REFRIGERATION SYSTEMS

INTRODUCTION

Refrigerant are used in many industries and occupancies for the coolant of products and people. The size of the refrigerant system could be as small as a room air conditioner and ice makers found in hotels and motels to as large as a system to freeze food or chemicals and industrial processes. The types of refrigerant used vary depending on the type of system, the temperature at which the unit must produce, and the size.

The refrigerant themselves vary depending on the end use temperature. Water could be used as a refrigerant in large air conditioning systems. Other refrigerants include:

- Ammonia (R717)
- Antifreeze mixtures
- Brines
- Carbon dioxide (R744)
- Chlorofluorocarbons (CFC), such as Chlorodifluoromethane, Chlorofluoromethane, Chlorotrifluoromethane, Dichlorodifluoromethane, Difluoromethane, Dichlorofluoromethane, and Trichlorofluoromethane
- Hydrocarbons (HC) such as Butane, Ethane, Methane, and Propane
- Hydrochlorofluorocarbons (HCFC) such as Chlorodifluoromethane, Chlorofluoromethane, Dichlorofluoromethane, Dichloromethane (methylene chloride), Octafluoropropane, Tetrachlorofluoroethane, and Trichlorodifluoroethane
- Hydrofluorocarbons (HFC) such as Difluoromethane, Fluoromethane, Pentafluoroethane, and Trifluoromethane (Fluoroform)
- Azeotropic blends, a blend of two or more refrigerants whose equilibrium vapor and liquid-phase compositions are the same at a given pressure
- Zeotropic blends, a blend of multiple components of different volatilities that, when used in refrigeration cycles, change volumetric composition and saturation temperatures as they evaporate (boil) or condense at constant pressure.

Due to their ozone depletion capabilities the Chlorofluorocarbon refrigerants are being phased out. Non halogenated hydrocarbons are increasing in their use. Chemicals that have Global Warming Potential (GWP) are also under scrutiny.

Early mechanical refrigeration systems employed sulfur dioxide, methyl chloride and ammonia. Since sulfur dioxide and methyl chloride are toxic they were stopped being used. Ammonia is still being used today.

Refrigerants system can be used as either a direct or indirect system. In the direct refrigerant system the fluid is in direct contact with the material being heated or cooled. In the indirect refrigerant system the fluid is heating or cooling a secondary medium to heat or cool the material.

Refrigerants are classified into safety groups depending on the toxicity and flammability. The classification rating will have an alpha character for the toxicity and a numeric number for the flammability.

The letter "A" is for those refrigerants with an occupational exposure limit (OEL), the time-weighted average concentration for an eight-hour workday and a 40-hour workweek where workers can be repeatedly exposed without adverse effect, of ≥400 ppm.

The letter "B" is for those refrigerants OEL of < 400 ppm.

The numeric value, 1 to 3 is based on flammability limit testing, heat of combustion, and the optional burning velocity measurement. Flammability tests shall be conducted in accordance with ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)*. The classes are broken down as follows:

- Class 1 - No flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa)
- Class 2L – Has a maximum burning velocity of ≤3.9 in./s (10 cm/s) when tested at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa)
- Class 2 - Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa), the lower flammability limit (LFL) > 0.0062 lb/ft³ (0.10 kg/m³), and the heat of combustion is <8169 Btu/lb (19,000 kJ/kg)
- Class 3 - Flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa), the lower flammability limit (LFL) ≤ 0.0062 lb/ft³ (0.10 kg/m³), and the heat of combustion is ≥8169 Btu/lb (19,000 kJ/kg)

Table 1 summarizes the requirements for flammability limit testing.

