REFRIGERATION AND AIR CONDITIONING

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REFRIGERATION

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2. Vapour Compression System (12 Hours)

Introduction, principle, function, parts and necessity of vapour compression system, T- ϕ and p– H charts, dry, wet and superheated compression. Effect of sub cooling, super heating,. actual vapour compression system. Introduction to air refrigeration system, advantage and disadvantage of air refrigeration over vapour compression system.

3. Refrigerants (04 Hours)

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5.5. Safety Devices-Thermostat, overload protector, LP, HP cut out switch.

AIR CONDITIONING

6. Psychrometry (06 Hours)

Definition, importance, specific humidity, relative humidity, degree of saturation, DBT, WBT, DPT, sensible heat, latent heat, Total enthalpy of air.

7. Applied Psychrometry and Heat Load Estimation. (08 Hours)

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Heating and humidification, cooling and dehumidification, window air-conditioning, split type air-conditioning, car air-conditioning, central air-conditioning.

8. Latest development in refrigeration and air conditioning:- (02 Hours)

CHAPTER -1

FUNDAMENTALS OF REFRIGERATION

INTRODUCTION TO REFRIGERATION

- Refrigeration is concerned with the cooling by absorbing heat from the space where cooling is required.
- The branch of science which deals with the process of reducing and maintaining the temperature of a space or material below the temperature of the surrounding.

INTRODUCTION TO AIR CONDITIONING

- The process of simultaneous control of Temperature , humidity, flow and purity of air within a space irrespective of the surrounding conditions is called air conditioning.

MEANING OF REFRIGERATION EFFECT

- The cooling effect produced by a refrigeration system in a given time is known as refrigeration effect.
- It is expressed as KJ/s or KJ/min.

UNIT OF REFRIGERATION

- The practical unit of refrigeration is expressed in terms of ‘tonne of refrigeration(briefly written as TR).
- A tonne of refrigeration is defined as the amount of refrigeration effect produced by the uniform melting of one tonne of ice from and at 0°C in 24 hours.
- Since the latent heat of ice is 335 kJ/kg, therefore one tonne of refrigeration

Since 1 Tonne = 2000 lb or 907.18 kg

Latent heat of ice = 335 kJ/kg

Therefore

$$1\ TR = \frac{907.18\ kg\ X\ 335\ KJ/kg}{24x60\ min}$$

=211 KJ/min or 3.517 KW

COP (CO-EFFICIENT OF PERFORMANCE)

- COP is defined as the ratio of desired effect (Refrigeration effect) produced to the work input.

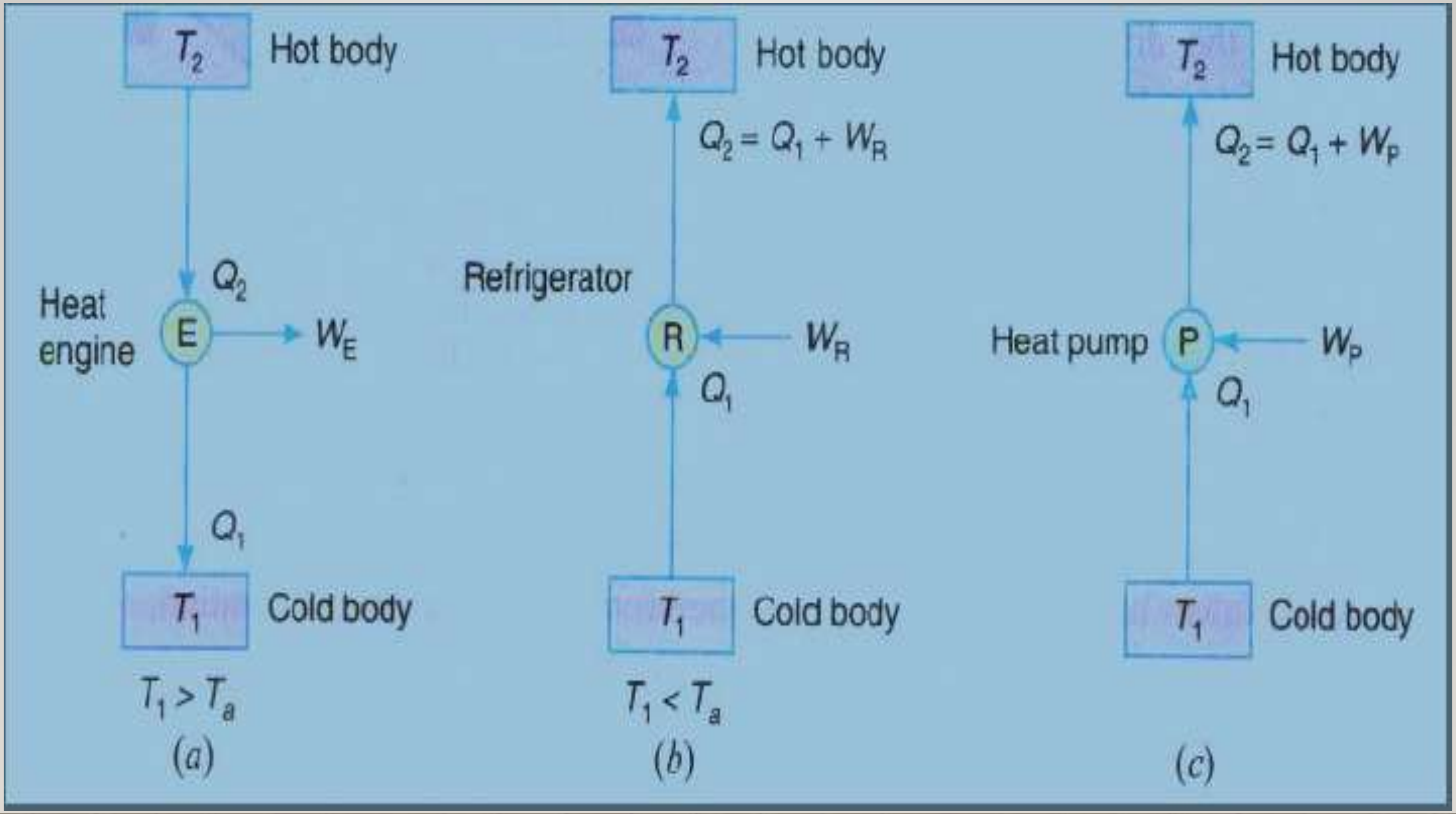
$$COP = \frac{\text{Desired or Refrigeration effect (Q)}}{\text{Work input (W)}} = \frac{Q}{W}$$

- The value of C.O.P is usually greater than unity.
- The ratio of actual C.O.P to the theoretical C.O.P is known as ***relative coefficient of performance***.

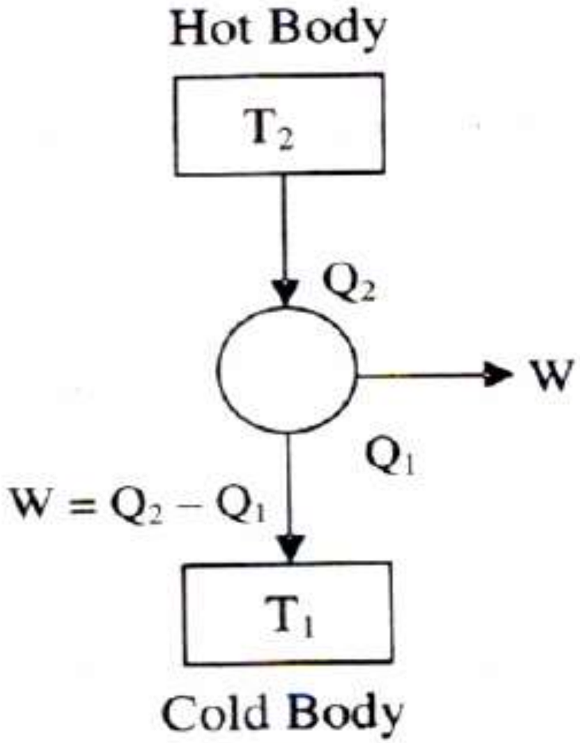
DIFFERENCE BETWEEN COP AND EFFICIENCY

- The term COP is taken for the power absorbing devices like refrigerator and heat pump. Its value is greater than one.
- The term efficiency is considered for power producing devices like heat engine. Its value is always less than one.

