

TRAINING MANUAL FOR TECHNICIAN IN REFRIGERATION & AIR-CONDITIONING SERVICING SECTOR (RACS)

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FOREWORD



Hydrochlorofluorocarbons (HCFCs) are ozone depleting substances (ODS) introduced in 1990s as transitional substitutes for CFCs. They are being widely used in the air conditioning, refrigeration, foam, solvent, aerosol and fire-fighting industries. The refrigeration and air-conditioning sectors are the major consumption of HCFCs particularly HCFC 22 thus servicing of the equipment is inevitable. Proper handling and good practices during servicing are crucial to ensure no release of the refrigerants into the atmosphere. It is of major concerns that the servicing sectors are to be carried out by the trained technicians that inculcate good environmental practices particularly in handling ODS refrigerants as well as High GWP refrigerants or flammable refrigerants which are also being introduced as alternatives to HCFC.

With technical guidance from UNEP, GIZ, UNIDO and local experts as well as financial support from Multilateral Fund of Montreal Protocol, we were able to publish a **Training Manual for Technician in Refrigeration and Air-Conditioning Servicing Sector**. The Training Manual emphasizes on good handling of refrigerants and good practices during servicing and installation of the refrigeration and air-conditioning systems. This manual will be used by the Authorised Training Centres (ATCs) to conduct programs on Certification of Service Technicians in Malaysia.

The Department of Environment wishes to thank the International organisations, Government institutions, private sectors and all individuals that have contributed to the making of this Training Manual possible and hope that it will be a very useful reference to the trainers and technicians participating in the certification programs.

A handwritten signature in black ink, appearing to read 'Halimah Hassan', written in a cursive style.

DATO' HALIMAH HASSAN
THE DIRECTOR GENERAL OF ENVIRONMENT, MALAYSIA

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CHAPTER 1

ENVIRONMENTAL AND HUMAN HEALTH IMPACT OF REFRIGERATION AND AIR-CONDITIONING

CHAPTER 1

ENVIRONMENTAL AND HUMAN HEALTH IMPACT OF REFRIGERATION AND AIR-CONDITIONING

1.1 INTRODUCTION

The energy-intensive living lifestyle in the modern world have resulted the dramatic increase in amount of green house gases and ozone depleted substances in the atmosphere which directly contribute to the climate change and global warming. The release of ozone depleting substances around the world has seriously damaged the ozone layers. In the 1970s, scientists discovered significant levels of ozone depletion in the stratosphere, producing a phenomenon commonly known as the 'Ozone Hole'. By the 1990s, the total ozone was less than half its value during the 1970s and this depletion has continued until today. In response to the threat to the ozone, in 1987 the governments of the world agreed to the United Nations Montreal Protocol as a means to address global environmental challenges.

Malaysia acceded to the Vienna Convention and ratified the Montreal Protocol on Substances that deplete the Ozone Layer in August 1989. As of October 2001, Malaysia has ratified all the amendments to the Montreal Protocol. Malaysia was classified as a party operating under Paragraph-1, Article-5 of the Montreal Protocol and thus qualified for technical and financial assistance, including transfer of technology, through the financial mechanism of the Montreal Protocol. Malaysia's Country Programme incorporating the National Strategy and Action Plan for controlling the use of Ozone Depleting substances was approved in 1992. Since then Malaysia has taken proactive measures such as phase-out project activities including technology transfer investments, technical assistance, training and capacity-building, information dissemination and awareness-raising and regulations.

Hydrochlorofluorocarbons (HCFCs) are classified as controlled substances under Annex-C Group-I of the Montreal Protocol and are subject to the adjusted control schedule for Article-5 countries; to freeze the consumption at baseline levels from 2013 and reduction of 10% from baseline levels from 2015 and ultimately phase-out in 2030. HCFCs are used in Malaysia in various industry sectors, such as Air Conditioning, Refrigeration, Foams, Firefighting and Solvents. The predominant HCFC used is HCFC 22 (commonly known as R22) mainly in the Refrigeration and Air Conditioning Sectors. Malaysia and other parties under the Montreal Protocol are implementing the HCFC Phase-out Management Plan (HPMP) by using alternative technologies in the air-

conditioners and refrigerators. Therefore, regulatory actions will be implemented to control the importation and consumption of HCFC in the manufacturing and servicing sector. The regulations to control HCFC have come into enforcement since 1st January 2013.

1.2 THE RELEVANT LAWS IN MALAYSIA

1.2.1 Environmental Quality (Refrigerant Management)

Malaysia's Environmental Quality (Refrigerant Management) Regulations 1999 and Environmental Quality (Refrigerant Management) (Amendment) Regulations 2004 came into force since 1st January 1999 and 1st December 2004 (Amendment).

Pertinent Regulations

a) Regulation 4

“The use of refrigerant environmentally hazardous substances as a refrigerant in any new installation of a building chiller, refrigeration system, vehicle air conditioner or an air conditioning equipment is prohibited”

b) Regulation 5

Handling of refrigerant environmentally hazardous substances

- Sub-regulation (1)

“No person shall handle any refrigerant environmentally hazardous substance unless he has received the approved training in the reclamation and recycling of any refrigerant environmentally hazardous substances and is in possession of and approved machine for the activity.”

c) Regulation 6

Offence to vent refrigerant environmentally hazardous substances

“No person shall knowingly vent any environmentally hazardous substances into the atmosphere, except with the prior written approval from the Director General”

The above regulations have been enforced since 1st December 2004



MALAYSIA

Warta Kerajaan

SERI PADUKA BAGINDA

DITERBITKAN DENGAN KUASA

HIS MAJESTY'S GOVERNMENT GAZETTE

PUBLISHED BY AUTHORITY

Jil. 43
No. 22

28hb Oktober 1999

TAMBAHAN No. 107
PERUNDANGAN (A)

P.U. (A) 451.

In exercise of the powers conferred by section 51 of the Environmental Quality Act 1974 [Act 127], the Minister, after consultation with the Environmental Quality Council, makes the following regulations:

Citation and commencement

1. These regulations may be cited as the **Environmental Quality (Refrigerant Management) Regulations 1999** and shall come into force on 1 January 2000.

Interpretation

2. In these Regulations, unless the context otherwise requires—

“approval” means approved by the Director General of Environmental Quality;

“approval criteria” means a criteria on the ability of a substance to cool a system, to refrigerate, or its ozone depleting potential or global warming potential and any other physical and chemical characteristics important for its proposed applications;

“destruction” means a process which, when applied to a refrigerant environmentally hazardous substance, results in the permanent transformation, or decomposition of all or a significant portion of the substance;

“Director General” means the Director General of Environmental Quality referred to in section 3 of the Act or any officer duly appointed under subsection 3(2) of the Act;

“handling” means being involved in an activity relating to any refrigeration and air-conditioning equipment that may result in the release of a refrigerant environmentally hazardous substance including the repair, maintenance or adjustment of the equipment;

“refrigerant environmentally hazardous substance” means any substance specified in the Schedule, whether existing alone or in a mixture;

“reclamation” means the recovery of any refrigerant environmentally hazardous substance from a unit for reuse, recycling, reprocessing or disposal;

“reprocessing” means the recovery of a refrigerant environmentally hazardous substance from a unit for return to a production plant and reformation before it is made available for reuse;

“retrofitting” means removing a refrigerant environmentally hazardous substance from a unit and making modification so that the unit can be recharged with one of the alternative substances.

Application

3. These Regulations shall apply to a person handling a refrigerant environmentally hazardous substance in an existing or a new installation.

Prohibition on the use of refrigerant environmentally hazardous substance

4. The use of refrigerant environmentally hazardous substance as a refrigerant in any new installation of a building chiller or refrigeration system is prohibited.

Handling of refrigerant environmentally hazardous substance

5. (1) No person shall handle any refrigerant environmentally hazardous substance unless he has received the approved training in the reclamation and recycling of any refrigerant environmentally hazardous substance and is in possession of an approved machine for the activity.

(2) For the purpose of subregulation (1), the Director General may, after consultation with the manufacturers of refrigeration systems, maintain a register of approved training courses for the reclamation and recycling of any refrigerant environmentally hazardous substance and approved machines for such activities.

Offence to vent refrigerant environmentally hazardous substance

6. No person shall knowingly vent any refrigerant environmentally hazardous substance into the atmosphere, except with the prior written approval of the Director General.

Prohibition on moving refrigerant environmentally hazardous substance out of Malaysia

7. (1) No person shall move a refrigerant environmentally hazardous substance out of Malaysia without the prior written approval of the Director General.

(2) The Director General shall not permit the movement of a refrigerant environmentally hazardous substance out of Malaysia unless he is satisfied that the refrigerant environmentally hazardous substance is intended for destruction or reclamation under a process which is not available in Malaysia and that after its destruction or reclamation the refrigerant environmentally hazardous substance or any other resultant product will be brought back to Malaysia. However, the Director General may impose other additional conditions as he deems fit.

Alternative

8. The Director General may approve an alternative to a refrigerant environmentally hazardous substance if he is satisfied that the alternative is safe and meets the requirements of the approval criteria.

Training programme for retrofitting activity

9. (1) A manufacturer of air-conditioners shall conduct a retrofitting training programme for a person involved in a retrofitting activity.

(2) The manufacturer shall ensure that during the training programme, the person involved is well-informed on the design of the air-conditioner system and its purpose.

Technical expertise

10. A manufacturer of air-conditioners shall, when required by the Director General, provide the technical expertise and supporting assistance in a retrofitting training programme organised by the Government.

SCHEDULE

(Regulation 2)

REFRIGERANT ENVIRONMENTALLY HAZARDOUS SUBSTANCES

Group	Chemical Formula	Substance
I	CFC ₁₃	Trichlorofluoromethane (CFC - 11)
	CF ₂ Cl ₂	Dichlorodifluoromethane (CFC - 12)
	C ₂ F ₃ Cl ₃	Trichlorotrifluoroethane (CFC - 113)
	C ₂ F ₂ Cl ₂	Dichlorotetrafluoroethane (CFC - 114)
	C ₂ F ₅ Cl	Chloropentafluoroethane (CFC - 115)

Made 2 June 1999.
[KSTAS(U) 01/B/(27); PN(PU)²280/8]

DATUK LAW HIENG DING
Minister of Science, Technology
and the Environment

Figure 1.1: Environmental Quality (Refrigerant Management) Regulations 1999



MALAYSIA

Warta Kerajaan

SERI PADUKA BAGINDA

DITERBITKAN DENGAN KUASA

HIS MAJESTY'S GOVERNMENT GAZETTE

PUBLISHED BY AUTHORITY

Jil. 48
No. 24

1hb Disember 2004

*TAMBAHAN No. 121
PERUNDANGAN (A)*

ENVIRONMENTAL QUALITY ACT 1974

ENVIRONMENTAL QUALITY (REFRIGERANT MANAGEMENT) (AMENDMENT) REGULATIONS 2004

In exercise of the powers conferred by section 51 of the Environmental Quality Act 1974 [Act 127], the Minister, after consultation with the Environmental Quality Council, makes the following regulations:

Citation and commencement

1. (1) These regulations may be cited as the **Environmental Quality (Refrigerant Management) (Amendment) Regulations 2004**.

(2) These Regulations come into operation on 1 December 2004.

Amendment of regulation 4

2. The Environmental Quality (Refrigerant Management) Regulations 1999 [P.U. (A) 451/1999] is amended in regulation 4 by substituting for the words "or refrigeration system" the words ", refrigeration system, vehicle air conditioner or an air conditioning equipment".

Made 3 November 2004

[AS(S)91/110/919/014 Jld. 11; PN(PU²)280/IX]

DATO' SRI HAJI ADENAN HAJI SATEM
Minister of Natural Resources and Environment

Figure 1.2: Environmental Quality (Refrigerant Management) (Amendment) Regulations 2004

1.2.2 Prohibition On Import

The Malaysian Cabinet agreed to implement the Control of Importations of HCFC Quota via Approval Permit (AP) mechanism on 25 March 2011. New amendment to Customs Order 2012 P.U (A) 192/2012 was gazetted on 31 December 2012 by inserting HCFCs on the Second Schedule of the Order and comes into force on 1 January 2013.

Approval Permit (AP) will be processed and approved by Department Of Environment (DOE) for forty (40) types of HCFCs. From 1st January to 28th February 2013, applications were processed manually before e-Permit online system commenced on 1st March 2013.



25 Jun 2012
25 June 2012
PU. (A) 192

WARTA KERAJAAN PERSEKUTUAN

FEDERAL GOVERNMENT
GAZETTE

PERINTAH KASTAM (LARANGAN MENGENAI IMPORT)
(PINDAAN) (NO. 3) 2012

CUSTOMS (PROHIBITION OF IMPORTS) (AMENDMENT)
(NO. 3) ORDER 2012



DISIARKAN OLEH/
PUBLISHED BY
JABATAN PEGUAM NEGARA/
ATTORNEY GENERAL'S CHAMBERS

PU. (A) 192

CUSTOMS ACT 1967

CUSTOMS (PROHIBITION OF IMPORTS) (AMENDMENT) (NO. 3) ORDER 2012

IN exercise of the powers conferred by subsection 31(1) of the Customs Act 1967 [Act 235], the Minister makes the following order:

Citation and commencement

1. (1) This order may be cited as the **Customs (Prohibition of Imports) (Amendment) (No. 3) Order 2012**.

(2) This Order comes into operation on 1 January 2013.

Amendment of Second Schedule

2. The Customs (Prohibition of Imports) Order 2008 [PU. (A) 86/2008] is amended in the Second Schedule by inserting after item 43 and the particulars relating to it the following item:

(1) Item No.	(2) Description of Goods	(3) Heading/ Subheading	(4) Country	(5) Ministry/ Department/ Statutory Body Issuing Licence
*44.	Hydrochlorofluorocarbons gas (HCFCs) covered under Montreal Protocol Annex C - Group 1:		All Countries	Department of Environment.
(1)	HCFC-21 Dichlorofluoromethane (CH ₂ ClF)	2903.45 110		
(2)	HCFC-22 Chlorodifluoromethane (CHF ₂ Cl)	2903.45 120		
(3)	HCFC-31 Chlorofluoromethane (CH ₂ FCl)	2903.45 190		
(4)	HCFC-121 Tetrachlorofluoroethane (C ₂ HFC ₄)	2903.45 130		
(5)	HCFC-122 Trichlorodifluoroethane (C ₂ HFC ₃ Cl ₂)	2903.45 210		
(6)	HCFC-123 Dichlorotrifluoroethane (C ₂ HFC ₂ Cl ₂)	2903.45 220		
(7)	HCFC-123 2,2-dichloro-1,1,1-trifluoroethane (CHCl ₂ CF ₃)	2903.45 220		
(8)	HCFC-124 Chlorotetrafluoroethane (C ₂ HF ₅ Cl)	2903.45 230		

(9)	HCFC-124 2-chloro-1,1,1,2-tetrafluoroethane (CHFClCF ₃)	2903.45 230		
(10)	HCFC-131 Trichlorofluoroethane (C ₂ H ₂ FCl ₃)	2903.45 299		
(11)	HCFC-132 Dichlorodifluoroethane (C ₂ H ₂ F ₂ Cl ₂)	2903.45 299		
(12)	HCFC-133 Chlorotrifluoroethane (C ₂ H ₂ F ₃ Cl)	2903.45 299		
(13)	HCFC-141 Dichlorofluoroethane (C ₂ H ₃ FCl ₂)	2903.45 240		
(14)	HCFC-141b 1,1-dichloro-1-fluoroethane (CH ₃ CFCl ₂)	2903.45 250		
(15)	HCFC-142 Chlorodifluoroethane (C ₂ H ₃ F ₂ Cl)	2903.45 260		
(16)	HCFC-142b 1-chloro-1,1-difluoroethane (CH ₃ CF ₂ Cl)	2903.45 270		
(17)	HCFC-151 Chlorofluoroethane (C ₂ H ₄ FCl)	2903.45 299		
(18)	HCFC-221 Hexachlorofluoropropane (C ₃ HFCl ₆)	2903.45 999		
(19)	HCFC-222 Pentachlorodifluoropropane (C ₃ HF ₂ Cl ₅)	2903.45 999		
(20)	HCFC-223 Tetrachlorotrifluoropropane (C ₃ HF ₃ Cl ₄)	2903.45 999		
(21)	HCFC-224 Trichlorotetrafluoropropane (C ₃ HF ₄ Cl ₃)	2903.45 910		
(22)	HCFC-225 Dichloropentafluoropropane (C ₃ HF ₅ Cl ₂)	2903.45 920		
(23)	HCFC-225ca 1,1-dichloro-2,2,3,3,3-pentafluoropropane (CF ₂ CF ₂ CHCl ₂)	2903.45 920		
(24)	HCFC-225cb 1,3-dichloro-1,2,2,3,3-pentafluoropropane (CF ₂ CF ₂ CF ₂ CHClF)	2903.45 920		
(25)	HCFC-226 Chlorohexafluoropropane (C ₃ HF ₆ Cl)	2903.45 999		
(26)	HCFC-231 Pentachlorofluoropropane (C ₃ H ₂ F ₅ Cl)	2903.45 999		
(27)	HCFC-232 Tetrachlorodifluoropropane (C ₃ H ₂ F ₄ Cl ₂)	2903.45 999		
(28)	HCFC-233 Trichlorotrifluoropropane (C ₃ H ₂ F ₅ Cl ₃)	2903.45 999		
(29)	HCFC-234 Dichlorotetrafluoropropane (C ₃ H ₂ F ₄ Cl ₂)	2903.45 999		
(30)	HCFC-235 Chloropentafluoropropane (C ₃ H ₂ F ₅ Cl)	2903.45 930		
(31)	HCFC-241 Tetrachlorofluoropropane (C ₃ H ₃ FCl ₄)	2903.45 999		
(32)	HCFC-242 Trichlorodifluoropropane (C ₃ H ₃ F ₂ Cl ₃)	2903.45 999		
(33)	HCFC-243 Dichlorotrifluoropropane (C ₃ H ₃ F ₃ Cl ₂)	2903.45 999		
(34)	HCFC-244 Chlorotetrafluoropropane (C ₃ H ₃ F ₄ Cl)	2903.45 999		
(35)	HCFC-251 Trichlorofluoropropane (C ₃ H ₄ FCl ₃)	2903.45 999		
(36)	HCFC-252 Dichlorodifluoropropane (C ₃ H ₄ F ₂ Cl ₂)	2903.45 999		
(37)	HCFC-253 Chlorotrifluoropropane (C ₃ H ₄ F ₃ Cl)	2903.45 999		
(38)	HCFC-261 Dichlorofluoropropane (C ₃ H ₅ FCl ₂)	2903.45 999		
(39)	HCFC-262 Chlorodifluoropropane (C ₃ H ₅ F ₂ Cl)	2903.45 999		
(40)	HCFC-271 Chlorofluoropropane (C ₃ H ₆ FCl)	2903.45 999		

Made 19 June 2012

[16 Sulit KE.HT(96)669/15-36 SK.33; Perb. 0.9060/18 Jld.27(SK.5); PN(PU2)338C/XVI]

DATO' SERI AHMAD HUSNI MOHAMAD HANADZLAH
Second Minister of Finance

Figure 1.3: Prohibition of Import under Customs Act 1967

1.2.3 Prohibition On Export

The Customs (Prohibition of Exports) (Amendment) (No.3) Order 2013P.U (A) 386 was gazetted on 31st December 2013 and came into force on 1st January 2014

Approval Permit (AP) for forty (40) types of HCFC listed in the Order will be processed and approved by DOE through electronic permit system (e-permit).



31 Disember 2013
31 December 2013
P.U. (A) 386

WARTA KERAJAAN PERSEKUTUAN

FEDERAL GOVERNMENT
GAZETTE

PERINTAH KASTAM (LARANGAN MENGENAI EKSPORT)
(PINDAAN) (NO. 3) 2013

CUSTOMS (PROHIBITION OF EXPORTS)
(AMENDMENT) (NO. 3) ORDER 2013



DISIARKAN OLEH/
PUBLISHED BY
JABATAN NEGARA/
ATTORNEY GENERAL'S CHAMBERS

P.U. (A) 386

CUSTOMS ACT 1967

CUSTOMS (PROHIBITION OF EXPORTS) (AMENDMENT) (NO. 3) ORDER 2013

IN exercise of the powers conferred by subsection 31(1) of the Customs Act 1967 [Act 235], the Minister makes the following order:

Citation and commencement

1. (1) This order may be cited as the Customs (Prohibition of Exports) (Amendment) (No. 3) Order 2013.

(2) This Order comes into operation on 1 January 2014.

