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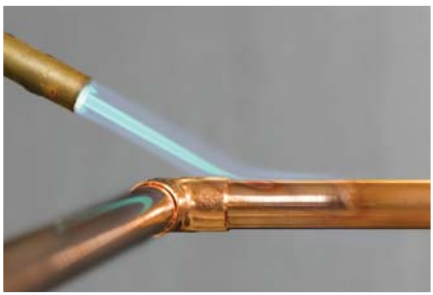
HPMP
HCFC Phase-Out Management Plan, Servicing Sector

Good Service Practices and Installation of Room Air-conditioners with HCFC-22 and Flammable Refrigerants

TECHNICIANS HANDBOOK





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New Delhi, India, September 2018

GOOD SERVICE PRACTICES AND INSTALLATION OF ROOM AIR-CONDITIONERS WITH HCFC-22 AND FLAMMABLE REFRIGERANTS

TECHNICIANS HANDBOOK

DISCLAIMER

The information in this handbook and the procedures described are for use only by persons with the appropriate technical skills and training, at their own discretion and risk. The technical and legislative information presented is current at the date of original publication. Due to rapid advancing technology and changing regulations in this field, no representation can be made for accuracy of this information in the future.

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डॉ. हर्ष वर्धन
Dr. Harsh Vardhan

सत्यमेव जयते

भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्री
GOVERNMENT OF INDIA
MINISTER OF ENVIRONMENT, FOREST & CLIMATE CHANGE

FOREWORD

Refrigeration and air-conditioning (RAC) servicing sector is very important as refrigeration and air conditioning equipment remains in use for nearly 10 years leaving a significant population with Ozone Depleting Substances (ODS) based equipment likely to be in operation. The refrigerant consumption in the Servicing Sector not only depends on the installed base of RAC equipment, but also on quality of the product and the quality of servicing during product life cycle. There could be potentially significant savings in refrigerant use if good service practices are followed. The good service practice is important not only because of environment issue but also to maintain the design energy efficiency of the air-conditioners.

As per informal industry level estimates, the number of servicing technicians for the residential Refrigeration and Air-conditioning (RAC) sector is estimated to be 200,000 this number will be growing with the growing market of room air-conditioners. The consumption in the servicing sector will be reduced mainly through training on better servicing practices and leak prevention in the present scenario the service technicians also need to be prepared on the introduction of alternatives to HCFC-22 like HC-290, HFC-32 etc. The technicians will have to be trained to appropriately handle the low GWP flammable refrigerants.

The HCFC Phase out Management Plans (HPMPs) in India are being implemented under the direct supervision of the Ozone Cell, Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India. RAC servicing sector project under HPMP

is being implemented by Government of Germany represented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and United Nations Environment Programme (UNEP) under the guidance of Ozone Cell, MoEF&CC. The aim of HPMP is to minimize the emissions of ozone depleting substances into the environment and, thus, mitigate the ozone layer depletion

The Ministry is focussing on synergizing the training of RAC service technicians under HPMP Stage II with Skill India Mission in order to have wider positive impact on environment protection and livelihood of technicians. In this regard, the Technicians Handbook and the Trainers Handbook on Good Service Practices and Installation of Room Air-conditioners with HCFC 22 and flammable refrigerants will be a great help training of RAC service technicians.

I wish the trainings to be imparted under HPMP Stage II to RAC service technicians all success.

Date: 14.09.2018

(Dr. Harsh Vardhan)

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ABOUT PROKLIMA

Proklima is a programme of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Since 2008 Proklima has been working successfully on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under its International Climate Initiative (ICI) to disseminate ozone-and climate-friendly technologies.

Proklima has been providing technical and financial support for developing countries since 1996, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) to implement the provisions of the Montreal Protocol on Substances that Deplete the Ozone Layer.

This publication has been prepared under the project HCFC Phase-Out Management Plan Service Sector under Multilateral Fund (MLF) to the Montreal Protocol.

ACKNOWLEDGEMENTS

This handbook is exclusively prepared for the Refrigeration and Air-conditioning (RAC) service technicians as a reference material for installation and servicing the air-conditioners charged with HCFC-22 and flammable refrigerant. We wish to thank Prof R.S. Agarwal, Mr. Ankur Khandelwal, Mr. C J Mathew and Mr. Ringkhang Muchahary for their valuable contributions to the handbook.

Our explicit thanks to Mr. Gyanesh Bharti, Joint Secretary (Ozone), Ministry of Environment, Forest and Climate Change (MoEF&CC), and Dr. Amit Love, Joint Director, Ozone Cell, MoEF&CC, Government of India for their continued support and guidance. Our exclusive appreciation and thanks to Mr. Bernhard Siegele, Program Manager, GIZ Proklima for his encouragement and aspiring guidance. A special thanks to my colleagues Mr. Marcel Nitschmann, GIZ Proklima HQs. and Ms. Suparna Dalal, GIZ Proklima, for their continued support.

Few pictures in this handbook were taken from the book 'Good Practices in Refrigeration', published by GIZ-Proklima in March/ April 2010.

SMITA VICHARE, GIZ – PROKLIMA

CONTENTS

INTRODUCTION

This handbook provides information to introduce and upgrade on good service practices during Installation and servicing of room air-conditioners. Room air-conditioner consumes high energy as compared to the other household appliances. The good service practice is important due to environmental issues and to maintain the design energy efficiency of the air-conditioners because efficiency decreases due to age, defects and poor service practices. The quality of servicing room air-conditioner depends on knowledge & skill levels of technicians and using appropriate equipment & tools.

The international environment treaty Montreal Protocol on Substances that Deplete the Ozone Layer was signed to reduce the ozone depleting substances (ODS) in the atmosphere by implementing control measures to phase-out ODSs. The production and consumption of ODSs like CFCs, CTC and halons are already phased out globally, including in India. The Protocol was ratified by India in 1992. The HCFC Phase-out Management Plan (HPMP) in India is being implemented under the direct supervision of the Ozone Cell, Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India to phase-out the production and use of HCFCs as per the phase-out targets.

HCFCs are widely used in India in various sectors including RAC servicing sector. The Servicing Sector has a significant consumption of HCFCs, more than 40% of the HCFC consumption due to large and increasing population of RAC equipment in the country. HCFC-22 is most suitable and commonly used refrigerant in the room air-conditioner as it has very good properties and it is widely used refrigerant for room ACs, 77% of its consumption is in room ACs. Although suitable for air-conditioner, HCFC-22 is being phased-out globally under the Montreal Protocol as it is one of the ozone depleting substances.

There are several factors that should be considered when selecting an alternative refrigerant, like performance, environment issues, cost & availability, safety, material compatibility etc. As there is a restriction on use

of ozone depleting substances, except zero ODP, other parameters have to be traded-off against one another to get the optimum. There are refrigerants suitable for alternative to HCFC-22 available, e.g. R-290, HFC-32, R-410A which are being used globally, including in India. R-290 has no ODP and GWP is negligible as compared to other refrigerants available commercially, but it is flammable. HFC-32 and R-410 are not having ozone depleting potential, but these are high global warming substances. So, these refrigerants are not suitable for long term replacement because Montreal Protocol has made an agreement to phase-down HFCs, called Kigali Amendment. As the alternative refrigerants are flammable and/or have higher pressure, good service practices and all safety procedures must be known and followed while performing servicing.

This handbook is prepared by GIZ Proklima for the technicians to be trained under HPMP project in India. The handbook provides preliminary and practical information to the technicians that can be applied on day-to-day basis during installation and servicing of air-conditioners. The principles of air-conditioning, how the impact of refrigerants and air-conditioner on environmental can be minimized; these are explained in a simple and easy to understand manner. Good copper tube processing is very important task for proper functioning of the air-conditioners and prevent leakage of refrigerants to environment. Incorrect installation can lead to high electricity bills, poor air circulation, as well as maintenance problems. Good servicing practices while repairing the air-conditioners together with following the safety measures yield customer satisfaction, repeat orders and contribute to save the environment too. Air-conditioners introduced with alternative refrigerants having specific properties and characteristic require to be installed and serviced by trained technicians. If he is certified technicians it is an approval process ensuring that the technician is competent to complete the installation and servicing of AC successfully and safely, work with RAC tools & equipment and flammable and high-pressure refrigerants. Training, assessment, and certification also give enhance assurance that servicing will be performed according to applicable standards. In additions the soft skill – behaviour of the technician plays a crucial role. The handbook briefly introduces the technicians to it.

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

01

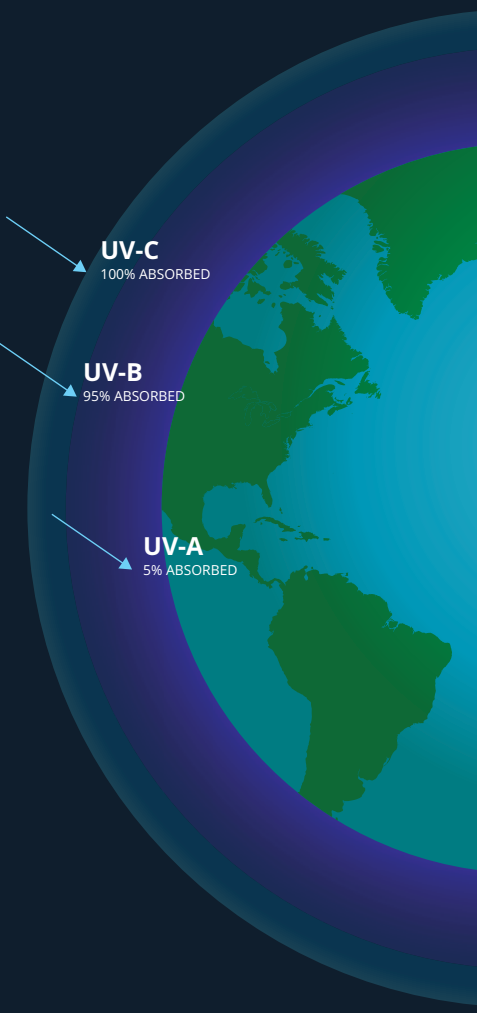
MONTREAL PROTOCOL AND IMPACT OF REFRIGERANTS ON ENVIRONMENT

Background

The depletion of the ozone layer and global warming are the two major environmental concerns associated with the refrigerants used in room air-conditioners. It was noticed by the world scientists that the man made chemical compounds containing chlorine and bromine elements like Chlorofluorocarbons (CFCs), Hydrochlorofluorocarbons (HCFCs), methyl chloroform, Carbon tetrachloride (CTC), halons and methyl bromide are responsible for the depletion of Ozone Layer in the earth's atmosphere. The international environment treaty the Montreal Protocol on substances that deplete the Ozone Layer was signed and came into force on 16th September, 1987 for the protection of the ozone layer by phasing out production and consumption of these substances. Montreal Protocol has been recognized globally as the most successful international treaty on environment so far. The Protocol has been universally ratified. All the 197 countries are the signatory to the Montreal Protocol and have ratified this agreement. India ratified the Montreal Protocol in June, 1992.

Historically, CFC-11 was used for manufacturing of aerosol products, foam products, in chiller. CFC-12 was used as refrigerant in refrigeration and air-conditioning (RAC) equipment. CFC-113 and methyl chloroform were used as solvent. CTC was used as solvent, process agent and feedstock in textile and metal-cleaning sector. CTC was also used as process agent in manufacturing chlorinated rubber, chlorinated paraffin and pharmaceutical products. Halon was used in fire extinguishers. HCFCs are being used as refrigerant in RAC equipment. HCFCs including HCFC-22 are widely used refrigerants because of their excellent thermodynamic and thermos-physical properties. However, all these chlorinated and brominated chemicals being ozone depleting substance are the controlled substances under the Montreal Protocol. The production and consumption of substances like CFCs, CTC and halons have already been phased out. HCFCs are being phased out globally with an agreed accelerated phase-out schedule of the Montreal Protocol.

Another major environmental issue is the increased global warming due to the emission of greenhouse gases (GHGs). The emission of ODSs including HCFC-22 used as refrigerants and the energy consumption by room air-conditioners (ACs) during its working life also contributes towards global warming. These compounds are also having high global warming potential, like other GHGs, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Sulphur-hexafluorides (SF_6), Halocarbons (HFCs), perfluorocarbons (PFCs) and Nitrogen Trifluoride (NF_3). The emissions of refrigerant occur during use in manufacturing, and servicing of air-conditioners, like charging refrigerant into the system, improper recovery of refrigerant and leakage from the air-conditioning system and the lines. As most of the room air-conditioners used currently are charged with HCFC-22, it is very important for the service technician to minimize the emission of HCFC-22 as much as possible during installation and servicing of air-conditioner.



Stratospheric Ozone Layer

Ozone is a gas that occurs naturally in the atmosphere. It is a tri-atomic form of oxygen (O_3) and an unstable molecule. It is found in the earth's upper atmosphere known as the stratosphere, about 15-60 km above the earth's surface. Ozone has a strong odor and is of blue colour. Ozone absorbs the sun's harmful UV-B radiation and protects living organisms on the Earth. Although ozone represents only a small fraction of the total amount of gases present in the atmosphere but it plays a vital role by shielding humans and other forms of life on the Earth from harmful ultraviolet (UV) rays from the Sun.

The amount of stratospheric ozone overhead varies on any given day and at any given location. The variation is due to vertical circulation of air in both the troposphere and the stratosphere. Total ozone varies strongly with latitude over the globe, with the largest values occurring at middle

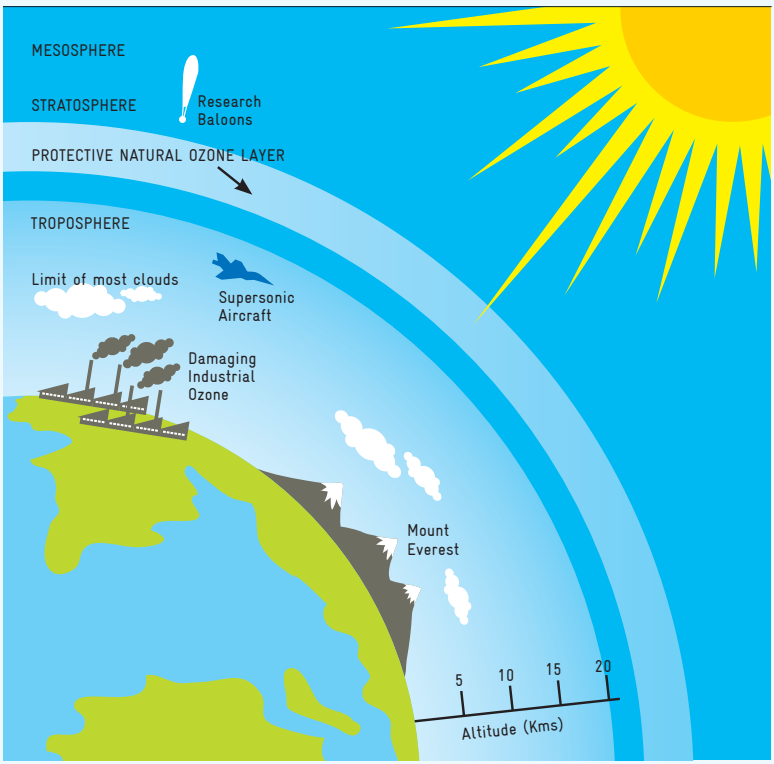


Figure 1.1: Ozone Layer

and high latitudes during all seasons. While stratospheric ozone which protects the earth from the sun is good, the ground level ozone produced due to atmospheric pollution in cities is harmful for human health. It causes breathing problems for some people and usually occurs during summer when the pollution over a city builds up.

With the increased industrial activities, in the past several decades, man-made chemicals such as CFCs, HCFCs and other that are increasingly released into the atmosphere, have contributed to the depletion of this important protective layer.

Ozone absorbs UV Radiation

The Sun emits radiations of varying wavelengths in the form of electromagnetic spectrum. The UV ray is one form of radiant energy coming out from the Sun along with the visible rays. Of these, UV-B and UV-C being highly energetic, are harmful to life on Earth. UV-B radiation is absorbed only by the stratospheric ozone (ozone layer) and thus only 2-3% of it reaches the Earth's surface. Ozone layer, therefore, is essential for protection of life on the Earth. Depletion of the Ozone layer would result in increase of UV-B and UV-C radiation reaching the Earth's surface leading to dangerous consequences for the life on Earth. The ozone layer, therefore, acts as Earth's sunscreen.

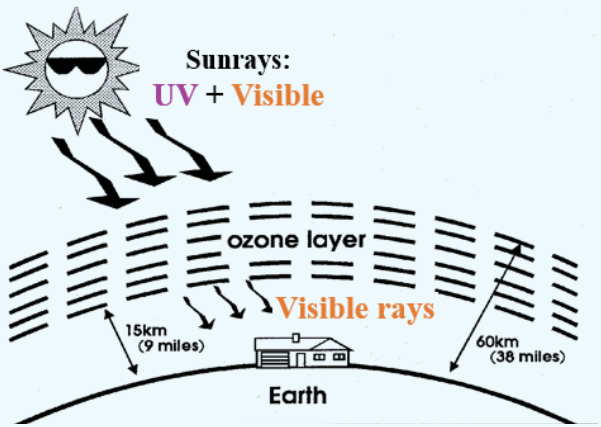


Figure 1.2 : Ozone Layer as Earth Sunscreen

Formation of Stratospheric Ozone

In the stratosphere, ozone formation and destruction are natural processes and take place simultaneously and continuously. Ozone (O_3) is a tri-atomic molecule of oxygen instead of normal two. It is formed from oxygen naturally in the upper levels of the Earth's atmosphere (stratospheric region) by high-energy UV radiation from the Sun. The UV radiation breaks down oxygen molecules, releasing free atoms, some of which bond with other oxygen molecules to form ozone.

The reverse is also true; some of the ozone is also decomposed into oxygen atoms, which join to become oxygen molecules. Thus, a continuous equilibrium is maintained between ozone and oxygen in the ozone layer. The amount of ozone in the atmosphere is very small and its maximum concentration, is at a height of about 17-25 km away from the earth, is only ten parts per million.

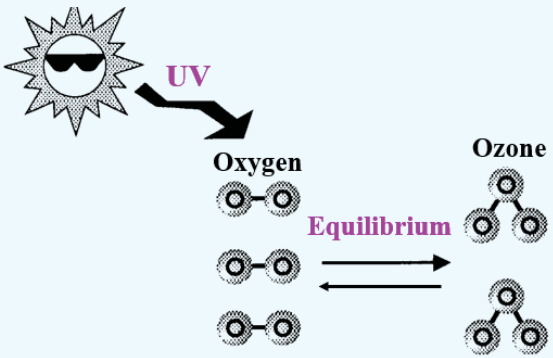


Figure 1.3 : Formation of Stratospheric Ozone

Mechanism of Destruction of Stratospheric ozone

When substances having ozone depleting potential like HCFC molecule reaches to the ozone layer, it triggers a chain of reactions which initiate the ozone layer depletion. Firstly, in presence of sun's UV rays, HCFC molecule decomposes and releases chlorine radical. This chlorine radical reacts with a molecule of ozone, yielding an oxygen molecule and a chloro-mono-oxide molecule. The chloro-mono-oxide molecule is unstable which breaks and releases a free chlorine radical. This chlorine radical starts again another cycle of similar reaction with another ozone molecule, and once again

returns to its chlorine radical state. Thus, through these repetitive cycles or chain reaction the ozone layer gets continuously depleted in the presence of the HCFCs.

All the ODSs exhibit similar reactions, as HCFC-22 refer Figure 1.4, thus contributing to depletion of ozone layer. The presence of chlorine and bromine atoms in the ODSs is what causes the ozone depletion.

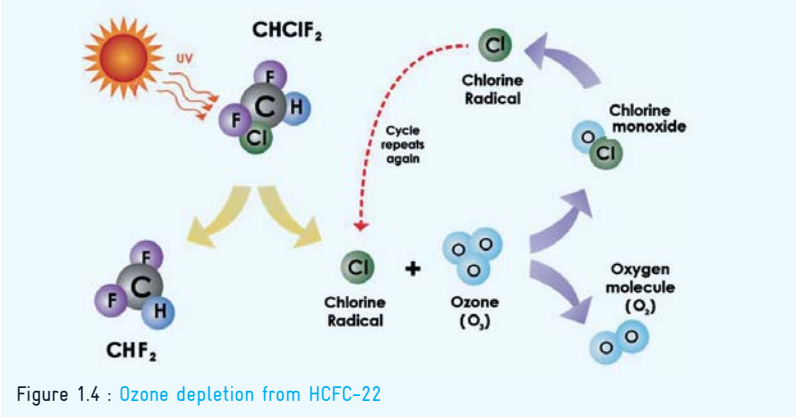


Figure 1.4 : Ozone depletion from HCFC-22

Measurement of Stratospheric Ozone

Ozone is measured in Dobson units (DU); 100 DU is equivalent to the quantity of ozone that would form a layer 1 mm thick at sea level, if compressed at Standard Temperature and Pressure (STP). Typical values vary between 200 and 500 DU over the globe .In September of 2017, the Antarctic ozone hole reached its smallest maximum area since 1988, dropping below 20 million square kilometers for the first time in the past 29 years.

Effects of Ozone Layer Depletion

UV radiation is classified in three ranges: UV-A, UV-B, UV-C. Of these, UV-A is the least energetic and less harmful. UV-B is energetic enough to cause biological interactions. The component of UV-C in the solar spectrum itself is small, and that reaching the earth is practically nil. Because of the damage to the ozone layer, it is essentially the UV-B which reaches the earth's surface and cause a number of harmful effects, such as.

- It leads to an increase in the probability of the incidents of skin cancer amongst human beings.

- It can also induce eye damage since the UV radiation is known to damage the cornea and lens of the eye, leading to cataract.
- The UV radiation results in suppression of the immune systems of human bodies, making them prone to a number of infectious diseases.
- The UV radiation also has a harmful effect on fish and other ocean life, since it adversely influences the productivity of aquatic systems, leading to decreased reproductive capacity and impaired development.
- An increased level of UV radiation is also known to have adverse effects on synthetic polymers, naturally occurring biopolymers and some other materials of commercial interest.
- Material used in buildings, paints, packaging and countless other substances could be degraded by UV-B. UV-B radiation accelerates the photo-degradation rates of these materials thus limiting their lifetimes. Typical damages range from discoloration to loss of mechanical integrity.
- Increased UV-B radiation could also cause decreased crop yields and damage to forest as well as increased cases of cancer.
- Materials are also affected by UV radiation. Paints, rubber, wood and plastic gets degraded, especially in tropical regions. The value of this damage could go into billions of US dollars.

Damage to aquatic life

Infectious diseases

Damage to skin

Damage to plants and crops

Figure 1.5 : Effects of Ozone Layer Depletion

Global Warming

Another important environmental impact of refrigerants relates to the phenomenon of Global Warming. The solar radiation interacts with earth's surface in several ways. Out of the total solar radiation, nearly 20% is reflected from the earth's atmosphere, 20% is dispersed into the atmosphere, and 9% is reflected from earth's surface or dust. The remaining, nearly 51%, penetrates in the atmosphere and reaches the earth's surface. Most of the solar radiation reaching the earth's surface are reradiated to the atmosphere. As the reradiated radiation leaves the earth, it once again interacts with the atmosphere. Some of this manages to escape (about 17%), but majority of radiation is returned back to the earth's surface by the presence of GHGs. This reflected energy warms the surface of the earth, leading to what we call the Greenhouse Effect or global warming.

However, some of the green-house gases, such as HCFCs along with other gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluorides (SF_6), halocarbons (HFCs), and perfluorocarbons (PFCs), essentially emitted through the human activities, cause an increase in the level of greenhouse effect leading to high global warming which is responsible for likely mean temperature rise of Earth's atmosphere.

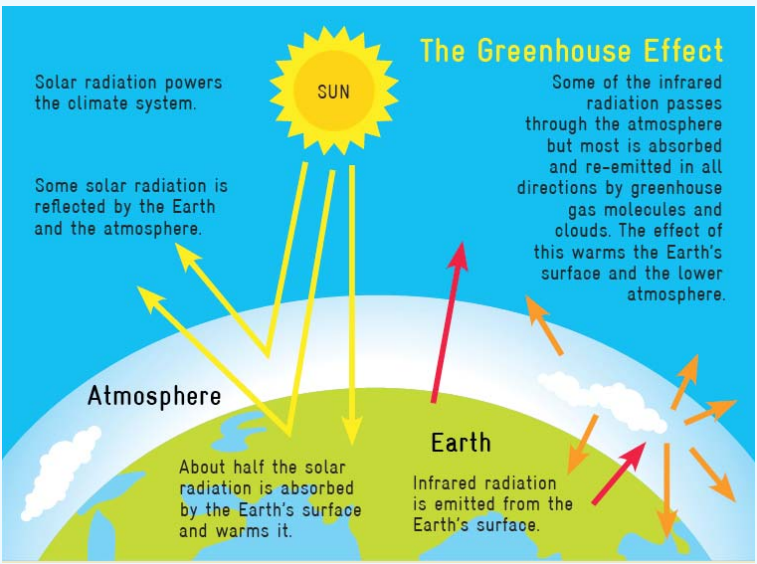


Figure 1.6 : Global Warming

Effects of Global Warming

In the last hundred years, the mean global temperature has increased by 0.3 to 0.6°C. Because of this, the sea water thermally expands, and the icecaps melt, leading to rise in sea levels. It destroys coastal towns making people homeless. An increase in global sea level of 4 to 10 inches has been observed over the last 100 years. This also affects rainfall pattern on the earth, leads to climate changes and thereby alters the bio-diversity.

Due to global warming there is changes in water supply and water quality. The habitat the plant and animal species are affected. It also has a negative effect on human health, as evidenced by increase in cases of Malaria, Dengue and Yellow Fever. According to experts, the world will see a definite impact of global warming in the next few decades. Increase in global temperatures, coupled with rapid growth of population, will make society more vulnerable to climate change. It will lead to climatic disorders, droughts, famines, floods and longer heat waves spreading to newer areas. Tropical islands and low-lying coastal areas will face the threat of being submerged.

Rising sea level

Increased temperature

Habitat damage and species affected

Changes in water supply

Figure 1.7: Effects of Global Warming

How Air-conditioner Contributes to Global Warming?

Air-conditioner contribute to global warming in two ways, direct and indirect contribution. Direct contribution is due to direct emission of refrigerant used in ACs. Refrigerant emits during installation and servicing, due to leakage, failure and at the end of life of ACs. As HCFCs and HFCs are having high global warming potential (e.g. GWP of HCFC-22 is 1820) small emission to environment contributes to high global warming.

Indirect contribution is the energy-related contribution that is represented by the emissions of green-house gases (mainly CO_2) that arise from the production of electricity. Over the entire working life cycle of the air conditioning equipment, considerable amount of electricity is consumed. In most of the countries, electricity generation is by fossil fuel. Various experiments and calculations have shown that the indirect contribution of ACs to the greenhouse effect is significantly higher than the direct contribution associated with the emissions of HCFCs.

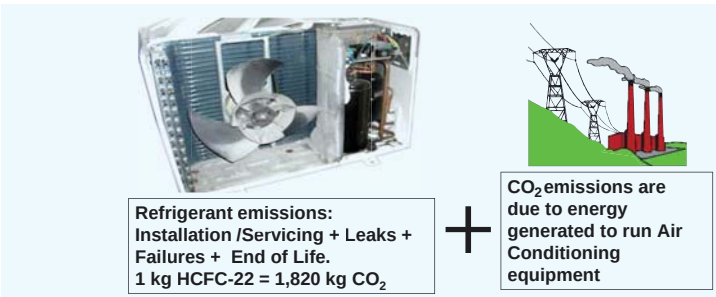


Figure 1.8 : Air-Conditioners Contribution in Global Warming

Ozone Depleting Potential (ODP) and Global Warming Potential (GWP)

The international regulation, the Montreal Protocol, mandates the phase-out programme of ozone depleting substances and the Kyoto Protocol deals with greenhouse gases.

ODP is a measure of the ozone depleting potential or capability of a refrigerant with respect to that of CFC-11 which has an ODP of 1.0. GWP is an index which compares the warming effect over time, of different gases, relative to equal emission of CO_2 by weight. Table 1.1 presents the ODP and GWP values of select refrigerants.

Table 3.1: ODP and GWP values of select Refrigerants

Refrigerant	ODP	GWP
CFC-11	1	4750
CFC-12	1	10900
HCFC-22	0.055	1810
Propane (R-290)	0	3
HFC-32	0	675
R-407C	0	1700
R-404A	0	4200
R-410A	0	2100
HFC-134a	0	1430
HFO-1234yf	0	<1
HFO-1233zd(E)	0	<1

HFCs refrigerants have been emerged as the main alternatives to ODSs which have been phased out under the Montreal Protocol. HFCs are not ozone depleting substances but have high global warming potential. So, the parties to the Montreal Protocol decided for an amendment to the Montreal Protocol for phase-down of HFCs at its 28th Meeting of Parties (MOP) held at Kigali, Rwanda. This amendment is called as Kigali Amendment to the Montreal Protocol.

Total Equivalent Warming Impact (TEWI)

Global warming or environmental impacts of air-conditioners are due to direct and indirect emissions of greenhouse gases. In addition to the direct impact due to emission of the refrigerant estimated by GWP, air-conditioning system while operating requires energy input, which indirectly affects the environment. This impact is originated from CO_2 emissions from the energy production processes. The global warming impacts from air-conditioners can be measured in TEWI (Total Equivalent Warming Impact in kg of CO_2).

TEWI combines the effects of:

- Direct emissions of refrigerants from air-conditioners during its life time.

- Indirect emission of CO_2 from the combustion of fossil fuels for generation of electricity used by the air-conditioner throughout its lifetime.

TEWI provides a measure of the environmental impact of refrigerant and other greenhouse gases from manufacture, operation, service and end-of-life disposal of equipment.

