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# Refrigerant Safety in HVAC Systems

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## REFRIGERANT SAFETY IN HVAC SYSTEMS (ASHRAE STANDARD 15 and 34)

### Overview

Maintaining a safe work environment is essential inside the heating, ventilation and air conditioning (HVAC) machinery rooms housing chillers, as well in occupied areas having direct expansion (DX) type refrigeration equipment including packaged units or variable refrigerant flow (VRF) type air conditioning. The failure to monitor these areas properly for leaking refrigerant gases can lead to accidents with deadly consequences.

Refrigerant hazards may be related to several aspects, in that they may:

- be stored at high pressure
- displace oxygen when released in air
- have toxicological effects
- be flammable
- have dangerous decomposition products

At least one of these characteristics applies to any refrigerant, and for that reason, a variety of precautions must be followed to ensure against injury to persons and damage to property.

To advise users on the way the refrigerants shall be handled or used, the American Society of Heating Refrigerant and Air conditioning Engineers (ASHRAE) provide safety guidelines through standards 15 and 34.

- ASHRAE 34, Designation and Safety Classification of Refrigerants, describes a simple means of referring to common refrigerants instead of using the chemical name, formula, or trade name. It also assigns safety classification to refrigerants based on toxicity and flammability data.
- ASHRAE 15, Safety Standard for Refrigeration Systems, sets forth the procedures for safe design, construction, installation, and operation of refrigerating systems.

In this course, we will discuss a set of minimum requirements to keep personnel safe while working inside machinery rooms containing refrigerants. We will also discuss the design requirements for the occupied areas containing Variable Refrigerant Flow (VRF) systems.

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## **CHAPTER - 1**

### **REFRIGERANT SAFETY**

#### **1.0. RISKS WITH REFRIGERANTS**

Refrigerants used in refrigeration and air conditioning systems must be handled, stored and used properly to avoid potential hazards. Most refrigerants have low boiling points and present dangers of frostbite and eye damage. Refrigerant liquids with higher boiling points can cause respiratory and skin irritation. The common risks include toxicity, flammability, asphyxiation, and physical hazards.

The refrigerant gasses primarily chlorofluorocarbons (CFC) and Hydrochlorofluorocarbons (HCFCs) have also been linked to the depletion of Ozone layer in the stratosphere. The ozone layer is often referred to as a protective layer because it absorbs and scatters ultraviolet light from the Sun, preventing some of the harmful ultraviolet light from reaching the earth's surface. Ozone depletion is a global concern and is associated with multiple health and environmental concerns including skin cancers, damage to crops, threat to animal life and global warming.

In the United States, the Environmental Protection Agency (EPA) has set strict standards for regulating and monitoring a refrigerant leak. The Montreal Protocol and Kyoto Protocols were both created to establish similar environmental standards internationally. These regulations include protocols for repairing refrigerant leaks or disposing of systems within a certain timeframe.

#### **1.1 Health and Safety**

A hazard in refrigeration and air conditioning equipment and systems is present when there is an uncontrolled, unexpected release of refrigerant from the system. The health and safety issues related to refrigerants may be attributed to several aspects and include the following:

##### **1.1.1. High Pressure Fluids**

Most refrigerants are stored under pressure, since they would be a gas at atmospheric pressure. A sudden release of pressure can cause personal injury and property damage by

propelling a cylinder or rupture of a part. Refrigerant cylinders, tubing, hoses, system components would fail at some elevated pressures without safety provisions.

### **1.1.2. Frostbite**

When liquid refrigerant is suddenly released from high pressure to atmospheric pressure, the liquid refrigerant will flash and boil to vapor. Naturally, the temperature of the refrigerant will drop quickly to the boiling point and the refrigerant will quickly absorb heat from whatever it is touching. If the refrigerant is touching skin, it can cause frostbite.

### **1.1.3. Oxygen displacement**

Most refrigerants are denser than air, which means, these will deplete oxygen levels, if released due to any failure. Since most refrigerants are odorless, occupants may become asphyxiated before they realize the problem. The rooms below ground, seated areas, and enclosed spaces are more susceptible to this problem as the refrigerant will settle down.

It is worth noting that within the field of refrigeration and air conditioning, there have been more fatalities associated with oxygen displacement than with any other aspect. Good ventilation must be provided in areas where high concentrations of the vapor could accumulate. The area must be ventilated using blowers or fans to circulate the air at floor-level: the lowest point possible. Before performing maintenance in areas where refrigerants could have accumulated, a thorough assessment must be carried out in order to determine whether respiratory protection is required.

## **1.2 Toxicological effects**

All refrigerants have some toxicological effects. Toxicity is a relative term, which becomes meaningful only when the degree of concentration and time of exposure is specified. Some fluids are toxic even in small concentrations while others are dangerous only when the concentration is large, and duration of exposure is long.

Exposure to refrigerant concentrations above the recommended exposure levels can result in loss of concentration, drowsiness, cardiac arrhythmia, and other fatal symptoms. If inhaled, medical help must be sought urgently.

### **1.2.1. Exposure Limits**

Exposure levels are values given to refrigerants to indicate how much of the chemical a person can regularly be exposed to without adverse effects. The American Conference of Government and Industrial Hygienists (ACGIH) sets the TLV---TWA values for chemicals. TLV---TWA stands for Threshold Limit Value--- Time Weighted Average, which is the amount of chemical a person can be exposed to for 8 hours a day, 40 hours a week, without adverse effects.

The maximum value for any chemical is 1,000 ppm, though many refrigerants have shown no effects in toxicity testing as values much higher than that.

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":

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

ASHRAE Standard 34 defines two safety classifications for toxicity. Class A denotes refrigerants of lower toxicity, and class B denotes refrigerants of higher toxicity.

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

### **1.3 Refrigerant Flammability**

Several refrigerants are flammable under atmospheric conditions. Fire and explosion are the primary risks with the possible ignition of a flammable concentration. Flammable gases can be ignited by an electric spark, static electricity or by a heat source, such as a flame or hot object. Ignition may occur wherever the refrigerant has leaked and mixed with air in dangerous proportions.

ASHRAE 34 defines a refrigerant's flammability by specific marking. There are three classifications and one subclass. The three main flammability classifications are class 1, for refrigerants that do not propagate a flame when tested as per the standard; class 2, for

refrigerants of lower flammability; and class 3, for highly flammable refrigerants such as the hydrocarbons. 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.

#### **1.4 Decomposed Products**

Refrigerants can decompose when exposed to flame or torch or other extreme heat, electrical burnouts or in refrigerant lines being soldered or brazed without being cleared first. When a refrigerant is decomposed, the primary products formed are acids: Hydrochloric Acid (HCl) if the refrigerant contains chlorine, and Hydrofluoric Acid (HF) if it contains fluorine. If oxygen is also present (from air or water), then it's possible to form carbon monoxide, carbon dioxide and various unsaturated carbonyl compounds – the most notorious of which is phosgene.

Phosgene formation is extremely toxic even in small amounts and is a real concern when traditional refrigerants (R-11, R-12, R-113, R-114) decompose. Decomposition of R-22 or HFCs may not form phosgene but will yield carbonyl fluorides, which is not as toxic as phosgene.

#### **1.5 Environmental Effects**

The refrigerant gases, primarily chlorofluorocarbons (CFC) and Hydrochlorofluorocarbons (HCFCs) have been linked to the destruction of Ozone layer. Other refrigerants including hydrofluorocarbons (HFC) are linked to Global Warming.

##### **1.5.1. Ozone Depletion**

Ozone depletion is a global concern, and is associated with multiple 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 16<sup>th</sup> September 1987.

According to the Montreal protocol, the Ozone Depletion Potential (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 (R-11). 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. R-11, R-12) or will be in near-future (e.g. R-22). 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.

### **1.5.2. 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 CO<sub>2</sub> 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.

### **1.5.3. 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.

### **Summary**

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.

It is important to “know your refrigerant” and understand the properties, uses, and safety precautions. Consult Material Safety Data Sheets (MSDSs) for safety information on the refrigerant that you will be using or being used in your facility.

## Chapter – 2

### REFRIGERANTS TYPES, DESIGNATION AND NUMBERING

#### 2.0. 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.

#### 2.1 Choice of Refrigerants

##### 2.1.1. 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.

Chlorofluorocarbons (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.

Hydrofluorocarbon refrigerants (HFCs) 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	R-11, R-12, R-113, R-114, R-115
HCFC	Hydrochlorofluorocarbon	H, Cl, F, C	R-22, R-123, R-141b
HFC	Chlorofluorocarbon	H, F, C	R-134a, R-404a, R-407c, R-410a

### 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.

- **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).
- **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/m<sup>3</sup>. 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.

- R-170, Ethane
- R-290, Propane
- R-600, Butane
- R-600a, Isobutane
- Blends of the above gases

#### **2.1.2. Inorganic Refrigerants**

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.

- Water
- Ammonia
- CO<sub>2</sub>

## 2.2 ODP and high GWP refrigerants

When selecting fixed refrigeration systems and refrigerated vehicles, those involved in the procurement procedure should consider the ODP and GWP of the refrigerating fluid used in the cooling equipment and the blowing agent in the insulating foam. Table below gives the ODP and GWP of popular refrigerating fluids used in refrigeration systems. 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 <sub>3</sub> F	4,750	1
CFC-12	dichlorodifluoromethane	CCl <sub>2</sub> F <sub>2</sub>	10,900	1
CFC-502	chlorodifluoromethane chloropentafluoroethane	CHClF <sub>2</sub> CClF <sub>2</sub> CF <sub>3</sub>	4,657	0.25
HCFC-141b	1,1-dichloro-1-fluoroethane	CCl <sub>2</sub> FCH <sub>3</sub>	725	0.12
HCFC-22	chlorodifluoromethane	CHClF <sub>2</sub>	1,810	0.05
HFC-134a	1,1,1,2-tetrafluoroethane	CH <sub>2</sub> FCF <sub>3</sub>	1,430	0
HFC-404a	pentafluoroethane	CHF <sub>2</sub> CF <sub>3</sub> CH <sub>3</sub> CF <sub>3</sub>	3,922	0

Refrigerant	Name	Structure	GWP	ODP
	1,1,1-trifluoroethane 1,1,1,2-tetrafluoroethane	CH <sub>2</sub> FCF <sub>3</sub>		
HFC-407a	difluoromethane pentafluoroethane 1,1,1,2-tetrafluoroethane	CH <sub>2</sub> F <sub>2</sub> CHF <sub>2</sub> CF <sub>3</sub> CH <sub>2</sub> FCF <sub>3</sub>	2,107	0
HFC-410a	difluoromethane pentafluoroethane	CH <sub>2</sub> F <sub>2</sub> CHF <sub>2</sub> CF <sub>3</sub>	2,088	0
HFO-1234yf	2,3,3,3-tetrafluoropropene	CF <sub>3</sub> CF=CH <sub>2</sub>	4	0
HFO-1234ze	trans-1,3,3,3-tetrafluoropropene	CF <sub>3</sub> CH=CHF	6	0
N/A	cyclopentane	C <sub>5</sub> H <sub>10</sub>	11	0
HC-290	propane	CH <sub>3</sub> CH <sub>2</sub> CH <sub>3</sub>	11	0
HC-600s	isobutane	CH(CH <sub>3</sub> ) <sub>2</sub> CH <sub>3</sub>	3	0
R-717	ammonia	NH <sub>3</sub>	0	0
R-744	carbon dioxide	CO <sub>2</sub>	1	0

### 2.3 Designation of Refrigerants (ASHRAE 34)

ASHRAE Standard 34, Designation and Safety Classification of Refrigerants, establishes a simple means of referring to common refrigerants rather than by their chemical name, formula, or trade name. ASHRAE assigns numbers and safety classification to the refrigerants based on toxicity and flammability data submitted by the refrigerant's producer. For pure compounds, the numbers are based on chemical formula. For blends, numbers are assigned sequentially based on the completion of a satisfactory review of data provided by the refrigerant's producer. Information is available in the current edition, ANSI/ASHRAE Standard 34-2019.

All the refrigerants are designated by R followed by a unique number. From the number one can get some useful information about the type of refrigerant, its chemical composition, molecular weight etc.

### **2.3.1. Identification of Refrigerants**

For each refrigerant an identifying number is assigned to it. This number consists of a prefix made up of letters and a suffix made up of digits. An example of this can be seen in R-22. R is a letter prefix and 22 is the numbered suffix. This standard numbering system was first developed by the DuPont Company in 1956. Since then ANSI/ASHRAE has adopted this numbering system under Standard 34.

The goal of this numbering system is to allow an engineer, technician, or anyone else to easily identify the chemical composition of the refrigerant that they are working with. Each number in the refrigerant name has its own specific purpose and provides a clue as to how the refrigerant is made.