Amendment of Second Schedule

2. The Customs (Prohibition of Exports) Order 2012 [P.U. (A) 491/2012] is amended in the Second Schedule by inserting after item 25 and the particulars relating to it the following item:

(1) Item No.	(2) Description of Goods	(3) Heading/ Subheading	(4) Destination	(5) Ministry/ Department/ Statutory Body Issuing Licence
*26.	Hydrochlorofluorocarbons gas (HCFCs) covered under Montreal Protocol, Annex C - Group 1:		All Countries	Department of Environment
(1)	HCFC-21 Dichlorodifluoromethane (CH ₂ Cl ₂)	2903.77 510		
(2)	HCFC-22 Chlorodifluoromethane (CHF ₂ Cl)	2903.71 000		
(3)	HCFC-31 Chlorofluoromethane (CH ₃ FCl)	2903.77 590		
(4)	HCFC-121 Tetrachlorodifluoroethane (C ₂ HFC ₄)	2903.77 660		
(5)	HCFC-122 Trichlorodifluoroethane (C ₂ H ₂ F ₃ Cl)	2903.77 610		
(6)	HCFC-123 Dichlorotrifluoroethane (C ₂ HFC ₃)	2903.72 000		

(7)	HCFC-123 2,2-dichloro-1,1,1-trifluoroethane (CHCl ₂ CF ₃)	2903.72 000		
(8)	HCFC-124 Chlorotetrafluoroethane (C ₂ H ₂ F ₄ Cl)	2903.77 620		
(9)	HCFC-124 2-chloro-1,1,1,2-tetrafluoroethane (CHFClCF ₃)	2903.77 620		
(10)	HCFC-131 Trichlorofluoroethane (C ₂ H ₃ FC ₃)	2903.77 690		
(11)	HCFC-132 Dichlorodifluoroethane (C ₂ H ₂ F ₂ Cl ₂)	2903.77 690		
(12)	HCFC-133 Chlorotrifluoroethane (C ₂ H ₂ F ₃ Cl)	2903.77 690		
(13)	HCFC-141 Dichlorofluoroethane (C ₂ H ₃ FC ₂)	2903.73 000		
(14)	HCFC-141b 1,1-dichloro-1-fluoroethane (CH ₃ CFCl ₂)	2903.77 630		
(15)	HCFC-142 Chlorodifluoroethane (C ₂ H ₃ F ₂ Cl)	2903.74 000		
(16)	HCFC-142b 1-chloro-1,1-difluoroethane (CH ₃ CF ₂ Cl)	2903.77 690		
(17)	HCFC-151 Chlorofluoroethane (C ₂ H ₄ FC ₂)	2903.77 690		
(18)	HCFC-221 Hexachlorofluoropropane (C ₃ HFCl ₆)	2903.77 999		
(19)	HCFC-222 Pentachlorodifluoropropane (C ₃ H ₂ F ₂ Cl ₅)	2903.77 999		
(20)	HCFC-223 Tetrachlorotrifluoropropane (C ₃ H ₂ F ₃ Cl ₄)	2903.77 999		
(21)	HCFC-224 Trichlorotetrafluoropropane (C ₃ H ₂ F ₄ Cl ₃)	2903.77 910		
(22)	HCFC-225 Dichloropentafluoropropane (C ₃ H ₂ F ₅ Cl ₂)	2903.75 000		
(23)	HCFC-225ca 1,1-dichloro-2,2,3,3,3-pentafluoropropane (CF ₂ CF ₂ CFCl ₂)	2903.75 000		
(24)	HCFC-225cb 1,3-dichloro-1,2,2,3,3-pentafluoropropane (CF ₂ CF ₂ CF ₂ CFCl)	2903.75 000		
(25)	HCFC-226 Chlorohexafluoropropane (C ₃ HFC ₆)	2903.77 999		
(26)	HCFC-231 Pentachlorofluoropropane (C ₃ H ₂ FCl ₅)	2903.77 999		
(27)	HCFC-232 Tetrachlorodifluoropropane (C ₃ H ₂ F ₂ Cl ₄)	2903.77 999		
(28)	HCFC-233 Trichlorotrifluoropropane (C ₃ H ₂ F ₃ Cl ₃)	2903.77 999		
(29)	HCFC-234 Dichlorotetrafluoropropane (C ₃ H ₂ F ₄ Cl ₂)	2903.77 999		
(30)	HCFC-235 Chloropentafluoropropane (C ₃ H ₂ F ₅ Cl)	2903.77 920		
(31)	HCFC-241 Tetrachlorofluoropropane (C ₃ H ₂ FCl ₄)	2903.77 999		
(32)	HCFC-242 Trichlorodifluoropropane (C ₃ H ₂ F ₂ Cl ₃)	2903.77 999		
(33)	HCFC-243 Dichlorotrifluoropropane (C ₃ H ₂ F ₃ Cl ₂)	2903.77 999		
(34)	HCFC-244 Chlorotetrafluoropropane (C ₃ H ₂ F ₄ Cl)	2903.77 999		
(35)	HCFC-251 Trichlorofluoropropane (C ₃ H ₄ FCl ₃)	2903.77 999		
(36)	HCFC-252 Dichlorodifluoropropane (C ₃ H ₄ F ₂ Cl ₂)	2903.77 999		
(37)	HCFC-253 Chlorotrifluoropropane (C ₃ H ₄ F ₃ Cl)	2903.77 999		
(38)	HCFC-261 Dichlorofluoropropane (C ₃ H ₅ FCl ₂)	2903.77 999		
(39)	HCFC-262 Chlorodifluoropropane (C ₃ H ₅ F ₂ Cl)	2903.77 999		
(40)	HCFC-271 Chlorofluoropropane (C ₃ H ₆ FCl)	2903.77 999		

Made 26 December 2013
[Sulit KE.HT(96)669/15-36 Klt.17 SK.32; Perb.0.9060/18 Jld.31(SK.1); PN(PU2)338C/XXI]

DATO' SERI AHMAD HUSNI BIN MOHAMAD HANADZLAH
Second Minister of Finance

Figure 1.4: Prohibition of Export under Customs Act 1967

1.2.4 Who Will Be Affected

- a) Manufacturer / Producer of air conditioning system for buildings and vehicles or instruments.
- b) Air-conditioning and refrigeration service contractor
- c) Building owners with chiller or refrigeration system
- d) Automotive air conditioning workshop
- e) All refrigerant handlers
- d) Department of Environment

1.3 THE STRATOSPHERE AND OZONE LAYER

1.3.1 The Stratosphere

Stratosphere stretches 7-30 miles above earth surface. The ozone layer is mainly found at the lower portion of the stratosphere from approximately 20 to 30 kilometers above sea level.

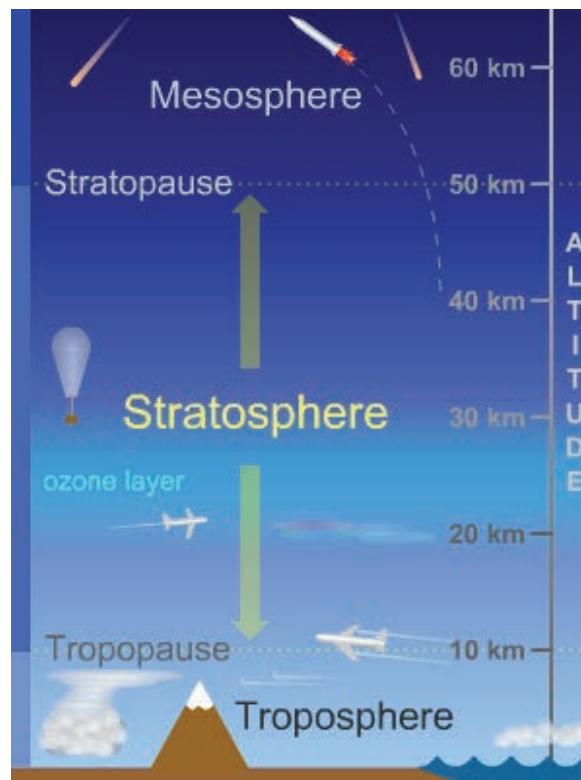


Figure 1.5: Stratosphere

1.3.2 The Ozone Layer

Although the ozone is a very small part of our atmosphere, its presence is vital to human well-being. It provides a protective shield that absorbs some of the potentially harmful ultraviolet (UV) radiation from the sun that can cause skin cancer and damage vegetation.

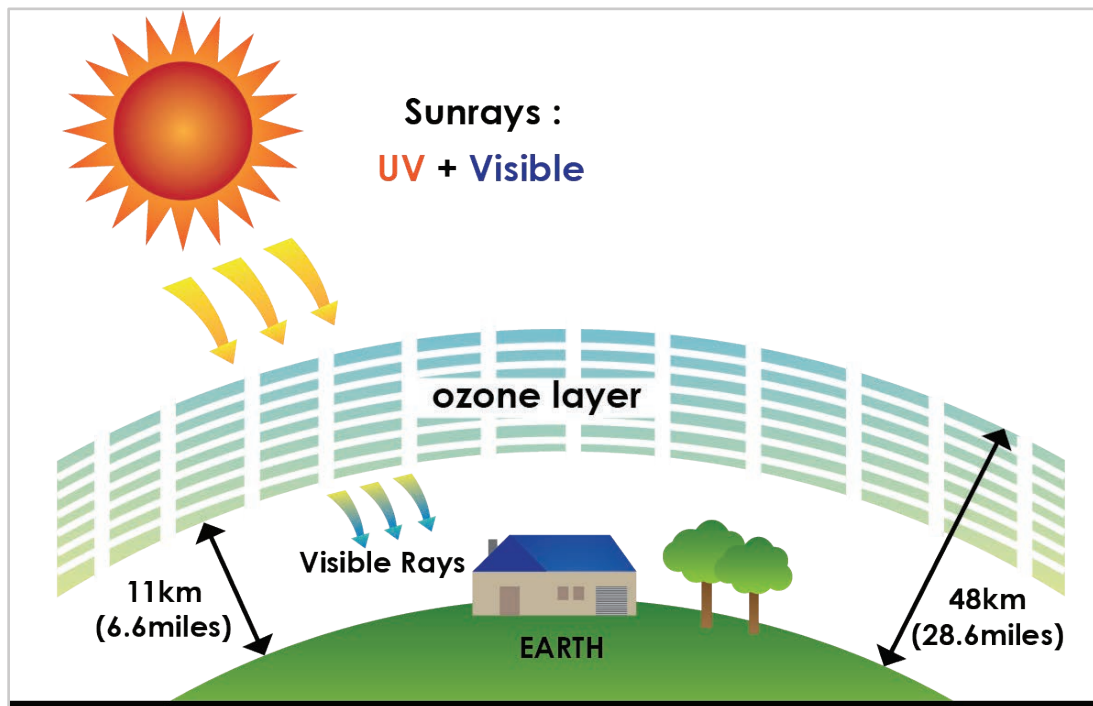


Figure 1.6: Ozone Layer

1.3.3 What Is Ozone

Ozone molecules are made of three atoms of oxygen. The ozone molecules together create an ozone layer in the stratosphere, in the upper atmosphere. The ozone layer is a thin invisible shield that blocks the Sun's harmful ultraviolet radiation and is therefore vital for all life on Earth. Ozone molecules are constantly formed and destroyed in the layer. The total amount, however, remains relatively stable. Ozone can be produced naturally in thunderstorms by the electrical charges from lightning. In the ozone layer, ozone molecules are created by:

1. Sun's energy breaking apart oxygen molecules so an (O_2), split apart into two single oxygen atoms (O and O)
2. One of these single oxygen atoms combined with an oxygen molecules to form an ozone molecules ($O + O_2 \rightarrow O_3$)

1.3.4 Ozone Formation

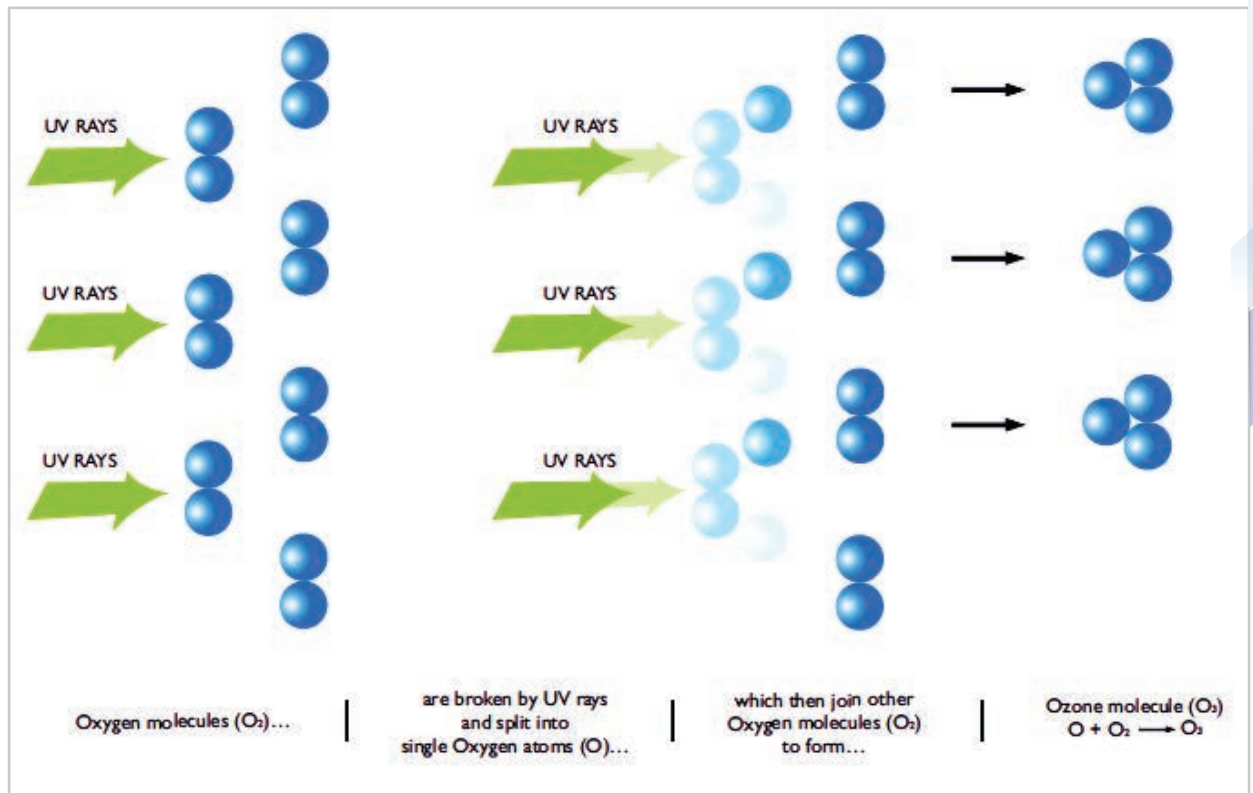


Figure 1.7: Ozone Formation

1.3.5 The Role Of The Ozone Layer

Ozone layer is vitally important to life because it absorbs biologically harmful ultraviolet (UV) radiation coming from the sun. Apart from the visible rays, the sun radiation reaching the earth contains ultraviolet (UV) rays which are harmful to life on earth. The thickness of Ozone layer can act as filter to screens out almost all the harmful ultraviolet from reaching earth surface.

Scientists have classified UV radiation into 3 types: UV-A, UV-B and UV-C.

- UV-A** : is not filtered at all and it is harmless
- UV-B** : is partially filtered by the Ozone layer, and these rays have severe impact on human health and environment
- UV-C** : is lethal, but all the rays are absorbed by the Ozone

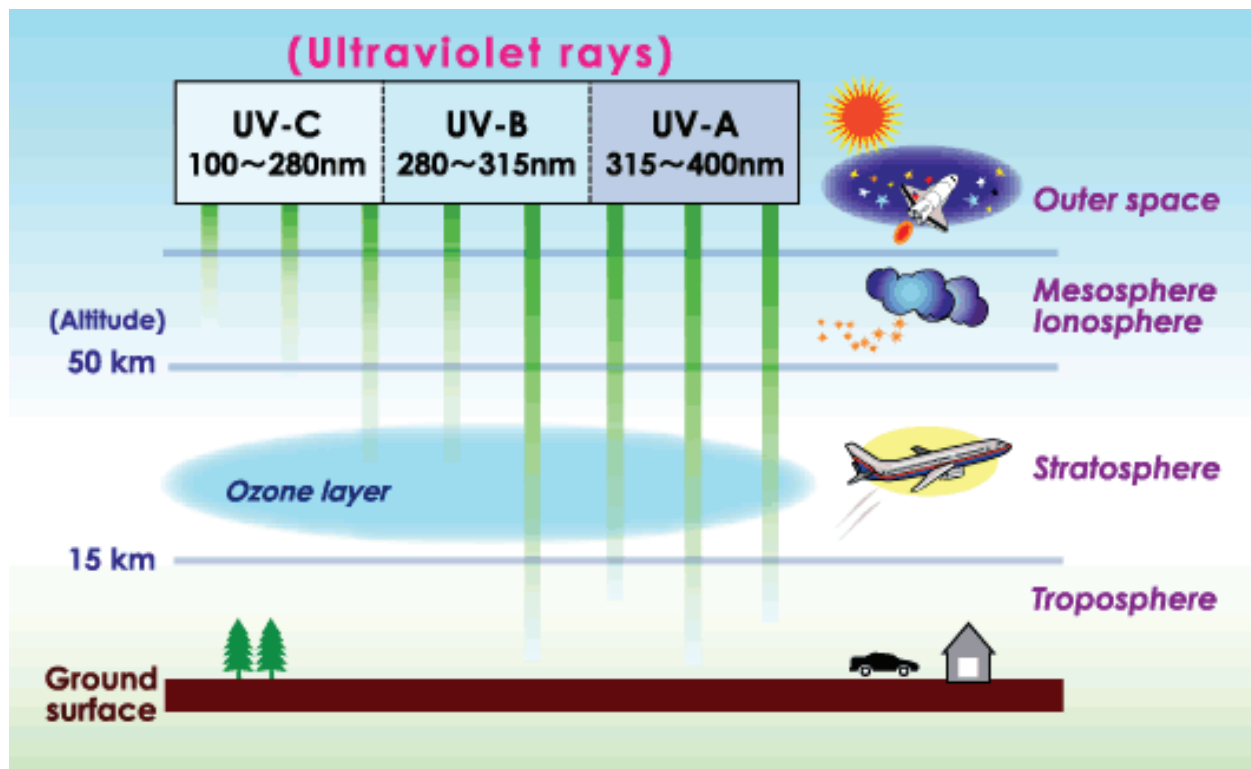


Figure 1.8: Role of Ozone Layer

1.3.6 Depletion Of The Ozone Layer

In the past 60 years, human activity has contributed to the deterioration of the ozone layer. In the 1970s, scientists discovered significant levels of ozone depletion in the stratosphere, producing a phenomenon commonly known as the 'Ozone Hole'.

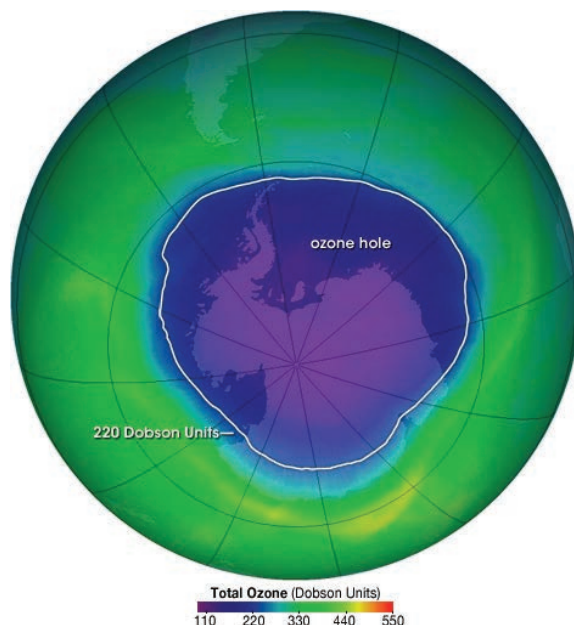


Figure 1.9: Ozone Hole

1.3.7 Consequences Of Damaging – The Ozone Layer

Loss of natural shield of Ozone layers, the harmful UV-B radiation reach earth surface and causes a series of bad effects on all living organisms' on mother earth. Exposure to higher amounts of UV radiation could have serious impacts on human beings, animals and plants, following are some examples:

a) Damage to marine life

- Planktons (microorganisms on the surface layer of oceans) are threatened by increased UV radiation. Planktons are the first organisms in aquatic food chains. Their survival is greatly affecting the balance of marine ecosystem.
- Decrease in plankton could disrupt the fresh and saltwater food chains, and may lead to extinction of some species in aquatic life.
- Loss of biodiversity in our oceans, rivers and lakes also will reduce fish yields for commercial fishing.