Total Equivalent Warming Impact in kg of CO_2

$$TEWI = m_{ref}.GWP_{ref}.z + m_{ba}.GWP_{ba} + t.E.f$$

Where,

m_{ref}: Mass of refrigerant in kg

GWP_{ref}: Global Warming Potential of refrigerant in kg of CO_2

z: Number of charges of refrigerant during service life

m_{ba}: Mass of blowing agent in kg

GWP_{ba} : Global Warming Potential of blowing agent in kg of CO_2

t: Service life of appliance in years

E: Annual energy consumption of appliance in kWh/yr

f: CO_2-factor of energy conversion in kg of CO_2/kWh_{el}

Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer was ratified by India in June 1992. India was classified as a party operating under Paragraph-1, Article-5 of the Montreal Protocol, was thus qualified for technical and financial assistance, including transfer of technology, through the financial mechanism of the Montreal Protocol. India prepared Country Programme incorporating the National Strategy and Action Plan for controlling the use of Ozone Depleting Substances and it was approved in 1993. Since then India has taken proactive measures for ODS phase-out projects including technology transfer investments, technical assistance, training and capacity-building, information dissemination and awareness-raising and regulations. India has established a comprehensive regulatory framework for controlling ODS. As a result, India has consistently been in compliance with the provisions of the Montreal Protocol. The Ministry of Environment, Forests and Climate Change (MoEF&CC) has been designated as the nodal ministry for the Montreal Protocol. It has

established a special directorate, the Ozone Cell, dedicated to managing and coordinating the implementation of the Montreal Protocol in India. India has already phased out production and consumption of CFCs, CTC and halons.

Although HCFCs have much lower ODP than CFCs, all these HCFCs have also been classified as controlled substances under Annex-C, Group-I of the Montreal Protocol. Recognizing the environmental benefits of phase-out of production and consumption of HCFCs earlier than the previous control schedule, the XIXth Meeting of the Parties to the Montreal Protocol in September 2007, through its Decision XIX/6, accelerated the phase-out schedule for HCFCs by 10 years.

The accelerated HCFC phase-out schedule for Article-5 countries is the freeze in 2013 at the base-line level (an average of 2009 and 2010) for production and consumption respectively and subsequently, 10% reduction of the baseline in 2015, 35% reduction in 2020, 67.5% in 2025 and complete phase-out in 2030 while allowing for servicing an annual average of 2.5% during the period 2030-2040. The Phase-out schedule for Article 5 countries is given in figure 1.9.

The phase-out schedule for Article 5 countries is:

- Base-level for production & consumption: average of 2009 and 2010
- Freeze of production & consumption by 2013 at the base level
- 10% reduction by 2015
- 35% reduction by 2020
- 67.5% reduction by 2025
- 100% reduction in 2030 with a service tail of 2.5% annual average during the period 2030-2040

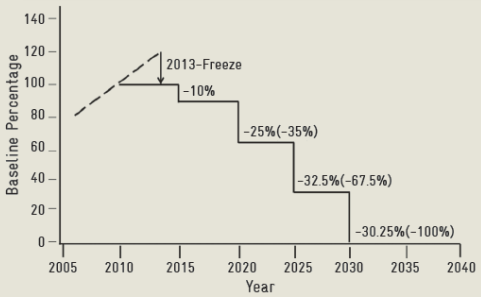


Figure 1.9 : HCFC phase-out schedule for Article 5 countries

HCFC Phase-out in RAC Servicing Sector under Montreal Protocol

The HCFC Phase out Management Plans (HPMPs) in India are being implemented under the direct supervision of the Ozone Cell, MoEF&CC, Government of India. RAC servicing sector project under HPMP is being implemented by Government of Germany represented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and United Nations Environment Programme (UNEP) under the guidance of Ozone Cell, MoEF&CC. India has achieved all the compliance target set by the Montreal Protocol for HCFCs. India has established base-line for production and consumption sectors – an average of 2009 and 2010 for production and consumption respectively, achieved the HPMP Stage-I targets, the 2013 freeze and 10% reduction of baseline in 2015 targets. India is now implementing the HPMP Stage-II.

HCFCs are widely used in India in various sectors including Foam, Refrigeration and Air-Conditioning (RAC) manufacturing sector, solvent sector, RAC servicing sector etc. The Servicing Sector has a significant consumption of HCFCs, namely, HCFC-22, HCFC-123 due to large and increasing population of RAC equipment in the country. The service sector in India has more than 40% of the HCFC consumption. HCFC has a range of applications however it is widely used in room air-conditioners. Sustainable phase-out needs to include the service sector due to the risk of reverse conversions.

HCFCs are being replaced by alternative refrigerants, like HFCs and natural refrigerants. Worldwide, there are well established and energy efficient technologies available with non-ozone-depleting refrigerants like R-290, HFC-32 and R-410A for the room air-conditioning sector. As R-410A has a high GWP and HFC-32 is having moderate GWP, these refrigerants are not a long-term solution. Due to environmental issues of high GWP refrigerants, natural refrigerants with negligible GWP are gaining more popularity for various applications, including room air-conditioners. Among the hydrocarbons, R-290 (Propane) has similar properties to HCFC-22. R-290 having the characteristics of being flammable, the safety issue needs to be addressed, by adequate changes in some electrical components and providing adequate ventilation surrounding the system/equipment.

Role of Service Technicians to phase-out HCFCs

Phasing-out HCFC in the RAC servicing sector is very important as refrigeration and air conditioning equipment remains in use for up to 10 - 15 years, a significant population of HCFC-based equipment is likely to be still in operation. The consumption in the servicing sector will be reduced mainly through training on better servicing practices and leak prevention but service technicians also need to be prepared on the introduction of alternatives like HC-290, HFC-32 etc. Technicians must be trained to appropriately handle the low GWP flammable refrigerants.

The servicing practices need to be improved not only for reducing the refrigerant requirement in servicing, but also for proper and efficient functioning of the RAC equipment. During servicing, recovery of refrigerant is not a common practice, especially in developing countries. The refrigerant is often vented out and after repair the equipment is recharged with the virgin refrigerant. There is also a practice to top up the RAC equipment with the refrigerant without proper leak detection and repair. There could be significant savings in refrigerant use if proper recovery of refrigerant and good servicing practices are implemented.

The refrigerant consumption in the Servicing Sector not only depends on the installed base of RAC equipment, but also on quality of the product and the quality of servicing during product life cycle. The quality of servicing depends on knowledge and skill levels of technicians, using appropriate equipment and tools etc. The total number of enterprises in the Servicing Sector in India is about 37,000 and the total number of technicians is about 200,000. There could be potentially significant savings in refrigerant use if good service practices are followed, like proper recovery and charging of refrigerants. The good service practice is important not only because of environment issue but also to maintain the design energy efficiency of the air-conditioners. The aim of HPMP is to minimize the emissions of ozone depleting substances into the environment and, thus, mitigate the ozone layer depletion.

Kigali Amendment to the Montreal Protocol

Montreal Protocol is successfully phasing out the production and consumption of ODSs. All 197 countries of the world are working together to phase-out ODSs. Although, HFCs are not ozone depleting substances,

but have high global warming potential. These refrigerants emerged as the main alternatives to ODSs which have been phased out under the Montreal Protocol. As ODSs are being phased out, there is a rapid growing of HFCs and it is estimated that by the end of century there will be temperature rise of 0.3 to 0.5°C because of HFCs production and consumption. So, the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer made agreement at their 28th Meeting of the Parties to the Montreal Protocol on 15 October 2016 in Kigali, Rwanda to phase-down HFCs. It is a dedicated effort to reduce GHG emissions through phase-down of HFCs and improve energy efficiency.

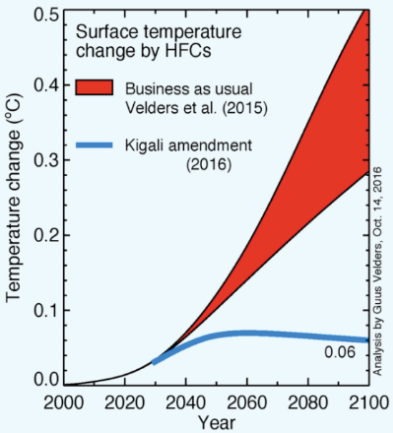
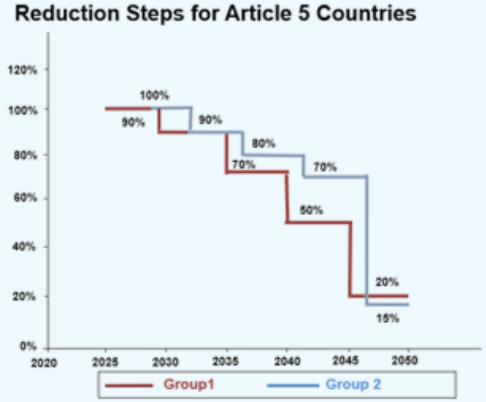


Figure 1.10 : Effect of Kigali Amendment on Surface temperature

Phase-Down Schedule of HFCs for Article 5 Countries

The figure 1.11 presents the phase-down schedule of HFCs for Article 5 countries as per the Kigali amendment to the Montreal Protocol. There are four groups, two for non-Article 5 countries and two for Article 5 countries. India opted for the Group 2, recognizing that penetration of cooling is very low in the country but growing rapidly and non-availability of alternatives for all the applications especially the high pressure applications which are needed in the country. The baseline for Group 2 Article 5 countries is the average HFCs production and consumption for the years 2024, 2025 and 2026 plus 65% of HCFCs baseline respectively.



Group 1 * Schedule		Group 2 ** Schedule	
Base-line	HFC (Avg.2020-2022)+ 65% of HCFC baseline	Base-line	HFC Avg. 2024-2026 + 65% of HCFC baseline
2024	100%	2028	100%
2029	90%	2032	90%
2035	70%	2037	80%
2040	50%	2042	70%
2045	20%	2047	15%

* China and other A5 countries.

** Bahrain, India, Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia and UAE

Figure 1.11: HFC phase-down schedule for Article 5 countries

02

AIR-CONDITIONING

Background

To perform good servicing and maintain system efficiency of air-conditioning, a technician should have knowledge of fundamentals of Air-conditioning including heat loads, vapor compression cycle, different types of air-conditioning systems, parts and components of air-conditioning and their functions, working principle of window and split air-conditioners and electrical components and controls for air-conditioner. The basics are discussed in this chapter along with commonly used new technologies such as invertor technology.

Purpose of Air-Conditioning

Air-conditioning is defined as "*the process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space*". As the definition indicates, the important processes involved in the operation of an air-conditioning system are:

- Temperature control
- Humidity control
- Air filtering, cleaning and purification
- Air movement and circulation

Figure 2.1: Purpose of Air-conditioning

The comfort temperature zone is 22.1°C to 26.7°C (a difference of 10-15°C below human body temperature). For comfort, relative humidity varies with the season. In summer, it is about 50-60% and in winter, it is about 45-55%. The air movement should be about 1m/s, for a better human comfort, the circulation of air is essential.

Heat Transfer

Heat is a form of energy and it flows from a body at a higher temperature to a body at a lower temperature, as shown in figure 2.2. For example, hot water in a glass kept in a room, cools down by transferring heat from the hot water to the room.

Air-Conditioning is a process that reduces the temperature of a confined space and maintain it at a temperature lower than the ambient temperature. In air-conditioner it is accomplished by transferring heat from the air-conditioned space to refrigerant used in refrigeration cycle and transferring the heat to the ambient (heat sink).

Removal of Heat by the Air-conditioner

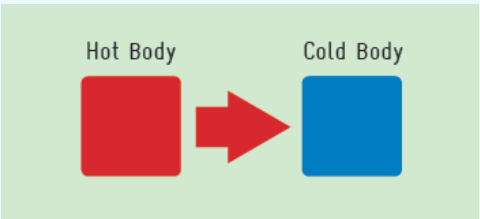


Figure 2.2: Heat Transfer

The figure 2.3 shows the external and internal heat sources in a confined space. The gained heat to be removed by air-conditioner to maintain temperature and humidity in the confined space to provide occupant comfort.

External heat source: Heat flows through the exterior walls, roof, windows and infiltration. Hot or warm air from outside entering the conditioned space through the window/doors gaps is called infiltration.

Internal heat Source: This includes electrical lighting, occupants (heat produced by metabolic activity in the human body) and appliances/ equipment such as computers, servers, printers, refrigerator, kitchen equipment etc. All these generates heat into the air-conditioned space.

Air Conditioner Removes Heat Gained in the Space from following sources:

- Heat transfer through the wall and roof,
- Heat gain through windows,
- Outdoor air infiltration,
- Lights,
- Occupants,
- Electrical/electronic equipment.

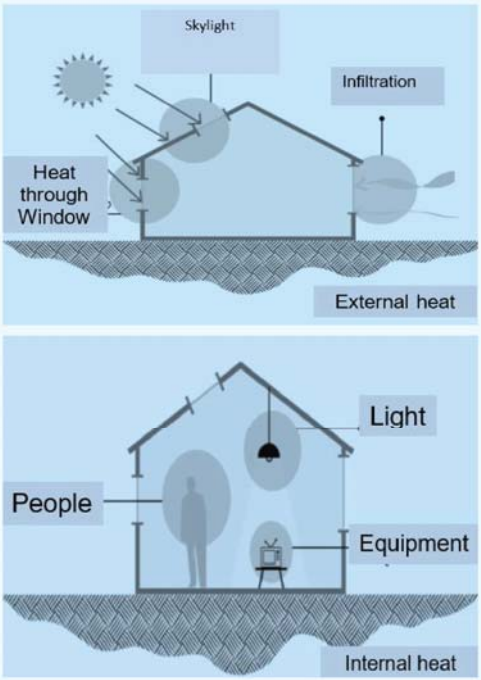


Figure 2.3: Source of Heat to be removed by Room AC

Vapour Compression Cycle

Room Air-conditioner works on the vapour compression refrigeration cycle. A vapour compression refrigeration cycle, as shown in figure 2.4, consists of four processes: (1) evaporation, (2) compression, (3) condensation, (4) expansion. Two different pressures exist in air-conditioning cycle - high pressure and low pressure. Evaporator is in low pressure side and condenser in the high pressure side. The two pressure areas are due to other two components, one, expansion device or capillary that reduces pressure from condenser pressure to evaporator pressure and controls the refrigerant flow. The other one is compressor, which increases the refrigerant pressure from evaporator pressure to condenser pressure to enable rejection of heat in the condenser.

The liquid refrigerant which is at low pressure in a heat exchanger absorbs heat from air to be cooled, changing its state to vapour. The process of a liquid refrigerant evaporating to a vapour state is called 'evaporation'. The component in which evaporation takes place is called an 'evaporator'. The design of an evaporator should be such that the refrigerant should reach a superheated state at its exit. The low pressure refrigerant vapour enters the compressor and gets compressed, in this process, the pressure and temperature of the refrigerant increases substantially. The refrigerant entering the compressor should be dry and adequately superheated. The vapour which emerges from the outlet of the compressor is highly superheated.

After compression, the high pressure superheated refrigerant flows through a heat exchanger where heat is rejected to a suitable sink e.g. atmospheric air. This heat exchanger is known as a condenser. The heat rejection in the first part of the condenser is known as desuperheating. The desuperheated refrigerant further rejects heat and it starts condensing in the heat exchanger to a liquid state. In the last part of the condenser, the condensed refrigerant is sub cooled. When the high pressure condensed liquid refrigerant flows through the capillary, its pressure decreases. The capillary also controls the refrigerant flow or quantity into the evaporator. Hence, appropriate capillary diameter and length should be used.

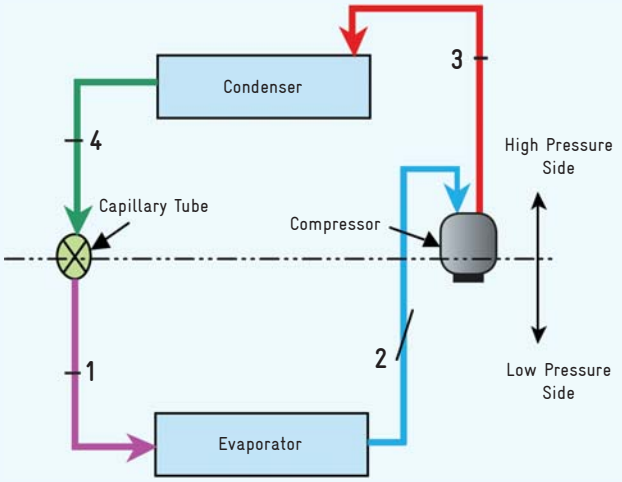


Figure 2.4: Refrigeration Cycle

Room Air Conditioning System

Room air-conditioner comprises of following components:

- **Compressor** — changes a low-pressure vapor to a high-pressure vapor. The common types of room air-conditioners have small hermetic reciprocating or rotary, and in select cases scroll compressors.
- **Condenser** — changes a high-pressure vapor to a high-pressure liquid by rejecting heat from the refrigerant causing the refrigerant to condense.
- **Expansion device or Capillary** — decreases the pressure to lower the saturation temperature and allow the refrigerant to evaporate or boil in the evaporator/cooling coil. In room air-conditioners it is capillary that acts as expansion device.
- **Evaporator** — changes (boils) the low-pressure two-phase mixture of liquid and vapor refrigerant into an all-vapor stream of refrigerant, drawing heat into the refrigerant (thus providing cooling) during evaporation.

The figure 2.5 shows the different component in the air-conditioning cycle with state of refrigerant with different colors. Refrigerant between compressor and condenser are in a high-pressure gaseous state. From condenser to expansion device is high pressure liquid state; Expansion device to evaporator is low pressure liquid state and evaporator to compressor is low pressure gaseous state.

Qe: Heat removed from the Space by the refrigerant in Evaporator

P: Power consumed by the Compressor

Qc: Heat removed to ambient by the refrigerant in Condenser, which is equivalent to sum of the Qe and P

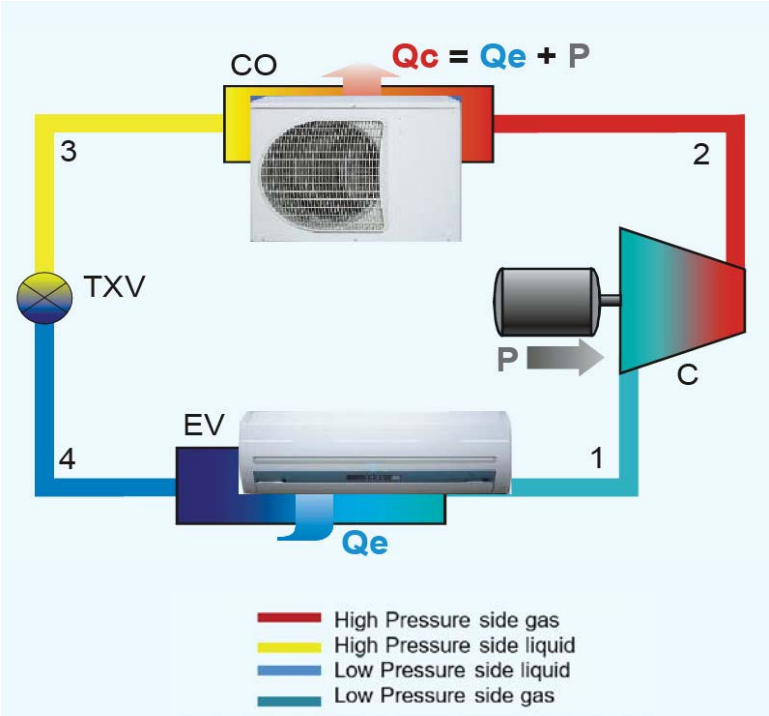


Figure 2.5: Air-conditioning components

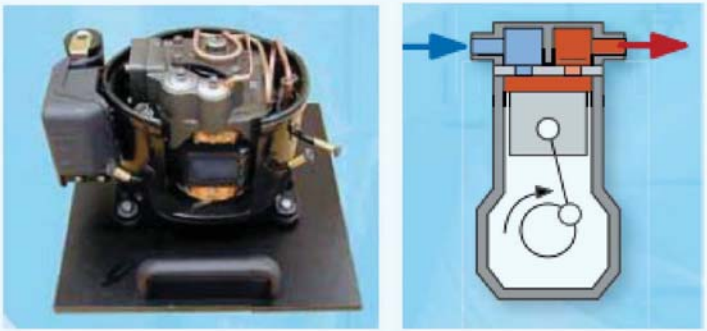


Figure 2.6: Air-conditioning Reciprocating Compressor

Compressor

Compressor is one of the most important components of air-conditioning cycle. It draws in the low temperature and pressure refrigerant gas and then compress it to a high pressure and temperature. The high pressure and temperature refrigerant gas is then transferred into the condenser. The commonly used compressors in the room air-conditioners are:

Reciprocating – hermetic: A reciprocating compressor is also known as piston compressor. The back and forth piston motion in a cylinder synchronized with suction and discharge valves helps to compress the refrigerant vapour from a low pressure and temperature to a high pressure and temperature. The operation cycle of reciprocating compressor consists of suction of the refrigerant gas, compression and discharge the compressed gas. In hermetic compressors, the motor and the compressor are enclosed in a housing so that there will be no leakage of refrigerant. The housing has refrigerant inlet and outlet and for power input socket connected. Motors reject a part of the power supplied to it due to eddy currents and friction and the compressor also gets heated-up due to friction and also due to temperature rise of the vapor during compression.

Rotary-vane compressor: The function of the vane in the rotary-vane compressor is similar to that of a piston, so, it is also known as a rotary piston compressor. The casing which is in stable position acts as a cylinder. The suction and discharge sections are made splitting the cylinder and piston rolling inside it with the help of vane. As piston rotates, due to changing of volume of suction and discharge side there will be suction of gas inside the

compressor, compressing it and then discharge of high pressure compressed refrigerant gas. Each crankshaft rotation can achieve these actions.

The rotary vane compressor is more efficiency and smaller in size and lighter weight per unit capacity as compared to reciprocating compressor. It has less components and less vibration as there is no conversion from rotations to reciprocating motion.

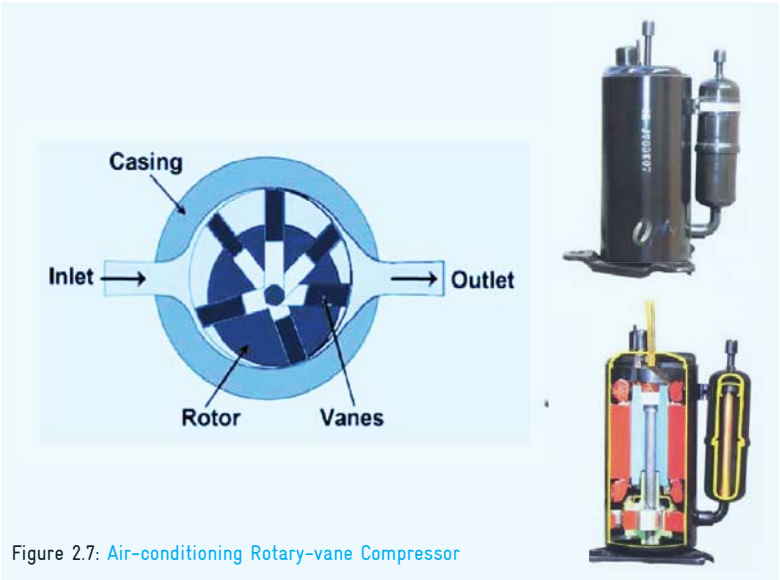


Figure 2.7: Air-conditioning Rotary-vane Compressor

Scroll Compressor: In case of scroll compressor, a fixed and orbital scroll is used to compress low pressure refrigerant gas to a higher pressure and temperature. The low pressure and temperature refrigerant vapour is drawn in the fixed scroll, The refrigerant gas is then compressed in between the fixed and the orbital scroll. After compression the high pressure and temperature compressed refrigerant gas is discharged from the centre of the fixed scroll.

It is more efficient compared to reciprocating or rotary vane compressor because it requires neither suction nor discharge valves, and minimum loss as there is no clearance volume. This compressor is more reliable due to simpler structure and less components. Vibration is also less and there is less surging due to continuous gas displacement through the sweeping motion of the rotors.

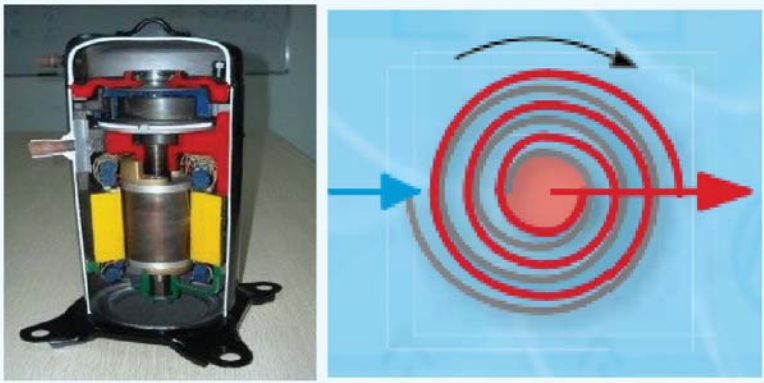


Figure 2.8: Air-conditioning Scroll Compressor

Expansion Devices

An expansion device reduces the pressure & temperature of the refrigerant coming from the condenser as per the requirement of the system. It also regulates the flow (metering) of refrigerant as per the load on the evaporator. Expansion device essentially offer resistance to flow so that the pressure drops.

Basically, there are two types of expansion devices

- Constant restriction type – Capillary tube
- Variable-restriction type – Expansion Valve

CONSTANT RESTRICTION TYPE

Capillary tube: The capillary tube is a fixed restriction type expansion device. It is a long and narrow tube connecting the condenser directly to the evaporator. The resistance to flow permits the capillary to be used as a pressure reducing device to meter the flow of refrigerant given to the evaporator.

Figure 2.9: Capillary Tube

The Pressure drop through the capillary tube is due to the following:

- Friction due to fluid viscosity, resulting in frictional pressure drop.
- Acceleration due to the flashing of the liquid refrigerant into vapour resulting in momentum pressure drop.

The cumulative pressure drop must be equal to the difference in pressure at the two ends of the tube. For a given state of refrigerant, the pressure drop is directly proportional to the length and inversely proportional to the bore diameter of the tube. Capillary tube is the most commonly used expansion device in room air conditioners. The advantage of a capillary tube is its simplicity, low cost and the absence of any moving parts. It should be ensured that the refrigerant must be free from moisture and dirt, otherwise it will choke the capillary and stop the flow of refrigerant.

VARIABLE RESTRICTION TYPE:

In this, the extent of opening area of flow keeps on changing depending on the type of control.

Two common types are

- Automatic Expansion Valve (Pressure Control)
- Thermostatic Expansion Valve

Automatic Expansion Valve: This works in response to the pressure changes in the evaporator due to increase in load (pressure increase) or due to decrease in load (pressure decreases). This valve maintains a constant pressure throughout the varying load on the evaporator controlling the quantity of refrigerant flowing into evaporator. This consists of a needle valve, a seat, a diaphragm and a spring. The opening of the valve is controlled by the two opposing forces, the tension (pressure) in the spring and the pressure in the evaporator acting on diaphragm. Once the spring is adjusted for a desired evaporator pressure and given load, the valve operates, automatically with

Figure 2.10: Automatic Expansion Valve

changing load conditions in the evaporator.

Thermostatic Expansion Valve: Thermostatic expansion valve controls the flow of refrigerant through the evaporator such a way that the quality of the vapour leaving the evaporator will always in superheated condition. Its operation is used for maintaining a constant degree of superheat at the evaporator outlet.

Figure 2.11: Thermostatic Expansion Valve

Air-conditioning Heat Exchangers – Condenser and Evaporator

FIN AND TUBE CONDENSER/ EVAPORATOR:

It is made of copper tubes coiled with one or more number of rows depending on the size of the air-conditioning unit. The surface area of the heat exchanger is increase by fixing the aluminum fins on the copper tubes.

Figure 2.12: Fin and Tube Type

MICROCHANNEL CONDENSER/ EVAPORATOR:

The Microchannel coil is constructed of parallel flow aluminum coils with multiple flat tubes containing small channels (microchannels) that are mechanically brazed to aluminum fins, resulting in better heat transfer and lighter in weight.

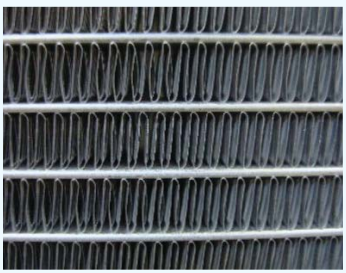


Figure 2.13: Microchannel Type

Microchannel coils are significantly smaller and efficient, and use less refrigerant than standard tube and fin coils.

Rooms Air-conditioners

Room air-conditioners are classified on the basis of their design and features. For example, window room air-conditioners are assembled and pre-charged systems, ready to plug in. Split room air-conditioners have to be assembled on the site. Some models, are designed for heating and cooling, with a reversible cycle they are called as a heat pump.

Working of a Window Air-conditioner (WAC)

The working of a window air-conditioner with typical operating temperatures and air flow at various locations is shown in figure 2.14. The colours indicate the temperature of hot or cold air and the refrigerant. The components of the window air-conditioner, namely compressor, condenser, capillary, evaporator and fans, are also shown in the figure. The window AC comprises of both indoor and outdoor components, but these are integrated in a single unit. The difference between supply and return air temperature is on order of 10-12.5°C.

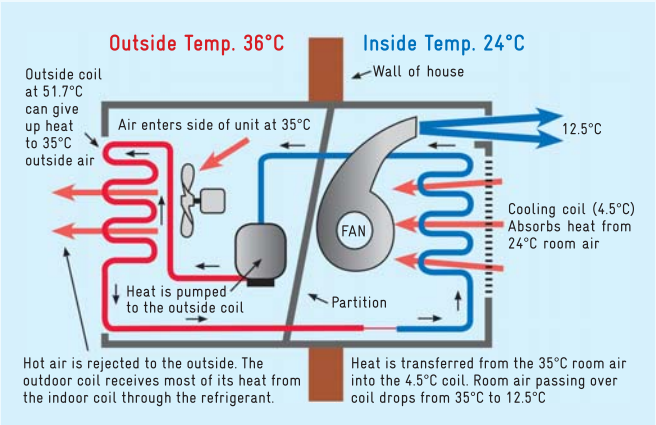


Figure 2.14: Working of a Window Air-conditioner

Working of a Split Air-conditioner (SAC)

The working of a split air-conditioner along with air temperatures, relative humidity and movements are shown in Figure 2.15,. This is very similar to the WAC but the unit is split into two parts, namely, Indoor Unit (IDU) and Outdoor Unit (ODU). The colours indicate the temperature of hot or cold air and refrigerant.