Broadly, the number designation is as follows:

<b>(x) (y) (z) Series</b>	<b>Chemical</b>	<b>Description</b>
000 Series	Methane Based	(x) = 0 is the methane series, but the 0 is ignored for these compounds. Examples are R-12 and R-22.
100 Series	Ethane Based	(x) = 1 is the members of the ethane series, such as R-114, R-124 and R-134a.
200 Series	Propane Based	(x) = 2 is the propane series, e.g. R-290 (propane).
300 Series	Cyclic Organic Compounds	(x) = 3 is the cyclic organic compounds.
400 Series	Zeotropes	(x) = 4 refers to zeotropic mixtures. The components in the mixture have different boiling points, and thus the refrigerant mixture has a temperature glide. R-407A and R-407C are examples of such refrigerants.

500 Series	Azeotropes	(x) = 5 refers to azeotropic mixtures. These act like homogeneous substances with one specific boiling point, and therefore they have no glide. R-502 and R-507 are examples of azeotropic mixtures.
600 Series	Organic Compounds	(x) = 6 means that the composition is organic, e.g. butane, R-600, and isobutene, R-600a. This group has several subgroups, for example hydrocarbons, oxygen compounds, sulfuric compounds and nitrogen compounds.
700 Series	Inorganic Compounds	(x) = 7 refers to inorganic compounds, such as ammonia, R-717, water, R-718, and carbon dioxide, R-744.
1000 Series	Unsaturated Organic Compounds	(x) = 11 stands for unsaturated ethane compounds, such as R-1150 (ethylene).  (x) = 12 stands for unsaturated propane compounds, such as R-1270 (propylene).

## 2.4 Refrigerant Designation

The refrigerant numbering is indicated by “Rxyz” coding as described below:

### 2.4.1. The Prefix

The prefix contains a letter. Usually this letter is composed of the letter ‘R’ for refrigerant. Further examples being R-12, R-22, R-134a, R-410A, etc.

### 2.4.2. The Suffix

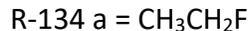
There are four numbers in the suffix of a refrigerant. If you notice only two numbers, for example, R-12 and R-22, the other two numbers in front are treated as a zero. Also, unlike standard convention, refrigerant numbers read from right to left instead of left to right.

Ok, so now that we have that established let's break down a refrigerant's name:

1. Starting from the right. The right most number equals the number of Fluorine atoms per molecule.
2. The second number from the right equals one plus the number of hydrogen atoms per molecule.
3. The third number from the right equals the number of carbon atoms minus one. If it is zero it is not normally written but assumed as I had mentioned earlier.
4. The fourth number is relatively new to refrigerants. This number equals the number of double bonds in the molecule. Like before this is omitted when zero. The only time I see this number used is when working with the new Hydro-fluoro-olefin refrigerants such as HFO-1234YF.

Another thing that you may have noticed when looking at refrigerant names are suffixes that end with an A, a, B, or C. While these are not as common, we should go into these as well:

A suffix with a lower-case letter such as a, b, or c indicate an isomer. Isomers are two or more compounds with the same formula but have a different arrangement of atoms in the molecule thus giving them different properties. For example, C<sub>2</sub>H<sub>2</sub>F<sub>4</sub> has two isomers:



Exact same refrigerant but arranged differently creating a different effect.

A suffix with an uppercase letter such as A, B, or C indicate the different percentages of refrigerants that are blended together. This is why you could see refrigerants that have a very

similar name such as R-401A and R-401B. These refrigerants are made of the same blended refrigerants but at different percentages.

## 2.5 Refrigerant Numbering

### 2.5.1. For saturated hydrocarbons and their derivatives – three-digit number

Description	How to decode the Refrigerant Number	How to write the chemical formula from the number
First digit	$C - 1$ [one less than the 'C' atoms in the compound]	$x+1$ indicates the number of Carbon (C) atoms
Second digit	$H + 1$ [one more than the 'H' atoms in the compound]	$y - 1$ indicates number of Hydrogen (H) atoms
Third digit	Number of fluorine atoms	$z$ indicates the number of Fluorine (F) atoms

The number of chlorine (Cl) atoms is found by subtracting the sum of the fluorine (F) and hydrogen (H) atoms from the total number that can be attached to carbon.

- With one carbon, the total number of attached atoms is four
- With two carbons, the total number is six
- With three carbons, the total number is eight

#### Example: Decode CH<sub>4</sub>

First digit =  $C - 1 = 1 - 1 = 0$

Second digit =  $H + 1 = 4 + 1 = 5$

Third digit = number of fluorine atoms = 0

Therefore, the number is R-050 or R-50

#### Example: Decode C<sub>2</sub>H<sub>2</sub>Cl<sub>2</sub>F<sub>2</sub>

First digit =  $C - 1 = 2 - 1 = 1$

Second digit =  $H + 1 = 2 + 1 = 3$

Third digit =  $F = 2$

Therefore, the number is R-132

**Example: Write chemical formula for R-22**

Read this as R022

$X = 0$  means that number of carbon atoms are  $0 + 1 = 1$

$Y = 2$  means that number of hydrogen atoms are  $2 - 1 = 1$

$Z = 2$  means that number of fluorine atoms are 2

With one carbon, the total number of attached atoms = 4

Therefore, number of chlorine atoms =  $4 - \text{no. of } (H + F) \text{ atoms} = 4 - 1 - 2 = 1$ .

Or the number of chlorine atoms = 1

Therefore, the chemical formula of R-22 is  $\text{CHClF}_2$

**Example: Write chemical formula for R-134a**

R 134

$X = 1$  means that number of carbon atoms are  $1 + 1 = 2$

$Y = 3$  means that number of hydrogen atoms are  $3 - 1 = 2$

$Z = 4$  means that number of fluorine atoms are 4

With two carbon, the total number of attached atoms = 6

Therefore, number of chlorine atoms =  $6 - \text{no. of } (H + F) \text{ atoms} = 6 - 2 - 4 = 0$

Or the number of chlorine atoms = 0

Therefore, the chemical formula of R 134 =  $\text{C}_2\text{H}_2\text{F}_4$

Letter "a" stands for isomer, e.g. molecules having same chemical composition but different atomic arrangement.  $\text{C}_2\text{H}_2\text{F}_4$  has two isomers:

R-134 = CHF<sub>2</sub>CHF<sub>2</sub>

R-134 a = CH<sub>3</sub>CH<sub>2</sub>F

### Note

- (x) = 0 is the methane series, but the 0 is ignored for these compounds. Examples are R-12 and R-22.
- (x) = 1 is the members of the ethane series, such as R-114, R-124 and R-134a.
- (x) = 2 is the propane series, e.g. R-290 (propane).

### 2.5.2. For Unsaturated Hydrocarbons and their derivatives – four-digit number

First digit = 1 (number of double or triple bonds)  
Second digit = C - 1 = one less than the 'C' atoms in the compound  
Third digit = H + 1 = one more than the 'H' atoms in the compound  
Fourth digit = Number of fluorine atoms

#### Example: Decode C<sub>2</sub>Cl<sub>2</sub>F<sub>2</sub>

First digit = **1**  
Second digit = 2 - 1 = **1** ----- [one less than the 'C' atoms in the compound]  
Third digit = 0 + 1 = **1** ----- [one more than the 'H' atoms in the compound]  
Fourth digit = **2** ----- [Number of fluorine atoms]

Therefore, the number is R-1112

### 2.5.3. Zeotropic and Azeotropic Mixtures

Here, (y) and (z) are ordinal numbers.

(x) = 4 refers to zeotropic mixtures. The components in the mixture have different boiling points, and thus the refrigerant mixture has a temperature glide. R-407A and R-407C are examples of such refrigerants.

(x) = 5 refers to azeotropic mixtures. These act like homogeneous substances with one specific boiling point, and therefore they have no glide. R-502 and R-507 are examples of azeotropic mixtures.

#### **2.5.4. Azeotropes**

**These are numbered starting from R-500**

First known azeotrope in refrigeration has been numbered as R-500. Next known azeotrope as R-501 and so on.

Azeotrope	B.P.	Composition by MASS
R-500	33.3	R-12/R-152, 73.8/26.2
R-501	45	R-22/R-12, 75/25
R-502	46	R-22/R-115, 48.8/51.2
R-503	88	R-23/R-13, 40.1/59.9
R-504	57	R-32/R-115, 48.3/51.7

#### **2.5.5. High Organic Compounds**

The subgroups have been assigned different number series within the main group, so (y) and (z) describe the subgroup and order within the subgroup.

(x) = 6 means that the composition is organic, e.g. butane, R-600, and isobutene, R-600a. This group has several subgroups, for example hydrocarbons, oxygen compounds, sulfuric compounds and nitrogen compounds.

#### **2.5.6. Inorganic compounds—700 + molecular weight**

These are designated by number 7 followed by the molecular weight of the refrigerant (rounded-off).

#### **Examples**

- Ammonia: Molecular weight is 17; therefore, the designation is R-717
- Carbon dioxide: Molecular weight is 44; therefore, the designation is R-744
- Water: Molecular weight is 18; therefore, the designation is R-718
- Air: Molecular weight is 29; therefore, the designation is R-729

When two or more inorganic refrigerants have the same relative molecular masses, uppercase letters (i.e., A, B, C, etc.) are added to distinguish among them.

### **2.5.7. Blends/Mixed refrigerants**

For example: R-401A is HCFC blend of R-32 + R-152a + R-124

R-404A is HCFC blend of R-143a + R-125 + R-134a

By mass (52% + 44 % + 4 %)

### **2.5.8. Unsaturated Organic Compounds**

The (y) and (z) are the same as for the ethane and propane series.

(x) = 11 stands for unsaturated ethane compounds, such as R-1150 (ethylene).

(x) = 12 stands for unsaturated propane compounds, such as R-1270 (propylene).

### **2.5.9. Letters at the end**

The last letter, if any, in the designation number means different things:

Refrigerants with same chemical formula as another molecule but with a different chemical structure are identified with a lower-case letter after the number. For example, R-600 is butane and R-600a is isobutane, these two compounds have the same chemical formula, but different chemical structure. They belong to category Isomers and have slightly different properties. Another common refrigerant example is R-134a.

Capital letters are used for Refrigerant blends having the same pure components but different compositions. For example, R-407A, R-407B, R-407C..., are mixtures of the refrigerants R-32, R-125 and R-134a.

R-407A has the following mixing proportions: 20% (R-32), 40% (R-125) and 40% (R-134a), while R-407C consists of 23% (R-32), 25% (R-125) and 52% (R-134a).

## **CHAPTER – 3**

### **SAFETY & HAZARDOUS CLASSIFICATION OF REFRIGERANTS**

#### **3.0. SAFETY CLASSIFICATION OF REFRIGERANTS**

Refrigerants are classified based on the

- Toxicity
- Flammability
- Occupancy
- Type of system

All new machinery rooms containing refrigerant equipment and the occupied spaces containing direct expansion (DX) type refrigeration system such as Variable Refrigerant Flow (VRF) system must be designed to comply with ASHRAE 15. This standard is also applicable to all current machinery rooms whenever new mechanical equipment is installed or current mechanical equipment is retrofitted.

#### **3.1 Toxicity Classification**

ASHRAE 34 defines two safety classifications for toxicity:

- Class A: no chronic toxicity effects have been observed below 400 ppm.
- Class B: chronic toxicity effects have been observed below 400 ppm.

#### **3.2 Flammability Classification**

The flammability classification depends upon whether or not the substances can be ignited in standardized tests.

ASHRAE -34 defines three main flammability classifications for flammability and one sub-classification. These are:

- Refrigerants with no flammability are categorized as – ‘Class 1’
- Refrigerants with lower flammability are categorized as – ‘Class 2’

- Refrigerants with higher flammability are categorized as – ‘Class 3’ (example hydrocarbons)

The safety classification matrix was recently updated to include a new flammability Subclass 2L, for flammability Class 2 refrigerants that burn very slowly. Some HFOs, which have very low global warming potential, are mildly flammable and are classified as A2L. This indicates they are of lower toxicity and have a low burning velocity of  $\leq 10$  cm/sec.

- **Class 1.** Refrigerants that do not show flame propagation when tested in air at 14.7 psia and 140°F.
- **Class 2.** Refrigerants having a lower flammability limit (LFL) of more than 0.00625 pound per cubic foot at 140°F (60°C) and 14.7 psia and a heat of combustion of less than 8169 Btu/lb.
- **Class 3.** Refrigerants that are highly flammable, having a LFL of less than or equal to 0.00625 pound per cubic foot at 140°F and 14.7 psia or a heat of combustion greater than or equal to 8169 Btu/lb.

### 3.2.1. Safety Group Classification

The toxicity and flammability classifications yield six separate safety group classifications (A1, A2, A3, B1, B2, and B3) and two subclasses (A2L and B2L) for refrigerants. These classifications are represented by the matrix shown in Figure below.

