10 Refrigeration and Air Conditioning

Introduction, What is refrigeration, Evaporation, Refrigerating effect, Early means of refrigeration, Unit of refrigeration, How refrigeration is produced, Main components and function of a system, Typical vapour compression system, Refrigerants, Absorption refrigeration system, Advantages and disadvantages, Air refrigeration, Air Conditioning. Window air conditioner, Split air conditioner.

10.1 Introduction :

- We know that heat is always flowing from higher temperature to lower temperature. Water is always flowing from high altitude to lower one. In order to fill the over head tank by water from sump. placcd at the ground, we need a pump. Similarly in order to flow heat from lower temperature to the higher temperature some mechanical means must be provided. This principle is used in Refrigeration. This principle you have also studied in Second Law statements.

What is second Law of thermodynamcis ?

- Heat is always flowing from the higher temperature to lower temperature. OR You cannot get something for nothing and you may not even get something for something i.e. any process is never 100% efficient.

10.2 What is Refrigeration ? **(Dec. 2008, Jan. 2009, Dec. 2013)**

Refrigeration has many definitions viz. -

(1) The Process of cooling or removing heat

(2) The process by which "cold" is produced.

(3) The process of removing heat from a space or substance to reduce its temperature and transferring that heat to another space or substance.

By carefully studying the above statements, it is clear what Refrigeration is.

10.3 Evaporation :

- The concept of evaporation is the key to produce a cooling effect. Let us take one example.
- Our body temperature is 37°C. Let the surrounding air at 37°C, blow over the body. We have no feeling of cooling. If you jump into the pool having a temperature of 37°C, you don't feel cooled in pool also. When you get out of the pool, you feel quite cool because the breeze outside will evaporate water on your skin. This evaporation absorbs its latent heat which is being drawn from our body and we feel cool.

When we are perspiring, standing in front of a fan will make us cool by evaporation of perspiration.

This principle is used in refrigeration to produce low temperature in a refrigeration system.

10.4. Refrigerating effect : **(Dec. 2008)**

- It is the amount of heat absorbed in the evaporator (equipment used to evaporate circulating substance) and which is the same as the amount of heat removed from the space to be cooled.

10.5 Some early means of refrigeration

- Before the advent of mechanical refrigeration, water was kept cool by storing it in semi porous earthenware jugs. The water that seep through the hole evaporate and cooling was produced - known as evaporative cooling. This system was used by Egyptians and Indians. Natural ice from lakes and rivers was often cut during winter and stored in caves and other insulated buildings. The ice was very widely used to produce cooling in early days. **(Dec. 2008)**

10.6 Unit of Refrigeration :

- Ton is the unit of Refrigeration. Now kW is used in S.I. units. The ton is normally the unit of mass. But in refrigeration, this is used in order to compare the capacity of the system with that of ice melting equivalent since ice was widely used for cooling in early days. It is very obvious to compare the capacity of the mechanical system with that of the heat absorbed by ice. For that, the cooling produced by melting of one ton of ice in a day is taken as a datum. This is equal to,

$$= \frac{\text{Mass of ice} \times \text{Latent heat of ice}}{24 \times 3600} \text{ kJ / Sec}$$

$$= \frac{900 \text{ (kg)} \times 335 \text{ (kJ / kg)}}{24 \text{ (Hr)} \times 3600 \text{ (Sec)}} \quad (\because \text{ one Short ton} = 900 \text{ kg.})$$

$$= 3.4895833 \approx 3.5 \text{ kJ/Sec} = 3.5 \text{ kW.}$$

$$\therefore \quad 1 \text{ Ton} = 3.5 \text{ kW}$$

- Even though this is very widely used unit, this unit is not popular for Domestic Refrigerators (Storage capacity is specified). Water cooler (cooling capacity of water in litre is specified). Bottle cooler (Capacity of bottle to be stored is specified.)
- **Work of compression :** This is the amount of energy required to drive the compressor.

10.6 A How efficiency of Refrigeration system is represented ?

- The efficiency of Refrigeration system is represented as C.O.P. (coefficient of performance).