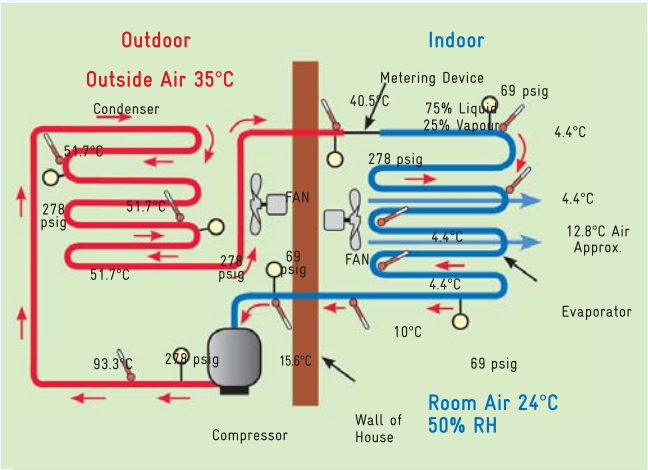


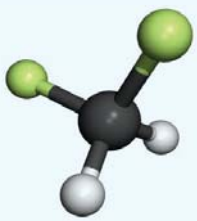
Figure 2.15: Working of a Split Air-conditioner

Designation of Refrigerants

Refrigerants are designated as given below.

1. Fully saturated halogenated compounds are designated with formula:
R XYZ

HCFC-22 ($CHClF_2$)



HFC-32 (CH_2F_2)

Where, R indicates refrigerant
X+1 indicates no. of Carbon atoms (C),
Y-1 indicates no. of Hydrogen atoms (H),
Z Indicates no. of Fluorine atoms (F)

For example

2. **Inorganic Refrigerants are designated by "7" followed by molecular weight.**

e.g.

R717 –NH3 (Ammonia);
R718-Water;
R744- CO_2

3. Mixtures or Blends of Refrigerants

- Azeotropic Mixtures are designated by 500 series
- Zeotropic mixtures are designated by 400 series ; e.g. R-410A, R-407C

Refrigerants like HFC-134a which has more than one molecular formulation are designated with lower case letters 'a', 'b', 'c' and so on at the end of the designation. In case of blends like R-410A, the upper case 'A' indicates specific composition i.e. percentage (%) composition. It has now become customary to indicate refrigerants by the chemical family along with their refrigerant designation number for example, HFC-134a to indicate that R-134a belongs to HFC family. Refrigerants like R-22 and R-32 are written as HCFC-22 and HFC-32 respectively. However, blends are always written only by their number designation for example, R-410A, although R-410A is a blend of HFCs.

Air-conditioner Performance Parameters

Cooling capacity of air conditioner is the amount of cooling produced by the air-conditioner unit used. Cooling capacity of air-conditioner is represented by several units, like, ton of refrigeration (TR), Btu/hr, kW etc. Ton of Refrigeration is defined as the amount of heat required absorbed by 1 ton (2000 lbs) of ice at 0 °C (32°F) to convert to water of 0°C in 24 hours.

1 TR = 2000×144/24 = 12,000 Btu/hr

1 TR = 3.517 kW = 3,000 kcal/hr

Coefficient of Performance (COP) or Energy Efficiency Ratio (EER) is defined as the ratio of Refrigeration Effect or cooling capacity in watt to the Electrical Power Input watt. The performance of any Refrigeration and Air-conditioning system is generally measured by its COP or EER. EER is a dimensionless number. The refrigeration effect may be expressed in watts (W) or kcal/hr or Btu/hr. The power required for running the system is conventionally expressed only in watts. Higher EER means that the power required to run the system is lower for an equivalent cooling capacity. Therefore, higher EER systems are generally recommended.

Importance of Energy Efficiency

The consumption of electricity will be less if air-conditioners have higher energy efficiency. Lower energy consumption leads to a reduction in the emissions of CO_2 leading to reduction in global warming. Better servicing of air-conditioners also leads to reduction of emission of HCFC-22, resulting in reduction of ozone depletion and global warming. Technicians must remember that neither refrigerant leakage nor excess charging of refrigerant is good and they must improve servicing procedures. In order to protect the environment, it should be ensured that air-conditioners consume less energy and avoid refrigerant leakages. The focus should be on achieving the best possible energy efficiency, with the lowest possible refrigerant emissions. This is a key to both environmental and economic sustainability.

Inverter Technology

Fixed speed ACs are lesser efficient, especially at part load because the system operates with ON-OFF control. Capillary, the constant restriction type is used as expansion devise for fixed speed ACs. The starting power is higher and there is a limitation of efficiency of AC motors compared to DC motors like compressor motor, condenser motor and evaporator motor.

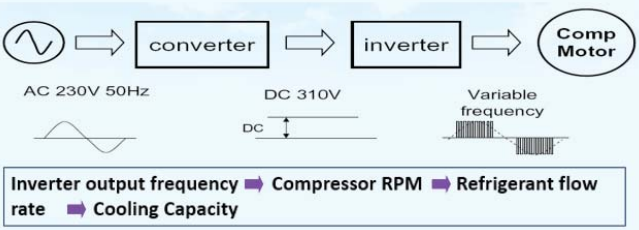


Figure 2.16: Working principle of Inverter ACs

The Inverter technology is the latest evolution of technology, control the speed of the compressor motor, so as to continuously regulate the temperature. The DC Inverter units have a variable-frequency drive that comprises an inverter to control the speed of the motor, thus the compressor and the cooling. The drive converts the incoming AC current to DC and then through a modulation in an inverter produces current of desired frequency. Through microcontroller adjust the speed of the compressor according to the ambient air temperature.

PERFORMANCE OF FIXED AND VARIABLE SPEED ACS:

Air conditioners without inverters consumes high energy during starting the system. It runs to cool a room to a set temperature, then turn OFF once the temperature is reached, then turn back ON again when the temperature rises. This repeated ON-OFF process increases the average power consumption. In case of invertor technology the compressor motor speed is regulated by the controller to provide required cooling for the space. The power drawn by the compressor motor is reduced accordingly, it enhances the COP of the system.

The figure 2.17 shows the comparison of COP of inverter and non-inverter AC with cooling capacity. COP of the non-inverter AC is constant because it always runs at its maximum capacity. In case of inverter AC, COP is almost same at 100% cooling capacity, however, at part load the COP is higher than fixed speed, as the power input is proportional to the cooling required at part load.

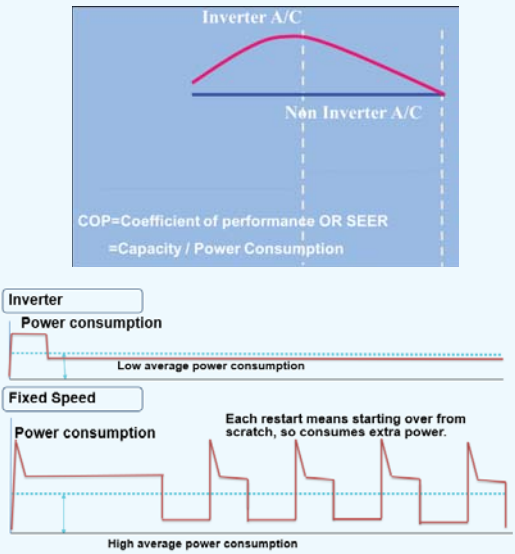


Figure 2.17: Power Consumption of Inverter and Fixed speed ACs

Electrical Components

Voltage, current and resistance are the three components in an electrical circuit through which electrons flow through their interconnections. An electric current is a flow of electric charge in an electric circuits, carried by moving electrons in a wire. The force required to move the electricity across the wire is voltage and the obstructions by some objects to the current flow is the resistance.

Ohms Law: Flow of current through a conducting material is directly proportional to the conductor's voltage

I=V/R

I = current

V = Potential difference

R= Resistance.

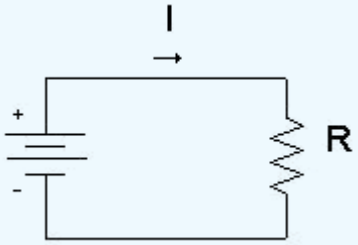


Figure 2.18: Electrical circuit

Alternating Current (AC): Alternating Current is the flow of current in which electrons keep switching directions, going either forward or backward. The magnitude of induced current varies with time. The path of alternating current in most electric power circuit is a sinusoidal . There are also Trapezoidal, Square and Triangular in some cases.

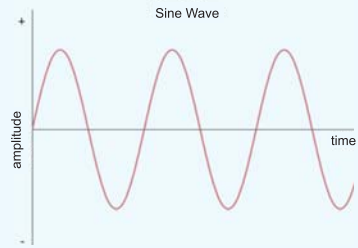


Figure 2.19: Alternating Current flow

Direct Current (DC): The flow of current or electric charge remains steady in a single direction is called direct current. In case of DC, magnitude of induced current remains constant.

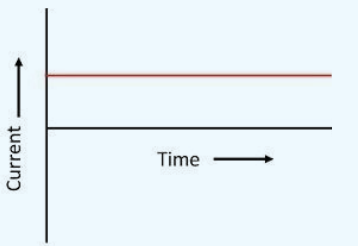


Figure 2.20: Direct Current flow

Electrical Power and Energy: The rate of flow of electrical energy through an electric circuit is the electrical power. It is a product of voltage and current. The unit of electrical power is Watt (W) or kW. Electrical energy consumption is the rate of electrical power consumed at the time duration. It is a product of power of an electrical appliance and time duration of its uses. If power of an appliance is 1 kW, and it is run for 1 hour, then electrical energy consumption will be 1 kWhr

LED: LED is made of a p-n junction diode. It releases light when it is oscillated. Energy is released as photons when a suitable voltage is applied to the leads.

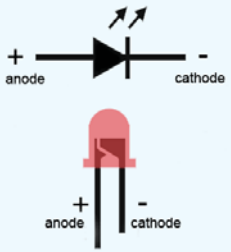


Figure 2.21: LED

Transistor: Transistor is used to amplify or switch electrical power and electronic signal consisting three or more terminals for connecting to an external circuit. It is made of semiconductor materials.


Figure 2.22: Transistor

Integrated Circuit (microchips): A semiconductor wafer on which a number of small resistor, capacitors and transistors are fabricated. It works as an oscillator, an amplifier, a timer, a counter, a microprocessor or a computer memory.


Figure 2.23: Integrated Circuit (microchips)

Transformer: Transformer consists of metal core with coils of wire around it. It converts alternating current to the required values by decreasing or increasing the alternating voltages in an electronic or electric circuit. Step down transformers are used for

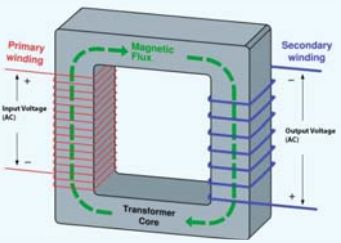


Figure 2.24: Transformer

air conditioning to step down the voltage from a line voltage to a safer and more efficient voltage for use in the control of the system.

Resistor: Resistor can be a small carbon device or big wire-wound power resistor, resist or limit the flow of current in the circuit.

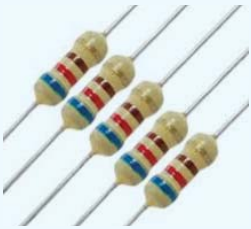


Figure 2.25: Resistor

Capacitor: Capacitor is made of one or more pairs of conductors and an insulator separating them. It is used to store electric charge. The following Capacitor are part of Air-Conditioner

- Compressor Motor Capacitor: This capacitor gets the motor running in the air conditioning unit.
- Start Capacitor: This capacitor provides auxiliary support give, helps the motor a boost to get it started.
- Indoor Blower Motor Capacitor: To start the indoor-blower-motor and keep it running efficiently.
- Outdoor Fan Motor Capacitor: It starts the outdoor fan and keeps the air flowing through the coils.

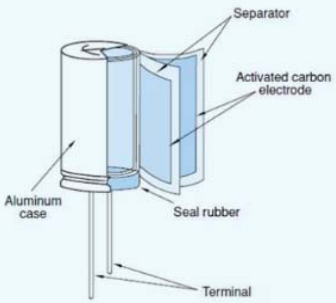


Figure 2.26: Capacitor

Inductor: Inductor consists of a coil or a wire loop. It is used to store energy in the form of a magnetic field. More the turns in the coil, the more will be the inductance.

Figure 2.27: Inductor

Thermistor: Thermistor is a kind of resistor which is more sensitive to temperature as compared to other resistors. It is used as an inrush current limiter, temperature sensor, self-regulating heating element and self-resetting overcurrent protector.

Figure 2.28: Thermistor

Printed Circuit Board (PCB): A PCB acts as a base for the components that are mounted on its surface and are interconnected with wires, conductive tracks and so on.

Figure 2.29: PCB

Relay: Relay is a switch that controls an electrical circuit by opening and closing contacts in another circuit, electromechanically by a magnetic force or electronically. Relays are used in air-conditioner in control circuits to turn system components on and off such as blower motor, condenser fan motor or a compressor.

Figure 2.30: Relay

Switch: Switch is used to make or break connections in an electric circuit. A switch is used to divert the current from one conductor to another.

Figure 2.31: Switch

Connector: A device which is used to join two circuit together. The connector may be a port, a plug, a cable connector etc.

Figure 2.32: Connector

Circuit Breaker: A control and protection device of electrical power system. A switching device which can be operated manually as well as automatically. Its main function is to shield an electric circuit from harm caused by overload or short circuit. It interrupts the current flow when protective relays find out a fault. In air-conditioner circuit breakers control all electrical circuit including indoor unit or compressor.

Figure 2.33: Circuit Breaker

Motor: Motor is used to transform electrical energy into mechanical energy, produces linear or rotary force. Air conditioner motors are crucial components that are required in the operation of the air conditioning.

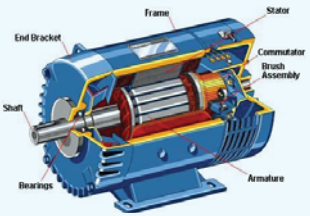


Figure 2.34: Motor

Capacitor Starts Motor:

The capacitor is connected in series with the starter winding, which causes current in starter winding. When motor reaches 75% of the rated speed, the capacitor and the starter winding is disconnected by a switch

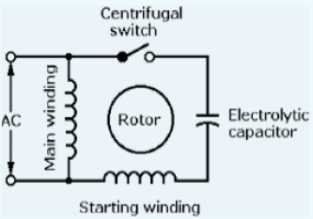


Figure 2.35: Capacitor Starts Motor

Relay Starts Motor: Relay is connected between the Starter and run winding, which causes current in starter winding. Resistance of motor increases with current, which cuts the start winding then the motor works only on run winding.

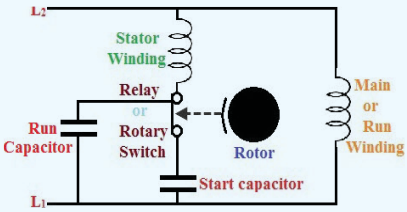


Figure 2.36: Relay Starts Motor

Permanent Split Capacitor (PSC) Motor: PSC Motor has a cage rotor and the two windings - main and auxiliary windings. It has only one capacitor connected in series with the starting winding. The capacitor is permanently connected in the circuit both at the starting and the running conditions.

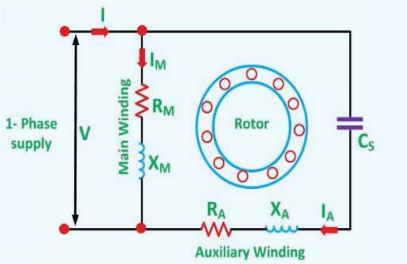


Figure 2.37: Permanent Split Capacitor (PSC) Motor

Capacitor Start Capacitor Run (CSR) Motor: CSR motor has a cage rotor, and its stator- two windings - Main and Auxiliary. Two capacitors - one is used at the time of the starting known as starting capacitor; other one is used for continuous running of the motor and is known as RUN capacitor

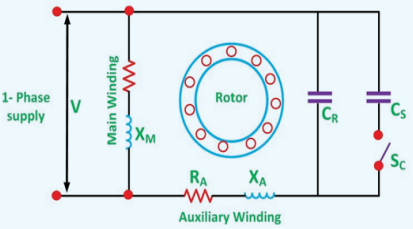


Figure 2.38: Capacitor Start Capacitor Run (CSR) Motor

Split Phase Induction Motor: Split Phase Induction Motor is also known as a Resistance Start Motor. It has a single cage rotor, and stator - two windings main winding and starting winding. The main winding has very low resistance and a high inductive reactance whereas the starting winding has high resistance and low inductive reactance.

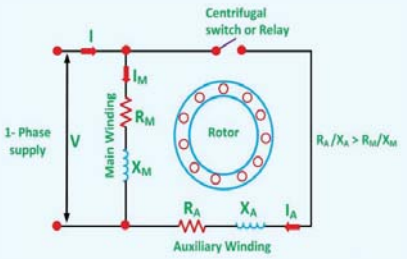


Figure 2.39: Split Phase Induction Motor

03

ALTERNATIVE REFRIGERANTS TO HCFC-22

Background

Refrigerant is a very important for functioning of any refrigeration and Air Conditioning Equipment. The refrigerant could be either a single component substance or mixture of two or more single components substances. . It absorb heat from the conditioned space and transfer the heat to atmosphere or any other heat sink. Refrigerant should have the certain properties to run the Air-conditioning system to get the desired cooling and comfort in the space to be air-conditioned and meet the safety and environmental issues. Hydrochlorofluorocarbons (HCFCs) are one of the family of refrigerants like HCFC-22, HCFC-123 etc., that are widely used as refrigerant for several applications including room ACs. All these HCFC refrigerants are being phased out, as they are having ozone depleting potential.

Need of Alternative Refrigerants to HCFC-22:

HCFC-22 is most suitable and commonly used refrigerant in the room Air-conditioner as it has very good thermodynamic and thermophysical properties and it is widely used refrigerant for room ACs, about 77% of its consumption is in room ACs manufacturing and servicing. But, it is an ozone depleting substance, although the ozone depleting potential is lower than that of CFCs. It is also having high global warming potential. The production and consumption of HCFC-22 is being phased out under the Montreal Protocol on substances that deplete the ozone layer. Therefore, we need alternative refrigerants to HCFC-22 which should have similar or better properties suitable for room air-conditioner, considering the zero-ozone depleting potential and low or negligible global warming potential. There are some alternative refrigerants commercially available and using all over the world. Although these refrigerants are suitable for air-conditioner, they have some different characteristics compared to HCFC-22 and some refrigerants have safety issues. So, as a technician it is very important to know the characteristics of these refrigerants.

Considerations for Selection of Alternate Refrigerants:

RAC technicians should perform the services such that the environmental effect due to room AC system is as much low as possible. This can be achieved

when room AC system consumes less energy (high energy efficient) and refrigerant leakages are minimum/negligible. Whether manufacturers, an engineer/technician, or an owner, the focus of achieving the higher energy efficiency, with the lower possible emissions is the key to the selected process of alternative refrigerant for maximum climate benefits.

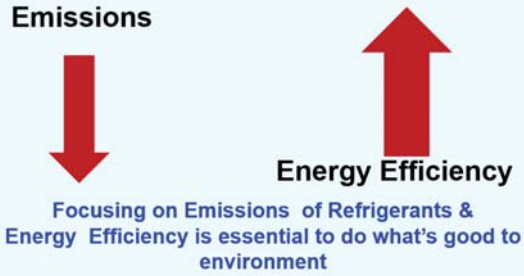


Figure 3.1: Two important parameters to be considered for Selection of Alternate Refrigerants

Figure 3.2: Desirable characteristics of Refrigerants

There are several factors that should be considered when selecting an alternative refrigerant for air- conditioning systems. The alternative refrigerant should have the following desirable characteristics as given in figure 3.2:

a. The air-conditioner with new refrigerant should have similar or higher efficiency as compared with HCFC-22.

b. It must have zero ODP and minimum/negligible GWP.

c. It must be available in the market and cost must not be too high.

d. It should be preferably non-toxic and non-flammable.

e. It must be compatible to all the materials used in air-conditioning system.

f. The alternative refrigerant must be having a good lubricant oil miscibility characteristic.

g. The stability of a refrigerant is linked to the way it behaves in the presence of other substances, particularly within the refrigerating system. It is important that the refrigerant will not react with, or act as a solvent with any of the materials within the system. These include tubes and other components, compressor motor winding insulation material, compressor oils and associated additives. This should also be considered with respect to the small quantities of contaminants such as moisture and air.

There are many refrigerants available, but none have all the characteristics as desired. Except zero ODP, the rest of the parameters have to be traded-off against one another to get the optimum to replace the HCFC-22. So, we have to select the refrigerant having nearest to the desired characteristics.

Safety Classification of Refrigerant

When selecting alternatives to HCFCs, in addition to the conventional desirable properties of refrigerants, safety features must be taken into account. The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Standard 34, specifies the class for safety of refrigerant and gives a designation to the refrigerant. Refrigerants are categorized for flammability and toxicity. The flammability of refrigerant is referred with numbers and toxicity with symbols A or B. This classification includes:

Flammability

- "1" – No flammability
- "2" – Flammable
- "2L"– Mildly Flammable
- "3" – Higher Flammability

Toxicity

- "A" – Lower toxicity
- "B" – Higher toxicity

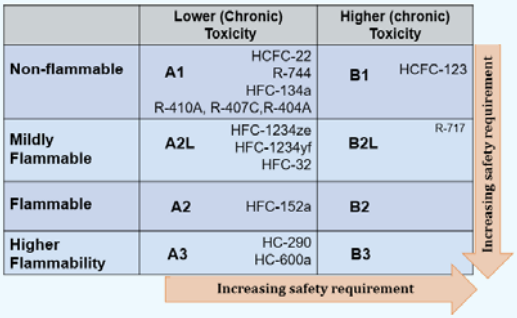


Figure 3.3: Safety Classification of Refrigerants

For example, HCFC-22 is non-flammable and low toxic, classified as A1. Likewise, R-744, R-410A, R-407C, R-404A are also non-flammable and low toxic. Propane and Isobutene are classified as A3 – indicating higher flammability and lower toxic, while Ammonia is classified as B2L indicating higher toxicity with mildly flammable.

Low-GWP Single Component Refrigerants

There are very limited single component refrigerants which meets the required properties especially with lower-GWP. The single component refrigerants could be classified in the two categories, namely, Natural Refrigerant and Synthetic Fluorocarbon Refrigerant.

1. **Natural refrigerants**
   - HCs (e.g. HC-290, HC-600a),
   - CO_2 (R-744),
   - Ammonia (R-717).

2. **Fluorocarbon refrigerants**
   - HFC-32 - high pressure refrigerant replacement for HCFC-22.
   - HFC-1234yf, HFO-1234ze(E), HFC-152a - medium pressure refrigerants can replace HFC-134a.

- HFO-1233zd(E), HFO-1336mzz - low pressure refrigerants for the replacement of HCFC-123.

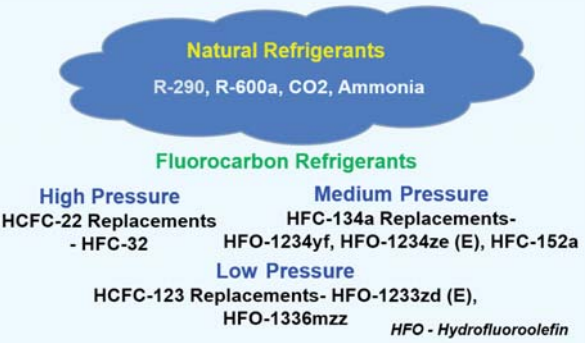


Figure 3.4: Low-GWP Single Component Refrigerants

With the continued attention on replacement of refrigerants, coupled with the ever-growing market for Room AC, efforts are being made to develop to develop and study the alternative refrigerants. A number of refrigerants have been developed but a very few have been commercially used.

Natural refrigerants

Some organic and inorganic compounds which are suitable for use as refrigerant in a refrigeration and air conditioning system applications are termed as natural refrigerants. Natural refrigerants occur in nature's biological and chemical cycles without human intervention. The most common natural refrigerants are hydrocarbons, ammonia and carbon dioxide. They have zero ODP and zero or negligible GWP. Although these refrigerants have safety issues, because of minimal environmental impacts and for being suitable in a sustainable technological development perspective, natural refrigerants could have an important role in the future in different air-conditioning systems. Propane or R-290 is used widely as alternative refrigerant to HCFC-22 for Room Air- Conditioners is discussed below.

PROPANE OR R-290:

R-290 Room ACs are successfully developed and are being markets. The R-290 newly designed Room ACs have better energy efficiency. It is an excellent alternative to HCFC-22 in the current situation, as it has zero ozone depleting potential and negligible global warming potential. It is a highly flammable refrigerant, so safety issues to be addressed adequately. It is commercially available and used by many countries including India.

The important characteristics of R-290 are

- It is a single fluid hydrocarbon refrigerant, so, easy to handle.
- It can be long term solutions due to their zero ODP and negligible GWP.
- Boiling point temperature of R-290 is -42.1°C which is slightly lower than HCFC-22.
- It is miscible with mineral oil and some other commonly used refrigeration oils with appropriate viscosities.
- No acid formation in combination with water.
- The system capacities with R-290 are close to with HCFC-22, with hydrocarbons purity class 99.5%.
- R-290 is not applicable for retrofitting for system with HCFC-22, it can only be used in properly designed.
- Requires lower refrigerant charge for the same cooling capacity than HCFC-22.
- It has higher heat transfer coefficient.
- Reduction of electrical power consumption due to lower pressure ratio and lower density than HCFC-22.
- It is easily available in the market.

The main disadvantage of R-290 is that they are flammable. R-290 is flammable in the range of 2 to 10% volume present in air. Ignition source temperature should be 470°C and above. Therefore, safety issue needs to

be addressed, by adequate changes in some electrical components and adequate ventilation surrounding the system/equipment. European Union regulation, EN378 Standard has restricted the refrigerant charge limit of R-290 in air-conditioning systems. There is no restriction for the equipment with R-290 charge quantity 150g or lower. But the equipment with charge quantity above 150g must follow charge limit as per the area of the space or room. R-290 vapour density at 20 ℃ and at atmospheric pressure is higher than that of air, so when leakage it flows downward. So, for wall mounted air-conditioners, IDU must be installed at a height of minimum 2.1m. It must be recommended that technicians handling R-290 refrigerant is well trained and always use the PPE.

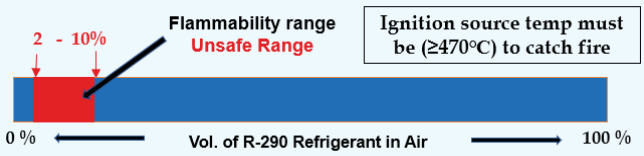


Figure 3.5: Flammability Characteristics of R-290

Fluorocarbon refrigerants

Fluorocarbon is a chemical compound part or all of hydrogen atoms of hydrocarbon including methane and ethane were replaced with fluorine. The fluorocarbon refrigerants are CFCs HCFCs and HFCs. The production and use of CFCs are phased-out globally. HCFCs are being phased-out globally under the Montreal protocol. HFCs are not having ozone depleting potential, but they are having global warming potential. HFC-32, the fluorocarbon refrigerant used in room AC is discussed below.

HFC-32:

It is a high-pressure refrigerant, higher than that of HCFC-22. It is mildly flammable. The new system with HFC-32 also have high efficiency. But, this refrigerant has moderate global warming potential (=675) which is much higher compared to R-290. The HFC-32 room ACs have been marketed since 2013 in India. It is also used commercially in many countries.

The important characteristics of HFC-32 are

- HFC-32 is an organic compound of the dihalogenoalkane variety. It is based on methane, except that two of the four hydrogen atoms have been replaced by fluorine atoms.
- It is also a single component refrigerant, easy to handle.
- It has high global warming potential of 675, although, 37% lower than HCFC-22 refrigerant.
- It is a high-pressure refrigerant, boiling point is -51.7°C.
- This refrigerant is miscible with Polyol Easter oils, the most suitable lubricant for system with this refrigerant.
- HFC-32 is mildly flammable, flammability range of 14 to 31% volume present in air. Its ignition temperature is higher (648°C).
- It has very high refrigerating capacity, about 1.6 times, as compared to HCFC-22, as it has high latent heat of vaporization.
- Refrigerating charge quantity required is lower than the HCFC-22, and so lower refrigerant circulating rate, thus require lower size of compressor.
- The heat transfer coefficient of HFC-32 is higher than HCFC-22.
- The cooling capacity and COP are higher.
- This refrigerant is available in the market at lower cost.

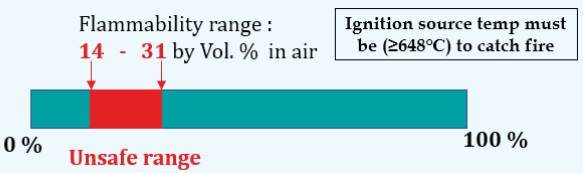


Figure 3.6: Flammability Characteristics of HFC-32

Issues of HFC-32 and R-290 refrigerants

HFC-32 is a high pressure and mildly flammable refrigerant. Although R-290 is low pressure, it is highly flammable and thus require safer design. Therefore, to handle R-290 and charge quantity the technician should have knowledge of regulation and standards relating to flammable refrigerant. HFC-32 is miscible with POE lubricants which is highly hygroscopic.

On the part of manufacturer safer design is required, but at the same time technicians must follow good service practices considering safety. It must be recommended that technicians handling R-290 and HFC-32 refrigerant is well trained and always use the PPE.

Refrigerants Blends

There are some HFC blends like R-410A and R-407C, available commercially which are being used in refrigeration and air-conditioning. These refrigerants are having no ozone depleting potential but having high global warming potential. So, these refrigerants are not long term solution for alternative to HCFC-22.

R-410A (HFC-32/HFC-125): It is also high-pressure refrigerant like HFC-32. It is widely used refrigerant in Room ACs globally including in India. It is non –flammable refrigerant. However it has high global warming potential, so, it is not a long term alternative. The phase-down of various HFCs will begin in next 5 to 7 years as per the agreed schedule in the Kigali Amendment to the Montreal Protocol.

R-407C (HFC-32/125/134a): It is also a blend of HFCs. It has a large temperature glide that results in lower cooling capacity as well as energy efficiency as compared to HCFC-22. Pressure is a little higher than HCFC-22. But, it is also having high global warming potential, so, it is not a long term alternative.