DIFFERENCE BETWEEN A HEAT ENGINE, REFRIGERATOR AND HEAT PUMP

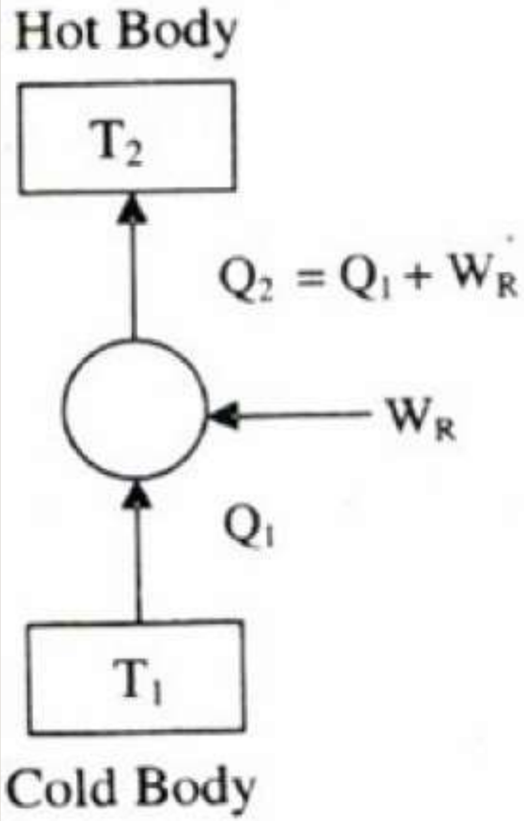


Heat Engine



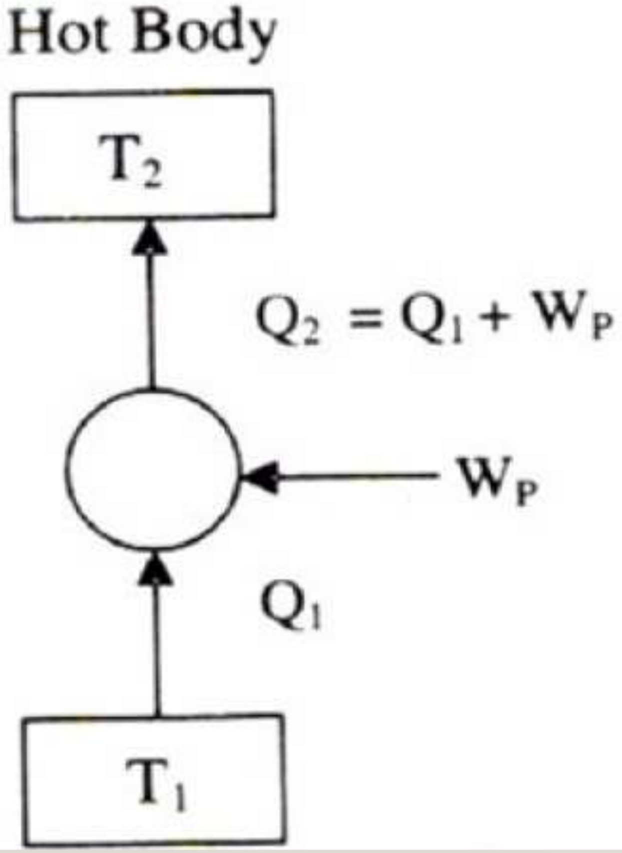
- Produces work by converting energy
- $H = W / Q_2$

Refrigerator



- Consumes work & extracts heat from a cold body & rejects it to a hot body.
- $COP = Q_1 / W$

Heat Pump



- Maintains the temp of body higher than surroundings.
- Consumes work & extracts heat from a cold body & rejects it to a hot body ie., surrounding.
- $COP = Q_2 / W$

METHODS OF REFRIGERATION

1.Ice refrigeration

2.Dry ice refrigeration

3.Evaporative refrigeration

4.Liquid gas refrigeration

5.Gas throttling refrigeration

6. Air expansion refrigeration

7.Vapour compression refrigeration

8.Vapour absorption refrigeration

9. Steam jet refrigeration

10. Thermo electric refrigeration

ICE Refrigeration System

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Refrigeration System
Air-conditioning System

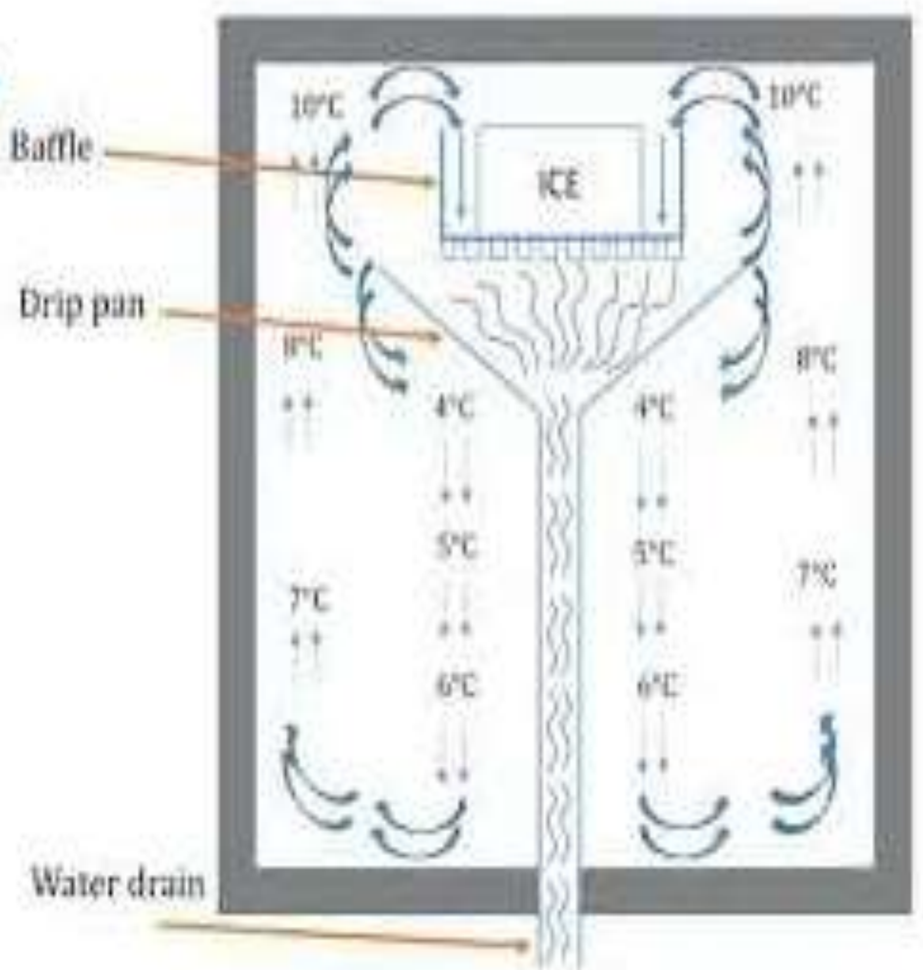
- Oldest cooling method
- Use Natural and Artificial ICE
- Latent heat of Ice is 335kJ/kg

Advantage

- It prevent dehydration of fresh vegetables

Disadvantage

- Controlling the rate of refrigeration makes it difficult



DRY ICE REFRIGERATION

- Dry ice solid carbon dioxide. It can be pressed in various sizes and shapes, blocks or slabs. As it absorbs heat, it changes directly from solid pair. He didn't come in a liquid state.
- Dry ice sublimates at standard atm. pressure by absorbing 573 KJ/kg latent heat of sublimation at -78.5 ℃ . thus it can produce much lower temp. than ice refrigeration.

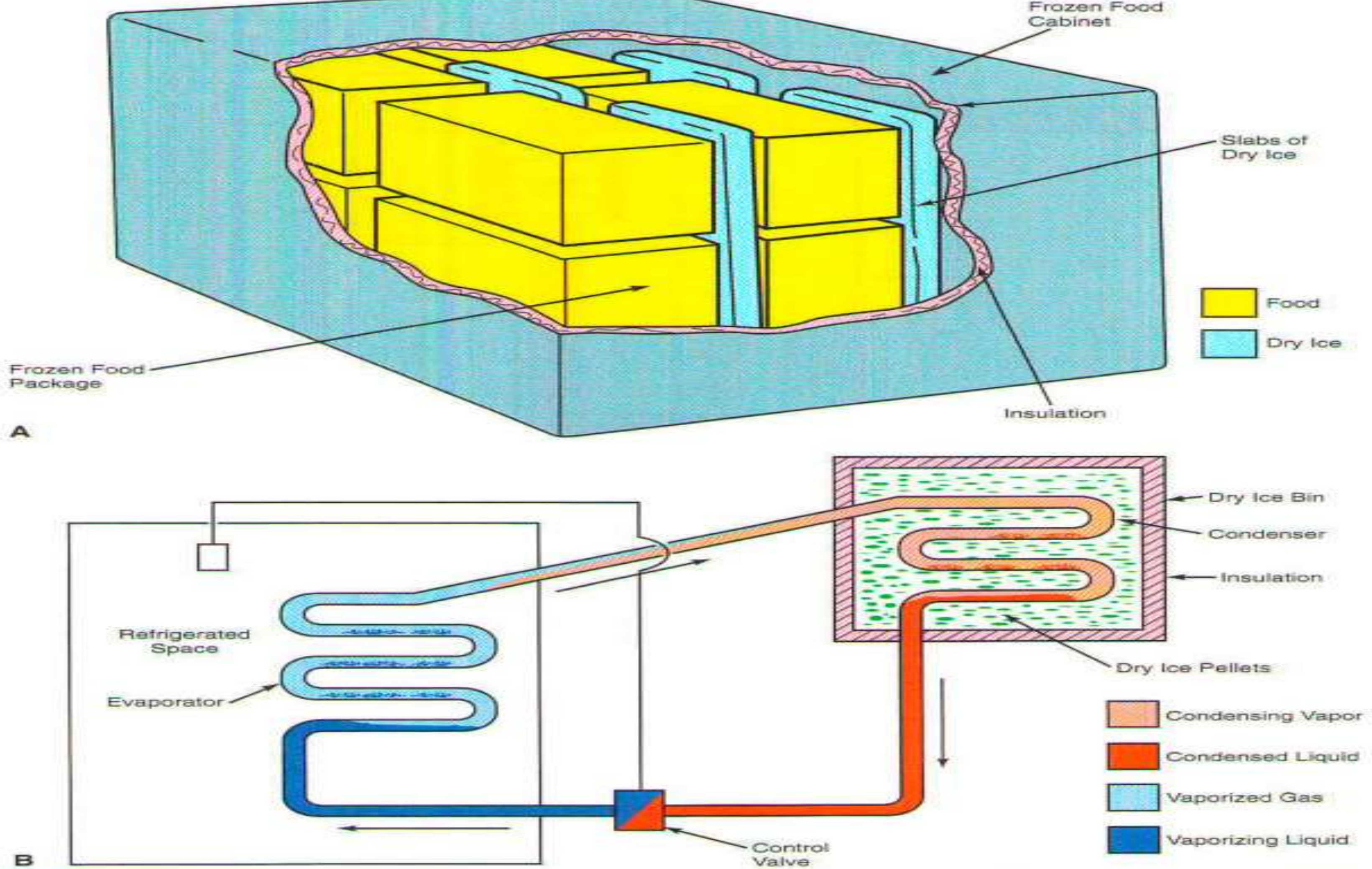


Figure 3-18. *A—Dry ice frozen food container. B—A dry ice refrigerator does not require a compressor.*