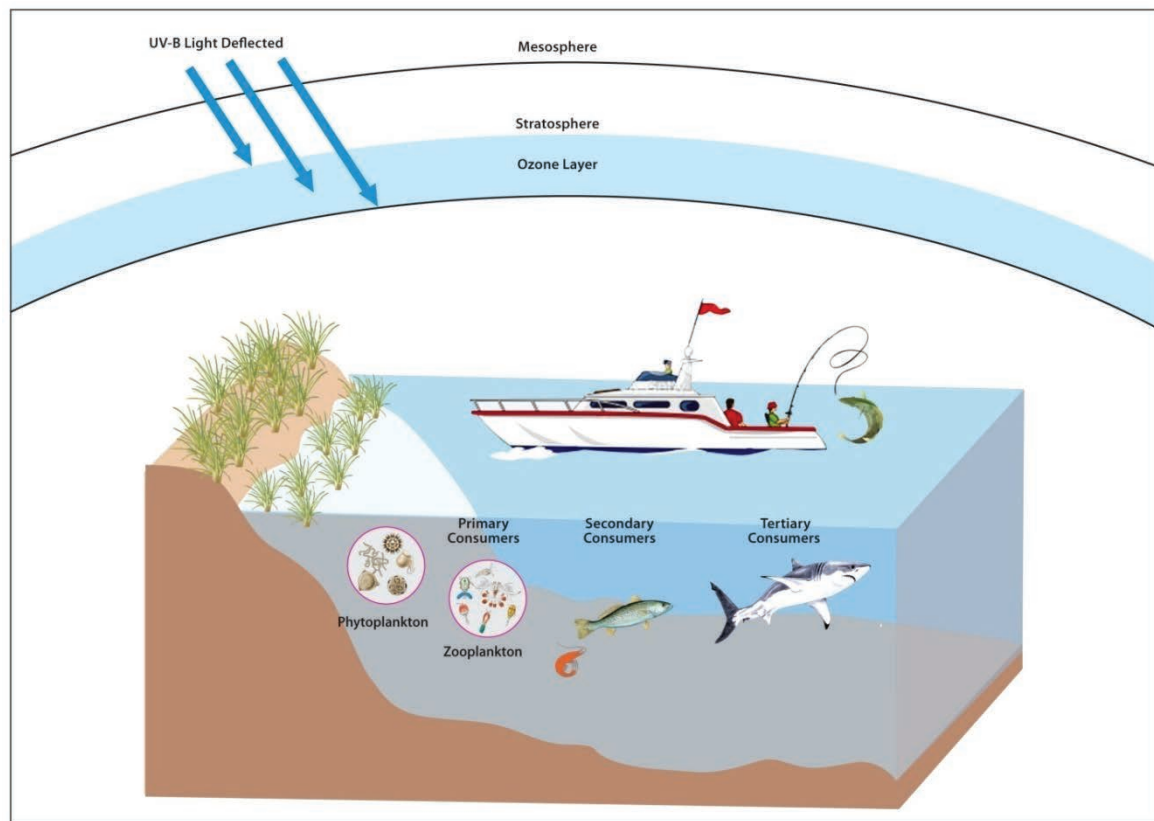


Figure 1.10: Marine Food Chain

b) Decrease of grain and crop production

Several of the world's major crop species are particularly vulnerable to increased UV rays which resulting in reduced growth and diseases. These plant species include wheat, rice, barley, oats, corn, soybeans, peas, tomatoes, cucumbers, cauliflower, broccoli and carrots



Figure 1.11: Crop Diseases

c) **Harm to human health**

- Skin cancer
- Cataracts, blindness and other eye diseases: UV radiation can damage several parts of the eye, including the lens, cornea, retina and conjunctiva
- Weakening of the human immune system (immunosuppression).



Figure 1.12: Skin cancer



Figure 1.13: With normal eye (left) and with cataract (right)



Figure 1.14: Normal human skin (left) and skin suffers from weak immune system (right)

d) **Degrading of materials**

- Wood, plastic, rubber, fabrics and many construction materials are degraded rapidly by UV radiation.



Figure 1.15: Rapid Material Degradation

1.4 OZONE DEPLETING SUBSTANCES (ODS)

The chemicals that destroy stratospheric ozone layer are called ozone depleting substances or ODS. These chemicals are man-made. The main types are:

1.4.1 Chlorofluorocarbons (CFC)

CFC is a substance which consists of the atoms chlorine, fluorine and carbon. CFC was created in 1928 as a safe, stable, nonflammable, low-toxicity, and inexpensive product. Over time, CFCs were used as refrigerants, (in refrigerators, air conditioners) as propellants in aerosol sprays, as solvents, foam-blowing agents, and in other smaller applications.



Figure 1.16: Example of CFC

1.4.2 Hydrochlorofluorocarbons (HCFC)

HCFC is a substance which consists of the atoms of hydrogen, chlorine, fluorine and carbon. It is widely used in refrigeration, foam, solvent, aerosol and firefighting products as a substitute for CFCs in the 1990s. HCFCs are also used as a raw material in the production of other chemical products. Although having considerably lower ozone depleting potential than CFCs, many HCFCs have high global warming potential; some of them have GWP up to 2000 times that of carbon dioxide.



Figure 1.17: Example of HCFC

1.4.3 Halon

Halons are used in fixed and portable fire extinguishers



Figure 1.18: Example of Halon fire extinguishers

1.4.4 Methyl Bromide

Methyl Bromide use in soil fumigation, quarantine pre-shipment treatment and maintenance of grass at golf course



Figure 1.19: Grass treatment using Methyl Bromide

1.4.5 Source Of Ozone Depleting Substances

The source of Ozone Depleting Substances (ODS) was contributed from a variety of applications. For example:

- HCFCs are being used as the refrigerant in air-conditioners and other cooling appliances;
- HCFC is the blowing agent in foam manufacturing industry;
- Solvent for cleaning operations in precision industries;
- In aerosol-based cosmetic and health products;
- In making of fire extinguishing systems;
- Disinfection agent in quarantine or pre-shipment applications

a) Air-conditioning in building and transport air-conditioner



Figure 1.20: Residential air-conditioning systems



Figure 1.21: Air-conditioning systems for transportation

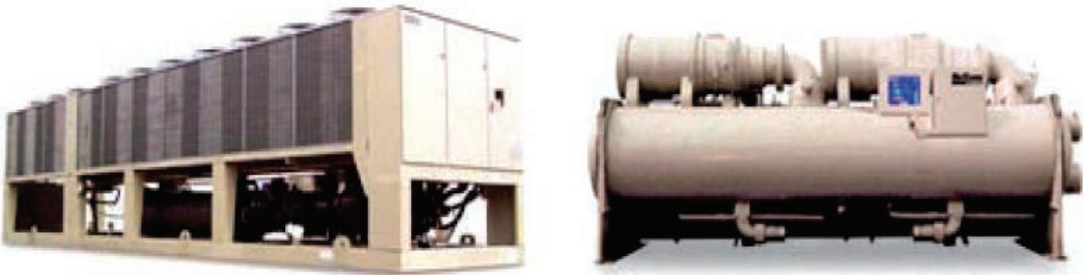


Figure 1.22: Commercial central air-conditioning systems

b) Refrigeration



Figure 1.23: Refrigerator and commercial refrigeration cabinet

c) Fire extinguisher



Figure 1.24: Fire extinguisher

d) Aerosol



Figure 1.25: Aerosol

e) Foam

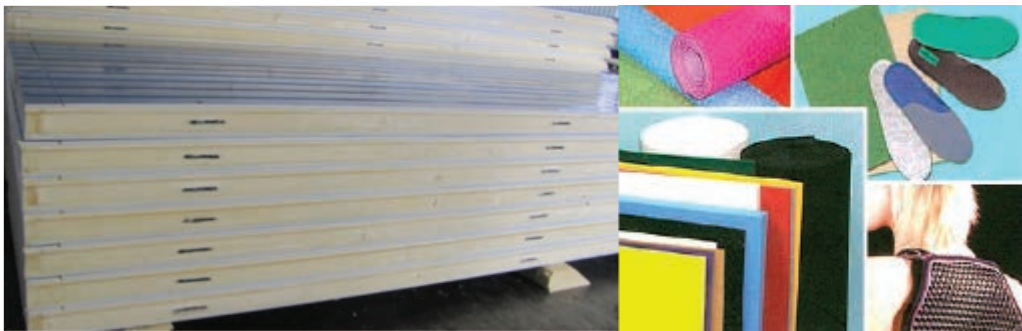


Figure 1.26: Sandwich panel (left) and shoe sole (right)

1.4.6 Ozone Depletion Potential (ODP)

Ozone Depleting Potential (ODP) is the measure of the ozone depleting capability of a refrigerant compared to that of CFC-11 as the baseline ODP of 1.0.

Table 1.1: Ozone Depletion Potential Measure

Refrigerant		Atmospheric Lifetime (Years)	ODP	GWP (100 Year)
CFC (Phase Out)	CFC-11 (Baseline ODP)	50	1	4000
	CFC-12	102	1	10900
HCFCs	HCFC-22	13.3	0.055	1820
	HCFC-123	1.4	0.02	93
	HCFC-141b	9.4	0.11	630
HFCs	HFC-134a	14.6	0	1300
	HFC-245fa	7.3	0	820
	R-32	-	0	675
HCs	HC-290 (Propane)	-	0	3
	R-1270 (Propylene)	-	0	<2
HFC Blends	R-404A	-	0	3260
	R-407A	-	0	1770
	R-407C	-	0	1530
	R-410A	-	0	1730
Ammonia	R-717	-	0	<1
CO2	R-744	-	0	1

1.5 OZONE DESTRUCTION PROCESS

Ozone is very stable molecule; it does not react easily with other substances in the atmosphere. Hence, the ozone molecules will raise and accumulate at the upper atmosphere.

CFCs are also very stable molecules that only exposure to strong UV radiation breaks them down. When that happens, the CFC molecule releases its chlorine atom which is then become a free radical atom to attack the ozone molecule and causing destruction of ozone layers. The **figure 1.27** below shows the Ozone Destruction Process.

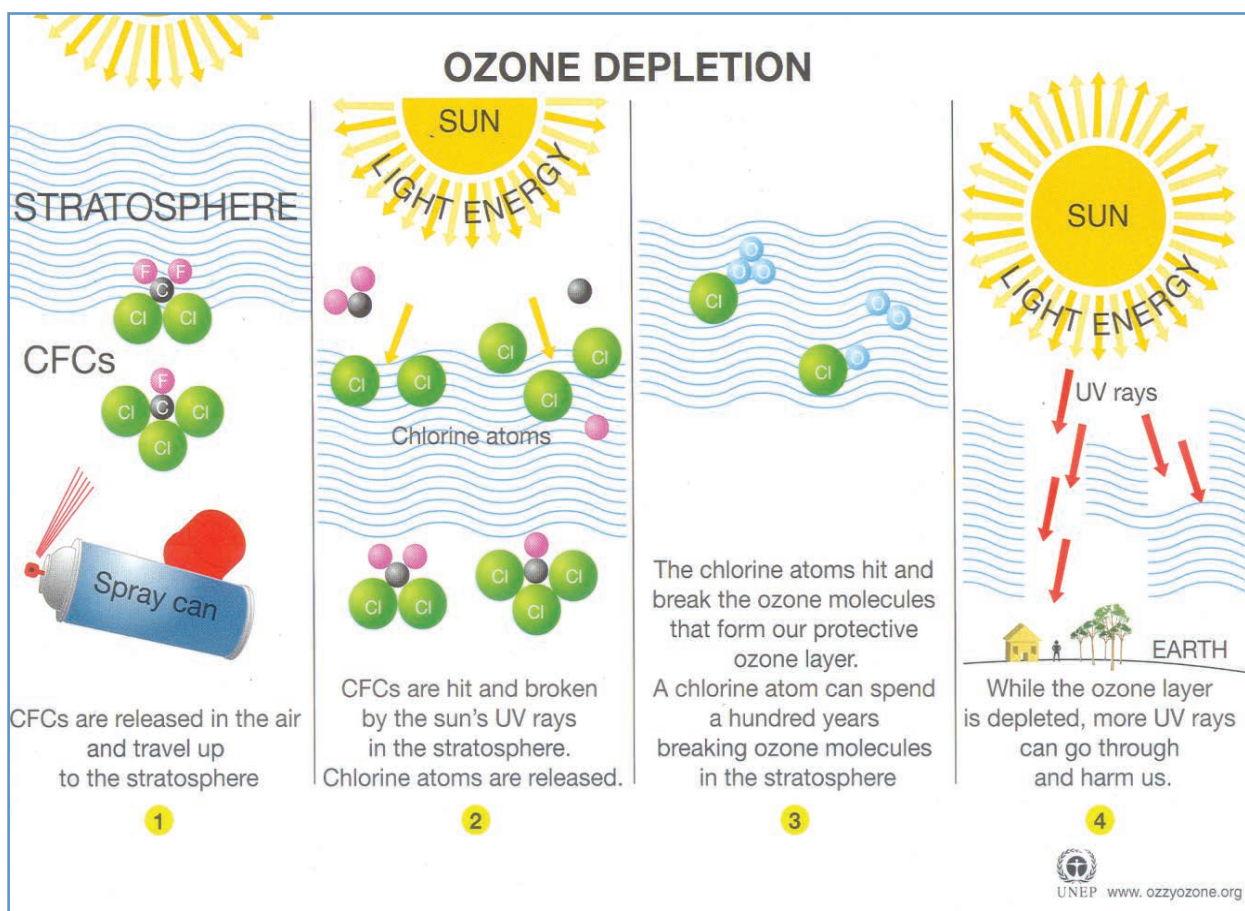


Figure 1.27: Ozone Destruction Process

The ODS can be released into the air during their manufacture, from leakage of equipments and when appliances containing ODS are abandoned or not disposed of properly. Hence, it is vital important to systematically recover and recycle all the ODS appliances to minimize the bad effect on Ozone layers.

1.6 CONTRIBUTION TO CLIMATE CHANGE FROM AIR CONDITIONER

The energy derived from fossil fuel has direct contribution to the emissions of Green House Gases (mainly CO₂).

Energy consumptions of the refrigeration and air conditioning equipments are significant. This indirect contribution of thermodynamics systems to the greenhouse effect is significantly higher than the direct contribution associated with the rejection of HCFCs. Direct & indirect contributions are both taken into account in a coefficient called TEWI (Total Equivalent Warming Impact).

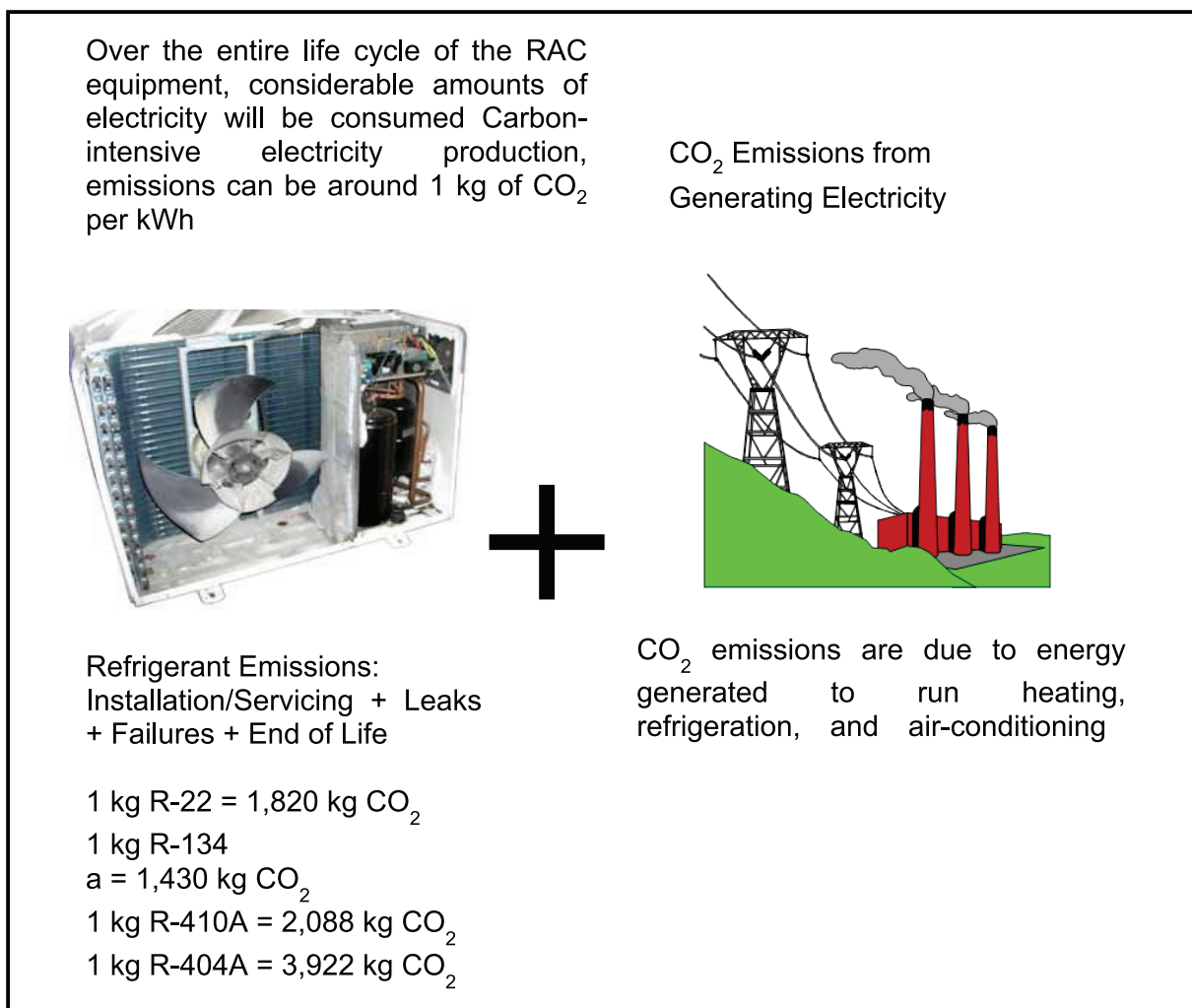


Figure 1.28: Contribution of Air-Conditioner to Climate Change

1.6.1 Global Warming Potential (GWP)

Global-warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. A GWP is calculated over a specific time interval, commonly 20, 100 or 500 years. GWP is expressed as a factor of carbon dioxide (whose GWP is standardized to 1). For example, the 20 year GWP of methane is 86, which means that if the same mass of methane and carbon dioxide were introduced into the atmosphere, that methane will trap 86 times more heat than the carbon dioxide over the next 20 years.

1.6.2 Global Warming

Another important environmental impact of refrigerants is relating to the phenomenon of Global Warming also known as “Greenhouse Effect”.

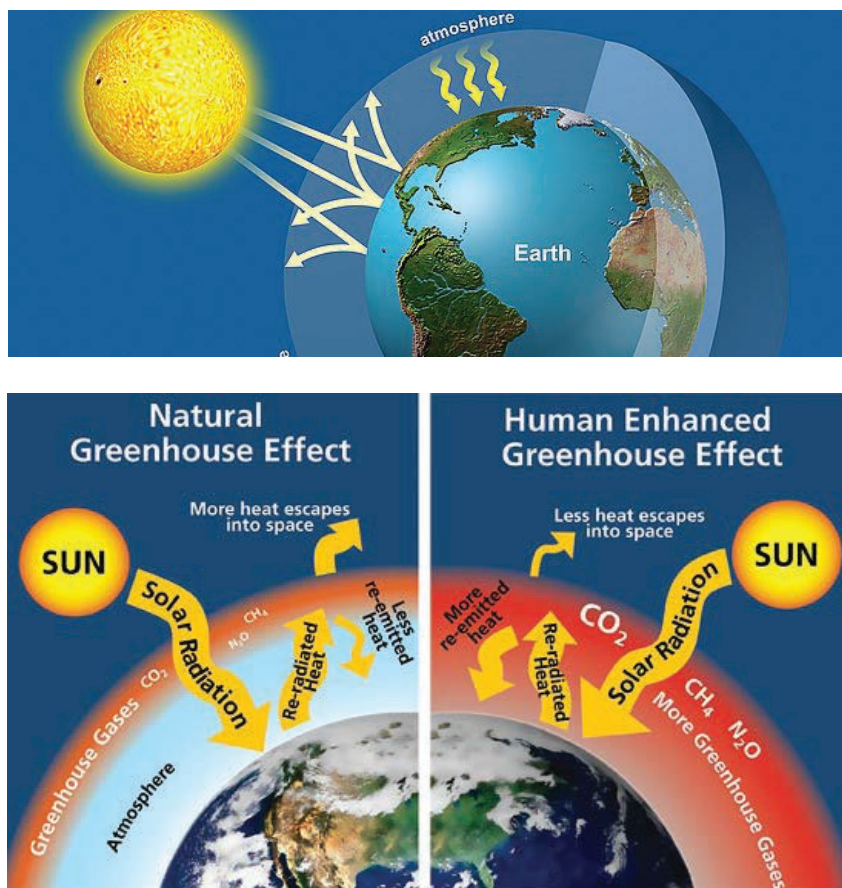


Figure 1.29: Greenhouse effect

A limited amount of Global Warming is necessary to sustain life on the earth. However, some of the greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO), sulfur hexafluoride (SF_6), Halocarbons and perfluorocarbons (PFCs), essentially emitted through the human activities, has cause accelerated global warming which threatened all living things in earth.