Issues with HFC Blends

Azeotropic blends: These types of blends are usually binary mixtures that behave like a pure fluid. A single temperature defines either the evaporation or the condensing pressure.

Zeotropic blends: A zeotropic blend is a mixture of refrigerants whose

different volatilities are seen when observing the performance of a refrigeration cycle. There is change in the molar composition and/or a change in saturation temperature during boiling or condensation, so, it does not behave like a single refrigerant when condensing or evaporating. Two different situations arise, depending upon the type of system.

The figure 3.7 shows zeotropic mixture of refrigerant components, as it flows through a heat exchanger tube. In the case of a pure fluid, the temperature of the refrigerant remains the same as the liquid vaporizes, or the vapor condenses. However, with a zeotropic blend, as the refrigerant vaporizes, the saturation temperature rises (or as the vapor condenses, the saturation temperature falls). The refrigerant is at the bubble temperature when it is just a pure liquid (e.g. when it is just evaporating) and is at the dew temperature when it is just a pure gas (e.g. when it is just condensing).

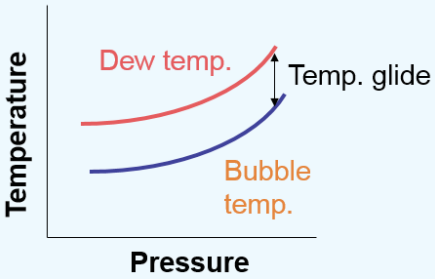


Figure 3.7: Issues with HFC Blends

Temperature glide: The characteristic called "temperature glide" occurs when the refrigerant blend has various temperatures as it evaporates or condenses at a single given pressure.

Unsaturated Fluorocarbons (HFOs)

Unsaturated fluorocarbons refrigerants are composed of hydrogen, fluorine and carbon atoms, but contain at least one double bond between the carbon atoms. These refrigerants have been developed as these are having zero ODP and very low atmospheric life resulting in negligible GWP (<1). Some of the recently developed refrigerants are described below.

- **HFO-1234yf:** It is unsaturated HFC and can replace HFC-134a in same systems since the pressure-temperature characteristics are almost

identical. It is classified as A2L. In general, this refrigerant produces efficiency levels comparable to HFC-134a although the theoretical COP is a few percent below that of HFC-134a.

- **HFO-1234ze(E):** It is an unsaturated HFC and can replace HFC-134a in new equipment where its lower volumetric capacity can be addressed in the design of the equipment. It is classified as A2L.
- **HFO-1233zd(E):** It is an unsaturated HCFC and has similar pressure to that of HCFC-123. It is classified as A1. When used with centrifugal compressors, this refrigerant produces efficiency levels similar to HCFC-123, allowing the design of systems with very high energy efficiency.

Characteristics of Commercialized Alternative Refrigerants for Room AC

In table 3.1 some important characteristics of alternative refrigerants are compared with HCFC-22.

Table 3.1: Comparison of important characteristics of alternative refrigerants with HCFC-22

Property	HCFC-22	HFC-32	R-290	R-410A
Chemical formula	$CHClF_2$	CH_2F_2	C_3H_8	CH_2F_2/C_2HF_5 (50% HFC-32+ 50% HFC-125)
Cooling capacity relative to HCFC-22	100	160	94	140
ODP	0.055	0	0	0
GWP	1810	675	3	2100
Flammability*	Non-flammable (A1)	Mild-flammable (A2L)	Higher Flammable (A3)	Non- flammable (A1)
Toxicity	Low	Low	Low	Low

In figure 3.8 the pressure vs. temperature of HCFC-22, R-290, HFC-32 and R-410A are compared. The vapour pressure curves for HCFC-22 and R-290 are very similar. At higher temperature, the pressure of R-290 is slightly lower than HCFC-22. However, for HFC-32 and R-410A, the pressures are higher than HCFC-22.

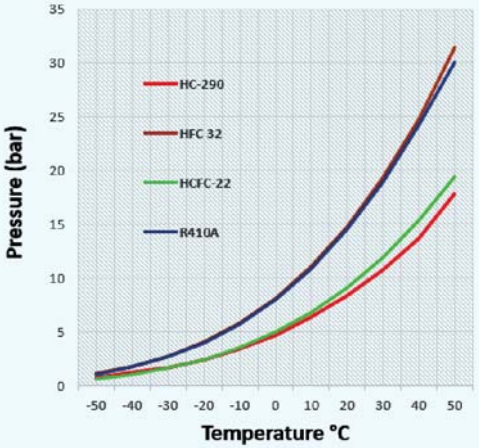


Figure 3.8: Pressure vs Temperature graph for available alternative refrigerants

Refrigeration Oil and Properties

Compressor manufacturers always specify oil type and fill each model of compressor accordingly. In hermetic systems, the lubricant is in intimate contact with the electrical motor windings. The oil must therefore provide good, material compatibility and have high thermal stability properties. Although the majority of the lubricant remains in the compressor, a small amount will be circulated into the rest of the refrigerant circuit. The lubricant must be able to resist both the high temperatures at the compressor discharge valves and the low temperatures at the expansion device. It must be sufficiently soluble with the refrigerant itself in order for it to be returned back to the compressor, so that over time, it does not become starved of oil, which could lead to mechanical failure.

The properties of a good refrigeration lubricant are:

- Low wax content. Separation of wax from the refrigeration oil mixture may plug refrigerant control orifices.
- Good thermal stability. It should not form hard carbon deposits and

spots in the compressor, such as in the valves of the discharge port

- Good chemical stability. There should be little or no chemical reaction with the refrigerant or materials normally found in systems
- Low pour point. This is the ability of the oil to remain in a fluid state at the lowest temperature in the system
- Good miscibility and solubility. Good miscibility ensures that the oil will be returned to the compressor, although a too high solubility may result in lubricant being washed off the moving parts
- Low viscosity index. This is the ability of the lubricant to maintain good oiling properties at high temperatures and good fluidity at low temperatures and to provide a good lubricating film at all times.

In the table 3.2 below the available lubricants suitable for refrigerants are presented.

Table 3.2: Suitability of Lubricants for the refrigerants used in Room AC

Refrigerants	Mineral Oil (MO)	Alkyl Benzene (AB)	Polyol ester (POE)	Polyalkalyne glycol (PAG)
HCFC-22	Suitable	Suitable	Suitable (moisture absorber)	Not Suitable
Propane (R-290)	Suitable with viscosity correction	Suitable with viscosity correction	Suitable with viscosity correction	Applicable with limitation (moisture absorber)
HFC-32	Not Suitable	Application with limitation	Suitable (moisture absorber)	Application with limitation (moisture absorber)

Charge Quantity Limits for R-290

The Charge quantity for air-conditioner with R-290 refrigerant should be based on as per the IEC 60335-2-40 for a given room size. Max Charge of R-290 in kg can be calculated by the formulae

$M_{max} = 2.5 \times (LFL)^{5/4} \times h \times (A)^{1/2}$

Where,

A = Room area in m^2

h = height of the indoor unit installed from ground in m.

LFL =Lower flammablility limit of propane = 0.038 kg/m3

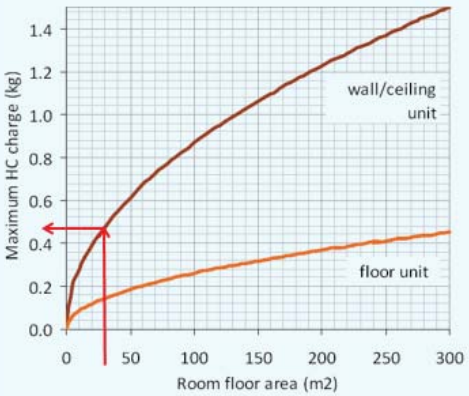


Figure 3.9: Charge Quantity Limits for R-290

The figure 3.9 shows the charge limit with respect to room floor area. This figure has been developed based on the principle explained above and could be used as to maximum for a given floor area and height of mounting of indoor unit of Room AC. As shown in the figure 3.9, for a 30 m^2 floor area and indoor unit of Room AC installed at a height of 2.1 m the maximum charge limit is 0.48 kg.

04

TOOLS AND EQUIPMENT AND MAINTENANCE

Background

Refrigeration and air-conditioning service technicians work mainly with hand tools and equipment. To be successful, the technicians must select quality tools, take good care of them and be skilled in their use. The technicians should always use the right hand tools and equipment for the right job and as recommended by the manufacturer of the air-conditioner. Using improper equipment and tools for a specific job may be unsafe. For example, using a flat screwdriver instead of a Phillips screwdriver - the flat screwdriver tip may slip and result in personal injury. Use of appropriate tools and equipment helps in improving the quality of installation as also repairs and servicing. This chapter provide useful information for selection, care and use of RAC tools and equipment.

RAC Tools

SPANNERS

Common types of spanners include open-end spanner, the box spanner and combination spanners. There are also tube-type spanners and adjustable spanners. The use of box-end and socket spanner-cum-screwdriver is the best choice when there is adequate space around the nut and bolt. The adjustable spanner 150 mm (6") is a popular type of adjustable wrench spanner necessary for opening / fixing odd-sized nuts and bolts.

ALLEN KEYS

Allen keys are made up of a hexagonal metal bar and can be used to tighten nuts having hexagonal recess on the head. The Allen key set comes with various sizes.

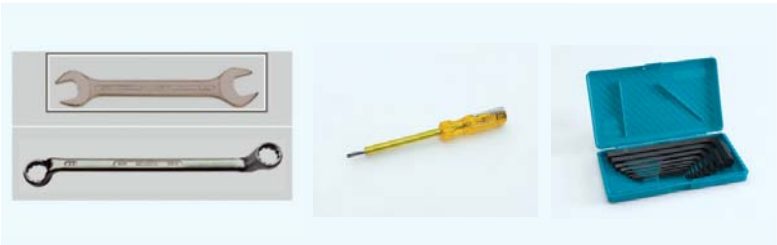


Figure 4.1 : Spanners, Line Tester and Allen Keys

LINE TESTER

Insulated electric tester (500 V) should be used before start of electric work to test live electric supply in wires and sockets. It also helps to check polarity in the electric socket.

PLIERS

Different pliers need to be used as per the requirement. Insulated combination pliers 150 mm (6") size] help to grip objects and to strip or cut wires. This is a handy tool for general use. For safety, it is not advisable to use this on nuts, bolts or fittings. To grip a small hardware or to strip or cut wires, insulated nose pliers are recommended. This helps to work in a narrow work space. To grip big objects like tubes, nuts or bolts, monkey pliers 100 mm (4") size can be used.

FILES

Depending on the requirement, various types of files can be used to remove unwanted burrs while doing operations on tubes or other metal surfaces. A Flat Rough File 200 mm (8") with a safe handle is recommended when metal is to be removed at a faster rate from a flat surface. A Round File 150 mm (6") can be used for cleaning metal surfaces and shaping metal parts in a circular shape.

Figure 4.2 : Pliers and Files

CRIMPING PLIERS

Crimping pliers are necessary for crimping closed end splice & fixing fastener clips to wire's end. These can be used to cuts wire and strips wire. These can be also used for crimping solderless connectors onto wires.

PINCH OFF PLIERS /SELF-LOCKING PLIERS

At the end of servicing of window type room air conditioners, tubes need to be pinched and sealed. Pinch off pliers are the ideal tool for this purpose. The gap between the jaws of the pinching plier can be adjusted as required.

The jaws of the pinch off plier should not be heated during the process of sealing.

Figure 4.3 : Crimping, Pinch off and Piercing pliers

PIERCING PLIERS / VALVE

Piercing valves are used for piercing tubes and accessing the refrigeration system for processes like recovery of refrigerant. This should not be used for evacuating the system. These pliers and valves are fitted with connections of 1/4" SAE threads.

HAMMER AND MALLET

Hammer and Mallet (400/500 g) are useful hand tools for accurate blows onto metal for bending or shaping as required, during the servicing or installation of air-conditioners.

CHISELS AND KNIVES

Chisels and knives are used for cutting metals or metallic wires. A flat cold chisel 20 mm (0.78") size is needed for cutting metals, where as a knife can be used for cutting/shredding small size wires.

Figure 4.4 : Hammer, Mallet, Chisels, knives, and Hacksaw

HACKSAW

The hacksaw is preferred for cutting larger, hard copper tubing. If a saw is used, a wave set blade of 32 teeth per inch is most suitable.

TORQUE WRENCH

A torque wrench is a tool used to apply precisely a specific torque to a fastener such as a nut or bolt to avoid over /under stressing. A set of torque wrenches (several heads) for up to 200 N.m (2039 kgf.cm) is required specially for tightening flare connections. An adjustable torque wrench can be used on different sizes of fittings suitable for open end spanners.

HAND DRILL MACHINE

It is used to drill the holes on sheet metal for fitting of screws. With additional attachment, to drill larger holes on walls for refrigeration tubes and drain pipes at the time of installation.

Figure 4.5 : Torque Wrench, Hand Drill Machine and Ratchet Wrench/Service Valve Wrench

RATCHET WRENCH/SERVICE VALVE WRENCH

This is also one of the important tools. To open or close the service/cylinder valve which can rotate clock wise or anti clock wise. Instead of this tool if field technicians use plier or adjustable spanner it will damage the valve spindle and it may not be possible to operate the valve after some time. Improper handling of any cylinder valve may cause uncontrollable leakage or worse may be the chances of the accident.

TUBE CUTTER

Tube cutters are available in different design and sizes. Tubing cutters make an accurate 90° cut on copper tubing. The standard tube cutter is available for tube sizes from 1/8" to 1 1/8". For confined areas mini tube

cutter can be used. During the cutting process, tube cutter is to rotate once around copper tube and then rotate the handle wheel slightly to the level of tightness and then again rotate around the tube. If the handle wheel is tightened too much, the tube will deform and the blade will get damaged.

Figure 4.6 : Tube cutter, Capillary tube cutter and Deburring tool

CAPILLARY TUBE CUTTER

It is very important tool for RAC technicians. It can cut the capillary at an angle and with no burs. It consumes very less time, without burs . One can make at an angle of 45 degrees with respect to capillary and apply the capillary cutter. Do not use wire cutters instead of capillary cutter as the wire cutter do not have angle inside the cutter.

DEBURRING TOOL

When a soft copper tube is cut with a tube cutter, it usually leaves some sharp burrs on the cut ends. Burrs must be removed by reaming in order to keep the tube wall surface smooth and clean. Most tube cutters have a reamer attached to it. Reamer/deburring tool can be used to remove the burr from inside as well as outside of the copper tube. While deburring, keep the tool at the bottom hand and tube on the upper hand, so that all the burs can be collected within the deburring tool otherwise all the burs will enter the copper tube.

FLARING TOOL WITH SWAGING KIT

To connect a copper tubing to a fitting, flared type connection is generally used. Flaring tools consist of a tube holding device called flaring block and a yoke assembly comprised of a feed screw and a smooth surfaced flare compression cone. The tubing is clamped in the flaring bar, yoke is engaged and feed screw advanced until the cone shape is formed and a moderate resistance is encountered.

In a combination flaring and swaging tool the block is used for holding the tube and the swaging adaptors attached to the yoke assembly, when tightened with the lever expands the tube to the proper size. Punch type swaging tools are also available for different types of tubes.

Figure 4.7 : Flaring tool with swaging kit

TUBE BENDER (LEVER TYPE)

Tube bender is an important tool for making neat and accurate bends that does not place any strain on the fittings after it is installed. Lever type tube benders do not allow the tubing to kink, flatten or buckle. Therefore it is a good practice to use a lever type tube bender during installation and servicing of Air-conditioners. Some technicians use spring bender as they are cheaper.

Figure 4.8 : Tube bender (lever type), Scrubber cum wire brush and Tongs

SCRUBBER CUM WIRE BRUSH

Use scrubber to clean outside of copper tubes joints before and after brazing.

TONGS

Tongs shall be used to lift the objects that are too hot to handle.

MALE AND FEMALE QUICK COUPLER

Male & Female couplers are used for joining tubes that eliminate need for flaring of tubes and save time, avoid leakages that can occur through ordinary valves during servicing. They are suitable for 1/4" copper tubes.

Figure 4.9 : Male and female quick coupler, Digital Clamp Meter and Core Removal Tool

DIGITAL CLAMP METER

The multifunctional digital clamp meter aids to check the resistance, AC/DC voltage and current. It measures resistance in the range 0-200kΩ, DC voltage up to 1000V, AC voltage up to 750V and AC current 0-300amp. It is also used as a continuity/diode tester with audible beep. This can be used for checking earthing in wall socket.

CORE REMOVAL TOOL

This tool is important for split air-conditioner service. This can be used to replace the pin valve on the service port of Split ACs without loss of refrigerant and also for removing the pin valve during recovery of refrigerant from the system and during evacuation of system. To operate this valve first tighten the valve clock wise and hook it on to the core/pin valve, after that attach a charging hose with valve attached to it and rotate anti-clock wise direction. Due to pressure in the system the spindle will be pushed outward, close the valve and do the required procedure.

2-WAY GAUGE MANIFOLD

Different types of gauge manifolds are available in the market. Very important to diagnose trouble in air-conditioning systems. This is mainly used during evacuation or charging operations. It contains two shut-off valves, three external connections, and two pressure gauges. The gauges and the flexible hoses that connect to the manifold to connect it to the system are colour coded; blue is the low side of the system, red is the high side. The left-hand gauge is called a compound or suction pressure gauge. The right-hand gauge is called the high pressure or discharge pressure gauge.

The right side shut-off valve will control the flow through the centre port

and the port on the left side (blue low side), with left shut-off valve (hand-knob) is in the open position. To allow flow only through the center port (yellow line) close the low side blue label shut-off valve.

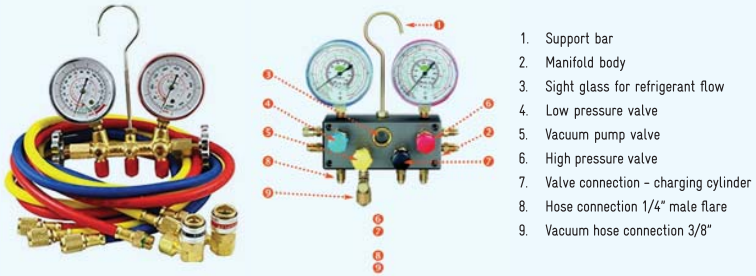


Figure 4.10 : 2-way and 4-way Gauge Manifolds

The gauges will indicate either vacuum or pressure depending whether hand-knobs are in the open or closed position.

4-WAY GAUGE MANIFOLD

A 4-way gauge manifold is an essential tool for air-conditioning technicians. This reads pressures on both high and low sides of the system. This can also be applied to read vacuum on the low-pressure side of the system.

A 4-way manifold saves time and prevents entry of air/moisture as there is no need to switch hoses for different processes. The low and high sides, the vacuum pump and the charging device can be hooked up right at the

Figure 4.11 : Evacuation and Charging Kit and Pressure gauges

beginning of the job. The manifold is a central control for service. One needs to just operate the appropriate valve.

EVACUATION AND CHARGING KIT

The portable gas charging station has hoses with female quick couplers, weighing balance, manifold, high vacuum pump, vacuum gauge and pressure gauges. This helps to evacuate the air-conditioning system to the desired vacuum, charge it with the exact /specified quantity of refrigerant.

PRESSURE GAUGES

There are different types of pressure gauges, Bourdon tube type is most commonly used gauge. They are available in different ranges for measuring pressure and vacuum. Vacuum gauge is used to measure pressures lower than the ambient atmospheric pressure (e.g.: –15 psig or –760 mmHg equals total vacuum). A compound gauge is useful to measure pressure at the low and high sides of a running system.

A thermo-couple vacuum gauge is useful for measuring the fine vacuum which is difficult to measure using a compound gauge. This gauge measures the vacuum in microns or Pascals. (1 micron = 0.001mm i.e. 1/1000mm Hg).

ELECTRONIC WEIGHING SCALE

This helps to charge the air-conditioners with the exact amount of refrigerant.

MEASURING TAPE

At the time of installation of window air-conditioners (WAC) and split air-conditioners (SAC), measuring tape is required to measure the room size to calculate heat load and for the proper positioning of the indoor and outdoor units. This also helps to cut the tubes of the required size.

Figure 4.12 : Electronic Weighing scale, Measuring Tape and Spirit Level

SPIRIT LEVEL

While installing the air-conditioner, especially the indoor unit, it is important to level the unit. A spirit level 150 mm (6") size will help to measure the same.

DIGITAL THERMOMETER

A digital thermometer with a puncture probe is an instrument to measure the temperature and humidity. This has an accurate electronic signal with indoor and outdoor temperature display. The indicator displays the temperature between -50°C to 100°C with Fahrenheit/Centigrade conversion switch.

LEAK DETECTOR

Leakage of refrigerant in a air-conditioning system is inevitable as there can be many imperfect joints fitting or welding points or leakage developed due to vibration, harsh temperature and environment.

Electronic Leak Detector is more accurate and easy to use. Higher end models use infrared sensor to accurately detect a leak of less than 2 gms per year. HFCs, HCs, HCFCs and HCFC-based refrigerant blends can be detected easily by using this advanced technology state of the art tool. This detector has a filter that prevent contaminants and water from entering it. It is also able to work in an environment contaminated by refrigerants by using the re-calibration feature.

Figure 4.13 : Digital thermometer, Leak Detector and Propane/LPG Gas

PROPANE/LPG GAS DETECTOR/ALARM

This is used to detect the presence of combustible, flammable and toxic gases in an area. While working with flammable refrigerants, this type of device is important because refrigerants like R-290 and HFC-32 are

odorless and any emissions or leakage is dangerous. A gas detector can sound an alarm to operators in the area where the leak is occurring, giving them the opportunity to take necessary precautions.

REFRIGERANT HOSES

The various types of hoses are refrigerant standard hose, vacuum hose, refrigerant hose with end-mounted ball valve and specially designed HC refrigerant venting hose. Refrigerant standard hose is with 50.8 mm x 6.35 mm (2" x 1/4") SAE size with female flare connections of 900 mm (35.43") length. For minimal refrigerant emission while charging, the refrigerant hose with end-mounted ball valve must be used.

Figure 4.14 : Refrigerant Hoses, Can Adapter with flexible hose and Control Valve

REFRIGERANT CAN ADAPTER WITH FLEXIBLE HOSE

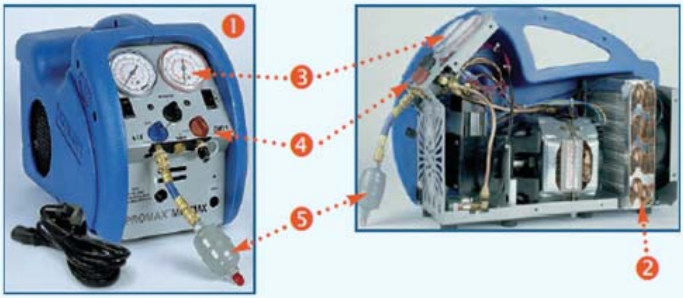
Propane is mostly available in cans. It is important to charge the air-conditioner with accurate quantity of refrigerant as specified by the manufacturer. Therefor it is important to place the refrigerant can properly on an electronic weighing scale and connect it to the gauge manifold with a flexible capillary type charging line. A refrigerant can adapter with flexible hose is most suitable for this.

CONTROL VALVE

Ideal for using it during refrigerant charging. Eliminates refrigerant or oil, from spraying during connections.

REFRIGERANT RECOVERY MACHINE WITH A RECOVERY CYLINDER

Since it is important to reduce HCFCs emission and in line with HCFC phase-out - it is important to recover as much HCFCs as possible. Likewise,



1. Recovery unit
2. Condenser and ventilator
3. High and low pressure gauges
4. Refrigerant inlet & outlet valves
5. Inline filter-drier

Figure 4.15 : Refrigerant Recovery Machine

1,3&4 – Refrigerant Recovery Cylinder
2 – Liquid level float
5 – Cylinder cut
6 – Liquid/Vapour valve
7 – Transfer line for gaseous refrigerant
8 – Transfer line for liquid refrigerant

Figure 4.16 : Recovery Cylinder

HFCs should also be recovered as they have high GWP. For such recovery of refrigerants, a recovery machine is required.

It is recommended to use recovery machine with oil-less compressor. Oil less recovery machine does not have the risk of addition of any oil from the compressor to the refrigerant.

Separate recovery cylinders should be used for recovery of different refrigerants. Do not use disposable cylinders for recovery of refrigerant.

BRAZING TOOL KIT

For proper brazing using adequate temperature, the minimum requirement is an LPG brazing kit. One example is the swirl jet or spit fire which can reach higher temperatures than the ordinary LPG torches. It is still better to have oxy-acetylene brazing torch – but economic consideration may not allow this.

Figure 4.17 : Brazing tool kit and Brazing filler metal

BRAZING FILLER METAL

Brazing filler metals can join similar and dissimilar metals at brazing temperature. Brazing filler metals melt at temperature range of 538 to 816 C. Some filler material used for brazing copper tubing are of two categories, alloys containing 30% to 60% silver, others are copper alloys which contain some phosphorous. These two classes vary in melting, flowing and fluxing characteristics. Strong joints can be made with either class of filler metal.

HEAT DEFLECTOR

An asbestos-lined heat deflector should be used to reflect the heat on to the joints while brazing.

Figure 4.18 : Refrigerant Identifier, Oil Can and Heat deflector

REFRIGERANT IDENTIFIER

Refrigerant identifier will provide a fast, easy and accurate means to identify refrigerants and to determine refrigerant purity in storage cylinders. It can be used to determine the concentrations of different refrigerants.

OIL CAN

Oil can is required for oiling the fan motor for better lubrication which is necessary at the time of service.

AIR VELOCITY METER (ANEMOMETER)

Anemometer is an apparatus for measuring the speed of air. The commonest kind of anemometer is a fan blades fixed in the circular ring. When placed in an airflow direction, the lightweight metal vanes present in the devise rotate due to the flow of air through it. This rotation speed of the vanes is proportional to the speed of air flow through the anemometer. A gearing and clutch mechanism that exists in the device records the number of rotations of the vanes and thus the speed of the air is displayed on the screen.

Figure 4.19 : Anemometer, Hand electrical air blower and Sound Level Meter

HAND ELECTRICAL AIR BLOWER

Used at the time of servicing the AC to remove the dust particles from the Evaporator or Condenser Coil & from exterior parts of air-conditioner. The high velocity air jet blow to remove dust and other contaminants from coils and exterior of the system.

SOUND LEVEL METER (DB METER)

This is used to measure the noise & vibrations produced by compressor/ Air-conditioner. It has a point at the top, which is the microphone that samples and measures the sound. Inside the box at the bottom of the meter, electronic circuits measure the sound detected by the microphone and amplify and filter it in various ways before showing a readout on a digital LCD display. Use of this is reliable when noise levels are concerned. However, the surrounding noise level must be at least 12 dB levels lower than that of object under test, otherwise reading becomes incorrect.

NITROGEN CYLINDER WITH 2 STAGE REGULATOR & HOSE

Nitrogen gas being inert, non-oxidizing, is recommended for flushing & leak testing of a refrigeration system. The pressure of nitrogen in the cylinder is above 2000 psi, and such pressure can cause serious accident. To avoid any unpleasant event, a 2-stage regulator must be used for regulating its output pressure to safe working limits of about 15-20 bar (220-290 psig).

Dual Stage Regulators reduce the source pressure down to the desired delivery pressure in two steps. The advantage of a dual stage regulator is its ability to deliver a constant pressure, even with a decrease in inlet pressure.

Figure 4.20 : Nitrogen cylinder with 2 stage regulator & hose and Fire Extinguisher

FIRE EXTINGUISHER

This is most important, do not forget to have a powder type fire extinguisher as only this can be used on any type of fire (oil, electricity, papers etc.). It should be placed in a safe but rapidly accessible location to make use of it in case of any eventuality. It is better to display the location near the entrance of any workshop or keep it close to brazing kit. The label of the extinguisher must be checked for its status.

Quality Maintenance of Select Tools and Equipment

'Maintenance' means all actions necessary for retaining an item, tool or equipment in a serviceable condition, or restoring it to a serviceable condition. This includes servicing, repair, modification, overhaul, inspection and condition verification. Maintenance increases the availability of tools and equipment when required and keeps the same in working order doing like lubrication, overhauling of equipment and tools and changing oils/ lubricants. Good and timely maintenance of tools and equipment ensures assured proper working of the same when required.

1. Routine maintenance is a must as electro-mechanical tools/ equipment are used by RAC technicians.
2. The basic goal of maintenance is to prevent the failure of tools and equipment before it actually occurs.
3. Maintenance is designed to preserve and enhance reliability of tools and equipment by replacing worn components before they actually fail.
4. It helps reliability, safety and productivity as also avoids waste, disruption, accidents and inconvenience.

VACUUM PUMP

Over time, vacuum pump oil can become oxidized or contaminated by moisture from the system and it reduces the pump's ability to reach its ultimate vacuum level. Therefore the oil must be carefully maintained and changed at proper intervals or after the pump is used for about 100 hours. Visually through the sight glass check the oil. If the oil looks milky or rusty, it should be replaced immediately. Always use the type of oil recommended by the manufacturer of the pump. Vacuum pump oil has a low vapor pressure. It is therefore absolutely different from normal hydraulic oil or motor oil.

Before performing any maintenance always disconnect the vacuum pump from the electrical source. Get the pressures measured with a calibrated vacuum gauge or micron gauge. Maintain a record of maintenance jobs done. Each month check for wear and tear or damage of electrical wires and plugs. If damage or excessive wear and tear is found, replace them. Steps for changing vacuum pump oil:

1. Operate the vacuum pump to heat up the vacuum pump oil.
2. Turn the vacuum pump switch off and disconnect the electrical cord plug from the electrical outlet.
3. Place the vacuum pump on a level surface.
4. Unscrew and remove the oil plug from the bottom of the pump housing to let the oil drain from the pump completely.
5. Refit the drain plug back into the pump housing.
6. Remove the oil fill plug at the top of the pump housing.
7. Add oil as noted on specification/amount of recommended vacuum pump oil, to raise the oil level to the full oil level marks of the oil sight glass.
8. Refit the oil fill plug.
9. Operate the vacuum pump for a short period of time.
10. Check the oil level through the oil sight glass.