NATURAL AND ARTIFICIAL REFRIGERATION SYSTEM

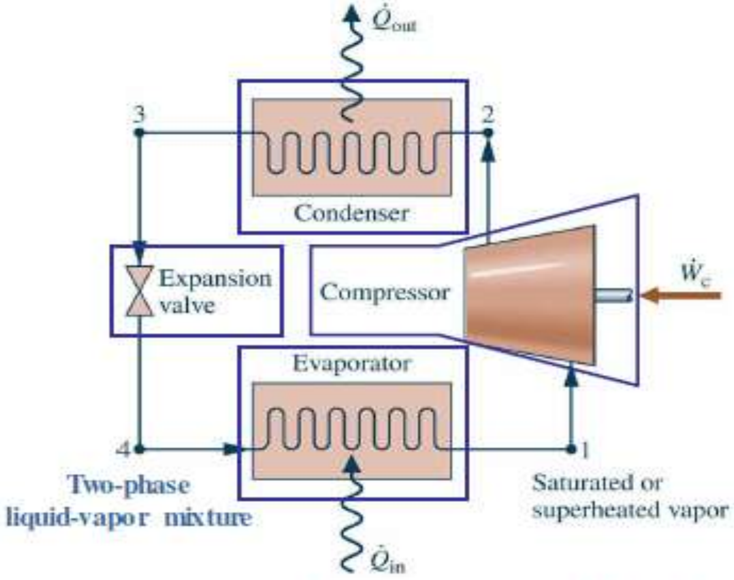
- Natural refrigeration system makes use of natural phenomenon such as natural ice, well water, spring houses etc.
- Whereas in artificial refrigeration system mechanical energy used to make a change in the condition required in refrigeration cycle. For example VCR cycle etc.

CHAPTER -2

VAPOUR COMPRESSION SYSTEM

INTRODUCTION

- Most common refrigeration cycle in use today
- There are four principal control volumes involving these components:
  - Evaporator
  - Compressor
  - Condenser
  - Expansion valve



All energy transfers by work and heat are taken as positive in the directions of the arrows on the schematic and energy balances are written accordingly.

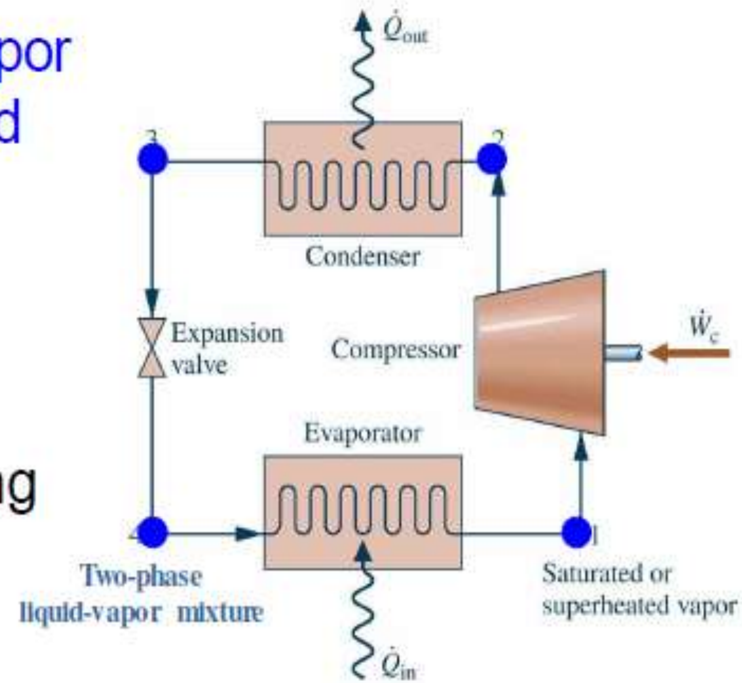
► The processes of this cycle are

Process 4-1: two-phase liquid-vapor mixture of refrigerant is evaporated through heat transfer from the refrigerated space.

Process 1-2: vapor refrigerant is compressed to a relatively high temperature and pressure requiring work input.

Process 2-3: vapor refrigerant condenses to liquid through heat transfer to the cooler surroundings.

Process 3-4: liquid refrigerant expands to the evaporator pressure.



WORKING WITH COMPONENTS OF SIMPLE VCR CYCLE

1. Evaporator – its function is to provide a heat transfer surface through which heat can pass from the refrigerated space to the refrigerant.

2. Suction line – it conveys the low pressure vapour refrigerant from the outlet of evaporator to the inlet of compressor

3. Compressor – it draws the vapour refrigerant from the evaporator and raise its temp. and pressure to a point such that the vapour can be condensed in the condenser . It is power consuming (absorbing) device.

4. Discharge line – it discharges the high pressure and high temp. vapour refrigerant from the outlet of the compressor to the inlet of the condenser.

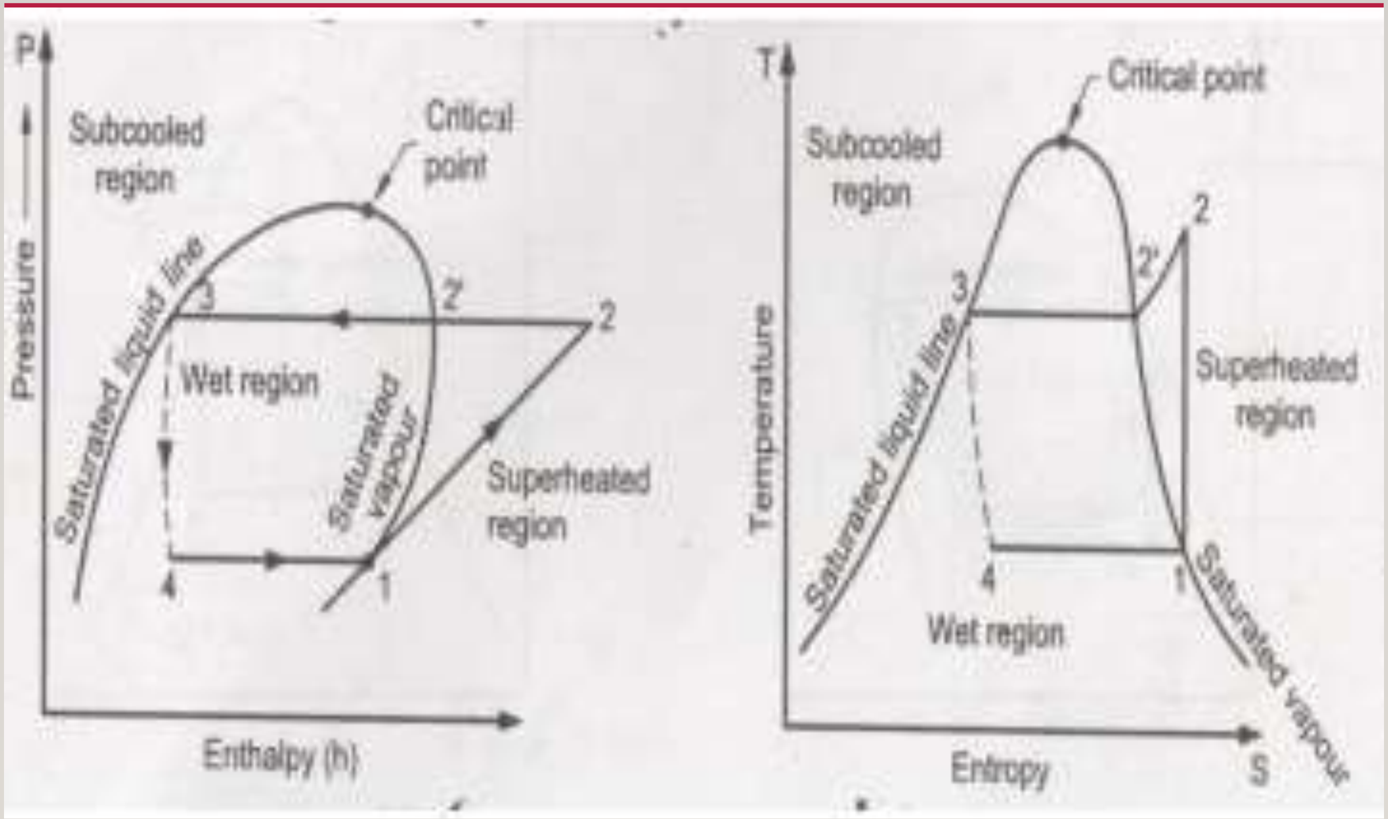
5. Condenser – its function is to provide a heat transfer surface through which heat from the hot vapour refrigerant can be transferred to the condensing medium (water or air).

