste heat. Refrigerant/absorber combinations today are ammonia/water for systems under 10 tons and water/lithium bromide for water chillers above 10 tons.

**Lubricants for alternatives**

Polyol ester oils must be used with HFC refrigerants. Existing systems will require oil flushing procedure, because of chemical incompatibilities between the refrigerants and lubricants. System charged with retrofit refrigerant can lead to early system failure due to chemical reaction between the chlorine from CFC and lubricating oils. Polyol ester synthetic oils are backwards compatible. Therefore, they are acceptable for use with, CFC-12, HCFC-22 and R-502.

The miscibility of HFC-134a with the POE is satisfactory (with mineral oil is very poor), about the same as the CFC-12 and mineral oil. Another important difference between mineral oils and POEs is the fact that POEs tend to absorb water. Therefore, they need to be handled with care before being used. Because of the increased water which may present in the system, a larger filter drier may require in a system, which has been retrofitted to POEs to make sure that all of the excess water is removed. POEs dissolve materials that CFCs or mineral oil did not. Therefore, the filter-dryers need to be frequently checked. Is strongly recommended that the manufacturer-specified lubricant be used to ensure that it is compatible with all the components, which it is in contact.

**Flushing method**

A major problem with retrofits is removing the residual mineral oil. This is important because enough mineral oil is not removed, it can deposit on the evaporator heat exchanger surfaces, severely degrading performance. Current experience dictates that for HFC-134a systems the concentration of residual mineral oil in the POE lubricant must be no more than 5% by weight to achieve miscibility equivalent to CFC-12 with mineral oil. Current retrofit procedures for refrigeration systems could require up to three or more lubricant changes (flushes) with POE to reach the required levels. A lubricant flush consists of removing as much oil as possible from the system, replacing it, and running the system with the new lubricant and the old CFC refrigerant.

Many recycling units can be modified at relatively low cost to perform the additional function on flushing with refrigerant. Using CFC-12 as the flushing fluid would allow mineral oil removal without introducing a new chemical into market.
Retrofit of CFC-12 with HFC-134a

Domestic and air conditioning system components that need to be compatible with any new working fluid (refrigerant/lubricant combination) include the filter-dryer, compressor, hoses, and O-rings. The general chemical stability of the system is also important. In many cases, system controls will require changing to maintain acceptable performance. The working fluid must allow for satisfactory refrigerant performance and adequate lubricant solubility/circulation to lubricate the compressor while, at same time, not deteriorating system materials. Ultimately, a retrofit must result in a refrigeration system durable enough to satisfy customer expectation.

The general guidelines for retrofit of CFC-12 with R-134a are:
1. Establish existing system operating performance.
2. Check the entire system for leaks and make necessary repairs.
3. Establish the necessary system component changes for the HFC-134a application.

Typical system concerns are:
1. Compressor sizing.
2. Expansion valve or capillary lube sizing.
3. Evaporator and condenser capacities.
4. Drain the existing mineral oil charge, measure the quantity and compare with recommended oil charge to determine the quantity of oil left in the system. Replace the mineral oil with the recommended charge of POE.
5. Run the system with CFC-12 and POE oil than drain the ester oil and replace with fresh charge. Note quantity of oil removed to see if residual mineral oil has returned. This oil charge procedure – flushing method should be repeated 3 times. Acceptable residual mineral oil must be between 1% and 5%.
6. It is recommended that the dryers be changed when retrofitting. Dryers should be selected for use with HFC-134a.
7. Remove the existing charge of CFC-12. Use a recovery unit and acceptable recovery cylinder.
8. Evacuate the system.
9. Break the vacuum with HFC-134a vapor.
10. Charge the system with HFC-134a. Caution should be taken not overcharge – 80% to 90% of the CFC-12 charge as a starting point.
11. Start-up the system and monitor for performance. The superheat settings should always be checked to ensure proper evaporator operation.
12. Check the system after 48 hours again.

Filter-dryer media
All current retrofit candidates are known to chemically incompatible with the existing filter-dryer media and would therefore require a component change to replace the desiccant with one compatible with the working fluid.
7. National legislation

Immediately after the start of the country action on ODS reduction and elimination in 1997, the Ministry of Environment and Physical Planning/Ozone Unit established a legal framework for the Montreal Protocol implementation. The ODS/ODS containing equipment import restrictions have been realized according the following schedule:

- As of 12.06.1998 import of the equipment (new and used refrigerators, freezers, cooling equipment, heat pumps etc.) containing ODSs is allowed only with permit issued by the Ministry of Environment and Physical Planning.
- As of 01.03.1997 import of the Ozone Depleting Substances (ODSs) is allowed only with permit issued by the Ministry of Environment and Physical Planning.

The above mentioned subsidiaries enable reduction, control and inventory of the imported ODS quantities. The Ozone Unit prepared special database for creation of complete inventories of the annual ODS import and consumption which gives clear picture of the country situation concerning this issue.

Few years later (December 2004) the Ministry of Environment and Physical Planning prepared Instructions for Special Data to be Submitted for Issuing Permit for Goods Imported-Exported under D4 (Official Journal of the Republic of Macedonia, No. 91/2004). This act defines all necessary data and information (documents and information) that should be provided for ODSs/ODS containing equipment import/export. The Instructions are available to the public (www.ozoneunit.gov.mk) and is extremely useful for the companies-importers of the ODSs/ODS containing equipment.

Law on Environment (Official Journal of the Republic of Macedonia, No. 53/2005, 81/2005), Chapter XVIII – Financing, prescribes that every natural or legal person who imports certain used products or produces/imports hazardous products and goods or products and goods containing hazardous substances to the environment and nature is obliged to pay tax defined by the Ministry of Environment and Physical Planning of the Republic of Macedonia.

In the case of the ODSs and ODS containing equipment, the tax depends of the type (ODP value) and quantity of imported ODSs, and quantity and volume of the imported refrigerators, freezers and other used cooling devices respectively (Article 164 of the Law on Environment).

The Law on Environment (Article 21 and 22) gives possibility the Minister on Environment to ban the production, trade and use of certain products and substances or to restrict and control the export and import of certain substances and products.

Following this direction the Ozone Unit has prepared Draft-Order on Ban of Import of Used Refrigerators, Freezers and Other Cooling and Freezing Devices Containing Substances of Annex A Group I of the Montreal Protocol and Gradual Reduction and Elimination of the Substances of Annex A Group I of the Montreal Protocol (CFC-11, CFC-12, CFC-113, CFC-114, CFC-115).

This Order foresees prohibition of the import of the used refrigerators, freezers and other cooling and freezing devices containing substances of Annex A Group I of the Montreal Protocol, eliminating the possibility of unnecessary import of the equipment potentially containing CFCs.
According to the recommendations and tasks identified in the project "Terminal phase-out management plan", the import of the ODSs classified in Annex A Group I of the Montreal Protocol (CFC-11, CFC-12, CFC-113, CFC-114, CFC-115) is going to be eliminated as follows:

- 35.000 kg. from 1 January 2004 to 31 December 2004;
- 25.000 kg. from 1 January 2005 to 31 December 2005
- 15.000 kg. from 1 January 2006 to 31 December 2006;
- 10.000 kg. from 1 January 2007 to 31 December 2007;
- 5.000 kg. from 1 January 2008 to 31 December 2008;
- Zero kg from 1 January 2009.

The implementation of this document will mean not only fulfilling of the Montreal Protocol provisions, but undertaking big step ahead towards complete elimination of the ODSs of Annex A Group I by 2010.
8. Annexes

Annex A: Definition
Annex B: Blends and their composition
Annex C: ARI Refrigerant color assignment stored by ASHRAE number
Annex D: ARI refrigerant container color assignments sorted by PMS number
Annex E: International Chemical Safety Cards
Annex F: Maximum contaminant levels of common refrigerants
Annex G: Trouble shooting
Annex H: Best Service Practices
Annex I: Mollier charts
## Annex A: Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adjustment</strong></td>
<td>Adjustments are changes to the Montreal Protocol with regard to the phase-out timetable for existing controlled substances as well as ODP values of controlled substances based on new research results. They are automatically binding for all countries, which have ratified the Protocol, or the relevant amendment, which introduced the controlled substance. Adjustments can also take Decisions, which do not change the text but interpret the text.</td>
</tr>
<tr>
<td><strong>Amendment</strong></td>
<td>Amendments are other more significant changes to the Montreal Protocol, such as adding new substances to the list of controlled substances, or new Obligations. Parties are not bound by these changes to the Protocol unless and until they ratify the Amendment. Adjustments have to be ratified in the chronological they were agreed. Countries, which have not ratified a certain document, will be considered as a non-Party with regard to new substances or obligations introduced by that amendment.</td>
</tr>
<tr>
<td><strong>Annex A substance</strong></td>
<td>Ozone depleting substances listed in Annex A of the Montreal Protocol: Group I: CFCs 11, 12, 113, 114 and 115 Group II: Halons 1211, 1301, 2402</td>
</tr>
<tr>
<td><strong>Annex B substance</strong></td>
<td>Ozone depleting substances listed in Annex B of the Montreal Protocol: Group I: ten “other CFCs” (most of them not in commercial use) Group II: carbon tetrachloride Group III: 1,1,1-trichloroethane (methyl chloroform)</td>
</tr>
<tr>
<td><strong>Annex C substance</strong></td>
<td>Ozone depleting substances listed in Annex C of the Montreal Protocol: Group I: 40 HCFCs (some 5-10 in commercial use) Group II: 33 HBFCs (most of them not in commercial use) Group III: bromochloromethane (added by Beijing Amendment in 1999)</td>
</tr>
<tr>
<td><strong>Annex D product</strong></td>
<td>List of products containing controlled substances specified in Annex A of the Montreal Protocol which may not be imported from countries that are not Parties to the Protocol</td>
</tr>
<tr>
<td><strong>ARI color assignments</strong></td>
<td>ARI Guideline N is a voluntary industry guideline for the uniform assignment of colors for containers used for new or reclaimed refrigerants that meet ARI Standard 700 purity specifications</td>
</tr>
<tr>
<td><strong>Article 5 countries</strong></td>
<td>Developing countries which are Party to the Montreal Protocol with an annual calculated level of consumption less than 0.3 kg per capita of the controlled substances in Annex A, and less than 0.2 kg per capita of the controlled substances in Annex B. These countries are permitted a 10 year grace period for most substances compared with the phase-out schedule for developed countries</td>
</tr>
<tr>
<td><strong>ASHRAE number</strong></td>
<td>The ASHRAE number applies to refrigerants and is defined in ASHRAE standard 34-1997 on “Number Designation and Safety Classification of Refrigerants”. The number designation of hydrocarbon and halocarbon refrigerants is systematic and allows determining the chemical composition of the compounds from the refrigerant numbers</td>
</tr>
<tr>
<td><strong>Azeotrope</strong></td>
<td>A constant-boiling mixture. A unique mixture of two or more chemicals that distils at certain constant temperature and has a constant composition at a given pressure. An azeotrope behaves like a pure liquid</td>
</tr>
<tr>
<td><strong>Beijing Amendment</strong></td>
<td>Refers to the amendments decided by the Eleventh MOP which introduced HCFC production controls, the listing of bromochloromethane as a controlled substance, and the reporting of methyl bromide uses for the exempted quarantine and pre-shipment applications</td>
</tr>
<tr>
<td><strong>Cataract</strong></td>
<td>Damage to the eye in which the lens is partially or completely clouded, impairing the vision and sometimes causing blindness. Exposure to ultraviolet radiation can cause cataracts</td>
</tr>
<tr>
<td><strong>Chlorofluorocarbon (CFC)</strong></td>
<td>A family of organic chemicals composed of chlorine, fluorine and carbon. These fully halogenated substances are commonly used in refrigeration, foam blowing, aerosols, sterilants, solvents cleaning and variety of other</td>
</tr>
</tbody>
</table>

