



*An Online PDH Course
brought to you by
CEDengineering.com*

HVAC Refrigerants and Clean Air Act

Course No: M06-044

Credit: 6 PDH

A.Bhatia



Continuing Education and Development, Inc.

P: (877) 322-5800

info@cedengineering.com

HVAC REFRIGERANTS AND CLEAN AIR ACT (EPA 608 Guidelines)

The refrigerants, primarily chlorofluorocarbons (CFC) and Hydrochlorofluorocarbons (HCFCs) have been linked to the destruction of the earth's protective Ozone layer, which in turn leads to adverse health and environmental concerns including:

- Increase in skin cancers
- Suppression of the human immune response system
- Increase in cataracts
- Damage to crops
- Damage to aquatic organisms
- Increase in global warming

Due to the connection between refrigerant gases and their effect on climate change, 24 nations and the European Economic Community (EEC) signed the "Montreal Protocol" on substances that deplete the ozone layer on 16th September 1987.

On August 1, 1988, the United States Environmental Protection Agency (EPA), has put this agreement into regulations establishing a national refrigerant management program. These regulations created requirements for refrigerant recovery, restricted sales of refrigerant only to trained and qualified technicians, safe disposal and reporting refrigerant losses within a certain timeframe. These regulations include protocols for repairing refrigerant leaks when annual leak rates of 35% (for commercial refrigeration appliances) or 15% (for comfort cooling appliances) were exceeded. EPA inspectors, governmental regulators, as well as many state officials can conduct spot checks of the refrigerant service records, purchase orders, transit logs of refrigerant transport in any commercial refrigeration and air conditioning facility.

EPA Sections 608 and 609 deal with ozone depletion. Section 608 pertains to stationary air-conditioning equipment, and Section 609 deals with the mobile motor vehicle open-driven air-conditioning industry. This course provides guidelines on the refrigerant recovery, recycling and

handling based on the requirements of the EPA Section 608 Guide. If your business operates or services larger refrigerant containing equipment, there is a good chance that this new rule will impact you.

Background

Refrigerants in commercial refrigeration and air-conditioning (RAC) industry may be referred to as Halogenated hydrocarbons primarily chlorofluorocarbons (CFC) and Hydrochlorofluorocarbons (HCFCs). Both these types are considered Ozone depletion substances (ODS) due to the presence of Chlorine atom. These refrigerant gases also have very high Global Warming Potential ratios which results in their detailed tracking, monitoring, and reporting related to their Global Warming effects.

CFCs

CFCs contain chlorine, fluorine, and carbon. Chlorine is found to be one of the major causes of the ozone layer destruction. The larger the number of chlorine atoms in the CFCs, the more their tendency to destroy the ozone layer. The CFC refrigerant R-11 (CCl_3F) that contains three atoms of chlorine has the maximum tendency to deplete the ozone layer. In fact, R-11 is used as the reference to compare the relative ozone destruction capacity of all the refrigerants. It has the highest ozone depleting rating of 1. Some other dangerous CFCs are R-12, R-113, and R-114. The manufacture of these refrigerants was discontinued as of January 1, 1996.

HCFCs

Hydrochlorofluorocarbons (HCFCs) refrigerants contain hydrogen, chlorine, fluorine, and carbon. HCFCs usually contain lesser numbers of the chlorine atoms and have less overall life in the atmosphere. This makes them less dangerous to the ozone layer depletion compared to CFCs. The most known HCFC refrigerant is R-22 (CCL_2F_2), which is used extensively in commercial air conditioning, transport refrigeration equipment, home air conditioners, refrigerators, freezers, and dehumidifiers, has an ozone depletion rating of 0.05. Manufacturing of these refrigerants has already been stopped and will be completely phased out in the year 2020.

HFCs

The risks associated with CFCs and HCFCs prompted exploration and development of alternative refrigerants, with certain Hydrofluorocarbon (HFC) refrigerants becoming the most common replacement. While HFCs do not contain chlorine and do not contribute to the depletion of the ozone layer, they still are considered greenhouse gases and can contribute to a very high global warming potential (GWP) given their fluorine content. HFCs are currently targeted for global phase down under the Montreal Protocol and phase-out by the U.S.A., Canada, Japan and other countries for use in certain applications.

ODP and GWP

The ozone depletion potential (ODP) of a chemical compound is the relative amount of degradation to the ozone layer it can cause. All measurements are relative to a similar mass of CFC-11, which is indexed at 1.0. ODP is determined by the number of Cl or Br atoms and the atmospheric lifetime.

The global warming potential (GWP) relates to the warming of earth's surface temperatures. A greenhouse gas has the potential to form a layer of gas in the upper stratosphere. These gases trap heat in the atmosphere causing climate change and global warming. GWP is a ratio developed to determine which chemical substances and refrigerant gases released into the atmosphere create more warming, compared to similar mass of carbon dioxide (CO₂).

Refrigerant Management for Environmental Safety

The Federal Clean Air Act (CAA), EPA Section 608 requires that all refrigerants, including hydrofluorocarbons (HFCs), must be recovered. By federal law, venting of chlorofluorocarbons (CFCs) (Class I) and hydrochlorofluorocarbons (HCFCs) (Class II) refrigerants was prohibited as of July 1, 1992. Venting substitute refrigerant was prohibited on November 15, 1995 and knowingly venting any refrigerant is a violation of the Clean Air Act (CAA). This includes CFC & HCFCs, and/or CFC & HCFCs refrigerant substitutes, such as 134-A or 410-A. All CFCs and HCFCs must be recovered before opening a system for service or disposing of appliances. The need to conserve or recover refrigerant has led the industry to develop a specific terminology defined by three R's: Recovery, Recycling and Reclaiming.

- a. **Recovery:** Remove refrigerant in any condition from a system and store it in an approved EPA container without testing or processing it in any way.
- b. **Recycling:** Reduce contaminants in used refrigerants by separating oil, removing non-condensables, and using devices such as filter-driers to reduce moisture, acidity, and particulate matter. This term usually applies to procedures implemented in the field or a service shop.
- c. **Reclaiming:** Process used refrigerant to new product specifications. This requires a chemical analysis of the product to ensure that it meets the Air-Conditioning and Refrigeration Institute's ARI Standard 700 for purity. This term usually implies the use of processes or procedures available only at a reprocessing or manufacturing facility.

Adherence to Clean Air Act – Who is Affected?

The United States Environmental Protection Agency (EPA) regulates section 608 of the Federal Clean Air Act. The Clean Air Act establishes the requirements intended to promote proper handling and use of ODSs and HFCs and harmonize refrigerant management requirements across all refrigerant types. The rule contains provisions that affect both owners/operators of refrigerant-containing appliances and the technicians who service them.

- a. The rule requires that if your business operates or services larger commercial or industrial refrigerant containing equipment, you need to understand the requirements and prepare for compliance. Violating the Clean Air Act (CAA) can result in a fine to the employee and employer of up to \$27,500.00 per day per violation. Reporting a violation resulting in a fine can earn a reward of up to \$10,000.00.
- b. The rule also requires that all persons who maintain, service, repair stationary air conditioners and refrigeration systems or dispose of appliances that contain regulated substances must be certified in proper refrigerant handling techniques under Section 608 of the Clean Air Act. The EPA has certification requirements for those who work with refrigerants. There are four different EPA certifications available, depending on the type of system you are working with. To become certified, you must pass a test or series of tests, consisting of multiple-choice questions.

Effective January 1, 2017, the requirements of Section 608 of the U.S. Clean Air Act are changing. The refrigerant handling and reporting requirements are being extended beyond CFCs and HCFCs to include all replacement refrigerants, including HFCs and HFOs.

This course outlines the main requirements of EPA 608 and provide guidance to technicians working on refrigerant equipment. The course is also useful to individuals preparing for the EPA Section 608 certification exam.

CONTENTS

CHAPTER 1: OVERVIEW OF REFRIGERANTS

- 1.0 Refrigerants
- 1.1 Refrigerants Progression
- 1.2 Refrigerant Types
- 1.3 ODP and GWP
- 1.4 Important Milestones for Environmental Awareness

CHAPTER 2: ESSENTIAL PROPERTIES OF REFRIGERANTS

- 2.0. Ideal Refrigerant
- 2.1 Thermodynamic and Thermo-physical Properties
- 2.2 Environment and Safety
- 2.3 Health and Safety

CHAPTER 3: FEDERAL CLEAN AIR ACT & EPA 608

- 3.0. Clean Air Act
- 3.1 EPA Certification Requirements
- 3.2 Documentation Requirements
- 3.3 Penalties and Fines
- 3.4 EPA 608 Definitions

CHAPTER 4: EPA 608 (CORE CERTIFICATION)

- 4.0. Refrigerant Handling
- 4.1 Ozone Depletion
- 4.2 Clean Air Act
- 4.3 EPA Section 608 Regulations

- 4.4 Substitute Refrigerants
- 4.5 Refrigerant Oils
- 4.6 Refrigeration Cycle
- 4.7 Conserving Refrigerants (Controlling Leakages)
- 4.8 Refrigerant Leaks
- 4.9 Leak Detection
- 4.10 Leak Detection Methods
- 4.11 System Charging
- 4.12 Recover, Recycle and Reclaim Refrigerants
- 4.13 Recovery Methods
- 4.14 Recycling of Refrigerant
- 4.15 Reclamation and Separation
- 4.16 Methods of Servicing and Good Practices
- 4.17 Dehydration/Evacuation
- 4.18 Refrigerant Cylinders
- 4.19 Identification
- 4.20 DOT Requirements
- 4.21 Shipping – Transporting Refrigerants
- 4.22 Safety

CHAPTER 5: EPA 608 (TYPE – I CERTIFICATION)

- 5.0 Small Appliances
- 5.1 Refrigerant Recovery Requirements for Small Appliances
- 5.2 Methods to Recover Refrigerant

5.3 Safety

CHAPTER 6: EPA 608 (TYPE – II CERTIFICATION)

6.0 High Pressure Appliances

6.1 Leak Detection

6.2 Recovery Techniques

6.3 Identify Refrigerant Type

6.4 Refrigeration Components

6.5 Safety

CHAPTER 7: EPA 608 (TYPE – III CERTIFICATION)

7.0 Low Pressure Appliances

7.1 Leak Detection

7.2 Recovery Techniques

7.3 Disposal of Refrigerant Containing Appliances

7.4 Purge Units

7.5 Low-Pressure Systems Pressurization Methods

7.6 Safety

Annexure -1 Addendum Requirement of EPA 608 (beginning January 2019)

Annexure -2 Glossary

CHAPTER -1

OVERVIEW OF REFRIGERANTS

1.0. REFRIGERANTS

A refrigerant is a chemical compound that absorbs heat at low temperature and low pressure and transfers it at a higher temperature and high pressure in a refrigeration system. Typically, refrigerants undergo phase-changes during heat absorption (evaporation) and heat releasing (condensation). Due to several environmental issues such as ozone layer depletion, global warming and their relation to the various refrigerants used, the selection of suitable refrigerant has become one of the most important issues in recent times.

The refrigerants are controlled substances regulated by the Environmental Protection Agency (EPA), which means not only are they dangerous to worker health and safety, but they are harmful to the environment. Failing to equip, train and protect technicians working in mechanical rooms from the potential hazard of oxygen deficiency and combustible gas leaks is a serious matter that can result in severe consequences for plant managers and building operators. There are mandatory reporting requirements when serious accidents occur. If releases exceed certain thresholds, the resulting investigations can lead to civil or criminal penalties.

1.1 Refrigerants Progression

The historic progression of refrigerants encompasses four generations:

First Generation (1830s-1930s): Whatever worked

Ammonia, Carbon dioxide, Sulphur dioxide, Hydrocarbons (HCs), Water, and others, many of them are now regarded as “natural refrigerants”

Second Generation (1931-1990s): Safety and durability

Primarily chlorofluorocarbons (CFCs), hydro chlorofluorocarbons (HCFCs), ammonia, and water.

Third Generation (1990-2010s): Stratospheric ozone protection

Primarily HCFCs, hydro fluorocarbons (HFCs), ammonia, water, hydrocarbons, and carbon dioxide.

Fourth Generation (Beyond 2012): Global warming mitigation

Include refrigerants with very low or no ozone depletion potential (ODP), low global warming potential (GWP), and high efficiency, like: unsaturated hydro fluorocarbons, ammonia, carbon dioxide, hydrocarbons and water.

1.2 Refrigerant Types

Refrigerants are divided into groups according to their chemical composition. Following the discovery that some of these chemical compounds may be harmful to the environment, they are being replaced with more environmentally friendly alternatives. The process is not easy, and although there are alternatives to old refrigerants, the new ones are usually not flawless.

1.2.1. Organic Refrigerants

Halocarbons

- a. **Chlorofluorocarbon (CFC)** is an organic compound that contains only carbon, chlorine, and fluorine, produced as a substituted derivative of methane and ethane. It is an ozone depleting compound, which is highly damaging to the environment. It is now illegal to operate fixed refrigeration and refrigerated vehicles using CFC's.
- b. **Hydrochlorofluorocarbons (HCFC's)** are similar to CFC's but contain hydrogen and have a lower ozone depleting potential. It is now illegal to purchase new fixed refrigeration and refrigerated vehicles using HCFC's, though HCFC-22, and blends can still be operated using recycled refrigerant.

- c. **Hydrofluorocarbon (HFCs)** refrigerants are composed of hydrogen, fluorine and carbon atoms connected by single bonds between the atoms; they do not deplete the ozone layer because they do not contain chlorine or bromine. However, they do have a high GWP.

Currently most fixed refrigeration equipment and refrigerated transport solutions depend on the use of HFC's, however HFC's with lower GWP should be considered.

Prefix	Meaning	Atoms in the Molecule	Examples
CFC	Chlorofluorocarbon	Cl, F, C	R11, R12, R113, R114, R115
HCFC	Hydrochlorofluorocarbon	H, Cl, F, C	R22, R123, R141b
HFC	Chlorofluorocarbon	H, F, C	R134a, R404a, R407c, R410a

Olefin Based

HFO (hydro-fluoro-olefin) refrigerants are the new generation of fluorine-based refrigerants. HFO refrigerants are composed of hydrogen, fluorine and carbon atoms, but contain at least one double bond between the carbon atoms. These compounds have zero ODP and a very low GWP. Therefore, these products offer a more environmentally friendly alternative, although there are issues with flammability. They are classed by ASHRAE as A2L, low toxicity, low flammability refrigerants.

These products are in an early stage of development but are beginning to be introduced into the market. When available they would be an acceptable alternative, providing machinery is correctly designed to consider their flammability.

- a. **HFO:** R-1234yf, R-1234ze, R-1233zd, R-1336mzz) next-generation refrigerants: non-ODS with ultra-low GWPs and very short atmospheric lives (measured in days vs. years or decades).
- b. **HFO blends** – blends of an HFC or HCFC with an HFO e.g. R-452B, R-452A, R-513A, R-514A.
 - **Zeotropes (400 series blends)** – have components that boil and condense at different temperatures (i.e. have some degree of temperature glide). Lower glide is typically preferred for HVAC applications.
 - **Azeotropes (500 series blends)** – behave like a single component refrigerant during phase change, with virtually no temperature glide.

Hydrocarbon Refrigerants

Several hydrocarbons have excellent refrigeration fluid properties, zero ODP, and very low GWP. The sole disadvantage of using HC's is their flammability and the risk of explosion. It is recommended that small refrigerators with refrigerant charges of less than 150g should be preferentially purchased where an option to do so exists. Larger charges can be used, provided safety conditions are met.

The limiting factor associated with the use of hydrocarbon refrigerants is the refrigerant charge size, the occupancy category and the room size. Systems with charge sizes of 0.15 kg or less may be installed in a room any size. However, for systems with charge size of more than 0.15kg and up to 1.5kg, the room size should be such that a sudden loss of refrigerant does not raise the mean gas concentration in the room above the practical limit 0.008kg/m³. If it is proposed to use even large charges of HC, this is permitted though it strongly recommended that Standard EN 378 be consulted for safety recommendations.

- R170, Ethane
- R290, Propane
- R600, Butane

- R600a, Isobutane
- Blends of the above gases

1.2.2. Inorganic Refrigerants

Inorganic refrigerants include: water, Ammonia and CO₂.

- Ammonia has excellent refrigerant properties and has been used for many years in larger cold stores. It is still widely used in gas and kerosene-fueled absorption refrigerators and freezers, which provide cold chain in places without a reliable electrical supply. Ammonia is inexpensive and leaks can easily be detected by smell, it has no ODP and low GWP. Its disadvantages are that it has moderate flammability and is toxic.
- Carbon dioxide could well be the refrigerant of the future. It has mostly good thermodynamic properties and it is starting to be used in supermarket, cold store and bottle cooler applications. It has no ODP and a GWP, by definition, of 1. Its main disadvantages are high operating pressures and a critical point (inability to condense) of 29°C, which makes it operate less efficiently, trans-critically, in hot environments.

1.3 ODP and GWP

When specifying new equipment, the table can be used to help select reagents with zero ODP and the lowest technically possible GWP.

ODP and GWP of common refrigerants and blowing agents

Refrigerant	Name	Structure	GWP	ODP
CFC-11	trichlorofluoromethane	CCl ₃ F	4,750	1
CFC-12	dichlorodifluoromethane	CCl ₂ F ₂	10,900	1
CFC-502	chlorodifluoromethane chloropentafluoroethane	CHClF ₂ CClF ₂ CF ₃	4,657	0.25

Refrigerant	Name	Structure	GWP	ODP
HCFC-141b	1,1-dichloro-1-fluoroethane	CCl ₂ FCH ₂	725	0.12
HCFC-22	chlorodifluoromethane	CHClF ₂	1,810	0.05
HFC-134a	1,1,1,2-tetrafluoroethane	CH ₂ FCF ₃	1,430	0
HFC-404a	pentafluoroethane 1,1,1-trifluoroethane 1,1,1,2-tetrafluoroethane	CHF ₂ CF ₃ CH ₃ CF ₃ CH ₂ FCF ₃	3,922	0
HFC-407a	difluoromethane pentafluoroethane 1,1,1,2-tetrafluoroethane	CH ₂ F ₂ CHF ₂ CF ₃ CH ₂ FCF ₃	2,107	0
HFC-410a	difluoromethane pentafluoroethane	CH ₂ F ₂ CHF ₂ CF ₃	2,088	0
HFO-1234yf	2,3,3,3-tetrafluoropropene	CF ₃ CF=CH ₂	4	0
HFO-1234ze	trans-1,3,3,3-tetrafluoropropene	CF ₃ CH=CHF	6	0
N/A	cyclopentane	C ₅ H ₁₀	11	0
HC-290	propane	CH ₃ CH ₂ CH ₃	11	0
HC-600s	isobutane	CH(CH ₃) ₂ CH ₃	3	0
R-717	ammonia	NH ₃	0	0
R-744	carbon dioxide	CO ₂	1	0

1.4 Important Milestones for Environmental Awareness

- a. **1974:** Professor Rowland and Molina presented the “Ozone Theory” that CFCs were depleting the Ozone Layer.
- b. **1985:** Stratospheric ozone hole discovered.
- c. **1987:** 24 nations and European Economic Community sign the Montreal protocol for the reduction of CFCs refrigerants.
- d. **1990:** London amendments to re-evaluate the world’s production of CFCs
- e. **1990:** Introduction of new HCFCs refrigerants into the refrigeration industry.
- f. **1992:** Introduction of azeotropic and zeotropic refrigerants blends.
- g. **1992:** Copenhagen Amendments to increase the percentage of Phase-out of CFCs.
- h. **1997:** Kyoto protocol intended to reduce worldwide global warming gas emissions. The greenhouse effects or global warming had become a major environmental issue.
- i. **1998-2005:** R410A, refrigerants blends, HFC based light commercial Air-Condition applications is used with scroll compressor.
- j. **2005:** The industry began searching for environmentally friendly, safe and technologically so advanced conversant in all areas like domestic, industrial, commercial and transport areas and Air-conditioning.
- k. **2006:** After considering the R-22 phase down scheduled, refrigerants blends have come in place in the refrigeration market for both retrofit and installation.
- l. **2010:** US banned R-22 from the new equipment’s from 1st January 2010, the focus has been made on the next generation refrigerants with low global warming natural refrigerants such as carbon dioxide (CO₂), ammonia (NH₃), Hydrocarbon refrigerants (HC), and HFC blends.
- m. **2012-2015:** R-134a and certain blends have replaced chlorinated compounds. These refrigerants also have ozone depletion potential and global warming potential.

- n. **2015:** Right now, the most likely replacement is another new class of fluorocarbon refrigerant called hydro-fluoro-olefin (HFO). Its primary advantage, other than its low GWP, is that it can be used with existing refrigeration system designs. This is good for the industry and their customers, but it's still a fluorinated gas, among the most potent and long-lived greenhouse gases made by humans. There's growing political pressure to regulate it out of production and force the industry to develop an even lower-impact refrigeration technology. So, the search continues.
- One popular 50/50 blend of R-32 and R-125 now being increasingly substituted for R-22 is R-410A, often marketed under the trade name Puron.
 - Another popular blend of R-32, R-125, and R-134a with a higher critical temperature, and lower GWP than R-410A is R-407C.
- o. **2016:** In October 2016, more than 170 countries agreed to a gradual phase down of HFCs through an amendment to the Montreal Protocol (referred to as the Kigali Amendment). Implementation of this amendment required ratification by 20 countries and 23 have ratified so far. The US has not yet ratified and will require Senate approval by a 2/3 majority vote to do so. Various industry leaders are encouraging the Federal administration to send the treaty to the Senate for a ratification vote. If ratified, Congress may be required to pass laws to establish the mechanisms to meet the requirements of the Kigali Amendment.
- p. **2016:** Separately, in September 2016 the EPA acted to "de-list" the use of R134a and R410A in new chiller applications effective Jan 1, 2024, under the SNAP (Significant New Alternatives Policy) program, referred to as SNAP Rule 21. A similar rule that covered other industry segments (SNAP Rule 20) was challenged in court by Mexichem and Arkema, and the court ruled in their favor, requiring Rule 20 (and presumably Rule 21) to be rescinded and reworked. An appeal was filed and on Jan. 26, 2018, the United States Court of Appeals for the District of Columbia Circuit made its final ruling that invalidates certain HFC de-listings based on the EPA's legal right to regulate replacement refrigerants and foam blowing agents under SNAP.

This ruling has now been appealed to the Supreme Court, and we will not know if the Supreme Court will decide to hear the case until sometime in 2019. Current thinking now is that Rule 21 will remain in place until final disposition of the case involving Rule 20.

- q. **2017:** Effective January 1, 2017, recovered ozone depleting substances (ODSs) and substitute refrigerants cannot be resold unless they were reclaimed by a certified reclaimer, or transferred into equipment belonging to the same owner. The actual sale of these refrigerants will be restricted to certified technicians beginning on January 1, 2018.
- r. **2018:** Beginning on January 1, 2018, refrigerant technician certification requirements will be extended to include technicians engaged in service, maintenance, repair or disposal of appliances containing ODS and substitute refrigerants. (The types of certifications available are not changing and currently certified technicians do not need to be re-certified). Additionally, technicians who dispose of appliances that contain between 5 and 50 pounds of refrigerants must keep detailed records related to refrigerant recovery and appliance disposal.
- s. **2018:** In November 2018, the US Environmental Protection Agency (EPA) amended Section 608 of the Clean Air Act. The amendments were intended to clarify existing requirements and to extend those requirements to hydrofluorocarbons (HFCs) which had previously not been subject to the rules.
- t. **2019:** Beginning on January 1, 2019, allowable leak rates from industrial process refrigeration (IPR) equipment, commercial refrigeration equipment and comfort cooling equipment containing 50 pounds or more of refrigerant will be reduced. Currently, annual leak rates for IPR and commercial refrigeration equipment cannot exceed 35% and annual leak rates for comfort cooling equipment cannot exceed 15%. These maximum annual leak rates will be reduced to 30% for IPR equipment, 20% for commercial refrigeration equipment, and 10% for comfort cooling equipment. Equipment exceeding these leak rates must be repaired within 30 days

and then must be verification tested. Periodic leak inspections will be required thereafter until the equipment is shown to be below the leak rate threshold for one year. Owners and operators of equipment that leaks 125% or more of its full charge in one calendar year will be required to report to EPA.

We will discuss the different types of refrigerants, their properties, environmental concerns and health & safety considerations in subsequent chapters.

CHAPTER – 2

ESSENTIAL PROPERTIES OF REFRIGERANTS

2.0. IDEAL REFRIGERANT

An ideal refrigerant is one that:

- a. doesn't poison people
- b. doesn't blow stuff up or catch on fire
- c. doesn't hurt the environment

The ideal refrigerant is noncorrosive and safe and has good thermodynamic properties such as:

- a. a boiling point somewhat below the target temperature
- b. a high heat of vaporization
- c. a moderate density in liquid form
- d. a relatively high density in gaseous form

Let's discuss the selection criteria as applicable to refrigeration and air-conditioning (RAC) industry.

Refrigerant selection involves compromises between conflicting desirable thermo physical properties such as chemical stability and safety. Other considerations include:

- a. Environmental impact
- b. Cost
- c. Availability
- d. Efficiency
- e. Compatibility with lubricants

2.1 Thermodynamic and Thermo-physical Properties

2.1.1. Chemical Stability

Refrigerant should be compatible with the materials used to fabricate and service refrigeration system components such as compressor, piping, evaporator and condenser. The refrigerant should be stable and inert in use. The chemical stability can also be a problem. When a refrigerant is emitted to the atmosphere, it should not be so stable that it can exist indefinitely. The ideal refrigerant should also be able to decompose easily in the atmosphere without the formation of any harmful substances.