TABLE 1
Flammability Limit Testing

Class	Flame Propagation at 140°F (60°C) and 14.7 psia (101.3 kPa)	Lower Flammability Limit		Heat of Combustion Btu/lb (kJ/kg)	Maximum Burning Velocity at 73.4°F (23°C) in/s (cm/s)
		In air by vol.%	lb/ft³ (kg/m³)		
1	N	N/A	N/A	N/A	- - - - -
2L	Y	> 3.5	> 0.0062 (0.10)	< 8169 (19000)	≤ 3.9 (10)
2					- - - - -
3	Y	≤ 3.5	≤ 0.0062 (0.10)	≥ 8169 (19000)	- - - - -

Refrigerant Cycle

There are three main refrigerant cycles, vapor-compression cycle, vapor absorption cycle, and gas cycle.

The vapor-compression cycle is used in many large commercial and industrial refrigeration systems. Figure 1 shows a typical vapor-compression refrigeration system and Figure 2 shows a typical vapor absorption refrigeration system.

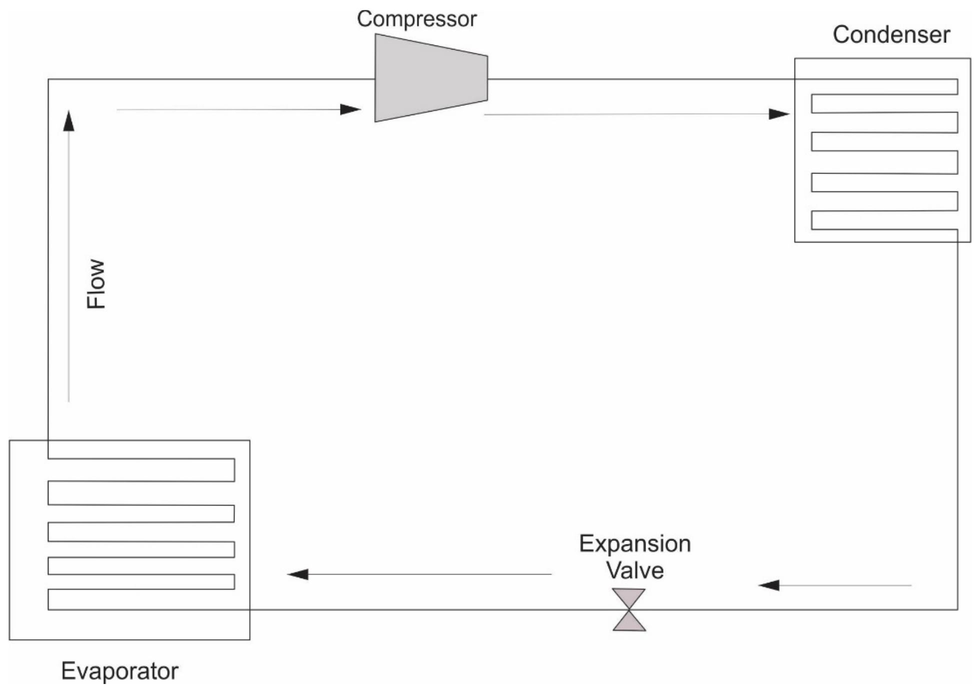

Figure 1: Typical Vapor-Compression Refrigeration Cycle

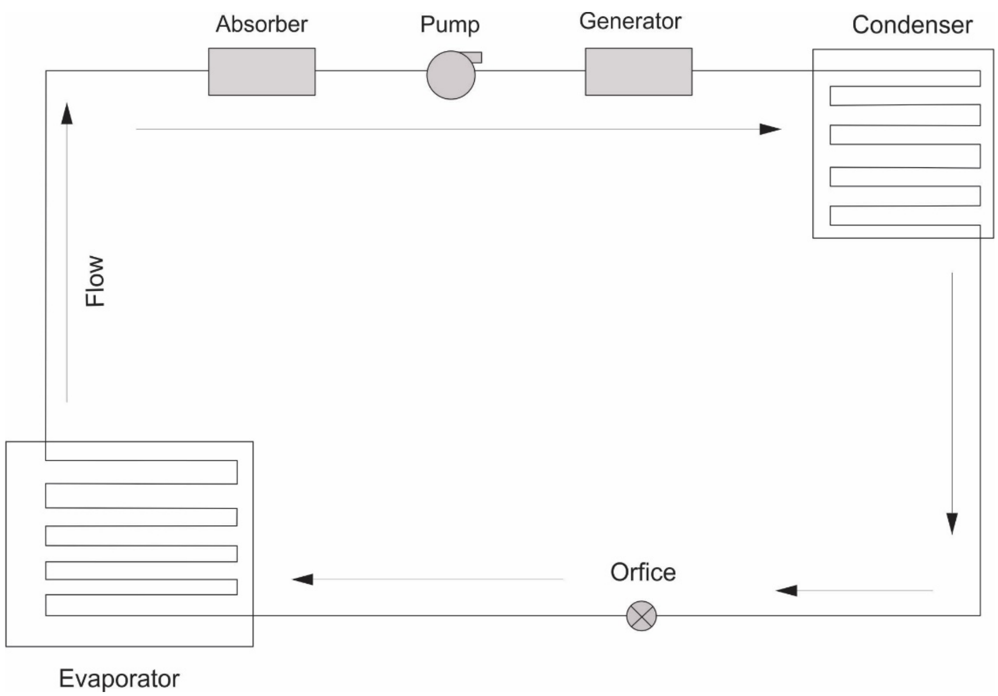

Figure 2: Typical Vapor-Compression Refrigeration Cycle

The Uses

The most common use of a refrigeration system is for cooling or freezing of food products. It is also used for climate control in office buildings, restaurants, hospitals, computer rooms, medical products warehouses, cooling off gases to their liquid state, keeping production machines from overheating, separating gases into their elements, and environmental chambers for testing.

The most common usage in food coolers and freezers is ammonia (R747), an B2 refrigerant. An ammonia systems is cheaper to build and use since it uses smaller diameter piping that the CFC, requires less energy to cool the object, more efficient, has a an Ozone Depletion Potential (ODP) rating of 0 and a Global Warming Potential (GWP) rating of 0, and cost less that hydrocarbon refrigerants.

POSITION

General

Install all components for the refrigerant systems such as the condenser, pumps, etc. either outdoors, in a detached building at least 20 ft (6.1 m) for all but ammonia systems or 50 ft (15.25 m) for ammonia systems from any other building or in a cut-off machinery room.