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99
<p>| <strong>Consumption</strong> | The Montreal Protocol defines the consumption of a controlled substance as a production plus imports minus exports. Most Article 5 countries are importing all ODS which is used in the country |
| <strong>Copenhagen Amendment</strong> | Refers to amendments decided by the fourth meeting of the Parties to the Montreal Protocol in Copenhagen 1992 whereby controls on Annex C and E substances were added. At this meeting, the phase-out schedules for Annex A and B substances were also accelerated |
| <strong>Global Warming</strong> | Global warming &amp; climate change is caused by the emission of greenhouse gases that trap the outgoing heat from the Earth causing the atmosphere to become warmer. Greenhouse gases include carbon dioxide, methane, CFCs, HCFCs and Halons. The global warming potential (GWP) is the relative contribution of each greenhouse gas to global warming relative to carbon dioxide whose GWP is defined as 1. It usually refers to a time span of 100 years (GWP 100) |
| <strong>Greenhouse Gas</strong> | A gas that traps heat in the Earth’s atmosphere, contributing to global warming |
| <strong>Ground Level Ozone</strong> | Photochemical pollution, car and industry emissions provide the basis for photochemical reactions. Has adverse effects on human health and the environment |
| <strong>Hydrocarbon (HC)</strong> | A chemical compound consisting of one or more carbon atoms surrounded only by hydrogen atoms. Examples of hydrocarbons are propane (C₃H₈, HC-290), propylene (C₃H₆, HC-1270) and butane (C₄H₁₀, HC-600). HCs are commonly used as substitute for CFCs in aerosol propellants and refrigerant blends. The hydrocarbons have an ODP of zero. Hydrocarbons are volatile organic compounds, and their use may be restricted or prohibited in some areas. Although they are used as refrigerants, their highly flammable properties normally restrict their use as low concentration components in refrigerant blends |
| <strong>Hydrochlorofluorocarbon (HCFC)</strong> | A family of hydrogenated chemicals related to CFCs, which contain hydrogen, as well as chlorine, fluorine and carbon. The hydrogen reduces their atmospheric lifetime, making HCFCs less damaging than CFCs in the longer term |
| <strong>Hydrofluorocarbon (HFC)</strong> | A family of chemicals related to CFCs, which contain hydrogen, fluorine and carbon, but no chlorine, and therefore do not deplete ozone layer |
| <strong>ISO Container</strong> | Used for bulk liquid shipments. ISO container provides the flexibility of using various transportation modes such as truck, rail and ship |
| <strong>London Amendment</strong> | Refers to amendments decided by the second MOP, whereby controls on Annex B substances were added. At this meeting, the phase-out schedules for Annex A substances were also accelerated and the Interim Multilateral Fund was established to assist developing countries in their efforts in phasing out ODS |
| <strong>Montreal Amendment</strong> | Refers to amendments decided by the Ninth MOP in Montreal, whereby, inter alias, requirements on import and export licensing systems were introduced. At some meeting, phase-out schedules for methyl bromide were accelerated |
| <strong>Montreal Protocol (MP)</strong> | The Protocol to the Vienna Convention, signed in 1987, which commits Parties to take concrete measures to protect the ozone layer by freezing, reducing and phasing-out the production and consumption of controlled substances |
| <strong>Ozone Depletion</strong> | The process by which stratospheric ozone molecules are destroyed by man-made chemicals, leading to a reduction in its concentration |
| <strong>Ozone Depleting Substance (ODS)</strong> | Any substance which is controlled under the Montreal Protocol and its amendments. ODS include CFCs, HCFCs, Halons, carbon tetrachloride, methyl chloroform, hydrobromofluorocarbons, bromochloromethane and methyl bromide. ODS have ozone-depleting potential grater than 0 and can deplete the stratospheric ozone layer |</p>
<table>
<thead>
<tr>
<th><strong>ODS-based product/equipment</strong></th>
<th>Product or equipment which contains ODS, including equipment whose continuous functioning relies on the use of ODS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ozone layer</strong></td>
<td>A term used to describe the presence of ozone molecules dispersed in the stratosphere. The stratosphere is that part of the Earth’s atmosphere, which follows the troposphere. Its start at 10-20 km above ground level and continues up to 40-50 km height. The ozone layer acts as a filter against the ultraviolet radiation (UV-B) coming from the Sun and protects life on Earth from the damaging effect of increased UV-B exposure.</td>
</tr>
<tr>
<td><strong>Ozone Depletion Potential (ODP)</strong></td>
<td>A measure of a substance’s ability to destroy stratospheric ozone based on its atmospheric lifetime, stability, reactivity and content of elements that can attack ozone, such as chlorine and bromine. All ODPS are based on the reference measure of 1 for CFC-11</td>
</tr>
<tr>
<td><strong>Ozone molecule</strong></td>
<td>Molecules containing three atoms of oxygen, and whose presence in the stratosphere constitutes the ozone layer</td>
</tr>
<tr>
<td><strong>Phase-out</strong></td>
<td>When the production and consumption of a controlled ODS is zero.</td>
</tr>
<tr>
<td><strong>Reclaim</strong></td>
<td>Re-processing used refrigerant to the product specification of new refrigerant. Chemical analyzes of the refrigerant is required to determine that the appropriate specifications are met.</td>
</tr>
<tr>
<td><strong>Recovery</strong></td>
<td>Removal of a refrigerant in any condition (vapor, liquid or mixed with other substance) from a system and store it in an external container</td>
</tr>
<tr>
<td><strong>Recycling</strong></td>
<td>Reduction of contaminants in used refrigerants by separating oil, removing condensables and using devices such as filter dryers to reduce moisture, acidity and particulate matter</td>
</tr>
<tr>
<td><strong>Retrofitting</strong></td>
<td>The procedure when replacing CFC-refrigerants in existing refrigeration, air-conditioning and heat pump plants with non-ODS refrigerants. This procedure usually requires modifications such as change as lubricant, replacement of expansion device or compressor. Drop-in replacements do not require major modifications</td>
</tr>
<tr>
<td><strong>Stratosphere</strong></td>
<td>A region of the upper atmosphere between the troposphere and the mesosphere, ranging from about 10-20 up to 40-50 km above the Earth’s surface</td>
</tr>
<tr>
<td><strong>Ultraviolet radiation</strong></td>
<td>Radiation from the sun with wavelengths between visible light and X-rays. UV-B (280-320 nm) is one of three bands of UV radiation and increased exposure to UV-B radiation can cause damage to human health and the environment</td>
</tr>
</tbody>
</table>
## Annex B. Blends and their composition