6. Receiver Tank- it provide storage for the liquid refrigerant coming from the condenser outlet so that a constant supply of refrigerant to the evaporator can be maintained.

7. Liquid line – it carries liquid refrigerant from the receiver tank to the expansion device

8. Expansion Device – it is used to supply a proper amount of refrigerant to the evaporator by reducing its pressure so that the liquid refrigerant can take sufficient heat from the storage space or evaporator.

T-S AND P-H DIAGRAMS



- The P-H and T-S diagram for the simple vapor compression refrigeration cycle is shown in the figure for vapour entering the compressor is in dry saturation condition.
- The dry and saturated vapour entering the compressor at point 1 that vapour compresses isentropically from point 1 to 2 which increases the pressure from evaporator pressure to condenser pressure.

- At point 2, the saturated vapour enters the condenser where heat is rejected at constant pressure, due to rejection of heat decreases the temperature and change of phase takes place i.e. latent heat is removed and reaches to liquid saturation temperature at point 3.
- Then this liquid refrigerant passed through expansion valve where liquid refrigerant is throttled keeping the enthalpy constant and reducing the pressure.

- Applying mass and energy rate balances

Evaporator

$$\frac{\dot{Q}_{\text{in}}}{\dot{m}} = h_1 - h_4$$

The term $\dot{Q}_{\text{in}}$ is referred to as the refrigeration capacity, expressed in kW in the SI unit system .

Compressor

Assuming adiabatic compression

$$\frac{\dot{W}_{\text{c}}}{\dot{m}} = h_2 - h_1$$

Condenser

$$\frac{\dot{Q}_{\text{out}}}{\dot{m}} = h_2 - h_3$$

Expansion valve

Assuming a throttling process

$$h_4 = h_3$$

$$\text{COP} = \frac{\text{Desired or Refrigeration effect}}{\text{Work input}}$$

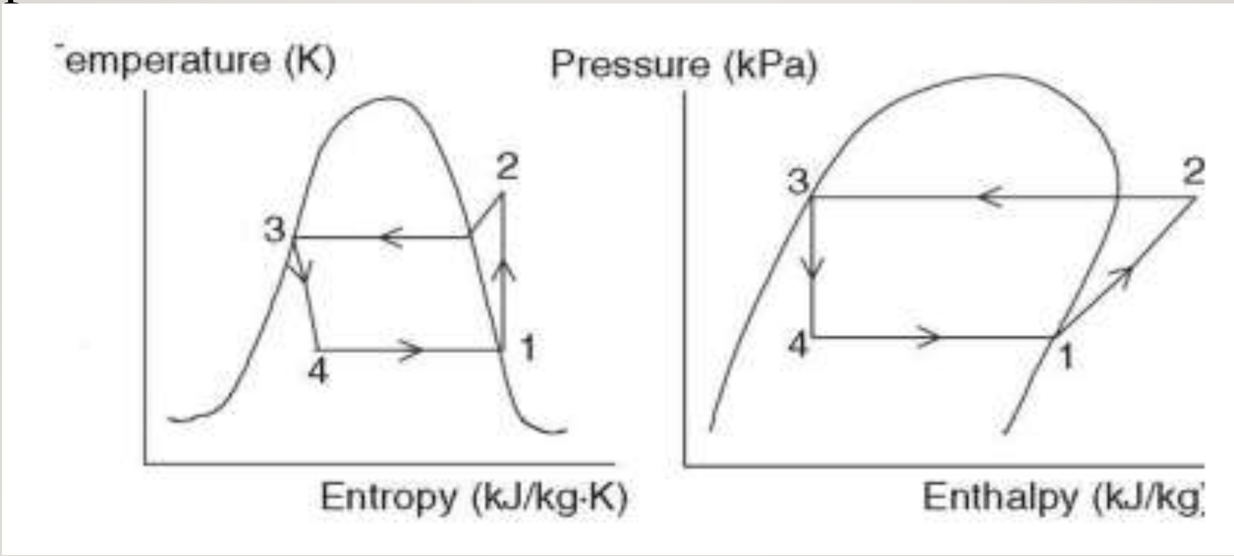
$$= \frac{\text{Heat absorbed in evaporator}}{\text{Work done on the compressor}}$$

$$\text{C.O.P} = \frac{Q_{in}/\dot{m}}{\dot{W_c}/\dot{m}} = \frac{h_1 - h_4}{h_2 - h_1}$$

