REFRIGERATION AND AIR CONDITIONING

UNIT-2

PRESENTED BY

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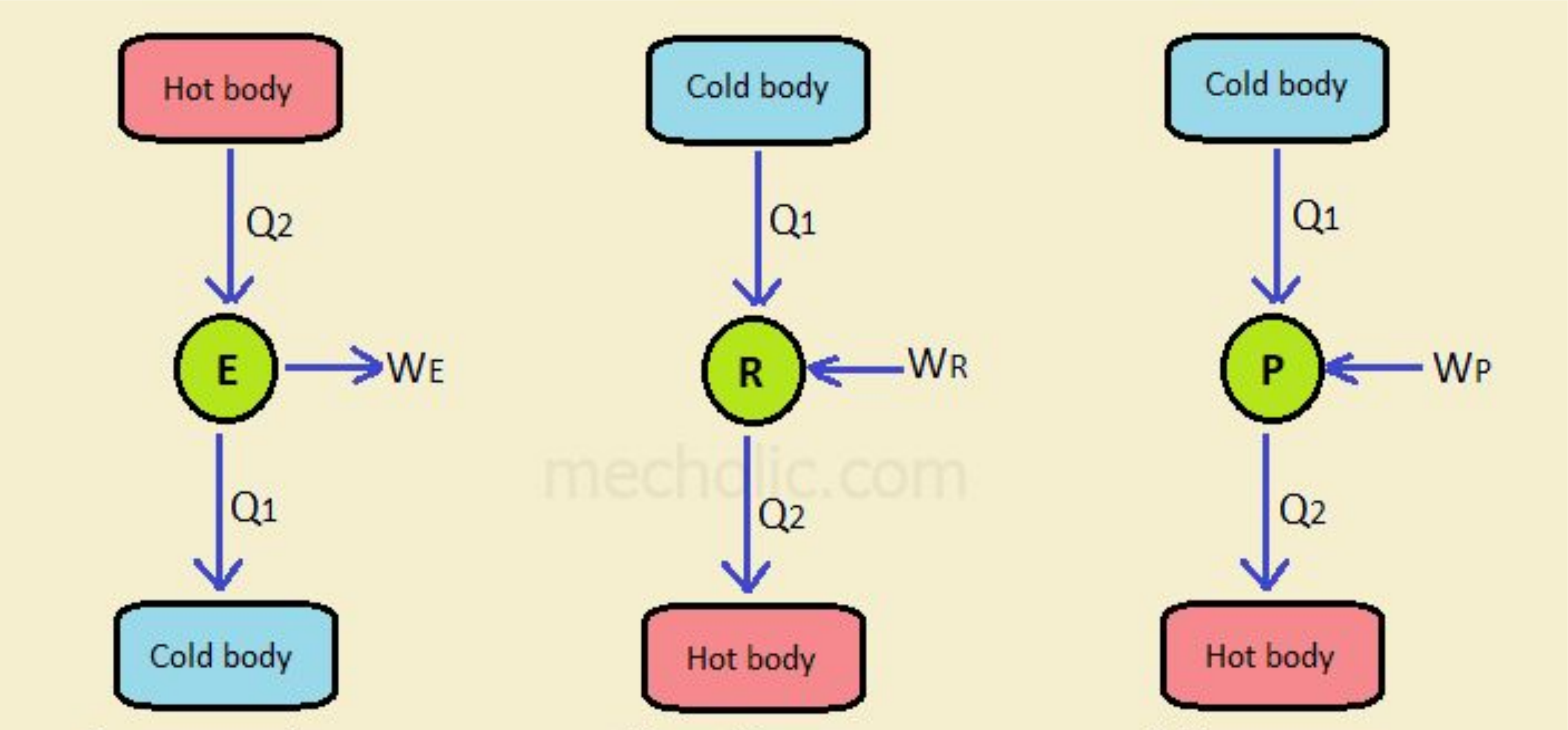
CONTENT

INTRODUCTION

- Refrigeration is the science of the producing and maintaining temperature below that of the surrounding atmosphere.
- The **unit of refrigeration** is expressed in terms of ton of **refrigeration** (TR). One ton of **refrigeration** is defined as the amount of heat absorbed from a body or space to be cooled equivalent to the latent heat of fusion of one ton(2000 lb) of ice from water at 0°C to form ice at 0°C in 24 hours. Theoretically one Ton of refrigeration taken as 232.6kJ/min, However in actual practice, it is taken as 210 kJ/min OR 1 ton of refrigeration = 3.5kW
- A **heat engine** may be defined as a device that operates in a thermodynamic cycle and does a certain amount of net positive work through the transfer of heat from a high temperature body to a low temperature body. A steam power plant is an example of a heat engine.
- A **refrigerator** may be defined as a device that operates in a thermodynamic cycle and transfers a certain amount of heat from a body at a lower temperature to a body at a higher temperature by consuming certain amount of external work. Domestic refrigerators and room air conditioners are the examples. In a refrigerator, the required output is the heat extracted from the low temperature body.
- A **heat pump** is similar to a refrigerator, however, here the required output is the heat rejected to the high temperature body.



a) Heat engine b) Refrigerator c) Heat pump

- **Applications of refrigeration**
- 1. Domestic refrigeration
- 2. Commercial refrigeration
- 3. Industrial refrigeration
- 4. Transport refrigeration
- 5.Comfort air conditioning
- 6. Industrial air conditioning

Energy Ratios or Coefficients of Performance

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The performance of a heat engine is described by its thermal efficiency.

Efficiency of heat engine, $= \dfrac{NET\ WORK\ OUTPUT}{TOTAL\ HEAT\ INPUT} = \dfrac{W}{Q_2} = \mathbf{1}\text{-}\ \dfrac{\boldsymbol{Q_1}}{\boldsymbol{Q_2}}$

The performance of a refrigerating machine or a heat pump is expressed by the ratio of useful heat to work, called the energy ratio or coefficient of performance (COP).