### Zeotrope mixtures

<table>
<thead>
<tr>
<th>Refrigerant Number (Trade name)</th>
<th>Component 1</th>
<th>Component 2</th>
<th>Component 3</th>
<th>Component 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>R401a (MP 39)</td>
<td>HCFC-22</td>
<td>HFC-152a</td>
<td>HCFC-124</td>
<td>34%</td>
</tr>
<tr>
<td>R401b (MP 66)</td>
<td>HCFC-22</td>
<td>HFC-152a</td>
<td>HCFC-124</td>
<td>28%</td>
</tr>
<tr>
<td>R401C (MP 52)</td>
<td>HCFC-22</td>
<td>HFC-152a</td>
<td>HCFC-124</td>
<td>52%</td>
</tr>
<tr>
<td>R402a (HP 80)</td>
<td>HFC-125</td>
<td>HC-290</td>
<td>HCFC-22</td>
<td>38%</td>
</tr>
<tr>
<td>R402b (HP 81)</td>
<td>HFC-125</td>
<td>HC-290</td>
<td>HCFC-22</td>
<td>60%</td>
</tr>
<tr>
<td>R403a (69S)</td>
<td>HC-290</td>
<td>HCFC-22</td>
<td>FC-218</td>
<td>20%</td>
</tr>
<tr>
<td>R403b (69L)</td>
<td>HC-290</td>
<td>HCFC-22</td>
<td>FC-218</td>
<td>39%</td>
</tr>
<tr>
<td>R405a (G2015)</td>
<td>HCFC-22</td>
<td>HCFC-152a</td>
<td>HCFC-142b</td>
<td>42.5%</td>
</tr>
<tr>
<td>R406a (GHG-12)</td>
<td>HCFC-22</td>
<td>HCFC-600a</td>
<td>HCFC-142b</td>
<td>41%</td>
</tr>
<tr>
<td>R408a (FX55)</td>
<td>HFC-125</td>
<td>HCF-143a</td>
<td>HCFC-22</td>
<td>47%</td>
</tr>
<tr>
<td>R409a (FX56)</td>
<td>HCFC-22</td>
<td>HCFC-124</td>
<td>HCFC-142b</td>
<td>15%</td>
</tr>
<tr>
<td>R409b (FX57)</td>
<td>HCFC-22</td>
<td>HCFC-124</td>
<td>HCFC-142b</td>
<td>10%</td>
</tr>
<tr>
<td>R411a (G2018A)</td>
<td>HC-1270</td>
<td>HCFC-22</td>
<td>HCFC-152a</td>
<td>11%</td>
</tr>
<tr>
<td>R411b (G2018B)</td>
<td>HC-1270</td>
<td>HCFC-22</td>
<td>HCFC-152a</td>
<td>3%</td>
</tr>
<tr>
<td>R412a (TP5R)</td>
<td>HCFC-22</td>
<td>FC-218</td>
<td>HCFC-142b</td>
<td>25%</td>
</tr>
<tr>
<td>R414b (Hotshot)</td>
<td>HCFC-22</td>
<td>HCFC-124</td>
<td>HCFC-142b</td>
<td>9.5%</td>
</tr>
</tbody>
</table>

### Azeotrope mixtures

<table>
<thead>
<tr>
<th>Refrigerant number</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>R500</td>
<td>CFC12</td>
<td>HCFC152a</td>
</tr>
<tr>
<td>R501</td>
<td>HCFC22</td>
<td>CFC12</td>
</tr>
<tr>
<td>R502</td>
<td>HCFC22</td>
<td>CFC115</td>
</tr>
<tr>
<td>R503</td>
<td>HFC23</td>
<td>CFC13</td>
</tr>
<tr>
<td>R504</td>
<td>HFC32</td>
<td>CFC115</td>
</tr>
<tr>
<td>R505</td>
<td>CFC12</td>
<td>HCFC31</td>
</tr>
<tr>
<td>R506</td>
<td>HCFC31</td>
<td>CFC114</td>
</tr>
<tr>
<td>R507</td>
<td>HCFC124</td>
<td>HCFC143a</td>
</tr>
<tr>
<td>R509</td>
<td>HCFC22</td>
<td>FC218</td>
</tr>
</tbody>
</table>

### Unnamed mixtures

<table>
<thead>
<tr>
<th>Trade name</th>
<th>Component 1</th>
<th>Component 2</th>
<th>Component 3</th>
<th>Component 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>FX-20</td>
<td>HCFC-125</td>
<td>45%</td>
<td>HCFC-22</td>
<td>55%</td>
</tr>
<tr>
<td>FX-10</td>
<td>HCFC-22</td>
<td>60%</td>
<td>HCFC-142b</td>
<td>40%</td>
</tr>
<tr>
<td>Di 36</td>
<td>HCFC-22</td>
<td>2%</td>
<td>HCFC-124</td>
<td>47%</td>
</tr>
<tr>
<td>Daikin Blend</td>
<td>HFC-23</td>
<td>39%</td>
<td>HFC-32</td>
<td>59%</td>
</tr>
<tr>
<td>FRIGC</td>
<td>HCFC-124</td>
<td>39%</td>
<td>HCFC-134a</td>
<td>59%</td>
</tr>
<tr>
<td>Free Zone</td>
<td>HCFC-142b</td>
<td>19%</td>
<td>HCFC-134a</td>
<td>79%</td>
</tr>
<tr>
<td>GHG-HP</td>
<td>HCFC-22</td>
<td>65%</td>
<td>HCFC-142b</td>
<td>31%</td>
</tr>
<tr>
<td>GHG-X5</td>
<td>HCFC-22</td>
<td>41%</td>
<td>HCFC-142b</td>
<td>15%</td>
</tr>
<tr>
<td>NARM-502</td>
<td>HCFC-22</td>
<td>90%</td>
<td>HCFC-152a</td>
<td>5%</td>
</tr>
<tr>
<td>NAF-S-III</td>
<td>HCFC-22</td>
<td>82%</td>
<td>HCFC-123</td>
<td>4.7%</td>
</tr>
<tr>
<td>NAF-P-III</td>
<td>HCFC-134a</td>
<td>10%</td>
<td>HCFC-123</td>
<td>55%</td>
</tr>
</tbody>
</table>
Annex C. ARI refrigerant container colour assignments sorted by ASHRAE number
(Source: ARI Coolnet at http://www.ari.org/er/guide-n.html)

<table>
<thead>
<tr>
<th>ASHRAE Number</th>
<th>PMS Number</th>
<th>Assigned colour (ARI Guideline N)</th>
<th>ASHRAE Number</th>
<th>PMS number</th>
<th>Assigned colour (ARI Guideline N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-11</td>
<td>021</td>
<td>Orange</td>
<td>R-407b</td>
<td>156</td>
<td>Cream</td>
</tr>
<tr>
<td>R-12</td>
<td>-</td>
<td>White</td>
<td>R-407c</td>
<td>471</td>
<td>Medium Green</td>
</tr>
<tr>
<td>R-13</td>
<td>2975</td>
<td>Light Blue (Sky)</td>
<td>R-407e</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-13B1</td>
<td>177</td>
<td>Pinkish-Red (Coral)</td>
<td>R-408a</td>
<td>248</td>
<td>Medium Purple</td>
</tr>
<tr>
<td>R-14</td>
<td>124</td>
<td>Yellow-Brown (mustard)</td>
<td>R-409a</td>
<td>465</td>
<td>Medium Brown (Tan)</td>
</tr>
<tr>
<td>R-22</td>
<td>352</td>
<td>Light green</td>
<td>R-409b</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-23</td>
<td>428</td>
<td>Light Blue-Grey</td>
<td>R-410a</td>
<td>507</td>
<td>Rose</td>
</tr>
<tr>
<td>R-32</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-410b</td>
<td>194</td>
<td>Maroon</td>
</tr>
<tr>
<td>R-50</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-411a</td>
<td>226F</td>
<td>Dark Purple (Violet)</td>
</tr>
<tr>
<td>R-113</td>
<td>266</td>
<td>Dark Purple (Violet)</td>
<td>R-411b</td>
<td>326F</td>
<td>Blue-Green (Teal)</td>
</tr>
<tr>
<td>R-114</td>
<td>302</td>
<td>Dark Blue (Navy)</td>
<td>R-412a</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-115</td>
<td>*</td>
<td>Unassigned</td>
<td>R-413a</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-116</td>
<td>424</td>
<td>Dark Grey (Battleship)</td>
<td>R-414a</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-123</td>
<td>428</td>
<td>Light Blue-Grey</td>
<td>R-414b</td>
<td>2995</td>
<td>Medium Blue</td>
</tr>
<tr>
<td>R-124</td>
<td>335</td>
<td>Deep Green (DOT Green)</td>
<td>R-416a</td>
<td>381</td>
<td>Yellow-Green (Lime)</td>
</tr>
<tr>
<td>R-125</td>
<td>465</td>
<td>Medium Brown (Tan)</td>
<td>R-500</td>
<td>109</td>
<td>Yellow</td>
</tr>
<tr>
<td>R-134a</td>
<td>2975</td>
<td>Light Blue (Sky)</td>
<td>R-501</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-141b</td>
<td>*</td>
<td>Unassigned</td>
<td>R-502</td>
<td>251</td>
<td>Light Purple (Lavender)</td>
</tr>
<tr>
<td>R-142b</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-503</td>
<td>3268</td>
<td>Blue-Green (Aqua)</td>
</tr>
<tr>
<td>R-143a</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-504</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-152a</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-505</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-170</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-506</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-218</td>
<td>*</td>
<td>Unassigned</td>
<td>R-507a</td>
<td>326</td>
<td>Blue-Green (Teal)</td>
</tr>
<tr>
<td>R-225</td>
<td>*</td>
<td>Unassigned</td>
<td>R-507b</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-236fa</td>
<td>*</td>
<td>Unassigned</td>
<td>R-508a</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-245fa</td>
<td>*</td>
<td>Unassigned</td>
<td>R-508b</td>
<td>302</td>
<td>Dark Blue (Navy)</td>
</tr>
<tr>
<td>R-290</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-509</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-401a</td>
<td>177</td>
<td>Pinkish-Red (Coral)</td>
<td>R-509a</td>
<td>*</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-401b</td>
<td>124</td>
<td>Yellow-Brown (Mustard)</td>
<td>R-600</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-401c</td>
<td>3268</td>
<td>Blue-Green (Aqua)</td>
<td>R-600a</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-402a</td>
<td>461</td>
<td>Light Brown (Sand)</td>
<td>R-717</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-402b</td>
<td>385</td>
<td>Green-Brown (Olive)</td>
<td>R-1140</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-403a</td>
<td>*</td>
<td>Unassigned</td>
<td>R-1150</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-403b</td>
<td>*</td>
<td>Unassigned</td>
<td>R-1270</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-404a</td>
<td>021</td>
<td>Orange</td>
<td>R-600a</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-405A</td>
<td>*</td>
<td>Unassigned</td>
<td>R-600a</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-406a</td>
<td>* F</td>
<td>Unassigned</td>
<td>R-600a</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
<tr>
<td>R-407a</td>
<td>368</td>
<td>Lime Green</td>
<td>R-600a</td>
<td>* F</td>
<td>Unassigned</td>
</tr>
</tbody>
</table>

Notes:

* These refrigerants are not produced in sufficient quantities to qualify own color or a producer has not requested a color assignment. Containers with these refrigerants are assigned PMS#414 (light green-grey)