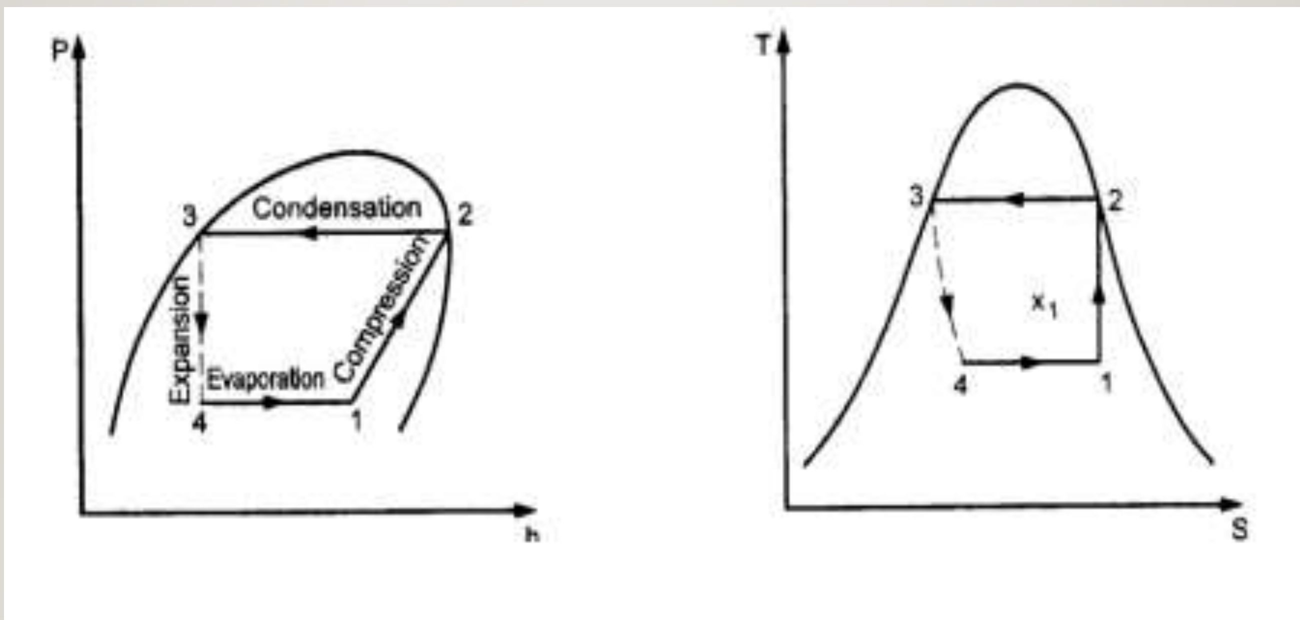
DRY, WET AND SUPERHEATED COMPRESSION

Dry Compression

1. When the refrigerant is dry at the beginning of the compression :-

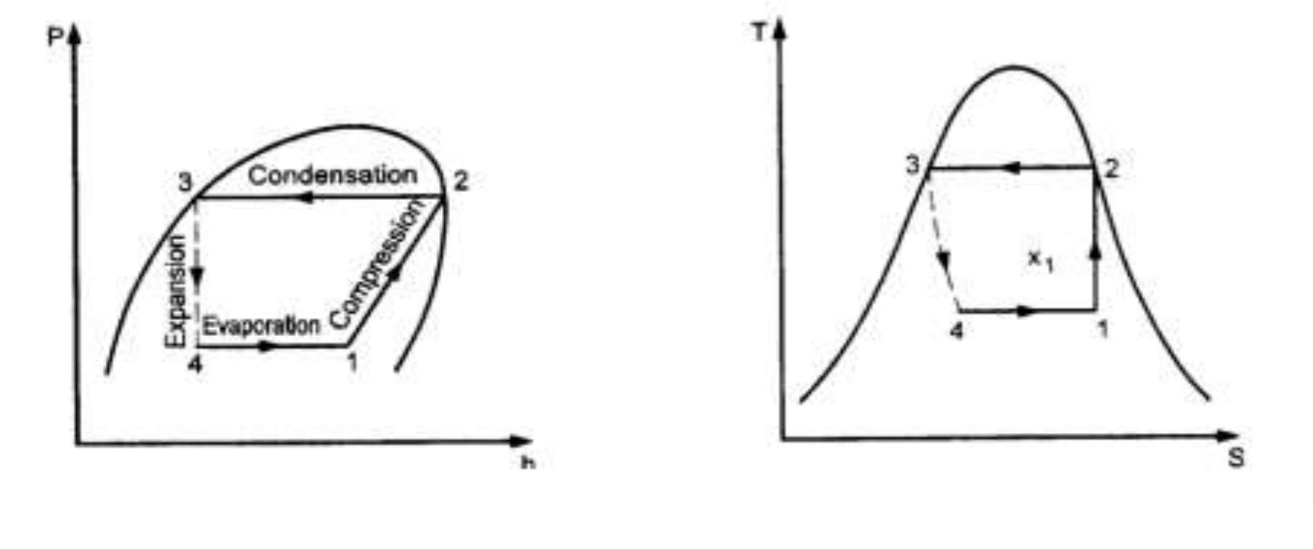


2. When the refrigerant is dry at the end of the compression :-

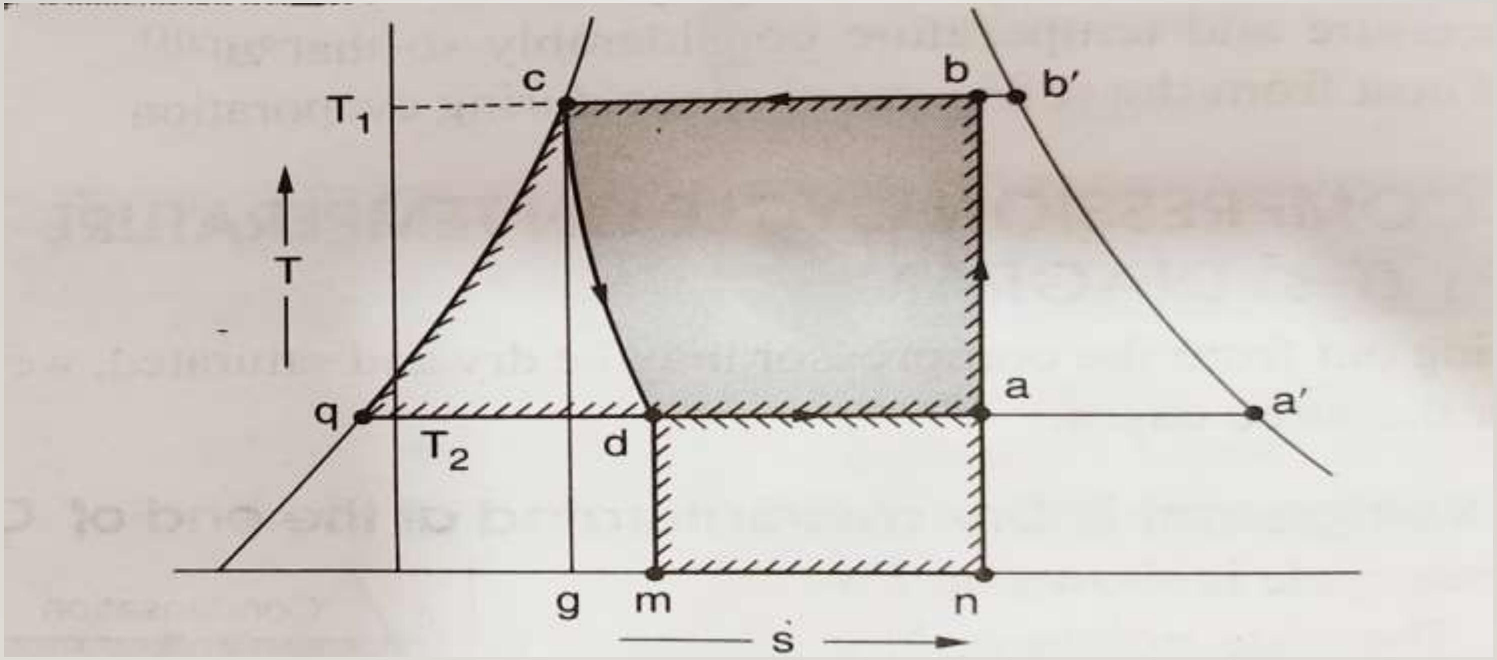


Wet Compression

- When the refrigerant is wet at the beginning of the compression :-

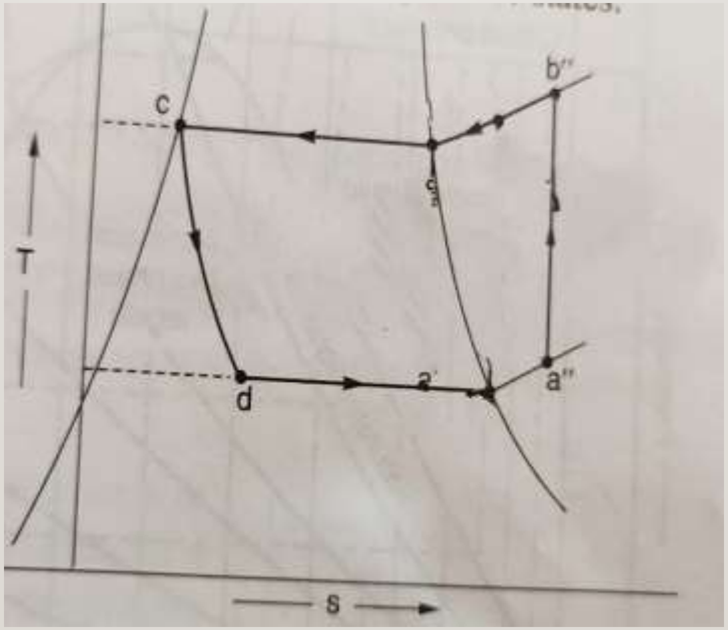


- When the refrigerant is wet at the end of the compression :-

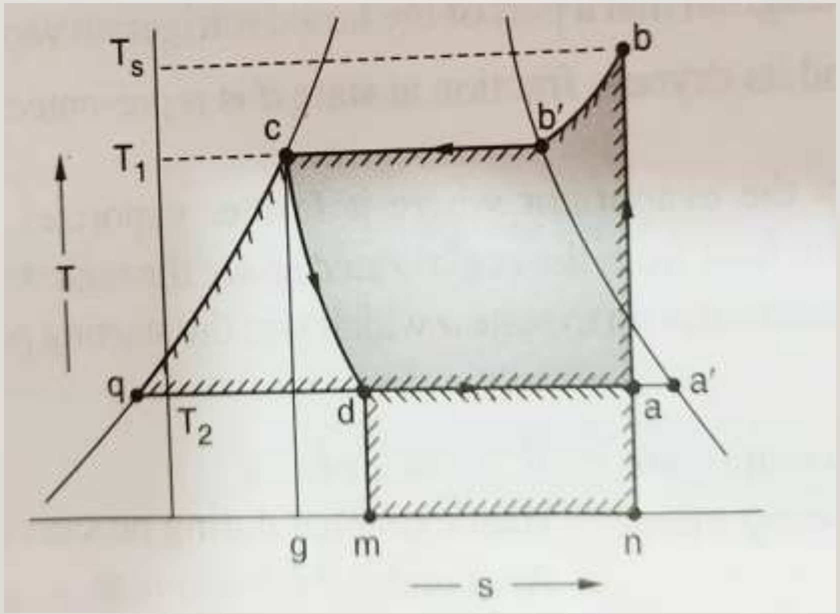


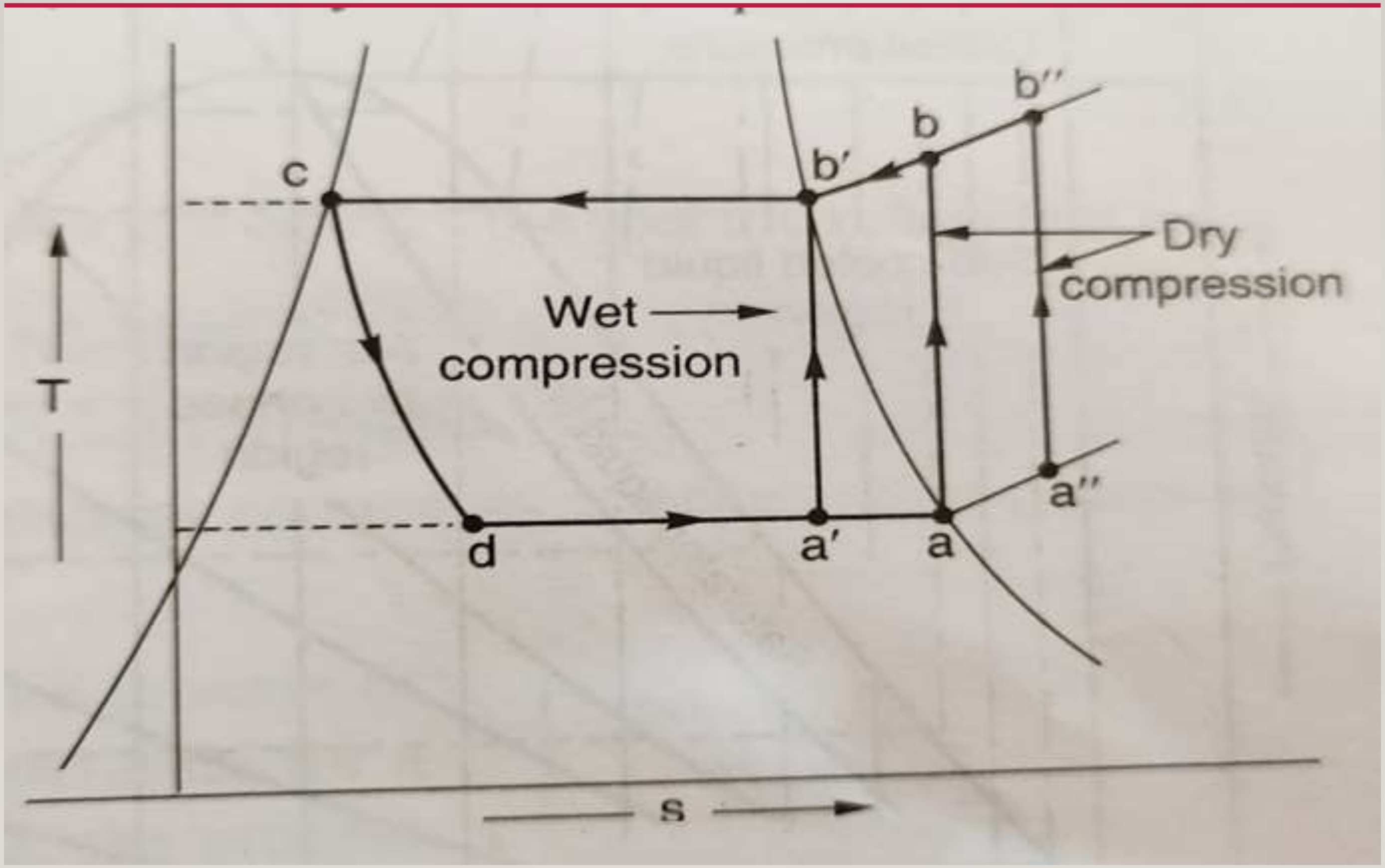
Superheated compression :-

1.When the refrigerant is superheated at the beginning of the compression



2. When the refrigerant is superheated at the end of the compression





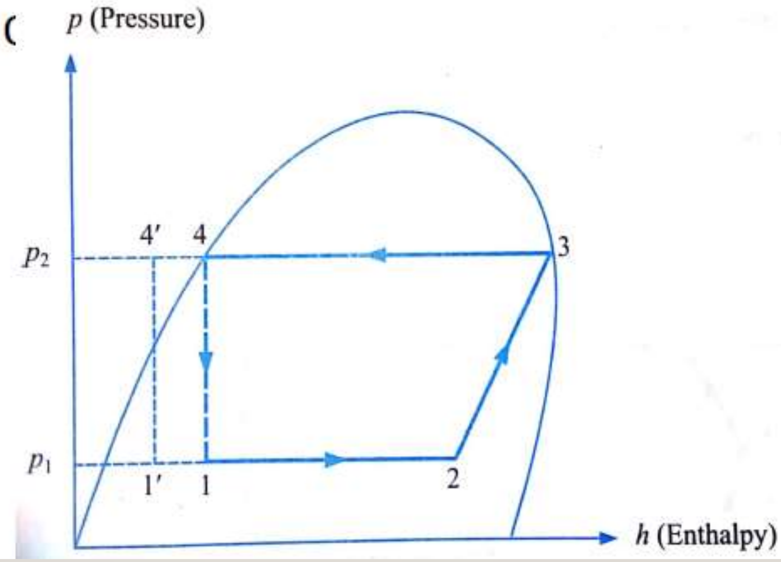
b″
b
b′
c
Dry
compression
Wet
compression
T
a″
d
a′
a
s

FACTORS AFFECTING THE PERFORMANCE OF A VAPOUR COMPRESSION SYSTEM

1. Effect of subcooling
2. Effect of superheating
3. Effect of change in suction pressure
4. Effect of change in discharge pressure