Higher flammability	<b>Group A3</b>	<b>Group B3</b>
Lower flammability	<b>Group A2</b>	<b>Group B2</b>
No flame propagation	<b>Group A1</b>	<b>Group B1</b>
	Lower toxicity	Higher toxicity

**Refrigeration Safety Group Classification**

For example, Propane and Isobutene are classified as A3 - indicating higher flammability; while Ammonia is classified as B2L indicating toxicity with lower flammability. Carbon Dioxide is classified as A1, indicating lower toxicity and non-flammability.

### **3.3 Occupancy Classification (ASHRAE Standard 15)**

Locations of refrigerating systems are described by occupancy classifications that consider the ability of people to respond to potential exposure to refrigerants. Where equipment or appliances, other than piping, are located outside a building and within 20 feet of any building opening, such equipment or appliances shall be governed by the occupancy classification of the building. Different occupancies are defined by ASHRAE as:

- Institutional occupancy is that portion of premises from which occupants cannot readily leave without the assistance of others because they are disabled, debilitated or confined. Institutional occupancies include, among others, hospitals, nursing homes, asylums and spaces containing locked cells.
- Public assembly occupancy is that portion of premises where large numbers of people congregate and from which occupants cannot quickly vacate the space. Public assembly occupancies include, among others, auditoriums, ballrooms, classrooms, passenger depots, restaurants and theaters.
- Residential occupancy is that portion of premises that provides the occupants with complete independent living facilities, including permanent provisions for living, sleeping, eating, cooking and sanitation. Residential occupancies include, among others, dormitories, hotels, multiunit apartments and private residences.
- Commercial occupancy is that portion of premises where people transact business, receive personal service or purchase food and other goods. Commercial occupancies include, among others, office and professional buildings, markets (but not large mercantile occupancies) and work or storage areas that do not qualify as industrial occupancies.

- Large mercantile occupancy is that portion of premises where more than 100 persons congregate on levels above or below street level to purchase personal merchandise.
- Industrial occupancy is that portion of premises that is not open to the public, where access by authorized persons is controlled, and that is used to manufacture, process or store goods such as chemicals, food, ice, meat or petroleum.
- Mixed occupancy occurs where two or more occupancies are located within the same building. Where each occupancy is isolated from the rest of the building by tight walls, floors and ceilings and by self-closing doors, the requirements for each occupancy shall apply to its portion of the building. Where the various occupancies are not so isolated, the occupancy having the most stringent requirements shall be the governing occupancy.

### **3.4 Refrigeration System Classification**

Refrigeration system classification provides an indication of the quantity of refrigerant in a system and the degree of probability that a leakage of refrigerant will enter an occupied area. The system is classified as:

- High-Probability System
- Low-Probability System

#### **3.4.1. Low Probability Systems**

It is any system in which the basic design or location of the components is such that leakage of refrigerant from a failed connection, seal, or component cannot enter the occupied space. Typical low-probability systems are indirect closed systems, double-indirect systems, and indirect open-spray systems.

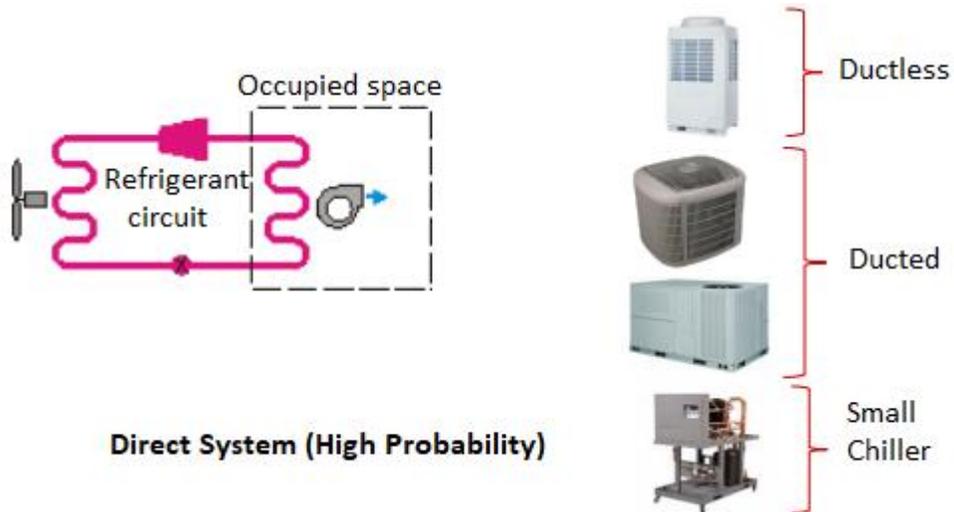
#### **3.4.2. High Probability Systems**

It is any system in which the basic design, or the location of components, is such that a leakage of refrigerant from a failed connection, seal, or component will enter the occupied space. Typical high-probability systems are direct systems or indirect open spray systems

where the refrigerant can produce pressure greater than the secondary coolant.

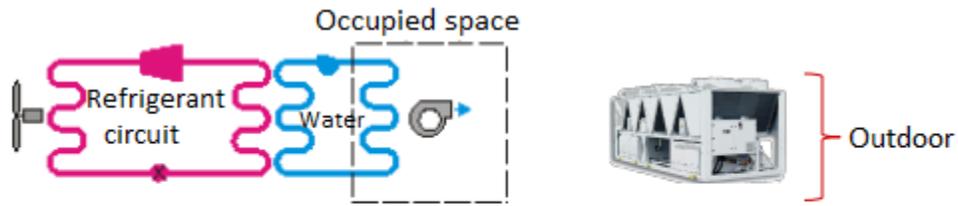
### 3.4.3. Direct Refrigeration System

A system in which the evaporator or condenser of the refrigerating system is in direct contact with the air or other substances to be cooled or heated. It is classified as High Probability System.

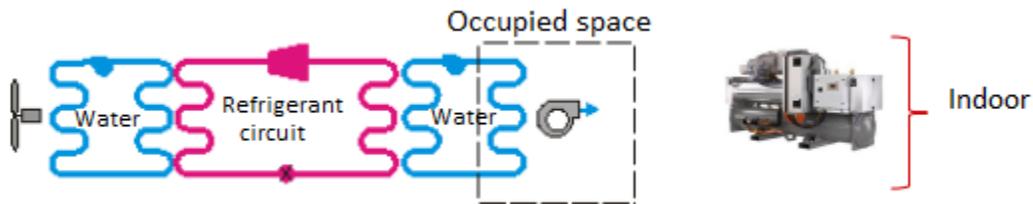


### 3.4.4. Indirect Refrigeration System

A system in which a secondary coolant cooled or heated by the refrigerating system is circulated to the air or other substance to be cooled or heated. It is classified as Low Probability System.



**Indirect System - Outdoor**



**Indirect System - Indoor Machine Room**

### **3.4.5. Regulatory Compliances**

In reviewing specific facilities, HVAC engineers must refer to ASHRAE Standard 34 to determine the maximum allowable refrigerant concentration, or RCL (refrigerant concentration limit) and then apply ASHRAE Standard 15 to validate if the RCL limits won't be exceeded for particular occupancy class and type of system.

We will learn in next chapter the application of ASHRAE Standard 15 in occupied spaces (Variable Refrigerant Flow, VRF systems). Following this chapter, we will learn how the ASHRAE 15 affects the larger chiller system machinery rooms, which are not to be occupied by anybody other than authorized personnel. The compliance path in a VRF system serving occupied space is quite different than machinery room, which calls for leak detection, alarms and increased ventilation.

## **CHAPTER - 4**

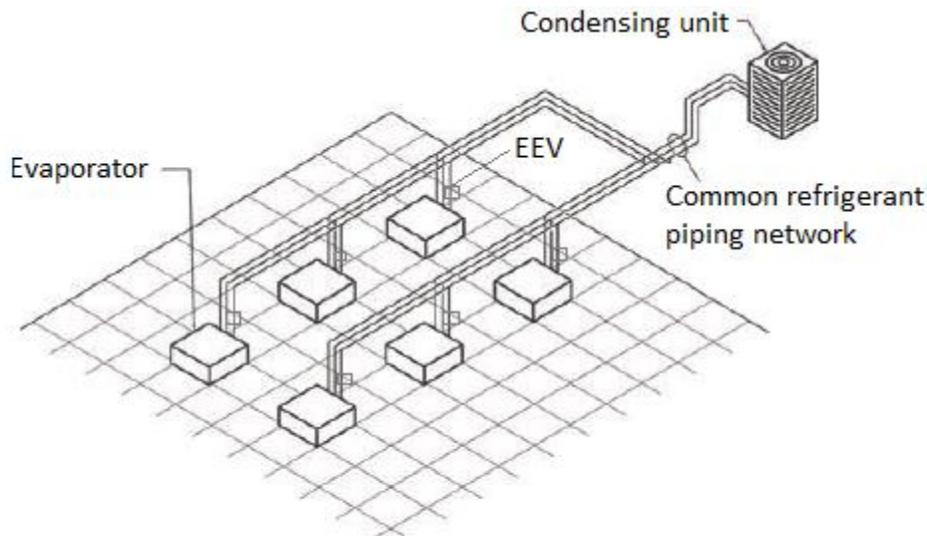
### **VARIABLE REFRIGERANT FLOW (VRF) SYSTEMS**

The information in this chapter is intended to provide guidance to specifying and designing a VRF system while applying ASHRAE safety Standard 15.

We have learnt in previous chapter that ASHRAE Standard 34 provides the refrigerant concentration limits (RCL) for various refrigerants and ASHRAE Standard 15 addresses the safety of occupied spaces by ensuring that the concentration of refrigerant in event of leakage shall not exceed the RCL. When the concentration of leaked refrigerant stays below the RCL, dangerous effects such as oxygen deprivation, flammability, cardiac sensitization, etc. are avoided and the occupants can easily escape from the affected area.

#### **4.0. VRF SYSTEMS**

The term Variable Refrigerant Flow (VRF) is used to describe the system's ability to continuously modulate the rate at which refrigerant is distributed to multiple indoor unit evaporator units serving the conditioned spaces. Most VRF systems use inverter compressors and electronic expansion valves (EEVs) or pulse modulating valve (PMV) to accomplish this flow control. This translates to the utilization of many indoor units of differing capacities and configurations, individualized comfort control, simultaneous heating and cooling in different zones, and the unique possibility for heat recovery from one zone to another.



**Typical VRF System**

These systems operate on the direct-expansion (DX) principle, where heat is transferred to or from the conditioned space directly by circulating refrigerant through the indoor units located near or within the conditioned area. In contrast, conventional HVAC systems transfer heat from the space to the refrigerant by circulating air or water throughout the building.

VRF systems are enhanced versions of the more widely known ductless multi-split systems, which connect one outdoor condenser to several indoor evaporators. In multi-split systems, each indoor unit has its own separate set of refrigerant pipe work connecting it to the outdoor unit. The entire multi-split system is completely turned ON/OFF in response to a single master controller. VRF systems, however, continually adjust the flow of refrigerant using an EEV whose opening is determined by the microprocessor receiving information from thermistor sensors in each indoor unit. This control is also linked to the outdoor unit, which responds by varying its compressor speed to match the total cooling and/or heating requirements. In turn, this allows multiple indoor units to be connected using a common refrigerant line, rather than requiring separate lines between each indoor unit and the outdoor unit.

VRF systems require the calculation of the amount of refrigerant that if leaked from the system would infiltrate the enclosed space it is feeding. For occupant's safety, the total quantity of refrigerant shall not exceed the Refrigerant Concentration Limit (RCL) in a confined space. Notably, the high-volume design of VRF systems pose a challenge to the HVAC designers, when

you have a small room such as hotel rooms, dormitories, supportive housing, and similar spaces being served by a VRF system. The thinking is that the if VRF system feeding that small space was to leak it would leak its total volume of refrigerant from the system into that room, raising the concentration of refrigerant to hazardous levels for the occupants.

#### 4.1 Refrigerant Concentration Limit (RCL)

Refrigerant Concentration Limit (RCL) is the amount of refrigerant released into a normally occupied, enclosed space beyond which acute toxicity is expected. Typically, it is expressed in pounds per thousand cubic feet (lbs./ft<sup>3</sup>) or parts per million.

ASHRAE Standard 34 defines (RCL) for various refrigerants. Few examples are depicted in table below:

**Refrigerant Safety Data from ASHRAE Standard 34-2010**

Refrigerant	Safety Group	RCL (lb./ft <sup>3</sup> )	Highly Toxic or Toxic Under Code Classification
R-22 (CHClF <sub>2</sub> )	A1	13	Neither
R-134A (CH <sub>2</sub> FCF <sub>3</sub> )	A1	13	Neither
R-407C	A1	18	Neither
R-410A	A1	26	Neither

For example, R-410A, a refrigerant commonly used in variable-refrigerant-flow (VRF) systems, has an RCL of 26 lb. per 1000 ft<sup>3</sup> of room volume or 140,000 ppm. For institutional occupancies where the occupants cannot readily leave without the assistance of others, for example the patient care areas of hospitals, the threshold is half that i.e. 13 lb./1,000 ft<sup>3</sup>. Note that even though R-410A is Group A1 (meaning non-flammable and non-toxic), its ability to displace oxygen is a danger to occupants, if released in large quantities into smaller-volume spaces.

