Refrigerant Monitoring Systems for Mechanical Equipment Rooms

Step-by-Step Guidelines for the Design Engineer

The refrigerants used in mechanical equipment rooms are potentially dangerous if leaks occur. Refrigerant monitors are available and each is suited to a particular scenario. The differences in design determine what type of monitors best suit the application. This step-by-step design guideline helps the designers select an optimal monitoring system. It covers the characteristics of various monitors and discusses how they can be used to provide a safe mechanical equipment room.

Codes and Standards

Step 1: **Determine the reason why you want to do refrigerant detection.**

- Area monitoring: Applying stationary sensor(s) where permanent monitoring is required in mechanical equipment rooms.
- Leak pinpointing: This requires portable hand held equipment to check for an individual leak(s) in refrigeration equipment (this document is not intended for leak pinpointing applications)

Step 2: **Be aware of the requirements of ASHRAE standard 15-2004 and applicable local building codes (ASHRAE standard 15-2004 makes recommendations such as:)**

- *Each machinery room shall contain a detector located where a refrigerant leak would concentrate.*
- *The detector shall trigger an alarm both inside and outside the mechanical room and actuate mechanical ventilation.*
- *The detector shall also shut down any combustion process in or near the mechanical room in the event of a refrigerant leak.*
- *A self-contained breathing apparatus (SCBA) is required. A second SCBA is recommended as a back-up.*

Step 3: **Recognize the reasons why installing refrigerant monitors is important**

- They provide early detection in case of a leak to help prevent significant refrigerant loss.
- They satisfy the requirements for equipment room emissions included in EPA regulations.
- Most importantly they limit the exposure of workers to refrigerant leaks for increased safety.

Sequence of Operation

Step 4: **Actuation of mechanical ventilation**

The mechanical ventilation should be designed to meet the requirements of ASHRAE standard 15-2004. Two distinct ventilation rates are defined for the mechanical equipment room (MER). The first is normal ventilation at a rate of 0.5 cfm per square foot (or more, if excessive heat is produced in the room), and is required whenever the MER is occupied; the second is the purge ventilation rate, and is based on the mass of refrigerant in the refrigeration system.

Step 5: **Actuation of audible and visual alarms**

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 mechanical room and must be loud enough to be heard in all parts of the mechanical equipment room. An audible alarm should also be located outside but close to the mechanical equipment room. A visual alarm should notify workers about the refrigerant concentration in the space. The color selection of the visual alarm should be adequate for the alarm status.

Step 6: **Combustion process shutdown in the mechanical equipment room**

As per ASHRAE standard 15-2004: A refrigerant detector is employed 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 mechanical equipment room.

Step 7: Chiller shutdown

Shutting down the refrigeration system at high concentration of refrigerant in the mechanical equipment room space is a good way to minimize refrigerant loss. This operation might have a major impact on the HVAC system of the building. It is therefore very critical that an analysis of all the effects of such actions on the facility be undertaken.

Step 8: Types of refrigerant, alarm levels* and sequence of operation

First alarm level:

- This level should be set for early detection to minimize refrigerant loss.
- 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).
- Depending on the mechanical room design, shut down any nearby combustion processes. (see Step 6 for details).
- Look for leak(s) with a hand held leak detector.

*See table below for recommended alarm level.

Second alarm level:

- This level should be set at high concentration (*see table below for recommended alarm levels).
- The refrigerant purge mechanical ventilation should be actuated.
- Strobe light (red) and horn is activated.
- The mechanical room should be evacuated immediately.
- Chiller shut down may be required (See Step 7 for details).
- Workers could return to the mechanical equipment room only with self contained breathing apparatus (SCBA).

Refrigerant monitor malfunction:

- Warn workers if refrigerant monitoring system is malfunctioning.
- Examples of system failure:
  - Electronics failure
  - Saturated sensor signal
  - Communication problem
  - Incorrect wiring connection
  - Power outage
- Normally notify the building automation system through a dry contact.
- Secondary actuation: Activate a fault warning strobe light (blue).
- Troubleshoot the refrigerant monitoring system after it is determined that no danger to personnel is present.