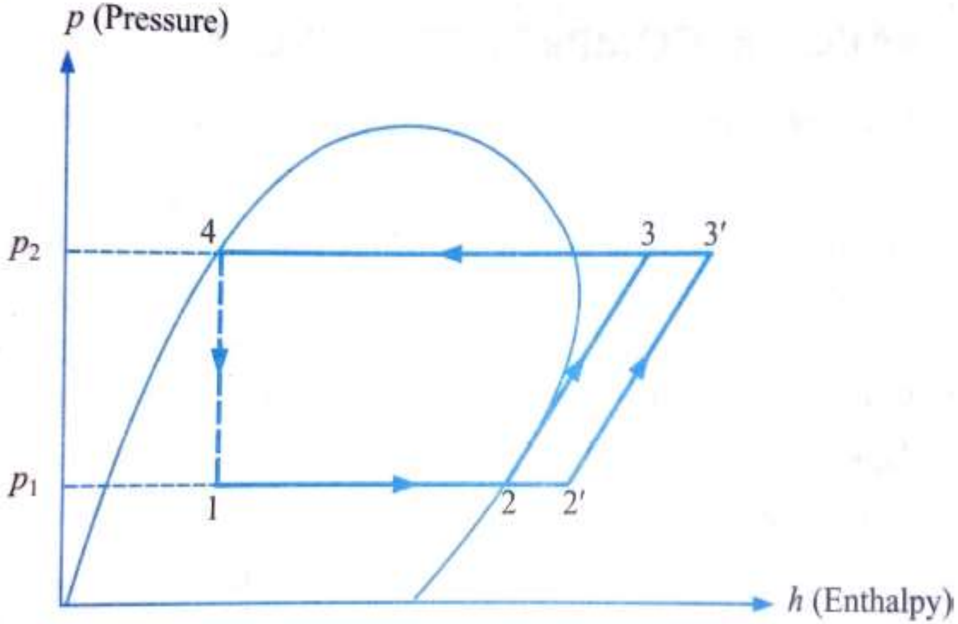
EFFECT OF SUBCOOLING

Sub-cooling is process of cooling the liquid refrigerant below the condensing temperature for given pressure. In the fig. the process of sub-cooling is shown by 4-4'. As is evident from the figure the effect of sub-cooling is to increase the refrigerating effect. thus result in increase of COP provided that no further energy has to be spent to obtain the extra cold (



EFFECT OF SUPERHEATING

The effect of superheating is to increase the refrigerating effect but this increase in refrigerating effect but this increasing effect is at the cost of increase in amount of work spent to attain the upper pressure limit



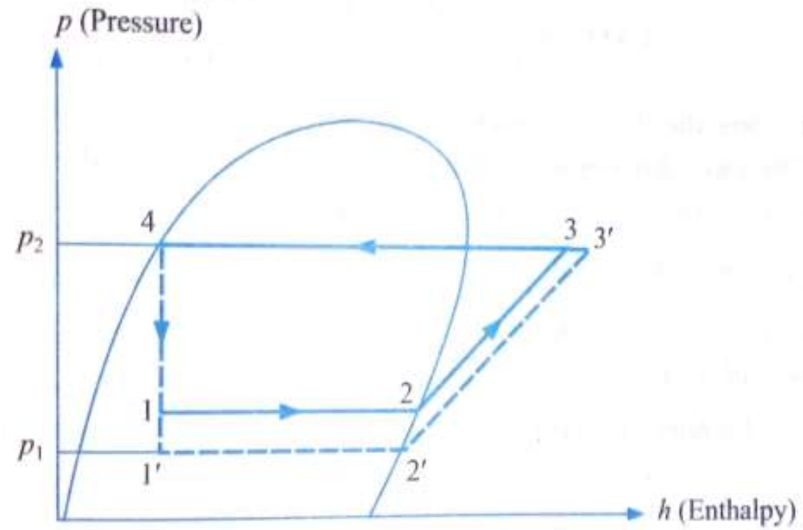
EFFECT OF CHANGE IN SUCTION PRESSURE

Effect of suction pressure: The effect of decrease in suction pressure.

The COP of the cycle when suction pressure is decreased,

$$\text{C.O.P} = \frac{h_{2'}-h_{1'}}{h_{3'}-h_{2'}} = \frac{(h_2-h_1)-(h_2-h_{2'})}{(h_3-h_2)-(h_{2'}-h_2)+(h_{3'}-h_3)}$$

This shows that the refrigerating effect is decreased and work required is increased