If the machine room is located in a building, locate the machinery room along an outside wall, preferably a room that has three (3) outside walls. For all but the HC refrigerants, construct the remaining wall(s) with at least a 1 hr fire resistance rated construction. For refrigerant systems using HC refrigerant, construct the remaining wall(s) with at least a 2 hr fire resistance rated construction. Construct these walls to be tight construction to prevent leakage of the refrigerant into the rest of the building.

Seal all pipe penetrations in the ceiling, floor, and walls.

Do not install Class 2, 2L or 3 refrigeration systems in basements.

Protect the machinery room with an automatic sprinkler systems designed to provide a design density of 0.20 gpm/ft² (8.14 L/min/m²) over a 3000 ft² (279 m²) area.

Install refrigerant detectors in the machinery room. Set the refrigerant detectors to sound an alarm and engage the emergency mechanical ventilation when the detector reaches the Threshold Limit Value-Time Weighted Average (TLV-TWA) values of the refrigerant.

Where Class 2, or 3 refrigerants are used and a leak of any circuit could cause the space to reach 25% of the LEL, install and use Class 1, Division 2 electrical equipment in the room.

Provide normal and emergency mechanical ventilation for the room. Normal ventilation rate of 1 ft³/min/ft² (0.3 m³/min/m²) of room area. Activate the emergency ventilation at 25% of the LEL. Provide dedicated exhaust and make-up air systems for the room. Locate the exhaust from the ventilation system at least 20 ft (6.1 m) from building openings and air intakes. Provide sufficient make-up air for the room for both normal and emergency venting rates.

> **NOTE:** Where the refrigerant is considered toxic or highly toxic by the building or fire code, precautions must be taken as to where to vent the room.

Arrange the alarm that the loss of ventilation alert employees.

Arrange to automatically shut down all power (excluding the exhaust fans) in the machinery room when the LEL levels reach 50% in the room. Supply power to the exhaust fans from a separate source other than machinery room.