2.1.2. Pressure ratio or Compression ratio

Compression ratio is an indication of the amount of work required from the compressor. The compression ratio needs to be as small as possible. A low compression ratio means a high COP.

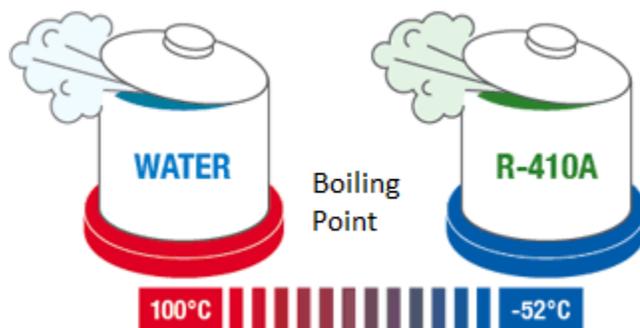
Higher suction pressure and lower discharge pressure leads to smaller compressor displacement and lower energy consumption.

2.1.3. Boiling Point - Latent heat of vaporization

It is a direct indicator of the temperature level at which a refrigerant can be used.

On a molar basis, fluids with similar boiling points have almost the same latent heat, while on a mass basis, latent heat varies widely among fluids.

Efficiency of a theoretical vapor compression cycle increases with low vapor heat capacity.



2.1.4. Specific heat

Liquid specific heat should be small so that the degree of subcooling will be large leading to smaller amount of flash at evaporator inlet.

Vapor specific heat should be large so that the degree of superheating will be small.

2.1.5. Thermal conductivity

The conductivity of the refrigerant should be as high as possible so that the size of the evaporator and condenser is manageable.

2.1.6. Density

Density is the mass per unit volume. A high value of density results in high pressure rise. So, a dense refrigerant needs a larger liquid line to accommodate the greater flow rate without an increase in the pressure drop.

Vapor density does not matter much in the refrigeration system but is very important outside the system. When a fluorinated refrigerant is accidentally or intentionally released from the system, it sinks to the ground and collects in low places. Good ventilation is required near the floor to disperse the gas.

2.1.7. Temperature/Pressure Relationship

The saturation pressure of a refrigerant is related to its saturation temperature. As the temperature increases, so does the pressure.

2.1.8. Viscosity

Viscosity should be small in both liquid and vapor phases for smaller frictional pressure drops.

2.1.9. Self-lubricating and Reaction with Oil

It also would be self-lubricating (or at least compatible with lubricants). It should mix with the oil appropriately so that the oil can do the job of lubrication in the compressor as well as return. High oil solubility is used in hermetic compressors, but immiscible oils are normally used when the working fluid is ammonia.

2.2 Environment and Safety

In contemporary times, environment friendliness of the refrigerant is a major factor in deciding its usage.

2.2.1. Ozone Depletion Potential, ODP

According to the Montreal protocol, the ODP of refrigerants should be zero, i.e., they should be non-ozone depleting substances. The ODP is the ratio of the impact on ozone of a chemical compared with the impact of a similar mass of CFC-11 (R11). Thus, the ODP of CFC-11 is 1.0 by definition. Other CFCs and HCFCs have ODPs ranging from 0.01 to 1.0.

Refrigerants having non-zero ODP have either already been phased-out (e.g. R11, R12) or will be in near-future (e.g. R22). Since ODP depends mainly on the presence of chlorine or bromine in the molecules, refrigerants having either chlorine (i.e., CFCs and HCFCs) or bromine cannot be used under the new regulations.

2.2.2. Global Warming Potential, GWP

Refrigerants should have as low a GWP value as possible to minimize global warming. Global warming occurs when solar energy penetrates the atmosphere and the resultant infrared energy from the earth's surface is absorbed by certain gases and not allowed to leave. This process is commonly known as the greenhouse effect. The GWP is the ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide. For example, the GWP of CO₂ is 1.0. CFC-12 has a GWP of 8500, while CFC-11 has a GWP of 5000. Various HCFCs and HFCs have GWPs ranging from 93 to 12100. Water, a substitute in numerous end-uses, has a GWP of 0.

2.2.3. Total Equivalent Warming Index (TEWI)

Another measurement of the impact on global warming is the TEWI value (Total Environmental Warming Impact). The factor TEWI considers both direct (due to release into atmosphere) and indirect (through energy consumption) contributions of

refrigerants to global warming. Naturally, refrigerants with as a low a value of TEWI are preferable from global warming point of view.

2.3 Health and Safety

The risks associated with the use of refrigerants in refrigeration and air-conditioning equipment can include toxicity, flammability, asphyxiation, and physical hazards. Although refrigerants can pose one or more of these risks, system design, engineering controls, and other techniques mitigate this risk for the use of refrigerant in various types of equipment.

A hazard may be presented when there is an uncontrolled, unexpected release of refrigerant from the system. These containment failures, or refrigerant leaks, are usually the result of one of two conditions:

- a. The refrigerant pressure has increased above the normal operating pressure of the container, component or system.
- b. A component, the piping or system was compromised such that it will no longer hold the operating refrigerant pressure.

The classification, by ASHRAE Standard 34, uses three groups (1, 2 and 3) and two classes (A and B) according to their flammability and toxicity.

2.3.1. Toxicity

Ideally, refrigerants used in a refrigeration system should be non-toxic. However, all fluids other than air can be called as toxic as they will cause suffocation when their concentration is large enough. Hence, toxicity is a relative term, which becomes meaningful only when the degree of concentration and time of exposure required to produce harmful effects are specified. Some fluids are toxic even in small concentrations. Some fluids are mildly toxic, i.e., they are dangerous only when the concentration is large, and duration of exposure is long. Some refrigerants such as CFCs and HCFCs are non-toxic when mixed with air in normal condition. However, when they

come in contact with an open flame or an electrical heating element, they decompose forming highly toxic elements (e.g. phosgene-COCl₂).

ASHRAE 34 classifies a refrigerant's toxicity based on its operational exposure limit (OEL). OEL refers to the time-weighted average concentration of refrigerant to which "nearly all workers can be repeatedly exposed without adverse effect" over the course of "a normal eight-hour workday and a 40-hour workweek":

- a. Class A refrigerants have an OEL \geq 400 ppm
- b. Class B refrigerants have an OEL $<$ 400 ppm

The refrigerants are mandatorily required to be marked for toxicity.

- a. "A" marking refrigerant cylinder have low toxicity
- b. "B" marking refrigerant cylinder have high toxicity

The most common toxic refrigerant is Ammonia and you would generally only find in large industrial applications.

2.3.2. Flammability

The refrigerants should preferably be non- flammable and non-explosive. The refrigerants are well marked, and the users must pay attention to the following best practices:

- a. "1" marking signifies low flammability
- b. "2" marking signifies low flammability but higher than 2L (introduced in 2010)
- c. "3" marking signifies highly flammable

In 2010, a new flammability category was created within ASHRAE 34 - termed "2L". It signifies only "mildly" flammable. Subclass 2L captures refrigerants with a Burning Velocity (BV) less than 10 cm/second and a high Minimum Ignition Energy (MIE), i.e. difficult to ignite and sustain a flame.

Summarizing....

Based on the above criteria, ASHRAE has divided refrigerants into six safety groups (A1 to A3 and B1 to B3).

Refrigerants belonging to Group A1 (e.g. R11, R12, R22, R134a, R744, R718) are least hazardous, while refrigerants belonging to Group B3 (e.g. R1140) are most hazardous.

No substance has proved to be an ideal refrigerant, under all operating conditions. In practical terms it is unlikely that any of the commercially available refrigerants can meet all the above criteria and therefore some compromise should be anticipated.

In some applications toxicity is of negligible importance, whereas in others, such as comfort cooling, a nontoxic and nonflammable refrigerant is essential. For example, a great variety of substances, such as butane, carbon tetrachloride, ethane, and hexane have been applied to refrigeration systems, but found to have little practical use because, these materials are either highly explosive or flammable or possess other combinations of undesirable properties. Therefore, in selecting the correct refrigerant, it is necessary to determine those properties which are most suitable for the application and strike a balance between several factors such as the availability and cost of the refrigerant (and the associated equipment), the system energy efficiency, the safety and convenience of applicability and environmental issues.

In general, the degree of hazard depends on:

- a. Amount of refrigerant used vs total space
- b. Type of occupancy
- c. Presence of open flames
- d. Odor of refrigerant, and Maintenance condition

CHAPTER – 3

FEDERAL CLEAN AIR ACT & EPA 608

3.0. CLEAN AIR ACT

In the United States, the Clean Air Act mandates that the Environmental Protection Agency (EPA) protect and improve air quality and stratospheric ozone layer. The Clean Air Act is a law that:

- a. Sets dates to phase out CFC's and HCFC's
- b. Prohibits venting of CFC and HCFC
- c. Requires the EPA to set standards for recovery of refrigerants prior to appliance disposal

In implementing the law, the EPA Section 608 has detailed regulations regarding chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) refrigerants that deplete the ozone layer, contribute to global warming, or both. The primary objective of EPA Section 608 is to prevent further “Depletion of the Ozone layer” in the earth's stratosphere in accordance with the Montreal Treaty.

EPA Section 608 bans the intentional release of Ozone Depleting Substances (ODS's) and sets guidelines for how they should be handled and recycled. It establishes laws for how technicians evacuate air conditioning and refrigeration equipment, recover refrigerant, and handle refrigerant leaks.

Section 608 defines the rules governing the sale and safe disposal of refrigerants, as well as establishes recordkeeping requirements for technicians, owners or operators, wholesalers, and reclaimers. The sales restriction is established by EPA regulations (40 CFR Part 82, Subpart F) under Section 608 of the Clean Air Act. Only EPA-certified technicians can purchase ozone-depleting substances (ODS) used as refrigerants. Technicians may be certified under either the Section 608 or Section 609 technician certification programs. The sales restriction covers refrigerants contained in cylinders, cans, or drums, except for the sale of small cans of substitute refrigerants (e.g., R-134a

for use in motor vehicle air conditioners. This sales restriction does not cover refrigeration and air-conditioning equipment or components containing refrigerants.

Section 608 requires HVAC professionals to keep records of their work with refrigerants. First, they must keep a copy of their certification at their place of business. Regulations require technicians to keep records of any appliance they dispose containing between 5 and 50 pounds of refrigeration. Also, HVAC technicians who service any appliance with 50 pounds or more of ozone depleting refrigerant, must give the owner documentation stating the amount of refrigerant added to the appliance. This will also apply to HFC and other non-exempt refrigerants started January 2019.

3.1 EPA Certification Requirements

All technicians working with refrigerants must satisfy EPA training and certification requirements imposed by the Clean Air Act Amendments (CAAA) of 1990 (PL 101-549) to work on AC/R equipment containing Class I or Class II refrigerants. In addition, all refrigerant recovery/recycling equipment must be certified by an EPA-approved organization and the certification copies for all base refrigerant recovery / recycling / reclaiming equipment must be kept onsite at the base.

“Technician” refers to any person who performs maintenance, service, or repair, that could be reasonably expected to release refrigerants from appliances, except for MVAC (motor vehicle air conditioning), into the atmosphere. Training and certification sessions may include practicing improved maintenance procedures, finding improvements for current AC/R equipment, and becoming familiar with new equipment. Apprentices are exempt from this requirement provided the apprentice is closely and continually supervised by a certified technician while performing any maintenance, service, repair, or disposal that could reasonably be expected to release refrigerant from appliances into the environment. The supervising certified technician is responsible for ensuring that the apprentice complies with all EPA requirements.

3.1.1. Class I and Class II EPA Requirements

EPA technician certification requirements do not differentiate between Class I and Class II refrigerants. Certification requirements apply equally to these types of refrigerants and are based on the type of appliance that is being serviced.

The EPA is proposing to extend the certification requirements for technicians who work with CFC and HCFC refrigerants to technicians who work with HFCs. Technicians certified to work with CFCs and HCFCs would not have to be retested to work with HFCs, but new technicians entering the field would have to pass a test to work with CFCs, HCFCs, and/or HFCs.

3.1.2. Certification Types

There are four different EPA certifications available, depending on the type of system you are working with. To become certified, you must pass a test or series of tests, consisting of multiple-choice questions. The test is divided into 4 sections: Core, Type I, Type II, and Type III:

1. **Core:** Information that applies to all certification types.
2. **Type I:** A Type I technician primarily works on small appliances containing under 5 pounds of refrigerant - such as domestic refrigerators, window air conditioners, PTACs and vending machines, etc...
3. **Type II:** A Type II technician primarily works on equipment containing over 5 pounds of refrigerant and using a high-pressure refrigerant such as HCFC-22. The equipment includes residential and commercial air conditioners and heat pumps, roof top units, supermarket refrigeration and process refrigeration.
4. **Type III:** A Type III technician primarily works on equipment using a low-pressure refrigerant such as HCFC-123 or CFC-11. These units are primarily chillers.

Any technician with a particular certification type can only fix or recover equipment that is specified for the certification type. A candidate passing all three types (Type I, Type II, and Type III) is certified as **Universal**.

Most residential and small commercial HVACR technicians need to be “Class II Certified” Everyone must pass the core test and one to 3 of the other sections. If you take and pass all four sections, you become universal certified.

Each section has 25 multiple choice questions. A technician must achieve a minimum score of 70% (18 out of 25) to pass that section of the exam. The Core section must be passed to receive any other certification.

For example: A technician could pass Core, Type I and Type III and fail Type II. In this case the technician would be certified as a Type I & Type III technician. Core must be passed to receive any certification. All sections must be passed to achieve Universal Technician status.

A technician may choose to take Core plus any combination of Type I, Type II or Type III. It is not required to take all four sections on the exam.

Tests are closed-book tests. The only outside materials allowed are a temperature/pressure chart and a calculator. The temperature/pressure chart and calculator are both available onscreen, on the online version of the exam. Otherwise, you may remove the chart at the end of this study guide for the exam.

It is important to note that the learning doesn't just end with obtaining the certification. It's important to stay informed about changes to laws and regulations. As the EPA continues to make advances for environmental health, HVAC techs might have to embrace new processes and safer products in their line of work regularly. For example, the new regulations which came on force on January 1, 2019, has further reduced the emissions coming from appliances containing refrigerants. Corrective action must be taken when an appliance with a full charge of 50 pounds or more is leaking refrigerant that exceeds the trigger rate. The new regulations reduce the trigger rate. Those current taking formal refrigeration classes will have to learn the regulations before they can receive their certification and work on such appliances. Other issues address include how soon leaks need to be repaired after they are discovered, when additional time is

necessary to repair leaks, and what to do when deciding to retrofit or retire an appliance that leaks above the trigger rate.

Appliance Type	Current Leak Rate	Leak Rate Effective 1/1/2019
Industrial process refrigeration	35%	30%
Commercial refrigeration	35%	20%
Comfort cooling	15%	10%
All other appliances	15%	10%

3.2 Documentation Requirements

Technician certification programs issue individuals a wallet-sized card (or equivalent) as proof of certification upon successful completion of the test. Each card includes, the name of the certifying program, the date the organization became a certifying program, the name of the person certified, the type of certification, a unique number for the certified person, and the following text: “[Name of person] has been certified as a [Type I, Type II, Type III, and/or Universal, as appropriate] technician”. Technicians must keep a copy of their proof of certification at their place of business.

In addition, a list of certified refrigerant recovery/recycling/reclaiming equipment that includes manufacturer names, evacuation certification types, the date of certification, and refrigerant type must be available in the facility. The owners of the facility must certify to the EPA that they have acquired certified equipment (according to Section 608 of the Clean Air Act of 1990) and are complying with applicable EPA requirements regarding proper use. The EPA requires that an initial one-time list of the purchased recovery and recycling equipment be submitted to the EPA regional office. Any equipment added after the initial submittal does not have to be reported; however, an updated list of equipment must be kept on file.

3.3 Penalties and Fines

Authorized representatives of the certification program administrator may require technicians to demonstrate on the business entity's premises their ability to perform proper procedures for recovering and/or recycling refrigerant. Failure to demonstrate or failure to properly use the equipment may result in revocation of the certificate.

The EPA performs random inspections and responds to tips. The EPA is authorized to assess fines of up to \$27,500 per day for any violation of these regulations. In addition, the technicians may lose their certification to handle refrigerants and may need to appear in US Federal Court for the charges.

3.4 EPA 608 Definitions

1. **Appliance:** Any device which contains and uses a class I (CFC) or class II (HCFC) substance as a refrigerant and which is used for household or commercial purposes, including any air conditioner, refrigerator, chiller, or freezer. EPA interprets this definition to include all air-conditioning and refrigeration equipment except that designed and used exclusively for military purposes.
2. **Apprentice:** Any person who is currently registered as an apprentice in service, maintenance, repair, or disposal of appliances with the U.S. Department of Labor's Bureau of Apprenticeship and Training (or a State Apprenticeship Council recognized by the Bureau of Apprenticeship and Training).
3. **High-pressure refrigerant:** High pressure refrigerant has a boiling point between -50°C and 10°C (or -58°F and 50°F) at atmospheric pressure (29.9 inches of mercury). Included refrigerants are 12, 22, 114, 500 and 502.
4. **Low pressure refrigerant:** Low pressure refrigerant has a boiling point above 10°C or 50°F at atmospheric pressure. Refrigerants included are 11, 113, and 123.
5. **Major maintenance, service, or repair:** Maintenance, service, or repair that involves removal of the appliance compressor, condenser, evaporator, or auxiliary heat exchanger coil.

6. **MVAC (motor vehicle air conditioning)-like appliance:** Mechanical vapor compression, open-drive compressor appliances used to cool the driver's or passenger's compartment of a non-road vehicle, including agricultural and construction vehicles. This definition excludes appliances using HCFC-22.
7. **Opening:** Any service, maintenance, or repair on an appliance that would release class I or class II refrigerant from the appliance to the atmosphere unless the refrigerant were recovered previously from the appliance. Connecting and disconnecting hoses and gauges to and from the appliance to measure pressures within the appliance and to add refrigerant to or recover refrigerant from the appliance shall not be considered "opening."
8. **Reclaim:** To reprocess refrigerant to at least the purity specified in the ARI Standard 700-1993, Specifications for Fluorocarbon Refrigerants, and to verify this purity using the analytical methodology prescribed in the Standard. Reclamation requires specialized machinery not available at a particular job site or auto repair shop. The technician will recover the refrigerant and then send it either to a general reclaimer or back to the refrigerant manufacturer.
9. **Recover:** To remove refrigerant in any condition from an appliance and store it in an external container without necessarily testing or processing it in any way.
10. **Recycle:** To extract refrigerant from an appliance and clean refrigerant for reuse without meeting all the requirements for reclamation. In general, recycled refrigerant is refrigerant that is cleaned using oil separation and single or multiple passes through devices, such as replaceable core filter-driers, which reduce moisture, acidity, and particulate matter. Under section 609, refrigerant can be removed from one car's air conditioner, recycled on site, and then charged into a different car.
11. **Refrigerant circuit:** The parts of an appliance that are normally connected to each other (or are separated only by internal valves) and are designed to contain refrigerant.

12. **Small appliance:** Any of the following products that are fully manufactured, charged, and hermetically sealed in a factory with five pounds or less of refrigerant: refrigerators and freezers designed for home use, room air conditioners (including window air conditioners and packaged terminal air conditioners), packaged terminal heat pumps, dehumidifiers, under-the-counter ice makers, vending machines, and drinking water coolers.

13. **Technician:** Any person who performs maintenance, service, or repair that could reasonably be expected to release class I (CFC) or class II (HCFC) substances from appliances, except for MVACs, into the atmosphere. Technician also means any person performing disposal of appliances, except for small appliances, MVACs, and MVAC-like appliances, which could be reasonably expected to release class I or class II refrigerants from appliances into the atmosphere. (See page 6 for a more detailed discussion)

14. **Very high-pressure appliance:** Uses a refrigerant with a boiling point below 50 degrees Centigrade (-58F) at atmospheric pressure (29.9 inches of mercury). This definition includes but is not limited to equipment utilizing refrigerants 13 and 503.

This chapter follows the outline from the EPA describing the subject material to be used for certification exam questions. Sample test questions are made available at the end of this course from the EPA bank of test questions.

CHAPTER - 4

EPA 608 (CORE CERTIFICATION)

4.0. REFRIGERANT HANDLING

The Core section is most important section and is prerequisite to achieve any other certification type. The Core Section provides general awareness and is also referred in other sections. In this section we will cover some pertinent facts about refrigerants:

1. Ozone depletion
2. Clean Air Act and the Montreal Protocol
3. Section 608 regulations
4. Substitute refrigerants and oils
5. Refrigeration
6. Three R's
7. Recovery techniques
8. Dehydration evacuation
9. Safety
10. Shipping

4.1 Ozone Depletion

Ozone is a gas molecule made up of three oxygen atoms (O_3). Ozone is produced naturally in the upper stratosphere when ultraviolet radiation from the sun strikes molecules of oxygen and dissociates them. This process of O_2 dissociation is called photolysis. Upon dissociation, O_2 liberates a free oxygen atom. This atom can then combine with another O_2 molecule to create ozone. The dissociation of O_2 requires ultraviolet (UV) light of wavelength shorter than 240 nm. Most of the ozone in the stratosphere is formed over the equatorial belt, where the level of solar radiation is greatest. The circulation in the atmosphere then transports it towards the pole. So, the

amount of stratospheric ozone above a location on the Earth varies naturally with latitude, season, and from day- to-day.

Ozone has the same chemical structure whether it occurs miles above the earth or at ground level and can be:

- a. "Good" ozone occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface and forms a layer that protects life on earth from the sun's harmful ultraviolet (UV) rays. Since 90% of the ozone is found in the stratosphere; therefore, this layer is also called the ozone layer.
- b. Ozone in the earth's lower atmosphere (stratosphere), ground-level ozone (or smog) is considered "bad" and it causes greenhouse gas effects contributing to global warming.

The Ozone layer protects life on earth from harmful ultraviolet rays. Depletion of ozone allows more of the sun's harmful UV rays to reach the earth resulting in the following problems:

- a. Increased temperature of the earth
- b. Increased cases of skin cancer
- c. Increased numbers of cataracts in the eyes
- d. Increased ground level ozone
- e. Crop and vegetation loss
- f. Reduced marine life

While the total amount of ozone in the stratosphere varies by location, time and season, the effect of ozone depletion is a global problem.

4.1.1. Types of UV Radiation

- a. UV-A: Wavelengths greater than 320 nm, not radically absorbed by ozone, needed in humans for the formation of Vitamin D.

- b. UV-B: Wavelengths between 280 and 320 nm, large amount of UV-B range blocked out by ozone, primarily affects exposed organs such as the skin and the eyes
- c. UV-C: Wavelengths between 200 and 280 nm, totally removed by stratospheric ozone, causes severe biological consequences.
- d. Each 1% of depletion in stratospheric ozone increases exposure to damaging ultraviolet radiation by 1.5 to 2 percent. [EPA]

4.1.2. Ozone-depleting Substance (ODS)

Ozone depletion is caused by chlorine and bromine atoms emitted into the atmosphere. When a chlorine atom meets with an ozone molecule, it takes an oxygen atom from the ozone molecule. The ozone molecule (O_3) changes to an oxygen molecule (O_2), while the chlorine atom changes to a compound called chlorine monoxide. Chlorine Monoxide doesn't last long, and the molecules soon return to the original chlorine state. This reaction continues with one chlorine destroying thousands of Ozone molecules. It is estimated that a single chlorine atom can destroy 100,000 ozone molecules.

All substances containing some combination of chlorine, fluorine, or bromine plus carbon, such as CFC and HCFC that has been shown to destroy the ozone. These are termed "Ozone-Depleting Substances (ODS)". They degrade slowly and can remain intact for many years. One chlorine or bromine molecule can destroy 100,000 ozone molecules, causing ozone to disappear much faster than nature can replace it.

4.1.3. Ozone Depletion potential (ODP)

Ozone Depletion potential (ODP) is the measurement of the ability of CFCs and HCFCs to destroy the ozone. CFCs have the highest ODP, followed by HCFCs. HFCs do not contain any chlorine and therefore do not have an ODP.

Refrigerants, CFC and HCFC, containing Chlorine are the source of the Ozone depletion problem. The refrigerants are harmless in the lower layer of the atmosphere, but they eventually drift up into the stratosphere. The increased UV in the stratosphere breaks the CFC and HCFV down releasing the Chlorine contained in the refrigerants.

ODSs are divided into two classes:

- a. **Class I:** includes the fully halogenated CFCs, halons, and the ODSs that are the most threatening to the ozone layer, with an ODP of 0.2 or higher.
- b. **Class II:** substances that are known or reasonably anticipated to have harmful effects on the stratospheric ozone layer such as HCFC, with an ODP of less than 0.2

4.1.4. Ranking Refrigerants for Potential Damage

Some refrigerants pose a danger to “Ozone depletion”. Ozone depletion lets too much UV in. Some refrigerants pose a danger to “Global Warming”. Greenhouse gases trap the heat contributing to global warming and climate change.

Refrigerants	Example	Elements	ODP
CFC	R-11, R-12, R-113, R-114, R-115, R-500 and R-502	Chlorine, Fluorine, Carbon	Higher
HCFC	R-22, R-123, R124	Hydrogen, Chlorine, Fluorine, Carbon	Lower
HFC	R-134a	Hydrogen, Fluorine, Carbon	None

4.1.5. Global Warming

Earth like any other object absorbs part of the sun light and reflects the other part. The emission of some substances (e.g. CFC) in the atmosphere reduces the reflection ability of earth and created what have been called “The Green House Effect” or “The Global Warming”.