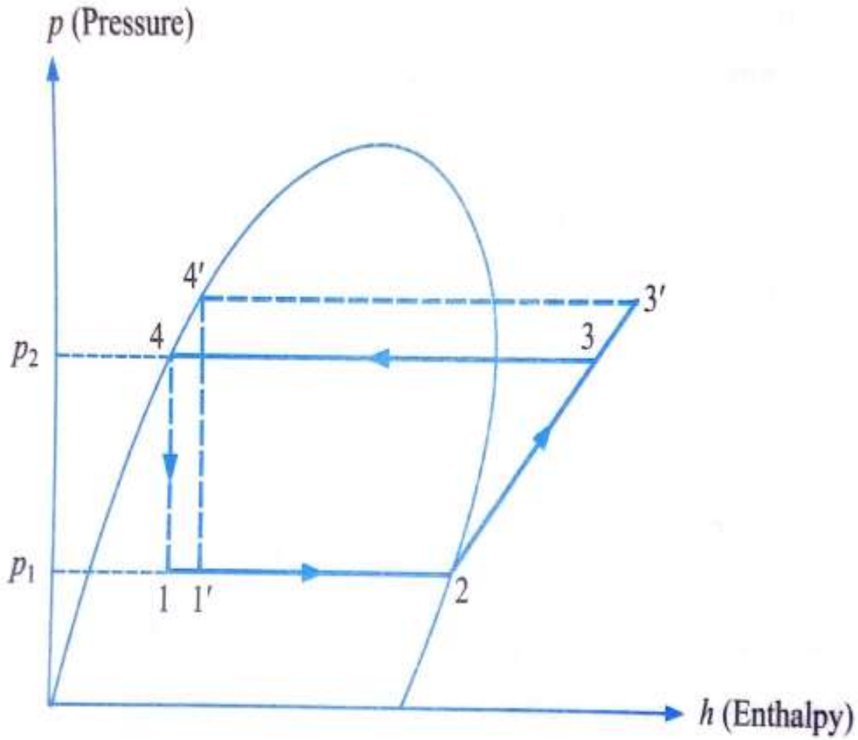


EFFECT OF CHANGE IN DISCHARGE PRESSURE

cop of the cycle when delivery pressure is increased,

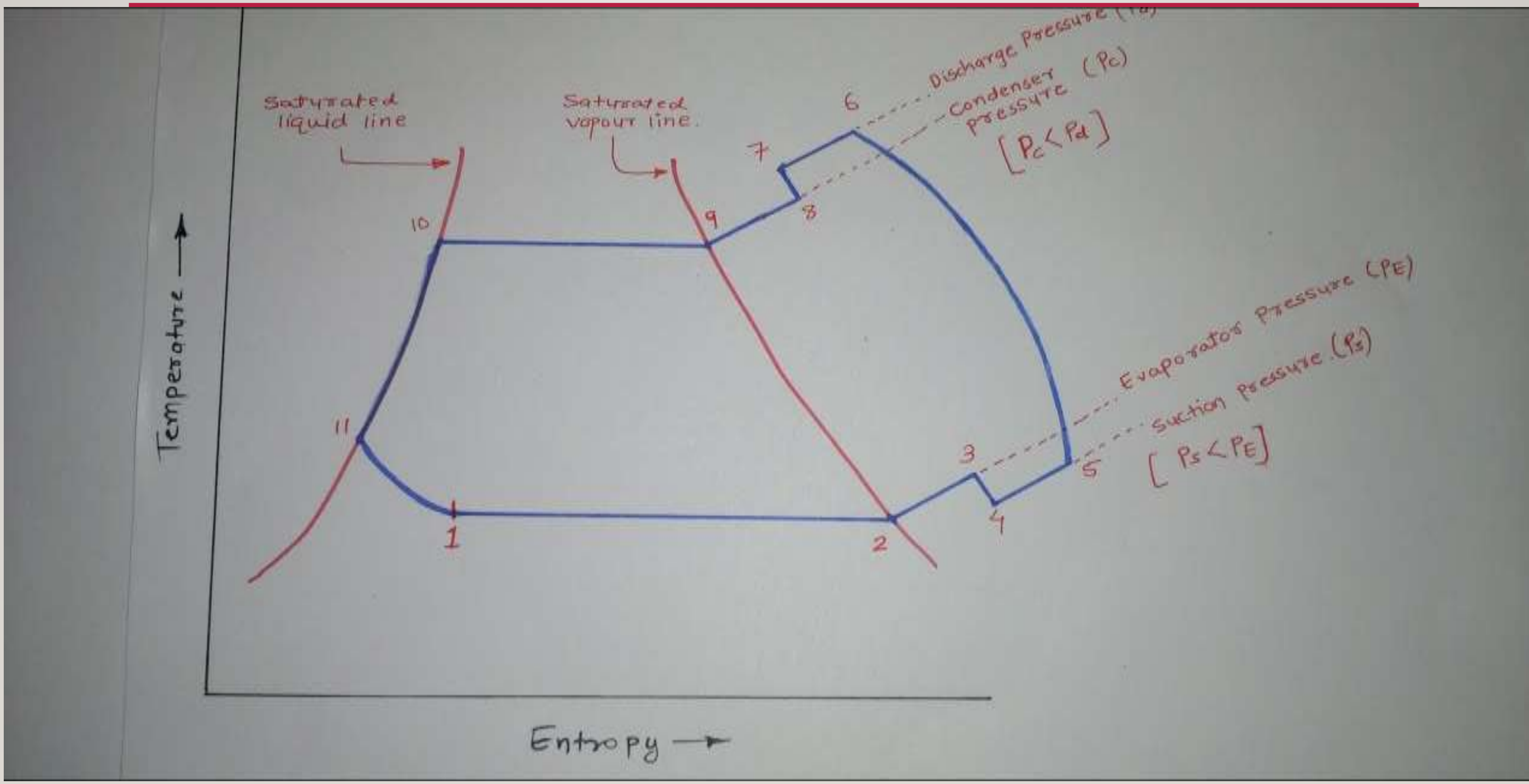
$$COP = \frac{(h_2 - h_1) - (h_{1'} - h_1)}{(h_3 - h_2) + (h_{3'} - h_3)}$$

The effect of increasing the delivery pressure is just similar to the effect of decreasing the suction pressure.



ACTUAL VAPOUR COMPRESSION SYSTEM

- In an actual vapour compression cycle, the liquid refrigerant in the condenser may be sub-cooled before passing through the expansion valve.
- Undercooling of liquid refrigerant increases the refrigerating effect.
- Gas leaves the evaporator in superheated condition before it enters the compressor.
- Compression is assumed to be isentropic, but in actual practice it is very complex that is neither isentropic nor polytropic.



Saturated liquid line
Saturated vapour line.
Discharge Pressure
Condenser pressure (Pc)
[Pc < Pd]
Evaporator Pressure (PE)
Suction pressure (Ps)
[Ps < PE]
1
2
3
4
5
6
7
8
9
10
11
Temperature
Entropy

- As the refrigerant has to flow through pipes in condenser, evaporator and other connecting pipes, due to frictional resistance to flow there is a pressure drop in pipes.

- In an actual vapour compression cycle, the cylinder walls of the compressor are hotter than the incoming gases from the evaporator.

AIR REFRIGERATION CYCLE:

1. Air is used as working fluid.

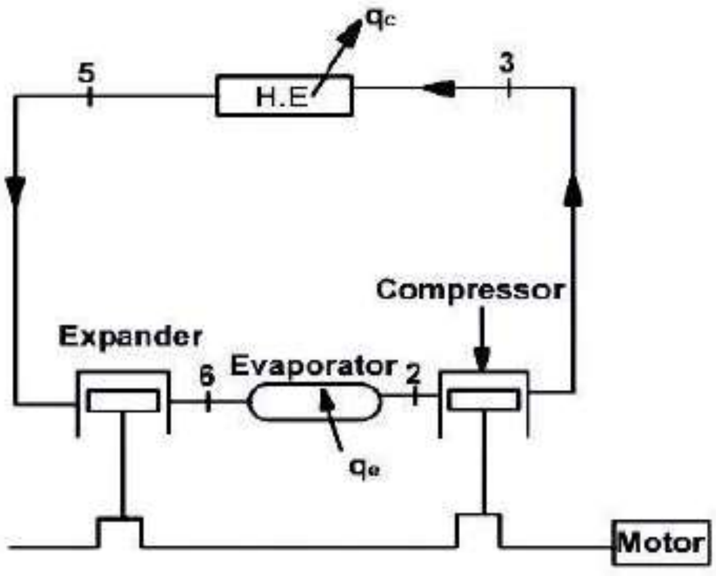
2. No change of phase through out.

3. Heat carrying capacity/kg of air is very small compared with other refrigerant systems. High pressure air readily available in the Aircraft .

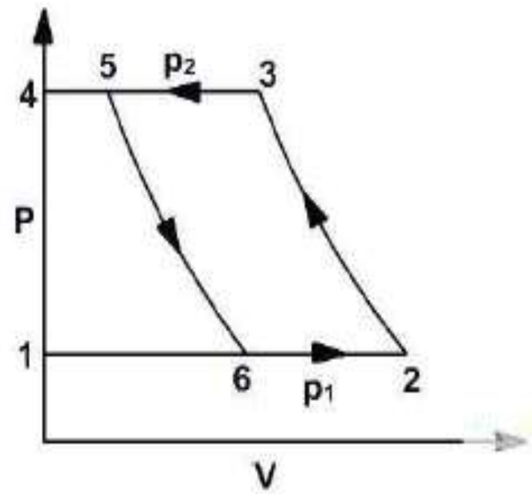
4. Low equipment weight.

- Basic elements: 1. Compressor 2. Heat exchanger 3. Expander 4. Refrigerator

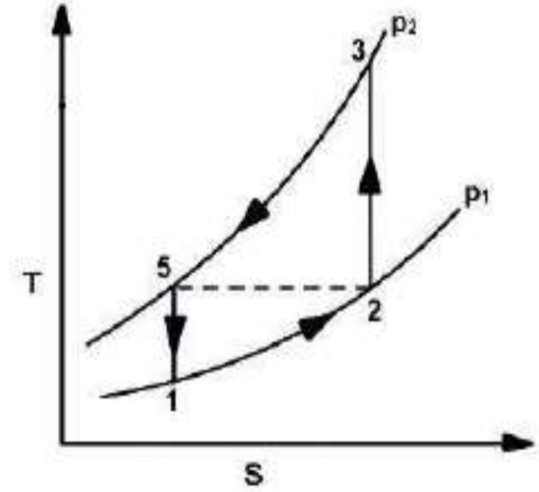
Air Refrigeration System And Bell-Coleman Cycle Or Reversed Brayton Cycle:



Air refrigeration system



Air refrigeration system



Air refrigeration system

The components of the air refrigeration system are shown in Fig. In this system, air is taken into the compressor from atmosphere and compressed. The hot compressed air is cooled in heat exchanger up to the atmospheric temperature (in ideal conditions). The cooled air is then expanded in an expander.

The temperature of the air coming out from the expander is below the atmospheric temperature due to isentropic expansion. The low temperature air coming out from the expander enters into the

evaporator and absorbs the heat. The cycle is repeated again. The working of air refrigeration cycle is represented on p-v and T-s diagrams in Fig.

Assumptions:

1) The compression and expansion processes are reversible adiabatic processes.

2) There is a perfect inter-cooling in the heat exchanger.

3) There are no pressure losses in the system.

ADVANTAGES OF AIR –REFRIGERATION SYSTEMS

1. As the air is easily available compared with the other refrigerant, it is cheap.

2. The air used is non-flammable, so there is no danger of fire as in NH3 machine.

3. The weight of the air refrigeration system / T.R is quite low compared with the other refrigeration systems which is one of the major causes selecting this system in air craft.