F These refrigerants are flammable. Containers for flammable refrigerants should also be painted with a red band around its top shoulder or cap

ASHRAE – The American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta, GA

PMS – color codes are following the Pantone® Matching System
Bold/grey – these are or contain ODS

Annex D: ARI refrigerant container colour assignments sorted by PMS number
(Source: ARI Coolnet under http://www.ari.org.er/color-a.html)

<table>
<thead>
<tr>
<th>PMS Number</th>
<th>Assigned colour</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>White</td>
<td>R-12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black C</td>
<td>Black (Print Black)</td>
<td>R-11</td>
<td>R-404a</td>
<td>R-12</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>Yellow</td>
<td>R-500</td>
<td>R-12</td>
<td>R-404a</td>
<td></td>
</tr>
<tr>
<td>124</td>
<td>Yellow-Brown</td>
<td>401b</td>
<td>R-12</td>
<td></td>
<td>R-404a</td>
</tr>
<tr>
<td>156</td>
<td>Cream</td>
<td></td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
</tr>
<tr>
<td>177</td>
<td>Pinkish-Red (Coral)</td>
<td>R-401a</td>
<td>R-12</td>
<td>R-404a</td>
<td></td>
</tr>
<tr>
<td>185</td>
<td>Red (DOT Red)</td>
<td></td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
</tr>
<tr>
<td>194</td>
<td>Maroon</td>
<td></td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
</tr>
<tr>
<td>248</td>
<td>Medium Purple (Purple)</td>
<td>R-500</td>
<td>R-12</td>
<td>R-404a</td>
<td></td>
</tr>
<tr>
<td>251</td>
<td>Light Purple (Lavender)</td>
<td></td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
</tr>
<tr>
<td>266</td>
<td>Dark Purple (Violet)</td>
<td>R-113</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>302</td>
<td>Dark Blue (Navy)</td>
<td>R-114</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>326</td>
<td>Blue-Green (Teal)</td>
<td>R-507a</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>335</td>
<td>Deep (DOT) Green</td>
<td></td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
</tr>
<tr>
<td>352</td>
<td>Light Green</td>
<td>R-22</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>368</td>
<td>Lime Green</td>
<td>R-407a</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>381</td>
<td>Yellow-Green (Lime)</td>
<td>R-416a</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>385</td>
<td>Green-Brown (Olive)</td>
<td></td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
</tr>
<tr>
<td>413</td>
<td>Light Green-Grey</td>
<td>Note 2</td>
<td>Note 2</td>
<td>Note 2</td>
<td>Note 2</td>
</tr>
<tr>
<td>424</td>
<td>Dark Grey (Battleship)</td>
<td>R-116</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>428</td>
<td>Light Blue-Grey</td>
<td>R-123</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>450</td>
<td>Dark Brown (Chocolate)</td>
<td>R-407d</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>461</td>
<td>Light Brown (Sand)</td>
<td>R-402a</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>465</td>
<td>Medium Brown (Tan)</td>
<td>R-409a</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>468</td>
<td>Light Tan</td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>471</td>
<td>Medium Brown (Brown)</td>
<td>R-407c</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>507</td>
<td>Rose</td>
<td></td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>2975</td>
<td>Light Blue (Sky)</td>
<td>R-134a</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>2995</td>
<td>Medium Blue (Blue)</td>
<td>R-414b</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
<tr>
<td>3268</td>
<td>Blue-Green (Aqua)</td>
<td>R-401c</td>
<td>R-12</td>
<td>R-404a</td>
<td>R-404a</td>
</tr>
</tbody>
</table>

Notes:
1. Reserved for red band marking of containers for flammable refrigerants. Containers for flammable refrigerants (Class IV) should also have a red band painted around its top shoulder or cap.

2. Reserved for refrigerants that are not assigned a colour.

Bold/Grey – these are or contain ODS
Annex E: International Chemical Safety Cards
(Source: World Health Organization and the European Union)

These safety cards may not reflect in all cases all the detailed requirements included in national legislation on the subject. The user should verify compliance of the cards with the relevant legislation in the country.

### Annex E1: TRICHLOROFLUROMETHANE CFC-11

<table>
<thead>
<tr>
<th>TYPES OF HAZARD/EXPOSURE</th>
<th>ACUTE HAZARDS/SYMPTOMS</th>
<th>PREVENTION</th>
<th>FIRST AID/FIRE FIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRE</td>
<td>Not combustible. Gives off irritating or toxic fumes (or gases) in a fire</td>
<td>In case of fire in the surroundings: all extinguishing agents.</td>
<td></td>
</tr>
<tr>
<td>EXPLOSION</td>
<td>Risk of fire and explosion (see Chemical Dangers).</td>
<td>In case of fire: keep drums, etc., cool by spraying with water.</td>
<td></td>
</tr>
<tr>
<td>SKIN</td>
<td>ON CONTACT WITH LIQUID: FROSTIBITE</td>
<td>Cold-insulating gloves.</td>
<td>ON FROSTIBITE: rinse with plenty water, do NOT remove clothes. Refer for chemical attention</td>
</tr>
<tr>
<td>EYES</td>
<td>Redness. Pain.</td>
<td>Safety goggles.</td>
<td>First rinse with plenty of water for several minutes (remove contact lenses if easily possible), than take to a doctor.</td>
</tr>
</tbody>
</table>

**SPILAGE DISPOSAL:** Ventilation. If in liquid form, allow to evaporate. NEVER direct water jet on liquid.

**STORAGE:** Separated from metals (See Chemical Dangers). Cool. Ventilation along the floor.

**PHYSICAL STATE; APPEARANCE:** Colourless gas or highly volatile liquid, with characteristic odour.

**PHYSICAL DANGERS:** The gas is heavier than air. The vapour is heavier than air and may accumulate in low ceiling spaces causing deficiency of oxygen.

**CHEMICAL DANGERS:** On contact with hot surfaces or flames this substance decomposes forming corrosive and very toxic fumes (hydrogen chloride, ICSC#0163; phosgene ICSC#0007; chlorine, ICSC#0126; hydrogen fluoride, ICSC#0283). Reacts violently with metals and various powdered metals, such as aluminium, barium, calcium, magnesium and sodium.

**ROUTES OF EXPOSURE:** The substance can be absorbed into body by inhalation.

**INHALATION RISK:** On loss of containment this liquid evaporates very quickly causing supersaturation of the air with serious risk of suffocation when in confined areas.

**EFFECTS OF SHORT-TERM EXPOSURE:** The liquid may cause frostbite. Exposure could cause cardiac arrhythmia and asphyxiation. See notes.

**EFFECTS OF LONG-TERM OR REPEATED EXPOSURE:** Repeated or prolonged contact with skin may cause dermatitis.

**PHYSICAL PROPERTIES:** Vapour pressure, kPa at 20°C: 89,0, Relative vapour density (air=1): 4,7, Relative density of the vapour/air-mixture at 20°C (air=1): 4,4.

**ENVIRONMENTAL DATA:** This substance may be hazardous to the environment; special attention should be given to water and air.

**NOTES:** To physicians: adrenergic agents are contraindicated. High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. Check oxygen content before entering area. The odor warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. Turn leaking cylinder with the leak up to prevent escape of gas in liquid state. Freon 11, Frigen 11, Halon 11 are trade names.
### Annex E2: DICHLOROFUROMETHANE CFC-12

<table>
<thead>
<tr>
<th>TYPES OF HAZARD/EXPOSURE</th>
<th>ACUTE HAZARDS/SYMPTOMS</th>
<th>PREVENTION</th>
<th>FIRST AID/FIRE FIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRE</td>
<td>Not combustible. Gives off irritating or toxic fumes (or gases) in a fire.</td>
<td>In case of fire in the surroundings: all extinguishing agents allowed.</td>
<td></td>
</tr>
<tr>
<td>EXPLOSION</td>
<td>Risk of fire and explosion (see Chemical Dangers).</td>
<td>In case of fire: keep cylinder cool by spraying with water.</td>
<td></td>
</tr>
<tr>
<td>SKIN</td>
<td>ON CONTACT WITH LIQUID: FROSTIBITE. Cold-insulating gloves.</td>
<td>ON FROSTIBITE: rinse with plenty of water, do NOT remove clothes. Refer for chemical attention.</td>
<td></td>
</tr>
<tr>
<td>EYES</td>
<td>Redness. Pain. Safety goggles.</td>
<td>First rinse with plenty of water for several minutes (remove contact lenses if easily possible), than take to a doctor.</td>
<td></td>
</tr>
</tbody>
</table>

**SPILAGE DISPOSAL:** Ventilation. NEVER direct water jet on liquid.

**STORAGE:** Separated from metals (See Chemical Dangers). Cool. Ventilation along the floor.

**PACKAGING & LABELLING:** Special insulated cylinder. UN Hazard class 2.2

**PHYSICAL STATE:** APPEARANCE: Colourless compressed liquefied gas, with characteristic odour.

**PHYSICAL DANGERS:** The gas is heavier than air and may accumulate in low ceiling spaces causing deficiency of oxygen.

**CHEMICAL DANGERS:** On contact with hot surfaces or flames this substance decomposes forming corrosive and very toxic fumes (hydrogen chloride, ICSC#0163; phosgene ICSC#0007; chlorine, ICSC#0126; hydrogen fluorine, ICSC#0283). Reacts violently with metals such as potassium, calcium, magnesium, sodium, zinc and powdered aluminium. Attack magnesium and its alloys.

**ROUTES OF EXPOSURE:** The substance can be absorbed into body by inhalation.

**INHALATION RISK:** On loss of containment, this gas can cause suffocation by lowering the oxygen content of their air in confined areas.

**EFFECTS OF SHORT-TERM EXPOSURE:** The liquid may cause frostbite. Exposure could cause cardiac arrhythmia and asphyxiation. See notes.