VRF systems require the calculation to determine that the amount of refrigerant if leaked from the system would not exceed the RCL of the confined space.

## 4.2 Calculations

Most VRF systems use refrigerant R-410A. Since the indoor unit fan coils are in direct contact with the air being distributed, system is classified as a Direct System according to Standard 15. By definition, a Direct System is also classified as a High Probability system, meaning that a leak of refrigerant can potentially enter the occupied space.

The safety classification of R-410A in Standard 34 is group 1 (meaning non-toxic and non-flammable), it has no ODP and it meets the stringent mandates of both the Montreal Protocol and the U.S. Environmental Protection Agency. However, due to the ability to displace oxygen, Addendum L to ASHRAE Standard 34 has established the maximum RCL to 26 lbs/1000 ft<sup>3</sup> of room volume for occupied spaces.

In calculating the RCL, the worst scenario of entire refrigerant charge dumped into the smallest occupied space is considered. The refrigerant level after a leak is determined by two main factors:

1. The amount of refrigerant used by air conditioning system (equipment +piping)
2. The volume available for dispersion

There is a clearly defined relationship between the amount of refrigerant in a system and the volume of the occupied space into which the refrigerant could flow.

### 4.2.1. Amount of Refrigerant used by Airconditioning Equipment

Published manufacturer data show a typical factory refrigerant charge of 2 to 3 lb. per nominal ton of capacity, with an additional 1 to 3 lb. per nominal ton in field piping for a practical range of 3 to 6 lb. per ton.

### 4.2.2. Volume Available for Dispersion

The volume of the smallest space served by an individual evaporator unit, or the smallest room through which refrigerant piping is installed, is used to determine the maximum potential refrigerant concentration in the event of a leak.

In addition, the following guidelines are applicable:

- a. If that room has permanent opening(s) to adjacent room(s), the combined room volumes may be used.
- b. Occupied space is not necessarily a single room or area. If a group of rooms or spaces (offices, corridors, other spaces off the corridor, etc.) are connected by ductwork or other means, then all their connected volumes are counted in calculating the affected volume. These “connected spaces” could also include louvers or “permanent” openings to adjacent spaces or to the outside, as in a ventilation source or exhaust, and even undercuts on connecting doors, provided there is forced movement of air.
- c. **Closures:** Closures in the air distribution system shall be considered. If one or more spaces of several arranged in parallel can be closed off from the source of the refrigerant leak, their volume shall not be used in the calculation.  
Exceptions: The following closure devices are not considered:
  - Smoke dampers, fire dampers, and combination of both dampers that close only in an emergency not associated with a refrigerant leak.
  - Dampers, such as VAV boxes, that provide limited closure where airflow is not reduced below 10% of its maximum.
- d. **Plenums:** The space above a suspended ceiling is not considered as part of the room volume unless it is used as part of the air supply or return path.
- e. **Supply and Return Ducts:** The volume of supply and return ducts shall be included when calculating the refrigerant quantity limit.

#### 4.3 Design Process

1. Develop a preliminary layout of the complete system (piping, indoor unit fan coil units, and outdoor units) based on the heat load data.
2. Select the VRF system and determine the Refrigerant used. Determine the RCL from ASHRAE Standard 34.
3. Determine the total amount of refrigerant for the system. Note that the total amount of refrigerant is the amount in the equipment and the piping. The equipment layout should

strive to minimize the piping lengths where possible. Obviously, longer the piping, the higher will be the refrigerant. In event of leakage, the worst scenario is applied, i.e. the full circuit refrigerant volume contained in the system may leak.

4. Determine the occupancy classification for the rooms. The classifications are: Institutional occupancy, Public assembly occupancy, Residential occupancy, Commercial occupancy, Large mercantile occupancy, Industrial occupancy, and Mixed occupancy. For Institutional occupancies (a premise where the occupants cannot readily leave without assistance of others), the maximum refrigerant concentration limit (RCL) is reduced by 50% compared to the other occupancy classifications.
5. Calculate the room volume of the smallest occupied room(s). In addition to the rooms where each indoor unit is located, all rooms that have any part of the refrigerant piping circuit installed should be examined. According to Standard 15, the minimum applied volume (MAV) calculation shall be based on the volume of smallest room(s) to which the refrigerant disperses in case of a leak. The minimum applied volume (MAV) needed to handle the full refrigerant charge of the system can be calculated as below:

$$MAV = \frac{RC}{RCL} \times 1000$$

Where,

- MAV = Minimum Applied Volume in ft<sup>3</sup>
  - RC = Refrigerant Charge of System in lbs ... [This includes equipment charge + refrigerant in piping]
  - RCL = Refrigerant Concentration Limit in lbs/1000 ft<sup>3</sup>... [For R-410A, it is 26 lbs/1000 ft<sup>3</sup>]
6. Verify that no room is too small. Using the calculated total refrigerant charge, verify that there are no rooms that have a part of the refrigeration circuit installed, that has a smaller calculated room size.
  7. Action if a room is too small. If the calculated room volume is too small in relation to the actual refrigerant charge in the system, there are generally three different ways to remedy this situation:

- a. Increase the room volume used in calculations
- b. Relocate/remove piping or indoor unit fan coil
- c. Reduce the refrigerant charge by dividing the refrigerant circuit into multiple smaller systems

Let's validate the design process with an example.

### Example

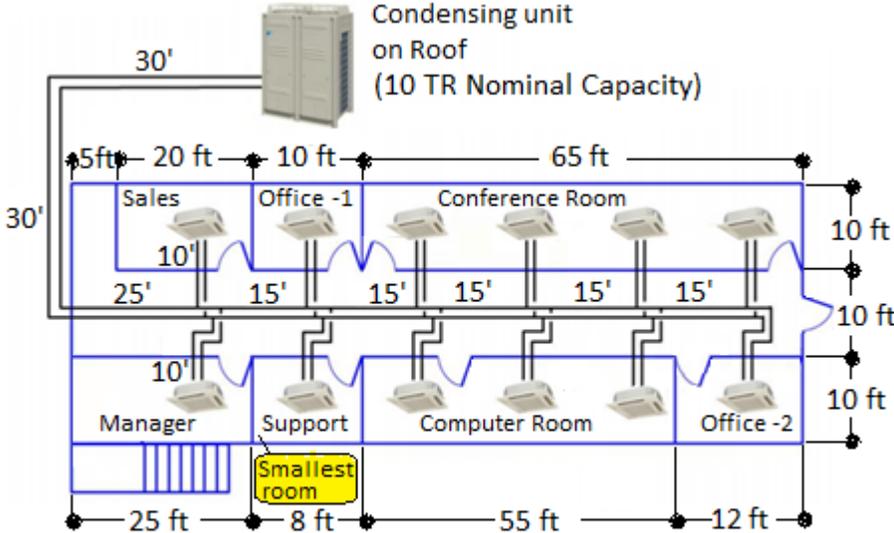
Consider a commercial office layout equipped with VRF refrigeration system. The nominal capacity of the VRF unit is 10 TR and uses R-410A refrigerant. The design parameters are defined below:

**Design Parameters: TABLE -1**

Sno.	Design Parameters	Data	Remarks
1	Occupancy type	Office	Commercial occupancy
2	VRF capacity	10 TR	Based on heat load calculations and equipment selection
3	Refrigerant used	R-410A	VRF system selection
4	<b>RCL*</b>	26 lb./1000 ft <sup>3</sup>	ASHRAE Standard 34
5	Refrigerant charge	3 lb./TR	Based on manufacturers data
6	Refrigerant in piping	Assume 1.5 lb./TR	Note that the designer must calculate the actual refrigerant in the volume of the piping. It depends on the inside diameter of refrigerant tubing and length. Manufacturers have software to calculate the quantity.
7	Total Refrigerant Quantity in	45 lb.	3 lb./TR + 1.5 lb./TR

Sno.	Design Parameters	Data	Remarks
	System (RC)**		30 + 15 = 45 lb.

The office layout is depicted below. The system has twelve ductless indoor evaporator units with one condensing unit installed at the roof.



**Typical Office Layout with VRF System**

**Calculate Room Volumes, MAV and Validate Conformance**

**Room Volumes: TABLE -2**

Room Name	Length (ft)	Width (ft)	Room Area (ft <sup>2</sup> )	Ceiling Height (ft)	Room Volume (ft <sup>3</sup> )	RCL* (lb./1000 ft <sup>3</sup> )	RC** (lb.)	MAV*** (ft <sup>3</sup> )	Conformance
Sales	20	10	200	10	2000	26	45	1730	A (Note 1)
Office -1	10	10	100	10	1000	26	45	1730	NA (Note 2)
Conference Room	65	10	650	10	6500	26	45	1730	A

Room Name	Length (ft)	Width (ft)	Room Area (ft <sup>2</sup> )	Ceiling Height (ft)	Room Volume (ft <sup>3</sup> )	RCL* (lb./1000 ft <sup>3</sup> )	RC** (lb.)	MAV*** (ft <sup>3</sup> )	Conformance
Manager	25	10	250	10	2500	26	45	1730	A
Support	8	10	80	10	800	26	45	1730	NA
Computer Room	55	10	550	10	5500	26	45	1730	A
Office -2	12	10	120	10	1200	26	45	1730	NA
Corridor	100	10	1000	10	10000	26	45	1730	A

\*RCL: Refer item 4 in Table -1

\*\*RC: Refer item 7 in Table -1

\*\*\*MAV: MAV is calculated as

$$MAV = \frac{RC}{RCL} \times 1000$$

Note -1: Acceptable as per ASHRAE Standard 15, since MAV < Room volume

Note -2: Not acceptable as per ASHRAE Standard 15, since MAV > Room volume

Concluding from Table-2; three rooms viz. Office -1, Office -2 and Support area do not comply with ASHRAE Standard 15.

### Corrective Actions

To comply with ASHRAE Standard 15, following solutions may be considered:

#### 1. Increase the Room(s) Volume

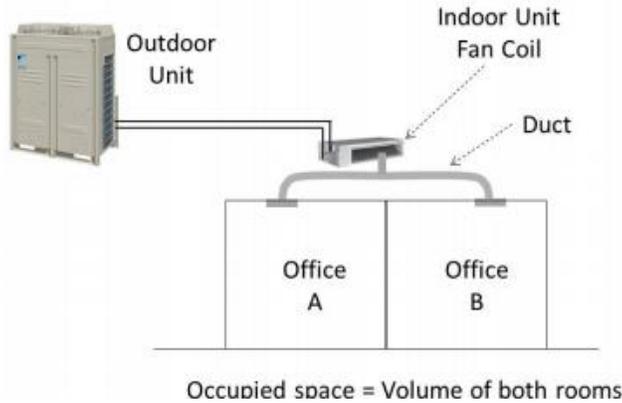
- a. Increase the room volume by adding transfer ducts, grilles or louvers to adjacent space and then include the volume of both spaces in the calculation. A permanent opening made to increase the room volume allows any leak of refrigerant to

disperse into the adjacent area(s). However, since Standard 15 does not address how to calculate a permanent opening, this should be determined by the Engineer of record and/or the AHJ. The Japanese standard JRA GL-13:2012 could serve as a guideline regarding the opening. It defines a permanent opening as one that has an area of 0.15% or more of the total floor area of the smaller enclosed occupied space in which refrigerant containing parts are located.

- b. If the attic or plenum space above the ceiling is used as a supply or return plenum then that area can be used in the volume calculations.
- c. A regular door that cannot be closed between two rooms should satisfy the requirement of enabling connected spaces. Removing the door completely is the safest way to make sure that the rooms always are connected.
- d. Remove, or raise, suspended ceiling. Since Standard 15 does allow the space above a suspended ceiling to be used in calculating the room volume if it is a part of the air supply or return system, one option could be to remove the ceiling completely. Alternatively, the suspended ceiling could possibly be raised to a height that provides the required room volume.

## **2. Ducted Distribution to Several Rooms**

If none of the actions above are possible for increasing room volume, an alternative could be to install the indoor unit fan coil outside the room that is too small. By ducting the supply air to several rooms, the rooms would be considered connected according to Standard 15. If a leak occurs in the indoor unit fan coil, the refrigerant would be dispersed to both rooms, as shown in the following figure.