Table 1 – Refrigerant data and suggested alarm levels

Prefix:"R" or…	No.	Chemical Name	Chemical Formula	1st Alarm Level LOW	2nd Alarm Level HIGH
CFC	11	Trichlorofluoromethane	CCl_3F	250 ppm[7]	500 ppm[1]
CFC	12	Dichlorodifluoromethane	CCl_2F_2	250 ppm[7]	500 ppm[2]
HCFC	22	Chlorodifluoromethane	$CHClF_2$	250 ppm [7]	500 ppm[3]
HCFC	123	2,2-dichloro1,1,1-trifluoroethane	$CHCl_2CF_3$	50 ppm[4]	150 ppm[5]
HFC	134a	1,1,1,2-tetrafluoroethane	CF_3CH_2F	250 ppm[7]	500 ppm[6]

1 - 50% of TWA, 8 Hr, PEL (OSHA) – Ceiling, TLV (ACGIH)
2 - 50% of TWA, 8 and 12 Hr, AEL (DuPont), WEEL (AIHA)
3 - 50% of TWA, 8 Hr, TLV (ACGIH)
4 - TWA, 8 Hr and 12 Hr, AEL (DuPont), WEEL (AIHA)
5 - Upon recommendation of DuPont
6 - 50% of TWA, 8 Hr and 12 Hr, AEL (DuPont), WEEL (AIHA)
7 - Early detection level

A broad range of other refrigerants can be detected. Alarm levels can be modified upon customer requirements

Abbreviations:
ACGIH: American Conference of Governmental Industrial Hygienists
AEL: Acceptable Exposure Limit
AIHA : American Industrial Hygiene Association
OSHA: Occupational Safety and Health Administration
TLV: Threshold Limit Value

Step 9: Interface with the Building Automation System (BAS)