**PHYSICAL PROPERTIES:** Vapour pressure, kPa at 20°C: 568. Relative vapour density (air=1): 4.2.

**ENVIRONMENTAL DATA:** This substance may be hazardous to the environment; special attention should be given to air.

**NOTES:** To physicians: adrenergic agents are contraindicated. High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. Check oxygen content before entering area. The odour warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. Turn leaking cylinder with the leak up to prevent escape of gas in liquid state. Freon 12, Frigen 12, Halon 12 are trade names.
## Annex E3: CHLOROTRIFLUROMETHANE CFC-13

<table>
<thead>
<tr>
<th>TYPES OF HAZARD/EXPOSURE</th>
<th>ACUTE HAZARDS/SYMPTOMS</th>
<th>PREVENTION</th>
<th>FIRST AID/FIRE FIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRE</td>
<td>Not combustible. Heating will cause rise in pressure with risk of sting.</td>
<td>No contact with hot surfaces.</td>
<td>In case of fire: keep cylinder cool by spraying with water.</td>
</tr>
<tr>
<td>EXPLOSION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKIN</td>
<td>ON CONTACT WITH LIQUID: FROSTIBITE.</td>
<td>Cold-insulating gloves.</td>
<td>ON FROSTIBITE: rinse with plenty water, do NOT remove clothes. Refer for chemical attention</td>
</tr>
<tr>
<td>EYES</td>
<td>(See Skin).</td>
<td>Safety goggles, face shield, or eye protection in combination with breathing protection.</td>
<td>First rinse with plenty of water for several minutes (remove contact lenses if easily possible), than take to a doctor.</td>
</tr>
</tbody>
</table>

### SPILAGE DISPOSAL:
Ventilation. NEVER direct water jet on liquid. In case of large spillage, extra personal protection: complete protection with self-contained breathing apparatus.

### STORAGE:
Fireproof if in building.

### PACKAGING & LABELLING:
UN Hazard Class: 2.2.

### PHYSICAL STATE; APPEARANCE:
Colourless liquefied gas, with characteristic odour.

### PHYSICAL DANGERS:
The gas is heavier than air and may accumulate in low ceiling spaces causing deficiency of oxygen.

### CHEMICAL DANGERS:
The substance decomposes on burning or on contact with hot surfaces producing toxic and corrosive fumes including hydrogen chloride, hydrogen fluoride and phosgene. Incompatible with certain metal powders (aluminium, zinc, beryllium).

### ROUTES OF EXPOSURE:
The substance can be absorbed into body by inhalation.

### INHALATION RISK:
On loss of containment this liquid evaporates very quickly causing supersaturation of the air with serious risk of suffocation when in confined areas.

### EFFECTS OF SHORT-TERM EXPOSURE:
The liquid may cause frostbite. Exposure could cause cardiac arrhythmia and asphyxiation. See notes.

### PHYSICAL PROPERTIES:
Relative vapour density (air=1): 3.6

### ENVIRONMENTAL DATA:
This substance may be hazardous to the environment; special attention should be given to its impact on the ozone layer.

### NOTES:
High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. Check oxygen content before entering area. Physician should give special attention to the drugs used in treatment because of the effects of the substance on cardiac rhythm. Do NOT use in the vicinity of a fire or a hot surface, or during welding. Arcton 13, FCC 13, Freon 13, Frigen 13, Genetron 13 are trade names.
## Annex E 4: CHLORODIFLUROMETHANE
### Monochlorodifluoromethane: HCFC-22 Cylinder

<table>
<thead>
<tr>
<th>TYPES OF HAZARD/EXPOSURE</th>
<th>ACUTE HAZARDS/SYMPTOMS</th>
<th>PREVENTION</th>
<th>FIRST AID/FIRE FIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRE</strong></td>
<td>Not combustible. Gives off irritating or toxic fumes (or gases) in a fire.</td>
<td>In case of fire in the surroundings: all extinguishing agents allowed</td>
<td></td>
</tr>
<tr>
<td><strong>EXPLOSION</strong></td>
<td>Risk of fire and explosion (see Chemical Dangers).</td>
<td>In case of fire: keep cylinder cool by spraying with water.</td>
<td></td>
</tr>
<tr>
<td><strong>INHALATION</strong></td>
<td>Confusion. Drowsiness. Unconsciousness.</td>
<td>Ventilation, local exhaust, or breathing</td>
<td>Fresh air, rest. Artificial respiration if indicated. Refer for medical attention.</td>
</tr>
<tr>
<td><strong>SKIN</strong></td>
<td>ON CONTACT WITH LIQUID: FROSTIBITE</td>
<td>Cold-insulating gloves.</td>
<td>ON FROSTIBITE: rinse with plenty of water, do NOT remove clothes.</td>
</tr>
<tr>
<td><strong>EYES</strong></td>
<td>Redness. Pain.</td>
<td>Safety goggles.</td>
<td>First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.</td>
</tr>
</tbody>
</table>

### SPIILAGE DISPOSAL:
Ventilation. NEVER direct water jet on liquid.

### STORAGE:
Separated from powdered metals such as aluminium and zinc. Cool. Ventilation along the floor.

### PACKAGING & LABELLING:
Special insulated cylinder. UN Hazard Class: 2.2.

### PHYSICAL STATE; APPEARANCE:
Colourless liquefied gas, with characteristic odour.

### PHYSICAL DANGERS:
The gas is heavier than air and may accumulate in low ceiling spaces causing deficiency of oxygen.

### CHEMICAL DANGERS:
On contact with hot surfaces or flames this substance decomposes forming corrosive and very toxic fumes (hydrogen chloride, ICSC#0163; phosgene ICSC#0007; chlorine, ICSC#0126; hydrogen fluorine, ICSC#0283). Reacts violently with powdered metals such as aluminium and zinc, causing fire and explosion hazard. Attacks magnesium and its alloys.

### ROUTES OF EXPOSURE:
The substance can be absorbed into body by inhalation.

### INHALATION RISK:
On loss of containment, this gas can cause suffocation by lowering the oxygen content of their air in confined areas.

### EFFECTS OF SHORT-TERM EXPOSURE:
The liquid may cause frostbite. Exposure could cause cardiac arrhythmia and asphyxiation. See notes.

### PHYSICAL PROPERTIES:
Vapour pressure, kPa at 20°C: 908. Relative vapour density (air=1): 3.0.

### ENVIRONMENTAL DATA:
This substance may be hazardous to the environment; special attention should be given to the air.

### NOTES:
To physicians: adrenergic agents are contraindicated. High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. Check oxygen content before entering area. The odour warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. Turn leaking cylinder with the leak up to prevent escape of gas in liquid state. Freon 22, Frigen 22, Halon 22 are trade names.
Annex E 5: 1,1,2 -TRICHLORO-
1,2,2 –TRIFLUROETHANE/
Trichlorotrifluoroethane: CFC-113

<table>
<thead>
<tr>
<th>TYPES OF HAZARD/EXPOSURE</th>
<th>ACUTE HAZARDS/ SYMPTOMS</th>
<th>PREVENTION</th>
<th>FIRST AID/FIRE FIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRE</td>
<td>Not combustible. Gives off irritating or toxic fumes (or gases) in a fire.</td>
<td>In case of fire in the surroundings: all extinguishing agents allowed</td>
<td></td>
</tr>
<tr>
<td>EXPLOSION</td>
<td>Risk of fire and explosion (see Chemical Dangers).</td>
<td>In case of fire: keep drums, etc., cool by spraying with water.</td>
<td></td>
</tr>
<tr>
<td>SKIN</td>
<td>Redness. Pain</td>
<td>Protective gloves.</td>
<td>Remove contaminated clothes. Rinse skin with plenty water or shower. Refer for medical attention.</td>
</tr>
<tr>
<td>INGESTION</td>
<td>Do not eat, drink, or smoke during work.</td>
<td>Rinse mouth. Refer for medical attention.</td>
<td></td>
</tr>
<tr>
<td>EYES</td>
<td>Redness. Pain.</td>
<td>Safety goggles.</td>
<td>First rinse with plenty of water for several minutes (remove contact lenses if easily possible), than take to a doctor.</td>
</tr>
</tbody>
</table>

**SPILAGE DISPOSAL:** Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place (extra personal protection, self-contained breathing apparatus).

**STORAGE:** Separated from metals and alloys (see Chemical Dangers). Cool.

**PHYSICAL STATE; APPEARANCE:** Colourless volatile liquid, with characteristic odour.

**PHYSICAL DANGERS:** The gas is heavier than air and may accumulate in low ceiling spaces causing deficiency of oxygen.

**CHEMICAL DANGERS:** On contact with hot surfaces or flames this substance decomposes forming corrosive and very toxic fumes (hydrogen chloride, ICSC#0163; phosgene ICSC#0007; chlorine, ICSC#0126; hydrogen fluoride, ICSC#0283). Reacts violently with powdered metals such as aluminium beryllium, zinc and magnesium, causing fire and explosion hazard. Attacks alloys containing more than 2% magnesium.

**ROUTES OF EXPOSURE:** The substance can be absorbed into body by inhalation.

**INHALATION RISK:** On loss of containment, this gas can cause suffocation by lowering the oxygen content of their air in confined areas.

**EFFECTS OF SHORT-TERM EXPOSURE:** The substance irritates the eyes and the respiratory tract. The substance may cause effects on the central nervous system in high concentrations, resulting in lowering of consciousness. Exposure could cause cardiac arrhythmia and asphyxiation.

**EFFECTS OF LONG-TERM OR REPEATED EXPOSURE:** Repeated or prolonged contacts with skin may cause dermatitis.

**PHYSICAL PROPERTIES:** Vapour pressure, kPa at 20°C: 36, Relative vapour density (air=1): 6,5, Relative density of the vapour/air-mixture at 20°C (air=1): 3,0.