Globally, the mercury is rising, and this is not only melting glaciers and sea ice, it’s also shifting precipitation patterns and setting animals on the move.

4.2 Clean Air Act

The United States Environmental Protection Agency (EPA) regulates section 608 of the Federal Clean Air Act. It is a violation of Section 608 to:

1. Falsify or fail to keep required records
2. Fail to reach required evacuation rates prior to opening or disposing of appliances
3. Knowingly release (vent) CFC's, HCFC's or HFC's while repairing appliances
4. Service, maintain, or dispose of appliances designed to contain refrigerants without being appropriately certified as of November 14, 1994
5. It is the responsibility of the final person in the disposal chain to ensure that refrigerant has been removed from appliances before scrapping
6. Vent CFC's or HCFC's since July 1, 1992
7. Vent HFC's since November 15, 1995
8. Fail to recover CFC's, HCFC's or HFC's before opening or disposing of an appliance
9. Fail to have an EPA approved recovery device, equipped with low loss fittings, and register the device with the EPA. Low loss fittings can be manually or automatically closed when disconnecting hoses in order to prevent refrigerant loss
10. Add nitrogen to a fully charged system, for the purpose of leak detection, and thereby cause a release of the mixture
11. Dispose of a disposable cylinder without first recovering any remaining refrigerant (to 0 psig.) and then rendering the cylinder useless, then recycling the metal

Failure to comply could cost you and your company as much as \$27,500 per day, per violation and there is a bounty of up to \$10,000, to lure your competitors, customers and fellow workers to turn you in.

Service technicians who violate Clean Air Act provisions may be fined, lose their certification, and may be required to appear in Federal court.

The EPA may require technicians to demonstrate the ability to properly perform refrigerant recovery/recycling procedures. Failing to demonstrate these skills can result in revocation of certification.

In addition, some state and local government regulations may contain regulations that are as strict as or stricter than Section 608.

4.2.1. Montreal Protocol

In 1987 an international conference held in Montreal resulted in a treaty called the "Montreal Protocol".

The Montreal Protocol is an international agreement (Treaty) regulating the production and use (phase out) of CFCs, HCFC's, halons, methyl chloroform and carbon tetrachloride entered into force in mid-1989. Halon is a chemical used in fire extinguishing.

The Montreal Protocol called for a stepwise reduction and eventual production phase out of various Ozone Depleting Substances in developed countries. CFC's were phased-out of production on December 31, 1995.

HCFC refrigerants are scheduled of phase out in the future. When virgin supplies of CFC's are depleted, future supplies will come from recovered, recycled, or reclaimed refrigerants.

4.2.2. Phaseout of Class I Ozone-Depleting Substances

Class I ODS include CFC's. CFCs are commonly used as refrigerants, solvents, and foam blowing agents. The most common CFCs are CFC-11, CFC-12, CFC-113, CFC-114, and

CFC-115. The ozone depletion potential (ODP) for each CFC is, respectively, 1, 1, 0.8, 1, and 0.6.

In 1990 the US Congress amended the "Clean Air Act" and assigned the EPA (Environmental Protection Agency) the responsibility of reducing Ozone depletion by managing air quality and atmospheric protection by giving the EPA regulatory powers.

CFC can no longer be manufactured or imported into the USA effective January 1, 1996.

However, refrigerant manufactured before this date or refrigerant recovered and recycled can be used.

4.2.3. Phaseout of Class II Ozone-Depleting Substances

Class II ODS include HCFC's.

The U.S. schedule for meeting the Montreal Protocol phaseout requirements is summarized in the following table.

Montréal Protocol		United States	
Year to be implemented	Percent reduction in consumption and production using the cap as a baseline	Year to be Implemented	Implementation of HCFCs phase-out to Clean Air Act regulations
2004	35.0%	2003	No production and no importing of HCFC-141b
2010	75.0%	2010	No production and no importing of HCFCs R-22 or R-142b except for use in equipment made before 1 January 2010

Montréal Protocol		United States	
Year to be implemented	Percent reduction in consumption and production using the cap as a baseline	Year to be Implemented	Implementation of HCFCs phase-out to Clean Air Act regulations
2015	90.0%	2015	No production and no importing of any HCFCs except for use as refrigerants and equipment manufactured before 1 January 2010
2020	99.5%	2020	No production and no importing of HCFC-142b and HCFC-22
2030	100.0%	2030	No production and no importing any HCFCs

4.2.4. Common HCFCs and Their Uses

- a. **HCFC-22:** used as a refrigerant in several applications such as unitary air conditioners, cold storage, retail food refrigeration equipment, chillers, and industrial process refrigeration. Also historically used (in smaller quantities) as a blowing agent for certain foam applications and as a propellant in aerosols.
- b. **HCFC-141b:** used as a blowing agent in rigid polyurethane foams and integral skim foams and in aerosol solvent cleaning applications.
- c. **HCFC-142b:** used as a blowing agent in extruded polystyrene board. Also used in small quantities in refrigerant blends and as a retrofit refrigerant, such as in motor vehicle air conditioners. A compound consisting of chlorine, fluorine, and carbon. CFCs are very stable in the troposphere.

- d. **HCFC-123:** used in centrifugal chillers and portable fire extinguishers.
- e. **HCFC-124:** used in some sterilant mixtures and as a component in some CFC-12 retrofit refrigerants. Can be used as a retrofit to replace CFC-114 in some heat pumps and special air conditioning equipment.
- f. **HCFC-225ca and HCFC-225cb:** used as a solvent and aerosol solvent. Also historically used in small quantities in adhesives, coatings, and inks.
- g. **HCFC-21:** used as a refrigerant in highly specialized cooling loops.

4.3 EPA Section 608 Regulations

4.3.1. Venting

Effective 13 June 2005, no person maintaining, servicing, repairing, or disposing of appliances may knowingly vent or otherwise release into the environment any appliance's refrigerant or its substitute. This includes CFC & HCFCs, and/or CFC & HCFCs refrigerant substitutes, such as 134-A or 410-A. The exceptions include nitrogen, water, ammonia, hydrocarbons, and chlorine.

Only the de minimis release is allowed during service, routine maintenance or repair, which refers to the small amounts of refrigerants emitted unintentionally during good faith efforts to recover refrigerants, during the normal course of appliance operation or during the connection/disconnection to charge or service an appliance.

4.3.2. Venting Prohibition at Servicing

Knowingly venting regulated refrigerants is prohibited except for the following:

- a. Release of minimal amounts of refrigerant while attempting to recapture, recycle or dispose of refrigerant.
- b. Release of refrigerant during normal operation of air conditioning and refrigeration equipment as opposed to release during service, maintenance or repair is allowed. An example is mechanical purging from a purge unit on a low-pressure chiller.

Leaks more than specified size must be repaired:

- a. Commercial refrigeration or industrial process refrigeration. Amount of charge is more than 50 pounds and leaking 35% annually must be repaired.
- b. All other leaking 15% annually must be repaired.
- c. Systems containing less than 50 pounds not specified.
- d. CFC or HCFC not used as refrigerant may be released. An example is R-22 mixed with nitrogen and used as a holding charge. You may not however add nitrogen to refrigerant to use this allowance.
- e. You may release small amounts of refrigerant to purge hoses used with manifold gauges. Recovery and recycling equipment manufactured after November 15, 1993 must have low-loss fittings.

4.3.3. Venting Prohibition at Disposal

When disposing of appliances and units containing CFC and HCFC refrigerants, the refrigerant must be recovered from all appliances at the same rate used for servicing the units.

Responsibility for disposal falls to the last person involved in the disposal. This is usually the metal recycler. This person must maintain records including statements that the refrigerant has been removed.

Nitrogen that is used for holding charges or as leak test gases may be released; however, nitrogen may not be added to a fully charged system for the purpose for leak detection and then released.

All CFCs and HCFCs must be recovered before opening a system for service or disposing of appliances.

4.3.4. Penalty

- a. Violating the Clean Air Act (CAA) can result in a fine to the employee and employer of up to \$27,500.00 per day per violation. Reporting a violation resulting in a fine can earn a reward of up to \$10,000.00.
- b. Refrigerant leaks not fixed within 30 days are subject to a \$32,500 fine per day, per unit.
- c. Purchasing used or imported refrigerant gas calls for fines of \$300,000 per 30-pound cylinder of refrigerant gas.

4.3.5. Cylinder & Appliance Disposal

Before disposing of any appliance containing a CFC or HCFC refrigerant, the refrigerant must be recovered. The person responsible for ensuring that refrigerants have been removed from household refrigerators before they are disposed of is the final person in the disposal chain.

All refrigerants in disposable containers have been recovered (0 psig or lower) and rendered useless before recycling the cylinder.

4.3.6. Sales Restriction

As of November 14, 1994, the sale of CFC and HCFC refrigerants is restricted to certified technicians. Only technicians certified under Clean Air Act Section 609 (Motor Vehicle Air Conditioning) can purchase refrigerants in containers smaller than 20 lbs.

4.4 Substitute Refrigerants

4.4.1. Use of Drop-In Refrigerants

The phasing-out of ODS refrigerants, has led to the development of new refrigerants that are often claimed to be direct replacements for the original ODS refrigerants. These refrigerants vary in compositions; some are synthetic fluorocarbons, others are natural refrigerants such as hydrocarbons (HCs), some are single substances, others are blends. However, it is important to thoroughly investigate any refrigerant that is being

considered for use, to ensure that it is a suitable replacement for the situation under consideration, and that those working with the refrigerant are fully aware of its implications.

The following should be carried out:

- a. Check the Material Safety Data Sheets (MSDS) to understand its safety characteristics
- b. Request relevant information related to the substance from the manufacturer of the substance
- c. Find out whether the existing mineral oil needs to be replaced or not.
- d. Technicians should also look for training on the proper handling of these new refrigerants.

Hydrocarbons are known to be flammable, although there are certain concentrations that must be reached prior to explosion if ignition occurs. That is why education and information dissemination is very important. Several developing countries are implementing these methods with the support of United Nations and other implementing agencies.

4.4.2. New Refrigerants

The new refrigerants are incompatible with the oils and lubricants used with CFC and HCFC refrigerants and therefore, oils must be checked and changed out as part of the retrofit procedure. Therefore, no drop-in replacements are not available.

R-134a (also called HFC-134a) is the leading replacement option for retrofitting R-12 systems. The oils used in most R-134a systems are ester-based oils and ester-based oils do not mix with other oils. Leak check an R-134a system using pressurized nitrogen.

Temperature glide is the difference in temperature that occurs when a refrigerant evaporates or condenses (changing from vapor to liquid or liquid to vapor) under constant pressure. This means the temperature in the evaporator and the condenser is not constant.

Temperature glide can also be understood as the difference between the dew point and the bubble point. The dew point occurs when the saturation temperature in the evaporator causes the refrigerant to change from a liquid to a vapor. The bubble point occurs when the saturation point in the condenser changes the refrigerant from a vapor to a liquid.

One problem with blended refrigerants is that since the different refrigerants in the blend have different vapor pressures, they leak from systems at uneven rates. Charging a blended refrigerant should be done as a liquid.

Ternary blends are three-part mixtures. They are common types of refrigerant blends that contain HCFCs. Ternary blends are used with a synthetic alkylbenzene lubricant. Alkylbenzene lubricant is hygroscopic, meaning that it absorbs (takes on) moisture.

A zeotropic (or non-azeotropic) refrigerant is a blend of components that change their composition and saturation temperatures as they evaporate or condense at constant pressure. In other words, the blend boils out at different temperatures (exhibits temperature glide) but at the same pressure. Zeotropes are blends of two or more refrigerants that retain the characteristics of each refrigerant. Because the components have different boiling points, they can leak at an uneven rate. Zeotropic mixtures should be charged as a liquid

Refrigerants with a 5xx numbering are azeotropic meaning they will act like a single refrigerant in regard to pressure/temperature. An azeotropic refrigerant contains compounds that boil out at the same temperatures (do not exhibit temperature glide) and act as a single refrigerant. Azeotropic refrigerants can be charged as a vapor or a liquid

Refrigerants numbered 4xx are zeotropic meaning each refrigerant in the blend keeps its own temperature/pressure characteristics. These refrigerants have “temperature glide”, meaning the higher-pressure refrigerant will vaporize first and condense last followed by the lower pressure refrigerant.

4.4.3. Fractionation

Fractionation is tendency of different components of blends to leak at different rates.

The component refrigerants in zeotropic blends can leak at different rates since they vaporize at different times. This characteristic, called fractionation can cause a change in the blend and a change in how the refrigerant performs. These refrigerants should be introduced into the system (charged) as a liquid and not a gas, so they keep their characteristics.

4.5 Refrigerant Oils

The purpose of refrigeration oil is to lubricate the compressor. The oil and refrigerant are present in the same sealed system. If the oil does not mix well with the refrigerant (miscible), the oil would be carried into the system and become separated and trapped.

4.5.1. Oil Properties

All refrigerant oils are hygroscopic (meaning they attract moisture). All refrigerant oils have certain properties in common.

The viscosity of an oil refers to its thickness, while the density of the oil refers to the composition of the oil at a given viscosity.

An oil's stability is its ability to lubricate without chemical breakdown; its solubility refers to its miscibility with various refrigerants. (Solubility of air refers to the air and moisture entrainment capacity of an oil.) Filter dryers are used to keep the refrigerant and oil dry.

Miscibility refers to the ability of an oil to be mixed; low temperature miscibility refers to the oil's ability to remain mixed (in other words, not separate) at a low temperature. Many compressors are equipped with a crankcase heater to keep the refrigerant from migrating to the compressor. Refrigerant can condense in the oil and boil off when the compressor starts causing compressor damage.

Foaming refers to the tendency of the oil to foam when it is subjected to pressure changes. Foaming will reduce the oil's ability to lubricate.

The dielectric strength of an oil is the threshold at which the oil conducts electricity.

An oil's oxidation value is its ability to resist sludge accumulation.

Its boundary film-forming ability is its ability to separate high pressure and low pressure.

Oil Compatibility: Due to the change in refrigerant use, you may encounter new refrigerants, old refrigerants, and blends of older refrigerants as well as different oils in the field.

Mineral, or petroleum, oils include paraffin-based oils, naphthene-based oils, and mixed oils (a combination of naphthene-based and paraffin-based oils).

Synthetic oils include silicate ester, silicone, neo-pentyl ester, dibasic acid ester, polyglycols such as polyalkylglycol (PAG), alkyl benzene (AB), and polyolyester (POE). Synthetic oils must be stored in metal containers. The ester oils are generally used with alternative refrigerants and are typically compatible with mineral oils and existing system components.

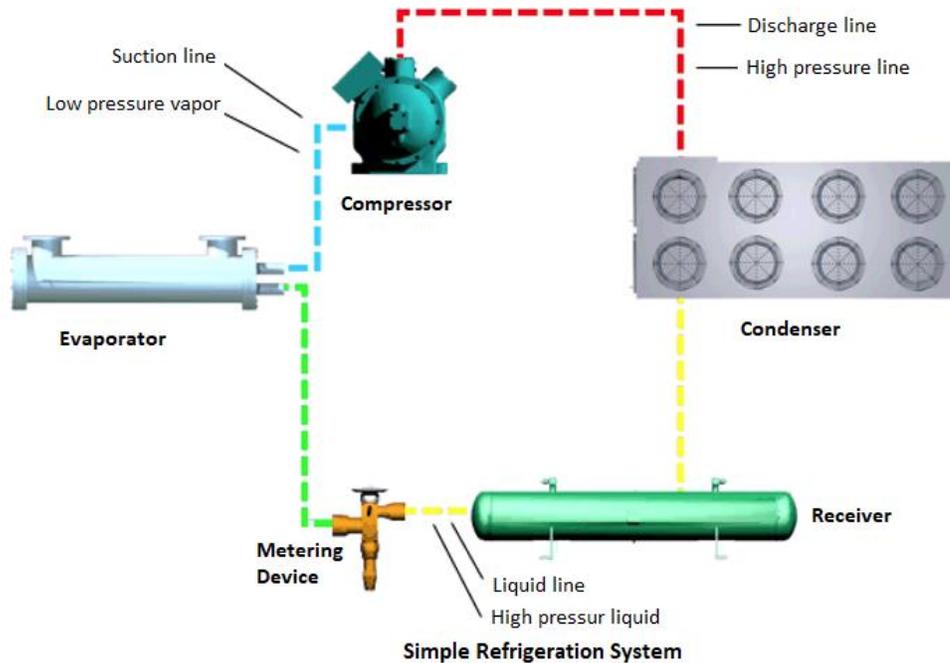
Refrigerant oil must be miscible (able to be mixed) at low temperatures; it must lubricate even when it is diluted; it must have electrical insulating properties; it must maintain its stability; and it must provide a pressure seal.

4.5.2. Oil Types

Oil Type	Abbreviation	Use
Mineral Oil	MO	CFC refrigerant systems
Alkylbenzene	AB	R-22 and other refrigerant systems
Polyolester	POE	HFC refrigerant systems
Polyalkylene	PAG	R-134a automotive systems
Polyalphaolefin	PAO	R-717 (ammonia) refrigeration systems

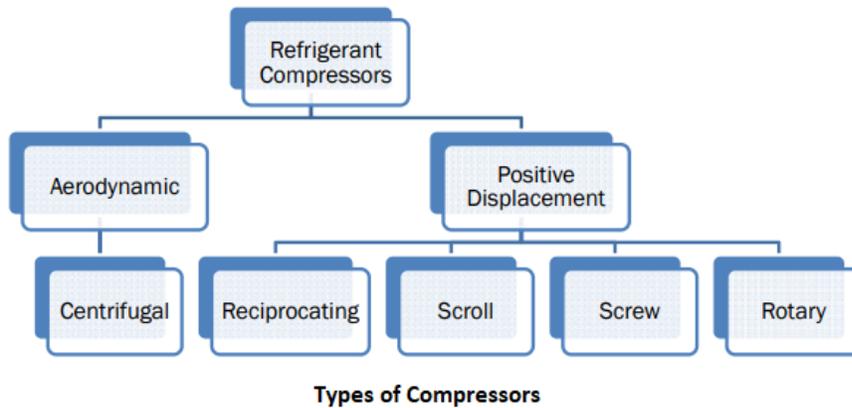
4.6 Refrigeration Cycle

Most refrigeration systems operate on the principle of vapor (gas) compression cycle. This cycle is based on the physical principle that a liquid extracts heat from the surrounding area as it expands (boils) into a gas. The figure below illustrate this basic refrigeration cycle.



Let's look at what happens in a simple refrigeration cycle, and to the major components involved. Two different pressures exist in the cycle - the evaporating or low pressure in the "low side," and the condensing, or high pressure, in the "high side." These pressure areas are separated by two dividing points: one is the metering device where the refrigerant flow is controlled, and the other is at the compressor, where vapor is compressed.

- a. The refrigerant is circulated through the system by a compressor, which increases the pressure and temperature of the refrigerant vapors and pumps it into the condenser.



Aerodynamic compressors operate by increasing the refrigerant pressure from a rotating member.

Positive displacement compressors operate by increasing the refrigerant pressure through work applied to mechanism.

- b. In the condenser, refrigerant vapor is cooled by air or water until it condenses into a liquid.
- c. The liquid refrigerant then flows to the flow control device, or expansion valve, where flow is metered, and the pressure is reduced, resulting in a reduction in temperature.
- d. After the expansion valve, refrigerant flows into the lower pressure evaporator, where it boils by absorbing heat from the space being cooled, and changes into a vapor.

The cycle is completed when the compressor draws the refrigerant vapor from the evaporator and, once again, compresses the gas so that the cycle can continue.

The refrigeration system contains refrigerant and requires some means of connecting the basic major components - evaporator, compressor, condenser, and metering device – by tubing that makes the system complete so that the refrigerant will not leak out into the atmosphere. The suction line connects the evaporator or cooling coil to the compressor, the hot gas or discharge line connects the compressor to the condenser, and the liquid line is the connecting tubing between the condenser and the metering

device (for example, Thermal expansion valve or capillary tube). A system that uses a thermostatic expansion valve is usually equipped with a receiver, which would be in the liquid line directly following the condenser. A system that uses a capillary tube or fixed bore metering device is usually equipped with an accumulator, which would be in the suction line directly following the evaporator.

Refrigerant is the primary working fluid used for absorbing and transmitting heat in a refrigeration system. These absorb heat at low temperature and low pressure and release heat at a higher temperature and pressure. Typically, refrigerants undergo phase-changes during heat absorption (evaporation) and heat releasing (condensation).

The mechanical refrigeration system described above is essentially the same whether the system be a domestic refrigerator, a low-temperature freezer, comfort air conditioning system, industrial chiller, or commercial cooling equipment. Refrigerants will be different, and size of the equipment will vary greatly, but the principle of operation and the refrigeration cycle remains the same. Thus, once you understand the simple actions that are taking place within the refrigeration mechanical cycle you should have a good understanding how a refrigeration system works.

4.7 Conserving Refrigerants (Controlling Leakages)

Refrigerant systems are designed as sealed units to provide long term operation. Refrigerant leakages from the system must be prevented or minimized to protect the environment. Cooling system manufacturers have defined minimum tightness requirements to guarantee permanent operation during defined periods. The American Society for Testing and Materials (ASTM) E 479 "Standard Guide for Preparation of a Leak Testing Specification" serves as a manufacturer's reference document. The standard has a large influence on the maximum allowable leakage flow for a cooling system based on the period during which the system must operate without refrigerant recharge. The refrigerant quantity may be lost by leakage during this period without significantly affecting the operational efficiency of the system. Following facts may be noted for conserving the refrigerant:

4.7.1. Design

Every attempt should be made to design tight systems, which will not leak during the life span of the equipment. The potential for leakage is first affected by the design of the system; therefore, designs must focus on minimizing the service requirements that lead to opening the system. Manufacturers select the materials, the joining techniques, and service apertures. They also design the replacement parts and provide the recommended installation and service procedures. Manufacturers are responsible for anticipating field conditions and for providing equipment designed for these conditions. If the equipment is installed and maintained according to the manufacturer's recommendations, the design and proper manufacturing of the refrigerating system determines the conservation of the refrigerant over the intended life of the equipment.

Among recommendations for conservation, leak tight valves should be installed to permit removal of replaceable components from the cooling system. The design must also provide for future recovery, for instance, by locating valves both at the low point of the installation and at each vessel for efficient liquid refrigerant recovery.

4.7.2. Minimize Refrigerant Charge

Minimizing the refrigerant charge will also reduce the quantity of possible emissions that could be emitted during catastrophic leak events. Historically, little attention has been given to the full charge of equipment, thus, its quantity is not often known (except for small equipment in which the units are shipped charged with refrigerant from the original equipment manufacturer).

Overcharging of equipment is common, as the amount of refrigerant contained in refrigerant receivers is not always known. Refrigerant receivers are equipment components that contain excess refrigerant that migrates through the system as a result of changes in ambient conditions. For such equipment, field charging is often continued until the evaporator supply is considered satisfactory. Without the check of weighing the charge, installation could be overfilled with two harmful consequences:

- a. a potential release of refrigerant

- b. the possibility of transferring the entire charge into the receiver.

The receiver-filling ratio, therefore, must be limited during nominal operation, and an inspection tool (indicator, level, etc.) must be provided.

It should be noted that there are negative effects of charge minimization, for example the system may be more sensitive to a charge deficit leading to an increase in energy consumption. There is a balance to ensure good efficiency despite minor leakage and reduced direct emissions.

4.7.3. Installation

Proper installation of refrigerating systems contributes to the proper operation and conservation during the useful life of the equipment. Tight joints and proper piping materials are required. Proper cleaning of joints and evacuation to remove air and non-condensable will minimize the future service requirements. Proper charging and weighing techniques, along with careful system performance and leak checks, should be practiced during the first few days of operation. The installer should also seize the opportunity to find manufacturer defects before the system begins operation. The installation is critical for maximum conservation over the life of the equipment.

4.7.4. Servicing and Maintenance

To limit the potential of accidental refrigerant emissions, it is important to follow procedures and make sure the refrigeration system is in good operating order. This includes making sure that equipment used is approved by the EPA, checking for leaks, repairing leaks and making sure that all fittings are tight during service and recovery.

The challenge however is that the emission reduction has always proved, so far, more expensive than topping-off cooling systems with refrigerant. It is necessary to make end-users understand that their previous practice of paying to top-off systems must cease, and those funds must be spent on improved maintenance. It is to be noted that such a step has already been taken in some cases, especially in countries like the U.S. where an annually increasing tax on the quantities of ozone-depleting refrigerants that

remain in stock at the end of the calendar year makes conservation or conversion to ozone-friendly refrigerant alternatives more cost-effective.

Refrigerating systems must be tested regularly to ensure that they are well sealed, properly charged, and operating properly. The equipment should be checked in order to detect leaks in time and thus to prevent loss of the entire charge. During maintenance and disposal of the system, refrigerant should be isolated in the system or recovered.

The technician must study the service records to determine history of leakage or malfunction. The technician should also thoroughly check for leaks and measure performance parameters to determine the operating condition of the cooling system. The technician will want to determine the best location from which to recover the refrigerant and assure that proper recovery equipment and recovery cylinders are available. The existence of a maintenance document enables the user to monitor additions and removals of refrigerant with recovery as well as the searches and repairs of leaks.