MICRON GAUGE

The micron gauge is very crucial in evacuation or system repairs. It must be maintained at its best. The sensor has to be regularly checked and kept safe. Always keep the connections clean. A vacuum gauge can sometimes get oil into the vacuum chamber and onto the vacuum sensor and this will affect the accuracy of the sensor, clean it only with Isopropyl alcohol. Any other solvents must not be used. This being delicate equipment, it must not be tampered on their own but contact the supplier or manufacturer for assistance. Notes to be maintained in the diary or mobile phone about the details of the repair for future reference. The record of maintenance has to be maintained.

MANIFOLD GAUGE AND CHARGING HOSES

The manifold gauge set has to be kept clean for better and safer performance and maintain it regularly. The manifolds are generally made of precision

machined aluminium with Teflon valve. These are designed for light touch operation, hence should not be over tightened. If there is any leak in the valves, the O rings on the valve piston require to be replaced. The manifold should not be exposed to rain or used in damp or wet environments. Before using gauge, if any part appears damaged it should be carefully checked to determine that it will operate properly and perform its intended function. If there is any doubt, it should not be operated. Pressure greater than the full scale reading should never be applied to a gauge. Applying pressure greater than full scale reading can cause the instrument to become inaccurate, cause system leaks and will severely shorten the life of the gauge. Gauges used on oxygen cylinders should be free from oil and grease and cleaned for oxygen service according to appropriate standards. The gauge must not be operated if under the influence of alcohol or drugs or if one is tired.

The hoses must be inspected periodically. Do not disconnect any pressurized hoses.

Always check hoses for cuts, cracks, abrasion, exposed reinforcement, etc. Never exceed the rated working pressure of a hose. Any hose which shows signs of wear or abuse must be removed from service immediately.

LEAK DETECTOR

Make sure and use the appropriate leak detector designed to detect the refrigerant you are working on. Care must be taken of their sensors. Direct contact of the sensors with any of the materials or any type of contamination needs to be avoided. A 2mm gap between the sensor of the leak detector and the joint under testing needs to be maintained. The sensor has to be stored in a dust free area.

REFRIGERANT CHARGING STATION

HCFC refrigerant can be charged into a system in the same way as CFCs and HCs are charged and generally the same equipment can be used. However, to avoid cross-contamination in equipment, it is better to flush the equipment and its attachments with Oxygen-Free Dry Nitrogen (OFDN). Always use separate suitable set of hoses for different types of refrigerants due to possible cross-contamination and higher pressures.

RECOVERY UNIT

Any assembled recovery unit may not be as reliable as commercially manufactured units. The compressor can fail and will need replacement if the machine is used on a regular and extensive basis. Therefore, it is recommended that a spare compressor is kept ready for this purpose.

1. A filter dryer must always be used between the recovery machine and its inlet hose.
2. Special care should be taken when recovering from a 'burnt-out' air-conditioner. Two high acid capacity filters in series are to be used. After recovery of the refrigerant from the system is complete, it is to be flushed with a small amount of OFDN or clean refrigerant and lubricant to purge off any foreign materials left inside.
3. the refrigerant is to be always removed into the external storage cylinder. Liquid refrigerant left in the condenser may expand, causing damage to the components.
4. Ensure that the power supply is disconnected. Before beginning any type of maintenance work.
5. If the unit is to be stored or not used for a long time, it is recommended that it be completely evacuated of any residual refrigerant and purged with OFDN.
6. If any abnormal noise is observed from the recovery machine, it may be an indication of a potential malfunction. Fan blade/ Guard/ mounting may be loose, if left unattended, it can damage the condenser. Check the capacitor mounting, internal hose connections and all electrical connections.
7. In case of under recovery of refrigerant, it may be due to presence of non-condensable gases in the recovery unit or recovery cylinder.
8. Purge all hoses properly and evacuate the recovery cylinder.
9. If it is difficult to start the unit, please turn on the purge valve, balance the internal pressure and make it easier to start.
10. Ensure that the inlet and discharge ports are protected and kept clean by replacing the plastic caps after every use.
11. For best results, keep a filter prominently connected to the inlet port and change it regularly.
12. Change hoses periodically as they develop leaks and a build-up of contaminants over time.

05

COPPER TUBE PROCESSING & BRAZING

Background

Most tubing used in refrigeration and air-conditioning (RAC) is made of copper. All tubing in air-conditioning is carefully processed to be sure that it is clean and dry inside. The quality of copper tube operations is very important in air-conditioning. It is very important to identify types and sizes of copper tubing, select and proper use of copper tubing tools, to understand the different steps needed for copper tubing, like bending, flared connections, brazed joints. Brazing is a process for joining two metal or alloy pipes in RAC. Technician should understand that refrigerant emissions impact the environment and copper tube processes like brazing and flare connections should be done properly to insure containment of refrigerant in the system. Brazing is a hot non-attachable process using flame, so safety precaution while doing brazing is very important.

Copper Tubes

ASTM or IS10773 standard tubes offer desired design, purity, size, compatibility with refrigerants, and safety of copper tubes. When copper tube for air-conditioning is manufactured, the inside of the tubing is dehydrated to remove all moisture. The tubing is then charged (filled) with low-pressure nitrogen gas and sealed with a cap at each end to keep the tubing safe from contamination by oxygen and moisture in the air. Oxygen atoms combine with copper atoms (a process called oxidation), a layer of copper oxide would form inside the tube. The caps also keep out dirt and

Figure 5.1 : Copper Tubes

other foreign matter that could contaminate a refrigeration system. Caps or plugs should be replaced after cutting a length of tubing.

The tubes used in air-conditioners are measured based on outside diameter. Air-conditioning and refrigeration tubes are classified based on the thickness of tubes.

Table 5.1: Size of Copper Tubes and their thickness

Outside Diameter inch (mm)	Wall Thickness inch (mm)
1/4 (6.35)	0.030 (0.762)
3/8 (9.525)	0.032 (0.813)
1/2 (12.7)	0.032 (0.813)
5/8 (15.875)	0.035 (0.889)
3/4 (19.05)	0.035 (0.889)
7/8 (22.225)	0.045 (1.143)
1 1/8 (28.575)	0.050 (1.27)
1 3/8 (34.925)	0.050 (1.27)

Three types of copper tubes are available in the market:

- K Class: Thick-walled tubes used for heavy duty applications and where corrosion might occur.
- L Class: Medium thick-walled tubes which are used widely in almost all applications. (L and K class tubes are suitable for room air-conditioners)
- M Class: Thin-walled tubes, it is not used in air-conditioning systems because it does not meet safety code requirements

Copper Tubing Operations

Copper tube operations involve the following processes.

- Straightening and measuring,
- Cutting,
- Reaming,
- Bending,
- Cleaning/polishing,
- Swaging soft-drawn copper tubing,

- Flaring soft-drawn copper tubing, and
- Brazing.

All these operations need to be done carefully in good service practicing. Using accurate sizes of copper tubes will correctly fit into each in a telescopic form e.g. 5/8 to ½",½ to 3/8", 3/8 to ¼" (15.8 mm to 12.7 mm, 12.7 mm to 9.5 mm,9.5 mm to 6.3 mm).

Tube Straightening and Measuring

A photograph of straightening operation of copper tubing used in air-conditioners is shown in figure 5.2. This is first step in copper tube processing. The straightening must be done from head to tail of tube. Straightening is done by supporting the coil upright with one hand and holding the free end of the tubing stationary on a flat surface with the other hand (or a foot). The coil is then rolled in a straight line to the desired length. Do not straighten out an excessive length of the copper tube as it is difficult to recoil the tubing without bends.

Before cutting, marking is important. The part marked to be placed on flat surface safely, free from damage. The correct dimensions must be made and incorporated while working on copper tubes.

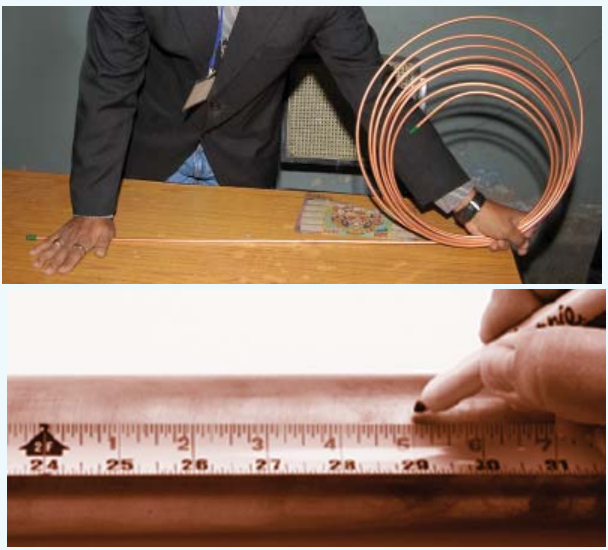


Figure 5.2 : Tube Straightening and Measuring

Copper Tube Cutting

In air-conditioners servicing, cutting of copper tube must be done precisely. Although, cutting copper tubing is a simple task, it must be performed properly. Care must be exercised not to damage the ends being cut. The cutting of the tube should be done using a tube cutter. Copper tubing cutters make an accurate 90°. The surface of the cut part should not be rough or slanted. It should be at a right angle to the axis of tube and smooth. Avoid excessive blade pressure; because of more pressure on the cutter, the tube gets cut like pinched and leaves some burr. Avoid twisting the tube and let cutting edge reach the bottom or another side. Select a cutter as per tube size; do not use hacksaw or any other tool to cut soft copper tubing. The Hacksaw is used only for cutting larger, hard tubing. The cutter blade should be kept sharp. After cutting off the desired length, place the cap or plug on the end of the coil to prevent contamination. A Mini tube cutter can be used in confined areas.

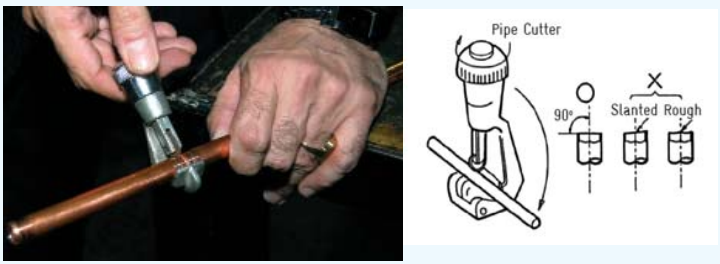


Figure 5.3 : Copper Tube Cutting

Reaming

After cutting, the tube ends will have some sharp burrs and it must be removed. Reaming is a process of removing burrs and scraping the ends to a flat surface. Tube face and reamer should be facing each other without deviation. To remove the burr, the reamer is positioned at the tube end to be reamed and rotated gently. Both the outer and inner burr is to be removed with the help of a reamer. Care must be taken that copper chips or burrs do not enter inside the tubing. The tube must be held upside down or at an angle during the reaming process so the chips will fall on the floor. It is important to have a proper dimension of the cut tubing end. Burrs or ridges

on the inside of the tube will cause problems while assembling them. The thickness of the tubing at the cut end should match the thickness of rest of the tubing.

Figure 5.4 : Reaming

Bending

Bending is one of the most important process in copper tubing in the air-conditioning system. This operation helps to avoid many joints in the air-conditioner during servicing. While bending care must be taken to ensure that the entire tube surface remains round at the bend. The tube should not be flatten. Proper bending does not allow the tubing to flatten or kink. Calibrated lever type bending tool should be used. Lever-type tubing benders are easy to operate and are calibrated to allow accurate short radius bends up to 180°. Some benders are designed to fit only one size of tubing, while others can be used with a range of sizes.

Figure 5.5 : Bending

Bending Steps

Positioning: The bending tool diameter must match the copper tube diameter. With the handles at 180° and the tube holding clip raised out of the way, the tube should be inserted in the forming wheel groove.

Bending Start Positioning: The tube holding clip to be placed over the tube and the handle to be brought into an approximately right-angle position, engaging the forming shoe over the tube. The zero mark on the forming wheel should then be even with the front edge of the forming shoe.

Bending the tube: Bend the tube by pulling the handles towards each other in a smooth, continuous motion. The desired angle of the bend will be indicated by the calibrations on the forming wheel.

Removal of the tool: Remove the bent tube by pivoting the handle to a right angle with the tube, disengaging the forming shoe. Then release the tube holding clip.

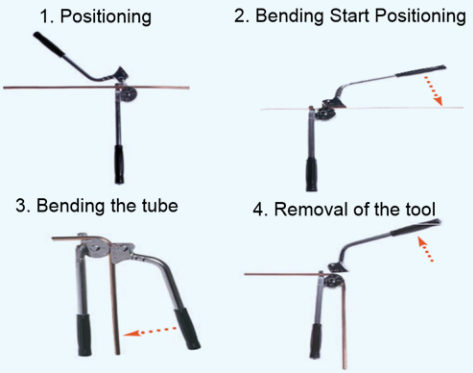


Figure 5.6 : Bending Steps

Cleaning and Polishing

The coper tubes must always be kept clean using abrasives like polish, emery cloth, wire brush etc. An abrasive plastic scouring pad to be used for cleaning the surface. Prevent cleaning particles or swarf from entering the tube. For interior fitting cleaning a proper sized fitting brush must be used.

Figure 5.7 : Cleaning (L) Polishing (R)

Swaging

The swaging operation helps to join the two tubes of the same diameter. Swaging is the process of enlarging the diameter of one end of a length of soft copper tubing, so the end of another length can be slipped into it. For this operation only, the soft copper tube should be used. The swaged copper tube connection to be then brazed. To perform swage, the flaring block, hammer, and proper size swaging tool are required. Selection of correct size hole to place the tube is very important. The position of the tube above the flaring block should be outer diameter (OD)+3 mm of the tube. The length of the overlap of the two copper tubes to be swaged should be equal to OD of the tubing.

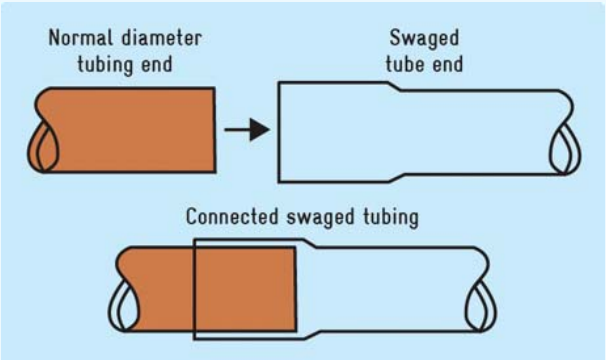


Figure 5.8 : Swaging

Flaring

When connecting tubing to fittings, it is a common practice to make flare connections. To join the copper tube with male threaded flare fitting in air-conditioner servicing, flaring operation must be perfectly performed. The end of the soft copper tube is flared at 45° angle. The flared end of tubing rests against the male portion of the fitting being connected. For flaring operation, a flaring block and a flaring yoke are required. It is a mechanical joint without any gasket in between. The soft copper flare takes the shape of the fittings and seals properly. Therefore, proper attention is very much required while doing the flaring process. The flared joint must be done carefully to avoid the emission of refrigerants.

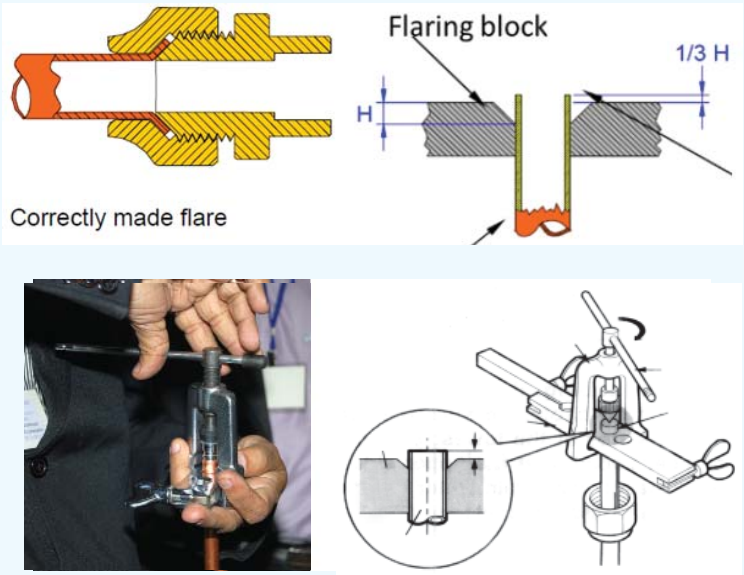


Figure 5.9 : Flaring

Flaring Steps

After cutting, reaming and cleaning process the following steps to be done.

Assemble the flaring tool with tube: Place the flare-nut over the end of the tube with the threads close to the end is flared. The tube to be inserted

between the flaring bars of the flaring tool. The opening of the flaring bars must match the diameter of the tube being flared.

Fabricate the flare: Align the compression cone on the tubing's end and tighten the screw. As one turns the handle, the cone flares the end of the tubing's.

Inspect your work: Inspection of the work must be done after removing the tubing from the flaring tool. If the tube end has split, the flared portion to be cut and repeat the process. It is essential to examine the tight position of male flare union, female flare-nut flared copper tube. Tight and clean fitting is requested.

Assembling: Position the flare union against the flared end of the tubing then slide down the nut. The fitting should be easily tightened by hand if done properly. Additional pipe jointing or sealing compound (e.g. oil or Teflon tape) is not necessary.

Tightening: Tighten the joint by placing one wrench on the union and one on the nut. Do not over-tighten a flare joint. Once the parts fit by hand, a half turn to be given on each nut/wrench to create a gas-tight joint.

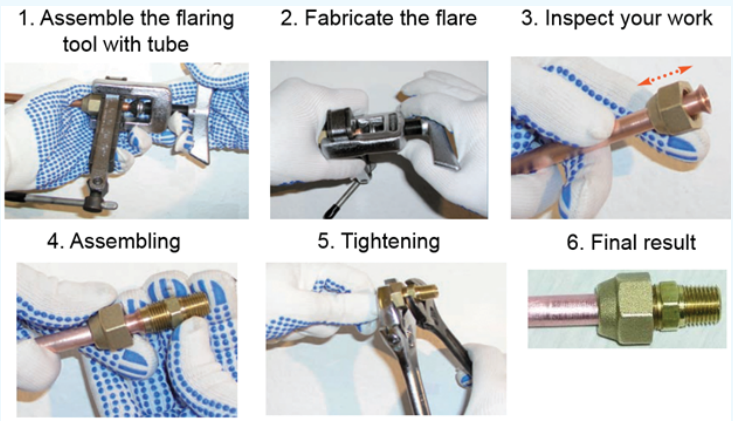


Figure 5.10 : Flaring Steps

Brazing

Brazing is a non-detachable joining process most common in air-conditioner parts or lines for producing strong and tough joints. Brazing can be done between Copper to Copper, Copper to Aluminum and Copper to Steel tubes to withstand vibrations, shocks, and tension etc. This is one of the best methods of making leak-proof connections.

To perform the brazing process a striker, air-conditioning service wrench, brazing rods or filler material, and an acetylene-oxygen cylinder and torch are required, as shown in the figure 5.11.

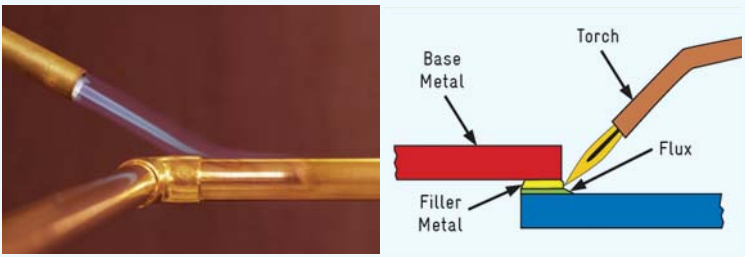


Figure 5.11 : Brazing

If the temperature required to melt the alloy used to join copper tubing is above 450°C it is considered brazing, if less than 450°C, then soldering. Heat source depends upon the size of tubes to be brazed. For air-conditioning application normally heat source should produce temperature above 450°C. The brazing rod should melt on contact with the heated copper tubes and should never be heated directly by the torch flame and melted. This can happen only if the copper tubes have been heated to the appropriate temperatures. The filler rod that has melted on contacting the heated base metals (copper tubes) flows into the clearance between the overlapping copper tubes that have to be joined, by capillary action. This capillary action will take place only when the clearances are maintained within certain limits and the movement of flame across and around the joint.

Introduction of Nitrogen as protective gas with a very low flow rate inside the tube assembly during the brazing process is a good method to avoid oxidation. Service valves should be protected with wet rags or heat sink material while doing brazing. Use only recommended fillers for various joints.

Safety Precaution while doing Brazing

"Safety First and Everywhere". During brazing, Personal Protective Equipment (PPE) like goggles, shoes, apron/lab coat and gloves exclusively designed for safety must be worn.

Figure 5.12 : Safety Precaution while doing Brazing

Safety has one more vital issue of smoking. One should never smoke in the work area or laboratory or workplace. Always make a practice to work in the safe working environment and to remind the same install the safety signs apart from First-aid kit and fire extinguisher at a convenient place. This is for self, others and property. While brazing, heat source depends upon the size of tubes to be brazed. It requires to use the tools and equipment with care. If flux is needed to be applied do not apply with fingers.

The torch should never be pointed towards an open flame or source of sparks. It is recommended that always a sparker to be used to light the torch, do not use match sticks or cigarette lighter. A flashback arrestor for both the acetylene and oxygen regulators should be used. Always keep a fire extinguisher near the work area.

Brazing Filler Material

Filler material in liquid state distributes between two or more close-fitting parts to be joined by capillary action. Filler material interacts with a thin layer of the base metal (known as wetting) and when cooled, it forms a sealed/leak-proof joint as a single component.

The brazed joint is stronger than the filler metals used because of the

geometry of the joint and the metallurgical bonding that occurs. For brazing steel base metal with copper, filler material normally used is silver (Ag) 35%. Fluxes made of sodium, potassium, lithium & borax is added as a paste, powder to brazed metal to remove oxides. At least 2% silver alloy to be used as filler material for copper to copper joints.

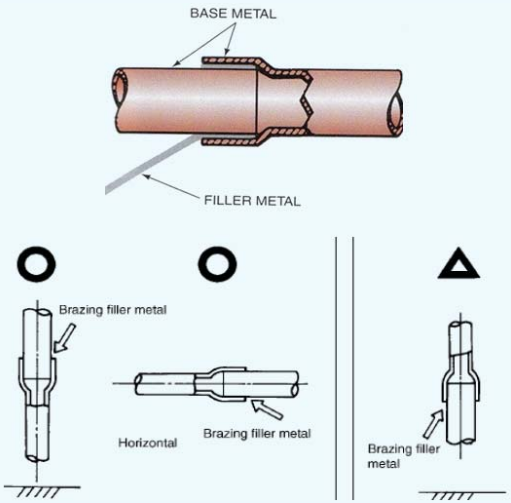


Figure 5.13 : Brazing Filler Material distribution in joints

Brazing joint

In the brazing process melted filler metal joins the base surface irregular voids such that metallurgical bonding occurs between the filler material and

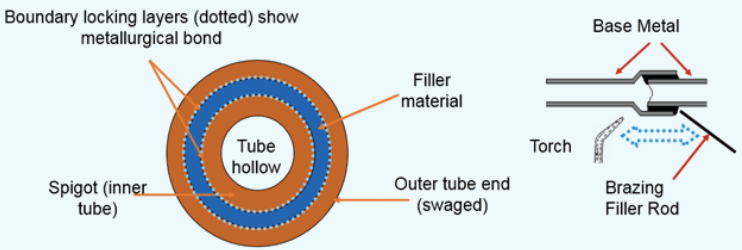


Figure 5.14 : Brazing Joint

base material. In a pictorial form a cross-section of the inner and outer tubes being brazed, along with the molten filler material is shown in figure 5.14. The melted filler rod as a liquid wet the surface of the copper tubes and penetrates superficially into the surface of the copper tubes to form a strong metallurgical bond between the outer surface of one tube and the inner surface of the other tube that overlaps this tube at the joint. The boundary-locking layers in the diagram show the metallurgical bond.

Brazing Joint Preparation

Before the start of the brazing process, the tubes are to be prepared. First swage one tube end in the case of the same size tubes. The clearance between two tubes should be in the range 0.05 mm to 0.5 mm. Length of joint should be at least equivalent to the diameter of tubes in the case of same size tubes. Clean the surfaces of tubes and ends of tubes with proper materials. While inserting the smaller diameter end into larger diameter end, the tubes must be straight and aligned with each other. There may be brazing of the two dissimilar tubes like ¼" to 3/8". In such case length of the joint should at least be equivalent to the 1.5 times diameter of the smaller tube. The first thing to be done before the commencement of brazing is to ensure that the joints are prepared correctly. This involves thorough cleaning of the surfaces to be joined using emery or wire brush to leave a clean and bright surface. This will ensure removal of all dirt, greases, oils and other impurities that will otherwise be present on the surfaces and prevent proper wetting of the surfaces. Insert the spigot end into the swaged end/ bigger tube end/ fitting end. Provide support to the tubes being brazed to retain uniform clearances and prevent slipping, disorientation etc.

Brazing Process

Assembly: The pipe and fitting or expanded pipes are to be kept together and the right joint depth in the system should be maintained.

Torch (flame) adjustment: Adjust the torch for a slightly reduced flame. Slowly pass nitrogen into the tube work to prevent oxide formation on the inner surface of the tubes. Once the refrigerant is circulating, oxide scale on the inside of the tubes can lead to serious problems. Flow rate should be about 1 to 2 liters per minute. Flow rate sensitively can be felt easily on the back of a moistened hand.

Apply heat: Heat to be applied uniformly to both, tube and fitting, by moving the torch around to ensure even heating before adding the filler material (rod).

Apply filler: As the heated area gradually changes color to red (a cherry red but not a bright red), apply filler material (rod) by lightly brushing the tip of the stick into the shoulder of the fitting. Care should be taken not to over-heat the tube.

Remove the heat: Heat to be removed until the molten brazing alloy solidifies to a tan black color (approx. 10 to 15 seconds).

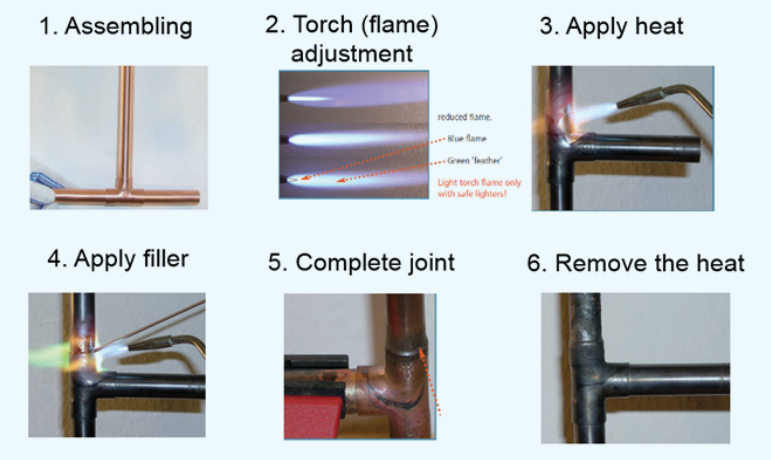


Figure 5.15 : Brazing Process

Types of Flame in Oxy-Acetylene/LPG Brazing

Brazing torch flame gets developed when acetylene (C_2H_2) and oxygen (O_2) burn together. The flame formed are of three types; neutral, reducing and oxidizing. The sketches are presented in the figure 5.16. In case of neutral flame, inner cone gives 2/3rd of heat whereas the outer envelope provides 1/3rd of the energy.

In the mixture of C_2H_2, and O_2, when excess C_2H_2 is present then combustion of acetylene is incomplete. This type of flame is good for aluminum alloys and high carbon steels. In burning mixture due to excess

O_2 oxidizing flame gets formed. For brass welding this flame is good. It is recommended to use neutral or reducing flame for brazing of RAC joints.

The flameout of Oxy-LPG too reaches over 2800°C temperature like an Oxy-acetylene flame. Use of correct flame is important else the metal tubes may burn or melt, or carbon will deposit at the joint portion of tubes leading to chokes in future. It is suggested to use neutral or reducing or carburizing flame and not oxidizing flame.

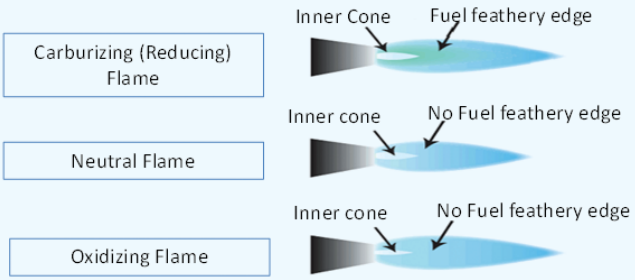


Figure 5.16 : Types of Flame in Oxy-Acetylene/LPG Brazing

Brazing Temperatures

For proper brazing, the process should be conducted at the desired temperature. The correct temperatures for various filler materials are given in the figure 5.17. If the temperature exceeds the desired temperature, then the filler starts flowing. The temperature should be in the range of 600°C to

Metal / Filler Material	Melts at °C	Flows at °C
Copper	1083	
Silver	950	
Cu-Phos (w/o Ag)	710	732
(5% Ag)	643	732
(15% Ag)	643	705
Cu-Ag (35% Ag)	607	703

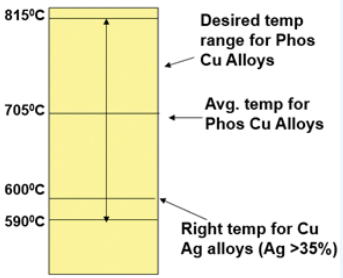


Figure 5.17 : Brazing Temperature

815°C, considering all brazing alloys for copper. The average temperature for such brazing rods is around 705°C.

The addition of silver contents in the filler lowers the melting point of the rods. Rods with 35% silver start melting at around 600°C. Phosphorus Cu rods with 5% silver start melting at around 643°C.The use of filler material with silver content is ideal and it avoids chances of burning or melting copper tubes.

Status of Flux at Different Temperatures

The figure 5.18 shows the status of brazing flux at different temperatures. The flux starts bubbling at about 100°C, becomes white at 315°C, milky at 425°C, and clear at 600°C. It becomes ready for brazing at 850°C. Since all this is possible without thermometer but due to the application of flux powder, it is necessary that the technician uses it carefully and always, especially when dissimilar metals like steel are under brazing. While doing brazing the flux helps to understand when to touch filler material or when the metals are ready to accept filler material through capillary action.