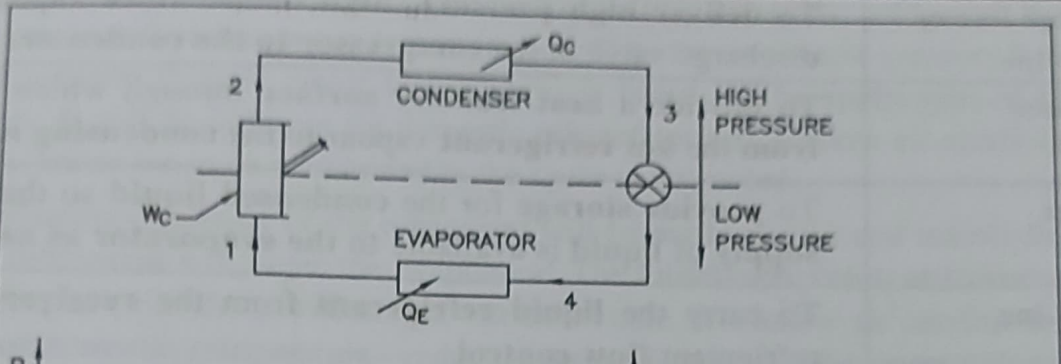
C.O.P. = Refrigerating effect / Work of compression

10.7 How refrigeration is produced ?

- Mechanical refrigeration is possible because of boiling of a volatile liquid, called refrigerant. under proper condition. This refrigerant will absorb heat from the surrounding objects. The actual cooling is produced because of this boiling.

The simple cycle is shown below :

The pressure enthalpy and temperature entropy skeleton charts are also shown in the above Fig. 10.1.


Q_C
CONDENSER
2
3
HIGH
PRESSURE
W_C
LOW
PRESSURE
EVAPORATOR
1
4
Q_E

10.8 Main components and function of a mechanical refrigeration system.

- There are mainly four main components of a mechanical refrigeration system.
  (a) Compressor (b) Condenser (c) Expansion device (d) Evaporator.
- This is being shown in Fig. 10.1 along with P-h and T-ϕ diagram.

The cooling is produced by evaporator. The purpose of the compressor, its drive, condenser, piping, and control devices etc., is to allow refrigerant to be reused again and again. As a matter of convenience and economy, it is not practical to permit the refrigerant vapour to escape to the outside, and be lost by diffusion into the air.

10.9. Typical Vapour compression system :

(March 2009, June 2009, June 2010, Jan. 2011, Dec. 2011, June 2012, Dec. 2014)

- A flow diagram of a simple vapour compression system is shown in figure 10.2. The principal parts of the system and their functions are as under.

Part	Function.
1. Evaporator	To **provide a heat transfer surface** through which heat can pass from the **refrigerated space** or product into the **vaporising refrigerant.**
2. Suction Line	To **convey** the low **pressure** vapour from the **evaporator** to the **suction** inlet of the **compressor.**
3. Compressor	To **remove** the vapour from the **evaporator** and to **raise the temperature** and **pressure** of the **vapour** to a point such that the vapour can be **condensed** with normally available **condensing media.**

4. Discharge line or hot gas line	To **deliver high pressure, high temperature** vapour from the discharge valve of the **compressor to the condenser.**
5. Condenser	To provide a **heat transfer surface** through which **heat passes from the hot refrigerant** vapour to the **condensing medium.**
6. Receiver	To **provide storage** for the **condensed liquid** so that a **constant supply** of **liquid** is available **to the evaporator as needed.**
7. Liquid Line	To carry the **liquid refrigerant** from the **receiver** tank to the refrigerant **flow control**
8. Refrigerant flow control	To **meter** the **proper amount of refrigerant to** the **evaporator** and to **reduce** the **pressure** of the liquid entering the evaporator so that **liquid will vaporize** in the evaporator at the **desired low** temperature.