4.7.5. Reduction of Emissions through Leak Tightness

Leak detection is a basic element, both in constructing and servicing cooling equipment, as it makes it possible to measure and improve conservation of refrigerant. Leak detection must take place at the end of construction by the manufacturers, at the end of assembly in the field, and during regularly scheduled maintenance of equipment.

There are three general types of leak detection:

- a. Global methods indicate that a leak exists somewhere, but they do not locate the leaks. They are useful at the end of construction and every time the system is opened for repair or retrofit;
- b. Local methods pinpoint the location of the leak and are the usual methods used during servicing;
- c. Automated performance monitoring systems indicate that a leak exists by alerting operators to changes in equipment performances.

4.7.6. End-of-Life Disposal

Safe disposal requirements should mandate disposal of ODS components in residential appliances such as refrigerant and foam. Some of the sources are:

Many household refrigerators and freezers produced prior to 1994 rely on CFC refrigerants. After 1996, most newly manufactured household refrigerators and freezers contain hydrocarbon refrigerants or ozone friendly refrigerants (HFCs).

Oil in the compressor is likely to be contaminated with refrigerant, be it CFC or HFC, so it too must be treated carefully. In addition, the foam blowing agents in most in-use refrigerators/freezers also use ozone depleting substances. Ultimately, if these foams are not properly recovered from appliances and properly disposed, additional ODS will be released to the atmosphere, leading to further destruction of the ozone layer.

Some chest freezers manufactured prior to 2000 may contain a mercury switch. Mercury is toxic and causes a variety of adverse health effects, including tremors, headaches, respiratory failure, reproductive and developmental abnormalities, and potentially, cancers. Also, older appliances may contain PCB capacitors. PCBs can lead to adverse effects ranging from minor skin irritations, to reproductive and developmental abnormalities, to cancers in humans and wildlife.

4.7.7. Retrofitting

In general, the retrofit of an equipment or installation means to substitute older parts for new or modernized ones in order to improve the performance. In RAC recently, retrofit has come to mean the procedure of replacing ozone depleting substances (ODS), or hydrofluorocarbon (HFC) refrigerants in existing plants with zero ozone depleting potential (ODP) or zero GWP refrigerants. Retrofitting usually requires modifications such as a change of lubricant, replacement of expansion device or compressor. If the conversion does not require such major modifications, the alternate refrigerant is called a drop-in replacement, or retro-fill process. Retrofitting from an ODS-using system to an ozone-friendly refrigerant requires a thorough investigation and study of the system.

Some factors must be considered:

- a. Retrofit the system if it is more cost-effective than replacement. If a major repair (e.g. compressor change, etc.) or modification of an ODS using system is necessary it shall be evaluated if retrofit can be done at acceptable cost.
- b. Properly working and leak-free systems are not recommended for retrofit, at least until there is a need to open the refrigeration system for repair. Properly operating systems can continue operating for many years without causing harm to the ozone layer. For older systems that are prone to faults, failures and leaks, it may be more cost-effective to replace the system rather than retrofit. In addition, new equipment will be more energy efficient.
- c. Upon evaluation of a system that requires major repair and is close to the end of its technical/economical life, consider replacement if it is more cost effective than retrofitting.
- d. The safety and environmental properties of alternative refrigerant to be used, such as flammability, toxicity, ODP and global warming potential shall be considered.
- e. Include in the assessment the compatibility of components and materials in the system, such as elastomers and oil. Also, components like sight glasses and oil separators must be checked for suitability.
- f. Assess and examine the operating conditions of the system and determine the service and its operational history.

4.8 Refrigerant Leaks

According to the EPA, “leakage rate” is the rate at which an appliance loses refrigerant, measured between refrigerant charges. The leakage rate is expressed in terms of the percentage of the appliance’s full charge that would be lost over a 12- month period, if the current rate of loss were to continue over that period.

Allowable EPA leakage rates are based on three main equipment categories: comfort cooling, commercial refrigeration, and industrial refrigeration. Comfort cooling refers to equipment designed for environmental control for occupant comfort. Commercial refrigeration refers to refrigeration appliances used in the retail food and cold storage warehouse sectors. (Retail food includes refrigeration equipment found in supermarkets, convenience stores, restaurants, and other food service establishments.) Industrial process refrigeration refers to complex, customized appliances used in the chemical, pharmaceutical, petrochemical, and manufacturing industries and is directly linked to the industrial process.

4.8.1. Comfort Cooling Refrigeration Equipment

Comfort cooling refrigeration equipment containing 50 pounds or more of refrigerant must have all refrigerant leaks repaired within 30 days, if the actual annual leakage rate exceeds 15% of the total charge. The annual leakage rate is based on the percentage of the appliance's full charge that would be lost over a 12-month period, if the current rate of loss were to continue over that period.

4.8.2. Commercial and Industrial Refrigeration Equipment

Commercial and industrial refrigeration equipment containing 50 pounds or more of refrigerant must have refrigerant leaks repaired within 30 days, if the actual annual leakage rate exceeds 35% of the total charge. The annual leakage rate is based on the percentage of the appliance's full charge that would be lost over a 12-month period if the current rate of loss were to continue over that period.

4.8.3. How to calculate leakage rates?

The leak rate can be determined using either an annualized method (most familiar and most used) or a rolling average method (intended to catch leaks more quickly). The results of the two methods differ only when leakage rates are calculated at periods of less than one year. Although not entirely clear in the EPA regulations, once a method is chosen, the same method must be used for all refrigeration or A/C equipment at the

facility. Therefore, use discretion before switching from the annualized method to the rolling average method.

Annualized method

$$\text{Leak rate \%} = 100 \times \frac{\left(\frac{\text{lbs refrigerant added}}{\text{lbs refrigerant in full charge}} \right)}{\left(\frac{\text{days since refrigerant last added}}{\text{or 365 days, whichever is shorter}} \right)} \frac{1}{365 \text{ days}}$$

Rolling average method

$$\text{Leak rate \%} = 100 \times \frac{\text{lbs refrigerant added over past 365 days or since leaks were last repaired if that period is less than 1 year}}{\text{lbs refrigerant in full charge}}$$

When the calculated leak rate exceeds the applicable threshold listed below, the owner or operate must repair, retrofit, or retire the appliance. The leak rate threshold is:

- a. 20% for commercial refrigeration equipment; and
- b. 10% for comfort cooling appliances or other appliances.

In addition, when a large appliance leaks 125% or more of the full charge in a calendar year, facilities must submit a report to EPA that describes the efforts taken to identify the leaks and repair the leaking appliance. If the report does not contain confidential business information, the report must be submitted electronically to 608reports@epa.gov. When the report contains confidential business information, the report must be submitted by mail to: Section 608 Program Manager; Stratospheric Protection Division; Mail Code: 6205T; U.S. Environmental Protection Agency; 1200 Pennsylvania Avenue NW; Washington, DC 20460. The report must be submitted by March 1 of the subsequent year.

A sample calculation based on the annualized method is as follows:

Example

An office building is cooled by a 200-ton rotary chiller containing a 400-pound HCFC R-22 refrigerant charge. Ten pounds of HCFC R-22 were added during the last servicing. Because the chiller provides comfort cooling, uses a regulated refrigerant, and contains 50 pounds or more of charge, the 15 percent leakage rate applies. If this were a commercial or industrial refrigerant system, the 35 percent leakage rate would apply.

Service Records/Dates

Calendar Date	Julian Date	Refrigerant Added
1 October	274	5 lb
4 December	338	10 lb

Determine the EPA maximum leakage rate (MLR):

$$\text{MLR} = 400 \text{ lb} \times 15\%/\text{yr} = 60 \text{ lb/yr}$$

(This is the maximum amount of refrigerant this unit can lose in a 12-month period without violating EPA regulations.)

Determine the actual leak rate (ALR):

$$\text{ALR} = \text{lb refrigerant added since last servicing} / [(\text{days between servicing}) / (365 \text{ days/yr})]$$

$$\text{ALR} = [(10 \text{ lb of HCFC R-22}) / (338 - 274 \text{ days}) / (365 \text{ days/yr})]$$

$$\text{ALR} = 57 \text{ lb/yr}$$

Is $\text{ALR} \geq \text{MLR}$?

57 lb/yr is less than 60 lb/yr

Action is not necessary. However, the unit used 10 pounds of refrigerant. Good conservation practice requires checking for and repairing any leaks.

4.8.4. What if ALR > MLR?

If the ALR had been \geq MLR, it triggers the requirement to repair the leak within 30 days of the leak discovery and to keep records of its timely repair. The repair must be verified

within 30 days as required by the EPA. If the appliance cannot be repaired within 30 days, document all repair efforts and have the base environmental office notify the EPA of the inability to comply within the 30-day repair requirement and the reason for not being able to comply in accordance with 40 CFR Part 82, Subpart F, Section 82.166. An extension beyond the 30-day period may be requested from the EPA, if the necessary parts are unavailable or if requirements of other applicable federal, state, or local regulations make repair within 30 days impossible.

If the appliance cannot be repaired within 30 days or within 30 days of a failed follow-up verification test, or after making a good-faith effort to repair the leaks, owners can develop a one-year retirement or replacement plan for the leaking appliance. A copy of the retirement or replacement plan needs to be sent to the EPA within 30 days of discovering the leak. Compliance with the 30-day requirement is based on the date the report was postmarked. Keep a copy of the replacement or retirement plan at the site of the appliance.

4.9 Leak Detection

Refrigeration and air conditioning systems are designed to operate adequately with a fixed charge of refrigerant. If it has been determined that a system has insufficient refrigerant, the system must be checked for leaks, then repaired to prevent refrigerant escaping into the atmosphere.

Leaks are indicated by:

- a. Low refrigerant charge
- b. High superheat
- c. Traces of oil on a tube or fitting joint
- d. Worn tubing due to vibration
- e. Access points such as Schrader valves and service valves
- f. Shaft seals on open compressors

Refrigerant leaks are caused by material failure. The mechanism that creates the material failure is normally attributable to one or more of the following factors:

- a. **Vibration** – Vibration is a significant factor in material failure and is responsible for “work hardening” of copper, misalignment of seals, loosening of securing bolts to flanges, etc.
- b. **Pressure changes** – Refrigeration systems depend on the changes in pressure for their operation. The rate of change of pressure has different effects on the various components in the system, which results in material stress and differential expansion and contraction.
- c. **Temperature changes** – Refrigeration systems frequently consist of different materials of differing thickness. Rapid changes in temperature result in material stress and differential expansion and contraction.
- d. **Frictional wear** – There are many cases of frictional wear causing material failure, and they vary from poorly-fixed pipework to shaft seals.
- e. **Incorrect material selection** – In a number of cases, inappropriate materials are selected e.g., certain types of flexible hoses have a known leakage rate, and materials that are known to fail under conditions of vibration and transient pressure and temperature changes are used.
- f. **Poor quality control** – Unless the materials used in the refrigeration system are of a high and consistent standard, changes in vibration, pressure and temperature will cause failure.
- g. **Poor connections** – Poorly made connections, either brazed joints, screwed connections, or not replacing caps on valves, can allow refrigerant to escape.
- h. **Corrosion** – Exposure to a variety of chemicals or the weathering can result in a variety of different corrosion modes, which decays the construction material resulting in the eventual creation of holes.

- i. **Accidental damage** – Accidental mechanical impacts to refrigerant-containing parts can happen under many circumstances, and therefore it is appropriate to ensure that all parts of the system are protected against external impacts.

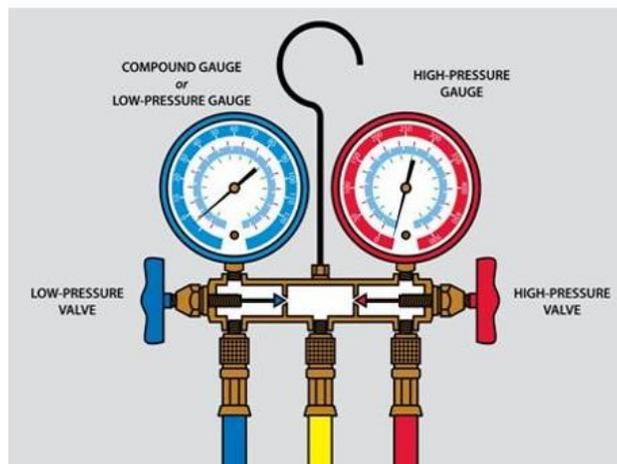
4.9.1. Pressure Testing

When a system is thought to have a leak, the whole system should be checked, with leaks found being marked for rectification. One should never assume a system has only one leak. Leak detection is the manual procedure, carried out by a qualified technician, of checking refrigeration systems to identify possible leaks in tubes, joints and/or connections, etc. Pressure testing new or repaired systems with nitrogen before charging with refrigerant is a good practice. If the system does not hold pressure a leak must be located and repaired. If the leak cannot be found using an inert gas and pressure test, the EPA allows, as a last resort, using some refrigerant as a trace gas and a refrigerant sensing tool to find the leak.

4.9.2. Gauge Manifold Set

One of the most important tools to the HVACR technician is the gauge manifold set (also known as a **service manifold**). It is an important tool for the Technician who measures pressure readings at different points in the refrigeration system.

The compound gauge (**blue**) and the high-pressure gauge (**red**) are connected to the manifold, and the manifold is then connected by hoses to access ports to measure system pressures.



The compound gauge measures low pressure (psig) and vacuum (inches Hg.). The high-pressure gauge measures high side (discharge) pressure.

The manifold is also equipped with a centre port (usually a yellow hose), that can be connected to a recovery device, evacuation vacuum pump, or charging device. EPA regulations require that hoses be equipped with **low loss fittings** that will minimize refrigerant loss when hoses are disconnected.

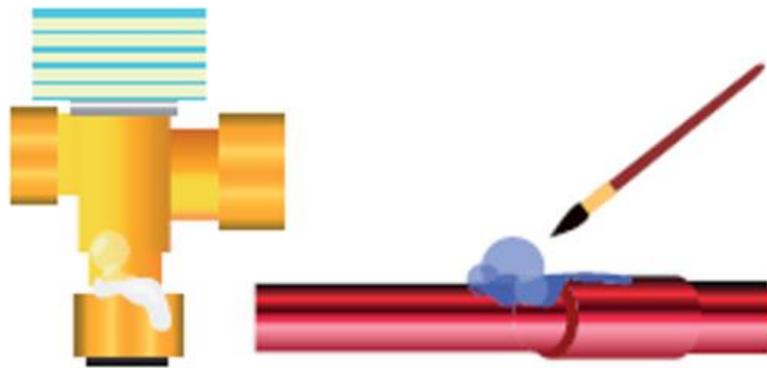
4.10 Leak Detection Methods

Generally, the main methods for detecting leaks in the servicing field are:

4.10.1. Using Soap-Solution

A water-soap solution is the most popular, minimal cost, and one of the most effective methods used among servicing technicians.

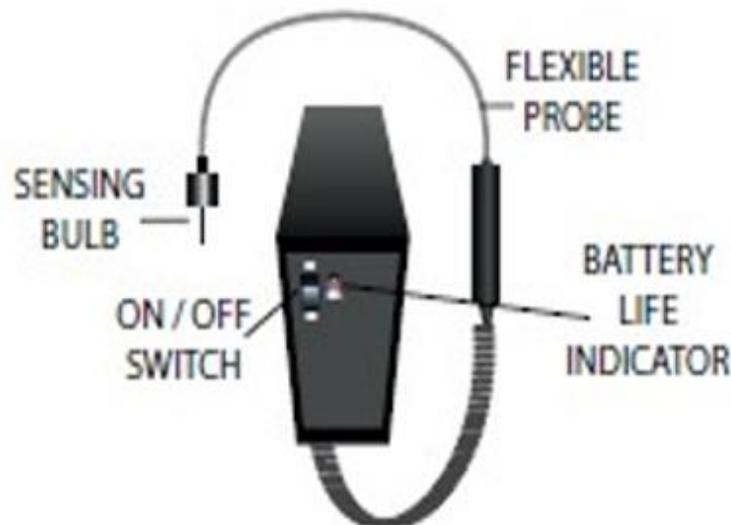
Applying a soap solution to joints, connections and fittings while system is running or under a standing pressure of nitrogen helps to identify leak points when bubbles appear.



Soap Bubble Testing

4.10.2. Using an Electronic Refrigerant Detector

Electronic refrigerant detectors contain an element sensitive to the chemical composition in a refrigerant. The device may be battery or AC-powered and often has a pump to suck in the gas and air mixture. Often, an audible “ticking” signal, and/or visible flashing indicating lamp increases in frequency and intensity as the sensor analyses higher concentrations of refrigerant, which suggests to the operator that the source of the leak is closer.



Electronic Refrigerant Detector

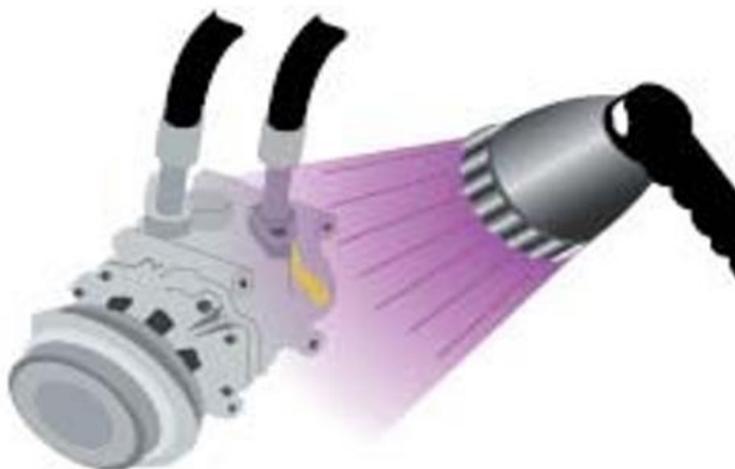
Many refrigerant detection devices also have varying sensitivity ranges that can be adjusted. Many modern refrigerant detectors have selector switches for switching between refrigerant types, e.g. chlorofluorocarbons (CFCs), hydrochlorofluorocarbons

(HCFCs), HFCs or HCs. HCFCs have less chlorine than CFCs and the sensitivity has to be changed by the selector switch. When using electronic refrigerant detectors in a workshop, always ensure good ventilation since sometimes it gives false signals due to other refrigerants being present in the surrounding area.

Electronic refrigerant detectors may be used to detect hydrocarbons (HCs), but the sensitivity may not be adequate, or may need re-calibration. The detection equipment should be calibrated in a refrigerant-free area. Ensure that the detector is not a potential source of ignition and is suitable for hydrocarbon refrigerants.

4.10.3. Using an Ultra-Violet Lamp

Ultra-violet lamp is a method commonly used in large systems where accessing all joints and connections by soap solution or electronic detectors is difficult.



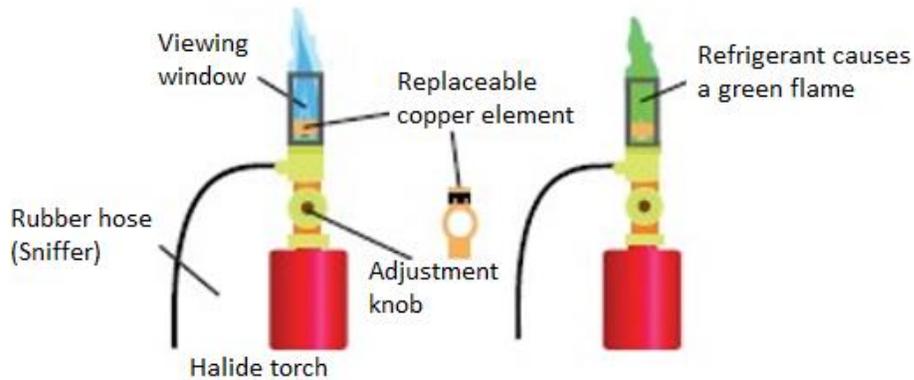
UV- Lamp Leak Detection

By adding an additive dye to the refrigerant, the leak will glow yellow green-colors when pointed by the ultra-violet lamp.

4.10.4. Using a Halide Torch

The halide torch used to be the traditional means of leak detection with CFC and HCFC refrigerants. It is the most effective method for checking for small leaks.

A blue flame draws air (and refrigerant) from the hose and across a copper catalyst. Refrigerant causes a green flame.



Halide Torch Leak Detection

Since HFCs do not contain chlorine, halide torches will not work when searching for leaks from HFC system. The same applies to carbon dioxide (R744), ammonia (R717) and hydrocarbons (R290, R600a etc.). Obviously, from a safety point-of-view, the halide torch should not be used to detect hydrocarbons or any other flammable refrigerants, anyway, or in the presence of other flammable gases.

4.10.5. Leak Repair Requirements

When the leak rate exceeds the applicable leak rate, the facility must identify and repair the leak with 30 days of adding the refrigerant.

- a. EPA **does not** require repair of leaks holding **less than 50 pounds** of refrigerant
- b. EPA **does** require repair of leaks in systems containing **50 pounds or more** of refrigerant when:
 - Commercial and industrial process refrigeration systems when the leak exceeds 35% of the charge per year.
 - Equipment other than commercial and industrial process refrigeration when the leak exceeds 15% of the charge per year.

To conduct the repair, a certified technician must conduct a leak inspection of the whole appliance to identify the location of the leak(s). All identified leaks must be repaired

with an initial and a follow-up verification test conducted to confirm that each leak was successfully repaired. Additional time is permitted for leak repairs where the repair parts are unavailable, or the equipment is mothballed, so long as an extension is submitted to EPA and EPA does not reject the request.

Following repair and successful verification tests, inspections must be conducted:

- a. For commercial refrigeration appliances with a full charge of 500 or more pounds, once every three months until the leak rate calculation is below the applicable leak rate for four quarters in a row.
- b. For commercial refrigeration appliances with a full charge of 50 or more pounds but less than 500 pounds, once per calendar year until the leak rate calculation is below the applicable leak rate for one year.
- c. For comfort cooling appliances and other appliances, once per calendar year until the leak rate calculation is below the applicable leak rate for one year.

These inspections are not required on appliances, or portions of appliances, that are continuously monitored by an automatic leak detection system that is audited or calibrated annually. The installation and the annual audit/calibration must be documented for three years.

4.10.6. Retrofit or Retirement

In lieu of conducting repairs, facilities may retrofit or retire refrigeration or A/C equipment. In this event, facilities must create a retrofit or retirement plan within 30 days after determining that the leak rate trigger has been exceeded or after a failed follow-up verification test, or if good-faith efforts to repair a leak are unsuccessful. A retrofit or retirement plan must:

- a. Identify the appliance and its location;
- b. Identify the refrigerant type and the full charge of the appliance;
- c. Identify the refrigerant type and the full charge to which the appliance will be converted (if retrofitted);

- d. Itemize the procedure for converting the appliance to a different refrigerant (if retrofitted);
- e. Plan for the disposition of recovered refrigerant;
- f. Plan for the disposition of the appliance (if retired);
- g. Include a schedule for completion of the appliance retrofit or retirement; and
- h. The date and signature of an authorized company official.

These plans must be maintained for at least three years.

All retrofit or retirement work must be completed within one year, unless an extension is submitted to EPA and EPA rejects the request.

4.11 System Charging

System charging is adding the proper quantity of refrigerant to refrigeration system so that it operates as intended. For a given set of conditions (design conditions) systems have an “optimum” charge – this is the mass of refrigerant that the highest efficiency and design cooling capacity (or heating capacity, in the case of a heat pump) will be achieved. At off- design conditions, for example, at a higher or lower ambient temperature, the optimum charge will be different. However, it is best to add the specified charge since this is what the system has been designed to handle.

Some systems can handle a wider variation of charge size, especially those with liquid receivers. Direct expansion systems with small condensers and capillary tube expansion devices tend to be very sensitive to refrigerant mass and are said to be “critically charged”.

In all cases, the system data-plate should contain useful information such as the design refrigerant charge size.

4.11.1. Volumetric Charging by Graduated Cylinder

It uses a glass tube liquid level indicator, which allows a technician to transfer refrigerant into a system and measure the amount on a scale. Some cylinders are

electrically heated to speed up the evaporation and maintain pressure in the cylinder. This process of electrically heating cylinder is usually done with an electrical insert. In some cases, the compressor itself is heated, using a heat gun so the refrigerant and oil will circulate and be purged more easily.

In both cases, it is extremely important that a pressure control relief valve and thermostat be used to provide the required temperature and pressure safety controls. The system has a pressure gauge and hand valve on the bottom for filling the charging cylinder liquid refrigerant into a system. It also has valve at the top of the cylinder. This valve is used for charging refrigerant vapor into the system.

4.11.2. Mass Charging by Balance

Electronic weight balance is typically one of the most accurate ways to charge refrigerant. System charging could be performed in vapor or liquid phase. This is generally done in smaller systems, which are more sensitive to charge size. Therefore, it is important to be aware of the additional refrigerant within the refrigerant hoses, and the artificial weight of the hoses themselves on the balance reading, so that the actual mass added to the system is not erroneous.

4.11.3. Charging to Sight Glass

This method normally applies to larger systems that have a liquid receiver. Refrigerant is charged into the system, and as it is metered in, the technician observes the sight glass in the liquid line. Eventually, once no more bubbles can be seen in the sight glass, the charge size has approximately been achieved.

However, as there is always a delay between adding the refrigerant and the effect on the sight glass, the technician should take extra time to ensure that the correct charge has been added. It should also be borne in mind that longer delays between adding refrigerant and the response of the sight glass occur with larger systems. As with all other systems, it is important to consider the ambient temperature and the possibility of adding a little more refrigerant so that no bubbles appear during warmer/cooler ambient conditions. In addition, the refrigerant cylinder(s) should be weighed before

and after, and the charged amount checked against the intended charge or compared against the size of the liquid receiver to ensure that it will not hydraulically fill during pump-down.