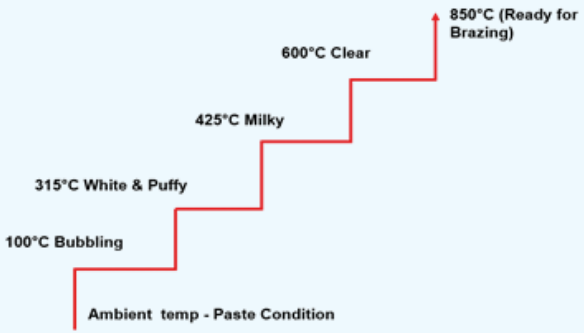


Figure 5.18 : Status of Flux at Different Temperatures

Quality of Brazed Joint

For longer life of brazed joints, the heating should be uniform for the entire portion of brazing. The joint should not be under heated. There should not be excessive clearance otherwise the voids will be formed in the filler material. Then the joint becomes weak. It is advisable to keep some fillets

at the joints to compensate for the voids. Always filler material should melt on its own and no attempt should be made to drop the filler material. This makes a good/strong joint.

Advantages of Brazing

The advantages of brazing are

- Dissimilar metals can be joined.
- Good for very thin metal joints.
- Metals with different thickness can be joined easily.
- Thermal stresses not produced in the work piece - no warping.
- Using this process, carbides tips are brazed on the steel tool holders.

06

QUALITY INSTALLATION OF SPLIT AIR-CONDITIONERS AND PREVENTIVE MAINTENANCE

Background

Implementation of correct installation practices is very important, as it affects the performance of the air conditioner. Incorrect installation can results in poor performance leading to high energy consumption/electricity bills irrespective of the certified star rating, poor air circulation, as well as maintenance problems. It will not work the way it has been designed, also will not have the expected working life. Many studies have proven that air conditioners that are improperly installed their cooling capacity and efficiency reduces by over 20 percent. Incorrect airflow is another common problem with improper installations of AC. In fact, proper installation of air conditioning system is one of the key elements needed for economical, efficient operation of the system.

Maintenance is a part of preserving air-conditioners for a long time and for better performance. Planned or scheduled and preventive maintenance is necessary in the servicing of air-conditioners. It is recommended that the dates on which regular maintenance is to be carried out, should be fixed for a year. Further maintenance helps reduce undesired expenses and sudden breakdown.

General Safety for Installation

The technician must learn and follow safety and good service practices while installing air-conditioners. It should be mandatory that only qualified, trained and experienced technicians do the installation of air-conditioners. All safety steps like proper electrical connections, switching off the main power supply while working on the system, grounding the air-conditioner as per code, not installing air-conditioners near hot surroundings, checking for leakage of refrigerant, pre and post cleaning of location, working in ventilated area, no components are left inside the air-conditioner, keep fire extinguisher near the work place and no one should smoke around the working area.

Tools and Equipment for Installation

Tools and equipment's are essential for installation of air conditioner. Most of the technicians possess such tools and equipment. The minimum set of tools and equipment required for installation of air-conditioners are listed below:

1. A screwdriver set
2. Phillips head screwdriver
3. Knife or wire stripper
4. Steel tape measure
5. Spirit level
6. Hacksaw
7. Core bits for drilling
8. Hammer
9. Drilling machine
10. Tube cutter
11. Tube flaring tool
12. Tube bender
13. Torque wrench
14. Adjustable wrench
15. Reamer (for deburring)
16. Refrigeration (thermal) insulation tape
17. Insulated staples for connecting electrical wires
18. Putty
19. Clamps or saddles to protect the refrigerant tubes
20. Thermometer
21. Multi-meter or clamp tester.
22. Guage manifold
23. Thermometer
24. Tong
25. Tester
26. Clamp meter
27. Brazing cap
28. Vacuum pump
29. Digital Vacuum meter

Electrical Power Point

Before starting the installation of the air-conditioner, electrical connections have to be verified for rated current, voltage, and phase connections on the right hand side (RHS) of the socket as shown in figure 6.1. The technician should ensure that adequate earthing, as per national standards, is provided.

Figure 6.1 : Electrical Power Point

Installation of Split Air-conditioner

In the case of the split air-conditioner, the evaporator is located at a higher position as compared with the window air-conditioner. Cool air has higher density than hot air. The air which comes in contact with the evaporator coil or cooling coil gets cooled and cold air is supplied through the supply grill to the space (room) with a certain throw and velocity. The cold air being of higher density, flows downward towards the floor. The warm air moves

Figure 6.2 : Proper Location for SAC

up as it is lighter than the rest of the air in the room. This phenomenon has been shown in figure 6.2.

Location for Indoor Unit (IDU)

The IDU must be mounted on a strong wall, away from direct heat and breeze. There should not be any obstruction to the circulation of air. There should be adequate space, more than 150 mm (6”), around the IDU. The distance between the ceiling and the IDU should be more than 50 mm (2”) in the case of front suction or grille design and more than 150 mm (6”) in the case of top suction or flat front panel design. For the drain, the tube should slope towards the outside of the wall. The location should be away from flammable materials and the tubing should have minimum bends and elbows. A hole should be drilled in the wall for the drain tube, refrigerant tubes and electrical cable, etc. The hole size should be decided to accommodate all the elements mentioned.

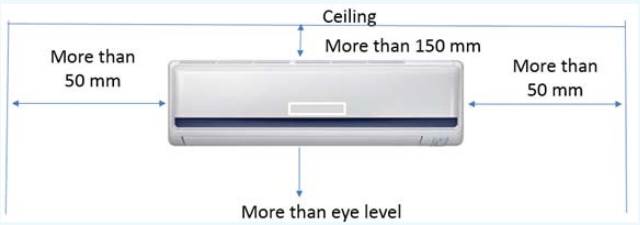


Figure 6.3 : Proper Location for Indoor Unit (IDU)

Installation of IDU

Following are the steps for installation of the IDU:

1. Align the installation plate on the wall horizontally, and mark locations for fasteners. Using the spirit level, mark the vertical center line.
2. Drill 6 mm (0.23”) holes at the marked points, insert sheaths/plugs and fit the installation plate with eight screws.
3. Open the cover of the hole of the plastic tube as per suitable direction for drainage.
4. Drill a hole of 70 & 100 mm (2.7” & 4”) diameter for 1.0 TR and 2.0 TR units respectively for tubing and wires.
5. The holes must be slightly sloping, 4 - 6 mm towards the outdoor side.

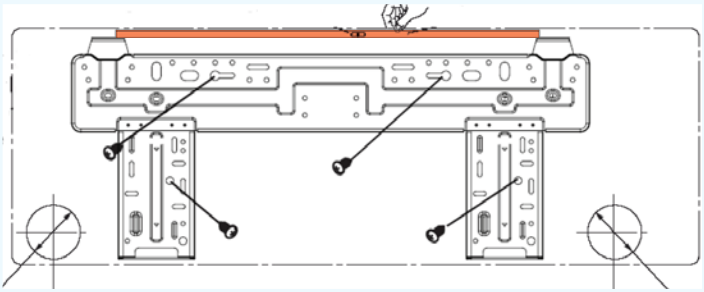


Figure 6.4 : Installation of Indoor Unit (IDU)

6. Drill the tubing hole on the right or left side of the installation plate as per the drain line.
7. Use a special conduit for allowing the tubes to smoothly slide out.

Location for Outdoor Unit (ODU)

For quality installation of ODU, a strong foundation is required, away from direct heat. There should be no obstruction to air circulation. The space around the ODU must be more than 150-250 mm (6"–9.8") in the rear and more than 1500 mm (59") in front of the unit. It should be placed away from any flammable materials. If there is a shade above the ODU, it will improve its performance. Avoid locating the ODU where it would be exposed to the salty atmosphere. The tubing should have minimum bends and elbows.

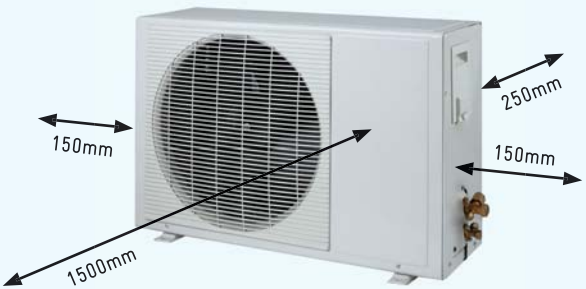


Figure 6.5 : Proper Location for ODU

Installation of ODU

The following instructions have to be followed while installing the ODU:

1. Ensure that the base for installation of the ODU is rigid.
2. In case the site is located where the breeze is strong, or if it is at a high altitude, install the ODU lengthwise along the wall, using a shield to protect the working of the fan. Select a site for ODU in such a way that its access is easy for installation and future servicing.
3. If the drainage is bad, or if water is likely to accumulate near the outdoor unit, place the ODU on a concrete block or raised platform, if possible.
4. If the outdoor unit vibrates too much, adjust the angle of the installation legs. In case the unit is likely to tilt or fall, bolt it with 8 mm (0.31") diameter anchor bolts.

Figure 6.6 : Installation of ODU

Installation of Split Air Conditioner Tubes

Following are the steps for the installation of refrigerant tubes. The technician should follow the procedure for installation of tubes without any deviation.

1. Make a hole of 70 -100 mm (2.75" – 4") diameter in the wall (L or R) for taking out tubes, drain tube and wires.
2. Measure the distance between the IDU and ODU, including all bends.
3. Cut the tubes a little longer than the measured distance.
4. Remove burrs from the cut edges of the tubes.

5. Remove the flare nut from the tube end.
6. Flare the tube ends after inserting flaring nuts.
7. Tape the flaring portion to protect it from dust or damage.
8. Align the centers of both flares at both IDU and ODU. Tighten the flare nuts.
9. Insulate all tubes for better performance.
10. Connect the drain hose and extend it with a rigid tube if required.
11. Insulate the drain hose laid indoors. The drain hose should be inclined downward.
12. Remove filters and pour water into the drain pan to confirm the smooth flow of water.

Connecting the Tubes

For connecting IDU & ODU with compressor, copper tubing is necessary. When height between IDU and ODU is about 3 m then the length of the tube should be 5 m and when height is 7 m then the length should be 10 m. Connect the piping to the Indoor Unit. Align the centers of both flares (IDU & piping) and tighten the flare nuts connecting the piping to the outdoor unit. Apply torque that is just right for flare nuts, over tightening shears the tubes, ultimately resulting into the leak.

Insulate all tubing's for better performance. The figure 6.7 shows the various color codes for tubes carrying liquid and gaseous refrigerant, drain, and 3 core electrical wires. It is just that the drain pipe should be inclined so that condensate drains. In the case of the drain pipe placed like siphon, the condensate will not flow.

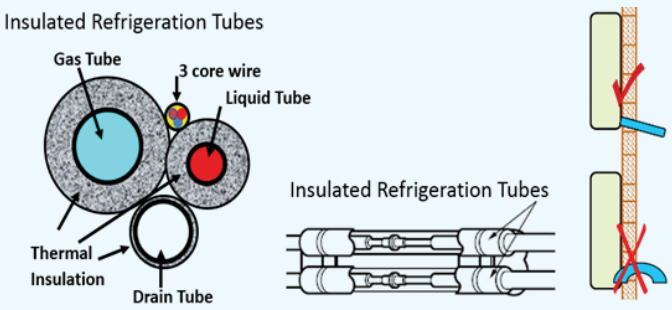


Figure 6.7 : Copper Tube Connections

For air-conditioners with flammable refrigerants it is advisable to avoid flare connections inside the room. If refrigerant tubings are to be connected indoors, cut the flare connections, swage the tube ends and join the tubes by brazing.

Tightening Torque Required for Different Size Flare Nuts

The torque required for tightening different tube sizes varies according to the diameter of the tube. Apply torque that is just right for flare nuts, over tightening shears the tubes, ultimately resulting into the leak. If a flare joint leaks even after tightening to the required torque, the reason for leakage may be due to bad flare, burrs on tube and wrong size flare. Then cut the tube and make the new flare.

Table 6.1: Torque required to tighten flare joints

Flare size			Min. Wall thickness (mm)	Torque (Nm)
Metric (mm)	Imperial Series			
	mm	inch		
6			0.8	14 to 18
	6.35	1/4	0.8	14 to 18
	7.94	5/16	0.8	33 to 42
8			0.8	33 to 42
	9.52	3/8	0.8	33 to 42
10			0.8	33 to 42
12			0.8	50 to 62
	12.7	½	0.8	50 to 62
15			0.8	63 to 77
	15.88	5/8	0.95	63 to 77
18			1.0	90 to 110
	19.06	4/4	1.0	90 to 110

Leak testing

For reliability and environment protection, the system must be pressure and leak tested. Do not purge the system with refrigerant or use it for leak testing. This is due to flammability and GWP concerns. The system should be checked for leakage using OFDN.

Nitrogen required for flushing and leak testing in refrigeration and air conditioning applications should be 99.995% pure free from oxygen, air dust etc. and dew point at least -40°C. If nitrogen of these specifications is not available, connect 25g drier-filter to the nitrogen cylinder hose prior to the inlet valve of hose to be connected to air-conditioner system. The test pressure of OFDN should be higher than operating pressure. Procedure for leak testing is similar for HCs & HFCs. Keep the system under pressure for 15 minutes and observe for any drop in pressure. If there is any drop in pressure identify the leak and rectify it. Use of soap solution for leak testing is permitted when the system is under positive pressure. Apply soap solution on each joint with the help of a brush and look for leakage, if any.

Evacuation

The system should be free from air, moisture, and non-condensable gases to ensure proper and efficient operation of the air conditioner. Therefore, it is important to evacuate the IDU during installation of the air-conditioner. For deep vacuum, a suitable 2-stage rotary vane vacuum pump should be deployed (100-120 lpm. & blank-off 20 microns). Use micron gauge

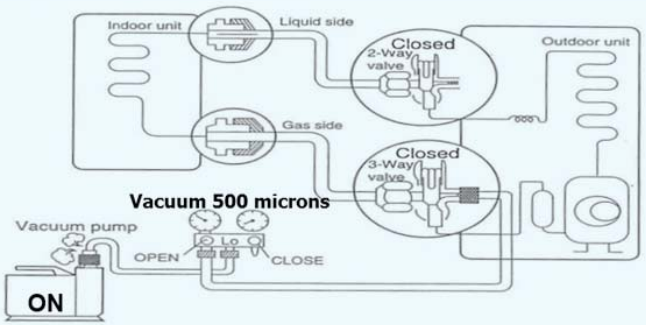


Figure 6.8 : Evacuation

to measure evacuation pressure. The evacuation must reach 500 or lower microns level. A Bourdon type vacuum gauge cannot read vacuum in microns – hence actual vacuum reached cannot be known.

However, in the absence of a micron vacuum gauge, the vacuum pump should be run for at least about 15 minutes after the Bourdon type vacuum gauge reading shows -30" / -760 mm / 0 millibar (at sea level).

Additional Refrigerant Quantity for SAC

If the distance between IDU and ODU are longer than OEM suggested one, the quantity of refrigerant specified by the manufacturer may not be sufficient and additional refrigerant will have to be charged.

Usually, the standard length of tubing is 4 meters only. Additional gas charge quantity varies with the length and diameter of the refrigerant tubing.

For air-conditioners with flammable refrigerants the selection of air-conditioner is made based on the room size and refrigerant charge quantity. Therefore, it is necessary to consult the manufacturer before extending the refrigerant tubes or charging additional refrigerant.

ADDITIONAL CHARGE FOR HCFC-22 UNIT IS CALCULATED AS:

For 6.35 mm (1/4") liquid tube and 12.7 mm (1/2") gas tube with a total measured length of 15 m (49.2 ft), the additional charge will be approximately 256 g of HCFC-22. The technician must use the table given here below for calculation of additional charge in case of HCFC-22 units. Alternatively, OEMs need to be contacted or their service manuals must be referred to for this purpose.

Table 6.2: Additional Refrigerant Charge

Gas Tube dia	g/m	Liquid Tube dia	g/m
12.7 mm (1/2")	1.87	6.35 mm (1/4")	21.38
15.87 mm (5/8")	3.71	7.94 mm (5/16")	37.16
19.05 mm (3/4")	5.58	9.52 mm (3/8")	57.66

Service Valves for SAC

Schematic diagrams of a two-way valve used on the liquid side and a three-way valve used on the gas side are shown in Figure 6.9. The technician must follow the connections of the tubes with the valves as shown in Figure 6.9 at the time of SAC installation. Use proper keys and not any tool. Here, a 3-way valve can be used for evacuation and/ or gas charging.

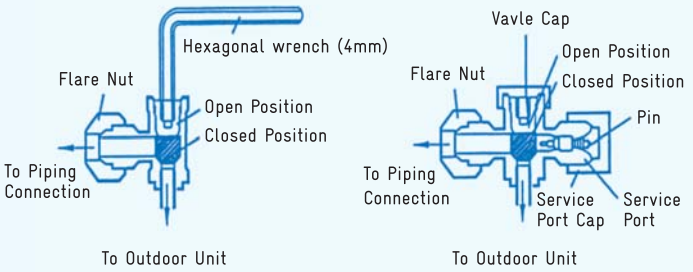


Figure 6.9 : Service valves for SAC

Installation of SAC Power Connections

The technician must follow the instructions/guidelines and procedure given by the original manufacturer of air-conditioners:

1. Cut the electrical cable 1500 mm (59”) longer than the length of the tube.
2. Ensure adherence to color codes of the wires and use only suggested wires.
3. Refer to the standard wiring diagram pasted on the unit (IDU & ODU).
4. Ensure that earthing is provided at the appropriate places.
5. Do not allow the electrical wiring to touch the refrigerant tubing, compressor, other components of the air-conditioner
6. Place batteries in the remote controller as necessary.
7. Operate the service valves to allow refrigerant flow in SAC.
8. Connect the power cord to the power point and switch on the electrical

power supply to the unit.

9. Set the control panel as desired and start the air-conditioner.
10. Permit the air-conditioner to run for about 20-25 minutes.
11. Observe suction pressure and supply and return air temperature.
12. Reinstall the locknuts on the service valves. Do the final leak testing. Ensure that there are no leaks.
13. Give a demonstration for effective use.
14. Fill up the warranty documents of the air-conditioner.
15. Record all observations as a report and fill up the checklist on completing the installation.
16. Before leaving the site, collect all the belongings.
17. Take your leave politely of the customer.

Post-Installation Check-up

The following is a questionnaire for evaluation of work done:

1. Is the air-conditioner installed securely?
2. Is there enough space provided around the IDU and ODU for better performance?
3. Is anything obstructing the circulation of air?
4. Are all gaps around the unit filled with thermal insulation?
5. Is care taken to avoid any potential complaints from neighbors about vibration and dripping of water?
6. Are electric wires used as per the requirements?
7. Is the earthing wire connected properly to the units?
8. Are line voltage and supply of current as specified?
9. Ensure no leakage of refrigerant.
10. Check operations of the electronic and electrical control panel.
11. Has the temperature of supply and return air been noted? (Difference to be 10-12°C)
12. Does the drain flow out smoothly?
13. Has the customer been educated with regard to benefits, filter cleaning, front grille panel, regular maintenance?

Installation Report

The technician must fill the installation report as per the format is given here below. The technician must learn all the procedures for proper installation of air-conditioners and further acquire the best skills for installation. The report is proof of good work done and for reference at a later date.

Table 6.3: Installation Report

Installation Company's Name:	
Installation Company's Name: Address:	
Tel No:	
Technician's Name:	
Customer's Name:	
Address:	
Tel No:	
Installation / Appliance Data:	
Model No:	Sr. No:
Date of Installation / Repairs	Time:
Refrigerant's Name/Type:	Refrigerant Qty in g:
Suction Pressure:	Discharge Pressure:
Air Temp Entering Condenser:	Air Temp Leaving Condenser:
Air Temp Entering Evaporator:	Air Temp Leaving Evaporator
Air Temp Leaving Evaporator	Elevation of Installation:
Electrical Data	
Power Supply (Voltage):	
Overall Ampere Reading:	
Current Draw Compressor:	
Other Executions for System Commissioning (Tick Box for Completion)	
Note: Use only Correct and Reliable Tools/Equipment for System Commissioning	
Functional AC System Check Including Performance Test	
Check the AC System for Refrigerant Leakage	
Check that Electric Connection are Tight	
Check that Condensate Drain is Tight and Down-grade	
Check Insulation of Refrigerant Transfer Tubes and Quick-coupler	
Check Free Run of Condenser and Evaporator Fans	
Check System Operation (Indoor / Outdoor) on Abnormal Operational Noise	
Clean System Components Including Air Filter (if Indicated)	
Check Display of the Remote Controller	

Installation Company's Name:
Installation Company's Name: Address:
Execute Briefing of the AC System User
Company Signature and Date
Customer Signature and Date:

Preventive Maintenance of Room Air-conditioners

Regular maintenance of room air-conditioners will improve their life, performance, reliability and safety. Preventive maintenance is also important to maintain the original energy efficiency of the system and for the environmental perspective, so that there would be no leakage of refrigerant to the environment. To prevent chance of sudden failure of the system, it is good to have periodic inspection, cleaning and replacing the defective parts. Also, due to poor functioning of some parts of the system, it is good to replace those parts before it will actually fail to work, otherwise it will lead to higher energy consumption or leakage of refrigerants. Manufacturers recommend the schedule for the preventive maintenance; the technicians are advised to follow the preventive maintenance as the schedule specified. Maintenance is necessary to be carried out by both customer and technical professionals viz. service technicians. Given below are the tasks to be performed by the customer and the technicians.

MAINTENANCE BY CUSTOMER

- Change and/or clean the primary filter every two months. If the unit is equipped with a plasma indoor air quality filter, clean it when the reminder light illuminates.
- Vacuum dust from the indoor evaporator coil and wipe away built-up dirt. Leave heavier, stubborn dirt deposits or mould accumulation for cleaning by a professional technician.
- Clean the condensate drain pan, drain and verify that the drain is open. If there's evidence of mould or other bacterial growth, let a technician handle it.
- Cut weeds or other encroaching vegetation from around the outdoor condenser to allow two feet of free space on all sides for airflow.

MAINTENANCE BY TECHNICIAN

1. Inspect and clean the evaporator coil.
2. Check the balance of the blower and fan wheel and verify there is sufficient airflow.
3. Inspect the condensate drain system for algae and treat with algaecide if necessary.
4. Check the refrigerant charge and top up as necessary. If the level is significantly low, perform leak detection procedures.
5. Clean the condenser coil and clear out debris such as grass clippings and leaves.
6. Verify electrical connections at the outdoor unit and weatherproof with non-conductive coating.
7. Lubricate the condenser fan and adjust belt tension, if required.
8. Check thermostat operation and calibrate, if necessary.
9. The technician must clean the evaporator coil, condensate pan and filters. Similarly, he must clean and flush the brazing torch with its tip.

REGULAR PREVENTIVE MAINTENANCE OF ROOM AIR-CONDITIONERS

1. Check voltage, current and earthing.
2. Inspect for refrigerant/lubricant/oil leaks and proper levels.
3. Confirm that the condenser coil is free from debris.
4. Straighten any bent heat exchanger fins on the condenser coil.
5. Examine suction pipe insulation and replace, if needed.
6. If the AC is of very old design, lubricate the fan motors/bearings.
7. Check fan/blower blades/fins for damage and cleanliness.
8. Ensure proper condition of 2- and 3-way service valves, with caps.
9. Check all wiring, electrical connections.
10. Test controls/thermostat/PCB for proper functioning.
11. Assess air filters for proper size and cleanliness.
12. Confirm that the evaporator coil is free from dust.
13. Check condensate pan and drain for cleanliness.
14. Confirm no leakages from RAC products, tools/equipment.
15. Record all the work done during preventive maintenance. Refer to the sample overleaf.

07

GOOD SERVICE PRACTICES FOR ROOM AIR-CONDITIONERS AND SAFETY

Background

Good service practices are important so that the designed energy efficiency of the air-conditioner is maintained and to minimize the emissions of ozone depleting and global warming substances into the atmosphere. While servicing, practices like recovery of refrigerant, leak and pressure testing and system evacuation are 'good service practices' (GSPs) that will increase the operative life of the equipment, as well benefit the environment. During servicing, recovery of the refrigerant is not a common practice. The refrigerant is often vented out during servicing or repair, and the air-conditioner will be completely recharged. There will be huge savings in refrigerant consumption if proper recovery is carried out by the service technicians.

Often, the air-conditioning system also just gets topped up with refrigerant without proper leak detection and will, therefore, continue to leak. Also, by toping up process, correct quantity of refrigerant cannot be charged into the system. Therefore, performance of the air-conditioner gets degraded. The HCFC-22 alternative refrigerants are flammable and/or have higher pressure, therefore, it is essential to follow good service practices and all safety procedures while performing servicing.

The term 'safety' is applicable to any air-conditioning activity. It may apply to safety of the operator, technician & customer and of the tools and equipment. Personal protective equipment (PPE) must be worn by the technician when at work, to protect him from hazards. There is no exception to the rule that 'The safe way is the right way.' Work must be done by properly trained personnel equipped with the tools and equipment in good condition and of good quality.

Good Service Practices

Following are the ten main steps during servicing or repairing of air-conditioners. All steps are necessary and must be followed one after another.

1. Recovering refrigerant from the sealed refrigeration system or venting and removal of leftover refrigerant like R-290 which has insignificant impact on environment.
2. Repairing/replacing inoperative spare parts
3. Cleaning/polishing and flushing the system

4. Careful brazing and/or flaring of tubes
5. Leak and pressure testing
6. Evacuation and vacuum holding
7. Refrigerant charging
8. Sealing the process tube and/or closing the valves
9. Routine checking for proper operation
10. Recording the details of work done

Before starting servicing of air-conditioners (ACs) with flammable refrigerants it is important to ensure that all the safety measures given at the end of this chapter are followed.

Recovery of Refrigerant from Sealed Refrigeration System

Before recovery work, technicians first need to identify the refrigerant type and quantity in the system he is servicing. Then, it is to be checked that recovery unit and cylinder is available. Also, have to keep all the required tools such as safety gloves, 3/8" or ¼" diameter short length hose pipe. It is advised to have at least one cylinder for every refrigerant type serviced so that the recovered refrigerant can be put back into the same system after finishing the service, plus an extra cylinder for burnouts refrigerants and other unknowns.

An approved in-line filter to be used to prevent contaminants from entering the system. The refrigerant is removed from the system in its present condition and stored in a cylinder. Vapour recovery method or liquid recovery method can be used to remove the refrigerant from the system.

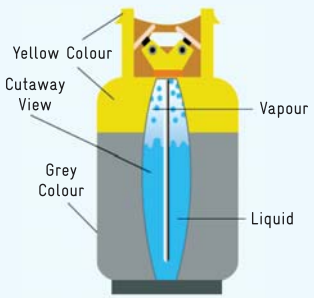


Figure 7.1 : Recovery Cylinder

The figure 7.1 shows the internal parts of the cylinder for recovery in vapor as also liquid state of refrigerant. One should be careful in selecting the cylinder for different types of refrigerant. Disposable cylinders are not safe for refilling. Only clean cylinders, free from contamination by oil, acid and moisture etc. must be used. It is also advised that only certified cylinders should be used, and they should be checked visually before using.

The cylinder should not be filled more than 80% of the rated capacity by volume. Never mix different refrigerants or recover one refrigerant into a cylinder meant for some other refrigerant. Always label the recovery cylinder by putting the refrigerant number, name weight of the cylinder and the total weight with date. It is important to evacuate the recovery cylinders and purge the hoses to avoid contamination or introduce non-condensable gases that would increase the discharge pressure.

RECOVERY MACHINE

The Figure 7.2 shows a schematic diagram of simple vaour recovery machine. The various components are systematically shown for ease of understanding.

It may be noted the system configuration of recovery machine to machine may vary due to design features. However, working principle remains the same. Check operation manual to find the proper configuration for the unit. Some of the essential aspects to be followed for proper functioning and use of recovery machine:

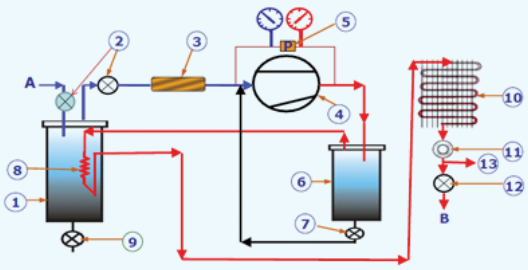


Figure 7.2 : Recovery Unit

- Confirm that the recovery unit was not used for recovering any other refrigerant other than refrigerant to be recovered. If so it needs to be evacuated properly.
- Use only certified recovery cylinders.
- Use safety gloves and goggles while recovering.
- Start the system and run it for 5 minutes to warm up the compressor. This will release the refrigerant mixed with the compressor oil.
- Turn off the system.
- Connect a hose from the service port of the vapor line valve to the gauge manifold (Low side). Connect another hose from the gauge manifold to the inlet of the recovery unit and from the recovery unit outlet to the recovery cylinder.
- Open the service valve of the system and carefully purge the lines upto the inlet of the recovery machine from service valve.
- Open the inlet valve of the recovery machine.
- Turn the selection knob to recovery mode.
- Open the outlet valve of the recovery unit and purge the line connected to the recovery cylinder.
- Place the recovery cylinder on a weighing scale and record the initial weight.
- Open the cylinder valve.
- Start the recovery unit and run it until the suction pressure drops to -20" Hg.

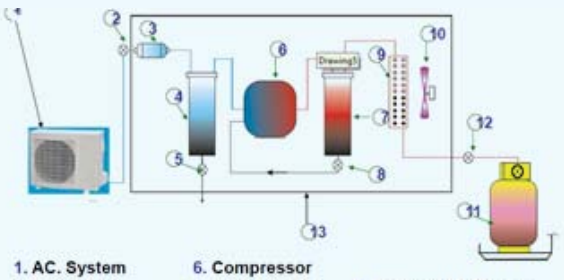


Figure 7.3 : Recovery of Refrigerant with Oil Separator

- Wait for a while, if the pressure increases, start the recovery unit and recover until the pressure drops to -20" Hg. Record the final weight. Never fill a cylinder more than 80% of its capacity.
- Fill the system with Oxygen Free Dry Nitrogen (OFDN) to break the vacuum and maintain a positive pressure of 2 to 5 psig.
- Close the service valve on the ODU.