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

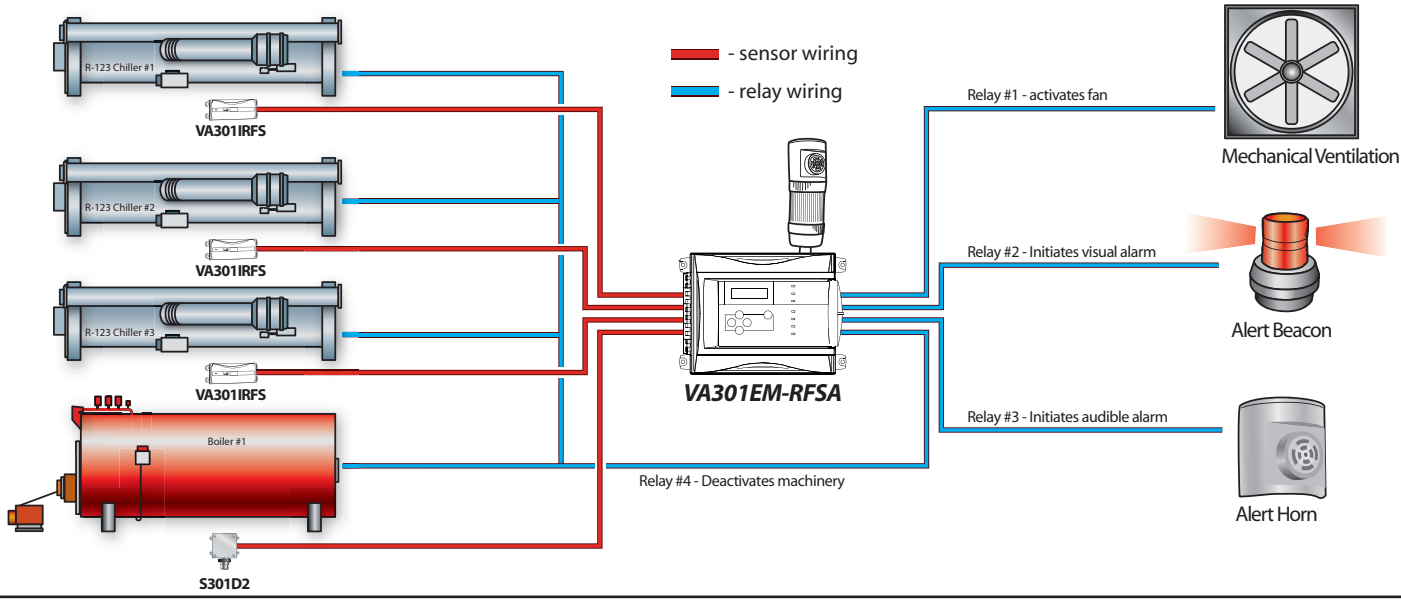
Equipment Selection and Location

CENTRAL PANEL and OUTPUT MODULE

Step 10: Types of monitoring system

- Stand-alone monitors: These are usually single point for small applications. They provide real-time readings with a limited amount of outputs and no moving parts (less maintenance).
- Network monitoring system: These are for multiple sensing points usually in large applications. They provide real-time readings with several programmable outputs and no moving parts (less maintenance), and are highly flexible (SEE FIGURE 1).

Figure 1 – Typical refrigerant monitoring system



- Sample draw: These are typically multiple sensing points, sequential (not real-time) readings, several programmable outputs, relays on pumps and solenoids to move multiple samples (more maintenance), generally used for medium to large applications. Used when low cost per point is the most important and an owner is willing to accept higher maintenance costs and intermittent monitoring.

Step 11: Gas detection central panel and relay module

- Must be easily accessible and visible.
- Normally close to the main entrance door of the mechanical equipment room.
- Should be installed inside the mechanical equipment room.

Step 12: Self-test diagnostic and malfunction warning

- Not all monitors offer such features.
- Ensures refrigerant leak protection at all times.

Step 13 : Output signals

- Alarm relay output: generally two are required (low and high level alarms).
- Failure relay output: only one required (indicates monitor failure).
- Analog output: one per type of refrigerant monitored (normally interlocked with BAS).

Step 14 : Gas detection controller and relay module

- The controller should allow several programmable alarm levels through relays
- The gas sensing transmitters are addressable and daisy-chainable utilizing a Modbus communication protocol.
- The refrigerant concentration level in the mechanical equipment room must be visible through a liquid crystal display.