Thus we have for a refrigerating machine:

Cooling energy ratio, or COP for cooling $= \dfrac{REFRIGERATION\ EFFECT}{WORK\ INPUT} = \dfrac{\boldsymbol{Q_2(RE)}}{\boldsymbol{W_R}}$

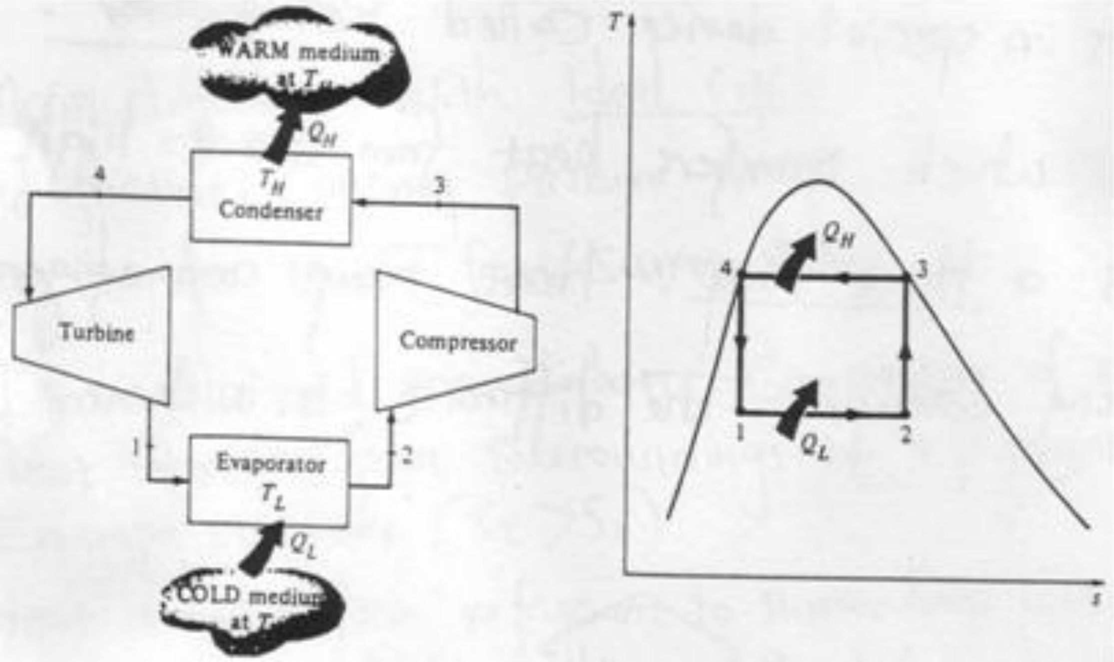
Heating energy ratio, or COP for heating $= \dfrac{DESIRED\ EFFECT}{WORK\ INPUT} = \dfrac{\boldsymbol{Q_1(DE)}}{\boldsymbol{W_P}}$

Here, DE= DESIRED EFFECT, RE= REFRIGERATION EFFECT,

* Q2 should be replaced by Q1 in the COP of Refrigerator.

REVERSE CARNOT CYCLE

- Carnot cycle is a totally reversible cycle which consists of two reversible isothermal processes and two isentropic processes.
- It has the maximum efficiency for a given temperature limit.
- Since it is a reversible cycle, all four processes can be reversed. This will reverse the direction of heat and work interactions, therefore producing a refrigeration cycle. The cycle consists of
- 1-2: Isothermal heat transfer from cold medium to refrigerant (Evaporator)
- 2-3: Isentropic (Reversible adiabatic) compression
- 3-4: Isothermal heat rejection (condenser)
- 4-1: Isentropic Expansion



$$COP_{ref,Carnot} = \frac{1}{\frac{T_H}{T_L} - 1} \quad \& \quad COP_{HP,Carnot} = \frac{1}{1 - \frac{T_L}{T_H}}$$

- Consider 1 kg of fluid fowing through the cycles.
- Refrigerating effect, N= T_L (S2-S1)
- Heat rejected = T_H(S2-S1)
- WORK INPUT W= heat rejected- heat extracted
- = (T_H-T_L)(S2-S1)
- C.O.P OF REFRIGERATOR= N/W
- = $T_L/(T_H-T_L)$

- C.O.P OF Heat pump = heat rejected/work input
- = $T_H/(T_H-T_L)$

VAPOUR COMPRESSION REFRIGERATION CYCLE/ SYSTEM(VCRS/VCRC)

- Vapour Compression Refrigeration Cycle is the most widely used refrigeration system. In this system, the working fluid is a vapor. It readily evaporates and condenses or changes alternatively between the vapor and liquid phase without leaving the refrigerating plant.
- During evaporation, it absorbs heat from the cold body and this heat is used as its latent heat for converting it from liquid to vapour whereas in Condensing or cooling, it rejects heat to external bodies, thus creating a cooling effect in the working fluid.
- The figure consists of the following five essential parts, those are:

1. Compressor
2. Condenser
3. Receiver
4. Expansion Valve
5. Evaporator

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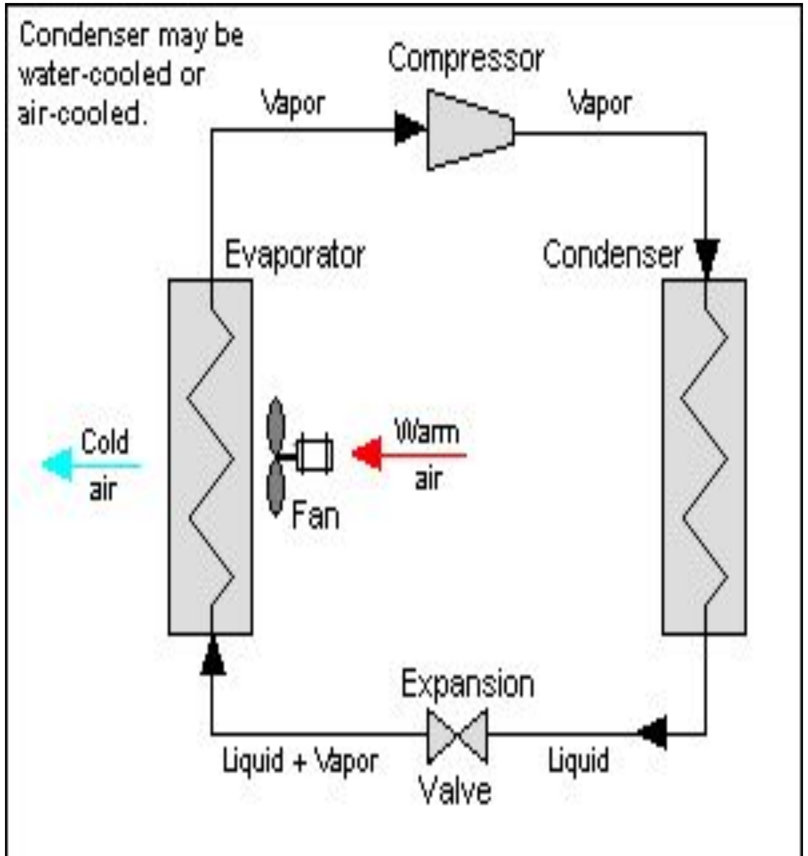