Provide an explosion venting ratio of a least 1:30 for ammonia refrigerant systems (1 ft² of venting for every 30 ft³ (1 m² of venting for every 9 m³)) of room volume) and 1:10 for all other refrigerant systems (1 ft² of venting for every 10 ft³ (1 m² of venting for every 3 m³)) of room volume). If lightweight vent panels (2.5 lb/ft² (0.12 kPa)) are used, they should release at an internal pressure of 20 lb/ft² (0.96 kPa). Provide lightweight vent panels with fasteners to prevent the panels from becoming missiles during a venting occurrence.

Brace all piping and components for earthquakes (see PRC.2.0.9.1).

Restrict access to the machinery room to authorized personnel.

Ensure all personnel who would work with and on the refrigeration system have proper training. Review the training every year.

Develop a written Pre-Emergency Plan (PEP) to respond with appropriate personal and equipment in case of a spill or leak. Practice this plan on an annual basis.

Use refrigerators and freezers that are tested and listed to UL 471 *Standard for Commercial Refrigerators and Freezers*.

Ammonia Refrigerant Systems

See PRC.7.2.1.2 for additional information.

For ammonia refrigerant systems; design, construct, commission, operate, and decommission to the following:

- Design and construct ammonia refrigeration systems in accordance with ANSI/IIAR 2 *Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems*.
- Install them in accordance with ANSI/IIAR 4 Installation of Closed-Circuit Ammonia Refrigeration Systems.
- Commission the systems in accordance with ANSI/IIAR 5 Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems
- Write operating and emergency procedures in accordance with ANSI/IIAR 7 Developing Operating Procedures for Closed-Circuit Ammonia Mechanical Refrigerating Systems
- Remove the system from service in accordance with ANSI/IIAR 8 Decommissioning of Closed-Circuit Ammonia Refrigeration Systems

All Other Refrigerant Systems

Design, construct, install and operate refrigeration systems in accordance with:

- ANSI/ASHRAE 15, Safety Standard for Refrigeration Systems.
- AS/NZS 1677.2 Part 2, Refrigerating Systems, Part 2: Safety Requirements For Fixed Applications
- EN 378 2, Refrigerating Systems And Heat Pumps. Safety And Environmental Requirements. Design, Construction, Testing, Marking And Documentation
- ISO 5149 Part 2, Refrigerating Systems And Heat Pumps — Safety And Environmental Requirements — Part 2: Design, Construction, Testing, Marking And Documentation

DISCUSSION

There have been reports of fires and explosions with refrigeration systems. Explosions are more likely to occur than fires. The explosions are mainly due to mechanical breakdown of the equipment, lack of maintenance, or improper installation. Depending on the refrigerant, contamination can occur and the room or area could be filled with toxic gasses.

The following list summarizes the common refrigerants.

- Chlorofluorocarbons (CFC) now banned because of their negative environmental impacts.
- Hydrochlorofluorocarbons (HCFC) is a temporary substitute for CFCs. In the European Union, HCFCs have been banned for refrigeration systems and air conditioning systems.
- Hydrofluorocarbons (HFC) are refrigerants that contain no chlorine and are not harmful to the ozone layer however; their impact on global warming is very large compared with traditional refrigerants.
- Fluorocarbons (FC) contain no chlorine and are not harmful to the ozone layer.
- Hydrocarbons (HC) are very environmentally friendly (Oxygen depletion potential (ODP) is 0 and global warming potential (GWP) is <5). However, they are highly flammable.
- Ammonia (NH_3) has been used in refrigeration systems since 1840. It is quite common in commercial refrigeration systems. Its ODP and GWP are 0. However, it is toxic.

- Carbon dioxide (CO_2) is non-flammable and does not cause ozone depletion, but is an asphyxiant gas. Concentrations of 7% to 10% (70,000 to 100,000 ppm) may cause suffocation.

For additional information on refrigeration systems see the NFPA *Fire Protection Handbook*.