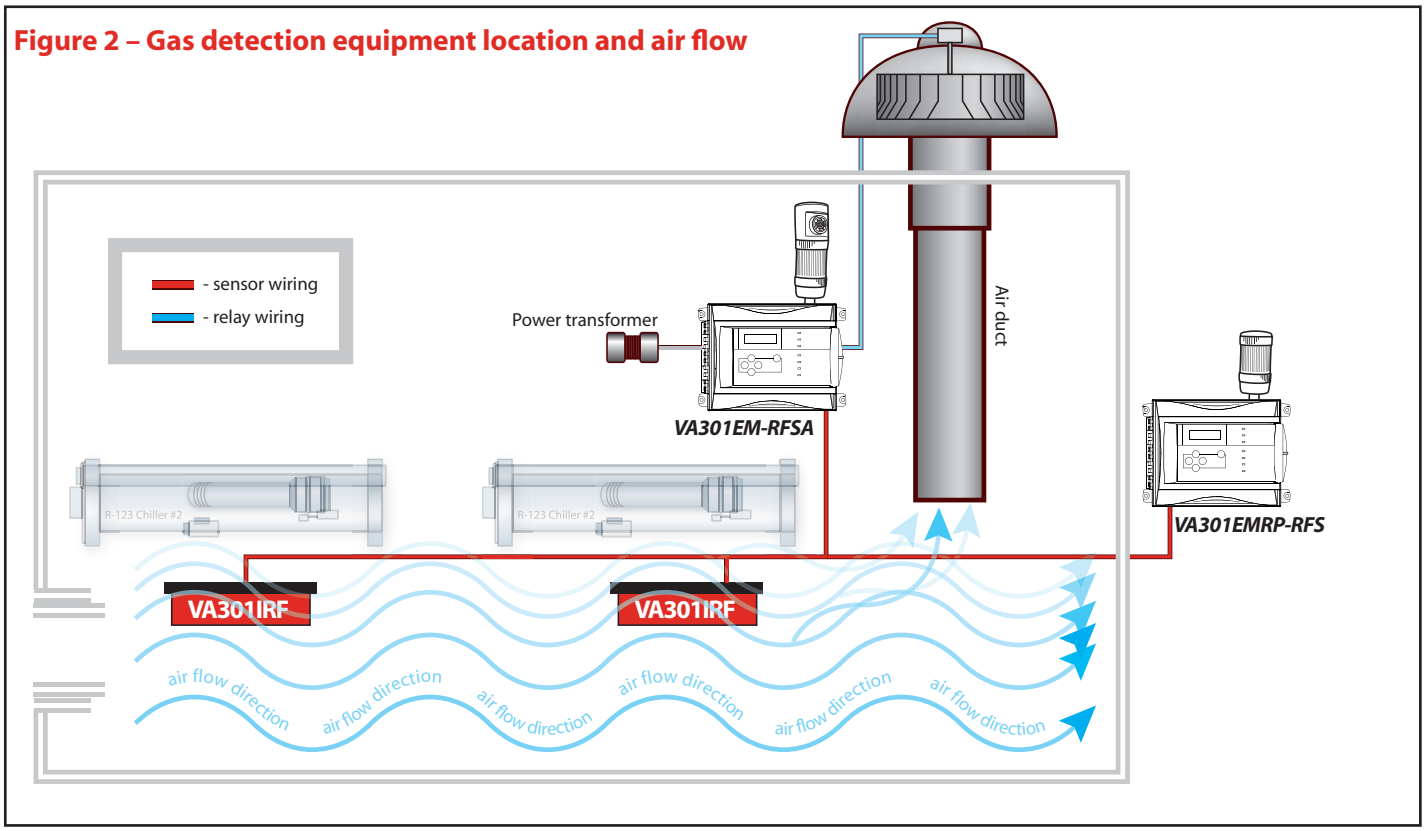
SENSORS

Step 15 : Locating Sensors

The following considerations should be kept in mind when determining the location of the actual refrigerant sensor:

1) Locate the sensor as close as possible to the purge unit of the chiller.
2) Determine the air flow pattern in the mechanical equipment room to:
   a) see where a refrigerant leak may accumulate if areas of the chiller room air flow become stagnant, creating pockets where refrigerant vapors can concentrate.
   b) locate the sensor in the air stream produced by the mechanical ventilation in the room (SEE FIGURE 2).
3) Remember that occupant safety is the primary motive for installing the sensor(s).
4) Recognize that occupants of the mechanical equipment room are most likely to be exposed to refrigerants through direct inhalation.