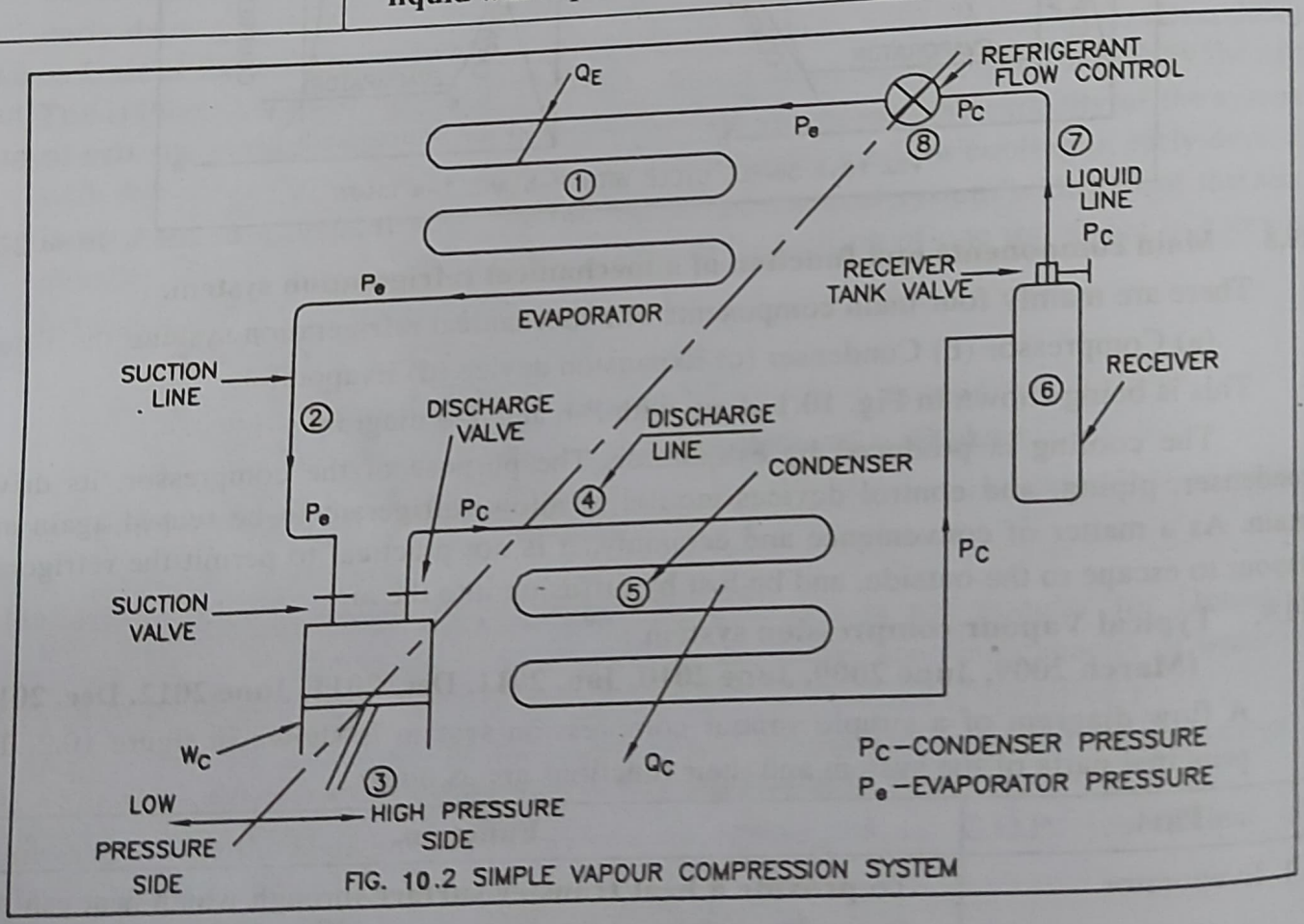


FIG. 10.2 SIMPLE VAPOUR COMPRESSION SYSTEM

Description of the cycle :

- High pressure, high temperature refrigerant will enter the condenser through discharge valve. In order to condense the refrigerant vapour to liquid the pressure and hence the temperature of the refrigerant vapour must be higher than the temperature of the normally available cooling medium - air or water.
- The refrigerant leaving the condenser will be in a liquid form. This liquid refrigerant will

enter the receiver. The liquid from the receiver than enters the refrigerant flow control. The pressure is reduced from condenser pressure P_c to the evaporator pressure P_e by flow control. This pressure P_e (and hence temperature) is based on the application of the refrigeration system. It will be different for domestic refrigerator and window air conditioner as different temperatures are to be maintained in the space to be cooled.