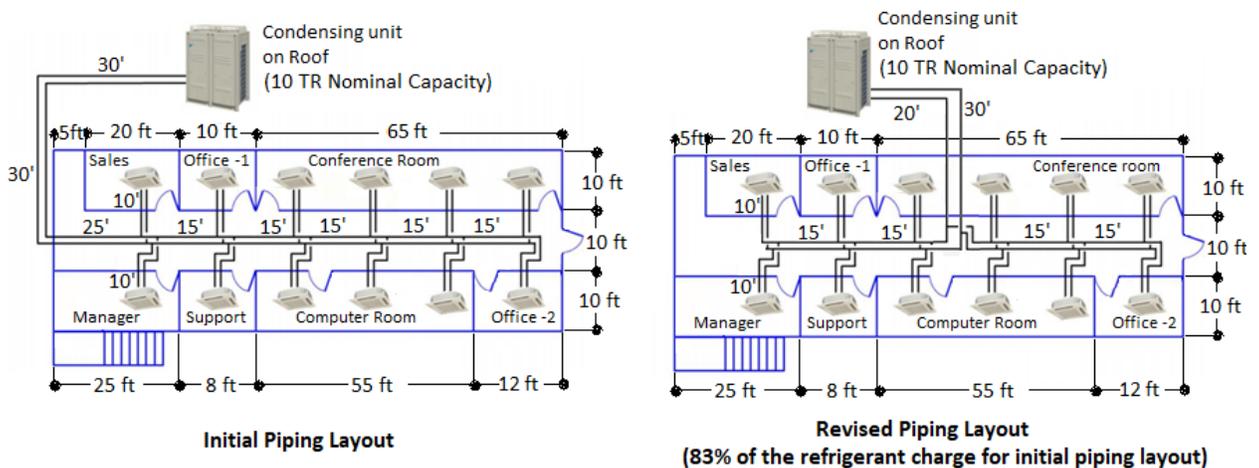


**3. Provide Standalone Split Unit for Small Rooms**

If none of the prescribed actions to increase the room volume can be accomplished, one option could be to remove the indoor unit from VRF circuit and install a separate split unit to handle the load in the room. Removing the unit from the system would also lower the total refrigerant charge in the VRF system.

**4. Optimize the piping layout**

Minimize the refrigerant piping. It can decrease the refrigerant charge in the circuit considerably. In the following figures, the revised piping layout lowers the total refrigerant charge in the circuit to 83% of the charge for the Initial Piping Layout.

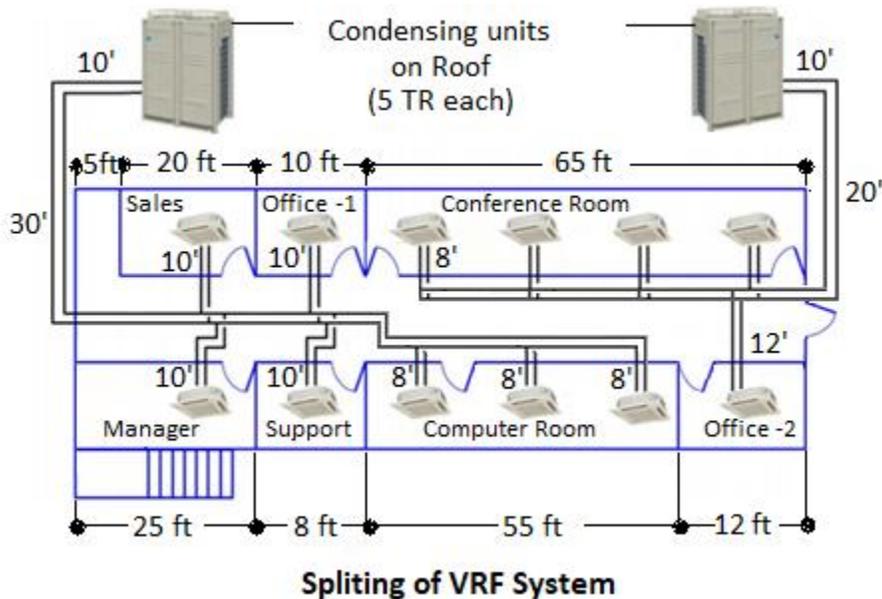


**5. Divide the VRF Capacity**

Reduce the refrigerant charge by dividing or splitting the refrigerant circuit into multiple smaller VRF systems. This would dramatically decrease the refrigerant charge in a single

circuit. Care should also be taken to not route refrigerant piping through small occupied rooms, especially if they aren't being served by the VRF system.

In the following figure, the divided system into half the original design capacity will reduce the refrigerant charge by half.



**Important:** Please check with Authority Having Jurisdiction (AHJ) for acceptability of compliance before installation.

### Summarizing....

To successfully comply with ASHRAE Standards 15-2010 and 34-2010, the designer must know the following:

- Total amount of refrigerant required for the system
- Classification of occupancy type in which indoor units and/or piping will be located
- Geometry of individual and connected occupied zone(s)
- Classification and refrigerant concentration levels (RCL) of the refrigerant used

Since the indoor unit fan coils are in direct contact with the air being distributed, a VRF system is classified as a Direct System according to Standard 15. By definition, a Direct System is also

classified as a High Probability system, meaning that a leak of refrigerant can potentially enter the occupied space.

A key element of compliance with these standards is the determination of the volume of the smallest occupied space not connected to other spaces through permanent openings. If the smallest occupied space (bathrooms, electrical rooms, closets, small offices, and areas of egress) in which any of the indoor units or piping network could be located is not capable of safely dispersing the refrigerant charge of the entire VRF system, design adjustments must be made so that this is possible. In cases where redesign is necessary, it may be beneficial to remove small rooms from the VRF system and serve those rooms separately; use more, smaller, separate VRF system networks in place of a single large system; or serve multiple small rooms with one common ducted evaporator.

Some additional requirements of ASHRAE Standard 15 are:

- a. Refrigerant Piping must not be less than 7.25 ft above the floor unless the piping is located against the ceiling and is permitted by the AHJ.
- b. Refrigerant piping cannot be placed in a shaft containing a moving object and must not be installed in an enclosed public means of egress.
- c. Refrigerant piping cannot be installed in enclosed stairway/landing or means of egress.
- d. Refrigerant pipe joints must remain exposed for visual inspection before they are covered or enclosed.
- e. Refrigerant piping must be properly supported and if it is installed in concrete floors the piping must be encased in pipe duct.
- f. Standard 15 only mentions refrigerant monitoring and alarm functions in case of a leak for refrigerating machinery rooms. For occupied spaces, refrigerant monitoring should be discussed with the local AHJ.

A VRF system is classified as a direct system and it must always be designed according to the leakage concentration limits in ASHRAE Standard 34. Therefore, the penetration restriction in

Section 8.10.3 in Standard 15 does not apply for VRF, if the system is designed correctly and the RCL is within the stated limits.

Also, if the RCL is above the stated limits in a non-industrial occupancy application, the penetration restriction does not apply if:

- a. Piping is enclosed by an approved duct/shaft with openings to the floors served by the system or
- b. Piping is located on the exterior wall of a building when vented to the outdoors or to the space served by the system and not used as an air shaft, or similar space.

## CHAPTER – 5

### ASHRAE STANDARD 15 - REFRIGERANT MACHINERY ROOMS

#### 5.0. REFRIGERATING MACHINERY ROOM

When reviewing your machinery room for compliance with ASHRAE 15, there are some primary areas to consider:

- Refrigeration system placement
- Ventilation
- Refrigerant monitoring
- Machinery Room Special Requirements
- Combustion and open-flame devices
- Pressure-relief protection
- Purge discharge
- General safety requirements
- Operation and field testing

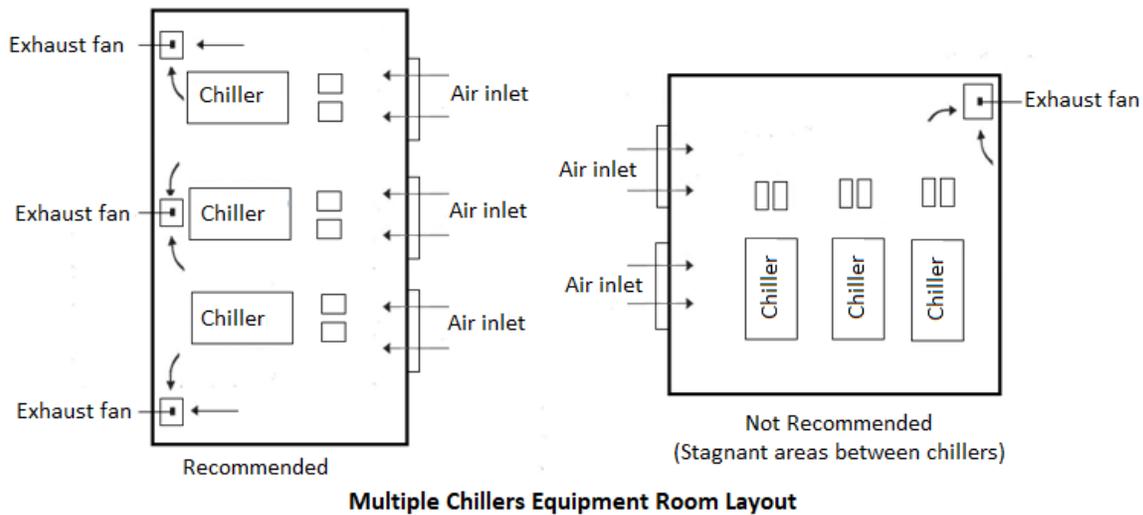
#### 5.1 Refrigeration System Placement

Chiller placement inside machinery room depends on various factors that include service work access, proximity to other equipment, and airflow ventilation through the machinery room. Consider all clearances to be minimum requirements for normal operation, maintenance, service, and repair.

- The spacing between chillers should be at least 5 ft. and must be greater than the control panel door opening.
- Clear head room of not less than 7.25 ft below equipment over equipment situated over passageways. This requirement is designed to prevent piping and equipment from being installed in a location that will present a physical hazard to people or equipment moving through the aisles.

Chillers should be positioned between the ventilation inlet and outlet. Areas with stagnant air should be avoided. Figure below shows both good and bad configurations for multiple-

chiller machinery room.



## 5.2 Ventilation

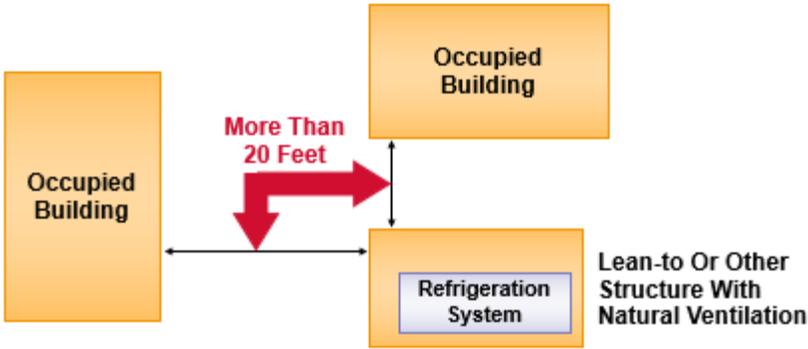
Plant room must have provision for mechanical ventilation for heat dissipation as well purging requirements of refrigerant in event of leakage.

The MER ventilation system shall be separate from all other building ventilation systems. That is, fans and ductwork used to ventilate the MER must not be used to ventilate any other part of the building. Further, the discharge must not interfere with any outside air intakes.

ASHRAE 15 standard recommends either the natural or mechanical ventilation, based on equipment location.

### 5.2.1. Natural Ventilation

When a refrigeration system is located outdoors more than 20 feet from any building openings, natural ventilation can be provided.



Natural ventilation requirements are provided by the formula:

$$F = G^{0.5},$$

Where

- F = the free opening area in square feet
- G = the weight of refrigerant in pounds in the largest system, any part of which is in the machinery room.

The free opening area, one or multiple openings shall be located with respect to the refrigerant density. For example:

- If the refrigerant being used is heavier than air (the specific gravity of the refrigerant is greater than 1), the opening(s) should be located flush or nearly level with the floor.
- If the refrigerant is lighter than air, the opening(s) should be located close to the machinery room ceiling for maximum ventilation effect.

For example, consider a chiller with an 800-pound refrigerant charge. The free opening area in square feet (ft<sup>2</sup>) would be calculated this way:  $F = 800^{0.5} = 28 \text{ ft}^2$ .

Thus, a 5-foot by 6-foot opening would slightly exceed this square-footage requirement.

### 5.2.2. Mechanical Ventilation

Mechanical ventilation is the use of fans to move air.

Two distinct ventilation rates have been established; one for normal ventilation and one for purging the MER of refrigerant.

The ventilation system shall operate at the higher rate and shall be activated either by ventilation requirements or by the refrigerant/ monitoring alarm. If the purge rate is significantly higher than the ventilation rate, multiple fans, multiple-speed fans, or other modulation devices may be used. For any automatically initiated ventilation system, a switch shall also be provided to manually start the system.

### **5.2.3. Normal Ventilation**

The mechanical ventilation shall be operated when the MER is occupied. Minimum ventilation rate shall be 0.5 cfm per square foot of MER area or 20 cfm per person.

Alternatively, the mechanical ventilation shall be operable for operator comfort. The minimum volume shall be required to maintain a maximum temperature rise of 15°F based on the heat produced by the machinery in the MER.