Figure 2 – Gas detection equipment location and air flow



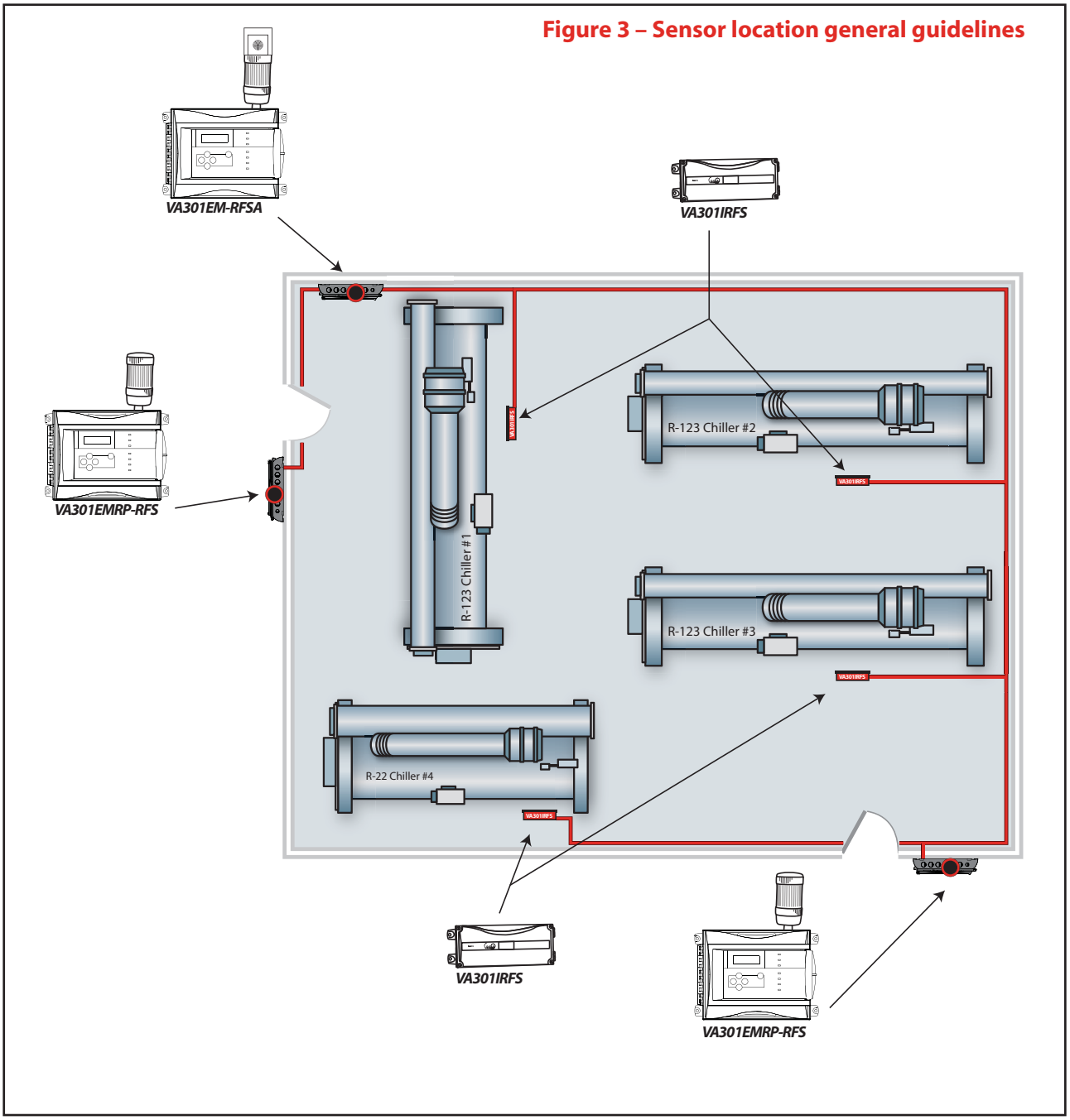
The quantity of sensors is generally governed by the following rules:

1) Consider a 20-ft radius per sensor (the sensor must be located within 20 feet of the chiller (SEE FIGURE 3).
2) There should be at least as many sensors in a given mechanical room as there are different types of refrigerants.
3) As refrigerants are heavier than air, monitor the presence of refrigerant in locations like pits, stairwells and trenches.
4) If possible, monitor the vent line of the chiller.
5) Remember to monitor the cylinder storage area if inside or near the chiller room in case of cylinder leakage.

6) Remember, as per ASHRAE standard 15-2004: locate the sensor where refrigerant is likely to concentrate.

After an optimal location is determined based upon the above recommendations, consider accessibility and maintenance issues. Sometimes a minor change in location of a sensor will enhance access with no detriment to functionality.

Figure 3 – Sensor location general guidelines



Step 16 : Height of sensors

CFC-, HCFC- and HFC-based refrigerants are all heavier than air, it is recommended to locate the sensor module 18 inches above the floor.