TYPICAL SINGLE-STAGE
VAPOR COMPRESSION REFRIGERATION

COMPONENTS OF VCRS

1. Compressor:

- The vapour at low pressure and low temperature enters the compressor from the evaporator where it is compressed to high pressure and high temperature. This high pressure and temperature vapour refrigerant are discharged into the condenser through the discharge valve.

2. Condenser:

- The condenser or cooler consists of coils of pipe in which the high pressure and temperature vapour refrigerant are cooled and condensed. The refrigerant while passing through the condenser gives up its latent heat to the surroundings condensing medium which is normally air or water.

3. Receiver:

- The condensed liquid refrigerant from the condenser is stored in a vessel known as a receiver from where it is supplied to the evaporator through the expansion valve.

4. Expansion Valve:

- It is also called a throttle valve. Its function is to allow the liquid refrigerant under high pressure and temperature to pass through it where it reduces its temperature and pressure.

5. Evaporator:

- It also consists of coils of pipe in which liquid-vapour refrigerant at low pressure and temperature is evaporated and converted into vapour refrigerant at low pressure and temperature

Working of Vapor Compression Refrigeration System:

- The working of Vapor Compression Refrigeration System can be completed under 4 processes and are as follows.

Compression Process:

- The vapour at low temperature and low pressure enter the compressor where it is compressed isentropically and subsequently, its temperature and pressure considerably increase.

Condensation Process:

- This vapour after leaving the compressor enters into the condenser, where it is condensed into high-pressure liquid and is collected in a receiver tank.

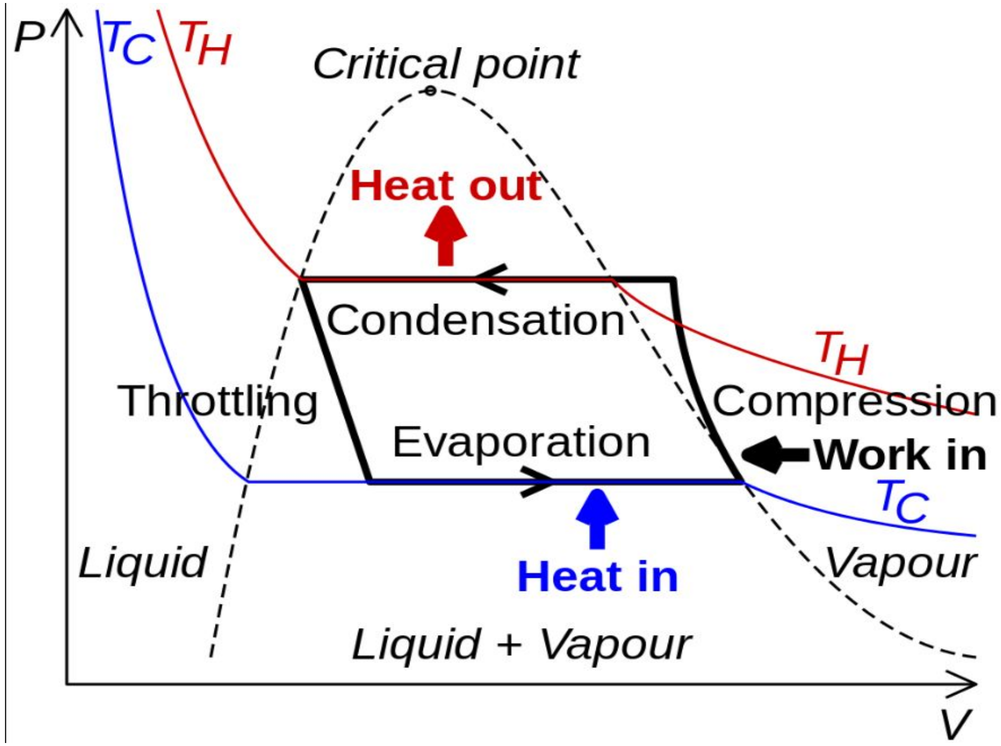
Expansion Process:

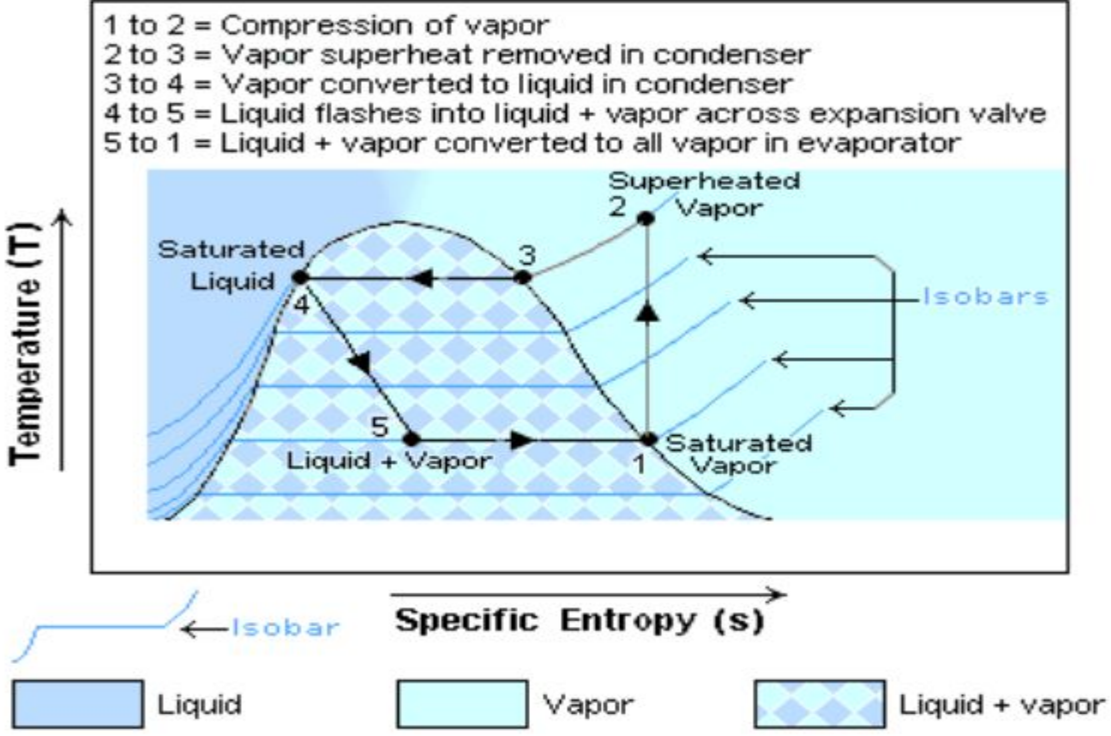
- From the receiver tank, it passes through the expansion valve, where it is throttled down to low pressure and temperature.