### **5.2.4. Purge Ventilation**

Whenever a refrigerant build-up occurs inside the machinery room, the exhaust fans must purge refrigerant from the machinery room. The minimum mechanical ventilation rate required to exhaust an accumulation of refrigerant due to leaks or a rupture of the system shall be the following quantity:

$$Q = 100 \times G^{0.5}$$

Where

- Q = the airflow in cubic feet per minute.
- G = the mass of refrigerants in pounds in the largest system, any part of which is located in the MER.

For example, consider a chiller with an 800-pound refrigerant charge.

Using the equation  $Q = 100 \times G^{0.5}$ , the required CFM rate would be:  $Q = 100 \times 800^{0.5} = 2800$  cfm.

According to ASHRAE 15, it is unnecessary to continuously run the purge ventilation at high volume. Only normal rate mechanical ventilation should be running.

Refrigerant build-up is indicated by the refrigerant vapor (or oxygen) monitor. Ventilation at purge volume must be initiated by the monitor's alarm contacts. A switch for manual control should be outside the machinery room's main entrance.

#### **5.2.5. When to operate Mechanical Ventilation?**

It is unnecessary to continuously run the ventilation at this volume if the following conditions are met:

- a. Ventilation is provided when occupied of at least 0.5 cfm per square foot of machinery room area or 20 cfm per person. This can be achieved by running the fan continuously, starting it automatically with a motion detector, or by providing a fan switch near the machinery room entrance(s). If a switch is provided, a posted sign or other prompt should display the ventilation requirement for occupancy.
- b. Operable, if necessary, for operator comfort, at a volume required to maintain a maximum temperature rise of 18 °F based on all heat-producing machinery in the room. Most electrical devices (e.g., motors and switchgears) are designed to operate in an environment where the ambient temperature does not exceed 104 °F. This requirement must be met whether or not the equipment room is occupied, and it may impose the higher ventilation flow rate requirement than those required for ventilating refrigerant gases following dilution.

#### **5.2.6. Can you have single mechanical and purge ventilation fan?**

A single ventilation system can serve both purge ventilation and normal ventilation requirements. If the required normal ventilation flow rate is higher than the required purge ventilation flow rate, no additional purge requirement is needed since the ventilation system will operate constantly when the room is occupied. If the purge ventilation flow rate is higher than the normal ventilation flow rate, the flow rate can be increased from the normal ventilation flow rate to approach the purge ventilation flow rate when the machinery room is occupied with two-speed fan motors, variable-speed fan motors, or additional exhaust fans. This higher flow rate can be achieved with motion detectors or by interlocking the fans with the local lighting circuits.

### **5.2.7. Ventilation Design**

Machinery rooms shall be vented to the outdoors, utilizing mechanical ventilation.

Make-up air must be tempered/conditioned to prevent damage caused by large, rapid temperature swings or freezing temperatures.

There shall be no airflow to or from an occupied space through a machinery room unless the air is ducted and sealed to prevent any refrigerant leakage from entering the airstream.

### **5.2.8. Location of Inlet and Discharge Vents**

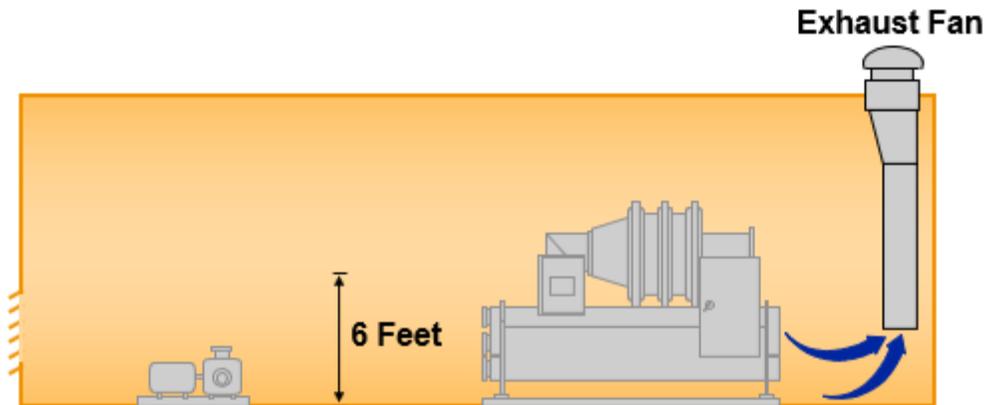
The ventilation system's inlet and discharge must be properly positioned for efficient machinery room ventilation. ASHRAE 15 addresses this requirement as follows:

- a. Provision shall be made for inlet air to replace that being exhausted.
- b. Openings for inlet air shall be positioned to avoid recirculation.
- c. Air supply and exhaust ducts to the machinery room shall serve no other area.
- d. Discharge of the air shall be to the outdoors in such a manner as not to cause a nuisance or danger.

### **5.2.9. Exhaust Fan(s) for purging**

To remove heavier-than-air refrigerants, the exhaust fan inlet should be located near the equipment and the floor whenever possible. Refrigerants released into an equipment room drop to the floor and fill the room from the bottom up unless it is disturbed by air turbulence. The equipment room occupants are safest when the exhaust fan intake is below the normal breathing zone.

Inlet(s) to the exhaust fan(s) shall be located near the refrigeration equipment and at a minimum of 18 inches and a maximum of 5 feet above the finished floor, because refrigerants, which are heavier than air, tend to drop to the floor and fill the room from the bottom. Special care shall be given to ventilate the lowest points in the room, such as pits, stairwells, or trenches where refrigerant may accumulate.



### **Suggested Exhaust Fan Location**

The ventilation shall provide an “air sweep” across all refrigeration equipment. The inlet(s) to the exhaust fan shall be located near the potential leak source and away from the outside air intake(s), producing a “sweeping” action that draws outside air across the machinery to the exhaust fan. Stagnant areas created by lack of airflow shall be avoided.

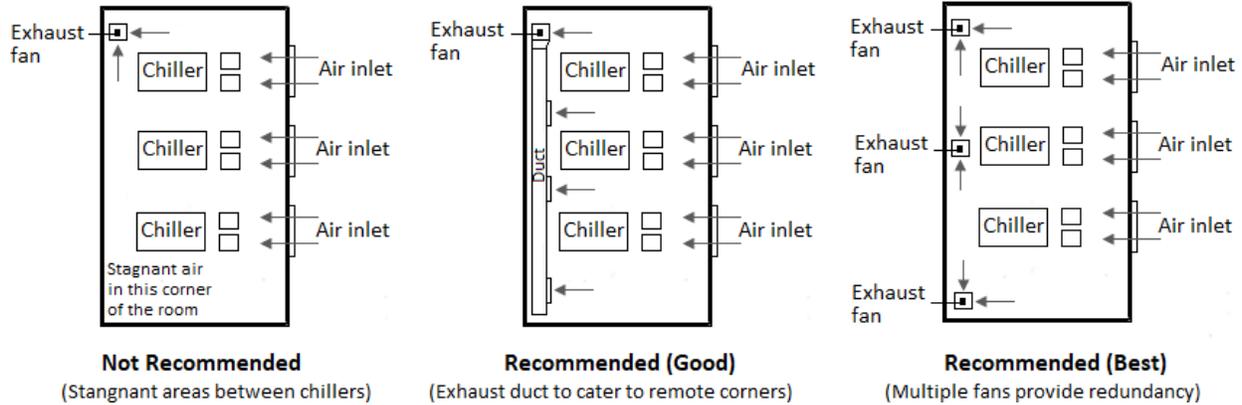
#### **5.2.10. Exhaust Fans for Normal Ventilation**

When exhaust fans are used to keep the equipment room cool or remove smoke from accidental fires, they are typically installed in the ceiling because heat and smoke both rise. However, if the ventilation system exhausts refrigerants and/or combustion products and removes heat from the machinery room, inlets should be present at the floor and ceiling levels. This can be achieved by using either separate fans or a ducted fan with inlets at the floor and ceiling levels.

Ventilation air should be drawn from the exterior of the refrigeration room at the lowest and coolest possible point on one of the room’s walls. On the opposite wall, the ventilation fans should be installed at the highest point of this wall.

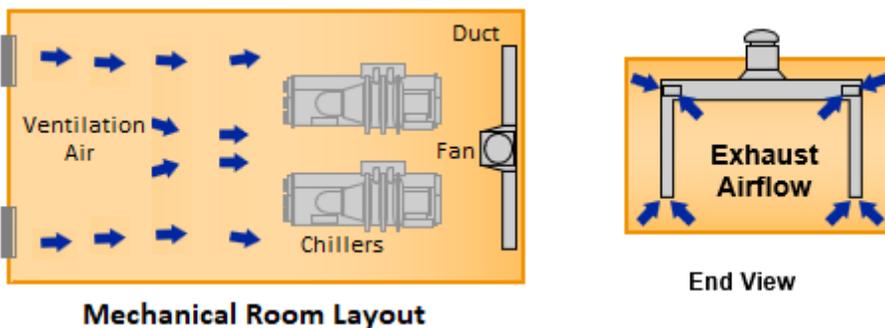
Cool air needs to flow across all the equipment in the room. Therefore, it is critical to have intake and exhaust ducts on opposite walls. If the design of the compressor room makes it too difficult for cooling air to flow across the equipment, then ducting is the best alternative. You have the option of ducting both the inlet and outlet air, or just one, depending on your current setup. Make sure to review the manufacturer’s specifications

on airflow and how to size your ventilation ducting to keep backpressure at a minimum. Most cooling fans are not designed to work effectively with more than 1/10 psi of backpressure.



### 5.2.11. Combination Purge and Normal Ventilation

The total ventilation volume required during refrigerant purging could be provided by the ceiling-level and floor-level fans. The most effective refrigerant purge includes a floor-level fan capable of meeting the calculated refrigerant purge rate. A ducted system can be used with or without flow-control dampers. If dampers are used, they should be designed and controlled to provide maximum exhaust from the floor-level inlet after a refrigerant alarm condition occurs. The fan inlet should be near a potential leak source and away from the fresh air intake. This arrangement will produce a sweeping action that draws fresh air across the leaking refrigerant toward the exhaust fan.



### Dual Duct Exhaust

### **5.3 Refrigerant Monitoring**

Permanently mounted, continuously operating area-monitoring systems shall be provided for the refrigeration MER. Monitoring systems insure occupant safety by detecting a build-up of refrigerant in the MER. Monitoring systems shall consist of refrigerant vapor detectors or oxygen depletion sensors (or both as appropriate to the type(s) of refrigerant used) and remote monitoring panels.

The detector/sensors shall trigger an audible and visual alarm to warn workers of a refrigerant leak. The alarm must be installed both inside and outside the machinery room.

The detector/sensors shall actuate mechanical ventilation and shut down any combustion process in or near the machinery room and refrigeration plant in the event of a refrigerant leak.

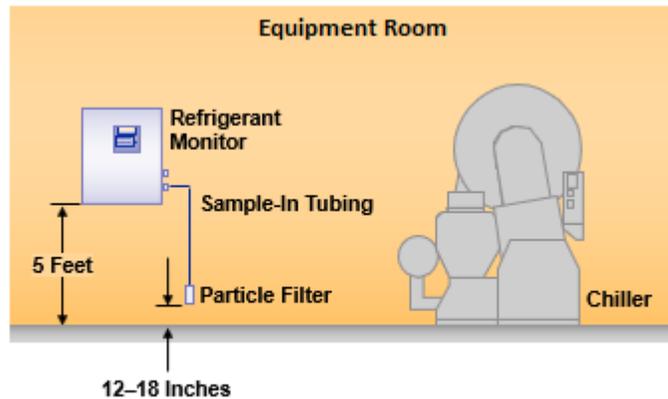
#### **5.3.1. Refrigerant Monitor**

Refrigerant gas monitors are typically installed or mounted vertically. Refrigerant gas monitors require proper ambient air cooling to operate properly. Be sure to allow at least 3" clearance around all surfaces except the mounting surface. Improper cooling can result in readings that are inconsistent, unreliable and require the premature replacement of gas sensors.

Close attention must be paid to installing the refrigerant gas monitor's air-sample points. Depending on the gas monitor selected, a sample point may be remotely located up to 150 feet from the monitor in an area where refrigerant vapors are most likely to leak or accumulate.

It is a widely accepted best practice to locate the sample point near the barrel of the chiller and on adjacent corners to enhance the ability to monitor leaks. Because refrigerants are heavier than air, be sure to monitor for refrigerant leaks in locations such as pits, stairwells and trenches. If possible, monitor the vent line of the chiller. Also, do not forget to monitor the cylinder storage area if it is inside or near the chiller room in case of cylinder leakage.

To prevent personnel from entering a contaminated equipment space, the monitor shall be located outside, but close to, the MER.