Step 17 : Sensing elements selection

Table 2 – Sensing element (sensor) selection criteria

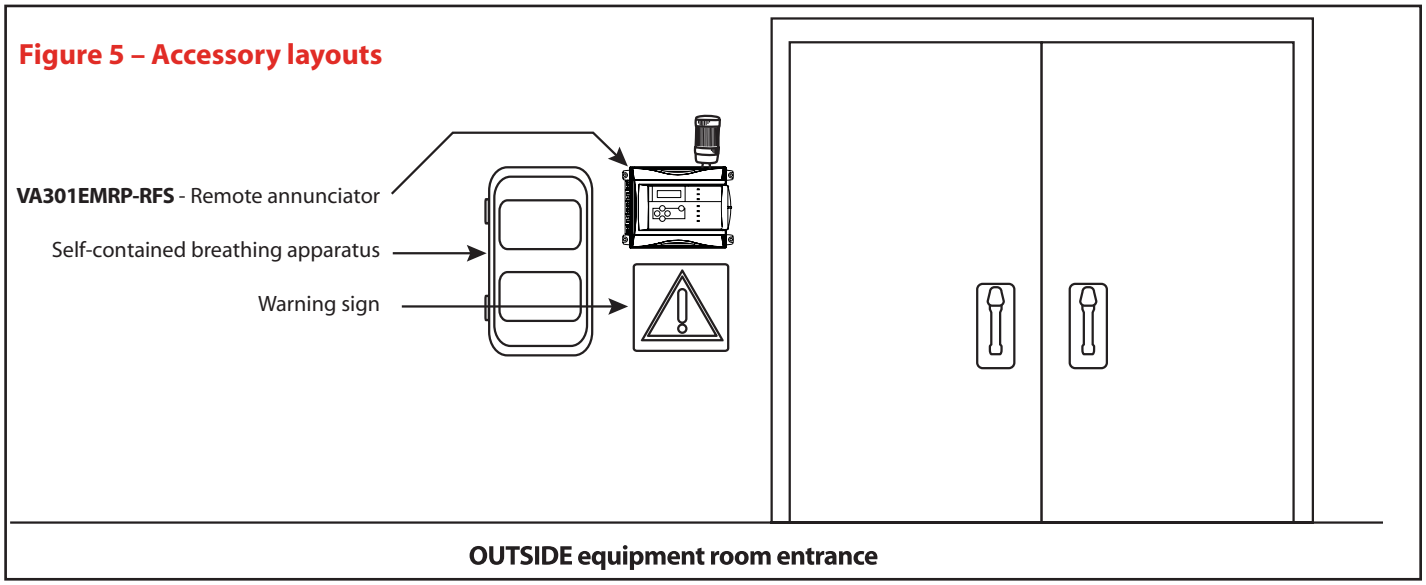
Category/Concern	Sensing technology	
Principle of detection	**Infrared (NDIR - Non-Dispersive Infrared)**	**Solid State (CMOS – Complementary Metal Oxide Semiconductor)**
	Many chemical compounds including refrigerants absorb light (energy) at specific wavelengths. Sensors based on the principal of Non-Dispersive Infrared detection look for the net increase or decrease that occurs at a characteristic wavelength when a given refrigerant absorption takes place. The light intensity is then correlated to refrigerant concentrations.	This sensing technology is also known as a Solid State Sensor. The semi-conductor material and electrodes are deposited on a ceramic tubular former which exhibits weak electro-conductivity in a normal atmosphere but increases in conductivity in the presence of refrigerants.
Sensitivity: The sensitivity of any gas detection device is defined as the amount of gas necessary to generate a measurable change in the output signal detection limit. The most common measure of how "sensitive" a detector can be is the detection limit, which is usually defined as the minimum amount of gas a unit can sense that provides a signal at least two times the background noise level.	Sensitive to 1 ppm of refrigerant	Requires a minimum amount of refrigerant in the room to react reliably (normally over 50 ppm). Cannot detect the presence of R-123 with accuracy and reliability.
Selectivity: Selectivity can be defined as the ability to detect only the refrigerant of interest without interference from other compounds that may be present in the area.	Gas specific - no cross sensitivity to other gases	Gas generic - reacts frequently to many other chemicals that are present in a mechanical room which can cause nuisance alarms.
Calibration intervals	12-18 months	6-8 months
Cost	More expensive	Less expensive to buy but costly to maintain