In the last hundred years, the mean global temperature has increased by 0.3 to 0.6°C . As the result, the sea water thermally expands and large area of ice particularly in North Pole has melted. This has leads to the rising of sea level. An increase of 4-10 inches in global sea level been reported in last 100 years. This also affects the rainfall pattern on certain part of the world and thereby affecting the balance of whole ecosystem.

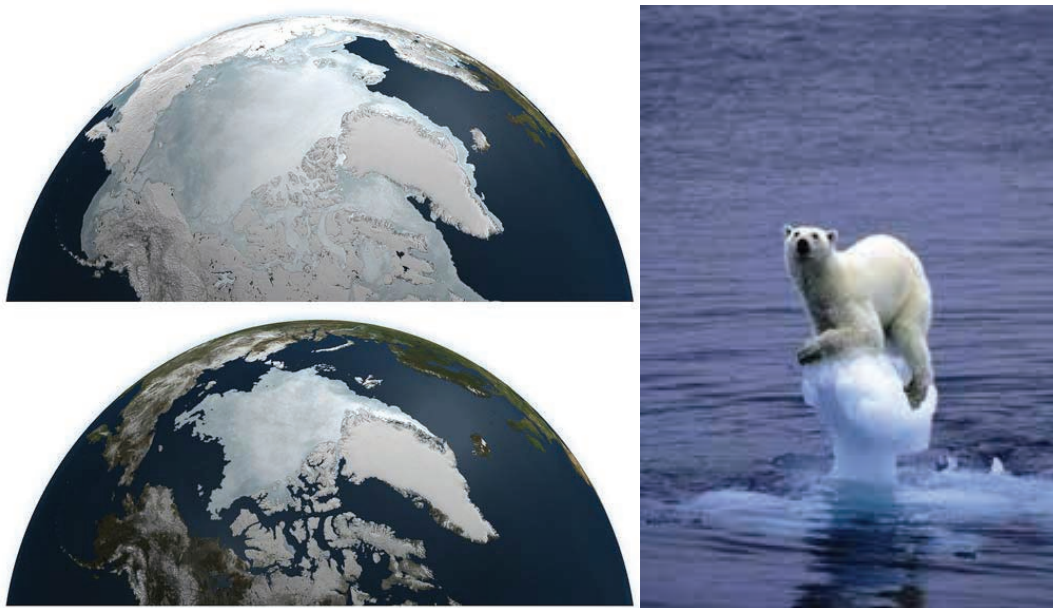


Figure 1.30: Ice mass loss

1.7 ENVIRONMENT DEGRADATION AND MITIGATION

HCFC and HFC refrigerants are known as the source of global warming, alongside with other greenhouse gases like carbon dioxide (CO₂), methane (CH₄), nitrous oxide (NO), sulphurhexafluorides (SF₆) and perfluorocarbons (PFCs). Thus, the use of these refrigerants must be in a proper and responsible manner. Our decision today may give a great impact to the future generations.

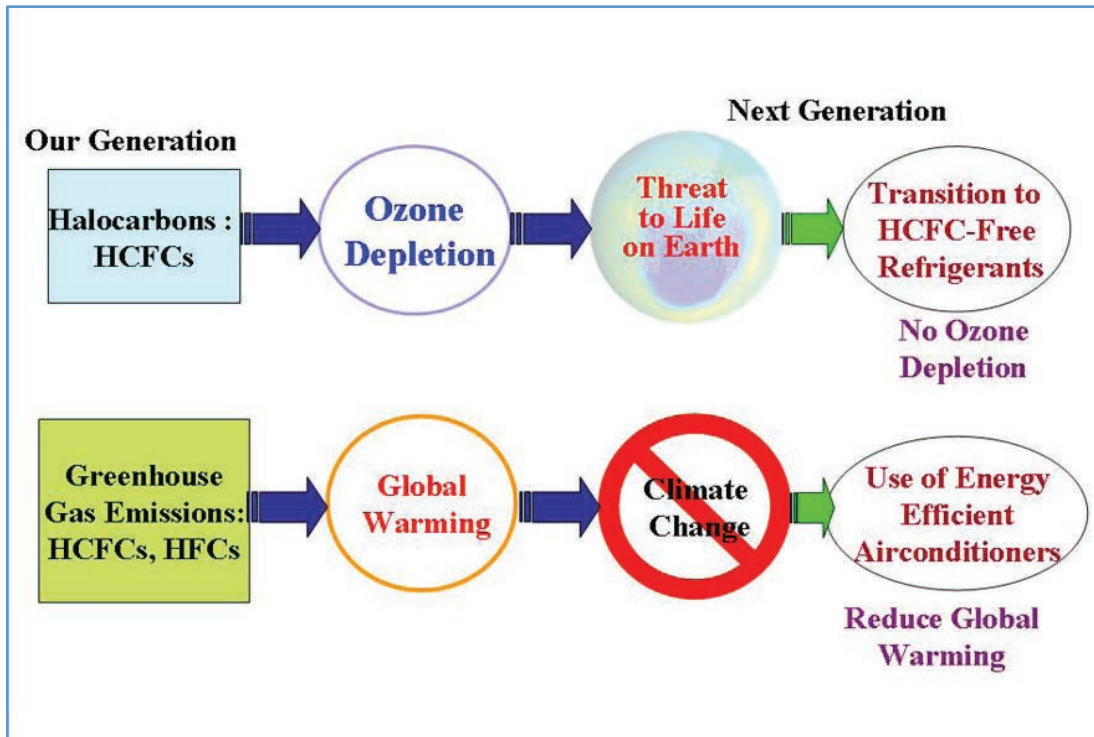


Figure 1.31: Environment Degradation and Mitigation

1.8 THE MONTREAL PROTOCOL

The Montreal Protocol is an international treaty. It regulates the production and use of CFCs, HCFCs, halons, methyl chloroform, methyl bromide and carbon tetrachloride.

1.8.1 Montreal Protocol Ratifications

As of January 2014, 197 countries ratified the Montreal Protocol on the Substances that Deplete the Ozone Layer. Malaysia ratified the Protocol on 29 August 1989 and its amendments are shown in **Table 1.2**.

Table 1.2: Status of Ratification of Montreal Protocol

MALAYSIA : RATIFICATION STATUS	
VIENNA CONVENTION	29 AUGUST 1989
MONTREAL PROTOCOL	29 AUGUST 1989
1990 LONDON AMENDMENT	16 JUNE 1993
1992 COPENHAGEN AMENDMENT	05 AUGUST 1993
1992 MONTREAL AMENDMENT	26 OCTOBER 2001
1999 BEIJING AMENDMENT	26 OCTOBER 2001

1.8.2 Adjustments To The Montreal Protocol

At the 19th Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer held on September 2007 in Montreal, an agreement was reached to adjust the Montreal Protocol's schedule to accelerate the phase-out of production and consumption of HCFCs.

Table 1.3: The new schedule targets in phase-out of HCFCs to be achieved by Article 5 Parties.

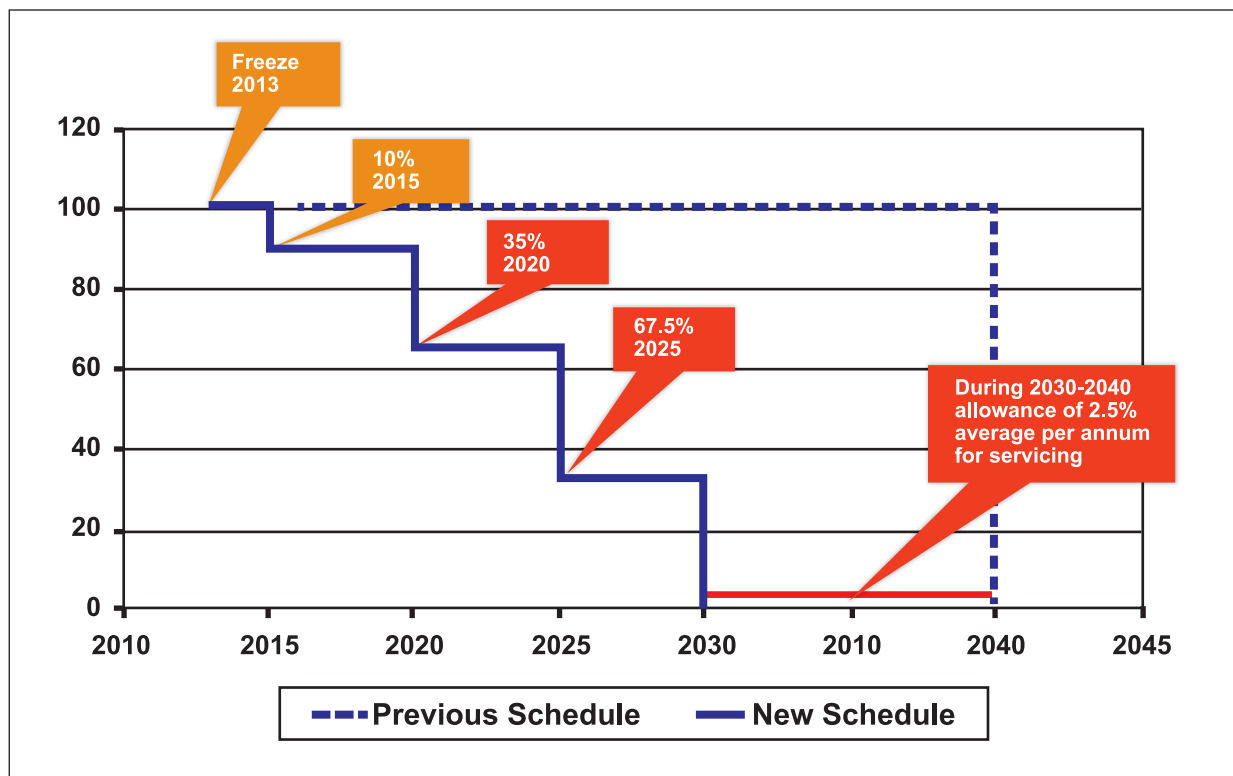


Table 1.4: Malaysia's Target for Compliance of HCFCs Phase-Out

Target	Maximum Consumption Level (ODP tonnes)
From 01 January 2013	515.8
From 01 January 2015	464.2
From 01 January 2020	335.3
From 01 January 2025	167.6
From 01 January 2030	Strictly for servicing 12.89

1.8.3 Policies and Regulations of HCFC Phase-out Management Plan (HPMP)

In order to achieve the phase-out target, Malaysia has developed policies and regulatory actions as shown in **Table 1.5**.

Table 1.5: Key Planned Regulatory Actions of HPMP Malaysia

YEAR	PLANNED REGULATORY ACTION
2012	Establishment of Approved Permit (AP) import quota system based on HCFC Baseline (515.08 ODPT – average consumption for 2009/2010)
	Amend existing regulations for controlling use, imports, manufacturing, assembly and installation of products containing HCFCs
2013	Licensing re-export of HCFCs
	Enforcement of Approved Permit (AP) quota system
	Prohibition of establishment and expansion of new HFCF-based manufacturing capacities
	Establish incentive system for promoting use of alternatives to HCFCs
	Certification of technicians for handling HCFCs
2015	Prohibition of manufacturing, assembly and import of HCFC-based air conditioners (2.5 HP and lower) for use in Malaysia
	Prohibit imports of polyols pre-blended with HCFCs
	Include HCFCs in the list of restricted gases
2020	Prohibit the manufacture, assembly and import of all products and equipment using HCFC (except for essential use)
	Prohibit HCFC 141b as blowing agent
	Prohibit the use of HCFC in the manufacturing and installation of new fire extinguishing systems
2025	No more installation of new products and equipment using HCFCs

CHAPTER 2

ALTERNATIVES TO HCFC AND THEIR CHARACTERISTICS

CHAPTER 2

ALTERNATIVES TO HCFC AND THEIR CHARACTERISTICS

2.1 INTRODUCTION

Under the Montreal Protocol the phase-out of HCFCs is making way for new ozone-friendly alternatives. These are primarily hydrofluorocarbons (HFCs), Hydrocarbons (HCs), Ammonia, carbon dioxide (CO₂) and other natural refrigerants.

Refrigerant is a chemical used in a cooling mechanism, such as an air conditioner and refrigerator, as the heat carrier which changes from vapour to liquid and back to vapour in the refrigeration cycle. It is important to consider the operating pressures in both the low and high sides of the system.

2.2 TYPES OF REFRIGERANT

In table 2.1 shown the types of refrigerant, refrigerant substances, Ozone Depleting Potential (ODP), Global Warming Potential (GWP), colour codes and their applications in RAC sector.

Table 2.1: Types of Refrigerant

Refrigerant Substance	Designation	ODP	GWP	Colour code	Typical Uses
Chlorofluorocarbons (CFC)					
Trichlorofluoromethane	R-11	1	4000	Orange	Centrifugal compressors. Large commercial plants.
Dichlorodifluoromethane	R-12	1	10900	White	Reciprocating compressors. Small units (e.g., refrigerators).
Hydrochlorofluorocarbons (HCFC)					
Chlorodifluoromethane	R-22	0.05	1820	Light green	Widely used AC&R, heat pumps.
Dichlorotrifluoroethane	R-123	0.02	93	Light blue grey	Industrial chiller, replacement for R11
Dichlorofluoroethane	R-141b	0.11	630		Solvent and Foam Sector
Hydrofluorocarbons (HFC)					
Tetrafluoroethane	R-134a	0	1300	Light blue	Automobiles, domestic appliances, heat pumps.
Pentafluoropropane	R-245a	0	1030		Centrifugal chillers
Tetrafluoropropane	R-1234yf	0	4		Potential replacement for HFC-134a
Refrigerant Azeotropic Mixtures					
R125+R143a+R134a	R-404A	0.04	3300	Orange	Low temperature refrigeration
R32+R125+R134a	R-407C	0	1610	Brown	Popular blend with higher critical temperature than R-410A
R32+R125	R-410A	0	1725	Rose	Popular blend being used in new AC equipment instead of R-22
R115+R22.	R-502	0.28	4.1	Light purple	Supermarket frozen food cabinets with high pressure apps.
R134a+R125	R-507	0	3300	Agua blue	Low temperature refrigeration. Potential replacement for-R502
Hydrocarbon (HC)					
Propane	R-290	0	20		Commercial refrigerators
Isobutane	R-600a	0	4		Domestic refrigerators

Note: The designation of a refrigerant may use the class or-"R" in front of its numeral, e.g., CFC-11, or-R-11, or-both, e.g., HCFC R-22

Sources: American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) site: www.ashrae.org/technology/page/1933

2.2.1 Pure Refrigerant

Pure refrigerant has single component type and does not change composition when boiling or condensing. Some examples of pure refrigerant are R-12, R-22, and R-134a. Details of characteristics and properties of these refrigerants are shown in **ANNEX-A**.

2.2.2 Synthetic Refrigerant

A) Chlorofluorocarbons (CFC)

Chlorofluorocarbon molecules are composed of chlorine, fluorine and carbon. These refrigerants are very stable and DO NOT breaks easily when released to the atmosphere. CFC has the highest Ozone Depleting Potential of 1.0. A single Chlorine atom can destroy 100,000 ozone molecules.



Figure 2.1: CFC Cylinder Colour Code

a) R-11

- Use in low pressure chillers
- Short term replacement R-123 (HCFC) which is highly toxic
- Caution when used
- Very stable compounds, atmospheric life of 75 to 120 years or longer.
- High Ozone Depletion Potential (ODP)
- High Global Warming Potential (GWP)

b) R-12

- Used in automotive systems and many small, medium “package” units and some large chillers
- Long term replacement R-134a (HFC)
- Very stable compounds, atmospheric life of 75 to 120 years or longer

- High Ozone Depletion Potential (ODP)
- High Global Warming Potential (GWP)

B) Hydrochlorofluorocarbons (HCFC)

Hydrochlorofluorocarbon (HCFC) is refrigerant contains Hydrogen, Chlorine, Fluorine and Carbon. HCFC is not a natural gas. It is a manmade chemical. Commonly used HCFC-22 is known as R-22. This is the refrigerant widely used in Air-conditioning industry from window units, central AC systems to transport refrigeration.



Figure 2.2: HCFC Cylinder Colour Code

a) R-22

R-22 is a popular refrigerant amongst all HCFC that is commonly used in a variety of refrigeration and air-conditioning equipment including residential users and commercial & industrial use.

Table 2.2: Properties of R-22

Characteristic	<p>Formula: CHClF_2</p> <p>Molar mass: 86.47 g/mol</p> <p>Density: 3.66 g/cm³</p> <p>Melting point: -175.42 °C</p> <p>Boiling point: -40.9 °C</p> <p>Low Ozone Depletion Potential (ODP)</p> <p>High Global Warming Potential (GWP)</p>
Refrigerant	- R22
Safety Classification	- A1
Application	<p>Residential User :</p> <ul style="list-style-type: none"> • Window / Split air-conditioning unit • Package air conditioners • Dehumidifiers • Heat Pump <p>Commercial & Industrial Use:</p> <ul style="list-style-type: none"> • Packaged air conditioners • Chillers • Central AC plant • Retail food refrigeration • Cold storage warehouses • Industrial process refrigeration • Transport refrigeration

b) R-123

R-123 is an HCFC retrofit refrigerant for R-11 in low-pressure centrifugal chillers. New centrifugal equipment designed with R-123 provides excellent energy efficiency. In retrofits of existing centrifugal chillers, systems modifications are often needed to increase capacity or avoid material in compatibility. Consult with the Original Equipment Manufacturer (OEM) for specific guidance.

Table 2.3: Properties of R-123

Characteristic	<p>Formula: C₂HCl₂F₃</p> <p>Molar mass: 152.93 g/mol</p> <p>Density: 1.46 g/cm³</p> <p>Melting point: -107 °C</p> <p>Boiling point: 27.6 °C</p> <p>Low Ozone Depletion Potential (ODP)</p>
Refrigerant	- R-123
Safety Classification	- B1
Application	<ul style="list-style-type: none"> - Low-pressure centrifugal chillers - New centrifugal equipment designed for R-123

C) Hydrochlorocarbons (HFC)

Hydrofluorocarbons do not contain chlorine which destroy ozone. These refrigerants are considered environmentally safe to the ozone layer. However, DOE requires recovery of all refrigerant, even HFCs.



Figure 2.3: HFC Cylinder Colour Code

a) R-134a

R-134a is an alternative refrigerant for R-12. It is used in new medium and high-temperature stationary commercial refrigeration systems, as well as chiller systems and home appliances. In addition, it can be used to retrofit existing R-12 refrigeration and air-conditioning systems. It is also the global standard for new mobile air-conditioning and can be used to retrofit existing R-12 mobile air-conditioning systems.

Table 2.4: Properties of R-134a

Refrigerant	R-134a
Safety Classification	A1
Application	Medium and high temperature Stationary commercial refrigeration Mobile air-conditioning system Chiller equipment Home appliances Retrofit existing R-12 refrigeration and air-conditioning equipment

b) R-32

HFC-32 (Difluoromethane) or R-32 is an organic compound of the dihalogenoalkane variety. It is based on methane, except that two of the four hydrogen atoms have been replaced by fluorine atoms. Hence the formula is CH_2F_2 instead of CH_4 for normal methane.