4.11.4. Charging According to System Performance

It is possible to charge a system according to the system's performance characteristics. This is done by monitoring the suction pressure, discharge pressure, evaporator superheat and liquid subcooling out of the condenser.

First, the design performance characteristics are noted: the ambient temperature, the application temperature (to be cooled to), the intended superheat and subcooling. From the ambient temperature and the application temperature, a typical condenser and evaporator temperature difference is assumed for the equipment under consideration (say, for example, 8 K), from which the saturated condensing and evaporating temperatures, and finally suction and discharge pressures are estimated.

Thermometers are tightly attached to the liquid line and suction line (using a heat transfer paste and insulated). Refrigerant is then gradually added into the system and the pressures and temperatures monitored. As the estimated suction and discharge pressures are approached, and the design subcooling and superheat values are achieved, a suitable charge is achieved. Again, as with the sight glass, there is a delay between adding refrigerant and the resulting performance characteristics being achieved, so these performance characteristics should be observed for some time to ensure that the reading are constant.

4.11.5. Electronic Charging Machines

During larger-scale manufacturing, equipment tends to be charged using electronically controlled charging machines. These generally measure refrigerant into a system using precise mass flow meters and are generally accurate to $\pm 0.5\text{g}$ or better.

4.11.6. Vapor Refrigerant Charging

Vapor refrigerant charging is the process of moving vapor out of the vapor space of the refrigerant cylinder to the low-pressure side of the system. Charging while the system is running is acceptable as long as the suction pressure is closely checked during the charging process. Due to pressure difference consideration, the cylinder pressure could become lower than system suction pressure during charging. Using a hot water or servicing charging heaters could solve this problem. Never use a brazing torch to heat cylinders.

Steps:

- a. Open the low-pressure side valve then open refrigerant graduated charging cylinder valve keeping eye on system pressure and refrigerant weight scale.
- b. When the pressure has equalized between the system and charging cylinder, close the charging cylinder valve and operate the system for 1-2 minutes until the low-pressure side reading indicates lower reading than the charging cylinder.
- c. Continue adding refrigerant by opening the charging cylinder valve until the proper charge is obtained.

Before connecting any refrigerant hose to a service or tap valve, the hose should be briefly purged (vented) with refrigerant from the cylinder to ensure that air and moisture does not enter the system.

4.11.7. Liquid Refrigerant Charging

Liquid refrigerant charging usually applies to high refrigerant charge systems, like large commercial systems and systems with liquid receivers. Charging liquid refrigerants always requires skill and caution.

The suction hand-valve is to be used carefully to monitor the liquid gauge pressure to not exceed approximately 20 psig above suction pressure; when the blue hose (suction line) frost is observed close to the hand-valve, check the suction pressure. Repeat until the desired charge is obtained.

Remember always to make sure that:

- a. If the refrigerant cylinder does not have a dip-tube, it should be placed in an upside-down position to guarantee liquid flow.
- b. Bypassing the low-pressure side control.

4.12 Recover, Recycle and Reclaim Refrigerants

The three R's of refrigeration are: recover, recycle, and reclaim.

- a. **Recover:** Removing refrigerant from a refrigeration system is known as recovery. Recovered refrigerant is stored in an external container without necessarily testing or processing it in any way.
- b. **Recycle:** When equipment operation shows signs of contamination or refrigerant deficiency, refrigerant can be recovered and recycled. Refrigerant can be put to reuse by separating the oil from the refrigerant and removing moisture, acidity and particulate matter from the refrigerant by use of products like core filter driers.
- c. **Reclaim:** If severe contamination occurs or exacting standards must be met, refrigerant must be reclaimed. Reclamation by refrigerant distillation can separate some refrigerants. Reclaimed refrigerant must meet the standard set forth in ARI 700 before it can be resold. If the refrigerant is so contaminated that distillation is ineffective, it must be disposed of at an authorized treatment facility.

Refrigerant Recovery and/or Recycling equipment manufactured after November 15, 1993, must be certified and labeled by an EPA approved equipment testing organization to meet EPA standards.

4.12.1. Recovery

Removing refrigerant from a refrigeration system in any condition and storing it in an external cylinder is known as recovery. Recovery is mandatory, if the system is opened to the atmosphere. If an equipment component that requires service is isolated, only

the isolated equipment section needs to be evacuated. Internal refrigerant storage should become the standard.

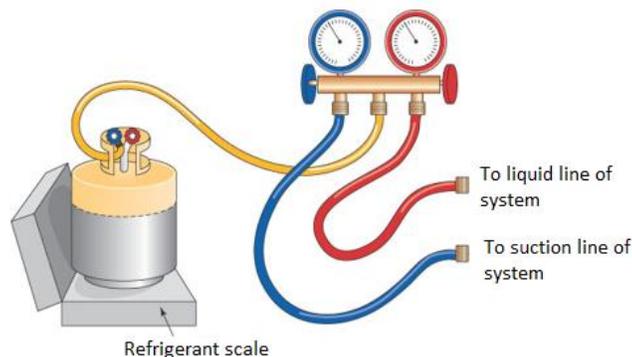
As of July 13, 1993, all systems in general that are to be opened to the atmosphere for any reason, including disposal, must have the refrigerant recovered and must be evacuated to the levels specified. The rule applies to all air conditioning and refrigeration equipment containing CFCs and HCFCs except motor vehicle air conditioners.

All refrigerant recovery and/or recycling equipment manufactured or imported after November 15, 1993 must be tested, certified and labelled by an EPA approved Laboratory or organization.

4.12.2. Recovery Devices

When the system is being repaired, the refrigerant needs to be removed from the system. Recovery can be done by having proper equipment for the process. Recovery equipment that can recover refrigerants with high pressure must be selected. There are two basic types of recovery devices.

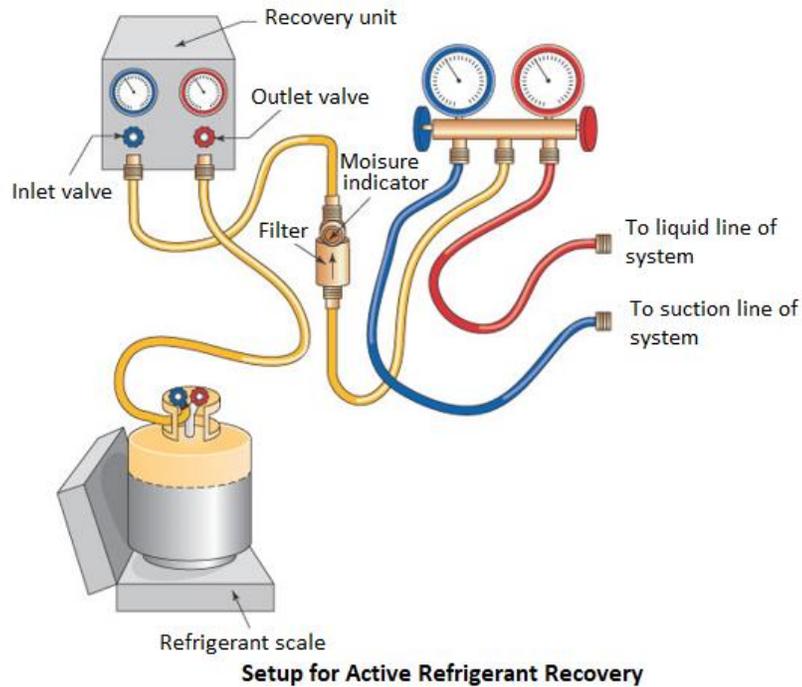
- a. **System dependent:** System dependent recovery or passive refrigerant recovery uses the system compressor to pump the refrigerant from the system to an approved DOT refrigerant cylinder.



Setup for Passive Refrigerant Recovery

- b. **Self- contained devices:** Self-contained recovery or active refrigerant recovery equipment has its own compressor/pump. Active recovery is required when the

system contains more than 15 pounds of refrigerant or if the system compressor is inoperative.



The EPA requires a **service aperture** or **process stub** on all appliances that use a Class I or Class II refrigerant to make it easier to recover refrigerant.

Schrader valves (which look like bicycle tire air valves) are common on both refrigerant systems and recovery equipment. When using Schrader valves, it is critical to:

- a. Check the valve core for bends and cracks
- b. Replace damaged Schrader cores to prevent leaks
- c. Cap the Schrader ports when not being used to prevent leaks

Due to the increased charges for recovering refrigerants, consumers have complained about paying for the process. To handle these complaints, let the consumer know that:

- a. Recovery is the law.
- b. Recovery is necessary to protect human health and the environment.

- c. All professional service personnel are duty bound to follow the law and protect the environment.

When recovering refrigerants, only put one type of a refrigerant in a tank and **do not** mix different refrigerant types into one tank. Mixed refrigerants in the same tank may be impossible to reclaim. When servicing a system that already has a mix of two or more refrigerants, the mixed refrigerants must be recovered into a separate tank.

4.12.3. Factors affecting Recovery Time

The longer it takes to recover the refrigerants, the higher chance of emissions of the refrigerants to the atmosphere. The following factors affect the time it takes to recover refrigerant.

- a. **Size of refrigeration system and recovery equipment.** The bigger the system, the longer the recovery process. The bigger capacity of the recovery equipment, the faster the recovery.
- b. **Size of suction hose.** The longer the suction hose and the smaller in diameter it is, the higher the pressure drop in the system and the longer it will take to recover refrigerants.
- c. **Ambient temperatures.** The colder the ambient temperature, the longer the recovery process. If the refrigerant system is warmer than the recovery cylinder, the recovery process will go faster due to a higher pressure in the refrigerant system and a lower pressure in the recovery cylinder.

4.12.4. How to speed up recovery?

In order to reach the vacuum levels that are required in some countries for larger systems, vapor recovery will be used after liquid recovery. Performance standards for refrigerant recovery equipment are available for service of both motor vehicle air conditioners (e.g., SAE J1990), and stationary refrigeration and air-conditioning systems (e.g. ARI Standard 740). Adoption of such standards as a part of common service procedures could be adopted by regulating authorities.

You can speed up recovery using these techniques:

- a. Keep the system pressure high to move refrigerant to the lower pressure recovery device faster.
- b. Keep the recovery container pressure as low as possible to draw out the refrigerant.
- c. High outside ambient temperature will produce a higher system pressure.
- d. Heating the system components with heaters will increase system pressures.
- e. Place the recovery container in ice to lower its pressure.
- f. Use short large diameter hoses to reduce pressure drop.
- g. Properly maintain your recovery equipment

4.13 Recovery Methods

Recovery of refrigerants is similar to evacuating a system using the vacuum pump. As with vacuum pumps, recovery units will work much more efficiently, if connection hoses are kept as short and as large in diameter as possible. However, not being able to get a recovery unit close to a system is not an acceptable excuse for not using one. If long hoses must be used, all that will happen is that recovery will take longer. There is no longer any acceptable reason or excuse for releasing refrigerants into the atmosphere.

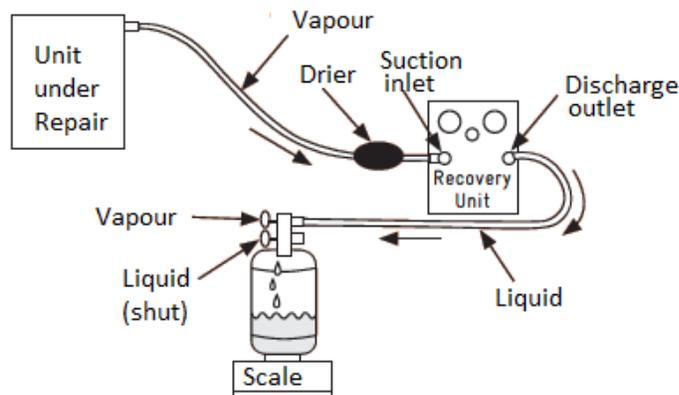
There are three different recovery methods: Vapor recovery method (most common); the Liquid recovery method; and the Push-Pull method. A filter-dryer or particulate filter must be used on the refrigerant recovery unit as acid and particulate matter may lead to damage of the refrigerant recovery system.

4.13.1. Vapor Transfer

The steps to be followed for vapor recovery are:

1. Connect a hose to the discharge side of the recovery equipment
2. Connect the other end of the hose connected to the recovery unit, to the liquid port on the recovery cylinder

3. Place the recovery cylinder on a weighing scale
4. Connect a hose from the low side service port of the system
5. Connect the other end of the hose connected to the system, to the center (charging) port of the manifold
6. Connect a hose to the low side of the manifold
7. Connect the other end of the hose connected to the manifold, to the suction side of the recovery equipment
8. Connect a hose from the cylinder vapor port to the high gauge on the manifold. This will allow monitoring of the cylinder pressure
9. Close valves on the manifold. Then:
 - Open vapor and liquid valves on the recovery cylinder
 - Start the recovery machine/unit
 - Allow the unit to pull into the suitable vacuum, as per the type of refrigerant
10. Close all valves and disconnect from the system



Vapour Recovery Method

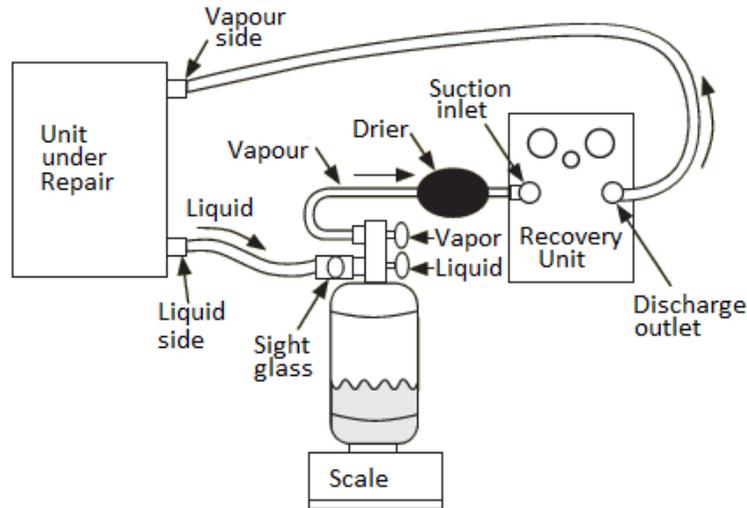
On larger refrigeration systems this will take appreciably longer than if liquid is transferred. The connection hoses between recovery units, systems and recovery cylinders should be kept as short as possible and with as large a diameter as practicable.

4.13.2. Liquid Transfer

Until recently, it was unheard of to recover direct liquid. But with the use of oil-less compressors and constant pressure regulator valves, it's become the preferred method of recovery by most recovery equipment manufacturers. Oil-less recovery equipment has an internal device to flash off the refrigerant. Oil-less compressors will tolerate liquid only if metered through a device like a CPR (crankcase pressure regulating) valve. Don't attempt to use the liquid recovery method unless your unit is designed to recover liquid.

The steps to be followed for liquid recovery are:

1. Connect a hose to the low side access point of the recovery unit compressor discharge valve.
2. A second hose is then connected from the recovery unit compressor suction valve, through a filter drier, to a two-valve external storage cylinder.
3. A third hose is connected from the high side access point (liquid valve at the receiver) to the two-valve external storage cylinder.
4. Turn on the recovery machine/unit. Here, the compressor pumps refrigerant vapor from the external storage cylinder into the refrigeration system, which pressurizes it. The difference in pressure between the system and the external storage cylinder forces the liquid refrigerant from the system into the external cylinder.
5. Once the liquid refrigerant is removed from the system, the remaining vapor refrigerant is removed using the vapor recovery method as explained earlier.



Liquid Recovery Method

Liquid recovery is performed the same way as standard vapor recovery. The only difference is that you will connect to the high side of the system. Recovering liquid is ideal for recovering large amounts of refrigerant.

If the recovery unit does not have a built-in liquid pump or is otherwise not designed to handle liquid, then liquid can be removed from a system using two recovery cylinders and a recovery unit. The recovery cylinders must have two ports and two valves, one each for liquid and one each for vapor connections. Connect one-cylinder liquid port directly to the refrigeration system at a point where liquid refrigerant can be decanted. Connect the same cylinder vapor port to the recovery unit inlet. Use the recovery unit to draw vapor from the cylinder, thereby reducing the cylinder pressure, which will cause liquid to flow from the refrigeration system in to the cylinder. Take care as this can happen quite quickly.

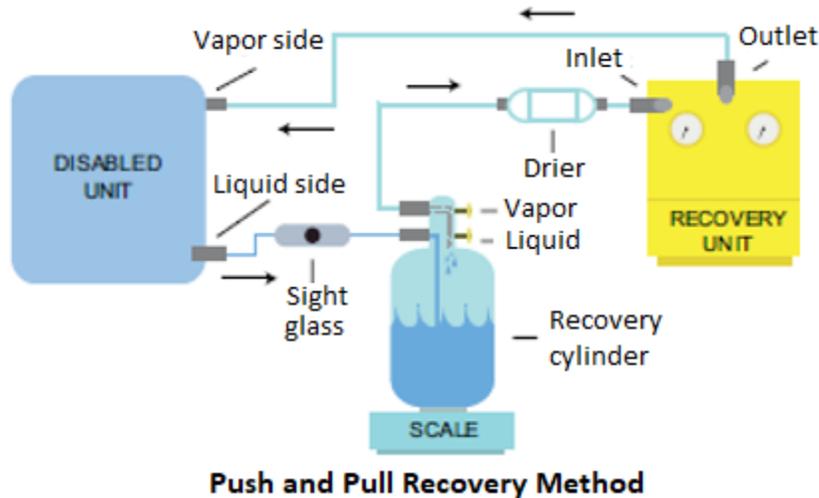
The second cylinder is used to collect the refrigerant from the recovery unit as it draws it from the first cylinder. If the recovery unit has adequate onboard storage capacity this may not be necessary. Once the entire liquid refrigerant has been recovered from the refrigeration system, the connections can be relocated, and the remaining refrigerant recovered in vapor recovery mode.

4.13.3. Push and Pull Liquid Recovery

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

The steps to be followed for Push-Pull recovery are:

1. Connect a hose from the vapor port of the cylinder to the center port of the manifold
2. Connect a hose from the low side of the manifold to the suction side of the refrigerant recovery unit
3. Connect a low-loss hose from the discharge side of the recovery unit, to the low side service port of the manifold
4. Connect the hose from the high side service port of the manifold to the cylinder liquid valve
5. Place the cylinder on a weighing scale
6. Open the valves of the recovery cylinder
7. Start the refrigerant recovery machine
8. Open the low side valve on the manifold
9. Monitor the weighing scale
10. Switch over the unit to vapor recovery once the weighing scale stops picking up weight



Important: On recovering the refrigerant using any one of the above methods, label the recovery cylinder indicating a) when it was recovered; b) type of refrigerant; and c) its weight.

4.13.4. Safety During Recovery

Safety is always a concern when recovering refrigerant. Manifold gauges, safety glasses/goggles, gloves, a refrigerant recovery cylinder (other than normal), a weighing scale, an approved refrigerant recovery unit, and suitable hoses will be required to recover refrigerant from the system. For safety, personal protective equipment (PPE) must always be worn. To avoid the formation of phosgene gas, refrigerant should not be recovered near an open flame. A weighing scale must be used to avoid overfilling of the recovery cylinder. Overfilling can cause the cylinder to rupture and severely damage the equipment.

4.14 **Recycling of Refrigerant**

The process of recycling consists of cleaning the refrigerant for reuse by oil separation and single or multiple passes through filter driers which reduce moisture, acidity etc. In the past, refrigerant was typically vented into the atmosphere, but currently the recycling equipment enables reuse of refrigerant.

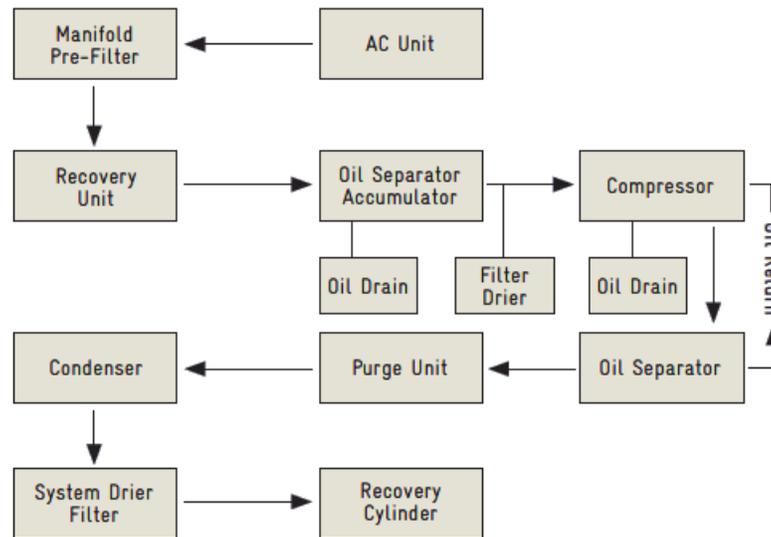
Refrigerant removed from a system cannot be reused in as-it-is form; it needs to be cleaned for any contamination. Recycling machines reduce the contaminants through oil

separation and filtration. Normally, recycling of refrigerants is carried out using equipment that does both recovery and recycling of the refrigerant. Recycling can be useful for drying refrigerants that contain moisture instead of water or for removing particulate matter.

Recycling machines use either the single pass or multiple pass method of recycling.

4.14.1. Single Pass Recovery Equipment

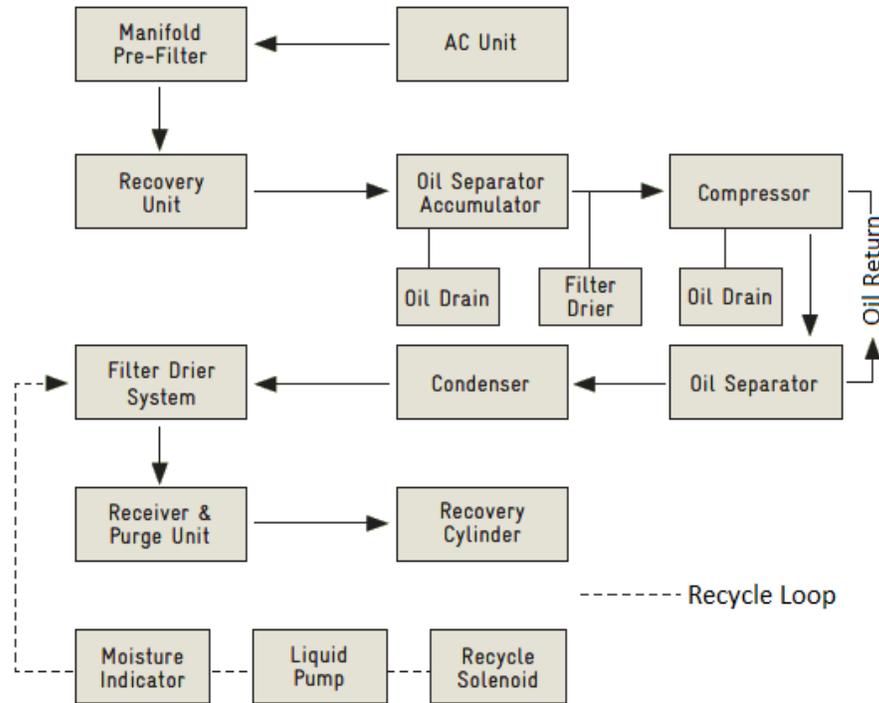
The single pass recycling machines process refrigerant through filter-driers and /or distillation. It makes only one trip from the recycling process through the machine and then into the storage cylinder.



Single Pass Recovery Equipment

4.14.2. Multi-pass Recovery Equipment

The multiple pass method re-circulates the recovered refrigerant many times through filter- driers. After a certain period or number of cycles, the refrigerant is transferred into a storage cylinder. Multiple-passes method recycling takes longer but depending on the refrigerant level of contamination and moisture it may be essential, for example, if it is particularly dirty.



Multiple Pass Recovery Equipment

Recovered refrigerant may be reused in the same system from which it was removed, or it may be removed from the site and processed for use in another system, depending upon the reason for its removal and its condition, i.e., the level and types of contaminants it contains. Even low levels of these contaminants can reduce the working life of a refrigeration system and it is recommended that recovered refrigerant should be checked before reuse.

4.14.3. Recycling Equipment

Recycling equipment is expected to remove oil, acid, particulate, chloride, moisture, and non- condensable (air) contaminants from used refrigerants. The effectiveness of the recycling process can be measured on contaminated refrigerant samples according to standardized test methods, such as those within the standards ISO 12810 and ARI 700. Unlike reclaiming, recycling does not involve analysis of every batch of used refrigerant and, therefore, it does not quantify contaminants nor identify mixed refrigerants. Subsequent restrictions have been placed on the use of recycled refrigerant, because its quality is not proven by analysis.

A variety of recycling equipment is available over a wide price range. Currently, the automotive air-conditioning industry is the only application that prefers the practice of recycling and reuse without reclamation. Acceptance in other sectors depends on national regulations, the recommendation of the cooling system manufacturers, the existence of another solution such as a reclaim station, variety and type of systems, and the preference of the service contractor. Recycling with limited analysis capability may be the preference of certain developing countries where access to qualified laboratories is limited and shipping costs are prohibitive. For most refrigerants there is a lack of inexpensive field instruments available to measure the contaminant levels of reclaimed refrigerant after processing.

