



HVAC SYSTEMS - CEM REFRESHER ONLINE TRAINING COURSE

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VAPOR COMPRESSION REFRIGERATION CYCLE FOR ENERGY PROFESSIONALS

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WHAT SHOULD YOU LEARN





- Brief Introduction about HVAC systems
- Types of Refrigeration System
- Common Refrigerants and Properties
- Compressor Types and Application
- Selection of a Suitable Refrigeration System
- Performance Assessment of Refrigeration Plants

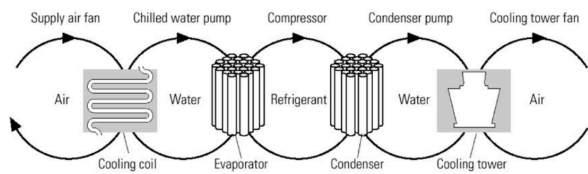
INTRODUCTION

The Heating, Ventilation and Air Conditioning (HVAC) and refrigeration system transfers the heat energy from or to the products, or building environment. Energy in form of electricity or heat is used to power mechanical equipment designed to transfer heat from a colder, low energy level to a warmer, high-energy level.

Refrigeration deals with the transfer of heat from a low temperature level at the heat source to a high temperature level at the heat sink by using a low boiling refrigerant.

There are several heat transfer loops in refrigeration system as described below:

HEAT TRANSFER LOOPS IN REFRIGERATION SYSTEM



HEAT TRANSFER LOOPS IN REFRIGERATION SYSTEM +

In the Figure above figure .1, thermal energy moves from left to right as it is extracted from the space and expelled into the outdoors through five loops of heat transfer:

- ✓ **Indoor air loop:** In the left most loop, indoor air is driven by the supply air fan through a cooling coil, where it transfers its heat to chilled water. The cool air then cools the building space.
- ✓ **Chilled water loop:** Driven by the chilled water pump, water returns from the cooling coil to the chiller's evaporator to be re-cooled.
- ✓ **Refrigerant loop:** Using a phase-change refrigerant, the chiller's compressor pumps heat from the chilled water to the condenser water.
- ✓ **Condenser water loop:** Water absorbs heat from the chiller's condenser, and the condenser water pump sends it to the cooling tower.
- ✓ **Cooling tower loop:** The cooling tower's fan drives air across an open flow of the hot condenser water, transferring the heat to the outdoors.

AIR-CONDITIONING SYSTEMS

Depending on applications, there are several options / combinations, which are available for use as given below:

- ✓ Air Conditioning (for comfort / machine)
- ✓ Split air conditioners
- ✓ Fan coil units in a larger system
- ✓ Air handling units in a larger system

REFRIGERATION SYSTEMS (FOR PROCESSES)

- ✓ Small capacity modular units of direct expansion type similar to domestic refrigerators, small capacity refrigeration units.
- ✓ Centralized chilled water plants with chilled water as a secondary coolant for temperature range over 5°C typically. They can also be used for ice bank formation.
- ✓ Brine plants, which use brines as lower temperature, secondary coolant, for typically sub zero temperature applications, which come as modular unit capacities as well as large centralized plant capacities.

REFRIGERATION SYSTEMS (FOR PROCESSES)

- ✓ The plant capacities upto 50 TR are usually considered as small capacity, 50 – 250 TR as medium capacity and over 250 TR as large capacity units.

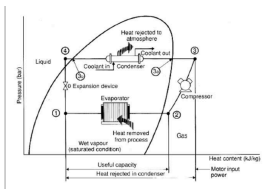
Large industry may have a bank of such units, often with common chilled water pumps, condenser water pumps, cooling towers, as an off site utility. The same industry may also have two or three levels of refrigeration & air conditioning such as:

- ✓ Comfort air conditioning (20° – 25° C)
- ✓ Chilled water system (8° – 10° C)
- ✓ Brine system (sub-zero applications)

Two principle types of refrigeration plants found in industrial use are: Vapour Compression Refrigeration (VCR) and Vapour Absorption Refrigeration (VAR). VCR uses mechanical energy as the driving force for refrigeration, while VAR uses thermal energy as the driving force for refrigeration.

TYPES OF REFRIGERATION SYSTEM

Vapour Compression Refrigeration



Heat flows naturally from a hot to a colder body. In refrigeration system the opposite must occur i.e. heat flows from a cold to a hotter body. This is achieved by using a substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source.