R-32 is a refrigerant that has zero ozone depletion potential. R-32 is classified as A2L refrigerant - slightly flammable according to ASHRAE 2009. Although it has zero ozone depletion potential, it has global warming potential of 675. The refrigerant R-32 is primarily seen as a candidate for R-410A alternatives and the working pressure is 50% higher than R-22. R-32 is not a drop-in alternative for R-22. The main advantage of R-32 is relatively low global warming potential.

HFC-32 is a single component refrigerant, there is no temperature glide. However, R-32 has a 20°C higher discharge temperature than R-410A; the safe running of compressor should be noticed.

Table 2.5: Properties of R-32

Refrigerant	R-32
Safety Classification	A2L
Application	Refrigerant for air conditioners

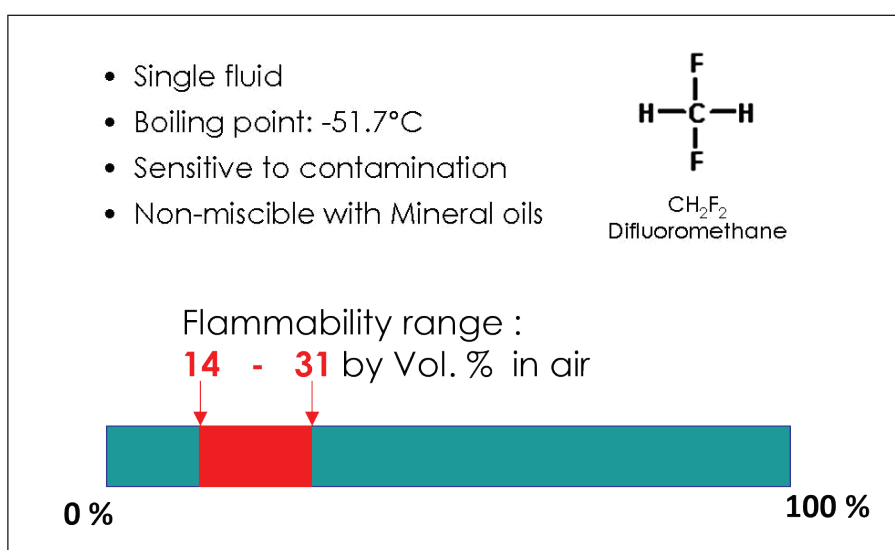


Figure 2.4: R-32 Characteristic

2.2.3 Non-Synthetic Refrigerant

A) Carbon Dioxide (CO₂)

Carbon Dioxide (CO₂) or R-744 contains carbon and oxygen. Since late 1990 its use is increasing in industrial refrigeration, cold storage, commercial refrigeration and hot-water heat pump. CO₂ preserve the ozone layer and low global warming potential (GWP). R-744 also has excellent thermodynamic properties and low energy usage making it suitable for a range application in Mobile air-conditioning, commercial refrigeration and industrial heat extraction.

Properties:

- Zero ODP
- GWP = 1
- Non-flammable

- Low toxicity
- Odorless and Colourless
- A1 safety classification

Characteristic:

- High pressure
- Low critical temperature
- Refrigeration system require special equipment design
- Refrigeration system require tight control on moisture, oil and other impurities



Figure 2.5: Example of Carbon Dioxide (CO₂) plant

B) Ammonia (NH₃)

Ammonia (NH₃) is a compound of nitrogen and hydrogen. Ammonia (R-717) is suitable for use in a larger refrigeration plants. The efficiency is as good as in system using R-22

Properties:

- Zero ODP
- GWP = 0
- Flammable
- Toxicity
- Corrosive
- Odor and Colourless
- B2 safety classification

Characteristic:

- Boiling Point: $-33.34\text{ }^{\circ}\text{C}$ at pressure of one (1) atmosphere
- Liquid must be stored under high pressure or at low temperature
- High-concentration commercial product
- Lighter than air
- Leak testing by using sulphur stick. When ammonia reacts with sulphur, a dense smoke is formed



Figure 2.6: Example of Ammonia (NH_3) plant

C) Hydrocarbon (HC)

Hydrocarbons are natural, non-toxic, low global warming potential and non ozone depleting replacements for CFC refrigerants which are safe to use with proper handling economical, highly efficient and able to replace CFC (R-12), HCFC (R-22), and HFC (R-134a) refrigerants in the existing systems without major components or oils having to be changed. Modifications to system design such as sealed electrical components or insulated potential spark igniters need to be made due to its high flammability nature.

Properties:

- Zero ODP
- $\text{GWP} = <8$
- Higher Flammable
- Lower Toxicity
- A3 safety classification

Characteristic:

- Single substance
- Boiling Point: $-42.2\text{ }^{\circ}\text{C}$
- Much lower vapor pressures
- Miscible with Mineral Oil and some other commonly used refrigeration oils with appropriate viscosities and application limitations
- Compatible with compressor materials
- Widely used in air-conditioners



Figure 2.7: HC Cylinder Colour Code

a) R-290 (Propane)

Refrigerant Propane R-290 produces a cooling capacity close to HCFC-22 with a same size compressor. The coefficient of Performance (COP) of R-290 is very near to that of HCFC-22. Sometimes, it offers the advantage of lower running costs, if the system is properly balanced and charged.

R-290 is a single component refrigerant with a normal boiling point of -42.2°C . The vapour pressure is much lower than other refrigerants. This is widely used in domestic air conditioning and chillers also. Furthermore, a rising trend can be seen in its use with commercial refrigeration systems and chillers

b) R-600a (Isobutene)

Refrigerant isobutene R-600a is a possible replacement for other refrigerants, which have high impact on the environment, in domestic refrigerators. It has zero ozone depleting potential ODP and a negligible global warming potential GWP. Furthermore it is a substance which is a part of petrol gases from natural sources.

2.3 REFRIGERANT BLENDS

Refrigerant blend refers to the mixture of two or more chemicals properties in a refrigerant. A refrigerant blend may be marketed under a proprietary trade name, but each constituent should be identified by a refrigerant (R) number and proportion following the trade designation.

When dealing with blends, pressure temperature tables are presented in an unconventional manner. Two pressures are listed for each temperature: the Dew Pressure and the Bubble Pressure (Please refer to ANNEX-A for refrigerant Blend R-410A)

The Dew Pressure is used for determining the system pressure when the refrigerant is in a saturated vapour or superheat condition (i.e. on the suction and discharge sides of the compressor).

The Bubble Pressure is used for determining the system pressure when the refrigerant is in a saturated liquid or sub-cooled condition (i.e. at the inlet to the expansion valve or capillary tube).

Refrigerant blends are mixtures of refrigerants that have been formulated to provide a match to certain properties of the refrigerants originally used. These blends have been researched and developed since the issue of the ODS phase-out emerged and are being produced by many chemical companies.

Blends can have 2-3 or even 4 components, and can have a major component of a HCFC, HFC or HC; in most cases they will consist of a combination of these chemicals. The common properties of refrigerant blends are:

- a) Very similar to traditional CFCs and HCFCs
- b) Designed for maximum efficiency and performance
- c) Blends are based on HCFCs, HFCs and HCs
- d) Low ozone depletion potential (ODP) and Global Warming Potential (GWP)
- e) Long-term replacements are HFC-based as well as HC for smaller and medium sized refrigeration systems
- f) Short-term replacements are HCFC-based

There are several refrigerant blends commonly in use. Some of the blends are called Ternary, which means they are a three-part blend. Ternary blends are used with synthetic alkyl benzene oil.

2.3.1 Azeotropic Refrigerants

An azeotropic mixture acts like a single component refrigerant over its entire temperature/pressure range. An azeotrope does not have a temperature glide.

Example: R-500, R-502, R-507

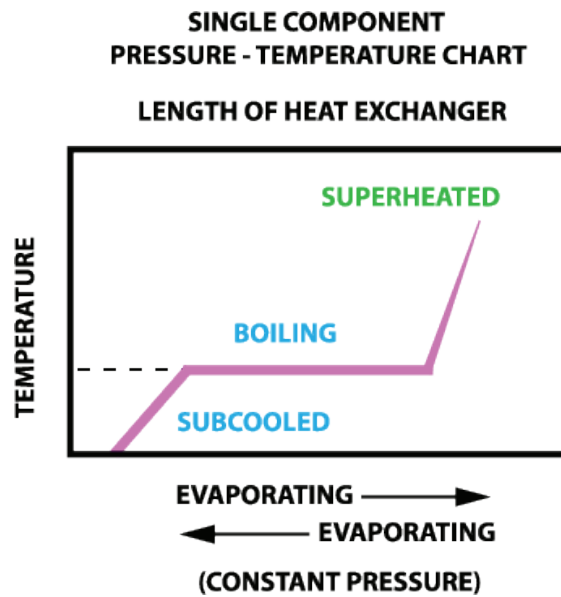


Figure 2.8: Temperature Chart for Single Component Refrigerant

2.3.2 Zeotropic Refrigerant

A blend of two to three different refrigerants and DO NOT has specific pressure for each temperature. They exhibit fractionation and temperature glides.

Example: R-401A, R402A, R409A

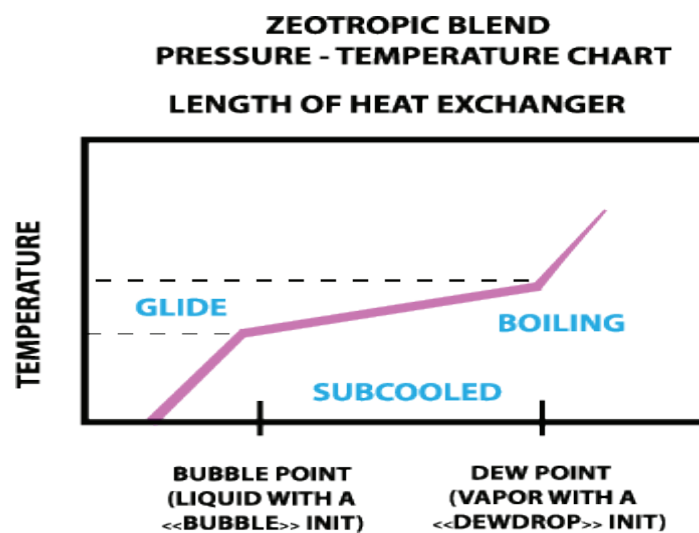


Figure 2.9: Temperature Chart for Zeotropic Blend Refrigerant

2.3.3 Blend Refrigerant Fractionation

Fractionation occurs when refrigerant in a blend leak at different rates.

Causes:-

- a) Blends are not pure compounds, but near azeotropic mixtures.
- b) Each refrigerant in a blend has different molecular properties.
- c) Each refrigerant in a blend has different vapour pressures. Weight in the proper amount of refrigerant into the high side of the refrigeration system and charge as a liquid.
- d) If a significant leak develops in a system containing a refrigerant. blend and a noticeable drop in performance is recorded then the system charge will have to be mechanically recovered, the source of the leak identified and repaired and finally the system will then have to be fully recharged with new refrigerant.
- e) It may be required to chemically analyze a charge to determine if the blended proportions are correct.
- f) Blended refrigerants must therefore only be charged into a system in the liquid state, otherwise partial separation of the blend will occur.

Table 2.6: Composition of Blend Refrigerant

Number	Refrigerant Composition (Mass %)
401A	R-22/152a/124 (53.0/13.0/34.0)
407A	R-32/125/134a (20.0/40.0/40.0)
407B	R-32/125/134a (10.0/70.0/20.0)
407C	R-32/125/134a (23.0/25.0/52.0)
407D	R-32/125/134a (15.0/15.0/70.0)
407E	R-32/125/134a (25.0/15.0/60.0)
407F	R-32/125/134a (30.0/30.0/40.0)
410A	R-32/125 (50.0/50.0)
502	R-22/115 (48.8/51.2)
507A	R-125/143a (50.0/50.0)

2.3.4 Refrigerant Blend Charging

The components of a blended refrigerant will leak from a system at uneven rates due to different vapour pressures. Therefore, the proper charging method for blended refrigerants is to weight into the high side of the system as a liquid.

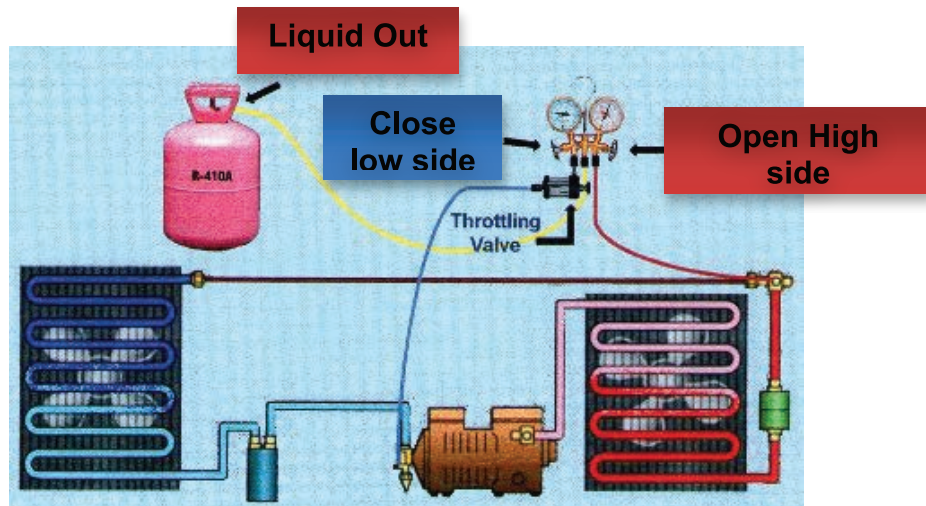


Figure 2.10: Refrigerant Blend Charging

2.3.5 Temperature Glides

The temperature difference that occurs between the vapor state and liquid state during evaporation or condensation at constant pressure, i.e. the temperature in the evaporator and condenser is not constant. Temperature glide occurs in near-azeotropic and zeotropic mixtures.

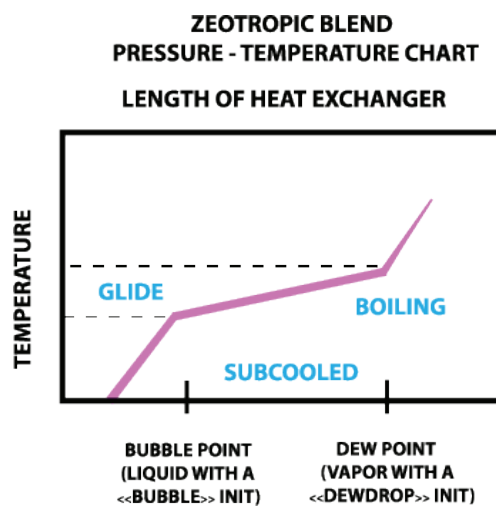


Figure 2.11: Temperature Glides

2.3.6 Types Of Blend Refrigerants

a) R-407C Blend

R-407C can be used instead of R-404A and R-507 in new system designs for low- and medium-temperature refrigeration. It can also be used for conversion of existing R-404A systems to run or operate on R-407A.



Figure 2.12: R-407C Cylinder Colour Code

Table 2.7: Characteristics of Blend Refrigerant R-407C

Refrigerant	R-407C
Mixture Ratio	HFC-32 (23%) + HFC-125 (25%) + HFC-134a (52%)
Safety Classification	A1
Application	New or existing residential and commercial air-conditioners New or existing residential and commercial heat pumps
Benefit	Similar to R-22 in capacity and energy efficiency Retrofitting is possible with certain changes in system

b) R-410A Blend

R-410A is the leading HFC refrigerant for replacing R-22 in positive displacement for residential and light commercial air-conditioning and heat pump systems. It has higher cooling capacity and significantly higher pressure than R-22 and should be used only in systems specifically designed for R-410A.



Figure 2.13: R-410A Cylinder Colour Code

Table 2.8: Characteristics of Blend Refrigerant R410A

Refrigerant	R-410A
Mixture Ratio	HFC-32 (50%) + HFC-125 (50%)
Safety Classification	A1
Application	New residential and commercial air conditioning and heat pumps
Benefit	Equipment designed for R-410A has up to 60% greater capacity than current R-22 equipment. Air-conditioning systems with R-410A can meet or exceed local energy performance guidelines according to Malaysian Standard (MS 1525:2007) for 10 SEER (Standard Energy Efficiency Ratio).

2.4 “DROP IN” REFRIGERANTS

A “Drop In” refrigerant is a term referred to a substitute refrigerant added to a particular refrigeration system without having to change any other component in the system inclusive of its lubricant, However, in normal circumstances, when synthetic oil is used, seals and the like would have to be replaced for compatibility and hence the term “Drop in” would no longer apply.

“Drop in Retrofit” is another term used loosely to describe a change to a substitute refrigerant with minimal changes to the system but as elaborated above, it is not exactly a “Drop In” let alone a “Direct Drop In”.

2.5 RETROFIT REFRIGERANTS

Refrigerants that require lubricant changes or system component changes are often described as retrofit refrigerants. Retrofit refrigerants will be probably not cost effective as the compressor or the heat exchangers need to be replaced.

R-407C has demonstrated to be acceptable retrofit refrigerants for HCFC-22. The performance and efficiency are very close to R-22. A good correspondence with the properties of R-22 in term of pressure, mass flow, vapour density and volumetric refrigeration capacity can be achieved

Please refer **Figure 2.14** for R-407C Operating Conditions similar to R-22 Operating Conditions.

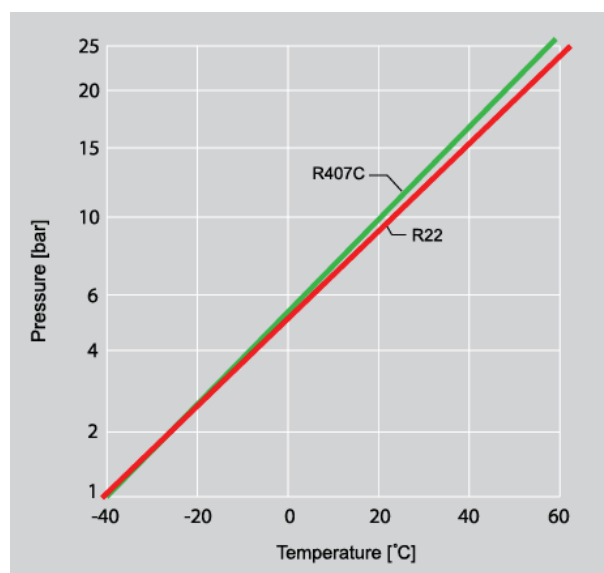


Figure 2.14: R-407C vs R-22 Operating Conditions

Please refer **Figure 2.15** for R-410A Operating Conditions. R-410A shows 50% higher cooling capacity in comparison to R-22 Operating Conditions. At high

condensing temperature, energy consumption/ Co-efficient of performance seems to be less favourable than R-22.

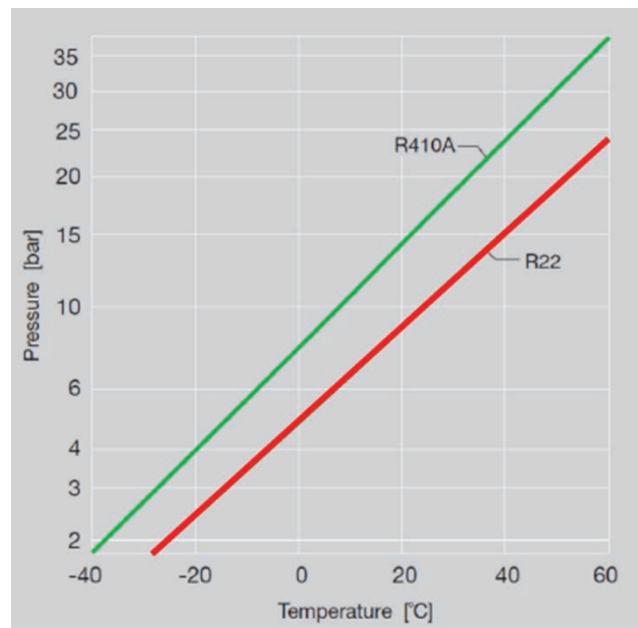


Figure 2.15: R-410A vs R-22 Operating Conditions

2.6 “CONVERSION” OF SYSTEM

When applying a flammable refrigerant to a system that ordinarily uses a non-flammable refrigerant, the term “conversion” is applied. When convert from a non-flammable refrigerant (such as R-22) to a HC refrigerant (such as R-290), additional considerations must be taken into account. These include identifying whether the HC can be applied given the particular circumstances from a safety perspective, and carrying out the required changes to the equipment that are related to mitigating the flammability risk. Switching from a non-flammable refrigerant to a flammable refrigerant should be considered in terms of an entire conversion of the equipment, not just a change of refrigerant.

a) Caution instructions

- Any technician involved with conversion must be fully trained, competent and certified to use this flammable refrigerant.
- Only convert the system with the permission from building owner.
- Only use proper service equipment suitable for use with HC refrigerants.
- Multi-split and ducted systems which use large refrigerant charges are not suitable for conversion to HC refrigerants

- Refrigeration systems with extensive pipe work and multiple evaporators, such as compound plants, are not suitable for conversion to HC system.
- If the situation permits, it is recommended that the equipment should be removed from its existing position to a controlled workshop environment where work can be conducted in a more controlled and safer manner.