4.15 Reclamation and Separation

Reclamation is a process when a refrigerant is processed equal to virgin refrigerant. Reclamation purifies, tests, and certifies used refrigerant to new product specifications using distillation or other methods. Refrigerant chemical analysis is required to assure that appropriate product specifications are met. Refrigerant reclamation from a system undergoing repairs is not required in most cases. Reclamation is required if, for example, free water stands in the system due to a tube failure or because a motor burned out.

Most types of reclaiming equipment operate on the same process, where the used or contaminated refrigerant enters the reclamation unit in vapor or liquid state. It is heated (distillation) till the pure refrigerant vapor is separated from the contaminated refrigerant. The refrigerant then enters a large, exclusive separator chamber where the velocity radically drops. This allows the high temperature vapor to rise. In the separator chamber, contaminants like copper debris, carbon, oil and acid settle at the bottom of the separator.

These contaminants can be removed during the 'oil out' or 'drain' operation. The distilled refrigerant in the vapor form from the separator enters an air-cooled

condenser. Here, it gets converted to a liquid form. The liquid refrigerant passes through a filter drier and then into a storage chamber.

Care should be taken to not cross-contaminate recovered refrigerant. Refrigerants that are combined after recovery, such as hydrocarbons with CFC refrigerants, will require separation (normally via distillation) prior to reclamation. High costs and the lack of availability of separation facilities provide disincentives to the proper recovery of refrigerant.

4.15.1. Reclaimed Refrigerant

The governing Standard for reclaimed refrigerant is ARI 700 Specifications for Fluorocarbon and Other Refrigerants. The purpose of this standard is to establish purity specifications, to verify composition, and to specify the associated methods of testing for acceptability of fluorocarbon refrigerants regardless of source (new, reclaimed and/or repackaged) for use in new and existing refrigeration and air-conditioning products within the scope of ARI.

4.16 Methods of Servicing and Good Practices

4.16.1. Avoid Contaminants

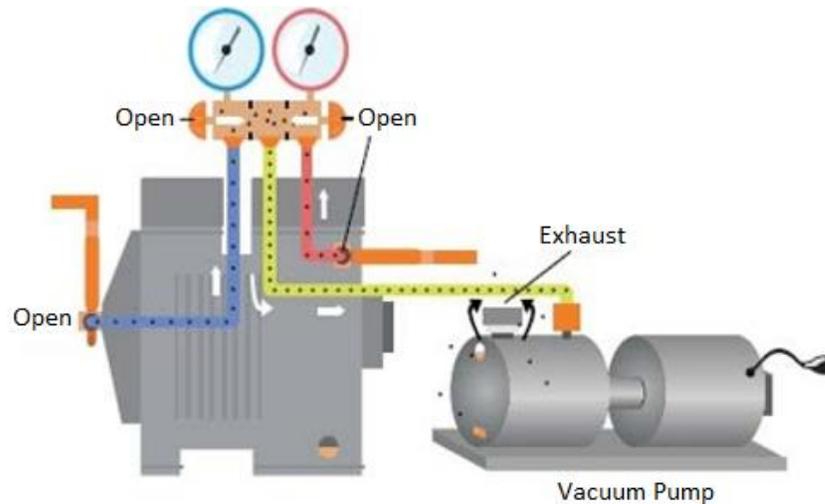
Before charging any system with refrigerant, precautions should be taken to avoid the presence of any type of contaminants in the system, so classifying contamination types in a refrigeration system is necessary to identify the proper servicing action required before charging any system with new refrigerant.

4.16.2. Evacuation

A refrigerating system must contain only the refrigerant in liquid or vapor state along with dry oil. All other vapors, gases, and fluids must be removed. Connecting the system to a vacuum pump and allowing the pump to run continuously for some time while a deep vacuum is drawn on the system can best remove these substances. It is sometimes necessary to warm the parts to around +50°C while under a high vacuum; in order to accelerate the removal of all unwanted moisture, heat the parts using warm air, heat

lamps, or water. Never use a brazing torch. If any part of the system is below 0°C, the moisture may freeze, and it will take a considerably longer time for the ice to sublimate to vapor during the evacuation process. The equipment necessary to carry out the evacuation is:

- a. Vacuum pump
- b. Manifold gauges two servicing valves (in the case system is not equipped with servicing valves)
- c. Vacuum gauge



It is essential to know that conventional manifold gauges have low sensitivity, particularly at lower pressures. As such, they are ineffective at determining whether or not a sufficient vacuum has been achieved. Therefore, it is essential to ensure that a proper vacuum gauge (such as a Pirani gauge) is used.

To understand why system evacuation is very important for moisture elimination, it is useful to remember the concept of vacuum and the relationship between boiling temperature and pressure. For a pure substance, like water, the boiling temperature for a fixed pressure is called saturation temperature at this pressure, and the pressure at which the water evaporates at a fixed temperature is called saturation pressure at this temperature.

Always evacuate a system when:

- a. Replacing a circuit component (compressor, condenser, filter-drier, evaporator, etc.)
- b. Whilst the system has no refrigerant Procedures to perform evacuation

To evacuate and dehydrate a system, before filling with refrigerant, take the following steps:

- a. First, the system should be tightness tested (i.e., “leak tested”). This can be done by pressurizing the system with oxygen free, dry nitrogen (OFDN). Shut off the supply of nitrogen and check the pressure over a period (a minimum of 15 minutes, but it depends upon the size of the system; a larger system requires more time). Keep checking the pressure gauge to see if the pressure reduces.
- b. If the pressure does fall, it is likely that the system has a leak, so leak searching, and repair procedures must be carried out.
- c. When the system is confirmed to be leak-tight, release the OFDN and immediately connect a proper vacuum pump to both suction side and discharge the side of the compressor (see diagrams), and make sure the vacuum gauge is connected. Open all the valves, including solenoid valves, so there is no part of the circuit that is “locked” in.
- d. Switch on the vacuum pump and wait.
- e. When satisfactory vacuum has been reached (below 100 Pa abs.) stop the pump and leave it for an appropriate length of time (around half an hour for a small hermetic system, to several hours for a large site-installed system) to see if the vacuum gauge indicates an increase in internal pressure. If the pressure rises there could be two reasons for it: either there is a leak or moisture still in the system. In this case, the evacuation procedure should continue, but if a constant vacuum pressure is never achieved, then it is likely that a leak is present, and the tightness test should be repeated.

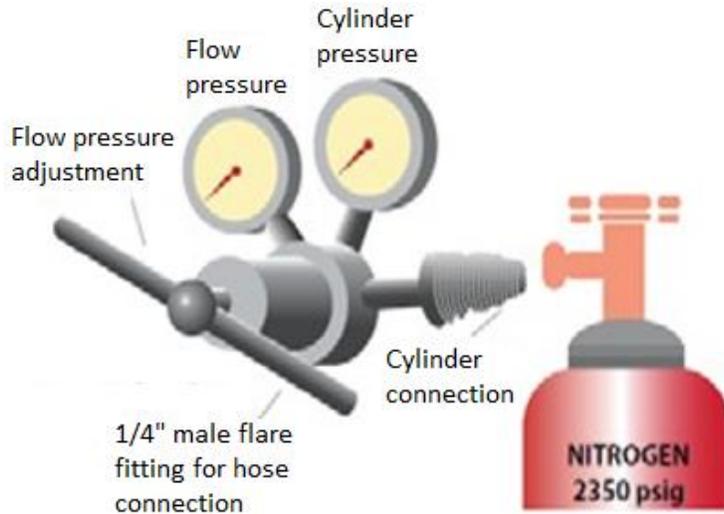
- f. If the vacuum pressure remains constant over a period of time, the circuit is correctly evacuated; dry and free of leakage. For large systems where is expected excess of moisture content, apply indirect heat (using a heat lamp or hot air-blower) to the system tubing (applying heat to one side only will cause moisture condensation in the coolest part).
- g. In case of closed solenoid valves in the system, air is usually trapped in-between valves where they should be opened manually if supplied with open screws, by applying direct electrical source to solenoid coil, or by using a service hand magnet.
- h. Charging of refrigerant can now begin, either direct to the high-pressure liquid side or charging into the suction side when the compressor is running.

4.16.3. Purging

The process of removing unwanted gases, dirt or moisture from the system is called purging. An inert gas such as nitrogen is introduced in the system to flow through the tubing, forcing unwanted contaminants out.

The following equipment is needed to perform purging:

- a. Oxygen free dry nitrogen cylinder equipped with pressure regulator
- b. Nitrogen cylinder equipped with pressure regulator
- c. Manifold gauges with hoses
- d. Vacuum pump
- e. Two servicing valves (or the system is equipped with servicing valves)



4.16.4. Purging procedure

The following steps should be followed when performing system cleaning (purging):

As with the evacuation procedure, ensure that all stop valves, solenoid valves and other such devices have been fully opened so not to restrict the flow around any parts of the system.

Open the low-pressure side and high-pressure side valves in the manifold gauges.

Open the nitrogen cylinder main valve using the pressure regulator on the cylinder to keep pressure of OFDN at less than the maximum working pressure indicated on the equipment nameplate.

Keep the OFDN flowing for several minutes or until dry clean gas is discharged, indicating that all the contaminants have been removed.

Remove the residual nitrogen with a vacuum pump using the proper procedure.

4.17 **Dehydration/Evacuation**

The purpose of dehydrating a refrigeration system is to remove air and moisture. Air, moisture and non-condensable gas are harmful to HVACR systems, their capacity and efficiency. The presence of moisture in an operating refrigeration system can create highly corrosive and toxic acids. The recommended method for dehydration is evacuation. Before evacuating a system, it is important to first recover all refrigerant

and attain the mandated vacuum level. The factors that affect the speed and efficiency of evacuation are:

- a. **Size of equipment being evacuated.** The larger the equipment, the longer it will take to evacuate.
- b. **Ambient temperature.** The warmer the temperature, the faster it will evacuate. You may heat the refrigeration system to decrease the evacuation time.
- c. **Amount of moisture in the system.** The more moisture in the system, the longer it will take to evacuate.
- d. **Size (capacity) of vacuum pump and suction line.** The bigger the capacity of the vacuum pump, the shorter the time.

4.17.1. Evacuation Procedure

Using a vacuum pump and lowering the pressure in the system causes any moisture to vaporize. The pump can then remove the vapor. Any system or tubing that has been exposed to the atmosphere should be evacuated before charging with refrigerant.

The piping connection to the pump should be as short in length as possible and as wide in diameter as possible. Vacuum lines (hoses) should be equal to or larger than the pump intake connection.

For the most accurate readings during evacuation, a micron gage should be used to determine effectiveness of your evacuation. The system should pull down to **500 microns**. After the 500-micron level is obtained the pump should be turned off from the system while you observe if the vacuum holds. The following will result in an observable loss of vacuum.

- a. The system contains liquid refrigerant that continues to vaporize
- b. Water in the system continues to vaporize
- c. There is a leak
- d. Loose connections

Dehydration is considered complete when the vacuum gauge shows that have reached and held the required finished vacuum. It is not possible to over-evacuate a system.

4.17.2. Evacuation Level Requirements for Appliances (effective July 13, 1993)

- a. Appliance, HCFC 22 w/ less than 200 pounds, (0) Inches of Hg Vacuum
- b. Appliance, HCFC 22 w/ more than 200 pounds (4 or 10*) Inches Hg vacuum
- c. Appliance, CFC 12, 500, 502, 114 less than 200 pounds (4 or 10*) Inches Hg vacuum
- d. Appliance, CFC 12, 500, 502, 114 more than 200 pounds (4 or 15*)
- e. Very high-pressure appliance CFC 13, 503 (0) Inches Hg Vacuum
- f. Low-pressure appliance CFC 11, 123 (25 or 25 mm Hg absolute*)

*On or after November 15, 1993, recovery equipment certified by EPA approved testing organization

4.18 Refrigerant Cylinders

Refrigerants are packed in both disposable and refillable shipping containers, commonly called "cylinders". Containers are designed for pressurized and liquefied gases and are considered pressure vessels. They are therefore subjected to national regulations. Some refrigerants are gases at atmospheric pressure and room temperature and are therefore transported and stored as liquefied compressed gases in pressurized cylinders. Other refrigerants are liquids at room temperature and contained in drums, barrels or other standard containers.

Normally, each cylinder is equipped with a safety-relief device that will vent pressure from the cylinder before it reaches the rupture point, in the event of, say, overheating.

4.18.1. Disposable Refrigerant Cylinders

These containers are used only with virgin refrigerant and may NEVER be used for recovery. These tend to be manufactured from thinner metal than the conventional, re-usable cylinders, rendering them more susceptible to rusting and mechanical damage

over time. They are not to be refilled. (The penalty for transporting a refilled disposable cylinder is a fine up to \$25,000 and five years of imprisonment per 49 CFR 178.65).

DOT Specification 39, 49 CFR 178.65, requires disposable refrigerant cylinders to be rated for a service pressure of 260 pounds per square inch (psi). Under laboratory tests, one cylinder per thousand produced is pressurized to the point of failure. The cylinder must not rupture below 650 psi.

When the cylinder is empty, ensure all pressure is released to 0 psi. The cylinders should be rendered useless for any purpose by breaking off the valve or puncturing the cylinder. After the cylinder has been rendered incapable of containing any compressed gas under pressure, it shall be disposed of as scrap metal.

4.18.2. Refillable Refrigerant Cylinders

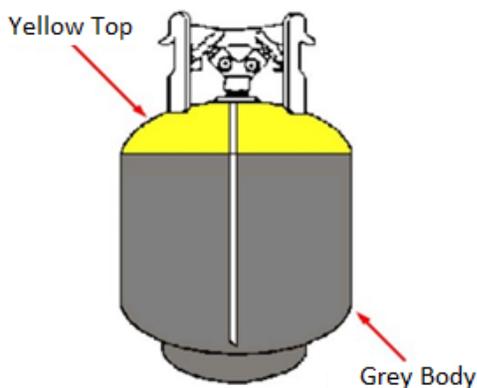
Refillable cylinders are the standard receptacles available for the storage and transportation of smaller quantities of refrigerant. They normally range in size from about 5 litres to 110 litres (approximately 5 to 100 kg of CFC, HCFC or HFC refrigerant). The cylinders are normally constructed from steel and have a combination valve, with separate ports for refrigerant removal, refrigerant filling and a pressure relief device. The port for refrigerant filling is normally locked so that only the refrigerant supplier can gain access. Some cylinders also have two separate removal ports: one for liquid and another for vapour, if the cylinder is fitted with a dip-tube. There is usually a metal collar around to the top of the cylinder to protect the valve from mechanical damage. Both the cylinder itself and the valve are usually subject to national regulations for their design, fabrication, and testing.

- a. The EPA requires that a refillable refrigerant cylinder **MUST NOT BE FILLED ABOVE 80%** of its capacity by weight, and that the safe filling level can be controlled by either mechanical float devices, electronic shut off devices (thermistors), or weight.
- b. Refillable cylinders must be hydrostatically tested, and date stamped every 5 years.

- c. Refillable cylinders used for transporting recovered pressurized refrigerant must be DOT (Department of Transportation) approved.
- d. The large, reusable cylinders bear a stamp on the shoulder that provides the following information: owner's name (abbreviated); DOT specification number for the cylinder; serial number of the tank; test date (month and year); manufacturer's symbol; and water capacity (in pounds weight).

4.18.3. Recovery Cylinders

Recovery cylinders are specifically intended for refrigerant that have been removed from refrigeration systems. The recovered refrigerant can then be re-used or sent for reclamation or disposal. The construction of the cylinders is normally very similar to a conventional refillable cylinder, except for two differences: one is that the cylinder valve has the refrigerant filling port enabled, so that refrigerant can be easily fed into the cylinder, and the second being the external marking. The cylinder shoulder and upper part is normally painted yellow, with the remainder of the cylinder body painted grey color code is also applied to cylinder to indicate the type of recovered refrigerant, as shown in the illustration.



It is important to ensure that the recovery cylinder is only ever used for one type of refrigerant. This rule should be followed for two reasons: first, if different refrigerants are mixed, it may not be possible to separate them again for re-used, and secondly, mixing two or more refrigerants can result in a pressure that exceeds the pressure of either of the refrigerants added into the cylinder.

For refrigeration technicians using recycling machines, it is suggested that the refrigeration technician utilize a 'CLEAN' recovery cylinder for recycled refrigerant and a 'DIRTY' recovery tank for recovered, but not recycled refrigerant. Marking the recovery tanks as clean and dirty will avoid contamination of otherwise clean refrigerant by putting clean refrigerant into a recovery tank that once held dirty refrigerant.

4.19 Identification

Both disposable and reusable cylinders are colour coded according to the type of refrigerant contained in the cylinder and the use of the cylinder. This code was voluntarily established by refrigerant manufacturers to identify their products. Common refrigerant colours and identification are set out in Table below:

R-22	light green
R-123	light blue-grey
R-124	dot green
R-134a	light blue (sky)
R-401a	pinkish-red
R-401b	yellow-brown
R-402a	light brown
R-402b	green-brown
R-403b	light grey
R-404a	orange
R-407c	brown
R-408a	medium purple
R-409a	medium brown
R-410a	rose

R-414b	medium blue
R-416a	yellow-green
R-417a	green
R-500	yellow
R-502	light purple
R-503	blue-green
R-507	aqua blue
R-508b	dark blue
R-717	silver
NH3	silver

Refer to Air-Conditioning, Heating and Refrigerating Institute (AHRI) Guideline N, 2008 Guideline for Assignment of Refrigerant Container Colours.

4.19.1. Container Pressure

All refrigerant cylinders come equipped with either a pressure-relief valve or relief plug designed to prevent the cylinder from being over- pressurized, either while filling the cylinder with refrigerant or during storage of the cylinder due to possible exposure of the cylinder to elevated temperatures. If the refrigerant pressure inside the cylinder exceeds the pre-set pressure of the pressure relief valve, the pressure-relief valve allows the automatic venting of refrigerant to reduce the pressure in the cylinder. Pressure-relief safety devices are frangible (rupture) disc style or spring-loaded relief integrated into the valve stem of the cylinder. Never adjust or tamper with the pressure-relief valves.

4.20 DOT Requirements

Specific container labelling and marking requirements apply for all DOT-regulated hazardous materials. DOT hazardous materials designations should not be confused

with EPA hazardous materials. They are solely concerned with material transportation issues, not environmental issues. For instance, DOT regulates material as hazardous if it can cause injury or property damage due to an accidental release or failure of its packaging during shipment on public roads, railways, and airways. There are nine classes of DOT hazards. Only Class 2, Division 2.2 (non-flammable gases), is pertinent to common refrigerants. This rating is attributable to the pressurized nature of the refrigerant in its container. The applicable AC/R refrigerants are R-12, R-22, R-134a, R-401a, R-401b, R-402a, R-402b, R-404a, R-410a, R-407a, R-407c, R-408a, R-409a, R-423a, R-437a, R-417a, R-422a, R-438a, R-500, R-502, and R-507 shipped in cylinders and ton tanks. They require marking and labelling R-11, R-113, R-114, and R-123 are not DOT-regulated hazardous materials; therefore, DOT labelling and marking requirements do not apply.

4.20.1. Labeling

Each cylinder shall display a DOT diamond (square-on-point) "Non-flammable Gas" label. The 4-inch by 4-inch green diamond-shaped label may be printed on a tag and securely attached to the cylinder's valve protection cap before shipment. Ton tanks require two DOT non-flammable gas labels, one on each end.

4.20.2. Marking

Each container shall be marked with a proper DOT shipping name and appropriate United Nations (UN) four-digit chemical or hazard class identification number. Markings must be stamped plainly and permanently in any of the following locations on the cylinder:

On shoulders and top heads when they are not less than 0.087 inch thick.

On a metal plate attached to the top of the cylinder or permanent part thereof; enough space must be left on the plate to provide for stamping at least six retest dates; the plate must be at least 0.0625-inch-thick and must be attached by welding or brazing. The brazing rod will melt at a temperature of 593 °C. Welding or brazing must be along all edges of the plate.

On the neck, valve boss, valve protection sleeve, or similar part attached to the top of the cylinder.

On the foot ring permanently attached to the cylinder, provided the water capacity does not exceed 25 pounds.

4.20.3. Precautionary Labels

Each container shall display a precautionary label prepared in accordance with American National Standards Institute (ANSI) Z400.1/Z129.1-2010, Hazardous Workplace Chemicals - Hazard Evaluation and Safety Data Sheet and Precautionary Labelling Preparation, and Compressed Gas Association (CGA) C-7, Guide to the Preparation of Precautional Labelling and Marking of Compressed Gas Containers. This label will include:

- a. Product identity; A4.7.3.2. Antidotes; A4.7.3.3. Signal word; A4.7.3.4. Notes to physicians;
- b. Statement of hazards;
- c. Instructions in case of contact or exposure; A4.7.3.7. Precautionary measures;
- d. Instructions in case of fire, spill, or leak; and A4.7.3.9. Instructions for container handling and storage.

4.20.4. Warning Labels

Since May 1993, warning labels have been required on containers of DOT Class 2, Division 2.1 (flammable gases) and Division 2.2 substances, and products containing or made with either substance.

4.21 Shipping – Transporting Refrigerants

The shipper of recovered refrigerant is responsible for determining if there are any state or local regulations restricting transportation, such as classifying recovered refrigerant and oil mixtures as hazardous waste. The EPA does not classify these materials as hazardous waste.

4.21.1. Documentation

Shipping papers are required whenever refrigerant is transported using public roadways, railroads, and airways. The shipper is required to properly fill out the shipping papers when returning the recovered refrigerant. The shipping papers must always contain the following information:

- a. The quantity and type of container used (for example, "2-RETURNABLE CYLINDERS");
- b. The total gross weight of recovered refrigerants.
- c. The shipping name (for example, "Chlorodifluoromethane Mixture"); A4.8.1.4. The DOT hazard class (for example, "NONFLAMMABLE GAS"); and A4.8.1.5. The UN identification number (for example, "UN1018").

Note: For material not regulated by DOT as a hazardous material, the words "Not Regulated by DOT" are recommended, but not required.

4.21.2. Shipping Tags and Placards

- a. DOT (Department of Transportation) requires proper tags/labels be attached to cylinders including the refrigerant type contained in the cylinder. The label must state the type, amount of refrigerant and classification for example indicating it is a "2.2 non-flammable gas".
- b. If a container is empty and has no residual pressure, a DOT hazard tag is not required. If the shipper is sending 1,000 pounds (gross weight) or more of a hazardous material on the truck, DOT regulations require the shipper to provide the motor carrier with four nonflammable gas placards. For materials being transported in ton tanks, the placards must also include the appropriate UN four-digit identification number. Affixing the placards to the truck is the responsibility of the motor carrier.
- c. DOT requires all cylinders be hydrostatically tested and stamped every five years.
- d. Disposable cylinders are designated as DOT Specification 39, non-reusable cylinders.

- e. Cylinders should be transported in an upright position.

4.22 Safety

The EPA is not only concerned with the prevention of refrigerant venting but is also concerned with the technician's overall safety. Gas under high pressure can be dangerous.

- a. When handling and filling refrigerant cylinders, or operating recovery or recycling equipment, you should wear Personal Protective Equipment (gloves, safety glasses, self-contained breathing apparatus – SCBA).
- b. Refrigerants at atmospheric pressure produce extremely cold temperatures and can cause frostbite. Wear safety glasses, goggles, rubber lined gloves, long sleeve shirts and long pants.
- c. Use pressure regulator and relief valve with nitrogen. Nitrogen cylinders are under high pressure, about 2000 psi. Always use a pressure regulator with nitrogen. System components such as coils can be damaged. Make sure a pressure relief valve is installed in case the pressure regulator fails. Don't install pressure relief valves in series.
- d. **Leak testing.** When leak checking a system, use Nitrogen. NEVER pressurize the system with oxygen or compressed air. Air containing compressed oxygen in the presence of oil, is highly explosive. To determine the safe pressure for leak testing, check the data plate for the low-side test pressure value.
- e. When using recovery cylinders and equipment with Schrader valves, it is critical to inspect the Schrader valve core for leaks, bends and breakage. Replace damaged valve cores to prevent leakage, and always cap Schrader ports to prevent accidental depression of the valve core. NEVER heat a refrigerant cylinder with an open flame. Do not cut or braze refrigerant lines on a charged unit.

- f. Refrigerants are heavier than air. If you are in a confined space the refrigerant can displace the oxygen resulting in suffocation. In the event of a “large” release of refrigerant in a confined area, Self-Contained Breathing Apparatus (SCBA) is required. If a large leak of refrigerant occurs in an enclosed area, and SCBA is not available, IMMEDIATELY VACATE AND VENTILATE the area. In large quantities, refrigerants can cause suffocation because they are heavier than air and displace oxygen. Inhaling refrigerant vapors or mist may cause heart irregularities, unconsciousness, and oxygen deprivation leading to death (asphyxia).
- g. NEVER expose R-12 or R-22 to open flames or glowing hot metal surfaces. At high temperatures, R-12 and R-22 decompose to form Hydrochloric acid, Hydrofluoric acid, and Phosgene gas.
- h. Always review the material safety data sheets, when working with any solvents, chemicals, or refrigerants.
- i. Never fill a refrigerant cylinder more than 80% to allow for expanding gas. Escaping gas can cause skin and eye damage.
- j. System components such as coils can be damaged. Make sure a pressure relief valve is installed in case the pressure regulator fails. Don’t install pressure relief valves in series.
- k. Some refrigerants are toxic. Others are considered non-toxic but are still dangerous in higher concentrations. Safe limits are measured in parts per million (ppm). Another common measure is the “Threshold Limit Value – Time Weighted Average” (TLV-TWA) Safety standard are developed for protection above these limits.
- l. **ASHRAE Standard 34.** This standard classifies refrigerants by a letter and a number; the letter indicates its toxicity and the number indicates its flammability. Refrigerants in the “A” category have a lower toxicity, while refrigerants in the “B” category have a higher toxicity. Similarly, refrigerants in

the “1” category have no flame propagation (minimal flammability), while refrigerants in the “3” category have high flammability.