Vaporization Process:

- After finding its way through an expansion valve, it finally passes onto the evaporator, where it extracts heat from the surroundings or circulating fluid and vaporizes to lower pressure vapour.

- If expansion takes place without throttling, temperature level drops to a very low level due to which it should undergo sensible heat and latent heat in order to reach the evaporation stage.





1**. C.O.P of the cycle**

Assuming 1 kg of refrigerant is flowing through the cycle

work input to the compressor W=h2-h1

referigerating effect N= h1-h5

C.O.P =N/W

2. **Mass of refrigerating circulating in the cycle**

refrigerating effect =h1-h5 KJ/KG of refrigerant

1 ton of refrigeration = 3.516 KJ/s

Mass of refrigerant in circulation m= 3.516/h1-h5 Kg/s ton

3**. power required to drive compressor**

Work input to compressor= h2-h1 kJ/kg

Power required = m(h2-h1) kW/ton

4. **Heat rejected to condenser**

Heat rejeted to condenser = h2-h4 kJ/kg

Total heat rejected = m(h2-h3) kW/ton

5.Piston displacement

P.D=mV1/ηvol. m3/s.ton

ADVANTAGES AND DISADVANTAGES

ADVANTAGES

- The temperature at the evaporator section can be controlled employing regulation of expansion valve.
- It exhibits high Coefficient of Performance due to the fact that the vapour compression refrigeration system works nearer to reversed carnot cycle.
- The running cost is low because the amount of refrigerant needed in VCRS is much less .
- IN VCRS, heat carried away by evaporation of vapour and the amount of refrigerant circulated is less per ton of refrigeration. This reduces the size of evaporator.

DISADVANTAGES

- Make sure that there should be no leakage of refrigerant from the pipes/hose.
- Refrigerant can affect the atmosphere.
- The cost of the system is high.

APPLICATIONS

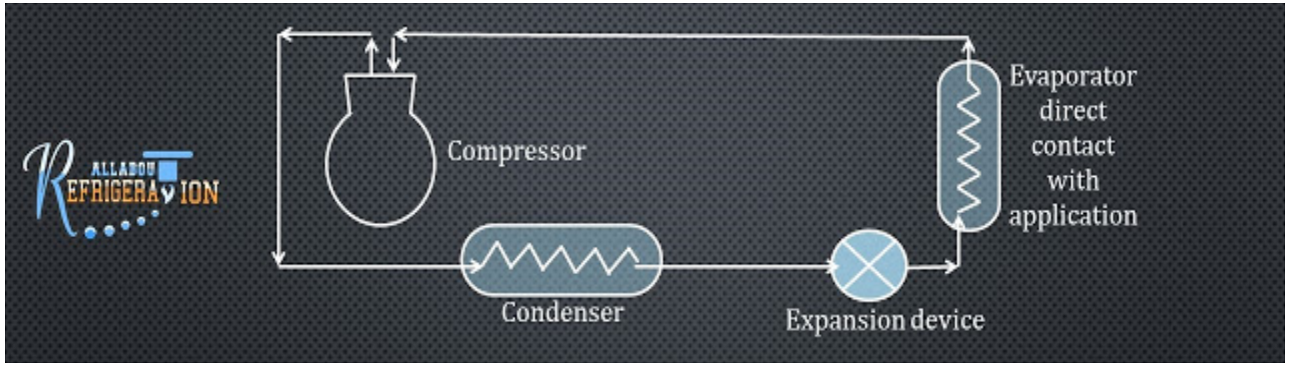
- It is used in domestic refrigeration for keeping the food.
- It is helpful in food processing and cold storages.
- It is useful in Industrial refrigeration for chemical processing, heating and cooling.
- It is useful in Cryogenic refrigeration, Medical refrigeration, Transport refrigeration and Electronic cooling.

REFRIGERANTS

- Refrigerant is a media which absorbs heat energy from lower body temperature and it rejects to higher body temperature(surrounding)by changing its phase. E.g. Air, Water, CO_2, SO_2,NH_3, freon group(R12, R22,R502)
- **Classification of Refrigerant :**
- 1. According to use :
- a) Primary Refrigerant
- b) Secondary Refrigerant
- 2. Refrigerant are also classified into four groups:
- a) Halo carbon Refrigerant
- b) Azeotropic Refrigerant
- c) Inorganic Refrigerant
- d) Hydrocarbon Refrigerant

a) Primary Refrigerant:

- In primary refrigerant, refrigerant absorb directly from the product which is to be cooled in the evaporator.