**ENVIRONMENTAL DATA:** This substance may be hazardous to the environment; special attention should be given to water.

**NOTES:** To physicians: adrenergic agents are contraindicated. High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. The odour warning when the exposure limit value is exceeded is insufficient. Do NOT use in the vicinity of a fire or a hot surface, or during welding. Freon 113, Frigen 113, Halon 113 are trade names.
<table>
<thead>
<tr>
<th>TYPES OF HAZARD/EXPOSURE</th>
<th>ACUTE HAZARDS/SYMPTOMS</th>
<th>PREVENTION</th>
<th>FIRST AID/FIRE FIGHTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRE</td>
<td>Not combustible. Heating will cause rise in pressure with risk of bursting. Gives off irritating or toxic fumes (or gases) in a fire.</td>
<td>In case of fire in the surroundings: all extinguishing agents allowed</td>
<td></td>
</tr>
<tr>
<td>EXPLOSION</td>
<td></td>
<td>In case of fire: keep cylinder cool by spraying with water.</td>
<td></td>
</tr>
<tr>
<td>INHALATION</td>
<td>Suffocation (See notes)</td>
<td>Ventilation.</td>
<td>Fresh air, rest. Artificial respiration if indicated. Refer for medical attention.</td>
</tr>
<tr>
<td>SKIN</td>
<td>ON CONTACT WITH LIQUID: FROSTBITE</td>
<td>Cold-insulating gloves.</td>
<td>ON FROSTBITE rinse with plenty water, do NOT remove the clothes. Refer for medical attention.</td>
</tr>
<tr>
<td>EYES</td>
<td>See Skin</td>
<td>Safety goggles or eye protection combination with breathing protection.</td>
<td>First rinse with plenty of water for several minutes (remove contact lenses if easily possible), than take to a doctor.</td>
</tr>
</tbody>
</table>

**SPILAGE DISPOSAL:** Ventilation. NEVER direct water jet on liquid. (Extra personal protection: chemical protection suit including self-contained breathing apparatus).

**STORAGE:** Fireproof if in building. Cool.

**PACKING & LABELLING:** UN Hazard Class: 2.2.

**PHYSICAL STATE; APPEARANCE:** Odourless, colourless, compressed liquefied gas.

**PHYSICAL DANGERS:** The vapour is heavier than air and may accumulate in low ceiling spaces causing deficiency of oxygen.

**CHEMICAL DANGERS:** On contact with hot surfaces or flames, this substance decomposes forming toxic fumes including hydrogen chloride and hydrogen fluorine.

**ROUTES OF EXPOSURE:** The substance can be absorbed into body by inhalation.

**INHALATION RISK:** A harmful concentration of this gas in the air will be reached very quickly on loss of containment.

**EFFECTS OF SHORT-TERM EXPOSURE:** Rapid evaporation of the liquid may cause frostbite.

**PHYSICAL PROPERTIES:** Vapour pressure, kPa at 20°C: 797, Relative vapour density (air=1): 5.3.

**ENVIRONMENTAL DATA:** This substance may be hazardous to the environment; special attention should be given to its impact on the ozone layer.

**NOTES:** High concentrations in the air cause a deficiency of oxygen with the risk of unconsciousness or death. Check oxygen content before entering area. Turn leaking cylinder with the leak up to prevent escape of gas in liquid state. Freon 115, Frigen 115, Genetron 115, Kaltron 115, and Refrigerant 115 are trade names.
Annex F. Maximum contaminant levels of common refrigerants
(ARI Standard 700 –93)

Table 1. Pure refrigerants

<table>
<thead>
<tr>
<th>Impurities</th>
<th>R-11</th>
<th>R-12</th>
<th>R-13</th>
<th>R-22</th>
<th>R-23</th>
<th>R-32</th>
<th>R-113</th>
<th>R-114</th>
<th>R-123</th>
<th>R-124</th>
<th>R-125</th>
<th>R-134a</th>
<th>R-143a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor phase contaminants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air and other non-condensables</td>
<td>N/A</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>N/A</td>
<td>1,5</td>
<td>N/A</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
</tr>
<tr>
<td>Liquid phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminant water – ppm by weight</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Chlorine ion Max ppm by weight</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Acidity Max ppm by weight</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>High boiling residue</td>
<td>0,01</td>
<td>0,01</td>
<td>0,05</td>
<td>0,01</td>
<td>0,01</td>
<td>0,03</td>
<td>0,01</td>
<td>0,01</td>
<td>0,01</td>
<td>0,01</td>
<td>0,01</td>
<td>0,01</td>
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</tr>
<tr>
<td>Max % by volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particulates/solids</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
</tr>
<tr>
<td>Visually clean to pass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other organic impurities</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
</tr>
</tbody>
</table>
Table 2. *Mixtures*

<table>
<thead>
<tr>
<th></th>
<th>R-500</th>
<th>R-502</th>
<th>R-503</th>
<th>R-401 (53/13/34)</th>
<th>R-401 (61/11/28)</th>
<th>R-402</th>
<th>R-402</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Refrigerant components</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal components, weight %</td>
<td>73,8/26,2</td>
<td>48,8-51,2</td>
<td>40,1/59,9</td>
<td>53/13/34</td>
<td>61/11/28</td>
<td>60/2/38</td>
<td>38/2/60</td>
</tr>
<tr>
<td><strong>Impurities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vapor phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air and other non-condensables (in filled container), (Max % by volume) at 24°C</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
</tr>
<tr>
<td>Liquid phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminant water – ppm by weight</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Chlorine ion Max ppm by weight</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Acidity Max ppm by weight</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>High boiling residue Max % by volume</td>
<td>0,05</td>
<td>0,01</td>
<td>0,05</td>
<td>0,01</td>
<td>0,01</td>
<td>0,01</td>
<td>0,01</td>
</tr>
<tr>
<td>Particulates/solids Visually clean to pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
<td>pass</td>
</tr>
<tr>
<td>All other organic impurities including refrigerant, Max % by weight</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
</tr>
</tbody>
</table>
## Annex G. Trouble shooting

### Annex G1. Trouble shooting of domestic refrigeration systems

<table>
<thead>
<tr>
<th>Trouble</th>
<th>Common cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unit will not run.</td>
<td>Blown fuse.</td>
<td>Replace fuse. Check outlet with voltmeter should check 220V plus or minus 10%. If circuit overloaded, either reduce load or have electrician install separate circuit. If unable to remedy any other way, install autotransformer. Jumper across terminals of control. If unit runs and connections are all right, replace control.</td>
</tr>
<tr>
<td></td>
<td>Broken motor or temperature control.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broken relay.</td>
<td>Check relay, replace if necessary.</td>
</tr>
<tr>
<td></td>
<td>Broken compressor.</td>
<td>Check compressor, replace if necessary.</td>
</tr>
<tr>
<td></td>
<td>Broken overload.</td>
<td>Check overload, replace if necessary.</td>
</tr>
<tr>
<td></td>
<td>Defective service cord.</td>
<td>Check with test light at unit; if no circuit and current are indicated at outlet, replace or repair. Repair or replace broken leads.</td>
</tr>
<tr>
<td></td>
<td>Broken lead to compressors, timer or cold control. Broken timer.</td>
<td>Check with test light and replace if necessary.</td>
</tr>
<tr>
<td></td>
<td>Cold control knob seat at too warm a position, not allowing unit to operate often enough. Freezer section grille not properly positioned. Freezer fan not running properly. Defective intake valve. Air duct seals not properly sealed or positioned.</td>
<td>Instruct user. Instruct user to allow foods to cool to room temperature before placing in cabinet. Level cabinet, adjust door seal. Check light switch; if faulty replace. Check if control knob to colder position. Check air-flow heater. Check if damper is opening by removing grille. With door open, damper should open. If control inoperative, replace control. Turn knob to colder position. Reposition grille.</td>
</tr>
<tr>
<td>Trouble</td>
<td>Common cause</td>
<td>Remedy</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>--------</td>
</tr>
</tbody>
</table>
| **4. Freezer section and refrigerator section too warm.** | Fan motor not running.  
Cold control set too warm or broken.  
Finned evaporator blocked with ice.  
Shortage of refrigerant.  
Not enough air circulation around cabinet.  
Dirty condenser or obstructed condenser ducts.  
Poor door seal.  
Too many door openings. | Check and replace fan motor if necessary.  
Check and replace if necessary.  
Check defrosts heater thermostat or timer.  
Either one of these could cause this condition  
Check for leak, repair, evacuate and recharge system.  
Relocate cabinet or provide clearances to airflow sufficient circulation.  
Clean the condenser and the ducts.  
Level cabinet, adjust door seal.  
Instruct customer. |
| **5. Freezer section too cold** | Cold control knob improperly set.  
Cold control capillary not properly claimed to evaporator.  
Broken cold control. | Turn knob to warmer position.  
Tighten clamp or position.  
Check control. Replace if necessary. |
| **6. Unit runs all time** | No enough air circulation around cabinet or air circulation is restricted.  
Poor door seal.  
Freezing large quantities of ice cubes, or heavy loading after shopping.  
Refrigerant charge.  
Room temperature too warm.  
Cold control.  
Defective light switch.  
Excessive door openings. | Relocate cabinet or provide proper clearances around cabinet – remove restriction.  
Check and make necessary adjustments.  
Explain to customer that heavy loading causes long running time.  
Undercharge or overcharge – check, recover, evacuate and recharge with proper charge.  
Ventilate room as much as possible.  
Check control; if allows unit to operate all time, replace control.  
Check if light goes out. Replace switch if necessary.  
Instruct customer. |
| **7. Noisy operation** | Loose flooring or floor not firm.  
Tubing contacting cabinet or outer tubing.  
Cabinet not levelled.  
Drip tray vibrating.  
Fan hitting liner or mechanically grounding.  
Compressor mechanically grounded. | Tighten flooring or balance floor.  
Move tubing.  
Level cabinet.  
Move tray – place on Styrofoam pad if necessary.  
Move fan.  
Replace compressor mounts. |
| **8. Unit cycles on overload** | Broken relay.  
Weak overload protector.  
Low voltage.  
Poor compressor. | Replace relay.  
Replace overload protector.  
Check outlet with voltmeter. Underloaded voltage should be 220 V plus minus 10%.  
Check for several appliances on same circuit or extremely long/undersized cord being used.  
Check compressor faulty for any reason, replace motor compressor. |
| **9. Stuck motor compressor** | Broken valve.  
Insufficient oil.  
Overheated compressor. | Replace motor compressor.  
Add oil; if still not operate, replace motor compressor.  
If compressor faulty for any reason, replace motor compressor. |
<table>
<thead>
<tr>
<th>Trouble</th>
<th>Common cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Unit runs all time, temperature normal</td>
<td>Ice builds up on the evaporator. Control bulb on thermostat not in contact with evaporator surface.</td>
<td>Check door gaskets – replace if necessary. Place control bulb in contact with the evaporator surface.</td>
</tr>
<tr>
<td>13. Freezer runs all the time. Temperature too cold</td>
<td>Faulty thermostat.</td>
<td>Check thermostat – test and replace if necessary.</td>
</tr>
<tr>
<td>14. Freezer runs all the time. Temperature too warm.</td>
<td>Ice built-up in insulation.</td>
<td>Remove breaker strips, stop unit, melt ice and dry insulation, seal outer shell and joints and then assemble.</td>
</tr>
<tr>
<td>15. Rapid ice built-up on the evaporator</td>
<td>Leaky door gasket.</td>
<td>Adjust door hinges. Replace door gasket if cracked, brittle or worn.</td>
</tr>
<tr>
<td>16. Door on freezer compartment freezes shut.</td>
<td>Faulty electric gasket heater. Faulty gasket seal.</td>
<td>Use alternate gasket or install new one. Inspect and check gasket. If worn, cracked or hardened, replace it.</td>
</tr>
<tr>
<td>17. Freezer works then warms up.</td>
<td>Moisture in refrigerant.</td>
<td>Install drier in liquid line.</td>
</tr>
<tr>
<td>18. Gradual reduction in freezing capacity.</td>
<td>Wax build-up in capillary tube.</td>
<td>Use capillary tube cleaning tool or replace capillary tube.</td>
</tr>
</tbody>
</table>
Annex G 2. Trouble shooting of commercial refrigeration systems