ASHRAE Classification	Lower Toxicity	Higher Toxicity
Higher Flammability	A3	B3
Lower Flammability	A2	B2
No Flame Propagation	A1	B1

- m. **ASHRAE Standard 15.** Refrigerant safety is addressed in ASHRAE Standard 15-1994, Safety Code for Mechanical Refrigeration. This standard specifies an oxygen sensor and alarm for A1 refrigerants, and a refrigerant detector for all other refrigerants, as well as specifying ventilation requirements, but may not prevent hazardous accumulations.

4.22.1. Safe Disposal Requirements

Under the EPA’s rule, equipment that is typically dismantled onsite before disposal (e.g., retail food refrigeration, cold storage warehouse refrigeration, chillers, or industrial process refrigeration) must have its refrigerant recovered according to the EPA’s servicing requirements. However, equipment that typically enters the waste stream with the charge intact (e.g., household refrigerators, freezers, or room air- conditioners) is subject to special safe disposal requirements. Under these requirements, the final person in the disposal chain (e.g., scrap metal recycler or landfill owner) must ensure the refrigerant is recovered before final disposal of the equipment. If the final person in the disposal chain accepts appliances that no longer hold a refrigerant charge, that person is responsible for obtaining a signed statement from whom the appliance is being accepted. The signed statement must include the name and address of the person who recovered the refrigerant and the date the refrigerant was recovered, or a copy of a contract stating that the refrigerant will be removed before delivery. The signed statement or contract must be available onsite for inspection. The EPA does not

mandate a sticker as a form of verification that the refrigerant has been removed prior to disposal of the appliance, but such stickers do not relieve the final disposer of their responsibility to recover any remaining refrigerant in the appliance. Technician certification is not required for individuals removing refrigerant from appliances prior to disposal; however, the equipment used to recover refrigerant from appliances prior to final disposal must meet the same performance standards as EPA-certified refrigerant recovery equipment used prior to servicing. Per EPA Section 608 of the Clean Air Act of 1990, disposable cylinders should be emptied (recover the refrigerant until the pressure is reduced to a vacuum). The container's valve should be closed and the container itself marked as empty; the container is now ready for disposal. It is recommended, but not required, by EPA Section 608 that the cylinder valve be opened afterwards to allow air to enter. The cylinder valve is then broken off while the valve remains open and the cylinder is punctured. This will prevent cylinder misuse by untrained individuals. Once the cylinder has been rendered useless as a container, it can be disposed of as scrap metal. For details on disposal rules, refer to Department of Transportation (DOT) Specification 39, 49 CFR 178.65.

CHAPTER – 5

EPA 608 (TYPE – I CERTIFICATION)

5.0. SMALL APPLIANCES

According to the EPA, a small appliance is one that is manufactured, charged, and hermetically sealed in a factory and contains **five (5) pounds** or less of refrigerant.

Refrigerators and freezers designed for home use, room air conditioners (including window air conditioners and packaged terminal air conditioners), packaged terminal heat pumps, dehumidifiers, under-the-counter ice makers, vending machines, and drinking water coolers are common example of a hermetically sealed system.

MVAC or motorized vehicle air conditioning systems **do not** fall under the small appliance and require separate certification.

5.1 Refrigerant Recovery Requirements for Small Appliances

Technicians that handle refrigerant during service, maintenance, or repair of small appliances must have a Type I or Universal certification. The sales of CFCs and HCFCs are restricted to certified technicians. If the EPA changes regulations after the technician is certified, it is the responsibility of the technician to comply with any future changes in the law.

Evacuation and recovery requirements for small appliances (under 5 pounds) with and without working compressors using recovery equipment are tabulated below.

	Before Nov. 15th 1993	After Nov. 15th 1993
Operating Compressor	80% of charge must be removed or 4" Hg of Vacuum	Remove 80% if appliance is not running and 90% if running or 4" Hg of Vacuum
Fittings	Low-loss Required	Low-loss Required
Approvals	None	EPA Lab Approved

Recovery equipment manufactured before November 15, 1993 must be capable of recovering 80% of the refrigerant whether or not the compressor is operating or achieve a 4-inch vacuum under conditions of ARI 740

Recovery equipment manufactured after November 15, 1993 must be capable of recovering 80% of the refrigerant without the compressor operating or achieve a 4-inch vacuum under conditions of ARI 740; be capable of recovering 90% of the refrigerant with the compressor operating or achieve a 4-inch vacuum under conditions of ARI 740; and must be approved by an EPA approved third-party laboratory.

Recovery equipment fittings must be equipped with low-loss fittings which can be manually or automatically closed when disconnecting hoses in order to prevent refrigerant loss

All appliances must have a service aperture valve for recovering and charging refrigerants. For small appliances, the service aperture valve is typically a straight piece of tubing that is entered with a piercing access valve.

When servicing a small appliance, it is not mandatory to perform a leak repair; however, it should be done whenever possible.

5.1.1. Recovery Techniques

Before beginning the refrigerant recovery process, you should always know the type of the refrigerant in the system first. One way to identify the refrigerants and non-condensables is by using the temperature/pressure chart (see annexure at the end of this course).

Once you have recovered the refrigerant and it is at room temperature, use a pressure/temperature chart to verify that the pressures in the cylinder match the pressures on the chart. Pressures and temperatures that do not match indicate the presence of air or other non-condensables.

Never mix refrigerants in a recovery cylinder. If a reclamation facility receives a tank of mixed refrigerants, they may either refuse to process the refrigerant and return it at the owner's expense or they may destroy the refrigerant but charge a substantial fee.

5.2 Methods to Recover Refrigerant

For small appliances, the technician may use either a self-contained recovery device or use a system dependent (or passive) recovery system.

5.2.1. Self-contained (active) recovery equipment

Self-contained (active) recovery equipment uses its own power to recover the refrigerant from systems and can reach the required recovery rates with or without the compressor operating.

The recovered refrigerant in a self-contained system is stored in a pressurized recovery tank.

Before operating a self-contained recovery device, make sure the tank inlet valve is open and that the tank does not contain excessive air or non-condensables. Not opening the tank inlet valve or having excess air will cause higher discharge pressures

Checking for air or non-condensables can be done by checking the pressure inside the recovery tank. References to the pressure/temperature chart are only valid if the temperature is known; therefore, when checking for non- condensables inside a recovery cylinder, allow the temperature of the cylinder to stabilize to room temperature before taking a pressure reading.

Refer to the recovery equipment instructions to purge air and non- condensables. All refrigerant recovery equipment should be checked for oil level and refrigerant leaks on a daily basis.

5.2.2. System-dependent (passive) recovery process

A system-dependent (passive) recovery process captures refrigerant into a non-pressurized container. Methods to assist passive recovery are:

- a. Use the appliance compressor to pump refrigerant.
- b. Use the pressure of the refrigerant to facilitate transfer.
- c. Use an external heat source and strike the compressor to cause the oil to give up refrigerant.

A vacuum pump can only be used as a recovery device in combination with a non-pressurized container and cannot be used with self-contained recovery equipment (pressurized container).

Any appliance with 15 pounds or less refrigerant can use a passive recovery device. Refrigerant can be an evacuated refrigerant cylinder or an atmospheric bag.

Recovery process with Operating Compressor

When using a system-dependent recovery process with an operating compressor, run the compressor and recover from the high side of the system. Normally, one access fitting on the high side will be enough to reach the required recovery rate as the compressor should be able to push the refrigerant to the high side.

Recovery process with Non-operating Compressor

When using a system-dependent recovery process with a non-operating compressor, it may be necessary to access both the low and high side of the system to achieve the required recovery level and it will speed the recovery. To release the trapped refrigerant from the compressor oil, it will be necessary to heat and tap the compressor with a mallet several times and/or use a vacuum pump.

If the appliance has a defrost heater as commonly found in domestic refrigerators, operating the defrost heater will help to vaporize any trapped liquid refrigerant and will speed the recovery process.

When filling a graduated charging cylinder, refrigerant that is vented off the top of the cylinder must be recovered if it is a regulated refrigerant.

When installing an access fitting onto a sealed system, the fitting should be leak tested before proceeding with recovery. It is generally recommended that solderless piercing type valves only be used on copper or aluminium tubing. These fittings tend to leak over time and should not be left on appliances as a permanent service fixture. After installing an access fitting, if the system pressure is 0 psig, do not start the recovery process

Small appliances used in campers or other recreational vehicles may use refrigerants not covered in Section 608, such as ammonia, hydrogen or water and therefore, should not be recovered using current EPA-approved recovery devices. Similarly, systems built before 1950 may have methyl formate, methyl chloride, or sulfur dioxide as refrigerants and require special recovery equipment and training.

5.2.3. Chemical changes from heat

Flames or high heat from soldering can produce acids or poisonous gases from refrigerants. Hydrochloric acid, hydrofluoric acid and phosgene gas can be deadly. Remove refrigerant and evacuate any components before soldering or welding. This compound can be decomposed by high temperatures (open flames, glowing metal surfaces, etc.) forming hydrochloric and hydrofluoric acids and possible carbonyl halides.

5.3 Safety

Refrigerants at atmospheric pressure produce extremely cold temperatures and can cause frostbite. Wear safety glasses, goggles, rubber lined gloves, long sleeve shirts and long pants.

Refrigerants are heavier than air. If you are in a confined space the refrigerant can displace the oxygen resulting in suffocation. In areas where large amounts of refrigerant exist, safety gear such as self-contained breathing apparatus (SCBA) should be available.

Evacuate the area until it can be ventilated.

Some refrigerants are toxic. Others are considered non-toxic but are still dangerous in higher concentrations. Safe limits are measured in parts per million (ppm). Another

common measure is the “Threshold Limit Value – Time Weighted Average” (TLV-TWA) Safety standard are developed for protection above these limits.

- a. **ASHRAE Standard 15-1994** This standard required that mechanical rooms contain sensors, alarms and ventilation systems to keep the concentration of covered refrigerants below the TLV-TWA.
- b. **ASHRAE Standard 34.** This standard classifies refrigerants into groups according to flammability and toxicity. Low toxicity refrigerants are class A, high toxicity are class B. Non-flammability refrigerants are class 1 and higher flammable refrigerants are class 3. (A1, A2, A3, B1, B2, B3)

CHAPTER – 6

EPA 608 (TYPE – II CERTIFICATION)

6.0. HIGH PRESSURE APPLIANCES

Technicians maintaining, servicing, repairing or disposing of high pressure or very high-pressure appliances such as roof top units, residential split systems, etc..., except small appliances and motor vehicle air conditioning systems (MVAC), must be certified as a Type II Technician or a Universal Technician.

6.1 Leak Detection

Diagnosing a system with a low refrigerant charge may indicate the system has a leak. Low superheat is the primary low charge indicator for fixed orifice systems.

6.1.1. Leak Detection Process

Leak checking, or testing can be accomplished by:

- a. Halide torch, flame turns green in the presence of refrigerant
- b. Adding dye to refrigerant
- c. Electronic leak detectors
- d. Brushing soap to produce bubbles on the suspected area

It is preferred that you use an inert gas such as nitrogen for leak checking. It is acceptable to use R-22 as a trace gas if required to locate the leak.

To determine the general area of a leak, use an electronic or ultrasonic leak detector. Once the general area of the leak is located the use of soap bubbles will pinpoint the leak.

A refrigeration unit using an open compressor that has not been used in several months is likely to leak from the rotating shaft seal. During a visual inspection of any type of system, traces of oil are an indicator of a refrigerant leak. Excessive superheat, caused by a low refrigerant charge, is also an indication of a leak in a high-pressure system.

Note – Leak testing shall be performed before charging or recharging equipment.

6.1.2. Allowable Annual Leak Rate and Repair Requirements

EPA regulations require that all Comfort cooling appliances containing more than 50 lbs. of refrigerant MUST be repaired when the annual leak rate exceeds **15%**.

EPA regulations require that all Commercial and Industrial Process Refrigeration containing more than 50 lbs. of refrigerant MUST be repaired when the annual leak rate exceeds **35%**.

6.2 Recovery Techniques

Proper recovery techniques begin with the use of appropriate recovery equipment that has been certified by an EPA approved laboratory (UL or ETL) to meet or exceed ARI standards.

Recovered refrigerants may contain acids, moisture, and oil. It is therefore necessary to frequently check and change both the oil and filter on a recycling machine. Both recycling and recovery equipment using hermetic compressors have the potential to overheat when drawing a deep vacuum because the unit relies on the flow of refrigerant through the compressor for cooling. Before using a recovery unit, you should always check the service valve positions, the oil level of the recovery unit and evacuate and recover any remaining refrigerant from the unit's receiver.

Technicians working with multiple refrigerants, before recovering and/or recycling a different refrigerant, must purge the recover/recycle equipment by recovering as much of the first refrigerant as possible, change the filter, and evacuate.

The only exception to this rule is for technicians working with R-134a who must provide a special set of hoses, gauges, vacuum pump, recovery or recovery/recycling machine, and oil containers to be used with R-134a only.

Although recovering refrigerant in the vapor phase will minimize the loss of oil, recovering as much as possible in the liquid phase can reduce recovery time. The technician may choose to speed up the recovery process by packing the recovery

cylinder in ice and/or applying heat to the appliance. After recovering liquid refrigerant, any remaining vapor is condensed by the recovery system.

When performing refrigerant system service on a unit that has a receiver/storage tank, refrigerant should be placed in the receiver. Refrigerant should be removed from the condenser outlet if the condenser is below the receiver. In a building that has an air-cooled condenser on the roof and an evaporator on the first floor, recovery should begin from the liquid line entering the evaporator.

After recovery, refrigerant may be returned to the appliance from which it was removed or to another appliance owned by the same person without being recycled or reclaimed, unless the appliance is an MVAC (Motor Vehicle Air Conditioner) like appliance.

The technician should always evacuate an empty recovery cylinder before transferring refrigerant to the cylinder. Quick couplers, self-sealing hoses, or hand valves should be used (as low loss fittings) to minimize refrigerant release when hoses are connected and disconnected.

6.2.1. Recovery Requirements

Refrigerant Recovery and/or Recycling equipment manufactured **after November 15, 1993**, must be certified and labeled by an EPA approved testing organization.

The following is a list of the required recovery levels (in inches of mercury) for Type II appliances:

Required Level of Evacuation (Except for Small Appliances & MVAC)		
Type of Appliance	Manufactured before 11/15/93	Manufactured after 11/15/93
	Inches Hg	
HCHF-22 appliance < 200 lbs. refrigerant	0	0
HCFC-22 appliance > 200 lbs. refrigerant	4	10

Required Level of Evacuation (Except for Small Appliances & MVAC)		
Type of Appliance	Manufactured before 11/15/93	Manufactured after 11/15/93
	Inches Hg	
Other high-pressure appliance* < 200 lbs. refrigerant	4	10
Other high-pressure appliances* >200 lbs. refrigerant	4	15
Very high-pressure appliance	0	0
Low-pressure appliance or isolated component	25	25

Appliances can be evacuated to atmospheric pressure (0 psig) if leaks make evacuation to the prescribed level unattainable. The technician must isolate a parallel compressor system in order to recover refrigerant. Failure to isolate a parallel compressor system will cause an open equalization connection that will prevent refrigerant recovery. System-dependent recovery equipment cannot be used on appliances containing more than 15 pounds of refrigerant.

Under EPA regulations, a “major repair” means any maintenance, service or repair involving the removal of any or all of the following components: the compressor, the condenser, the evaporator or an auxiliary heat exchanger coil.

6.2.2. Methods of Speeding Refrigerant Recovery

- a. Recover the liquid refrigerant first to speed up the recovery process.
- b. Other methods to speed recovery:

- c. Keep the system pressure high and the recovery cylinder pressure low. Warm the system to increase pressure and cool the cylinder to reduce pressure and more readily accept the refrigerant.
- d. Use large diameter and short hoses to reduce the friction pressure loss in recovery hoses.

6.2.3. Method for Reducing Cross-contamination and Emissions

- a. Make sure you never mix refrigerants in a cylinder.
- b. Check your recovery equipment often and change the oil and filter on a regular schedule.
- c. Need to wait a few minutes after reaching required recovery vacuum to see if system pressure rises. (indicating that there is still liquid refrigerant in the system or the oil).
- d. After you have completed recovery, make sure you wait enough time for any remaining liquid in the system or in the oil to vaporize. The pressure may increase as trapped refrigerant vaporizes. If pressure rises continue the recovery.

6.3 Identify Refrigerant Type

Use standard pressure temperature chart to confirm the refrigerant type. Be aware of need to add 14.7 to translate psig to psia.

- a. Psig represents the pressure read from a gauge on a closed system
- b. Psia represents the pressure at atmospheric pressure. Atmospheric pressure is 14.7 psi

6.4 Refrigeration Components

- a. Condenser: Condenses high pressure gas from the compressor to high pressure liquid.
- b. Receiver: Receives high pressure liquid from the condenser
- c. Expansion device: converts high pressure liquid to low pressure vapor

- d. Evaporator: Evaporates low pressure vapor from the expansion device
- e. Accumulator: Accumulates any low-pressure liquid from the evaporator so it can vaporize before entering the compressor
- f. Compressor: Compresses low pressure vapor to high pressure vapor

(Refer core section for more details).

Filter driers will remove moisture from the refrigerant in a system, but there is a limit to their capacity. Some systems are equipped with a moisture indicating sight glass. When the sight glass changes color, the system contains excessive moisture and will need to be evacuated. The filter-drier should be replaced anytime a system is opened for servicing. If a strong odor is detected during the recovery process, a compressor burn-out may have occurred. When recovering refrigerant from a system that experienced a compressor burn-out, watch for signs of contamination in the oil.

A crankcase heater is often used to prevent refrigerant from migrating to the oil during periods of low ambient temperature.

Refrigerant in the oil will cause oil foaming in the compressor at start-up. When evacuating a vapor compression system, the vacuum pump should be capable of pulling 500 microns (29.90" hg.) of vacuum. The more accurate and preferred method of measuring a deep vacuum is in microns.

6.5 Safety

Warning: Should not energize hermetic compressors under vacuum. A hermetic compressor's motor winding could be damaged if energized when under a deep vacuum.

The use of a large vacuum pump could cause trapped water to freeze. During evacuation of systems with large amounts of water, it may be necessary to increase pressure by introducing nitrogen to counteract freezing.

The source of most non-condensables is air. Non-condensables will cause higher discharge pressures.

Where there is a risk of freezing, charging of an R-12 refrigeration system should begin with vapor from a vacuum level to a pressure of approximately 33 psig. followed by a liquid charge through the liquid-line service valve. This is also the proper method to charge a system that contains a large quantity of refrigerant.

ASHRAE standard 15 requires a refrigerant sensors, alarms and ventilation system to keep the concentration of covered refrigerants below the TLV-TWA.

(Additional Safety and shipping information is covered in the core section of this manual.)

CHAPTER – 7

EPA 608 (TYPE – III CERTIFICATION)

7.0. LOW PRESSURE APPLIANCES

Technicians maintaining, servicing, repairing or disposing of low-pressure appliances must be certified as a Type III Technician or a Universal Technician.

As of November 14, 1994, the sale of CFC and HCFC refrigerants is restricted to certified technicians.

NOTE: If EPA regulations change after the technician is certified, it will be the technician's responsibility to comply with any future changes.

7.1 Leak Detection

Low pressure appliances (usually large chillers) operate at below atmospheric pressure (in a vacuum). Because of low pressure, leaks in the gaskets or fittings will cause air and moisture to enter the system.

Preferred leak check methods are:

- a. Raise the system pressure (not exceeding 10 psig)
- b. Recover refrigerant and pressurize with nitrogen
- c. Check the shaft seal on open compressors for leaks
- d. If water tube leaks are suspected a hydrostatic tube test can be performed.

The most efficient method of leak checking a charged low-pressure refrigeration unit is to pressurize the system using controlled hot water or heater blankets. When controlled hot water or heater blankets are not feasible, use nitrogen to increase system pressure.

When pressurizing a system, do not exceed 10 psig. Exceeding 10 psig can cause the rupture disc to fail.

When leak testing a water box, be certain the water has been removed before placing the leak detector probe through the drain valve. To leak test a tube, use a hydrostatic tube test kit. Systems with open drive compressors are prone to leaks at the shaft seal.

Controlled hot water can be used to pressurize a system for opening the system for a non-major repair.

Under EPA regulations, a “major repair” means any maintenance, service or repair involving the removal of any or all the following components: the compressor, the condenser, the evaporator or any auxiliary heat exchanger coil.

7.1.1. Signs of Leakage

Since low pressure systems operate at below atmospheric pressure, air and moisture will leak into the refrigerant circuit through seals, gaskets or other leaks. A component called a purge unit will remove these non-condensables from the top of the condenser when they are present. Excessive purge unit operation indicates a leak. Some refrigerant is purged in this process.

7.1.2. Maximum Leak Test Pressure (for low pressure centrifugal chillers)

These systems will have a component called a rupture disk. The rupture disk is a pressure relief device that will release the refrigerant when pressures exceed the disk rating, usually 15 psig.

Maximum test pressure should be 10psig or lower.

7.1.3. Leak Repair Requirements

EPA regulations require that all comfort cooling appliances containing more than 50 lbs. of refrigerant be repaired when the annual leak rate exceeds **15%**.

EPA regulations require that all commercial and industrial process refrigeration containing more than 50 lbs. of refrigerant be repaired when the annual leak rate exceeds **35%**. EPA does not require repair of leaks holding less than 50 pounds of refrigerant. It is good practice to find and repair leaks.

Leaks requiring repair must be repaired within 30 days of discovery. Exception, when the owner of the equipment develops a plan to retrofit or retire the equipment within one year.

Documentation of the plan must be kept on site and work completed within one year.

(See Type II for definition of commercial and industrial appliances.)

7.2 Recovery Techniques

- a. Recovery machines for low pressure chillers should be equipped with a pressure relief device to prevent over pressuring the chiller. Rupture disks may release at 15 psig. High pressure relief should be set at 10 psig.
- b. Refrigerant recovery from a system using R-11 or R-123 starts with liquid removal and is followed by vapor recovery.
- c. A substantial amount of vapor will remain in the appliance after all liquid is removed. For instance, an average 350-ton R-11 chiller at 0 psig still contains 100 lbs. of vapor after all the liquid has been removed.
- d. Water must be circulated through the tubes when evacuating refrigerant to prevent freezing the water. Lowering the pressure in the refrigerant circuit will cause liquid to vaporize. Refer to a pressure temperature chart for the refrigerant being used during evacuation to insure the temperature remains above freezing. Water in the chiller or condenser could freeze and rupture tubes if allowed to fall below freezing.
- e. When recovering refrigerant, the system water pumps, the recovery compressor, and the recovery condenser water should all be on.
- f. Recovering liquid refrigerant first before it vaporizes, will speed up the recovery process. All refrigerant must be removed before nitrogen can be used to pressure test.
- g. If a chiller is suspected of tube leaks, the water sides of the evaporator and condenser should be drained prior to recovering the refrigerant.

- h. The ASHRAE Guideline 3-1996 states that if the pressure in a system rises from 1 mm Hg to a level above 2.5 mm Hg during vacuum testing, the system should be leak checked.
- i. A temperature of **130° F** should be attained when removing oil from a low-pressure system. Less refrigerant is contained in the oil at this higher temperature.

7.2.1. Recharging Techniques

Refrigerant is added through the lowest access point on the low-pressure side at the evaporator charging valve. However, if low pressure liquid is fed into an evacuated refrigerant circuit, the liquid will boil off and could freeze water tubes causing damage. Therefore, vapor should be added first until the refrigerant pressure boiling point is above freezing. This is applicable to centrifugal compressors.

Before charging with liquid, an R-11 refrigeration system requires a vapor pressure of 16.9" hg. vacuum, or a saturation temperature of 36° F.

7.2.2. Recovery Requirements

Refrigerant Recovery and/or Recycling equipment manufactured after November 15, 1993, must be certified and labeled by an EPA approved equipment testing organization to meet EPA standards. All equipment must have low loss fittings to minimize refrigerant loss when hoses are disconnected.

The following is a list of the required levels of evacuation for Low Pressure appliances:

Using recovery or recycling equipment manufactured or imported on or after Nov. 15, 1993

25 mm Hg absolute

Once the required vacuum has been achieved, the technician should wait for a few minutes and monitor the system pressure.

If the pressure rises, indicating that there is refrigerant remaining in the system, recovery must be repeated. When leaks in an appliance make evacuation to the

prescribed level unattainable, the appliance should be evacuated to the lowest attainable level prior to a major repair.

7.3 Disposal of Refrigerant Containing Appliances

CFC and HCFC refrigerants must be recovered from appliances prior to disposal at the same rate or percentage as would apply when servicing the appliance. The last person in the disposal chain is responsible for removing the refrigerant. This is normally the metal recycler. This person must maintain records documenting recovery.

7.4 Purge Units

Purge units are used with low-pressure chillers and refrigerant recovery equipment to remove non-condensable material that entered the system. All low-pressure chillers (R-11 or R-123) should have high-efficiency purges either by retrofit or when they are purchased. High discharge pressure is also an indication of air in the system.