ALTERNATIVE REFRIGERANTS FOR VAPOUR COMPRESSION SYSTEMS

- ❑ The use of CFCs is now beginning to be phased out due to their damaging impact on the protective tropospheric ozone layer around the earth.
- ❑ The Montreal Protocol of 1987 and the subsequent Copenhagen agreement of 1992 mandate a reduction in the production of ozone depleting Chlorinated Fluorocarbon (CFC) refrigerants in a phased manner, with an eventual stop to all production by the year 1996. In response, the refrigeration industry has developed two alternative refrigerants; one based on Hydrochloro Fluorocarbon (HCFC), and another based on Hydro Fluorocarbon (HFC). The HCFCs have a 2 to 10% ozone depleting potential as compared to CFCs and also, they have an atmospheric lifetime between 2 to 25 years as compared to 100 or more years for CFCs (Brandt, 1992). However, even HCFCs are mandated to be phased out by 2005, and only the chlorine free (zero ozone depletion) HFCs would be acceptable.
- ❑ Until now, only one HFC based refrigerant, HFC 134a, has been developed. HCFCs are comparatively simpler to produce and the three refrigerants 22, 123, and 124 have been developed. The use of HFCs and HCFCs results in slightly lower efficiencies as compared to CFCs, but this may change with increasing efforts being made to replace CFCs.



ABSORPTION REFRIGERATION

- ❑ The absorption chiller is a machine, which produces chilled water by using heat such as steam, hot water, gas, oil etc. Chilled water is produced by the principle that liquid (refrigerant), which evaporates at low temperature, absorbs heat from surrounding when it evaporates. Pure water is used as refrigerant and lithium bromide solution is used as absorbent.
- ❑ Heat for the vapour absorption refrigeration system can be provided by waste heat extracted from process, diesel generator sets etc. Absorption systems require electricity to run pumps only. Depending on the temperature required and the power cost, it may even be economical to generate heat / steam to operate the absorption system.



EVAPORATIVE COOLING

- ❑ There are occasions where air conditioning, which stipulates control of humidity up to 50 % for human comfort or for process, can be replaced by a much cheaper and less energy intensive evaporative cooling.
- ❑ The concept is very simple and is the same as that used in a cooling tower. Air is brought in close contact with water to cool it to a temperature close to the wet bulb temperature. The cool air can be used for comfort or process cooling. The disadvantage is that the air is rich in moisture.
- ❑ Nevertheless, it is an extremely efficient means of cooling at very low cost. Large commercial systems employ cellulose filled pads over which water is sprayed. The temperature can be controlled by controlling the airflow and the water circulation rate. The possibility of evaporative cooling is especially attractive for comfort cooling in dry regions. This principle is practiced in textile industries for certain processes.



COMMON REFRIGERANTS AND PROPERTIES

A variety of refrigerants are used in vapor compression systems. The choice of fluid is determined largely by the cooling temperature required. Commonly used refrigerants are in the family of chlorinated fluorocarbons (CFCs, also called Freons): R-11, R-12, R-21, R-22 and R-502.

The properties of these refrigerants are summarized in Table 1 and the performance of these refrigerants is given in Table 2.

The choice of refrigerant and the required cooling temperature and load determine the choice of compressor, as well as the design of the condenser, evaporator, and other auxiliaries. Additional factors such as ease of maintenance, physical space requirements and availability of utilities for auxiliaries (water, power, etc.) also influence component selection.

PROPERTIES OF COMMONLY USED REFRIGERANTS

Refrigerant	Boiling Point ** (°C)	Freezing Point (°C)	Vapor Pressure * (kPa)	Vapor Volume * (m ³ /kg)	Liquid Enthalpy * (kJ/kg)	Vapor Enthalpy * (kJ/kg)
R - 11	-23.82	-111.0	25.73	0.61170	191.40	385.43
R - 12	-29.79	-158.0	219.28	0.07702	190.72	347.96
R - 22	-40.76	-160.0	354.74	0.06513	188.55	400.83
R - 502	-45.40	---	414.30	0.04234	188.87	342.31
R - 7 (Ammonia)	-33.30	-77.7	289.93	0.41949	808.71	487.76

* At -10°C

** At Standard Atmospheric Pressure (101.325 kPa)

Refrigerant	Evaporating Press (kPa)	Condensing Press (kPa)	Pressure Ratio	Vapor Enthalpy (kJ/kg)	COP** _{sat}
R - 11	20.4	125.5	6.15	155.4	5.03
R - 12	182.7	744.6	4.08	116.3	4.70
R - 22	295.8	1192.1	4.03	162.8	4.66
R - 502	349.6	1308.6	3.74	106.2	4.37
R - 717	236.5	1166.5	4.93	103.4	4.78

* At -15°C Evaporator Temperature, and 30°C Condenser Temperature

** COP_{sat} = Coefficient of Performance = $\frac{\text{Temp}_{\text{Evap}}}{(\text{Temp}_{\text{Cond}} - \text{Temp}_{\text{Evap}})}$

COMPRESSOR TYPES AND APPLICATION

For industrial use, open type systems (compressor and motor as separate units) are normally used, though hermetic systems (motor and compressor in a sealed unit) also find service in some low capacity applications.

Hermetic systems are used in refrigerators, air conditioners, and other low capacity applications. Industrial applications largely employ reciprocating, centrifugal and, more recently, screw compressors, and scroll compressors.

Water-cooled systems are more efficient than air-cooled alternatives because the temperatures produced by refrigerant condensation are lower with water than with air.