### Open compressor trouble diagnosis chart

#### A. Staring troubles

<table>
<thead>
<tr>
<th>Observation</th>
<th>Possible cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Compressor will not start</td>
<td>Power off</td>
<td>Check main switch, fuses and wiring</td>
</tr>
<tr>
<td></td>
<td>Thermostat set too high</td>
<td>Reset</td>
</tr>
<tr>
<td></td>
<td>Thermal overloads switch open</td>
<td>Reset manually</td>
</tr>
<tr>
<td></td>
<td>Oil safety switch</td>
<td>Reset manually</td>
</tr>
<tr>
<td></td>
<td>Dirty contacts</td>
<td>Clean the contacts and all switches and controls</td>
</tr>
<tr>
<td></td>
<td>Loose electrical connections or faulty wiring</td>
<td>Tighten connections. Check wiring and rewire if necessary</td>
</tr>
<tr>
<td></td>
<td>Compressor motor burned out</td>
<td>Check and replace if defective</td>
</tr>
<tr>
<td></td>
<td>Solenoid valve closed</td>
<td>Check for burned out holding coil. Replace if defective</td>
</tr>
<tr>
<td></td>
<td>Evaporator fan off</td>
<td>Check fuses overload. Start up</td>
</tr>
<tr>
<td></td>
<td>Evaporator condenser or cooling tower fan or pump not operating</td>
<td>Check fuses, overloads and controls. Re-start</td>
</tr>
<tr>
<td></td>
<td>High pressure switch contacts opened by high pressure</td>
<td>Push reset button</td>
</tr>
<tr>
<td></td>
<td>No charge of refrigerant in system</td>
<td>With no refrigerant, there is insufficient suction pressure to close low pressure switch. Repair leaks and re-charge system</td>
</tr>
</tbody>
</table>

#### B. Erratic operation

<table>
<thead>
<tr>
<th>Observation</th>
<th>Possible cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Compressor cycles intermittently</td>
<td>Low pressure switch erratic in operation</td>
<td>Check tubing to switch to see if clogged. Check setting of switch. It may be too high</td>
</tr>
<tr>
<td></td>
<td>Insufficient refrigerant in system</td>
<td>Check leaks, repair them and add refrigerant</td>
</tr>
<tr>
<td></td>
<td>Capacity control setting incorrect</td>
<td>Reset</td>
</tr>
<tr>
<td></td>
<td>Thermostat differential too narrow</td>
<td>Reset</td>
</tr>
<tr>
<td></td>
<td>Suction valve closed or throttled</td>
<td>Open</td>
</tr>
<tr>
<td>3. Compressor continually cycles on dual pressure-stat</td>
<td>Dirt or restriction in tubing to pressurestat</td>
<td>Check and clean tubing</td>
</tr>
<tr>
<td></td>
<td>Faulty pressurestat</td>
<td>Repair or replace</td>
</tr>
<tr>
<td></td>
<td>Condenser capacity reduced by a refrigerant over-charge accompanied by a high discharge pressure</td>
<td>Remove excess refrigerant</td>
</tr>
<tr>
<td>Insufficient water flowing through condenser or clogged condenser</td>
<td>Adjust water regulating valve to condenser. Clean condenser</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Discharge or suction shut-off valve not fully open</td>
<td>Open valves</td>
<td></td>
</tr>
<tr>
<td>Air in system</td>
<td>Purge</td>
<td></td>
</tr>
<tr>
<td>Water pumps not operating</td>
<td>Check and start</td>
<td></td>
</tr>
</tbody>
</table>

### C. Operating pressures too high or too low

<table>
<thead>
<tr>
<th>4. High discharge pressure</th>
<th>Condenser inlet temperature too high</th>
</tr>
</thead>
</table>
| Insufficient water flowing through condenser | 1. Increase quantity by adjusting water regulating valve  
2. Obtain source of colder water |
| Plugged or scaled tubes in condenser | Clean tubes |
| Discharge shut-off valve partially closed | Open the valve |
| Too much refrigerant | Remove excess |
| Air in the system | Purge |

<table>
<thead>
<tr>
<th>5. Low discharge temperature</th>
<th>Excessive water flow through condenser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suction shut-off valve partially closed</td>
<td>Open the valve</td>
</tr>
<tr>
<td>Leaky compressor suction valves</td>
<td>Pump down, remove the cylinder head, examine valves seats replace if necessary</td>
</tr>
<tr>
<td>Worn piston rings</td>
<td>Replace if worn</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. Flooding</th>
<th>Defective or improperly set expansion valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient refrigerant in system</td>
<td>Check for leaks, repair them and add refrigerant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Low suction pressure</th>
<th>Excessive superheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient refrigerant in system</td>
<td>Check for leaks, repair them and add refrigerant</td>
</tr>
</tbody>
</table>

### D. System noises

<table>
<thead>
<tr>
<th>8. Compressor noisy</th>
<th>Loose or misaligned coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient clearance between piston and valve plate</td>
<td>Replace worn parts</td>
</tr>
<tr>
<td>Motor or compressor bearings worn</td>
<td>Replace bearings</td>
</tr>
<tr>
<td>Loose or misaligned belts</td>
<td>Check alignment and tension. Belt slack should be at the top</td>
</tr>
<tr>
<td>Loose foundation belts or hold down bolts</td>
<td>Tighten bolts</td>
</tr>
<tr>
<td>Foundation improperly isolated</td>
<td>Provide sufficient right angle bends in piping to absorb vibration and support firmly with hangers</td>
</tr>
<tr>
<td>Issue</td>
<td>Solution</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Slugging due to floodback of refrigerant</td>
<td>1. Check setting of expansion valve</td>
</tr>
<tr>
<td></td>
<td>2. Check thermal bulb for looseness and correct location</td>
</tr>
<tr>
<td></td>
<td>3. Loop suction lines to prevent floodback on “off” cycle</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic knock due to excess of oil in circulation</td>
<td>1. Remove excess oil</td>
</tr>
<tr>
<td></td>
<td>2. Check expansion valve for floodback</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Noise level varies with unloading due to defective valve lifter mechanism</td>
<td>1. Replace stuck filter pins</td>
</tr>
<tr>
<td></td>
<td>2. Check unloaded fork for alignment</td>
</tr>
<tr>
<td></td>
<td>3. Check power element for stuck piston</td>
</tr>
<tr>
<td></td>
<td>4. Leakage of oil at tube connection to power element</td>
</tr>
</tbody>
</table>
### Annex G 3. Trouble shooting of air-conditioning systems