The figure 7.3 shows another design of recovery machine with oil separator. The working principle is similar to the simple vapour recover machine. All the components of the machine are labeled in the schematic diagram for ease of understanding.

SAFE VENTING IN CASE OF ROOM AC CHARGED WITH R-290

R-290 is non-ODS and has negligible global warming potential. Hence it need not be recovered and can be safely released into the atmosphere. It is highly flammable therefore it should be vented to safe outside open area and not to be released indoors, working area and near sources of ignition. Connect a long hose to the service valve of the AC and vent the refrigerant gradually. Use piercing plier/valve for appliances without service valve. After venting the refrigerant, it is necessary to remove the residual refrigerant remaining in the system. This is to prevent the risk of flash fire during de-brazing of system lines. Using a vacuum pump, evacuate the system to about -20" of Mercury (Hg). After evacuation break the vacuum by filling the system with dry Nitrogen to a pressure of about 5 psig. It is important to break the vacuum with dry nitrogen or else air will enter the system and contaminate the refrigerant circuit. Ensure that the work area is well ventilated and the discharge from the vacuum pump does not get accumulated near the work area.

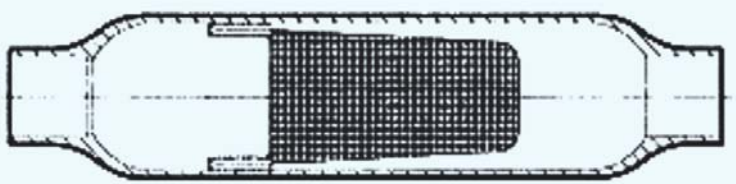


Figure 7.4 : Cut section of strainer

Repair and/or Replacement of Inoperative Spares

Release the OFDN from the system and disconnect the lines from the service valves. The inoperative spare parts should be replaced with genuine and recommended spares. Each time a system is being repaired, a new strainer and filter should be installed. Install a filter with a molecular sieve. This will desiccate and purify the refrigerant.

There should be very less chances of capillary getting choked due to internal frost formation. The selection of drier/strainer depends on the basis of two system characteristics, 1) type and amount of contaminants that can be expected to develop in the system and 2) maximum operating pressure of the system. A strainer having adequate screen area to catch and hold moisture and other foreign particles that accumulate during the life of the unit and yet permit the refrigerant flow to continue without excessive pressure drop, it is necessary to consider the size and quantity of the contaminants. Strainer wire mesh is normally made of stainless steel, brass or phosphor bronze and sizes are from 100 x 90 to 150 x 140 etc. The filter/strainer must be replaced during servicing if system is opened for recharging.

Cleaning and Flushing

Upon dismantling the system, all the parts of the system must be cleaned and then polished using emery cloth / paper. The system must be flushed using OFDN (Purity: 99.995%, Dew Point: - 40°C at least) at a pressure of about 10 bar (150 psi). The Nitrogen cylinders as shown in Figure 7.5 fitted with two stages regulator should be used. It is a must to have proper

Figure 7.5 : Nitrogen Cylinder with two stage pressure regulator

regulator. Atmospheric air contains moisture, which is detrimental to the system. Use of air should be totally avoided. Use of petrol as a solvent is to be avoided totally, petrol contains impurities that can destroy the compressor. If solvent cleaning is required for removing any sludge formation, solvents like Per Chloroethylene (PCE), Hexane or Methylene Dichloride (MDC) or any other branded chemical solvent should be used. Trichloro ethylene (TCE) should not be used as it is suspected carcinogen. Refrigerants and lubricants are very sensitive to contaminants and moisture.

Brazing or Flaring of Tubes

Clean the metal parts adequately and carry out brazing and/or flaring as explained earlier under the chapter 'Copper Tube Processing and Brazing'. Connect the lines properly. Use torque wrench and tighten the nuts. Do not over tighten the flare nuts

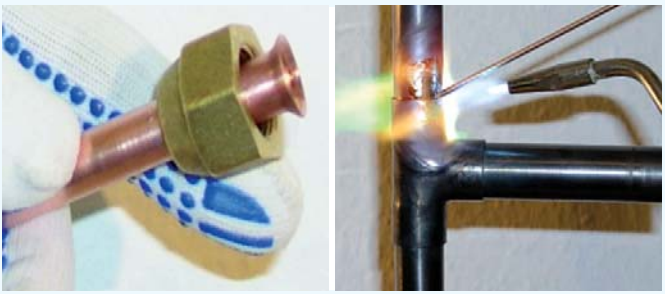


Figure 7.6 : Flaring and Brazing

Leak and Pressure Testing

It is must that after joining the spares with system, entire system has to be tested for leakage. For reliability and environment protection the system must be pressure and leak tested. Joints in entire system should be checked for leakage using OFDN as shown in Figure 7.7. The system should not be pressurized with pressures that are above the system's test pressures (1.1 x operating pressure). For leakages, the system must be checked by leaving it under pressure for 15 minutes (pressure holding). ***The system should never be started when pressurized with OFDN.***

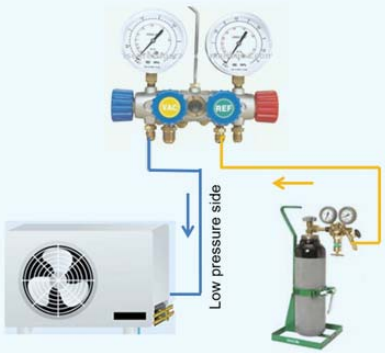


Figure 7.7 : Leak and Pressure Testing

SOAP SOLUTION/ BUBBLE METHOD:

Leakage of refrigerant from the system is normally identified using methods like soap solution bubble method. Use of soap solution for leak testing is permitted when the system is under positive pressure. Soap solution is the most popular, cheapest, and most effective method used by service technicians. Applying soap solution to joints, connections and fittings while the system is running or under a standing pressure of nitrogen and watching for bubbles to appear, helps to identify leak points.

Figure 7.8 : Leak testing with soap solution

ELECTRONIC DETECTOR:

Electronic refrigerant detectors contain elements sensitive to a particular chemical component in a refrigerant. The detector has a pump that can suck in the gas and air mixture. An audible "ticking" signal and/or increased frequency/intensity of the flashing of the lamp occurs as the sensor analyses

Figure 7.9 : Electronic refrigerant detector

higher concentrations of refrigerant, indicating the source and location of the leak.

The most common locations of leakages in joints are at:

1. Flare connections/nuts
2. Service valve: O-rings, access fitting, mounting
3. Cracked brazed joint in tubing
4. Deteriorated evaporator and / or condenser end bends
5. Tubes rubbing with each other or with other materials

When refrigerant leaks out, it increases the cost of repairing and servicing. It also has harmful effects on the environment. The efficiency of the system drops and power consumption increases. Therefore, CO_2 consumption increases and there is a greater impact on environment or climate change. Hence, care must be taken to avoid refrigerant leakages.

Evacuation and Vacuum Holding

Evacuation is a process by which pressure in the sealed system is reduced, causing moisture to boil off into vapor. It removes air, moisture and other non-condensable gases from the system. Frozen moisture in the system may lead to one of the following problems:

- Choked capillary tube, metering device and strainers
- Choked filter driers
- Reduced system effectiveness and efficiency

To speed up evacuation, large valve port/hoses (9.52 mm or 3/8") must

be used. To measure the desired level of evacuation, connect the micron gauge to the manifold. Before charging refrigerant to the system, if possible, evacuate the system from both high and low pressure sides, using a double-stage rotary vacuum pump (100 lpm and blank off 20 microns). Only two-stage rotary vacuum pumps are able to pull the vacuum to the required level. The ideal vacuum should be about 0.666 mbar (500 micron) or lower. The compressor of the system must not be operated while the system is in a vacuum. On achieving the vacuum (500 microns), disconnect the pump and allow the system pressure/vacuum to settle down for 5-7 minutes. (During vacuum holding of 5-7 minutes, pressure should not rise above 1500 microns). If the evacuation is not achieved to the desired level of 500 microns, the effect of the presence of air and moisture in the compressor could lead to compressor seizing or failure due to excessive wear of compressor moving parts or motor overheating and burn-out. (Please note that water can boil even at lower temperatures, if the pressure is reduced by pulling vacuum. So, pulling deep vacuum will help in removing the above-mentioned undesired materials from the system.

Table 7.1: Pressure vs boiling temperature of water

Microns	Temp. in ^{0}C
7,59,968	100
5,35,000	96.11
5,25,526	90
3,55,092	80
2,33,680	70
1,49,352	60
92,456	50
55,118	40
31,750	30
25,400	26.67
22,860	24.44
20,320	22.22
17,780	20.56
15,240	17.78
12,700	15
10,160	11.67
7,620	7.22
4,572	0
2,540	-6.11
1,270	-14.44
500	-23
254	-31.11

Figure 7.10 : Step 1 of evacuation process

Following are the steps for proper evacuation of the system as shown in figure 7.10.

- Open the service valve and release the Nitrogen pressure from the system.
- Connect the system to an evacuation and charging unit using a 4-way gauge manifold. (Use a double stage vacuum pump with gas ballast and digital micron meter.)

Figure 7.11 : Step 2 of evacuation process

- Before connecting the system, check the vacuum pump and ensure that the blank off pressure is below 100 microns.
- Open the valve and start evacuating the system.
- Evacuate the system to 500 microns or below
- Once desired vacuum is achieved, disconnect pump and check vacuum holding (Should not raise above 1500 microns after 5 minutes)
- If the vacuum levels increase more than 1500 microns repeat the evacuation and vacuum holding process.

After the vacuum gauge shows the vacuum, then close the valve and remove the micron gauge. Then attach the charging cylinder with valve in close position as shown in figure 7.11. Run the vacuum pump for two minutes with high side valve in open position to remove the non-condensable gases from the charging hose. By doing this there will be no need to purge the refrigerant from the charging hose.

Refrigerant Charging

For better performance of the air-conditioner, charging with accurate quantity of refrigerant is important. Charge always in a well evacuated system. Sweep charge or charge by feel, is not recommended. Charging should be done slowly and gradually, so that no liquid goes into the compressor. Since there is no effect of atmosphere (pressure /temperature) on mass or weight of the refrigerant, weight system must be deployed for measuring the amount of refrigerant while gas charging as shown in figure 7.12. A digital weighing scale/ balance for accurate quantity of charge must be used. This is a must for efficient functioning of the air-conditioner and it is a GSP. In case the system gets over charged, the excess charge of refrigerant should not be vented out into the atmosphere but recovered. Refrigerant should enter the compressor only in a vapour state. After 5 minutes of refrigerant charging, pressures and temperatures of refrigerant must be checked. High or low pressures and temperatures indicate that the system is overcharged or undercharged. Undercharged systems are less efficient, have higher running costs and might not be able to meet the load. Overcharged

Figure 7.12 : Charging of refrigerant into the air-conditioner

systems have greater potential of leakage. In extreme cases, overcharging will increase head pressure and reduce performance and efficiency. After disconnection of gauges and hoses, a leak test must be carried out.

CHARGING OF REFRIGERANT BLENDS

Refrigerant blends are a mixture of different refrigerant components. If the blend is a zeotropic mixture (i.e. R4xx) and it is charged as vapour, the refrigerant with the highest vapour pressure will be charged at a higher proportion than the other component(s). Charging as a liquid is the only way to guarantee that the blend is charged within its intended composition.

Fractionation of a refrigerant blend (separation of the individual components) can occur by removing the refrigerant from the cylinder as a vapour instead of a liquid. This can potentially lead to both safety and performance issues. As such, it is recommended charging all blends in liquid phase only by reversing the refrigerant cylinder if not fitted with liquid uptake valve as shown in Figure 7.13. But one care must be taken that after charge do not start the machine immediately. Charge gradually from the suction side of the system using a short length capillary. Give sometime to refrigerant to settle in the system.

Figure 7.13 : Charging of refrigerant Blends

Tube Sealing Process / Closing Valve

After correct charging of refrigerant, the charging tube should be sealed or the valve should be closed properly. Follow these steps:

1. Crimp/pinch the tube to be sealed at two places

2. The pinching tool must not be removed until the tube is sealed
3. Braze or seal the tube
4. Remove the pinching and / or crimping tool
5. Final leak test must be done

OR

1. Close the three-way service valve properly
2. Check for leaks
3. Put the lock-nut
4. Final leak test must be done

Routine Check-up for Proper Functioning

As part of a routine checkup, measure temperatures of supply and return air after 20 minutes. Measure the current drawn by the air-conditioner. Keep a record on the job cards. Label the system and leave it in order. Record all observations.

Record Details of Work Done / Report Writing

It is recommended that the service personnel should maintain a record book or log book for serviced AC and enter pre-and post repair details as shown in the Table 7.2.

Figure 7.14 : Recording Observations

Table 7.2: Record book for serviced AC

Pre- and Post- Details of Refrigeration System Repairs	
Customer & Product Details	Post Repairs
Customer	Current I
Address	Current I
WAC/SAC Sr No.	Low Pressure
Model No.	High Pressure
Type of Refrigerant	Gas Leak Jt # Repaired
Chargeable / Under Warranty / AMC	Vacuum Achieved
Diagnosis – Pre Repairs	G L Jt # Reconfirmed
Voltage V	New Compr #
Current I	Parts Replaced
Low Pressure	
High Pressure	Charged Refrigerant Quantity
Gas Leak Jt #	# of Leak Tests
Old Compr. #	Supply & Return air Temp
Original Refrigerant Charge Qty	Misc. Info.
Tech Name or Code #	Tech Name or Code #

Personal Safety

Air-Conditioner's service technicians using hand and power tools are exposed to hazards like falling, flying, abrasive and splashing objects/ materials, or harmful dusts, fumes, mists, vapours/gases or lubricants. Work must be done by properly trained personnel equipped with the tools and equipment in good condition and of good quality. When at work, the technician must protect himself from any injuries. PPE viz. safety glasses, protective shoes, gloves and safety belt should be worn. A proper dress code must be observed. Wear a lab coat. Never wear loose jewelry, it may come in contact with the electrical terminals or wires causing electrical shocks. Put up posters mentioning safety rules and guidelines at the work place as safety reminders. Care should be taken in selecting gloves and other protective clothing as different solvents, oils and refrigerants affect the materials from which they are made in different ways. For example, leather gloves should not be used for handling refrigerants. Viton, Neoprene and PVA gloves are most suited for RAC servicing. Use Ear Plugs or Ear Muffs for protection from noise. The Figure 7.15 shows the PPEs. Ensure PPEs are used and maintained in a clean and reliable condition.

Figure 7.15 : Personal Protective Equipment

ELECTRICAL SAFETY

- The most common reasons for failure in the working of air conditioners are faults in electrical circuits or items.
- Ensure the appliance is disconnected from the mains electric supply before carrying out any work on it.
- The electrical wires/cables in an air-conditioning unit must be grounded without fail. This protects from electric shock by allowing current to by-pass the human body.
- Power tools and extension cords normally have three prongs connected to the electrical wires. These prongs should never be cut or removed, leaving the electrical wire naked.
- Technicians must be well aware of the potential hazards that exist and the precautions to be taken to reduce the risk of accidents.

FIRE SAFETY

A fire extinguisher should be kept /carried to the workplace / place of servicing and / or installation site as a safety measure in case of accidental

fire. Fire extinguishers are classified in three groups, based on the cause of fire that requires to be extinguished:

- Class A fire extinguishers are designed for use on fire occurring from burning wood, paper, or other ordinary combustibles.
- Class B fire extinguishers are designed for use on fire due to flammable liquids like grease, petrol or oil.
- Class C fire extinguishers are designed for use on electrical fires.
- Use of ABC powder-type fire extinguisher is ideal.

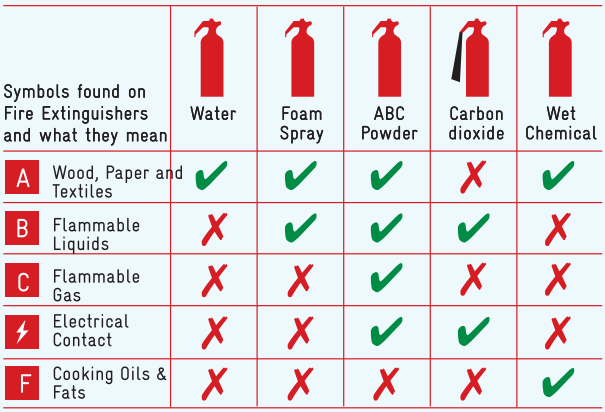


Figure 7.16 : Fire Extinguisher and Symbols

ADDITIONAL SAFETY GUIDELINES FOR GOOD SERVICE PRACTICES

1. Take care while opening the system as the pressure inside the system is generally higher than atmospheric pressure
2. Liquid refrigerant causes frostbite if it comes into contact with human skin. For protection, wear personal protective equipment (PPE)
3. The refrigerant in the air-conditioner may be contaminated with acids. Ensure it does not come into contact with the skin
4. The compressor oil may also be acidic, so wear gloves and goggles when removing and/or repairing a faulty compressor
5. Always use a two-stage pressure regulator (up to 50 bar) when using nitrogen

6. Ensure that all hoses are free from cracks and have adequate strength to withstand high pressures
7. Charge the system with correct quantity of good quality refrigerant
8. Seal the charging point by brazing/closing of valve and then test for leakage
9. Label the air-conditioner correctly with information of the refrigerant used
10. Make sure the refrigerant cylinder/can valves are in good condition and are capped when not in use
11. Do not modify cylinder/can or valves
12. Do not re-fill disposable cylinders/cans

ADDITIONAL SAFETY MEASURES FOR FLAMMABLE REFRIGERANTS

Servicing room Air-conditioners with flammable refrigerants need adequate training and experience. Some safety measures to be strictly taken during servicing of air conditioners with flammable refrigerants as given below.

- Work in well ventilated area, outdoors or use forced / induced ventilation system.
- No ignition sources should be there within 2 meter radius of working area.
- Ensure that suitable fire extinguishing equipment (ABC-powder type) is available.
- Cut off power supply connection before starting of work.
- Discharge the capacitor completely before conducting repair work/

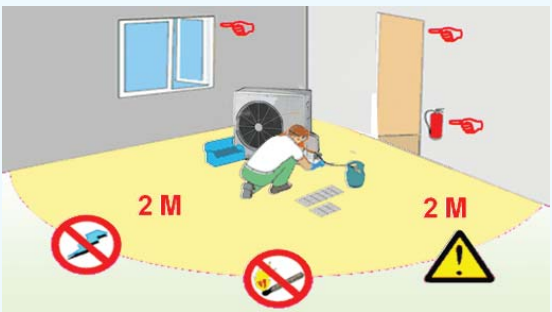


Figure 7.17 : Safety measures for flammable refrigerants

servicing.

- Keep refrigerant sensor detectors for flammable refrigerant.
- Display “no smoking “or “access denied “signs.

Ignition source include flames due to brazing torches, match or cigarette lighter or sparks from unsealed components such as electrical switches, relays, OLPs or loose wires or even static electricity. The basic safety logic is that in order to have an explosion, there should be a combustible mixture of gas and air (Oxygen) within the flammable limits, and simultaneously, there should be an ignition source with sufficient intensity to initiate and sustain the explosion. Therefore, the first step is to avoid the possibility of any leak. Even if there is a leak, make sure that a combustible mixture is not formed. In addition to this, the area should be controlled in such a way that the sources of ignition are eliminated or avoided.

Safety of Tools and Equipment

- The right tools must be used for doing the job.
- These must be operated according to the instructions of the manufacturers.
- Hacksaw blades, knives, drill bits or other tools must be directed away from walkways and other technicians working in close proximity. Dull tools can be more hazardous than sharp ones.
- Technicians operating the tools and equipment have personal responsibility of using them carefully by learning the appropriate skills.

SAFETY WHILE USING POWER TOOLS

- Disconnect tools when not in use, before servicing and cleaning and when changing accessories.
- People who are not involved with the ongoing work should be kept away from the worksite.
- Secure work with clamps or a vise, freeing both hands to operate the tool.
- Do not keep your hand on the tool switch while carrying the plugged-in tool.
- Keep tools sharp and clean.
- Remove damaged electric tools and tag them: ‘Do Not Use’.
- Do not carry or pull portable tools by the cord.
- Do not use electric cords to hoist or lower tools.
- Do not pull the cord or hose to disconnect the tool.

- Keep cords and hoses away from heat, oil and sharp edges.
- Replace damaged cords immediately.

Safe Handling and Storage of Refrigerant Cylinders

Figure 4.18 : Storage of refrigerant cylinder

Cylinders filled with the refrigerant have to be handled with utmost care. Refrigerants like HFC-32 and R-410A have higher operating pressures. These refrigerants should not be stored in cylinders rated for refrigerants like HCFC-22. Always check the pressure rating of the cylinder before filling the cylinder with any refrigerant. The test pressure of any cylinder should be 2 to 2.5 times the service pressure. Following guidelines are recommended for storage of refrigerant cylinders:

- Gas cylinders should be stored in a covered area where the temperature is below 50°C.
- Cylinders must be kept away from sources of ignition, including static discharges.
- The work area and where the cylinders are stored, should be a 'no smoking' zone.
- Certified stickers on the cylinders must not be removed or destroyed When the cylinder is not in use, ensure that the cap is closed.
- Gas cylinders must be stored and transported only in an upright position.

Figure 7.19 : Safety storage for flammable refrigerants

- During transportation, gas cylinders should not be thrown or dropped. All main electrical power controls should be installed outside the work area.
- The recovery cylinders must be filled to only 80% of their total capacity.

Table 7.3: Refrigerant cylinder Service pressure at 0°C temperature

Refrigerant	Cylinder service pressure PSIG
R-22	260
R-134a	260
R- 404A	300
R-407C	300
R-410A	400
R-32	400

Source: The Refrigeration Service Engineers Society, USA

More Safety measures for Storage of Flammable Refrigerant Cylinders

The service technicians should strictly follow safe storage process, handling and use of R-290 cylinders. Do not allow direct exposure of cylinders to sun light. Regularly check valve of R-290 cylinder making sure that there is no leakage. R-290 disposable cylinders should not be refilled.

- Flammable refrigerants should be handled and stored in the same way as LPG or any other flammable gases.
- Cylinders should be stored in dry and ventilated areas away from fire. Any build-up of static electricity should be avoided.
- It is ideal to store the cylinders outside in a secure and locked compound, protected from weather and direct sun light.
- The cylinders should be kept upright with valves closed and capped.
- There should be no ignition sources in the proximity of the storage area.
- Cylinders can also be kept inside provided all safety measures are implemented. However, they should not be stored inside, if the premises are residential.
- A flammable gas alarm should be fitted in the bulk storage area.
- Cylinders should preferably be stored on the ground floor and never in basements. If stored in a basement, in case of any leakage the refrigerants

will accumulate there and will not be easily dispersed.

- This can eventually lead to an explosion, if there is any spark in the room. Cylinders should not be stored with other flammable substances, particularly flammable gases.
- Storage of empty cylinders should be segregated from that of the filled-up cylinders.
- Follow the Petroleum and Explosive Safety Organization (PESO) Regulations for transport of flammable and high-pressure refrigerants. Do not transport refrigerant in the passenger compartment of a vehicle.
- Always keep First - Aid box. Use dry powder fire extinguisher.

08

GOOD SERVICE PRACTICES FOR ENERGY EFFICIENT OPERATION OF ROOM AIR-CONDITIONERS

Background

Room air-conditioner consumes significantly higher energy as compared to other household appliances. The efficiency of the Room Air-conditioner decreases due to age, defects and poor service practices. To maintain the designed energy efficiency of Room Air-conditioner it is necessary to follow good service practices (GSP) and periodic preventive maintenance. With proper maintenance of Air-conditioner (AC), there will be significant saving of energy use. The household energy consumption can be lowered by efficient operation and adopting high Bureau of Energy Efficiency (BEE) energy star labeled Room Air-conditioner. Most of the refrigerants have harmful impact on the environment, so during installation and/or servicing, greater care should be taken to avoid release of refrigerants to the environment. Following good services practices for energy efficient operations will give service satisfaction to the customer and will help the technician in getting enhanced and repeated business.

Sources of Emissions – Global Warming Contribution

There are direct emissions of refrigerant used in ACs during installation due to leakages, servicing and disposal of ACs at the end of life. As HCFCs and HFCs are having high global warming potential (e.g. GWP of HCFC-22 is 1820, R-410A is 2080). Such emissions to environment contribute towards global warming.

Indirect emission and contribution in global warming are due to electricity consumption during the working life time of the air-conditioner. Generation of electricity in the power plants results in Greenhouse Gases

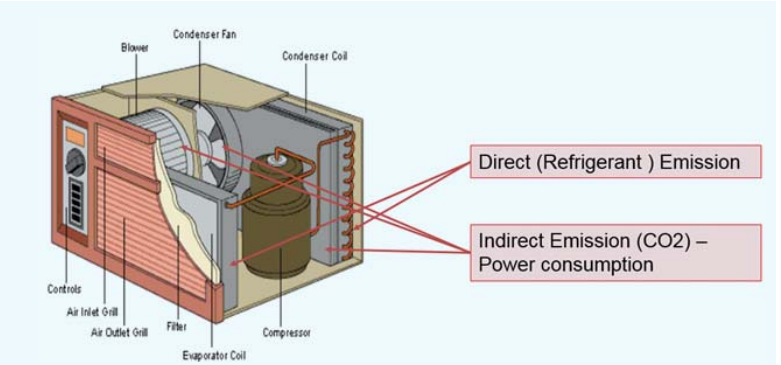


Figure 8.1 : Sources of Emission – Window Room Air-Conditioner

(GHGs) production and emission to the environment. The contribution in global warming of indirect emissions are about 4 times that of refrigerant emissions. Figures 8.1 and 8.2 outlines the sources of direct and indirect emissions.

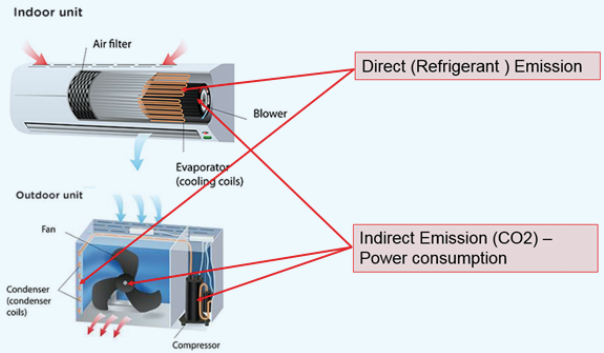


Figure 8.2 : Sources of Emission – Split Room Air-Conditioner

Preventive Maintenance for Efficient Operation of ACs

Preventive maintenance is important to maintain the original designed energy efficiency of the system and for the environmental perspective, so that there would be no leakage of refrigerant to the environment. The filter of ACs must be cleaned on periodic basis at least once in fortnight to ensure proper cooling, air circulation and less running time of ACs. It is a simple process that the customer can do it themselves, it requires customer education.

To prevent chance of sudden failure of the system, it is good to have periodic inspection, cleaning and replacing the defective parts. Also, due to poor functioning of some parts of the system, it is good to replace that parts before it will actually fail to work, otherwise it will lead to higher energy consumption or leakage of refrigerants. Manufacturers recommend the schedule for the preventive maintenance; the technicians are advised to follow the preventive maintenance as per the specified schedule.

Good Service Practices for Energy Efficient Operation

This section discusses the service practices that should be followed for energy efficient operation of Room Air-conditioners.

CLEANING OF CONDENSER AND EVAPORATOR COILS

Dust debris or contaminant creates fouling on evaporator surfaces, which reduce airflow and poor heat transfer in condenser and evaporator resulting in less cooling and reduction in overall performance and efficiency of AC. The excessive accumulation of dirt on the evaporator may have ice formation on coil surface.

Dust, debris can be sucked into the fins of a condensing unit coil as air is drawn through them by the fan. These obstructions will lower the effectiveness of the coil, elevate condensing temperature, and reduce cooling efficiency. A visual inspection is generally adequate to determine whether the coil must be cleaned, though cleaning a relatively unobstructed coil is likely to improve efficiency.

Both the evaporator and condensers coil should be cleaned at least twice in a year. The filters of ACs should be cleaned frequently.

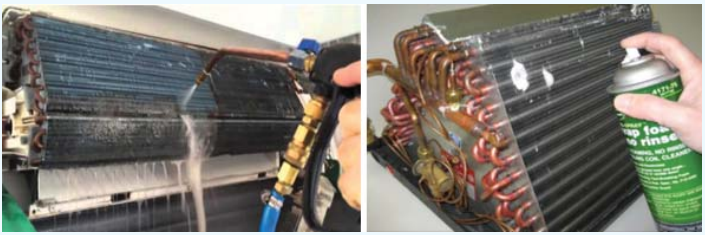


Figure 8.3 : Cleaning of condenser and evaporator coils

ENERGY EFFICIENCY CONSIDERATION ON ELECTRICAL COMPONENTS

While servicing it is to be checked that all wires/cables are properly connected, any loose connections should be avoided completely. There will be energy loss due to loose connections of wires and also chances of overheating and sparking which is a heavy danger in case of flammable refrigerant.

When replacing electrical parts like capacitor only select the parts recommended by the manufacturer. A wrong size capacitor could cause the compressor/fan motor to overheat, decrease the efficiency and shorten its

life. Also, the relay specified by the manufacturer should be used.

AVOID RESTRICTION OF AIRFLOW OVER CONDENSING COIL AND EVAPORATOR COIL:

There should not be any obstruction to the circulation of air, restriction on air flow will reduce performance of the AC. The space around the ODU must be more than 150-250 mm (6”–9.8”) in the rear and more than 1500 mm (59”) in front of the unit. There should be adequate space, more than 150 mm (6”), around the IDU. The distance between the ceiling and the IDU should be more than 50 mm (2”) in the case of front suction or grille

Figure 8.4 : Cleaning of Air filter

design and more than 150 mm (6”) in the case of top suction or flat front panel design.

AIM FOR ZERO REFRIGERANT EMISSIONS

Leakage of refrigerant is harmful to environment. The reduction of refrigerant charge in the system due to leakage results in decrease in system performance and efficiency. It is important to follow the correct method

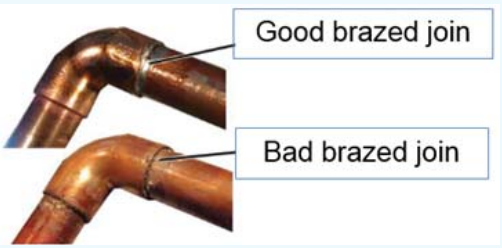


Figure 8.5 : Aim for zero refrigerant

and good service practices for copper tube operation to ensure no leakage is there from copper tubing joints.