2.7 REFRIGERANT PROPERTIES

Many chemicals, including refrigerants, can be harmful if used improperly. Three important categories of health and safety concerns are toxicity, flammability, and oxygen (O₂) displacement (asphyxiation hazard).

An international group of refrigerant manufacturers, through the Program for Alternatives Fluorocarbon Toxicity (PAFT) testing, have conducted extensive toxicology tests on some HCFC and HFC refrigerant. With these results, manufacturers have recommended concentrations that humans can tolerate for a given time without harmful effects, called Allowable Exposure Limits (**AELs**). These values are given in parts per million (ppm), indicating the maximum amount of refrigerant that can be safely tolerated. Other toxicity indicators include Threshold Limit Values (**TLVs**) and Permissible Exposure Levels (**PEL**).

Refrigerant manufacturer indicate the AEL, TLV and PEL of the refrigerant on the Material Safety Data Sheet (MSDS). ASHRAE Standard 34, *Number Designation and Safety Classification of Refrigerants*, classifies toxicity of concern

Material Safety Data Sheet



DuPont™ FREON® 22 Refrigerant

Version 2.3

Revision Date 10/04/2011

Ref. 130000024323

This SDS adheres to the standards and regulatory requirements of the United States and may not meet the regulatory requirements in other countries.

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product name : DuPont™ FREON® 22 Refrigerant
Product Grade/Type : ASHRAE Refrigerant number designation: R-22
Tradename/Synonym : R-22
FREON® 22
CHLORODIFLUOROMETHANE
HCFC-22
DYMEL® 22
MSDS Number : 130000024323
Product Use : Refrigerant
Manufacturer : DuPont
1007 Market Street
Wilmington, DE 19898
Product Information : 1-800-441-7515 (outside the U.S. 1-302-774-1000)
Medical Emergency : 1-800-441-3637 (outside the U.S. 1-302-774-1139)
Transport Emergency : CHEMTREC: 1-800-424-9300 (outside the U.S. 1-703-527-3887)

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview
Rapid evaporation of the liquid may cause frostbite.
Potential Health Effects
Skin
Chlorodifluoromet hane (HCFC-22) : Contact with liquid or refrigerated gas can cause cold burns and frostbite.
Eyes
Chlorodifluoromet hane (HCFC-22) : Contact with liquid or refrigerated gas can cause cold burns and frostbite.




Figure 2.16: Example of Material Safety Data Sheet (MSDS) by DuPont

2.8 REFRIGERANT CLASSIFICATION

CLASS A: Refrigerant with lower toxicity, and with a weighted Threshold Limit Value (TLV) over time higher than 400 ppm.

CLASS B: Refrigerant with higher toxicity and with weighted Threshold Limit Value (TLV) over time lower than 400 ppm.

Table 2.9: ASHRAE 34 matrix with some refrigerant example

FLAMMABILITY	 3	R-600a(isabutane) R-290(propane)	R-1140 (vinyl chloride)
	 2	HFC-32 HFC-143a HFC-152a	R-717 (Ammonia)
	 2L	HFC-32 (Proposed) HFO-1234yf (Proposed)	
	1	CFC-11 CFC-12 HCFC-22 HFC-125 HFC-134a	HCFC-123
	CATEGORY	A Lower Toxicity	B Higher Toxicity
TOXICITY			
ASHRAE 34 Matrix with some Refrigerant Examples			

Note reference: ANSI/ASHRAE 34 (2007) Designation and Safety Classification of Refrigerants

2.9 REFRIGERANT NAMING SYSTEM

- a) The standard of naming refrigerant was adopted from Dupont since 1956.
- b) All refrigerant should start with the letter 'R'.
- c) CFCs and HCFC are therefore referred to as:
 - CFC 12 = R-12
 - CFC 11 = R-11
 - HCFC 22 = R-22

The numbering system is formulated as follows:

First digit on the right	= number of Fluorine atoms
Second digit from the right	= number of Hydrogen Atom + 1
Third digit from the right	= number of carbon atoms - 1 (not used when equal zero)
Forth digit from the right	= number of unsaturated carbon bonds (carbon bonds in the compound. Not used when equal zero)

For example;

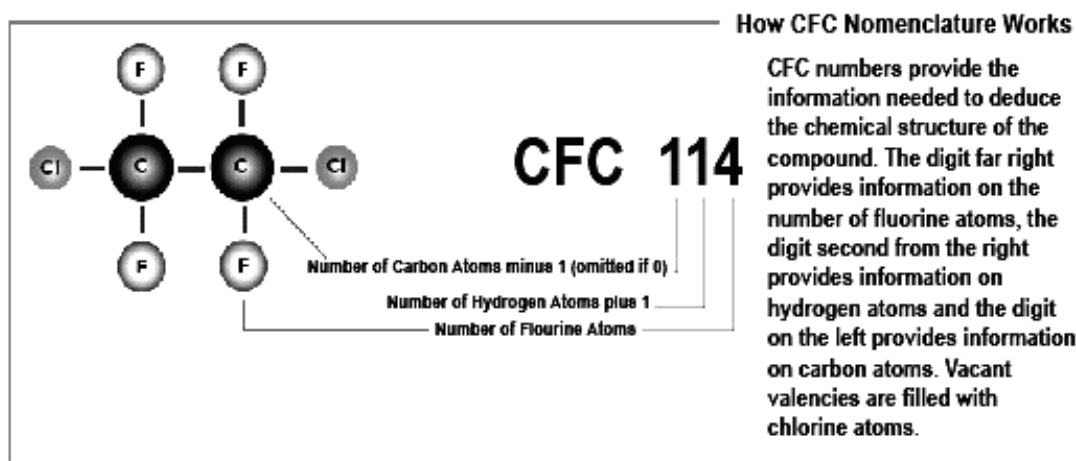


Figure 2.17: Nomenclature of refrigerant

2.10 REFRIGERANT SYSTEM OIL AND GOOD PROPERTIES

2.10.1 Refrigeration System Oil

There are many variety of lubricant oil in the market. Compressor manufacturers always specify the oil type to be used in their compressor. Technician must check and determine the correct type of lubricant before any servicing to prevent **damage** to the system due to non-compatibility with refrigerant and system components.

- In hermetic systems, the lubricant is in intimate contact with the electrical motor windings. The oil must therefore provide good material compatibility and have high thermal stability properties.
- Although the majority of the lubricant remains in the compressor, as small amount will be circulated into the rest of the refrigerant circuit.

- c) 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 overtime, it does not become starved of oil, which could lead to mechanical failure.
- d) Minimizes wear
- e) Reduces friction
- f) Noise reduction
- g) Heat transfer properties (cools)

2.10.2 Good Lubricant Properties

The properties of a good refrigeration lubricant are:

- a) **Low wax content** - Separation of wax from the refrigeration oil mixture may plug refrigerant control orifices.
- b) **Good thermal stability** - It should not form hard carbon deposits and spots in the compressor, such as in the valves of the discharge port.
- c) **Good chemical stability**- There should be little or no chemical reaction with the refrigerant or materials normally found in systems.
- d) **Low pour point** - This is the ability of the oil to remain in a fluid state at the lowest temperature in the system.
- e) **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.
- f) **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.
- g) **Dielectric strength** - oil's relative electrical resistance to electrical current.

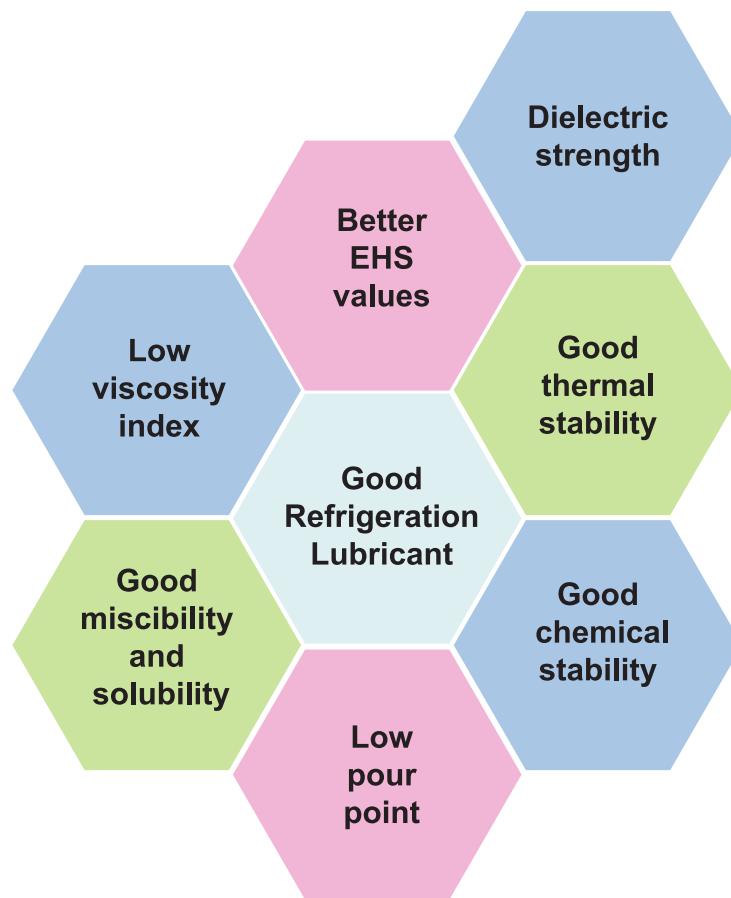


Figure 2.18: Good Lubricant Properties

2.10.3 Refrigerant Oil Types

Basically there are **five main** categories of refrigeration lubricants:

- a) Mineral Oils (**MO**)
 - Paraffinic
 - Naphthenic
 - Aromatics
- b) Alkyl Benzene Oils (**AB**) - Synthetic Lubricants
- c) Polyol Ester Oils (**POE**) - Synthetic Lubricants
- d) Poly Alpha Olefin Oils (**PAO**) - Synthetic Lubricants
- e) Poly Alkyl Glycol Oils (**PAG**) - Synthetic Lubricants

Table 2.10: Type of Refrigerant Oils

Refrigerant	Appropriate Lubricant				
	Mineral Oil (MO)	Alkyl benzene (AB)	Polyol Ester (POE)	Poly alpha oelfin (PAO)	Poly alkyl glycol (PAG)
CFC-11	✓	✗	□	□	✗
CFC-12	✓	✓	□	□	✗
R-502	✓	✓	□	□	✗
HCFC-22	✓	✓	□	□	✗
HCFC-123	✓	✓	□	□	✗
HFC-134a	✗	✗	✓	✗	□
HFC-404A	✗	✗	✓	✗	□
HFC-407C	✗	✗	✓	✗	□
HFC-410A	✗	✗	✓	✗	□
HFC-507A	✗	✗	✓	✗	□
HC-600a	✓	□	✓	✓	□
HC-290	✓	□	✓	✓	□
R-717 (NH ₃)	✓	□	✗	✓	□
R-744 (CO ₂)	□	□	✓	✓	✓

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

2.11 REFRIGERANT AND OIL COMPATIBILITY

- Know what type of refrigerant, oil and component material you are working with. (refer to unit specification)
- Assure oil is compatible with refrigerant
- Assure refrigerant is compatible with equipment components
- Assure recovery unit is compatible with refrigerant and oil.

2.12 SUBSTITUTE REFRIGERANTS AND OILS

HFCs are considered Ozone friendly. HFC-134a (R-134a) is the leading candidate for CFC 12 (R-12) retrofit, but it is not a drop-in substitute. Actually, there is not a drop-in alternative, but R-134a can be used in most R-12 systems by following appropriate retrofit procedures. HFCs will not mix with most refrigerant oils used with CFCs & HCFCs. The oils used for most of HFC systems are Ester, which cannot be mixed with other oils. It is also important to remember to use pressurized nitrogen when performing leak testing on HFC system.

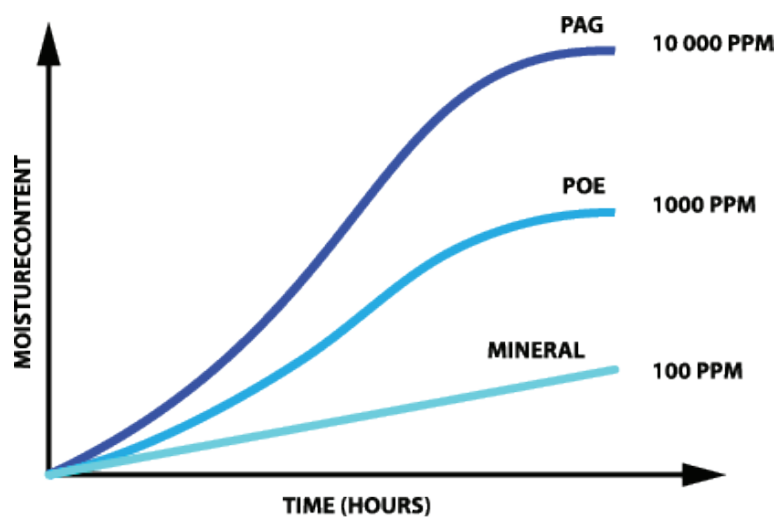
NOTE: When servicing a system, it is imperative to ensure that air and moisture contamination to polyol ester (POE) lubricants and polyalkylene glycols (PAG) does

not occur. These oils are very hygroscopic, meaning they readily absorb moisture when left exposed to the air. Keep the oil containers closed and hoses sealed-off when not in use. Cross contamination of the oil can result in unwanted chemical reactions in the system, refrigerant breakdown, and material corrosion.

2.13 POLY ALKYL GLYCOL OIL (PAG) & POLYOL ESTER OIL (POE) ISSUES

The characteristics of the synthetic lubricants:

- PAG and POE oils are more hygroscopic** than mineral oils as shown in the diagram below. They saturate an approximately 1000 ppm from atmospheric moisture, compared to about 100 ppm for mineral oils.
- The **POE** lubricants are considerably **less hygroscopic** than **PAG** lubricants. This diagram shows lubricant compatibility for some refrigerants.
- High hygroscopic caused reliability problems and servicing issues.



Hygroscopy of POE and mineral lubricants

Figure 2.19: Hygroscopy of POE and Mineral Lubricants

2.14 REFRIGERANT HAZARDS

Refrigerant hazards are as follows:

- Oxygen Deprivation.** Refrigerants are heavier than air and can displace oxygen causing chest pains, breathing difficulty and even death.

- b) Heated refrigerant can be turned into **phosgene gas** which is poisonous and can kill rapidly.
- c) Refrigerants are extremely cold and exposure can cause **frostbites**.
- d) Refrigerant gas can also **irritate the eyes**.
- e) Refrigerants are kept in high pressure containers. A slight mistake can cause **explosions**.
- f) Refrigerants are circulated in a system in **extreme pressure and temperature**. Care must be taken to avoid injury.

2.15 HANDLING REFRIGERANTS

The refrigerants should be handled properly as follows:

- a) All refrigerants must be properly stored, handled, and used.
- b) DO NOT expose container to flame.
- c) Burning refrigerant creates poisonous gas.
- d) DO NOT identify cylinder simply by colour only.
- e) DO NOT mix refrigerants.

2.16 SELECTING THE REFRIGERANT

This **Figure 2.20** shows the criteria to be considered when changing to alternative of HCFC. The selection of an alternative refrigerant should be based on the following criteria:

- a) It must have zero ODP and minimum GWP.
- b) Performance of the new refrigerant.
- c) It should be readily available in the market and cost effective.
- d) It should preferably have the property of non-toxicity and non-flammability.
- e) It should be compatible to all the materials used in air-conditioning system
- f) It is important that the refrigerant is not reactive with materials within the system. These include metals used for metallic pipes and other components, compressor oils and associated additives, plastic motor materials, elastomers such as seals, O-rings in valves and fittings, and desiccants within filter dryers.
- g) Although all the mentioned criteria are hard to be met by a single refrigerant, we should always choose a refrigerant which are most suitable to the working environment and comply with the respective country regulation.

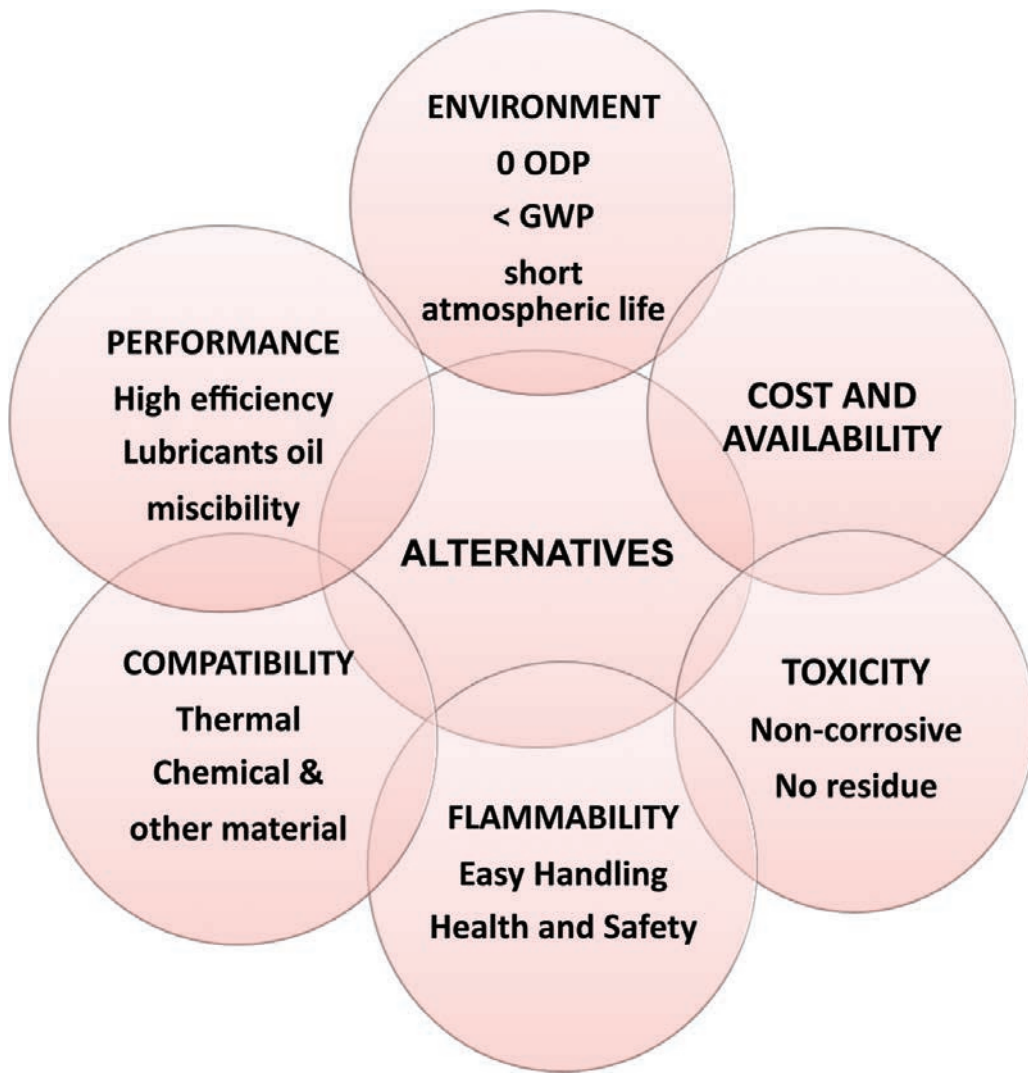


Figure 2.20: Consideration of Refrigerant

2.17 ENVIRONMENTAL CHARACTERISTICS

The **table 2.11** below shows the 'Environmental Impact' of refrigerants.