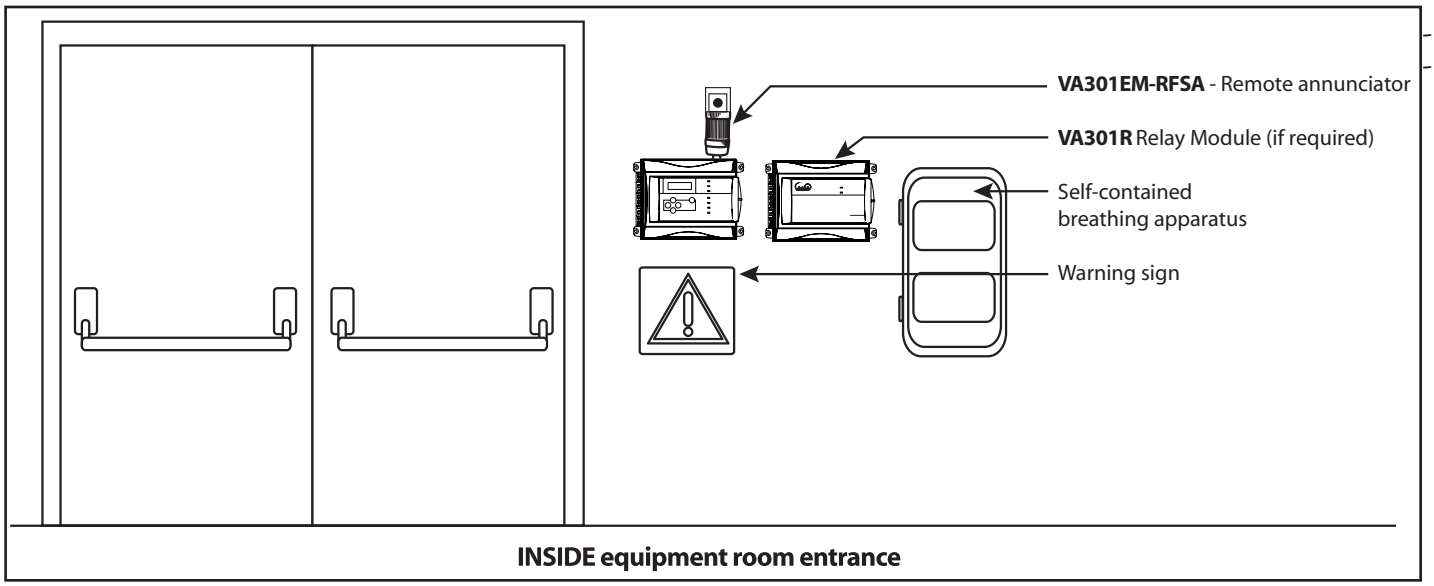
ACCESSORIES

Step 18: Audible and visual alarm devices

- Audible and visual alarm devices must be installed inside the mechanical room to warn workers of a refrigerant leak.
- Installing audible and visual alarm devices such as a remote annunciator, a flashing beacon and a horn at each entrance and outside of the mechanical room shall be considered to prevent entrance to the mechanical room in the event of the presence of a high concentration of refrigerant (SEE FIGURE 5).
- Remote display: located outside the mechanical room. It displays the refrigerant level inside the room before entering it.
- Visual Alarms
  - It is recommended to use flashing beacons.
  - Stackable beacons can also be used when multiple visual alarms are required.
  - The recommended status colors are:
    - Blue: Refrigerant monitoring system malfunction
    - Amber: Low refrigerant concentration
    - Red: High refrigerant concentration