- The entering condition of the refrigerant will be partly vapour and mainly liquid refrigerant. This refrigerant will enter the evaporator. The liquid refrigerant, at lower temperature will absorb heat from the surroundings - Room in case of window air conditioner and cabinet in case of domestic refrigerators - reducing the temperature of the surroundings and converting liquid refrigerant into a vapour form. Low temperature, low pressure vapour refrigerant enter the compressor. The cycle is then repeated.

10.11. Air Conditioning :

- Air conditioning is dealing with conditioning or controlling the air. It is defined as under :

  "It is the simultaneous control of air temperature, air humidity air movement and air cleanliness".

- Air conditioning is not simply a matter of heating or cooling air to some desired temperature. The complete process of air conditioning is also concerned with humidification (addition of moisture) and/or dehumidification (removal of moisture) with ventilation (introduction of fresh outside air to reduce concentration of CO_2) and with air cleaning and air distribution.

- The control of air is based on human comfort. The standards of human comfort vary with, location on the earth, climate, the seasons of the year, the life style and habits of dress of the population, and the nature of their physical activity.

- Of all the properties that affect air conditioning, moisture content or humidity is perhaps the most important. The science which investigate the properties of air-water vapour mixtures is called psychrometry.
- Air which is too dry affects the nasal passages and skin adversely. It is also damaging to some materials and furnishings. Air which is too moist makes people uncomfortable. Many products require precise control of temperature, humidity, and air cleanliness.
- Air conditioning is essential for computers, electronics industries, precision manufacturing, communications network, schools, hospitals, hotels, theaters, restaurants, office, drug manufacturing companies etc.
- Air conditioning is one of the application of refrigeration, to achieve desirable conditions inside the space to be air conditioned. The cycle as studied in Art 10.9 is also used here.

10.11.1 Window Air conditioner : **(Sept. 2009, Dec. 2010, Dec. 2013)**

- It is also known as room air conditioner as it is mainly used for conditioning room air. For majority of the applications, since this unit is mounted in a window hence it is very widely known as window air conditioner. The construction of window units is shown in figures 10.3 and 10.4
- These units shown in figures are designed for the delivery of conditioned air to the room.
- Each unit includes a prime source of refrigeration (a compressor) dehumidification (by means of cooling coil or evaporator) means of circulation (by means of a fan) and cleaning (with the help of filter) the air.
- The basic **Function** of a room air conditioner is to provide comfort cooling (reducing the temperature of outside air or room air) dehumidification, filtering and circulating the room air. It may also provide **ventilation** by introducing outside air into the room or exhausting room air to the outside by means of suitable dampers that can be operated with the help of a knob placed in the front of air conditioner.
- Supply air temperature to the room is controlled by selecting desired thermostat setting with the help of the knob again placed in the front of air conditioner.

(1) Compressor. (2) Condenser
(3) Capillary tube - Expansion device (4) Evaporator
(5) Condenser fan. (6) Evaporator fan.
(7) Filter. (8) Thermostat and other controls
(9) Exhaust and ventilation damper (10) Starting switch
(11) Grille (12) Tray

The cycle of operation is same as described in Art 10.9. The function of different components are shown below.

Component	Function
1. Compressor	To remove the vapour from the evaporator and to increase the temperature and pressure required for condensation.
2. Condenser	To provide a heat transfer surface and to convert the hot refrigerant gas into the liquid form.