Table 2.11: Environment Impact of Selecting Refrigerants

Refrigerant		Atmospheric Lifetime (Years)	ODP	GWP (100 Year)
CFCs (Phased-out)	CFC-11 (Baseline ODP)	50	1	4000
	CFC-12	102	1	10900
HCFCs	HCFC-22	13.3	0.055	1820
	HCFC-123	1.4	0.02	93
	HCFC-141b	9.4	0.11	630
HFCs	HFC-134a	14.6	0	1300
	HFC-245fa	7.3	0	820
	R-32	-	0	675
HCs	HC-290 (Propane)	-	0	3
	R-1270 (Propylene)	-	0	<2
HFC Blends	R-404A	-	0	3260
	R-407A	-	0	1770
	R-407C	-	0	1530
	R-410A	-	0	1730
Ammonia	R-717	-	0	<1
CO2	R-744	-	0	1

Note : Yellow box : Gases control under Montreal Protocol (MP)

2.18 ALTERNATIVES TO HCFC

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

- HCFCs (e.g. HCFC-22) contain Hydrogen, Chlorine, Fluorine and Carbon.
- HFCs (e.g. HFC-134a) contain Fluorine, Hydrogen and Carbon.
- HCs (e.g. HC-290, HC-600a) contain Hydrogen and Carbon
- CO₂ contains one atom of Carbon and two atoms of Oxygen
- Ammonia contains one atom of Nitrogen and three atoms of Hydrogen

The Refrigerants containing chlorine have to be phased out from the RAC sector. Trainer should now focus on switching over from HCFC to promoting low GWP or negligible GWP refrigerants.

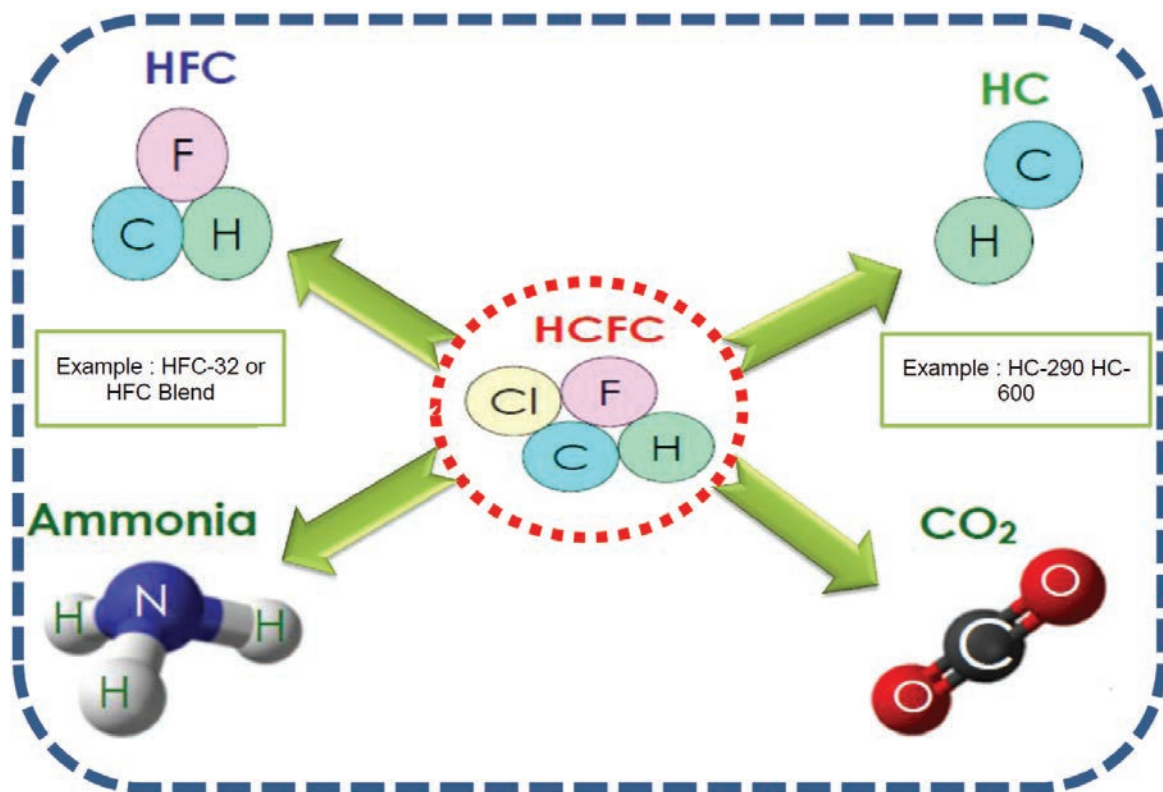


Figure 2.21: Choices of Alternative for HCFC

2.19 REFRIGERANT OPTIONS

A chart has been given here to show that we have to move from colour red to green. Due to ozone depletion, global warming and climate change, we should push towards adopting alternative refrigerants with zero ODP and low or no global warming potential (GWP). There are many alternative refrigerants currently commercially available in the market. RAC technicians should know the different handling techniques with the variety of refrigerants.

Refrigerants are widely used since the 1930s in applications like commercial refrigeration, cold storage, transport refrigeration, stationary air conditioning and chillers. The time has come to phase out HCFCs concerning the protection of global Environment. We need to phase out HCFC due to ozone depletion potential & status as a potent greenhouse gas.

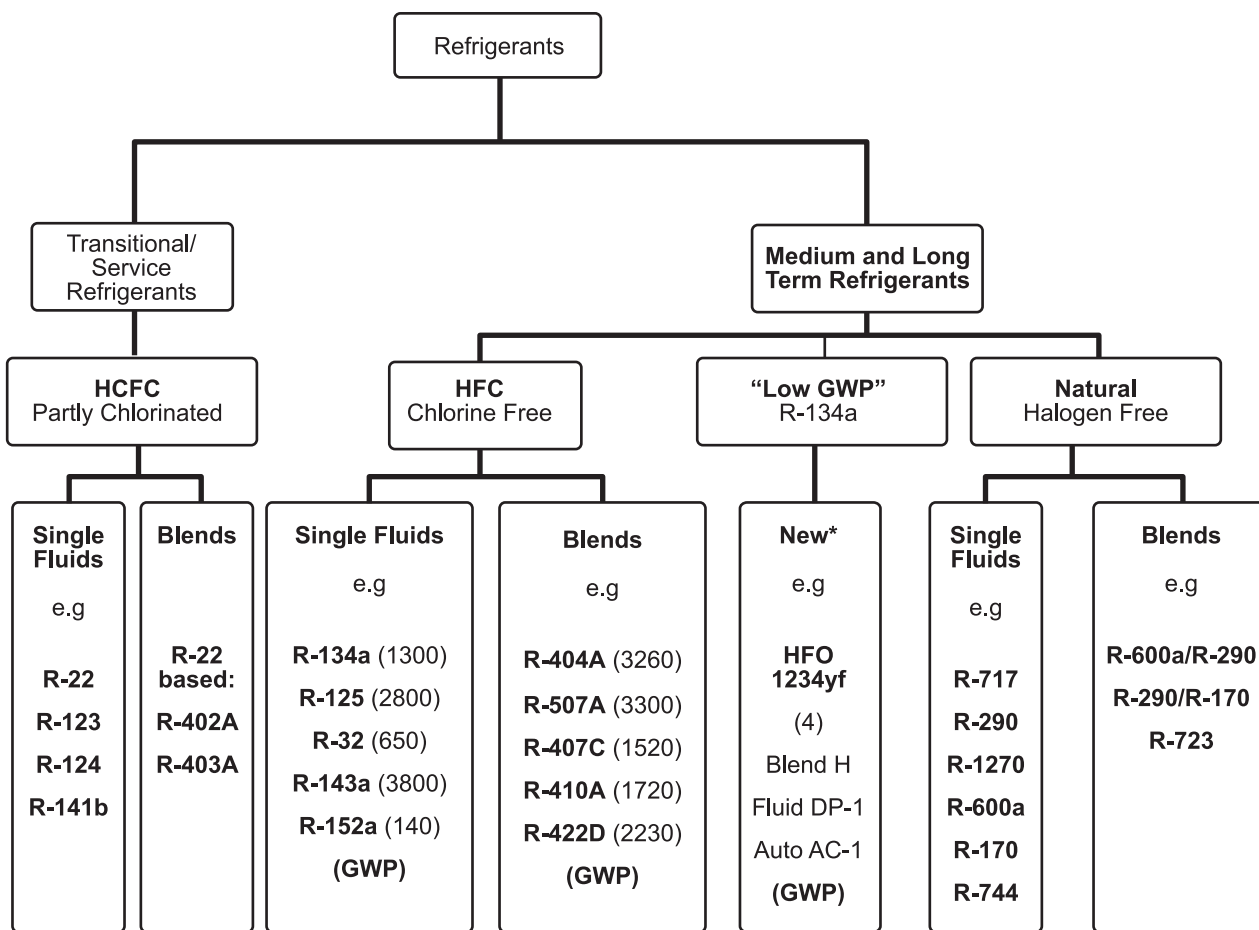


Figure 2.22: Options of Refrigerants

2.19.1 Hydrofluorocarbons (HFCs)

Hydrofluorocarbons (HFCs) consist of hydrogen, fluorine, and carbon. The most common refrigerants in this group are R-134a, R-32, R-125 and R-143a (mostly within blends, such as R-404A, R-407C and R-410A). They have been use in large scale since the 1990s, in nearly all applications that have traditionally used CFCs and HCFCs, including domestic and commercial refrigeration, cold storage, vehicle air conditioning, transport refrigeration, stationary air conditioning and chillers. HFCs are chemically stable. However, they are not miscible with traditional lubricants, so specific types of synthetic oils must be used. Across the range of HFCs, there are a variety of pressure-temperature characteristics. **Table 2.12** explains the advantages and the disadvantages of HFCs.

The advantages are: HFCs are nonflammable, have zero ODP. The cooling capacity of R407C is close to HCFC 22.

The disadvantages are: HFCs have relatively high GWP and are included in the basket of six greenhouse gases under the Kyoto Protocol. With HFCs there are reliability/compatibility issues with material of construction and lubricating oil in HCFC systems. Therefore, using HFCs in the existing HCFC system require some changes in case of retrofitting. As HFCs are not miscible with mineral oils, special synthetic oils known as Polyol Ester Oils (POE) and Poly Alkyl Glycol (PAG) have been developed.

Example: **R-134a, HFC-32, R-404A, R-407C, R-410A, R-507A**

Table 2.12: Advantages and Disadvantages of HFCs

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> • Zero ODP • Non-flammable • Capacity is similar to HCFC (R-22 vs. R-407C) 	<ul style="list-style-type: none"> • Moderate GWP • Oil (POE/PAG) used is highly hygroscopic • COP less than HCFC • Reliability/Compatibility issues with the materials of system construction • System changes necessary

a) The HFCs Potential usage

- R-407C as a substitute to HCFC-22
 - Retrofit possible
- R-410A as a substitute to HCFC-22
 - For new systems
 - It has higher pressures
 - It is not recommended as retrofitting refrigerant
- R-507A as a substitute to HCFC-22
 - HFC blend replacement option for R-22 in commercial refrigeration systems.
 - It can be used in new and existing systems, and provides very similar performance over the entire operating range.

2.19.2 Hydrocarbons (HCs)

Hydrocarbons (HC) molecules consist of hydrogen and carbon. HC are natural, non toxic, low global warming potential and non ozone depleting replacements for CFC refrigerants. HC are safe to use with proper handling, economical, highly efficient and able to replace CFC (R-12), HCFC (R-22), and HFC (R-134a) refrigerant in existing systems without major components or oils having to be changed. Modifications to system design such as sealed electrical components or insulated potential spark igniters need to be done before hand due to its high flammability nature.

Example: **HC-290 (C₃H₈ Propane)**, **HC-600A (C₄H₁₀ Isobutane)**, **HO-1270 (C₃H₆ propylene)**

Table 2.13: Advantages & Disadvantages of HCs

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none">• Zero ODP• Negligible GWP• Long term solution• Work with Mineral Oil and some other commonly used refrigeration oils with appropriate viscosities and application limitations• Capacity close to HCFCs to HC-290 and HC-1270	<ul style="list-style-type: none">• Flammable• Changes needed to some electrical components• Adequate ventilation surrounding the system / equipment essential

a) Hydrocarbons (HCs) issues

- For hydrocarbon refrigerants, flammability is the main concern. Therefore, safety design and manufacturing processes need to be followed while servicing such appliances.
- Due to the flammability of HCs, the electrical components attached close to the system must be non-sparking.
- The liquid density of HCs is much lower as compared with HCFCs. Therefore, the charge of HCs required by weight is much lower than the HCFC.
- HCs are also fully miscible with the traditionally used mineral oil. Hence, retrofitting is possible.
- For HCs, safe manufacturing and servicing practices are essential. This requires some special training.
- Electrical devices attached to/close to system must be non-sparking (sealed type) or solid state or installed in separate/ adjacent room.

b) HC characteristic

HC-290 has lower condensing and evaporating pressures. The operation of the machine will be quieter than running with other refrigerants. The amount of charging quantity is quite significant.

Note: *At this stage, retrofitting with HC is not encouraged as the related R&D is still underway.*

- Single substance
- Boiling Point: -42.2 °C
- Much lower vapor pressures
- Miscible with Mineral Oil and some other commonly used refrigeration
- Oils with appropriate viscosities and application limitations
- Compatible with compressor materials
- Widely used in air-conditioners
- Different compressor design
- Lower noise in operation
- Different capillary tube
- Lower condensing pressures
- Lower evaporating pressures
- Rising trend for use in domestic and commercial systems
- Less friction, reduced maintenance and increased lifetime

c) HC basic requirement

The R-290 produces a cooling capacity close to R-22. The Coefficient of Performance (COP) of R-290 is very near to R-22.

- Provision of adequate ventilation surrounding system/equipment
- HC charge is lower by more than 50% of HCFC by weight
- Safe manufacturing / servicing essential
- Proper training needed

Sometimes, HC offers the advantage of lower running costs, if the system is properly balanced and charged.

Figure 2.23 Shows the 'Pressure vs Temperature' graph plotted for R-22, R-1270 and R-290. The vapour pressure curves for R-22 and R-290 are very similar. However for R-290, the pressures are lower than for the other two refrigerants.

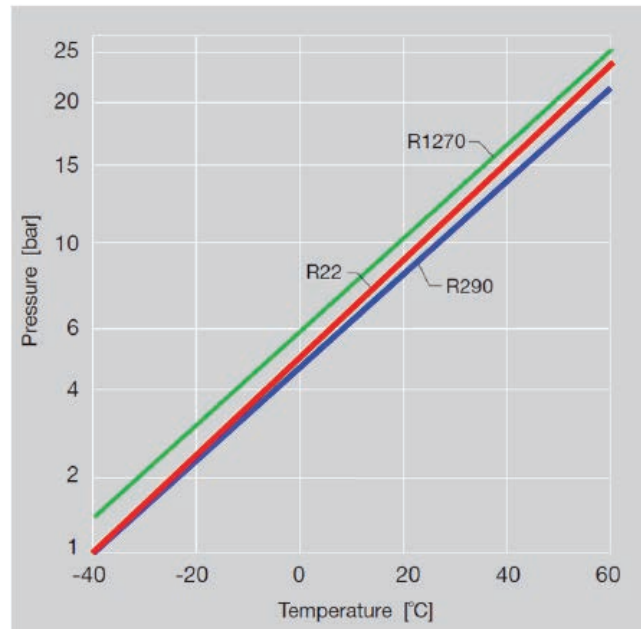


Figure 2.23: R-290, R-1270 and R-22 Operating Conditions

2.20 CARBON DIOXIDE (CO₂)

Carbon Dioxide (CO₂) or R-744 is widely used as the refrigerant in many industries. From the later 1990s, it is increasingly applied in industrial refrigeration like cold storage, commercial refrigeration and hot-water heat pumps. R-744 is chemically stable, and does not react under most conditions. R-744 has no ozone depleting potential, a negligible direct global warming potential (GWP = 1), chemically inactive, non-flammable and mildly toxic. Therefore CO₂ is not subjected to the stringent demands regarding containment as apply for HFCs (F-Gas Regulation), and flammable or toxic refrigerants.

The pressure-temperature characteristic of R-744 are different from most conventional refrigerants, it operates at high pressures, for example, approximately seven times higher than R-22, which necessitates the system to be designed with special consideration to high pressures. In addition, it has a low critical temperature, such that when ambient temperatures exceed about +25°C, a special system design is required. R-744 has classified as A1 refrigerant (lower toxicity and non-flammability). R-744 is cheap and widely available from specialist retailers.

a) **Carbon Dioxide (CO₂) properties**

- A liquefied gas under pressure
- Non flammable
- In high concentration can be toxic and may cause asphyxiation.
- Heavier than air
- Odourless and colorless
- Not possible for retrofit.
- Carbon Dioxide can exist as a gas, liquid or solid (dry ice), and can be used under high pressure as a refrigerant.
- CO₂ has been used as a refrigerant since 1850 and is now regaining popularity due to its low environmental impact.
- Zero ODP and a GWP = 1.
- Excellent thermodynamic properties make it suitable for a range of applications.

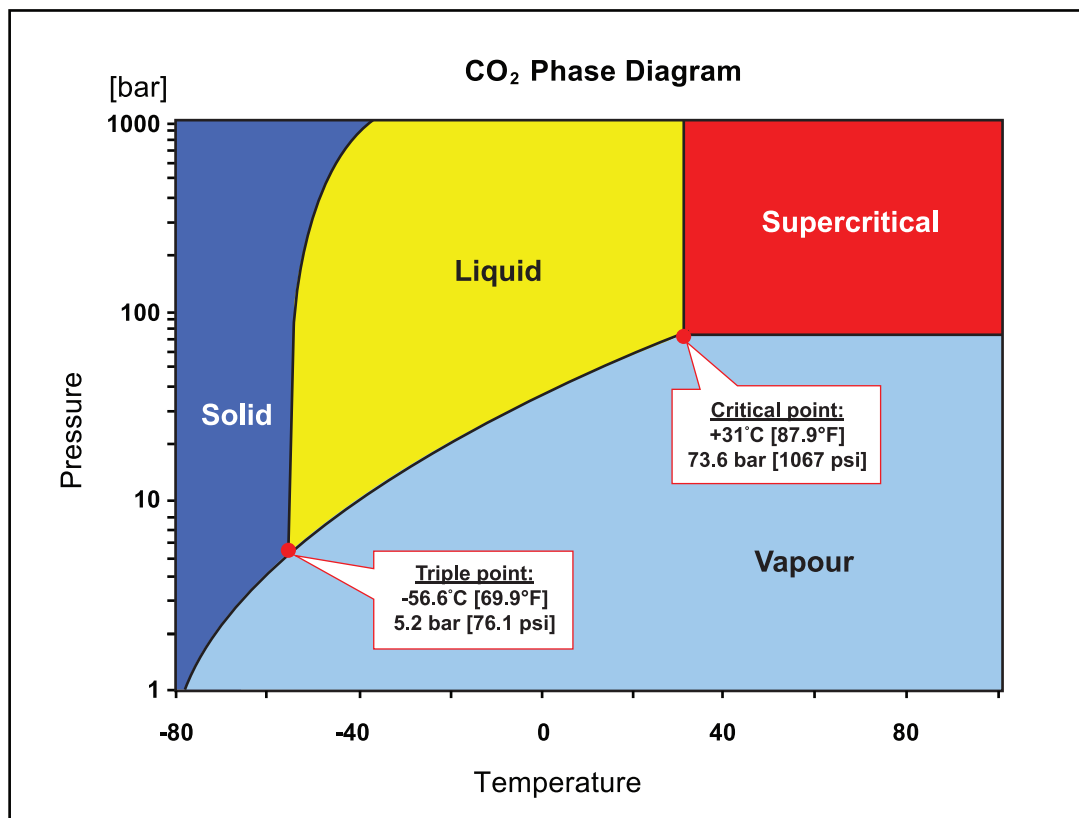


Figure 2.24: Graph Pressure vs Temperature for CO₂

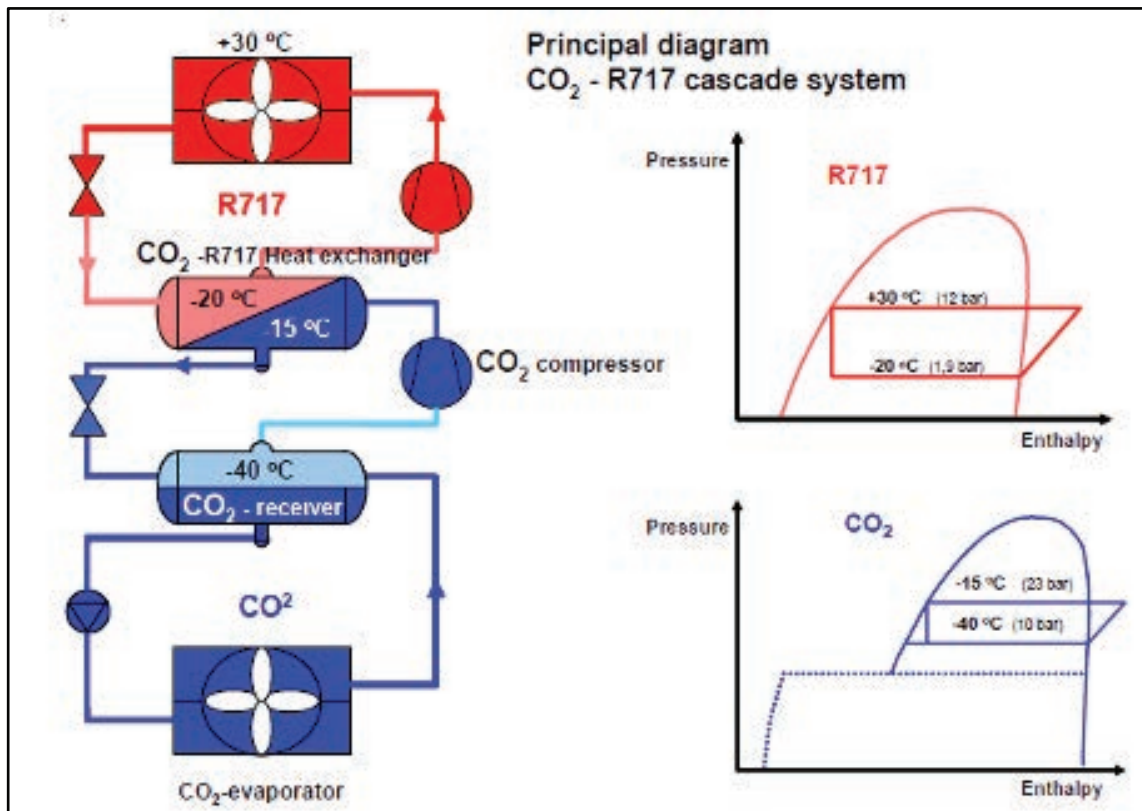


Figure 2.25: Principal diagram for CO₂ (R-717)

2.21 AMMONIA (NH₃)

NH₃ (Ammonia) has been used as refrigerant for more than a century in industrial and larger refrigeration plants. It has no ozone depletion potential and no direct global warming potential. The efficiency is as good as with R-22. In addition it is incomparably low in price. It has the highest refrigerating capacity per pound of any refrigerant.