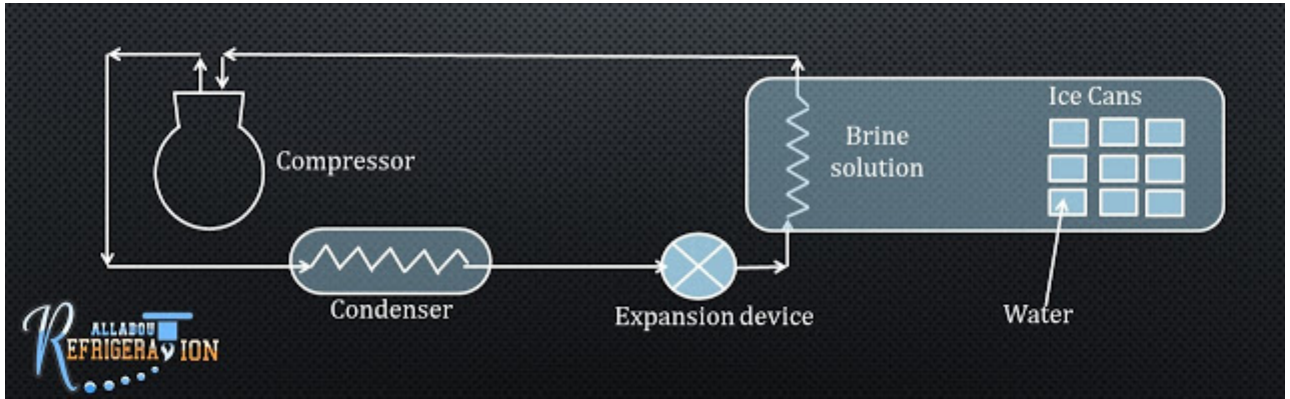
b) Secondary Refrigerant

- Fig. shows the example of Ice-Plant. In this case NH3 is used as primary refrigerant. Primary refrigerant flows through compressor, condenser, expansion device, and evaporating coils. Evaporating coils are dipped in the brine solution and water cans are immerged in the brine solution. The product obtained is Ice.

- In this case brine solution absorb heat energy from the product and primary refrigerant absorb heat from brine solution.

- The brine solution act here as media between the product and primary refrigerant such media knows as secondary refrigerant.

Brine solution = water + NaCl.



- **Other Types details are as follows:**

a) Halo carbon refrigerant:

- In older days initially air, water, SO2, CO2 and NH3 are widely used as refrigerant in refrigeration and Air conditioning field but they are having some limitations.
- To remove this limitations American companies synthetically produce 42 compounds out of them a very few used as refrigerant like R12.
- The above compound is treated freon family refrigerant. This group is widely used up to 1995.
- It is responsible for ozone layer depletion. There is totally ban from 2005 and alternative refrigerant are known as eco-friendly refrigerant E.g. 134a.
- India's contribution for ozone layer depletion is about 1.5%.
- ASHRAE – American society for Heating, Refrigeration and Air conditioning Engineers. E.g. R12, R34 etc.
- First Freon family R12 in 1930.

b) Azeotropic Refrigerant:

- Azeotropic Refrigerant is mixture of two Freon family Refrigerant in definite proportion and then third component obtain is Azeotropic refrigerant.
- Its liquid vapor phases are remain constant for a wide range of temperature. Azeotropic refrigerant having totally different properties than its parent refrigerant.

Azeotropic Refrigerant	Parent Refrigerant
R500	73.2%= R12 & 26.8% = R152
R502	48.8% = R22 & 51.2 = R115
R503	40.1% = R23 & 59.9% = R13
R504	48.2% =R32 & 51.8% = R115

c) Inorganic Refrigerant:

This refrigerant are widely used from the beginning of the Refrigerant field.
E.g. Air, Water, CO2, NH3 etc.
Freon family refrigerant invented in 1930, to replace this group is widely use till today.NH3 having following inherent property:
1. Boiling point = 33.3 at atmospheric pressure.
2. Latent heat of vaporization = 1315 kJ/kg at -150 C.

d) Hydrocarbon Refrigerant:
From this group Butene, Propene are having good property but this refrigerant are not used RAC field because they are highly explosive compound’s.

Properties of Ideal Refrigerant:

Refrigerant are compared at -150 C evaporator temperature and 300C at condenser temperature. There is no single compound can be treated as ideal refrigerant, but ideally refrigerant should be having following properties.

1. It should be having low boiling point at atmospheric pressure. If it is high, the compressor works increases, and capacity of compressor decreases and then operating cost of system. Eg- Boiling point of NH3 -33.30C.

2. Refrigerant should have low freezing point. It should be well below operating evaporator temperature. Most of the refrigerant are having freezing point temperature below -350C, hence it is not consider while selecting refrigerant.

3. High latent heat of vaporization. E.g.- Latent heat of vaporization of NH3 is 1315kJ/kg to obtain 1 TON refrigerant supplied is less.

4. It should be having low specific heat of liquid refrigerant. This minimizes the amount of vapour formed during throttling process in the expansion value and helps to improve the refrigeration capacity.

5. The pressure required to maintain evaporator and condenser should be low enough to reduce material cost must be positive to avoid leakage of air into the system.

6. It must be having high critical pressure and high critical temperature. The critical pressure and temperature must be well above the maximum operating pressure and temperature limits.The refrigerant has a better heat transfer rate below the critical point.

Properties of Ideal Refrigerant:

7. It should be having low specific volume of vapor to reduce size of compressor.
8. It should have non-flammable, non-toxic, non-corrosive.
9. It should not bad effect on sored material of food. When any leakage develops in the system.
10. It must be high thermal conductivity, to reduce material.
11. It must have high duplicity with lubricating oil and it should not have any reactive property with lubricating oil.
12. It should give high COP in working temperature range
13. It should be easily available at lower cost.

DOMESTIC REFRIGERATOR

- The working principle of a refrigerator (and refrigeration, in general) is very simple: it involves the removal of heat from one region and its deposition to another. When you pass a low-temperature liquid close to objects that you want to cool, heat from those objects is transferred to the liquid, which evaporates and takes away the heat in the process.
- You may already know that gases heat up when you compress them and cool down when they are allowed to expand. That's why a bicycle pump feels warm when you use it to pump air inside a tire, while sprayed perfume feels cold.
- The tendency of gases to become hot when compressed and cold when expanded, along with the help of a few nifty devices, helps a refrigerator cool the stuff being kept inside it.
- An aerosol air freshener feels cold to the touch because the gas is allowed to expand suddenly, which brings down its temperature.

- In above figure An aerosol air freshener fe lowed to expand suddenly, which brings down its temperature.