REPLACE WITH ONLY CLEAN AND CORRECT SIZE OF COPPER TUBES

The copper tube coils are filled with low-pressure nitrogen gas and sealed with a cap at each end to keep the tubing safe from contamination by oxygen, dust and moisture in the air.

Figure 8.6 : Copper Tube with Caps

Oxygen reacts with copper and creates a layer of copper-oxide inside the tube. Air should never be used for pressurizing and cleaning of the system. It may cause contamination in the system so always close the remaining parts of the copper tubes with caps after cutting as well as those in the system, if it is opened for servicing.

Ensure the use of proper size of the copper tubes. Incorrect size and more number of bends results in pressure drop in the refrigeration circuit which increases energy consumption of the AC. This changes the performance characteristics, so maintain right size of tubes and try minimum bends.

LEAK AND PRESSURE TESTING

Air-conditioners are designed to operate with a fixed amount of refrigerant charge. If it has been detected that a system has insufficient refrigerant, the system must be checked for leaks, then repaired and recharged. Leak test is important for reliability and environmental protection. Apply soap

Figure 8.7 : Leak and Pressure Testing

solution to joints, connections and fittings while system is running or under a standing pressure of nitrogen to identify leak points through appearance of bubbles. Electronic leak detector can also be used for leak detection.

USE OXYGEN-FREE DRY NITROGEN (OFDN)

After repairing and joining processes the system must be tightened and pressure tested. This is to be done by pressurizing the system with OFDN to a pressure higher than the operating pressure and check the system for pressure holding for at least fifteen minutes to ensure there is no leak in the system. Keep noticing the pressure gauge for the pressure drop, if any.

AVOID SLUDGE AND OXIDE FORMATION

After long operation and due to some contaminants, there may be sludge and oxide formation inside the system that can reduce the heat transfer rate and thus cooling capacity. So, it is required to clean the condenser and evaporator coil with solvents and flush the system thoroughly with OFDN when system is opened for servicing. Slowly pass low pressure OFDN through the tubes.

PROPER EVACUATION OF THE SYSTEM:

For better performance of air-conditioner the system should be free from air, moisture, and non-condensable gases. Presence of moisture leads to choking of capillary, strainers, and filter/drier. The non-condensable gases increase system pressure, higher condenser and discharge pressure and result in decrease in energy efficiency of the system. This results in increased power consumption and, also, lesser cooling capacity of the system. Therefore, deep evacuation (proper vacuum) of system is important before charging the refrigerant. The evacuation must be carried out to 500 or lower microns level. Evacuate the system at least for 30 minutes to ensure adequate vacuum, if micron gauge is not available.

USE QUALITY REFRIGERANTS AND COMPATIBLE LUBRICATION OIL

Contaminated refrigerant may contain non-condensable gases and moisture; these will result in sludge formation and creates chocking of capillary and sludge formation in the system. Ensure that refrigerants of proper quality and purity are used, cross contamination of refrigerants should be avoided, it may result in reduced performance and even failure of the system.

Lubrication of moving parts is very important in room air-conditioning system. Always use good quality recommended lubricating oil. The change in oil may result in improper miscibility of refrigerant and lubricant. This would result in separation of oil in the cooling coil.

Replace strainer/filter so that there will be minimum possibility of moisture and other contaminants in the system while servicing the system.

REFRIGERANT CHARGE QUANTITY AS SPECIFIED ON THE OUTDOOR UNIT OF THE AIR-CONDITIONER

The capillary systems like ACs are very sensitive to charge quantity. Charge the quantity of refrigerant as per the manufacturer recommendation (specified on the outdoor unit). The Figure 8.8 shows variation in energy efficiency with higher and lower charge quantities, the energy efficiency drops in both the cases It is necessary the ACs should be charged with refrigerant by weight.

Overcharging of refrigerant increases the compressor power consumption. High operating pressures/temperatures indicate that system is overcharged. There is more chance of leakage from overcharged system. Undercharged will cause less cooling effect thus decrease the system efficiency.

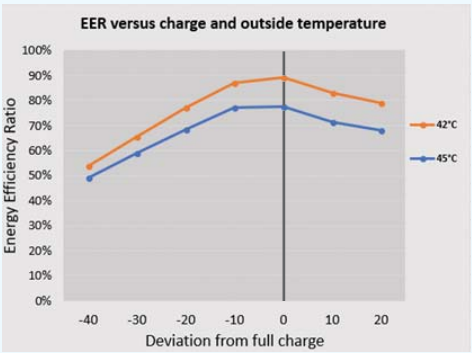


Figure 8.8 : Energy Efficiency Deviation with Charge Quantity

Important to note : Charging of refrigerant by weight is the right procedure for Room ACs.

Education to Customer on Energy Saving

Following are few advices that the technicians should provide to the AC users for operating the systems efficiently.

1. Doors and windows of air-conditioned spaces where AC is operating should be closed so that there will be no outside hot air entering the space.
2. Run ceiling fan, it helps proper circulation of the air inside the room. Also, due to a little higher speed of air using ceiling fan, the temperature set point can be increased, by which we can lower energy consumption of Room AC.
3. Use LED lights which consume less energy and also generate less heat for same output lumens. LED lights consume less both lighting and air- conditioner energy.
4. While buying new air-conditioner, opt higher BEE Star rating system, which consumes less energy as compared to low star rating system. 5 Star rated Room AC consume about 20 to 25% lower energy than 1 Star AC.
5. Draw curtains, drapes and blinds if possible, this helps to lower the heat transfer through windows and walls, lowering the cooling energy required and thus less energy consumption.
6. Run the system at higher temperature set in a range 24-27°C. At lower temperature setting, it will consume more power.
7. Air filter should be cleaned by customer periodically and AC should be serviced at least twice in a year. The air filters accumulates dirt which restrict the air circulation.
8. Electricity saving is equivalent to lower electricity bill to the users.
9. The customer should be made aware that servicing of the air-conditioner should be got done from certified technicians.

Impact of Temperature settings on Energy Consumption

The thermostat temperature setting plays a critical role in cooling capacity requirement of the space to be air-conditioned, lower the set point temperature, more is the cooling requirement and more energy

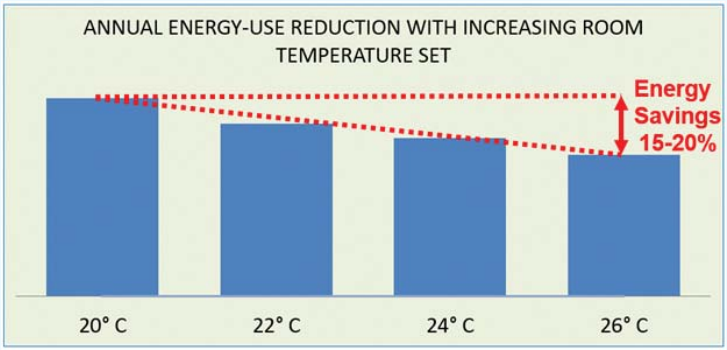


Figure 8.9 : The Impact of Indoor Temperature settings on Energy Consumption

consumption for the space. Making the room temperature set to 26°C the energy savings will be around 15 to 20% lower than the room temperature set of 20°C.

Air-conditioner Energy Labelling Standard

BEE started mandatory energy efficiency Star rating from 2010 for room air-conditioner up to a rated cooling capacity of 10.465 kW. The room air conditioner of the vapour compression type which are of unitary air conditioner and split air-conditioner up to a rated cooling capacity of 10,465 Watts (9,000 kcal/hour) being manufactured, commercially purchased or sold in India shall –

- meet the compliance requirements of the maximum operating conditions test in accordance with IS 1391(Part1) for unitary air conditioner and IS 1391(Part2) for split air conditioner.
- be certified against IS/ISO 9000 or above.

The BEE label to room air conditioner is maximum of 5 stars with an interval of 1 star, and the room air conditioner is rated from star 1 to star 5 based on their relative energy efficiencies.

Earlier BEE used to label the system based on the Energy Efficiency Ratio (EER), means the ratio of capacity (in Watts) to the power consumption at nominal voltage and frequency. From 2018 BEE labels the system based on the Indian Seasonal Energy Efficiency Ratio (ISEER), means the ratio of the total annual amount of heat that the equipment may remove from

2016 - 2017			2018 - 2019		
Star Level	Min EER	Max EER	Star Level	Min ISEER	Max ISEER
Star 1	2.70	2.89	Star 1	3.10	3.29
Star 2	2.90	2.99	Star 2	3.30	3.49
Star 3	3.10	3.29	Star 3	3.50	3.99
Star 4	3.30	3.49	Star 4	4.00	4.49
Star 5	3.50	-	Star 5	4.50	-

Figure 8.10 : Star Level up-gradation for Split AC

the indoor air when operated for cooling in active mode to the total annual amount of energy consumed by the equipment during the same period.

The methodology for calculating the cooling seasonal total load, cooling seasonal energy consumption and ISEER shall be in accordance with the ISO 16358.

The labelling program is a dynamic system, every two years BEE revise and enhance energy efficiency values which is illustrated in the figure 8.10.

Checklist for Good Service Practices

	Action
☐	Check air filter and perform cleaning
☐	Check Condenser coil wash outdoor unit condenser coil annually at least once a year to maximize efficiency and enhance AC working life;
☐	Check Evaporator coil and clean it at least once a year;
☐	Perform leak and pressure testing
☐	Use Oxygen Free Dry Nitrogen to remove contaminants from the system
☐	Ensure correct Refrigerant Charge as recommended by the manufacturer
☐	Treat AC drain pans to prevent its clogging may be due to algae growth
☐	Check compressor amps
☐	Check condenser fan amps
☐	Tighten electrical connections
☐	Check capacitance of Capacitors
☐	Educate customer on Energy Efficient operations

09

SOFT SKILLS

Background

Customers are the backbone of any business and for any company to survive, the customers should be satisfied with the products and services the company offers. In the case of air-conditioning sector, the technician who visits the customer becomes the one of the face or image of the company. Therefore, it is important that the technician understands the need and expectation of the customer. Customer expectation varies according to income, race, geography, and culture. So, the technician should know not only to repair and service the equipment but also communicate to the customer in a proper way and understand that customer satisfaction depends highly on the behavior of frontline service providers. Alternatively the technician may be a self-employed working in a team or independently visiting / meeting the customer in such a situation too he has to ensure the customer is satisfied with his services and mannerism.

The soft skills are personality traits that characterize one's relationships in a particular situation. These skills can include social graces, communication abilities, language skills, personal habits, emotional empathy, time management, teamwork and leadership traits.

Role of RAC Technician

When a customer purchases an air-conditioner from the showroom and make the payment the role of the salesperson ends there, but for the service

Figure 9.1 : Role of RAC Technician

technician, it is the beginning of long-term relationship. His/her role starts with the identification of a proper location for installation, installing the AC, educating the customer on proper usage, giving energy saving tips, doing preventive maintenance, attending breakdown calls etc.

Soft Skills

The technicians must understand what is "Good service" all about, it is not just knowing all about the equipment and servicing techniques but a combination of many factors with work ethics at the core of it.

Attitude: An effective customer relationship starts with the attitudes of the customer service representatives. Maintaining a positive attitude is about putting oneself in the customer's position and viewing the problem from their point of view. This would help the service technician to make better decisions and know how to deal with different customers. Attitude of the technician should be that of **"Help and Support".**

Communication skills: Communication is the key component of an excellent service, as it is the art of conveying the message. As to how the technician can steer the conversation toward a positive outcome this is possible thorough effective communication. Being cheerful and calm even in a tough situation helps to win the customer.

Language skills: Politely communicating in the language that can be understood by the customers and peer group enhances the ability to explain and execute the work appropriately.

Time management: Visiting and /or completing the tasks in time as specified is one of the important characteristics necessary for a technician to be successful.

Effective Communication Skills

Eye to eye contact: Eye to eye contact is important, it is also an important form of non-verbal communication and can create an instant connection between the technicians and their customer and provides a positive step towards building a successful human connection with a customer.

Body language: Body language is an added tool of communication. With a positive attitude, the technician will appear more amenable, amicable,

responsive, and attuned to the needs and expectations of customers. This, in turn, would reflect in their behavior towards customers, who would feel heard, respected, and cared for by the technician. A smiling face and the tone of voice can make a huge positive impact.

Silence: Silence though is not golden in customer service, sometimes it is better to keep silent, especially when there is a situation of arguments and if you feel your response is going to make customer uncomfortable.

Quick take away: Summarizing what was discussed, listening to what the customer have to say about the quality of work, will lead to doing a better next time. Pay attention to the needs of the customer make a special effort to hear what the customer are saying. Encourage them to continue and ask questions.

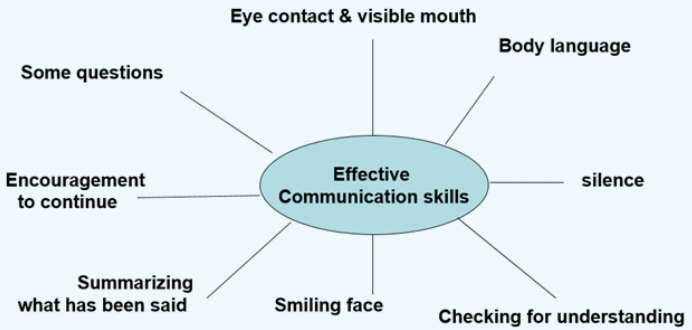


Figure 9.2 : Effective Communication Skills

Communication with Customers

COMMUNICATION PRACTICES BEFORE START OF THE WORK

While visiting customers keeping an appointment is important. That is going to be the first chance of impressing the customer. Check the customer location and give the costumer an appropriate time. The most important thing is to be on time, checking the route through GPS for route planning. Informing customer about visit charges.

Ring the bell and wait, introduce yourself and your company, greet the customer formally. Use customer title and surname, if someone does not have a professional title, use the title “Sir” or “Madam”. Show the ID card.

Ask permission before entering the house. Smile on your face and the tone of your voice can make a huge difference.

Can ask customer about the warranty status of the equipment or whether they have taken any annual maintenance contract for the appliance. Request to show the relevant document and inform the customer about visiting charges if any.

The ability to listen to customers is very crucial for providing good service. Paying attention to their needs; making a special effort to hear what they're saying.

COMMUNICATION PRACTICES DURING START OF THE WORK

Examine the appliance and ask questions in sequence, to correctly ascertain the problem. Customer may not be familiar with technical terminologies and hence talk in a simple language that could be understood by the customer. Suggest possible solutions and approximate cost involved and the time required for completion of the job

Before replacing any part or doing any service, seek customers approval. Don't take things for granted. This can prevent the possibility of any confrontational situation.

Before installation the customer must be informed about pre-installation masonry, electrical and other related work to be carried out and whether the cost of these are included in the installation charges or not. Even if permission is taken to enter the house the technician cannot just start walking into the rooms where AC is to be installed or serviced. Seeking permission before entering the room is vital and good manners.

Figure 9.3 : Explain about installation

COMMUNICATION PRACTICES DURING THE WORK

Know from customer where the air-conditioner is to be installed and / or serviced. For installation check the location and explain the best possible

options. the advantages and disadvantages of different locations need to be explained and allow the customer to decide.

At the time of installation, while opening the package of the air conditioner check and ensure that all the supporting accessories are available in the pack and inform the customer about it.

Educate the customer about the precautions to be taken, good practices to be followed, energy saving tips and proper temperature settings.

Ensure that installation and servicing is done diligently but write it down in black and white get it acknowledged by the customer. If the customer is very happy with your service, encourage them to write their feedback in the acknowledgment form.

Communication with Co-workers

Whatever occupation or industry team matters the most. Team members are partners and not competitors so it's important to create a happy environment amongst the teams. This will result in heightened confidence in the team and excellent service delivery. Listening to what coworkers have to say, helping and supporting each other to complete the task at hand creates a cordial environment at work.

Figure 9.4 : Effective Communication Practices with Collogues

It is important viz. to resolve any interpersonal issues among team members. Early indications of problems and resolving them at the earliest are signs of team effectiveness.

Pass knowledge on new technologies, procedures, and precautions to team members. All humans are with different skills and knowledge, and learning from other members of the team goes a long way forward in thinking innovatively and coming up with solutions that will suit the job and make customer happy. Discussing the problems faced in the field with colleagues will help all to come up with better solutions.

Pass on customer complaints to colleagues in the respective geographical area. Working together produces good customer service. Strong teams, for example, assure consistency of communication with the customer, deadlines are more easy to be met and everyone takes responsibility for their actions.

Telephone Skills

Before answering a call relaxing the mind is important, if the phone call is answered in an agitated mood, it will affect the tone and voice. The phone call have to be answered with a smile.

Start the conversation by greeting the customer. Speaking clearly, with a vibrant tone and voice is an attribute to clear communication. Practice speaking skills at home, with friends or colleagues. While answering a phone call state name and organization and write down the caller's name and other information the customer is providing. Have a writing pad and pencil ready to take notes or messages. Never answer a call while eating food or chewing gum.

Writing Skills

During installation or attending service complaints communicate the information like the nature of the complaint, corrective actions required to be taken, post completing the task type of work done, precautions to be taken and payment received from customers etc. Clear writing minimizes issues with customers, cuts complaints and promotes loyalty. All required format to be filled up immediately on completion of work. This will help to keep the maintenance records properly.

Reading Skills

It is important to acquire good reading skills as it allows to understand written sentences and paragraphs in work related documents. Habit to read all product operating manuals, standard operating procedures, MSDS of different types of solvents and refrigerants used in your workplaces.

Professionalism

Professionalism is particularly important for those who work in customer service since job skills, good judgment and polite behavior can leave customers feeling satisfied and encourage them to remain loyal customers.

Competency is the sum total of the skills, knowledge, practical behaviors and attitudes.

Punctuality - A skill that a customer service representative should have is the ability to effectively manage time.

Follow up- As far as possible don't keep work pending. Like the NIKE tag line "Just Do It" Follow it up and keep the customer informed about the progress. It's a fact that passion in the workplace creates excitement.

Always upgrade knowledge and skills- Customer expectations are always changing, and with new technologies and products are being introduced to the market, it is necessary to for technicians to constantly upgrade skills and knowledge.

Personal Hygiene

Maintaining good hygiene helps to reduce the risks of ill health, but equally important affects how we and others perceive ourselves and can influence our levels of confidence and self-esteem which can affect many aspects of our lives.

Clean and neatly ironed clothes, polished shoes and clean socks to be worn when at work. Bathing and regularly washing hands, keeping oneself neat and clean helps give a good impression. While working the appliances and walls of the customer should not be soiled by touching with oily and greasy hands. Some stains caused by greasy hands may not be able to remove easily. Avoid wearing heavy jewelry to work.

10

CERTIFICATION: REFRIGERATION AND AIR-CONDITIONING SERVICE TECHNICIAN

Background

Around the world in most of the countries have certification system for refrigeration and air conditioning (RAC) trade that includes installation and servicing of Room air conditioners (Room ACs). Only certified service technicians are allowed to work in this area. India also has introduced on voluntary basis technician certification program in room AC It may become mandatory in future. The certification to service technicians for room air-conditioner is being based on evaluation through a competency examination covering theoretical and practical assessment. In this chapter the certification process, its needs and benefits are discussed. It also includes information on elements of examination and assessment process.

Certification for room air-conditioner service technicians is important as a proof of their professional competency and it enhances employability within the country as well as abroad. Over the years the need for certification in RAC trade: Room air conditioners has been recognized as RAC is an interdisciplinary and complex subject. It requires knowledge and hand on experience on mechanical, electrical and electronic technologies. The servicing personnel require the handling of high pressure, flammable and toxic gasses. Further, it has been well understood that trained and certified technicians could provide better services to the customers, increase their income and help in reducing refrigerant consumption and their emissions as well as maintain designed energy efficiency of the system resulting in conservation of energy.

Why Certification

The certification is based on assessment of competency which ensures that technician has needed subject understanding and capable of doing the work to the satisfaction of the customer with his/her own safety. It has become increasingly essential as HCFCs, including HCFC-22, are being phased-out under Montreal Protocol, globally, as these chemicals deplete ozone layer. Many of the refrigerants alternative to HCFC-22 are flammable and/or toxic or high working pressures. Most of the technicians are not familiar with servicing of ACs with these alternative refrigerants. The installation and servicing of air-conditioning equipment operating with such refrigerants need to be handled carefully and considered in the context of safety issues. It is therefore essential to have training followed with a certificate based on the assessment theory and practical of the technician.

Certification is an approval process to ensure that the technician is competent to complete the installation and servicing of AC successfully, giving an assurance to the customer of quality work performance. Training, assessment, and certification also give enhance assurance that servicing will be performed according to applicable standards.

Benefits of Certification

Certification is a measure undertaken voluntarily for enhancement of professional skills of RAC servicing personnel. It will help the service technicians in a number of ways, the social status and identity, safety, increased employability within the country and abroad and increaed earnings. Certification has been one of the requirements for taking any such employment especially abroad as skilled peronnel for Indian certified room AC technicians. The certification process will enhance skills of the RAC technicians through further education and training, required for preparation for the assessment/exam. The education and skill enhancement in addition to the upgrading the skills will create health & safety awareness and significant value addition for technicians leading to better quality of life.

Role of HPMP in Certification Process

Technicians participating in the two day technicians training programs conducted by GIZ under HPMP in the country will receive a Certificate of Participation. In addition will allow the technicians to make himself aware of his competence requirements and do self-evaluation leading to identify the gaps in what they know and what is required for acquiring

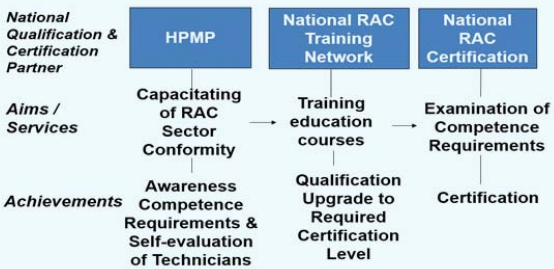


Figure 10.1 : Overview of National Qualification & Certification Network

the certificate. Figure 10.1 shows the role of various elements of process of certification.

The National Training Network will provide training and education courses making qualification upgrade to the required certification level. Certification will be provided through examination, which will be based on the competence required for the service technicians.

Elements of HPMP Technicians Workshop

Technicians training under HPMP is of two day duration which includes theory through classroom training and practical – hand on training.
During the training the topics covered will be primarily on good service practices and installation of room air-conditioners with HCFC–22 and

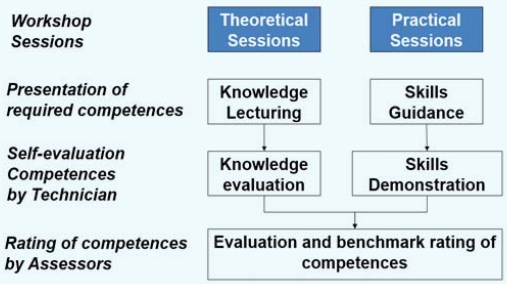


Figure 10.2 : Elements of HPMP Technicians Workshop

flammable refrigerants, energy efficiency and soft skills. These contents of the training provided for example form the syllabus / topics of the proposed national certification

Contextualizing Qualification → Benchmarking

Figure 10.3 shows a graph of the percentage of proficiency along with time. By training efforts of a national network, the achievement of technician's performance level can be benchmarked.

Techncinas traning program under HPMP is prepared through gaps analysis/ pre-assessment and the required skills/education/tools. On undergoing the training under HPMP the service technician can achieve a benchmark for planning to write the examination for the certification. Upon the successful

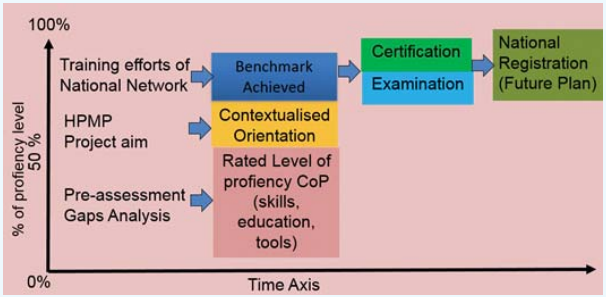


Figure 10.3 : Contextualizing Qualification– Benchmarking

completion of the certification exam, technician can be registered as a nationally certified technician for servicing room air-conditioner.

International Scenario

Many countries have a certification system for room air-conditioner service technician and it is mandatory to have for installation and servicing of room ACs.

In the USA Environmental Protection Agency (EPA) gives a certificate to qualified service technicians. It is a mandatory requirement of Refrigeration and air-conditioning technicians to pass an EPA approved test implemented by an approved certifying organization.

In European Union, the technicians are required to follow regulation 'EN 13313 Competence of Personnel and EU "F-Gas" Regulation No 517/2014'. According to the EN 13313, persons responsible for installation, inspection, testing, maintenance, repair, commissioning, and disposal of air-conditioning systems and their parts, must have the competencies to be certified by an approved national organization. The "F-gas" Regulation requires all personnel and companies to have a certification proving their ability to manipulate systems using "F-gases". The personnel certification is obtained after a theoretical and practical assessment (EC No 303 & 304/2008 for examination requirements).

Japan has a certification body - High-Pressure Gas Safety Act and the Refrigeration Safety Regulations. It is a mandatory requirement of Refrigeration and air-conditioning technicians to hold a Refrigeration Safety Manager Certificate.

Ministry of Human Resources and Social Security (MHRSS), Australian Government give certificate III in Air-conditioning and Refrigeration to perform servicing work. In China Ministry of Human Resources and Social Security (MHRSS) gives certification systems for refrigerant servicing technicians.

Country	Certification Body /Regulation	Certification
USA	Environmental Protection Agency (EPA)	**Mandatory** requirement of Refrigeration and air-conditioning technicians to pass an EPA approved test implemented by an approved certifying organization
European Union (EU)	EN 13313 Competence of Personnel EU "F-Gas" Regulation No 517/2014	Specifications required for personnel covering a large variety to tasks and equipment related to the refrigeration and air-conditioning sector
Japan	High Pressure Gas Safety Act and the Refrigeration Safety Regulations	**Mandatory** requirement of Refrigeration and air-conditioning technicians to hold a Refrigeration Safety Manager Certificate
Australia	Australian Government	Certificate III in Air-conditioning and Refrigeration
China	Ministry of Human Resources and Social Security (MHRSS)	Certification systems for refrigerant servicing technicians

Figure 10.4 : International Scenario

Certification – Roles and Responsibility

The roles and responsibility of certification system in India are as follows:

Certification Standards is one standard framework across the nation as per National Skills Qualification Framework (NSQF) Standard. The technicians must be qualified as per Qualification Packs (QPs) & National Occupational Standards (NOSs). An NSQF Certification with Skill India logo is provided to the certified technicians.

NOSs – National Occupational Standards (NOSs) specify the standard of performance, knowledge, and understanding when carrying out a particular activity in the workplace. Each NOS defines one key function in a job role.

QPs – A set of NOSs, aligned to a job role, called Qualification Packs (QPs), would be available for every job role in each industry sector. This drive both the creation of curriculum, and assessments.

The affiliations of certification are::

- Adjoined industry and Govt certificate e.g. (ESSCI)
- Training Partner (TP) & Trainer

- Assessment Partner (AP) & Assessor
- Master Trainer

Preparation for Exam

Training material prepared under HPMP for RAC technicians viz. the Technicians Handbook - Good Practices in Installation and Servicing of Room Air-conditioners with HCFC – 22 and flammable refrigerants (technicians receive it as reference material on undergoing the technicians training programs – HPMP Stage –II).

Participant Handbook – Field Technical Air Conditioner, published by ESSCI and some other relevant reading/reference material prepared by experts from RAC Industry Experts and other experts.

Follow "Qualifications Pack- Field Technician: Air Conditioner" Published by ESSCI, Skill India for Electronics. Participants must go through the Qualification Pack that consists of the following topics:

- Installation of room air conditioner
- Repair of the dysfunctional air conditioner
- Interaction with colleagues
- Maintaining of health and safety
- Engagement with the customer for service

Technicians can also refer E-learning contents in the student section of ESSCI website, www.essc-india.org

Examination and Assessment

The examination process involves following elements:

i. Assessment and certification is done as per the National Skills Qualifications Framework (NSQF). This is a competency-based framework that organizes all qualifications according to a series of levels of knowledge, skills and aptitude.

ii. Assessment is by third party assessors who are affiliated with ESSCI on all of the National Occupational Standards (currently there are 4 for AC technicians).

iii. Written part of the assessment is done online at computer terminals (questions are selected from a common knowledge bank and are of

varying levels of difficulty).

iv. Practical assessment which would include viva questions as well as demonstration of skills is done by the assessment agency's assessors.

v. Grading and weightage of the various skills is as per the Qualification Pack published by ESSCI for various trades including RAC Field Technicians: Room ACs

vi. The technician should score a minimum of 70% of aggregate marks to successfully clear the assessment.

Certificate Sample

HCFC Phase-Out Management Plan (HPMP) for Service Sector in India: The Government of India has planned to reduce consumption of HCFC in the servicing sector during Phase 1 (2012 – 2014) in order to meet its compliance targets in 2013 (freeze) and 2015 (10% reduction) in line with the accelerated phase-out schedule of the Montreal Protocol. In the servicing sector HCFC-123, HCFC-124, HCFC-142b and HCFC-22 are consumed, however, during Phase I only the consumption of HCFC-22 will be addressed. Awareness raising, early adoption of better servicing practices and recovery would have an immediate phase-out impact and could significantly reduce the consumption of HCFC in the country

The Refrigeration and Air Conditioning (RAC) servicing sector contributes to a large extent to the consumption of HCFCs, in particular in the room air-conditioner segment. GIZ-Proklima on behalf of the Government of Germany and in close co-operation with the Ozone Cell in the Ministry of Environment and Forests will implement phase-out activities in the Indian RAC servicing sector. The consumption will be reduced mainly through training on better servicing practices and leak prevention but service technicians also need to be prepared on the introduction of alternatives like HC-290, HFC-410a and HFC-32. There are already 15 training partners in the country which will reach out to train as many technicians as possible and to address all the identified sub-sectors in metros and towns all over India.

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