<table>
<thead>
<tr>
<th>Fault</th>
<th>Cause</th>
<th>Check/Corrective Action</th>
</tr>
</thead>
</table>
| 1. High discharge pressure (cooling operation) | Air to the out door heat exchanger is extremely hot, or there is insufficient air through the outdoor coil. | 1. Check the operation of the outdoor fan.  
2. Check discharge and suction air circulation. |
| | Outdoor heat exchanger is clogged. | Clean the outdoor heat exchanger. |
| | Air is in the refrigerant cycle | Purge air from the cycle. |
| | Suction pressure is higher than standard. | See “high suction pressure”. |
| | Check valve does not move | Exchange the check valve |
| | Refrigerant is overcharged. | Remove refrigerant. |
| 2. High discharge pressure (heating operation). | Air to the indoor heat exchanger is extremely hot or there is insufficient air through indoor coil. | 1. Check the operation of the indoor fan  
2. Check discharge and suction air circulation. |
| | Indoor heat exchanger is cooled | Clean the indoor heat exchanger. |
| | Air is in the refrigerant cycle | Purge air from the cycle. |
| | Suction pressure is higher than standard | See “high suction pressure”. |
| | Check valve does not move | Exchange check valve. |
| | Refrigerant is overcharged | Remove refrigerant. |
| 3. Low discharge pressure (cooling operation). | Air to the outdoor heat exchanger is extremely cold. | 1. Check the operation the outdoor heat exchanger.  
2. Check the ambient temperature. |
| | Faulty discharge or suction valves in the compressor. | 1. Check compressor input.  
2. Check the ambient temperature. |
| | Insufficiently charged refrigerant or leaks. | Add refrigerant; repair leakage, if any. |
| | Suction pressure is lower than standard. | See “low suction pressure”. |
| | Check valve does not move | Exchange the check valve. |
| 4. Low discharge pressure (heating operation). | Air to the indoor heat exchanger is extremely cold. | 1. Check the operation of the indoor heat exchanger.  
2. Check the ambient temperature. |
| | Faulty discharge or suction valves in compressor. | 1. Check compressor input.  
2. Check the suction pressure |
| | Insufficiently charged refrigerant or leaks. | Add refrigerant, repair leakage, if any. |
| | Suction pressure is lower than standard. | See “low suction pressure”. |
| | Check valve does not move | Exchange the check valve. |
| 5. High suction pressure (heating operation) | Intake air is extremely hot or excessive air flow exists through the indoor coil. | Check the air flow quantity. |
| | Intake air is extremely hot or excessive air flow exists through the outdoor and indoor coil. | Remove refrigerant. |
| | Faulty discharge or suction valves in compressor. | Check compressor input. |
| | Check valve does not move | See “high discharge pressure”. |
| | Check valve does not move | Exchange the check valve. |
| 6. Low discharge pressure (cooling operation). | Air to outdoor heat exchanger is extremely cold. | 1. Check the operation of the outdoor heat exchanger.  
2. Check the ambient temperature. |
| | Faulty discharge or suction valves in the compressor | 1. Check compressor input.  
2. Check the suction pressure. |
<table>
<thead>
<tr>
<th>Issue</th>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficiently charged refrigerant or leaks.</td>
<td>Add refrigerant, repair leakage, if any.</td>
<td></td>
</tr>
<tr>
<td>Suction pressure is lower than standard.</td>
<td>See “low suction pressure”.</td>
<td></td>
</tr>
<tr>
<td>Check valve does not move</td>
<td>Exchange the check valve.</td>
<td></td>
</tr>
</tbody>
</table>

7. Low suction pressure (cooling operation).

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
</table>
| Intake air is extremely cold or insufficient air flows through the outdoor coil. | 1. Check for short cycling air.  
2. Check the airflow quantity.  
3. Check the outdoor coil for frosting.  
4. Check the ambient air temperature.  |
| Refrigerant is shortcharged or leakage exists. | Repair leak, if any, add refrigerant.  |
| Restricted liquid or suction line. | Check the capillary tube and the strainer. |
| Refrigerant piping diameter is smaller or refrigerant piping is longer. | Exchange corrects piping. |

8. Low suction pressure (heating operation).

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge pressure is lower than standard.</td>
<td>See “low discharge pressure”.</td>
</tr>
<tr>
<td>Check valve does not move</td>
<td>Exchange check valve.</td>
</tr>
</tbody>
</table>

9. Internal thermostat.

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single phase running (for three-phase unit).</td>
<td>Check the power supply line and the contactor.</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>High or low voltage, or phase imbalance.</td>
<td>Check voltage and phase imbalance.</td>
</tr>
<tr>
<td>Refrigerant shortcharged or leakage.</td>
<td>Repair leaks; if any; add refrigerant.</td>
</tr>
</tbody>
</table>

11. Pressure switch.

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge pressure is extremely high.</td>
<td>See “high suction pressure”</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch is incorrectly set, or faulty contact.</td>
<td>Check the setting pressure or the contact.</td>
</tr>
</tbody>
</table>

13. Over current relay for compressor.

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge pressure and suction pressure are extremely high.</td>
<td>See “discharge pressure” or “high suction pressure”</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>High or low voltage, or phase imbalance.</td>
<td>Check voltage and phase imbalance.</td>
</tr>
</tbody>
</table>

15. Cut-off.

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single phase running (for three-phase unit).</td>
<td>Check the power supply line and contactor.</td>
</tr>
<tr>
<td>Faulty compressor motor.</td>
<td>Check electric resistance among the compressor terminals and from the terminals to ground.</td>
</tr>
<tr>
<td>Faulty fan motor.</td>
<td>Check electric resistance among the fan terminals and from the terminals to ground.</td>
</tr>
<tr>
<td>Loose connections.</td>
<td>Check the electric connections.</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient fuse size.</td>
<td>Check the fuse size with the nameplate amperage.</td>
</tr>
<tr>
<td>Loose connections.</td>
<td>Check electric connections.</td>
</tr>
<tr>
<td>Single phase running (for three-phase unit).</td>
<td>Check power supply line.</td>
</tr>
<tr>
<td>Faulty motor.</td>
<td>Check electric resistance among the motor terminals and the terminals to ground.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
</table>
| Disconnection. | 1. Check electric the wires and connection, where necessary.  
2. Check the contactor holding oil.  |
| Faulty contact. | Check the contacts in the magnetic contactor, overcurrent relay, high pressure switch, thermostat and other switches. |

17. Noisy fan.

<table>
<thead>
<tr>
<th>Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runner knocks in the casing.</td>
<td>Check the runner and fix properly.</td>
</tr>
</tbody>
</table>
| 18. Noisy compressor | Liquid refrigerant is flooding back from the suction line. | 1. Check for refrigerant overcharge.  
2. Check to see if the intake air temperature is extremely cold.  
3. Check for insufficient air flow. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor shipping bolts and brackets are not removed.</td>
<td>Remove the shipping bolts and brackets.</td>
<td></td>
</tr>
<tr>
<td>Worn bearings.</td>
<td>Replace the compressor.</td>
<td></td>
</tr>
<tr>
<td>Faulty discharge and suction valve.</td>
<td>Replace the compressor.</td>
<td></td>
</tr>
<tr>
<td>19. Other noises.</td>
<td>Loose fixed screw.</td>
<td>Tighten the screws all parts.</td>
</tr>
<tr>
<td></td>
<td>Weak foundation installation.</td>
<td>See the installation guide.</td>
</tr>
<tr>
<td>20. Heavy frosting to the indoor heat exchanger (cooling operation).</td>
<td>Suction pressure is lower than standard.</td>
<td>See “low suction pressure”.</td>
</tr>
<tr>
<td></td>
<td>Capillary tube is clogged.</td>
<td>Exchange the capillary tube.</td>
</tr>
<tr>
<td>21. Heavy frosting to the outdoor coil (heating operation).</td>
<td>Faulty contact of sensor of defrosting thermostat.</td>
<td>Check the sensor of the defrosting thermostat.</td>
</tr>
<tr>
<td>22. No start of cooling heating operation.</td>
<td>Faulty remote control switch.</td>
<td>Check electric resistance among the terminals and from the terminals to ground.</td>
</tr>
<tr>
<td></td>
<td>Faulty auxiliary relay.</td>
<td>Check electric resistance among the fan motor terminals and from the terminals to ground.</td>
</tr>
</tbody>
</table>
Annex H. Best Service Practices

DO:
- Think CFC conservation and safety.
- Follow and use recommended procedures and equipment for handling refrigerants.
- Replace and tighten all seal caps on all valves after servicing.
- Shut down system and make repairs when leaks exist.
- Use closed loop refrigerant transfer equipment when removing, charging, and storing refrigerants.
- Recover vapor and liquid refrigerant from charging hoses.
- Leak test all charging hoses and refrigerant handling equipment.
- When pressurizing a refrigeration system with nitrogen, always use a pressure regulator and never charge with liquid nitrogen.
- Excessive superheat is one indicator of leak in high-pressure refrigeration system.
- Install service isolation valves to limit refrigerant losses during servicing and purge operations.
- Eliminate unnecessary mechanical joints. Use welded or brazed joints.
- Establish proper leak testing routines.
- Follow the published leak test procedures.
- Use industry accepted tools/equipment for leak testing.
- Confirm overall leak tightness by using a standing vacuum test.
- After major service, evacuate and dehydrate to a minimum 757 mm Hg using deep vacuum or triple evacuating method.
- Install more efficient purges that reclaim exhaust vapor.
- Install external oil filters.
- Elevate oil temperature before service work.
- Run auxiliary oil pump weekly to flood oil seals on open-drive systems.
- Use only approved cylinders for storing refrigerant.
- Install charging valve quick connects.
- Cool refrigerant drums to atmospheric pressure before opening.
- Install refrigerant sensors on/near all refrigerant systems.
- Before beginning any type of refrigerant recovery it is always necessary to known the type of refrigerant. Do not mix refrigerants.
- Recover all refrigerant for recycling/reclaiming.
- Use non-CFC gas as tracer gas when conducting leak tests.
- Install alarm system to warn of excessive machine pressure during shutdown.
- Use purge compressor or portable evacuation device to recover refrigerant liquid/vapor from refrigerant cylinders.
- Add refrigerant carefully to avoid overcharging.
- Calibrate controls with air, nitrogen, or control calibration sets.
- Inspect for abnormal vibration.
- Implement an effective water treatment control.
- Never overfill containers.
- Never heat a refrigerant storage or recovery tank with an open flame.
- Depose of used refrigerant containers properly.
- Retrofit or convert ODS using refrigeration and AC systems to alternatives.
**DON'T:**
- Use refrigerants as cleaning solvents
- Open the refrigerant side of system unless absolutely necessary.
- Use CFC tracer gas for leak test.
- Operate equipment with leaks.
- Vent/blow off air (non-condensable gases/refrigerants) to the atmosphere.
- Blow off refrigerant “empty” tanks, cylinders.
- Blow off vapor still in refrigeration system after liquid refrigerant removal.
- Throw away any refrigerant.
- Contaminate recovered refrigerants with other refrigerants, solvents, oils, or other materials.
- Exceed manufacturers recommended pressure when leak testing.
- Refill disposable cylinders.
- Substitute alternative refrigerants into old systems without approval.
Annex I3