Parts of a Refrigerator

- A refrigerator consists of a few key components that play a vital role in the refrigeration process:

1) Expansion valve

- Also referred to as the flow control device, an expansion valve controls the flow of the liquid refrigerant (also known as ‘coolant’) into the evaporator. It’s actually a very small device that is sensitive to temperature changes of the refrigerant.

2) Compressor

- The compressor consists of a motor that ‘sucks in’ the refrigerant from the evaporator and compresses it in a cylinder to make a hot, high-pressure gas.

3) Evaporator

- This is the part that actually cools the stuff kept inside a refrigerator. It consists of finned tubes (made of metals with high thermal conductivity to maximize heat transfer) that absorb heat blown through a coil by a fan. The evaporator absorbs heat from the stuff kept inside, and as a result of this heat, the liquid refrigerant turns into vapor.

COMPRESSOR

4) Condenser

- The condenser consists of a coiled set of tubes with external fins and is located at the rear of the refrigerator. It helps in the liquefaction of the gaseous refrigerant by absorbing its heat and subsequently expelling it to the surroundings. As the heat of the refrigerant is removed, its temperature drops to condensation temperature, and it changes its state from vapor to liquid.

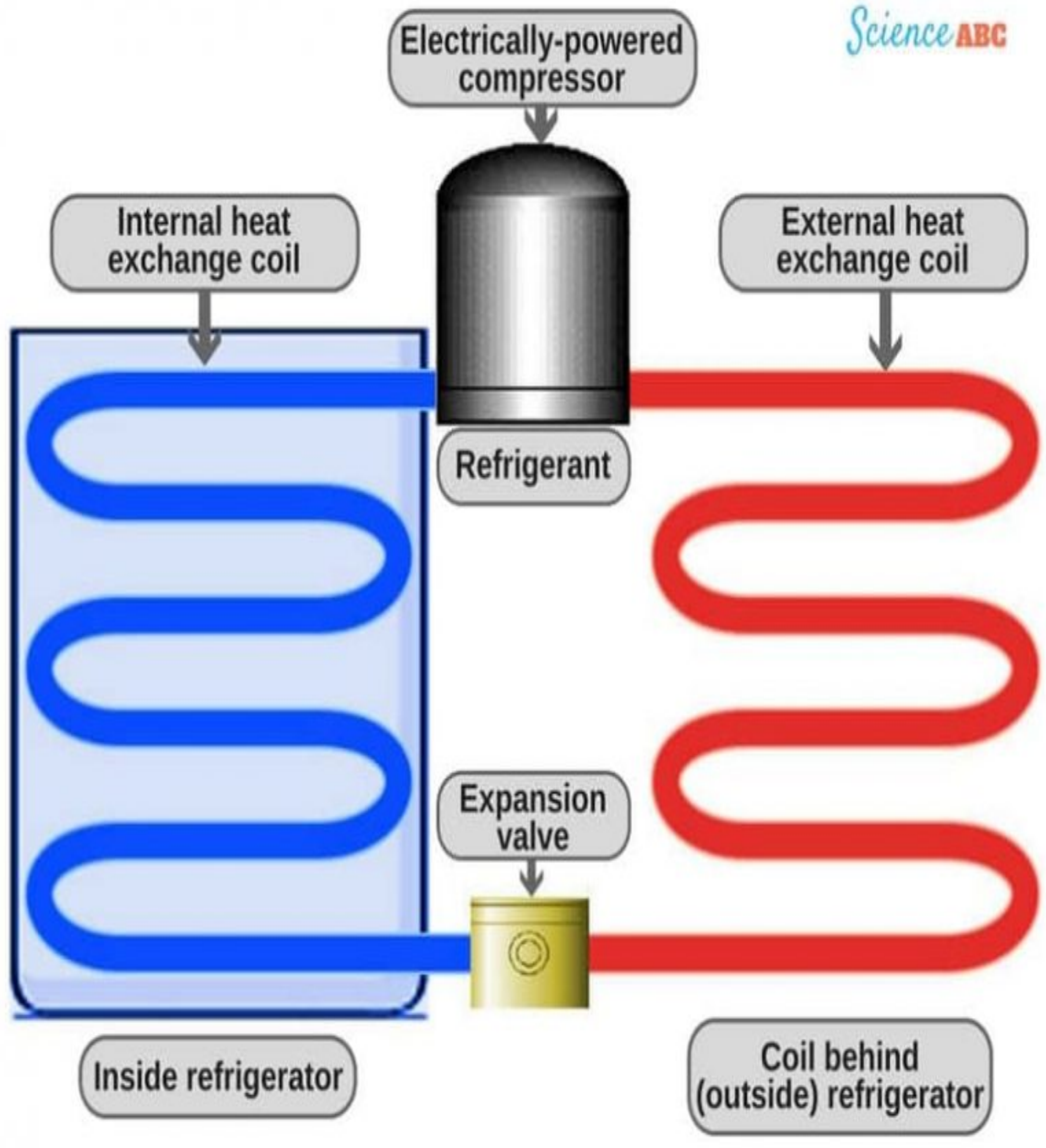
5) Refrigerant

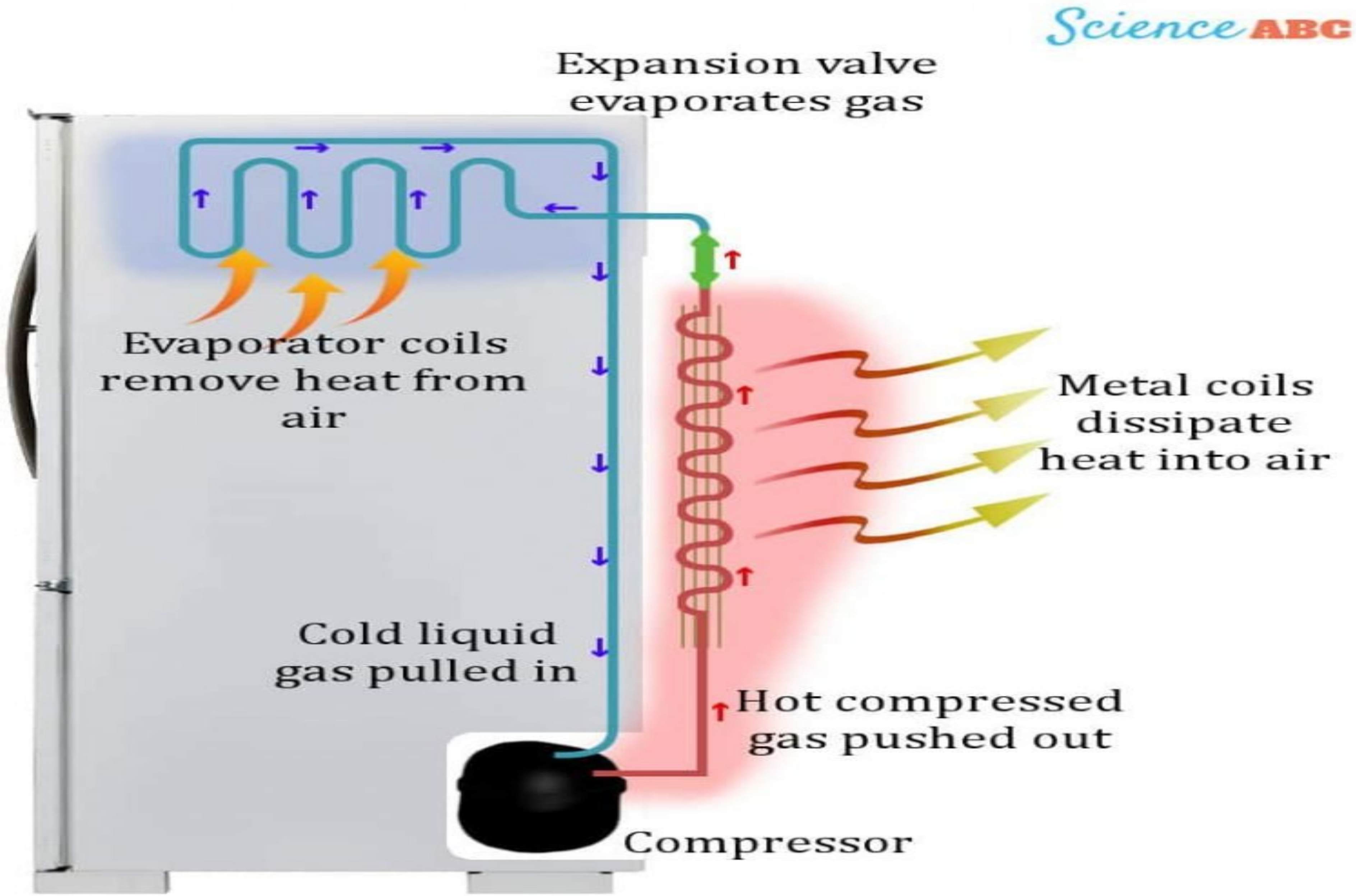