Ammonia is a very good refrigerant suited to large installations; however its toxicity, mild flammability and compatibility with copper are the main drawbacks.

- Environmental friendly
- Boiling point is -28°F (-2.22°C)
- Highest refrigerating capacity per pound of any refrigerant
- Toxic, explosive and flammable within certain conditions
- Corrosive nature of ammonia
- Leak testing either by using sulfur sticks. When ammonia reacts with sulfur, a dense smoke is formed.

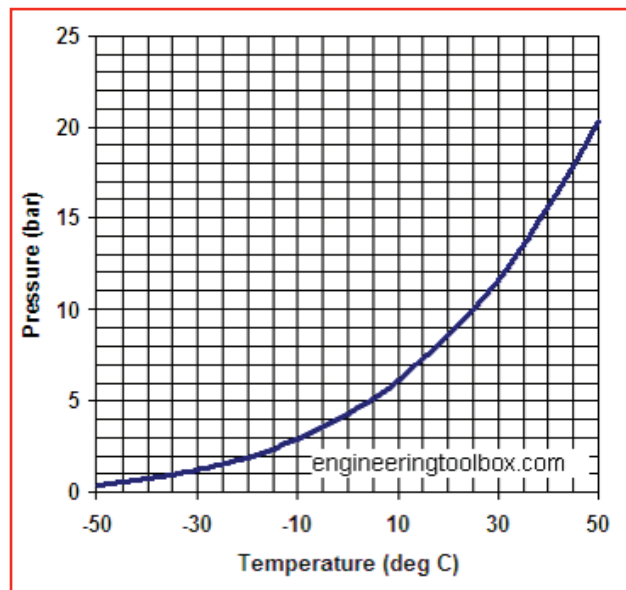


Figure 2.26: Characteristics of Ammonia

2.22 ISSUE WITH ALTERNATIVE REFRIGERANTS

a) HFC Blends and Hydrocarbons

- HFC-based blends are an interim HCFC replacement solution.
- Due to the non-azeotropic and possible flammable characteristics, the servicing procedures would be more complicated. Technicians should be well trained and follow the proper handling procedures.
- It is more difficult to estimate the amount of superheat and sub-cooling when commissioning or servicing a system.
- Leakage from heat exchangers and subsequent re-filling will lead to a gradual change in refrigerant composition, thereby resulting in a change in performance and operating characteristics over time.
- Due to the Hydrocarbons flammability issues, fire safety handling is required by technicians.
- Manufacturer is required to provide safer design.
- Technicians must follow good service practices. The technicians should join training/workshop in order to sharpen their skills in handling these refrigerants.

Table 2.14: Requirement of Alternative Refrigerants - HFC blends and Hydrocarbons

HFC blends	Hydrocarbons
<p>POE lubricants are highly hygroscopic</p> <p>Better manufacturing & servicing practices</p> <p>Training required</p>	<p>Require safer design</p> <p>Better manufacturing & service practices</p> <p>Knowledge of legislations, regulations and standards relating to flammable refrigerants</p> <p>Detailed knowledge of and skill in handling flammable refrigerants including blends, personal protective equipment, refrigerant leakage prevention, handling of cylinders, charging, leak detection, recovery and disposal</p> <p>Training required</p>

b) Carbon Dioxide (CO₂) and Ammonia (NH₃)

- CO₂ is having very high operating pressures and require special training for service technicians.
- Ammonia has also the same disadvantage of high discharge temperature, so while servicing lot of care has to be taken and which also leads to a specific training requirements.
- Ammonia is a very good refrigerant suited to large installations; toxicity, mild flammability and compatibility with copper are the main drawbacks.

Table 2.15: Requirement of Alternative Refrigerants - Carbon Dioxide and Ammonia

CO ₂	Ammonia
<p>High pressure refrigerant</p> <p>Better manufacturing & servicing practices</p> <p>Require safer design</p> <p>Training required</p>	<p>Require safer design</p> <p>High discharge temperature of ammonia gas</p> <p>Better manufacturing & service practices</p> <p>Training required</p>

CHAPTER 3

REFRIGERATION CYCLE

CHAPTER 3

REFRIGERATION CYCLE

3.1 INTRODUCTION

A refrigeration cycle is a continuous cycle where refrigerant absorb heat from the passenger compartment and then transfer the heat to the outside air (ambient).

The series of operation consist of 4 phases:-

- a) Vaporisation
- b) Compression
- c) Condensation
- d) Pressure Reduction.

Basic refrigeration cycle consist of 2 changing states;

1. Vaporisation

Vaporisation is the term used when enough heat is added to a liquid substance to change it into a vapor (gas). For example: when water is boiled. This condition occurs within the A/C system.

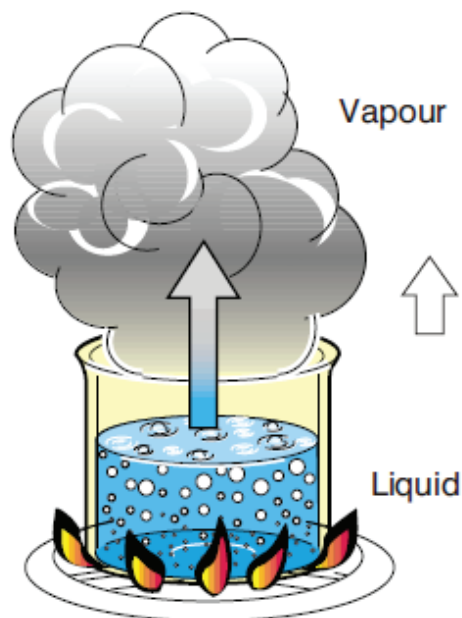


Figure 3.1: Vaporisation

2. Condensation

Condensation is the term used to describe the opposite of the evaporation process i.e. if you take a vapour and remove enough heat from it, a change of state occurs. The vapour becomes a liquid. The change of vapour to a liquid is called condensation

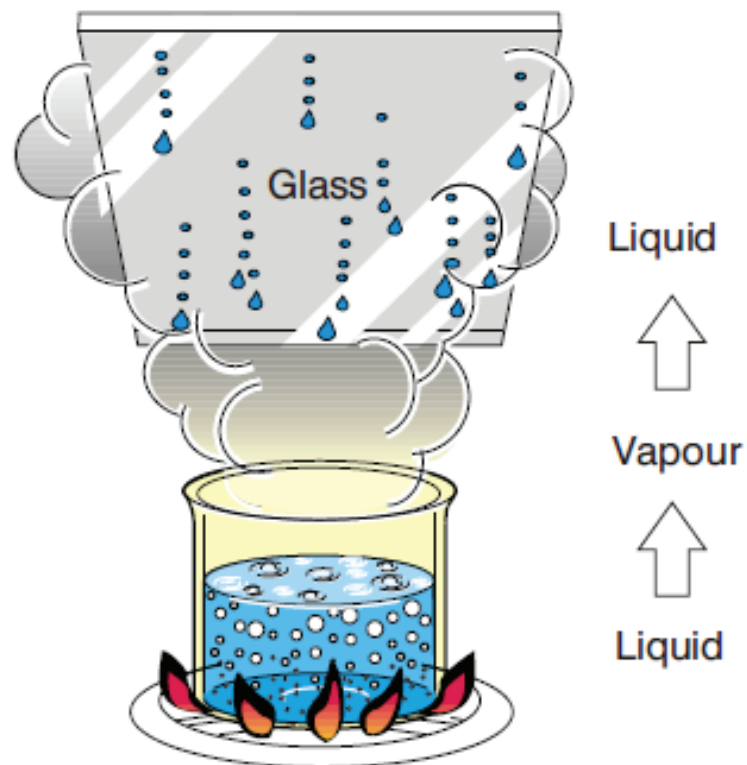


Figure 3.2: Condensation

3.2 THE REFRIGERATION CYCLE

In the vapour/compression refrigeration cycle, liquid refrigerant at a high pressure is delivered to a metering device; the metering device causes a reduction in pressure, and therefore a reduction in saturation temperature.

The refrigerant travels to the evaporator; heat is absorbed in the evaporator and causes the refrigerant to boil from liquid to vapour. At the outlet of the evaporator, the refrigerant is now a low temperature, low pressure vapour. The refrigerant vapour then travels to the inlet of the compressor.

The refrigerant vapour is then compressed and moves to the condenser, the refrigerant is now a high temperature, high pressure vapour. As the refrigerant expels heat, the refrigerant condenses to a liquid. At the condenser outlet, the refrigerant is a high pressure liquid. The high pressure liquid refrigerant is delivered to the metering device and the sequence begins again.

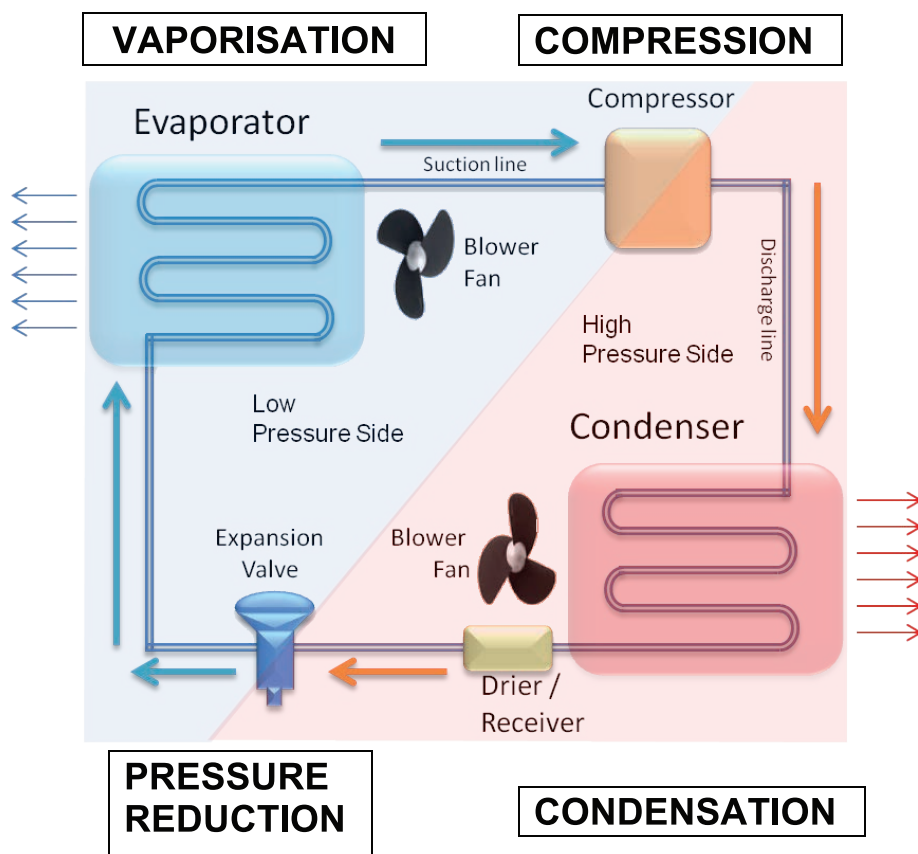


Figure 3.3: The Refrigeration Cycle

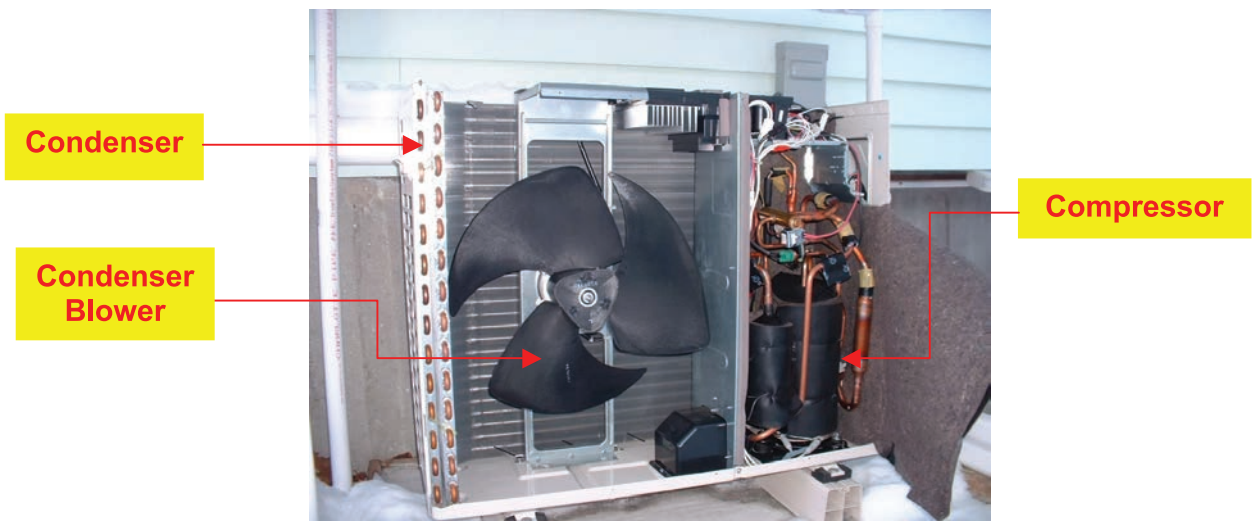


Figure 3.4: Outdoor unit

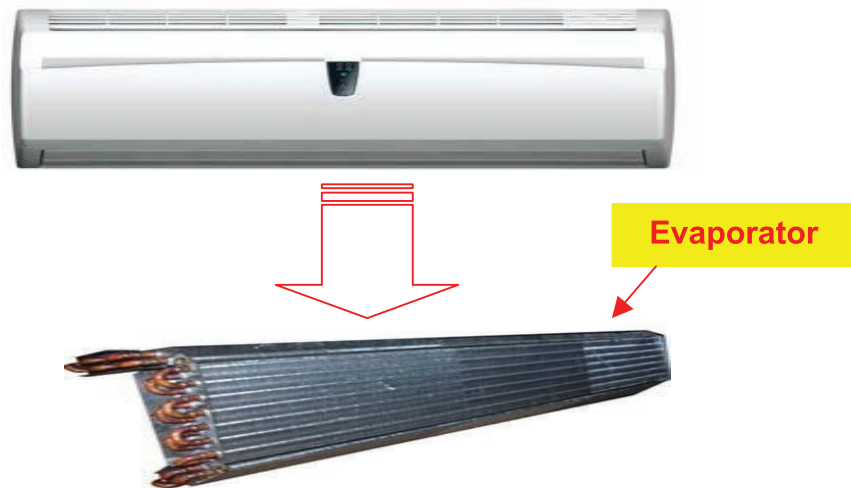


Figure 3.5: Indoor unit

3.3 COMPONENT OF A REFRIGERATION SYSTEM

The Refrigeration Circuit Subsystem contains four basic components. They are the evaporator, condenser, expansion device and compressor.

The refrigerant circuit also contains other key components such as:

- a) The filter-drier, which serves to remove acid, water, and other impurities from the refrigerant. Even if you have not added a filter drier, there is usually a small copper-spun drier that is installed by the manufacturer to capture any moisture that may have been added during system fabrication and charging in factory. On any split system, a filter-drier should always be added as the split systems are prone to more leaks due to the field-installed piping.



Figure 3.6: Filter-drier

- b) A Service access valve is the attachment point for the services manifold. The refrigerant circuit may also contain other components which are not necessary in all applications, such as :

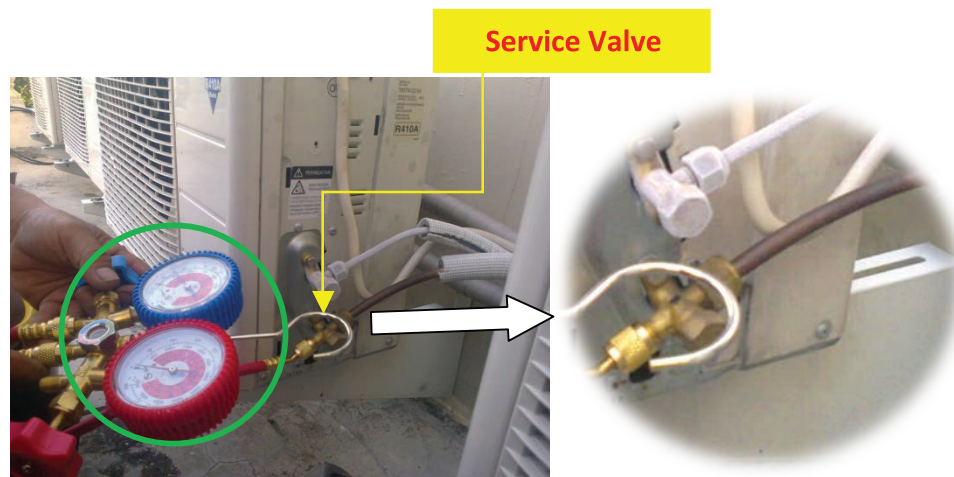


Figure 3.7: Service Valve

- c) Vibration isolators, to isolate the compressor vibration from the remaining plumping and lower the stress and strain on the tubing.

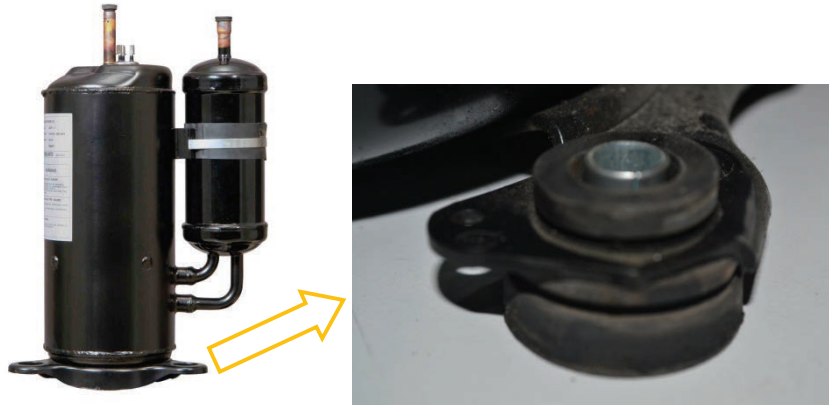


Figure 3.8: Vibration Isolators

- d) A Sight Glass on upstream of the expansion device is to verify a complete charge and to check for moisture (if equipped with a moisture indicating paper).



Figure 3.9: Sight Glass