3. Capillary tube	It is an expansion device. It is a very small diameter and long length tube. Because of the high frictional resistance and because of long length and small bore, pressure is dropped from condenser pressure to evaporator pressure.
4. Evaporator	To produce useful cooling by absorbing heat from the air as it is placed inside the area to be cooled.
5. Condenser Fan	The cooling medium- air-is circulated with the help of this fan.
6. Evaporator Fan	This fan is controlling the velocity of air entering the room. Fan with very low noise level is generally used for evaporator. This will help in reducing room noise level.
7. Filter	Placed before the evaporator. The air that is entering the unit is cleaned with the help of it. This will help in supplying clean air to the room.
8. Controls	Thermostat – Control room temperature. Placed ahead of filter and that will sensed the temperature of air entering the unit Relay – It is used to remove the starting circuit from operation when the motor reaches approximately 75% of its normal rated speed. Overload Protector – To protect the compressor motor from damage because of an over current or over temperature or both. Capacitor – To improve the starting and running characteristics of motor. Filter drier – To absorb and hold moisture and other impurities in a system.
9. Exhaust and Ventilation damper	To exhaust the room air. Exhaust damper and Ventilation damper will provide fresh outside air for ventilation. Both can be operated with the help of knob placed on the front of the air conditioner.
10. Starting Switch	To start and stop the unit. Located on the front of the air conditioner.
11. Grille	Decorative cover placed with guided vanes. These vanes are used to adjust the direction of conditioned air to the room
12. Tray	Collects condensate (water coming out from the air after dehumidification) because of cooling of the air and thus controlling humidity. Placed below the evaporator. Water is to be removed from the tray through the tube connected with the tray.

Advantages of window air conditioner :

1. Smaller length of tubes are required to connect condenser and evaporator which will reduce friction losses.
2. Fresh air intake is possible to introduce.

Disadvantages of window air conditioner :

1. Suitable gap based on the size of the cabinet be made either in the window or wall.
2. Installation is costly and requires more time and expertise.
3. Evaporator location is fixed since it is in cabinet.
4. Once the unit is installed the condenser is also installed.
5. Location is not possible for a room without any outside wall/windows.
6. Since compressor is in the cabinet noise due to compressor is present.

10.11.2 Split Air Conditioner :- This is the recent development of window air conditioner.

- Split air conditioner is known by that name because in this, the window air conditioner is split in two parts.
  - (a) Evaporator, filter, evaporator fan and grille are placed in the room.
  - (b) Condenser, condenser fan and compressor being placed outside the room.
  - (c) Both these parts are connected by two tubes. Thus restricting the hole in the wall corresponding to the outside diameter of two tubes.

  The three disadvantages of window air conditioner are-
  - (a) Operating sound level is high because of compressor is very near to the room.
  - (b) Requires outside air for condenser cooling and thus cannot be used for interior rooms.
  - (c) Hole of appropriate size be made either in the window or in the wall in order to fit the conditioner.

10.11.3 Comparision between window Air conditioner and split Air conditioner

Window Air Conditioner	Split Air Conditioner
1. It is a package unit having all components placed in a cabinet.	1. It is not packaged unit.
2. Evaporator and condenser/compressor are nearer to each other.	2. Evaporator is placed in the room while condenser/compressor is outside the room at a convenient place.
3. Suitable gap based on the size of the cabinet be made either in the window or wall.	3. Only suitable hole to be drilled in the wall in order to pass two tubes connecting evaporator and condenser.
4. Smaller length of tubes are required to connet condenser and evaporator.	4. Longer length of tubes are required to connect condenser and evaporator.
5. Installation is costly and requires more time and expertise.	5. Since only two holes are to be drilled installation is simple.
6. Evaporator location is fixed since it is in cabinet.	6. Evaporator can be placed any convenient place in the room.
7. Once the unit is installed the condenser is also installed.	7. Seperate location for condenser is to be selected outside and it is installed.
8. Since compressor is in the cabinet, noise due to compressor is present.	8. Since compressor/ condenser is placed away from the room, the noise due to compressor is not present.
9. Pressure loss in the tubes connecting condenser and evaportaor is comparatively less due to shoter length.	9. Pressure loss in tubes connecting condenser and evaporator is more due to longer length.
10. Fresh air intake is possible to introduce.	10. No fresh air intake is possible.
11. Location is not possible for a room without any outside. wall/windows.	11. Can be located on any wall in the room.