- Also commonly referred to as the coolant, it's the liquid that keeps the refrigeration cycle going. It's actually a specially designed chemical that is capable of alternating between being a hot gas and a cool liquid. In the 20th century, fluorocarbons, especially CFCs, were a common choice as a refrigerant. However, they're being replaced by more environment-friendly refrigerants, such as ammonia, R-290, R-600A etc.

CONDENSER

Refrigerator Function: How Does A Refrigerator Work?

- The refrigerant, which is now in a liquid state, passes through the expansion valve and turns into a cool gas due to the sudden drop in pressure.
- As the cool refrigerant gas flows through the chiller cabinet, it absorbs the heat from the food items inside the fridge. The refrigerant, which is now a gas, flows into the compressor, which sucks it inside and compresses the molecules together to make it into a hot, high-pressure gas.
- Now, this gas transports to the condenser coils (thin radiator pipes) located at the back of the fridge, where the coils help dissipate its heat so that it becomes cool enough to condense and convert back into its liquid phase. Because the heat collected from the food items is given off to the surroundings via the condenser, it feels hot to the touch.




Science ABC
Expansion valve evaporates gas
Evaporator coils remove heat from air
Metal coils dissipate heat into air
Cold liquid gas pulled in
Hot compressed gas pushed out
Compressor

Desert Air Cooler

What is DESERT COOLER?

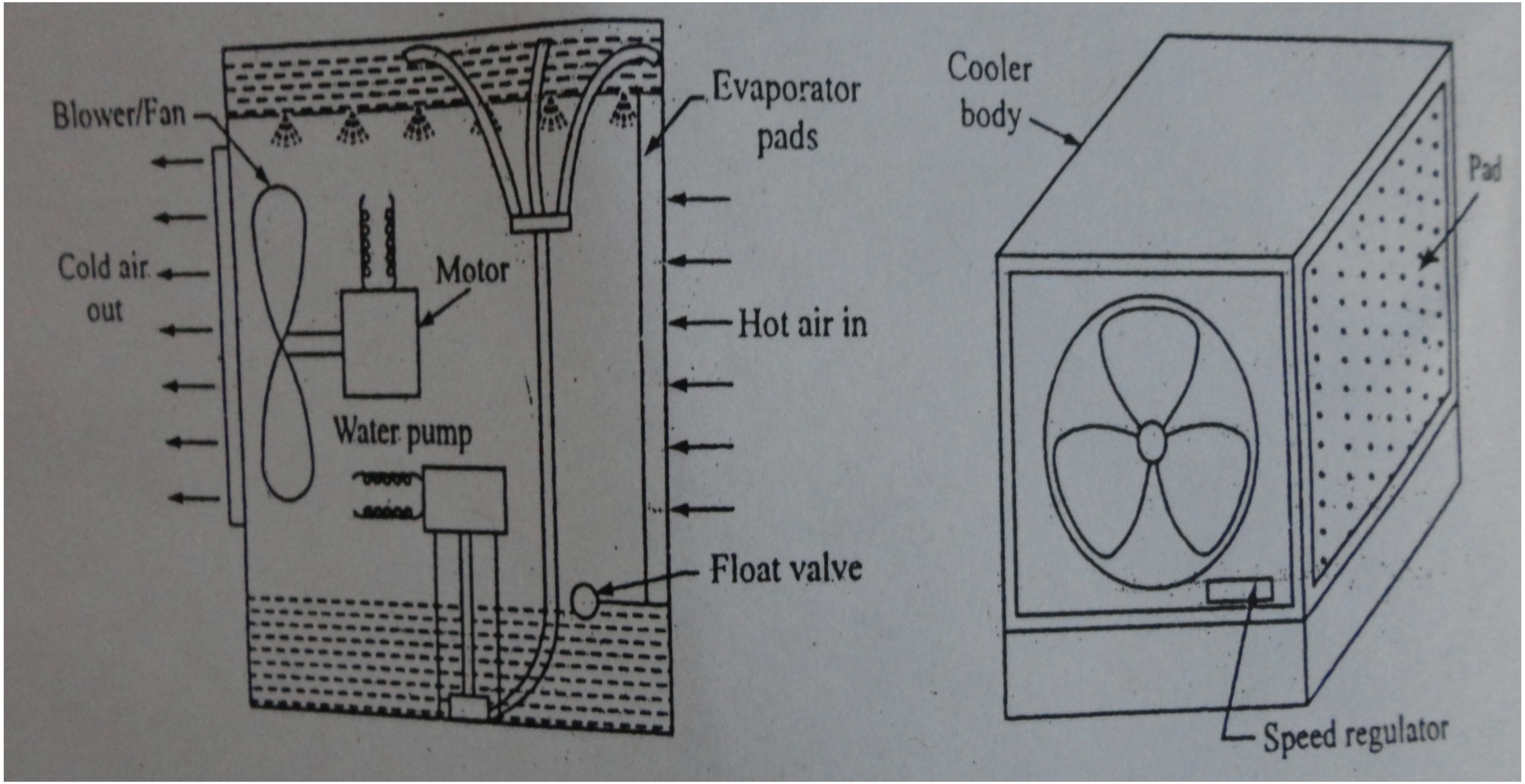
- It is a device that cools air through simple evaporation of water.