Figure 5 – Accessory layouts





Audible Alarms

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

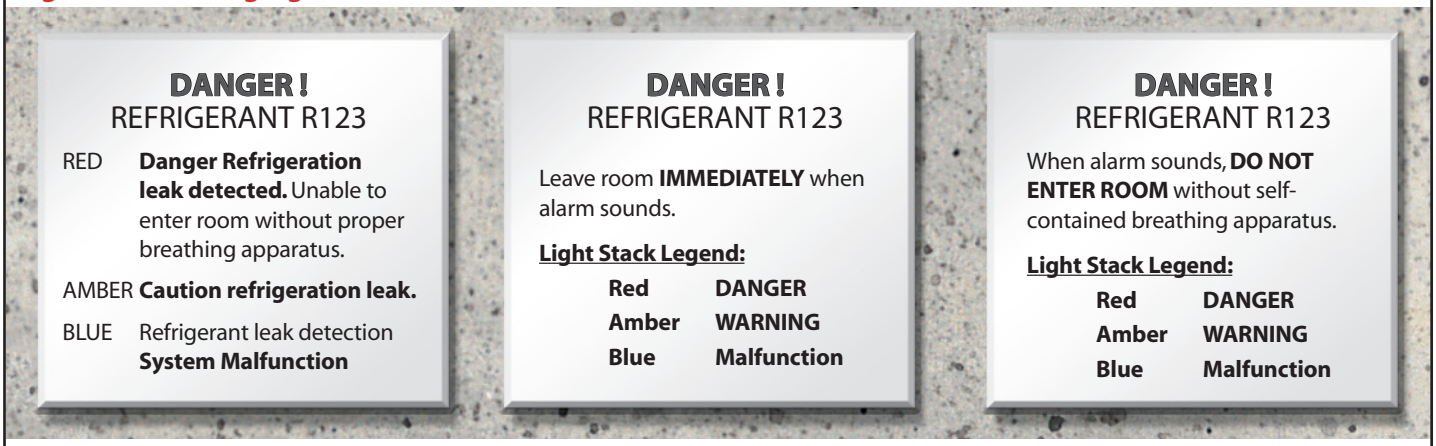
Step 19: Self-contained breathing apparatus (SCBA)

- SCBAs should be NIOSH-approved and contain the following:
  1) 30-minute aluminum cylinder (filled with breathing air), adjustable harness and backpack
  2) Face mask, whistle and pressure gauge with luminous face
  3) 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
- As per ASHRAE standard 15-2004: When a mechanical room is required per the rules of 7.4, at least one approved self-contained breathing apparatus, suitable for the refrigerant used, shall be located outside of, but close to, the machinery room. A second, backup, self-contained breathing apparatus shall also be provided.
- SCBAs must be installed in a dedicated wall mountable cases

Step 20 : 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 (SEE FIGURE 6)
- They should be located close to every warning device
- Warning signs should also be installed at each door entrance of the mechanical room

Figure 6 – Warning signs



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

Closeout Procedures

Step 21: Start-up and Commissioning

Utilize a factory-authorized service representative to perform the following:

- Inspect field-assembled components, equipment installation, and electrical connections for compliance with requirements.
- Test alarm set points of the refrigerant monitoring system with calibration gases and verify sequence of operation.
- Prepare a written report to record test procedures, test results and corrective actions if required
- Report should also cover the requirements for accessories like adequacy of alarm types, signs and protective equipment.

Step 22: Demonstration and Training

Utilize a factory-authorized service representative to train owner's maintenance personnel to adjust, operate, diagnose, calibrate and maintain the refrigerant monitoring system.

Step 23: Calibration

- Calibration intervals must comply with manufacturer's recommendations.
- Calibration kits should be provided at the date of delivery of the gas detection system
- Owner may consider using factory-authorized service representative to maintain and calibrate the gas monitoring system periodically.

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