**Typical Refrigerant Monitor Installation**

The monitoring panels required shall be stable over a range of temperatures, humidities and barometric pressures to which it is exposed, and shall require little maintenance. It shall have alarm limits that correspond to the refrigerant being monitored and have the outputs required to signal alarm conditions and start auxiliary ventilation equipment.

### **5.3.2. Sensors**

Each refrigerating machinery room shall contain a sensor, located in an area where refrigerant from a leak will concentrate, that actuates an alarm.

Sensors to detect refrigerant loss can be based on diffusion based photoacoustic infrared technology and non-dispersive infrared (NDIR) technology. Infrared type sensors are more expensive but more reliable and do not exhibit sensitivity to other gases.

Detection of refrigerant can be set as low as 1 ppm to 1000 ppm. It is recommended that the set point for the actuation of emergency ventilation be no greater than one half (1/2) of the Threshold Limit Value for the refrigerant with the lowest TLV. The TLV is the concentration of refrigerant vapor in air for a normal 8- hour workday and 40-hour work week to which occupants may be repeatedly exposed without adverse effect. Specific TLV's are available from the American Conference of Governmental and Industrial Hygienists or from the manufacturer.

Sensors should be calibrated and tested so that the allowable exposure limit for the refrigerant will not be exceeded. Periodic tests of the sensor(s) or detector(s), alarm(s) and mechanical

ventilating system shall be performed in accordance with manufacturers' recommendations and/or local jurisdictional authority.

The quantity of sensors is generally governed by the following rules:

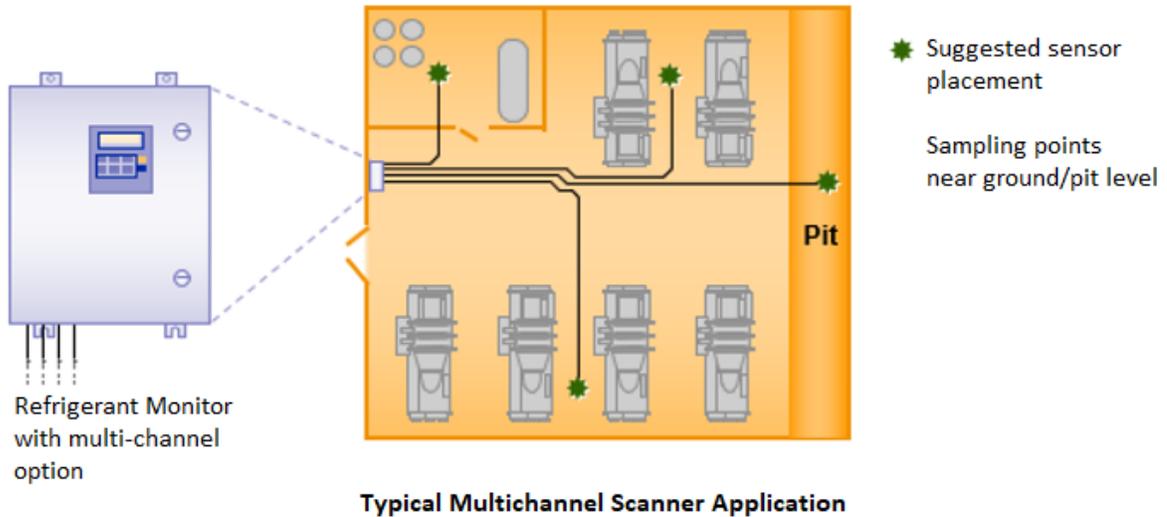
- a. Consider a 20-ft radius per sensor. The sensor must be located within 20 feet of the chiller.
- b. There should be at least as many sensors in a given machinery room as there are different types of refrigerants.
- c. Multiple sensors can be connected to a single monitoring unit.
- d. As refrigerants are heavier than air, monitor the presence of refrigerant in locations like pits, stairwells and trenches. If possible, monitor the vent line of the chiller.
- e. Remember to monitor the cylinder storage area, if inside or near the chiller room in case of cylinder leakage.

### **5.3.3. Sensors Location**

The vapor detector(s) and/or oxygen depletion sensor(s) shall be located where a leakage is likely to concentrate. There will be cases where a single sensor or detector is enough; however, large rooms, multiple-level rooms, and pits are examples of cases where multiple sensors or detectors are required.

Mount detectors and sensors close to the perimeter of a chiller, between two chillers, and between the refrigerating system and entry door. A refrigeration system shall not be more than 50 feet from a sensor.

The recommended height for the sensor shall be a maximum of 18 inches above the floor, as refrigerants, which are heavier than air, tend to drop to the floor and fill the MER from the bottom.



#### 5.3.4. Audible and Visual Alarms

If the refrigerant vapor detector is actuated, an alarm shall sound, and the mechanical ventilation shall be activated. Also, all air handling units within the MER shall be deactivated.

The audible and visual alarms' primary function is to warn workers about a high level of refrigerant. The audible alarm should be located inside the machinery room and must be loud enough to be heard in all parts of the machinery room. An audible alarm should also be located outside but close to the machinery room.

A visual alarm such as a flashing beacon and a horn at each entrance and outside of the machinery room should notify workers about the refrigerant concentration in the space. The color selection of the visual alarm should be adequate for the alarm status.

#### 5.3.5. Visual Alarms

The recommended status colors of flash beacon are:

- Blue: Refrigerant monitoring system malfunction Amber: Low refrigerant concentration
- Red: High refrigerant concentration

### 5.3.6. Audible Alarms

- A minimum of 70 dBa at 10 feet is required for horns installed inside the machinery room
- A minimum of 65 dBa at 3 feet is required for horns installed outside the machinery room

### 5.3.7. What do Refrigerant Monitoring Achieve?

Refrigerant monitoring is used to automatically shut down the combustion process in the event of refrigerant leakage. This only applies when both boilers and chillers are in the same machinery room.

### 5.3.8. Refrigeration plant shutdown

Shutting down the refrigeration plant upon refrigeration leakage/loss should be exercised with caution as the operation might have a major impact on the HVAC system of the building. Dual level alarms (set at low and high concentration) are recommended for action for different refrigerants. See table below for recommended alarm level.

#### **Refrigerant data and suggested alarm levels**

<b>Refrigerant Type</b>	<b>No.</b>	<b>1st Alarm Level LOW</b>	<b>2nd Alarm Level HIGH</b>
HCFC	22	250 ppm	500 ppm
HCFC	123	50 ppm	150 ppm
HFC	134a	250 ppm	500 ppm

### 5.3.9. Sequence of Operation

#### First alarm level:

This level should be set for early detection to minimize refrigerant loss. Upon sensing the 1<sup>st</sup> level alarm:

- The mechanical ventilation should be activated at normal speed (minimum of 0.5 cfm per square foot). As a secondary action, actuate a warning strobe light (amber).
- Shut down any nearby combustion processes.
- Look for leak(s) with a hand-held leak detector.

**Second alarm level:**

This level should be set at high concentration. Upon sensing this level:

- The refrigerant purge mechanical ventilation should be actuated.
- Strobe light (red) and horn is activated.
- The machinery room should be evacuated immediately.
- Chiller shut down may be required.
- Workers could return to the machinery room only with self-contained breathing apparatus (SCBA).

**5.3.10. Interface with the Building Management System (BMS)**

- a. The BMS might be used to trigger the mechanical ventilation equipment and alarms of the machinery room following detection of a high refrigerant level by the refrigerant monitoring system. This is often an analog signal to the BMS representing the concentration level of refrigerant detected.
- b. Alternatively, the BMS may only receive emergency outputs from the refrigerant monitoring system (typically alarm relay contact closure) and initiate alarm procedures accordingly.
- c. In all cases, the refrigerant monitoring system shall be capable of providing either direct digital and/ or analog outputs to the BMS.

#### **5.4 Machinery Room Special Requirements**

- a. The total of all groups A2, B2, A3 and B3 refrigerants, other than R-717 ammonia, shall not exceed 1100 pounds (500 kg) without approval by the authority having jurisdiction.
- b. Walls, floor, and ceiling separating the refrigerant machinery room from other occupied spaces shall be of at least one-hour fire-resistive construction.
- c. The refrigerant machinery room shall have a door that opens directly to the outside or through vestibules equipped with self-closing, tight-fitting doors.
- d. Exterior opening, if present, shall not be under any fire escape or any open stairway.
- e. All pipes piercing the interior walls, ceiling, or floor of such rooms shall be tightly sealed to the walls, ceiling, or floor through which they pass.
- f. If refrigerant groups A2, A3, B2, and B3 are used, the machinery room shall conform to Class I, Division II of the NEC. If refrigerant groups A1 and B1 are used, the machinery room is not required to meet Class I, Division II, of the NEC.

##### **5.4.1. Location of Refrigerant Piping**

- a. Refrigerant piping crossing an open space that affords passageway in any building shall not be less than 7 ft. above the floor.
- b. Passages shall not be obstructed by refrigerant piping.
- c. Refrigerant piping shall not be placed in any elevator, dumbwaiter, or other shaft containing a moving object or in any shaft that has openings to means of egress.
- d. Refrigerant piping shall not be installed in an enclosed public stairway, stair landing, or stair landing, or means of egress.
- e. Refrigerant piping shall not penetrate floors, ceilings, or roofs.

##### **5.4.2. Equipment Room Doors, Passageways and Access**

Each refrigerating machinery room shall have adequate number of doors for persons to escape in an emergency.

Doors shall be tight-fitting and shall open outward. Further, they shall be self-closing if they open into the building. Other than doors, there shall be no openings in the MER that will allow escaping refrigerant into other parts of the building.

Access to the refrigerating machinery room shall be restricted to authorized personnel only. Doors shall be clearly marked with a “Refrigerating Machinery Room — Authorized Personnel Only” sign, at each entrance to indicate this restriction.

#### **5.4.3. Refrigerant Storage**

The total amount of refrigerant stored in a machinery room in all containers not provided with relief valves and piped in accordance with the standard should not exceed 330 lbs., according to Section 11.5 of ASHRAE 15-2019. If you have more than the allowable amount of refrigerant, it must be housed in separate machinery rooms.

#### **5.4.4. Materials**

- a. Materials used should not deteriorate because of the refrigerant or the lubricant in the presence of air or moisture to a degree that poses a safety hazard.
- b. Aluminum, zinc, magnesium, or their alloys shall not be used in contact with methyl chloride.
- c. Copper and its alloys shall not be used in contact with ammonia except as a component of bronze alloys for bearings or other non-refrigerant-containing uses.
- d. Aluminum and its alloys are suitable for use in ammonia systems.
- e. Piping material used in the discharge line of a pressure relief device or fusible plug shall be the same as required for refrigerants.

#### **5.5 Combustion and Open Flame Devices**

No open flame or any equipment (boilers, furnaces, hot water generators etc.) that uses combustion air from the machinery room shall be installed where any refrigerant is used. Erecting a partition wall to isolate the flame-producing device from the refrigerant-containing device is NOT an option. If necessary, combustion air may be ducted directly from outside the MER to the point of use.

ASHRAE 15 states combustion equipment shall not be installed in the same machinery room with refrigerant-containing equipment except under one of the following conditions:

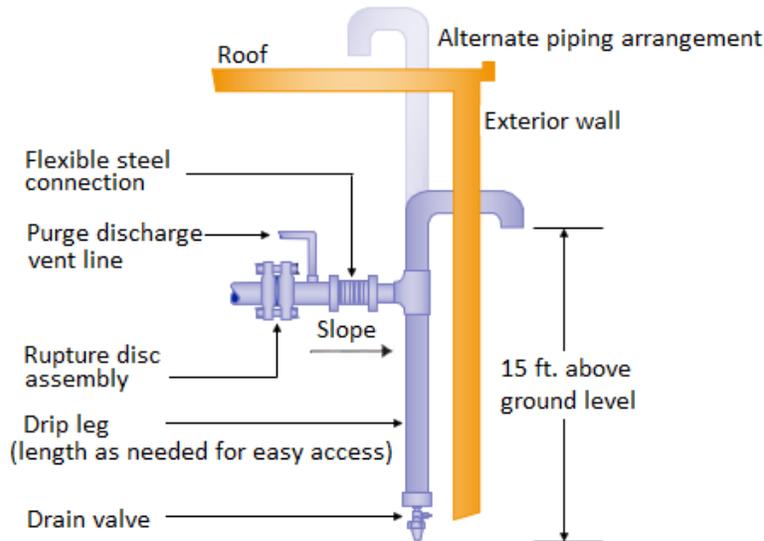
- a. Combustion air is ducted from outside the machinery room and sealed in such a manner as to prevent any refrigerant leakage from entering the combustion chamber; or
- b. A refrigerant detector, conforming to ASHRAE 15, is employed to automatically shut down the combustion process in the event of refrigerant leakage.

A refrigerant detector shall be used to shut down combustion automatically if a refrigerant leak occurs.

Exceptions are available for machinery rooms that use only carbon dioxide or ammonia for refrigerant and internal combustion engines are the prime mover for compressors.