Principle Of Working:

- As the name implies , it is suitable for places where the humidity is quite low and temperature quite high. These conditions are in conformity with desert areas. Hence the coolers are called ‘Desert coolers’. The principle on which a desert cooler works is ‘ Evaporative cooling’. Evaporative cooling is a process in which sensible heat is removed and moisture added to the air. When air passes through a spray of water it gives up heat to water, some of the water evaporated and picks up heat from the air equivalent to its latent heat . The vapour thus formed are carried along in stream. In this way air is cooled and humidified.

Contruction and working of a desert cooler:

1. Blower/ Fan
2. water circulating pump
3. Water wetted pads
4. water tank
5. Float valve



WORKING

- The water is filled in the sump of the cooler from water supply mains , the level of which is controlled by a float valve. A water pump lifts the water and supplies it at the top of the cooler to the water distribution system which consists of small branches of copper pipe or so equipped with orifices which deliver equal amount of water to the troughs which in turns supply water to the wetted pads. The water which drops back from the pads is recirculated. The pump may be made of brass , stainless steel or even plastic. The blower pulls the air through the wetted pads and deliver it to space to be cooled through an opening in the fourth side of the cabinet of desert cooler. The air which is sucked through the pads is cooled by the principle of evaporative cooling . The blower gives adequate velocity to the air before it is delivered to the spaces to be cooled.
- To have long life of the desert cooler and better performance , pads should be changed every year and holes for water distribution system should be cleaned. The tank should be cleaned just after the season and coated with corrosion resisting paint .

Window Air Conditioner

- Window air conditioner is a simple air conditioning unit fitted with the room wall or window. In this unit air is not supplied to the room through duct system. This consists of a complete vapor compression system having compressor, condenser, evaporator, expansion device with motor, blower, fan, air filter, grills, fresh air damper, and control panels as shown in Fig. 6.16.

- The unit draws air continuously from the space to be cooled and it is cooled by cooling the coil of the unit and delivered back into the same space to be cooled. The process of drawing, cooling, and recirculation cools the space at a lower temperature required for the comfort. Regarding the installation of this unit, the evaporator unit should be mounted inside the room and the condenser will be mounted on the outer side of room wall.

- The air supply grills have adjustable louvers or deflectors for changing the direction of air flow. It is generally operated with a 220-V single phase ac supply. The cooling capacities for such unit are available in market between 0.5 TR and 3 TR.

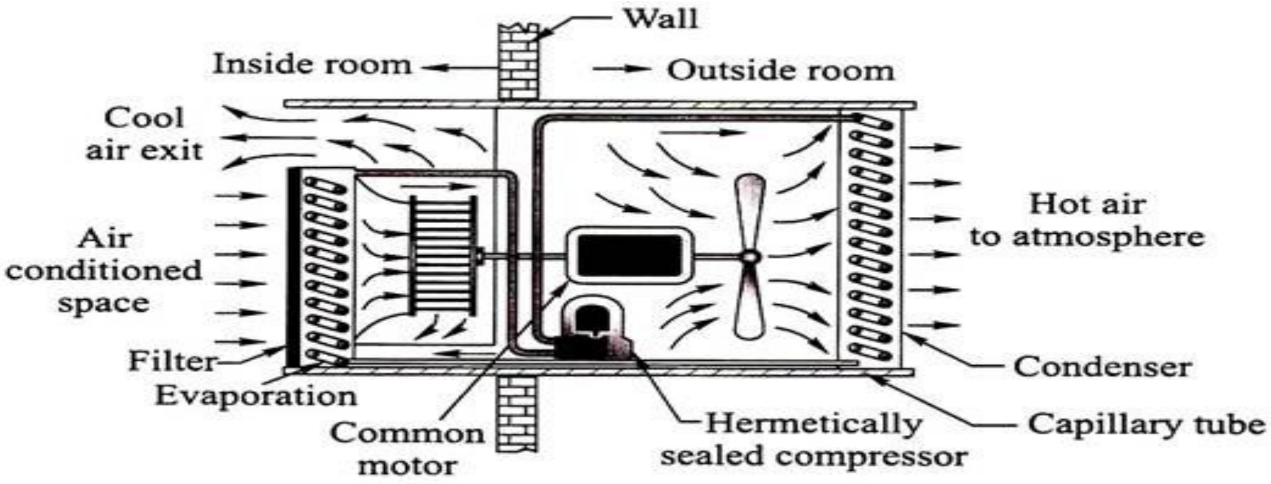


Fig. 6.16 Window air conditioner