All new low-pressure chillers include a high-efficiency purge as standard equipment. Traditional purge unit designs could expel large amounts of refrigerant. High-efficiency purge units allow non-condensable material to be vented while leaking very little refrigerant. There are two high-efficiency levels: (1) discharges of approximately 0.7 to 1 pound of refrigerant per pound of non-condensable material and (2) an ultra-high-efficiency discharge of 0.0005 pound of refrigerant per pound of non-condensable material. Most low-pressure chillers are equipped with ultra-high-efficiency purge units. Given information about runtime and the refrigerant amount lost per unit of non-condensable matter during purges, maintenance technicians can determine the amount of runtime that would result in refrigerant losses that exceed EPA limits. Choose a purge unit with a safety system to prevent excessive purging resulting from malfunctions or large leaks. These safety systems limit the time that a purge unit operates so a control malfunction will not cause a complete refrigerant purge.

A centrifugal chiller's purge condensing unit takes its suction from the top of the condenser, removes air and other non-condensables from the system, and returns refrigerant to the evaporator. Although a high efficiency purge unit discharges a low

percentage of refrigerant with the air they remove, frequent purging and subsequent refrigerant loss can indicate that a leak is allowing air into the system.

7.4.1. Low-Pressure Chiller Purge Units

The EPA has not established any requirements for chiller purge units. However, the Air Force replaces older purge units with new, high- efficiency purge units equipped with runtime meters.

7.4.2. Recycling Equipment Purge Units

The EPA's maximum purge-loss limit for recycling equipment purge units is 3 percent of the total refrigerant being recycled.

7.4.3. Servicing Purge Systems

Most purge systems require regular service: purge tanks and oil separators must be cleaned; gasket materials must be renewed; purge compressors must be overhauled. Servicing should be performed according to the purge system manufacturer's guidelines. To open the purge system for service, isolate it from the chiller refrigeration system and recover the refrigerant from the purge unit. To provide a convenient, efficient means of accomplishing this on an ongoing basis, permanent access and isolation valves should be installed in the system whenever a new high-efficiency unit is introduced.

7.5 Low-Pressure Systems Pressurization Methods

Low-pressure systems can be under a vacuum when they are not in operation. Their purge systems remain in operation to keep air and moisture out of the system. If the machine leaks, it will cause the purge to discharge refrigerants and non-condensable materials more often. Installing a pressurization system can solve this problem. There are two types of systems: blanket heater and water heater/pump. Both operate on the principle of increasing system pressure through heat added to the refrigerant.

7.5.1. Blanket Heater

The most common pressurization system is an electric-resistant blanket heater installed between the evaporator's outer shell and its insulation jacket. Because it is mounted on

the underside of the shell, it is commonly known as a belly heater. A blanket heater is used to prevent refrigerant air infiltration by heating the refrigerant until the pressure is at or nearly at atmospheric level. The blanket heater can also be used to raise the system pressure above atmospheric pressure to allow leak testing. Typically, temperature or pressure sensors monitor the condenser conditions and control the blanket heater. To prevent system over-pressurization and refrigerant loss, temperature and pressure sensors should be checked before energizing the blanket heater.

7.5.2. Water Heater/Pump

The second system type uses a small electric water heater and circulating pump package. It heats and circulates water through the evaporator tubes to raise the refrigerant temperature. This raises the system pressure. Before beginning the heating process, isolate the evaporator from the distribution piping system. The heat added to the water is typically controlled by monitoring the water temperature once it has left the evaporator. To prevent system over-pressurization and any resulting refrigerant loss, the temperature sensor should be checked before starting the water heater/pump system.

To protect the system from over-pressurization, low-pressure chillers typically use a rupture disc mounted on the evaporator housing. The typical design burst pressure for a rupture disc is 15 psig.

7.6 Safety

7.6.1. ASHRAE Standard 34 Designation and Safety Classification of Refrigerants

This standard classifies refrigerants into groups according to flammability and toxicity refrigerant concentration limits for the refrigerants. Low toxicity refrigerants are class A, high toxicity are class B. Non-flammability refrigerants are class 1 and higher flammable refrigerants are class 3. (A1, A2, A3, B1, B2, B3)

Chemical changes from heat. Flames or high heat from soldering can produce acids or poisonous gases from refrigerants. Hydrochloric acid, hydrofluoric acid and phosgene

gas can be deadly. Remove refrigerant and evacuate any components before soldering or welding.

Standard 34 also provides an unambiguous system for numbering refrigerants and assigning composition-designating prefixes for refrigerants instead of using the chemical name, formula, or trade name.

7.6.2. ASHRAE Standard 15: Safety Standard for Refrigeration Systems

ASHRAE Standard 15 specifies safe design, construction, installation, and operation of refrigeration systems. The key requirements are stated below:

- a. It applies to substitutions, if refrigerant having a different designation.
- b. It describes occupancy classifications (Institutional, public assembly, residential, commercial, large mercantile, industrial and mixed occupancy) that consider the ability of people to respond to potential exposure to refrigerant.
- c. It defines different refrigeration systems (direct, indirect, indirect open spray, double indirect open spray, indirect closed and indirectly vented closed system)
- d. It classifies the refrigeration systems according to the degree of probability that a leakage of refrigerant will enter occupancy-classified areas (High-probability, low- probability systems)
- e. Changing the refrigerant requires and for safety purposes, notification the authority of jurisdiction, the user.
- f. Safety classification is set as per type if single-compound or blend.
- g. Allowance of amount of refrigerant in institutional occupancy is halved.
- h. Additional restrictions applied on flammable refrigeration and refrigeration system in corridors and lobbies, type and purity of refrigerant, recovered or recycled, reclaimed, applications for human comfort and on higher flammability refrigerants.

- i. It restricts the installation in its equipment foundation, guards, safe access, water connections, electrical safety, gas fuel equipment, refrigerant pipe joint inspection, location of the refrigerant piping, machinery room in general requirements and special ones and purge discharge.
- j. It restricts the installation in its equipment foundation, guards, safe access, water connections, electrical safety, gas fuel equipment, refrigerant pipe joint inspection, location of the refrigerant piping, machinery room in general requirements and special ones and purge discharge.
- k. It describes the materials that may or may not be used in the construction and installation of the refrigerating system.
- l. It specifies the maximum design pressure.
- m. It describes the pressure vessel characteristics and pressure relief protection, devices.
- n. It clarifies the method of refrigerant discharge, selection of pressure limiting devices and refrigerant piping and requirements of factory testing and name plates
- o. It requires field tests by explaining the testing procedures.
- p. In addition, it provides general requirements including identification of piping and controls, changes in the refrigerant, refrigerant storage, periodic tests and how codes take precedence over the standards.
- q. Normative appendices are provided including calculation of the maximum allowable concentration of a blend, normative reference, method for calculating discharge capacity of positive displacement compressor pressure relief device, allowable equivalent length of discharging piping, and what to do in emergencies in refrigerating machinery rooms.

Additional Safety and shipping information is covered in the Core section of this course.

Summary

This course discussed and provided the guidelines of EPA 608. EPA requires that all maintenance activities including handling, storage and retrofitting of refrigerant are carried out in accordance with good practice, and this must be stipulated in contract conditions. For larger facilities the inclusion of a KPI that monitors the amount of refrigerant usage is essential. Refrigerant leakage monitoring systems are increasingly being specified together with liquid receivers large enough to store the system charge. For all facilities, maintenance log books must record the amount of refrigerant added to systems and Maintenance Staff must bring to the attention of the Facilities Manager any abnormal consumption. It is a legal requirement for tradesmen working on refrigeration plant including chillers and air conditioning equipment to be appropriately licensed.

References:

- a. U.S. EPA: Section 608 Rule Summary:
<http://www.epa.gov/ozone/title6/608/608fact.html>
- b. Summary of the Clean Air Act <https://www.epa.gov/laws-regulations/summary-clean-air-act>
- c. U.S. EPA Clean Air Act, Title VI, Section 608, Refrigerant Recycling Rule
<https://www.usgbc.org/resources/us-epa-clean-air-act-title-vi-section-608-refrigerant-recycling-rule-0>

Annexure -1

Addendum Requirement of EPA 608 (beginning January 2019)

Beginning January 1, 2019, the documentation of amounts of refrigerant removed or added to appliances extend to substitute refrigerants such as HFCs, as well. Earlier, the requirement was restricted to the ODS's.

The outline summary of the new rules is highlighted below:

1. Lowers the leak rate threshold triggering requirement to repair refrigerant-containing equipment containing 50 pounds or more of refrigerant. Beginning January 1, 2019 owners/operators must now identify and repair leaks that exceed 30% for industrial process refrigeration (previously 35%), 20% for commercial refrigeration (previously 35%), and 10% for comfort cooling (previously 15%) within 30 days of when the ODS or substitute refrigerant is added. Leaks must be repaired such that the leak rate is brought below the applicable leak rate. More information on leak repair requirements and EPA definitions of these three appliance types are available here.
2. Mandates that beginning January 1, 2019 owners/operators of all three appliance types listed above must perform and document both an initial and follow-up verification test of leak repairs whenever appliances exceed the applicable leak rate. An initial verification test must be performed before any additional refrigerant is added to the appliance. A follow-up verification test must be performed only after the appliance has returned to normal operating characteristics and conditions.
3. Stipulates that verification tests must demonstrate that leaks were successfully repaired. If either the initial or follow-up verification test indicates that repairs were not successful, owners/operators may conduct as many additional repairs and verification tests as needed within the allotted 30-day repair period. The repair period is extended to 120 days if an industrial process shutdown is required. If repair within the applicable timeframe is not feasible, owners/operators of these three appliance types may request limited extensions to the deadline.

4. States that if the leak rate still cannot be brought below the acceptable threshold, either because the leak cannot be identified or because the appliance still leaks following repairs, owners/operators must create a retrofit or retirement plan for the appliances. A retrofit/retirement plan is also required if the owner/operator chooses to retrofit or retire rather than repair the leaks. The retrofit/retirement plan must contain the identification of the appliance, type and full charge of refrigerant used, type and full charge of alternative refrigerant (if retrofitting), plan for disposition of recovered refrigerant, plan for disposition of appliance (if retiring), and a schedule for completion of the retirement or retrofit within one year.
5. Requires owners/operators to conduct leak inspections for appliances that have exceeded applicable threshold leak rate starting on January 1, 2019. All inspections must be conducted by a certified technician and must include all visible components of an appliance. The frequency of leak inspections is determined as follows:
 - a. Commercial refrigeration and industrial process refrigeration: Appliances containing 50 to 500 pounds of charge must be inspected once per calendar year until the owner/operator can demonstrate through leak rate calculations that the leak rate has not exceeded 20% (for commercial refrigeration) or 30% (for industrial process refrigeration appliances) for four quarters in a row. Appliances with more than 500 pounds of charge require inspection once every three months.
 - b. Comfort cooling: All appliances containing 50 pounds or more of charge must per inspected once per calendar year, until the owner/operator can demonstrate through leak rate calculations that the leak rate has not exceeded 10% for one year.
 - c. Requires owners/operators to submit reports to the EPA if any appliance containing 50 pounds or more of refrigerant leaks 125% or more of its full charge within one calendar year. The report must document efforts to identify leaks and repair the appliance.
6. Imposes new sales restrictions for refrigerants. Effective since January 1, 2017, recovered ODSs and substitute refrigerants may not be resold unless they were

reclaimed by a certified reclaimer, or transferred into equipment belonging to the same owner. The actual sale of these refrigerants will be restricted to certified technicians beginning on January 1, 2018.

7. Requires owners/operators to maintain hard or electronic copies of the following:
 - a. Documentation of the full charge of appliances.
 - b. Records (such as invoices) showing when service or maintenance is performed, when refrigerant is added or removed, when leak inspections are conducted, and when verification tests are conducted.
 - c. Owners/operators using automatic leak detection systems must document that the system is installed and calibrated annually, and record leaks identified by the monitoring system, including the time and location of the leak.
 - d. Retrofit/retirement plans.
 - e. Requests submitted to EPA to extend repair/retrofit deadlines.
 - f. Documentation of when a system was “mothballed” (temporarily taken out of service) to suspend a repair deadline, if applicable. Corresponding documentation must be maintained when refrigerant is added back into the appliance and it is brought back on-line.
 - g. Records to demonstrate a seasonal variance.
 - h. Reports for appliances identified as leaking 125% or more of their full charge within a calendar year.
8. Requires technicians to keep records of refrigerant recovered during system disposal from any systems with a 5 to 50-pound charge size. The records must include the location, date of recovery and type of refrigerant recovered for each disposed appliance, the quantity and type of refrigerant recovered within each calendar month, and information about quantities and types of refrigerant shipped for reclamation or destruction, including the party to which the material was transferred. This requirement goes into effect on January 1, 2018.

9. Requires technicians to evacuate ODSs or substitute refrigerants to levels specified in the regulations, using certified recovery/recycling equipment. Technicians evacuating refrigerant from motor vehicle air conditioning (MVAC) appliances must either evacuate the refrigerants or reduce the system pressure to below 102 mm of mercury. This requirement goes into effect on January 1, 2018.

The rule does not change certification requirements for currently certified technicians. Starting on January 1, 2018, technicians who have not yet been certified must pass a certification exam updated to reflect the new rule and offered by an approved certification program to maintain, service, repair or dispose of appliances containing ODSs or substitute refrigerants. Technicians must maintain a copy of their certificates at their place of business and must maintain a copy until three years after they cease operating as a technician.

Summary.... Key Takeaways

Lower Leak Rate Thresholds

- a. Leak rates must be lowered across all categories of refrigerant, including comfort cooling, commercial refrigeration and industrial process refrigeration.
- b. Comfort cooling needs to be reduced from a 15% annual rate to 10%, industrial refrigeration from 35% to 30% and commercial from 35% to a much lower 20%.
- c. Commercial refrigeration not only assumes the biggest percent drop, but they are the most exposed to having multiple systems of 50 lbs. or more.

Track All Efforts Related to Maintaining Leak Rates

- a. The new regulations also require operators to track all efforts related to maintaining a system's sub-threshold leak rate.
- b. Any system that hits the 125% leak rate in a calendar year is required to be self-reported to the EPA, along with any and all documentation related to work done on that system. That report is to be shared with the EPA by March 1st of the following year. The first year this is mandatory is 2020 for all 2019 data starting from January 1, 2019.

Follow-Up Inspections

- a. The new guidelines introduce immediate and periodic leak inspections to verify systems are back to sub-threshold leak rates.
- b. Depending on the size of the system, operators are subject to an annual or quarterly inspection to verify that systems have been properly maintained and not leaked further beyond the equipment type threshold. 50 to 500 lbs. systems require annual inspections as soon as they hit their threshold and any system over 500 lbs. will require quarterly inspections.
- c. Inspections can cease once a system has stayed below the leak rate for a 12-month cycle. This should add operational discipline to track and inspect individual system across multiple sites, banners or geographical locations on time.

Annexure -2

GLOSSARY

ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers): An international organization that advances heating, ventilation, air conditioning and refrigeration; among other things, they developed a standard for classifying the safety of refrigerants.

Blended refrigerant: Also called a **near-azeotropic mixture** (sometimes referred to as NARM), a blended refrigerant contains refrigerants with different boiling points, but that act as one substance when they are in either a liquid or a vapor state. Near-azeotropic mixtures exhibit temperature glide when they change from vapor to liquid, or vice versa. However, the temperature glide is less than 10°F. Near-azeotropic mixtures can exhibit fractionation (when the mixture's composition changes as a result of vapor charging) and may affect the leak ratio. Near-azeotropic mixtures should be charged as a liquid.

Azeotrope: A blend of two or more components whose equilibrium vapor phase and liquid phase compositions are the same at a given pressure. These refrigerants are given a 500 series ASHRAE designation and behave like a single refrigerant. They can be charged as a liquid or vapor.

Disposal: The process leading to and including any of the following:

- The discharging, depositing, dumping, or placing of any discarded appliance into or on any land or water.
- The disassembly of any appliance for discharging, depositing, dumping, or placing of its discarded component parts into or on any land or water.
- The disassembly of any appliance for reuse of its component parts.

$(\text{Refrigerant added}/\text{Total charge}) \times (365 \text{ days}/\text{year}/D) \times 100\%$ where D = the shorter of: # days since refrigerant last added or 365 days

Filter-Drier: An accessory that filters the refrigerant and protects it from dirt and moisture, as well as acids.

Fractionation: The separation of a liquid mixture into separate parts by the preferential evaporation of the more volatile component

Halocarbon: A halogenated hydrocarbon containing one or more of the three halogens: fluorine, chlorine, and bromine. Hydrogen may or may not be present.

High-Pressure Appliance: (prior to March 12, 2004, referred to by the EPA as higher- pressure appliance). An appliance that uses a refrigerant with a liquid phase saturation pressure between 170 psia and 355 psia at 104°F. This definition includes but is not limited to appliances using R-410A, R-22, R-401B, R-402A/B, R-404A, R-407A/B/C, R-408, R-409, R- 411A/B, R-502 and R-507A.

Hydrocarbon: A compound containing only the elements hydrogen and carbon.

Leak Rate: The rate at which an appliance is losing refrigerant, measured between refrigerant charges or over 12 months, whichever is shorter. The leak rate is expressed in terms of the percentage of the appliance's full charge that would be lost over a 12-month period if the current rate of loss were to continue. The rate is calculated using the following formula:

Low-Loss Fitting: Any device that is intended to establish a connection between hoses, appliances, or recovery/recycling machines, and that is designed to close automatically or to be closed manually when disconnected to minimize the release of refrigerant from hoses, appliances, and recovery or recycling machines.

Low-Pressure Appliance: (definition unchanged by the EPA's March 12, 2004 rule change): An appliance that uses a refrigerant with a liquid phase saturation pressure below 45 psia at 104°F. Evacuation requirements for the low-pressure category apply to these appliances. This definition includes but is not limited to appliances using R-11, R-113, and R-123.

MSDS (Material Safety Data Sheet): A material safety data sheet (MSDS) is a form with data regarding the properties of a particular substance. An MSDS provides workers with physical data and information about handling that substance in a safe manner.

Major Repair: Maintenance, service, or repair that involves removal of the service or repair appliance compressor, condenser, evaporator, or auxiliary heat exchanger coil.

Medium-Pressure Appliance: (prior to March 12, 2004, referred to by the EPA as high-pressure appliance). An appliance that uses a refrigerant with a liquid phase saturation pressure between 45 psia and 170 psia at 104°F. R-114 appliances are at the low-pressure end since the saturation pressure of R-114 at 104°F is slightly above 45 psia. This definition includes but is not limited to appliances using R-12, R-114, R-124, R-134A, R-401C, R-406A and R-500

Mixture: A blend of two or more components that do not have a fixed proportion to one another and that no matter how well blended, still retain a separate existence (oil and water, for example).

Motor Vehicle Air Conditioner (MVAC): Mechanical vapor compression refrigeration equipment used to cool the driver or passenger compartments of any motor vehicle. This definition is NOT intended to encompass the hermetically sealed refrigeration system used on motor vehicles for refrigerated cargo or the air conditioning systems on passenger buses. Section 609 certification is required for working on MVAC systems, while either Section 608 Type II or Section 609 certification is required for MVAC-like A/C systems (e.g. farm equipment and other non-roads vehicles). Section 608 certification is required for working on hermetically sealed refrigeration systems used on motor vehicles for refrigerated cargo or the air conditioning systems on passenger buses.

Non-Azeotropic Refrigerant: A synonym for zeotropic, the latter being the preferred, though less commonly used term. Zeotropic: blend with multiple components of different volatilities that, when used in refrigeration cycles, change volumetric composition and saturation temperatures (exhibit temperature glide) as they evaporate (boil) or condense at constant pressure. These refrigerants are given a 400 series ASHRAE designation.

Normal Charge: The quantity of refrigerant within the appliance or appliance component when the appliance is operating with a full charge of refrigerant.

Person: Any individual or legal entity, including an individual corporation, partnership, association, state, municipality, political subdivision of a state, Indian tribe, and any agency,

department, or instrumentality of the United States and any officer, agent, or employee thereof.

Process Stub: A length of tubing that provides access to the refrigerant inside a small appliance or room air conditioner that can be resealed at the end of repair or service.

psia: The absolute pressure in pounds per square inch, where 0 psia corresponds to 29.9 inches of mercury vacuum and 14.7 psia corresponds to 0 psig (pounds per square inch gauge).

psig: The gauge pressure in pounds per square inch, where 0 psig corresponds to atmospheric pressure (14.7 psia). A positive psig value indicates the pressure in pounds per square inch above the ambient pressure.

Reclaim: To reprocess refrigerant to at least the purity specified in the ARI Standard 700, Specifications for Fluorocarbon Refrigerants, and to verify this purity using the analytical test procedures described in the Standard.

Recovery Efficiency: The percentage of refrigerant in an appliance that is recovered by a unit of recycling or recovery equipment.

Recover: To remove refrigerant in any condition from an appliance and to store it in an external container without necessarily testing or processing it in any way.

Recycle: To extract refrigerant from an appliance and to clean refrigerant for reuse without meeting all of the requirements for reclamation. In general, recycled refrigerant is refrigerant that is cleaned using oil separation and single or multiple passes through devices such as replaceable-core filter dryers, which reduce moisture, acidity, and particulate matter.

Refrigerant: The substance used for heat transfer in a refrigeration system. A refrigerant absorbs heat during evaporation at low temperature and pressure, and releases heat during condensation at a higher temperature and pressure.

Refrigerant: Any class I or class II substance used for heat transfer purposes, or any substance used as a substitute for such a class I or class II substance by any user in a given end-use, except for the following substitutes in the following end uses:

- Ammonia in commercial or industrial process refrigeration or in absorption units.

- Hydrocarbons in industrial process refrigeration (processing of hydrocarbons).
- Chlorine in industrial process refrigeration (processing of chlorine and chlorine compounds).
- Carbon dioxide in any application.
- Nitrogen in any application
- Water in any application

Self-Contained Recovery: Recovery or recycling equipment that is capable of removing refrigerant from an appliance without the assistance of components contained in the appliance

Small Appliance: Any of the following products that are fully manufactured, charged, and hermetically sealed in a factory with five pounds or less of refrigerant: refrigerators and freezers designed for home use, room air conditioners (including window air conditioners and packaged terminal air conditioners), packaged terminal heat pumps, dehumidifiers, under-the-counter ice makers, vending machines, and drinking water coolers.

Substitute: Any chemical or product substitute, whether existing or new, that is used by any person as a replacement for a class I or II compound in a given end-use.

System-Dependent Recovery Equipment: Recovery equipment that relies upon the compressor in the appliance and/or the pressure of the refrigerant in the appliance.

System-Dependent: Recovery equipment that requires the assistance of recovery components contained in an appliance to remove the refrigerant from the appliance.

Technician: Any person who performs maintenance, service, or repair that could reasonably be expected to release Class I (CFC) or Class II (HCFC) substances into the atmosphere, including but not limited to installers, contractor employees, in-house service personnel, and in some cases, owners. Technician also means any person disposing of appliances except for small appliances.

Very-High-Pressure Appliance: (definition unchanged by the EPA's March 12, 2004 rule change) An appliance that uses refrigerants with a critical temperature below 104°F or with a liquid

phase saturation pressure above 355 psia at 104°F. This category includes but is not limited to appliances using R-13, R-23, R-503.

Refrigerant Temperature / Pressure Chart							
Temperature (°F)	Pressure PSI						
	Bold and Red numbers = inches-Hg (indicates vacuum)						
	Black numbers = psig						
	R-11	R-12	R-22	R-123	R-134A	R-500	R-502
-100	29.8	27.0	25.0	29.9	27.8	26.4	25.3
-90	29.7	25.7	23.0	29.8	26.9	24.9	20.6
-80	29.6	24.1	20.2	29.7	25.6	22.9	17.2
-70	29.4	21.8	16.6	29.6	23.8	20.3	12.8
-60	29.2	19.0	12.0	29.5	21.5	17.0	7.2
-50	28.9	15.4	6.2	29.2	18.5	12.8	0.2
-40	28.4	11.0	0.5	28.9	14.7	7.6	4.1
-30	27.8	5.4	4.9	28.5	9.8	1.2	9.2
-20	27.0	0.6	10.2	27.8	3.8	3.2	15.3
-10	26.0	4.4	16.4	27.0	1.8	7.8	22.6
0	24.7	9.2	24.0	26.0	6.3	13.3	31.1
10	23.1	14.6	32.8	24.7	11.6	19.7	41.0
20	21.1	21.0	43.0	23.0	18.0	27.2	52.4
30	18.6	28.4	54.9	20.8	25.6	36.0	65.6
40	15.6	37.0	68.5	18.2	34.5	46.0	80.5
50	12.0	46.7	84.0	15.0	44.9	57.5	97.4

60	7.8	57.7	101.3	11.2	56.9	70.6	116.4
70	2.8	70.2	121.4	6.6	70.7	85.3	137.6
80	1.5	84.2	143.6	1.1	86.4	101.9	161.2
90	4.9	99.8	168.4	2.6	104.2	120.4	187.4
100	8.8	117.2	195.9	6.3	124.3	141.1	216.2
110	13.1	136.4	226.4	10.5	146.3	164.0	247.9
120	18.3	157.7	259.9	15.4	171.9	189.2	282.7
130	24.0	181.0	296.8	21.0	199.4	217.0	320.8
140	30.4	206.6	337.2	27.3	230.5	247.4	362.6
150	37.7	234.4	381.5	34.5	264.4	280.7	408.4