## **5.6 Pressure-Relief Protection**

Refrigeration systems shall be protected by a pressure-relief device to safely relieve pressure due to fire, hydrostatic expansion or other abnormal conditions. ASHRAE 15 includes very specific descriptions for determining when pressure-relief devices are necessary and how to size them. The original equipment manufacturer provides such devices on packaged systems and on major system components built-up in the field. However, ASHRAE 15 should be reviewed in all cases to ensure compliance with that standard.



**Suggested Refrigerant Vent Piping**

The following guidelines must be followed:

- a. Pressure-relief devices shall be direct-pressure actuated or pilot operated.
- b. When part of a limited charge system is protected by a pressure-relief device, the design pressure of the part need not exceed the setting of the pressure-relief device.
- c. Stop valves shall not be located between a pressure relief device and parts of the system protected thereby.
- d. Pressure-relief devices shall be connected directly to the pressure vessel or other parts of the system protected thereby.
- e. The seats and discs of pressure-relief devices shall be constructed of suitable material to resist refrigerant corrosion or other chemical action caused by the refrigerant.
- f. Pressure vessels containing liquid refrigerant that are capable of being isolated by stop valves from other parts of the system shall be provided with overpressure protection.
- g. Pressure vessels with an internal gross volume of 3 ft<sup>3</sup> or less shall use one or more one or more pressure-relief devices or a fusible plug.
- h. Pressure vessels of more than 3 ft<sup>3</sup> but less than 10 ft<sup>3</sup> internal gross volume shall use one or more pressure-relief devices.

- i. Pressure vessels of 10 ft<sup>3</sup> or more internal gross volume shall use one or more rupture member or dual pressure-relief valves when discharging to the atmosphere.
- j. Pressure-relief valves for refrigerant-containing components shall be set and sealed by the manufacturer according to the ASME Boiler and Pressure Vessel Code.
- k. Each rupture member for refrigerant pressure vessels shall be marked with the data required by the ASME Boiler and Pressure Vessel Code.
- l. Fusible plugs shall be marked with the melting temperatures in Fahrenheit or Celsius.

#### **5.6.1. Piping Rupture Devices**

ASHRAE 15 requires pressure-relief devices and rupture disks on any system containing:

- Group A3 or B3 refrigerant;
- Any system containing more than 6.6 pounds of a group A2, B1, or B2 refrigerant;
- Any system containing more than 110 pounds of a group A1 refrigerant

The discharge shall be terminated in a manner that will prevent the discharge refrigerant from being sprayed directly on personnel in the vicinity and for material or debris from entering the discharge piping. The vent through the roof or side wall should be at least 15 feet above adjoining ground level and not less than 20 feet from any window, ventilation opening, or exit in a building.

Discharge piping connected to the discharge side of the fusible load or rupture member should have provisions to prevent plugging the pipe in the event the fusible plugs or rupture member functions.

If a pressure relief valve is used in series with a rupture disc, the rupture disc should be a non-shattering type. A metallic non-fragmenting rupture disc is normally specified in this situation. The size of rupture members installed ahead of relief valves shall not be less than the relief than the relief valve inlet. The conditions of application shall conform to the requirements of the ASME Boiler and Pressure Vessel Code.

It is critical that the materials used in the pipe and joints of the relief device piping are compatible with the vented refrigerant. Acceptable materials like steel or copper pipe are

commonly used. Polyvinylchloride (PVC) piping is not recommended. Many adhesives and flexible connection devices that isolate vibration are untested for refrigerant compatibility with these types of piping constructions. A flexible stainless- steel pump connector or its equivalent is recommended.

Vent pipes should be equipped with a drip leg capable of holding up to 1 gallon (3.8 liters) of liquid. Use a standard 0.25-inch FL by 0.25-inch NPT capped refrigerant service valve to remove the liquid. Accumulated liquid should be removed from the drip leg as part of a regular maintenance schedule once every six months.

## **5.7 Purge Discharge**

Purge units that remove non-condensable gas from the refrigeration system should have their discharge lines piped in accordance with relief piping requirements. The most convenient way to properly exhaust the purge discharge to the atmosphere is to route it into the valve (rupture disc) vent pipe. The purge discharge line must be free of liquid traps and sloped away from the purge unit to prevent liquid from collecting near it. Additionally, do not allow liquid to collect at the pressure-relief valve or rupture disc. Consult the purge equipment manufacturer about properly sizing the purge discharge line.

### **5.7.1. Minimize Loss**

Low purge-related refrigerant loss minimizes atmospheric refrigerant discharge and reduces refrigerant replacement costs. To minimize purge-related refrigerant loss:

Choose a purge unit with a low refrigerant-to-non-condensable-gas discharge ratio that can operate while the chiller is off. The EPA has not defined high-efficiency with respect to purge units. However, several commercially available units are now capable of achieving 0.0005 pound of refrigerant discharged per pound of air purged.

## **5.8 General Safety Requirements**

### **5.8.1. Signage**

Signage should be provided for areas dedicated for changing, charging and storing refrigerants.

Safety and warning signage should be provided.

### 5.8.2. Warning signs

- Signs should be 12-16 inches square
- Black engraved letters on white bond
- They must designate and identify the meaning of all system status from visual and audible alarm devices.
- They should be located close to every warning device
- Warning signs should also be installed at each door entrance of the machinery room



SIGN 1 to be installed beside the stackable flashing beacon inside the mechanical room

SIGN 2 to be installed close to the main entrance door inside the mechanical equipment room

SIGN 3 to be installed at each entrance door outside of the mechanical equipment room

### Warningsigns

When technicians enter any machinery room, they need to be alerted to potential toxic or combustible gas leaks. There should be Danger sign in the entrance of the machinery room adjacent to the Visual Alarm Lights. The signage should say, “DO NOT ENTER WHEN LIGHTS ARE FLASHING”.

### 5.8.3. Protective Clothing and Apparatus

If a large release of refrigerant occurs, the area should be evacuated immediately.

Protective clothing, gloves and eye protection are effective at preventing frostbite by keeping liquid refrigerant away from the skin.

#### **5.8.4. Self-contained Breathing Apparatus (SCBA)**

At least one approved self-contained breathing apparatus (SCBA) shall be provided outside of, but close to, the MER. The availability of a second SCBA for back up is strongly recommended. The SCBA shall be stored in a brightly colored, durable case to protect it from dirt and damage.

SCBAs should be NIOSH-approved and contain the following:

- 30-minute aluminum cylinder (filled with breathing air), adjustable harness and backpack
- Face mask, whistle and pressure gauge with luminous face
- Medium pressure hose, first stage pressure regulator and positive pressure second stage regulator

Avoid using NFPA-compliant SCBAs as they are made for fire fighting.

### **5.9 Operation and Field Testing**

The high-side and low-side of each system shall be tested and proved tight at not less than the lower of the design pressure or the setting of the pressure-relief device protecting the high-side or low-side of the system, respectively.

Testing Procedure Notes:

- a. Tests shall be performed with dry nitrogen or another nonflammable, nonreactive, dried nonreactive, dried gas.
- b. Oxygen, air, or mixtures containing them shall NOT be used.
- c. The pressure-relief device shall be set above the test pressure but low enough to prevent permanent deformation of the system's components.

#### **5.9.1. Tools and Equipment's**

For technicians and engineers that are working directly with flammable refrigerants, it is essential that workers have available and use the appropriate tools and equipment. Whilst it is often the case that certain tools and equipment are equally applicable to most refrigerants, there are some that may ordinarily compromise safety and some specialised equipment is required.

Item	Remarks
Gas detectors	Should be electronic and intended for use with flammable gases and the refrigerant intended
Balance/scales	If electronic, should be suitable for use in an area where flammable refrigerant may be present, as confirmed by the manufacturer.
Manifold/gauge/hose set	Materials should be compatible, be able to withstand the maximum pressure and, if electronic, be suitable for use in the presence of flammable refrigerant
Vacuum gauge	If electronic, be suitable for use in the presence of flammable refrigerant, as confirmed by the manufacturer.
Vacuum pump	Should be suitable for use with flammable gases (e.g., not with a brushed motor) or arranged so that it can be switched on/off in a location where a release of flammable refrigerant cannot reach.
Refrigerant cylinder adapters	Ensure that the correct type of cylinder adapter is present to enable safe removal of refrigerant from the cylinder
Recovery cylinder	Must be rated for the maximum pressure of the refrigerant being used and have the appropriate flammable gas warnings, also proper refrigerant cylinder handling rules must be adhered to
Refrigerant recovery machine	Must be suitable for use with the type of refrigerant under consideration and also be designed appropriately for flammable refrigerants
Venting hose	Due to the negligible environmental impact of direct releases for certain flammable refrigerants, specifically hydrocarbons,

Item	Remarks
	venting is sometimes practiced instead of recovering (generally for small refrigerant charges); in this case, a venting hose with sufficient length to allow venting directly to a safe place in the open air is necessary.
Mechanical ventilation	When working with larger charges of refrigerant, it can be beneficial to use a safe mechanical ventilation unit to help dilute refrigerant that has been accidentally released
Personal protective equipment (PPE)	Normally standard items such as goggles, gloves, fire extinguisher

### Summary

Industry practices for handling refrigerant are intended to minimize personal exposure as well as reduce releases into the atmosphere. AHSRAE Standard 15 provides the rules for Safety in Machinery Rooms, which are mandatory requirements for new installations as well as all machinery rooms being upgraded for all air conditioning retrofit or replacement projects. Here are some key requirements:

- a. Never intentionally release refrigerant in a confined space. Even the safest refrigerant can still displace enough oxygen to cause suffocation.
- b. Access to the machinery room shall be restricted to authorized personnel only.
- c. Plant room must have provision for mechanical ventilation for heat dissipation as well as purging requirements of refrigerant in event of leakage. The machinery room ventilation system shall be separate from all other building ventilation systems. That is, fans and ductwork used to ventilate the machinery room must not be used to ventilate any other part of the building. Further, the discharge must not interfere with any outside air intakes.

- d. Special care shall be given to ventilate the lowest points in the room, such as pits, stairwells, or trenches where refrigerant may accumulate.
- e. Inlet(s) to the exhaust fan(s) shall be located near the refrigeration equipment and at a minimum of 18 inches and a maximum of 5 feet above the finished floor, because refrigerants, which are heavier than air, tend to drop to the floor and fill the room from the bottom.
- f. The ventilation shall provide an “air sweep” across all refrigeration equipment. The inlet(s) to the exhaust fan shall be located near the potential leak source and away from the outside air intake(s), producing a “sweeping” action that draws outside air across the machinery to the exhaust fan. Stagnant areas created by lack of airflow shall be avoided.
- g. An adequate number of doors shall be provided to ensure easy escape for occupants in an emergency. Doors shall be tight-fitting and shall open outward. Further, they shall be self-closing if they open into the building. Other than doors, there shall be no openings in the machinery room that will allow escaping refrigerant into other parts of the building.
- h. No open flames or any equipment (boilers, furnaces, hot water generators etc.) that uses combustion air from the machinery room shall be permitted in the machinery room. If necessary, combustion air may be ducted directly from outside the machinery room to the point of use.
- i. Permanently mounted, continuously operating area-monitoring systems shall be provided for the refrigeration machinery room. Monitoring systems shall consist of refrigerant vapor detectors or oxygen depletion sensors (or both as appropriate to the type(s) of refrigerant used) and remote monitoring panels. These sensors should be capable of detecting refrigerant loss. The sensor should be positioned in areas where vapor from a refrigerant leak would most likely concentrate, thus providing personnel with a means to avoid catastrophic refrigerant loss.

- j. If the refrigerant vapor detector is actuated, an alarm shall sound, and the mechanical ventilation shall be activated. Also, all air handling units within the machinery room shall be deactivated.
- k. Mount detectors and sensors close to the perimeter of a chiller, between two chillers, and between the refrigerating system and entry door. A refrigeration system shall not be more than 50 feet from a sensor.
- l. The recommended height for the sensor shall be a maximum of 18 inches above the floor, as refrigerants, which are heavier than air, tend to drop to the floor and fill the machinery room from the bottom.
- m. To prevent personnel from entering a contaminated equipment space, the monitor shall be located outside, but close to, the machinery room.
- n. Periodic tests of the sensor(s) or detector(s), alarm(s) and mechanical ventilating system shall be performed in accordance with manufacturers' recommendations and/or local jurisdictional authority.
- o. At least one approved self-contained breathing apparatus (SCBA) shall be provided outside of, but close to, the machinery room. The availability of a second SCBA for back up is strongly recommended. The SCBA shall be stored in a brightly colored, durable case to protect it from dirt and damage.
- p. If someone is exposed to refrigerant get him/her to fresh air, give oxygen if needed and get him/her checked by a doctor.

**References:**

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- e. Mechanical Equipment Rooms by [www.honeywellanalytics.com](http://www.honeywellanalytics.com)