DISADVANTAGES OF AIR –REFRIGERATION SYSTEMS

- Very Low COP
- Large power requirement
- More space
- Volume of air to be circulated is more compared to other refrigerators. This sets the limitation of its usage to small capacity plants.

CHAPTER -3

REFRIGERANTS

INTRODUCTION

- The refrigerant is heat carrying medium which during their cycle (i.e. Compression, condensation, expansion and evaporation) in the refrigeration system absorb heat from a low temperature system and discard the heat so absorbed to a higher temperature system.

CLASSIFICATION *OF REFRIGERANTS*

1. Primary Refrigerants

2. Secondary refrigerants

1. Primary refrigerant : -primary refrigerants are those which cool the substance by absorption of latent heat mainly.

These directly participate in the refrigeration process. Such refrigerants are ammonia, carbon dioxide, methyl chloride, methylene chloride, freons etc. these refrigerants find much use in VCR system.

2. Secondary refrigerants :-

- secondary refrigerants are those which cool the substances by absorbing sensible heat and without undergoing any changes of state.
- These refrigerants do not directly participate in the refrigeration process but are employed as the intermediate cooling agents.

- These are first cooled by the primary refrigerants and then circulated through the places where the cooling or refrigeration is to be produced.
- Such indirect cooling finds wide applications in ice plants, commercial and industrial refrigeration and air-conditioning plant etc.
- These refrigerants include water, brines, air , antifreeze solutions etc.

PROPERTIES OF REFRIGERANTS

1. R-717 (NH_3)

- High latent heat
- High refrigerating capacity
- Non-miscible with oil
- Non corrosive
- Low boiling point
- Colourless
- Never be used with copper and copper based alloys

2. R-22 ($CHClF_2$)

- Non corrosive and Non toxic
- Odourless
- Non explosive
- Stable under operating condition
- Latent heat is higher than R-12
- Ozone depletion potential (ODP) is very less

3. R-134a (CH_2FCF_3)

- Zero ODP as it is chlorine free.
- Non flammable
- Non toxic
- Highly chemically stable
- Low boiling point
- High specific heat capacity

4. CO_2

- Colourless
- Odourless
- Non explosive
- Non corrosive
- Chemically stable
- Non miscible with oil
- High vapour density. So the required compressor size is small

5. R-12(CCl_2F_2)

- Non toxic
- Non flammable
- Non explosive
- Low boiling point (-29.8 ℃)
- Highly stable under operating conditions
- ODP is higher than that of R-22 , R- 134a

6. R-502

- It is an azeotropic mixture of R22 and R115. used for low temperature applications
- Non toxic
- Non corrosive
- Non flammable
- Good oil solubility at temperature above 80 °C .

PROPERTIES OF AN IDEAL REFRIGERANT

Since there is no ideal refrigerant. But a refrigerant is said to be ideal if it has all of the following properties:

- Low Boiling point
- High critical temperature
- High latent heat of vaporization
- Low specific heat of liquid
- Low specific volume of vapour of

- Non-corrosive to metal
- Non-flammable and non-explosive
- Non-toxic
- Low cost
- Easy to liquefy at moderate pressure and temperature
- Easy of locating leaks by odour or suitable indicator, and
- Mixes well with oil.

SELECTION OF REFRIGERANT

While selecting a refrigerants for a particular application, the thermodynamic, physical, chemical and safe working properties etc. of refrigerant should be properly considered. like

- Working temp. and pressure
- Toxicity flammability and corrosiveness
- Miscibility with oil
- Type of equipment and its size
- Applications and cost

Pressure and Temperature Range	Utility	Refrigerants Used
Low pressure and high temperature refrigerants.	(*i*) For Air-conditioning of theatres, offices, factories and auditoriums. (*ii*) Industrial cold water supply used for distillation and cooling of the equipment.	R–11, R–113, R–718 (Water), R–30 (Methylene chloride)
Intermediate pressure and low temperature refrigerants.	(*i*) For domestic refrigerators and water coolers. (*ii*) Small air-conditioners.	R–12, R–134*a* R–764 (SO_2), R–40, R–601 (Isobutane)
High pressure and low temperature refrigerants.	(*i*) Domestic and commercial freezers. (*ii*) Cold storage plants, ice cream factories, breweries etc.	R–717 (NH_3), R–12 R–22, R–744 (CO_2), R–134 *a*
High pressure and very low temperature refrigerants.	(*i*) Liquifaction of gases. (*ii*) Metallurgical operations. (*iii*) Aerodynamic wind tunnels.	R–13, R–14 R–170 (Ethane) R–1150 (Ethylene)

CHAPTER -4

VAPOUR ABSORPTION SYSTEM

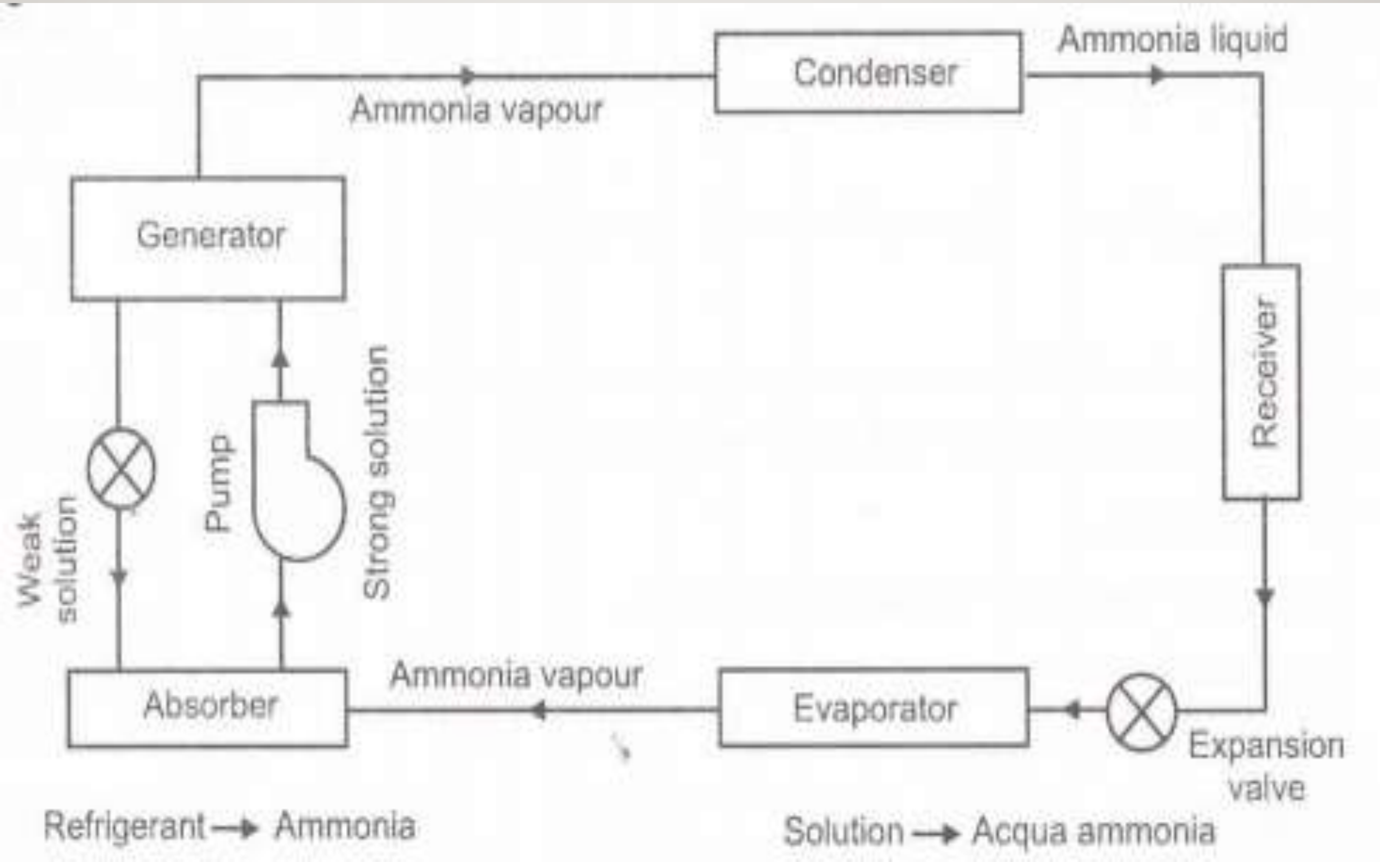
INTRODUCTION

- The vapour absorption system makes use of heat energy rather than mechanical energy to operate the system.
- The compression of the VCR system is replaced by an absorber, a generator and a pump while the other components such as condenser, expansion device and evaporator remain as such.

PRINCIPLE OF SIMPLE VAPOUR ABSORPTION SYSTEM

The operating principle in this system is to absorb the vapour refrigerant after its leaves the **evaporator** in a solution in the **absorber** at relatively low temp. and pressure, to **pump** mechanically this solution into the **generator** at a higher pressure and after distillation pass it to **condenser**. The refrigerant that goes to the **expansion device** follows the usual course of events until it absorbs the heat from the **evaporator** and produces the refrigeration effect therein (storage space).

WORKING OF SIMPLE VAPOUR ABSORPTION SYSTEM



- A Simple Vapor absorption system consists of evaporator, absorber, generator, condenser, expansion valve, pump & reducing valve.
- In this system the solution used is aqua ammonia. Where ammonia is used as refrigerant and water is used as absorbent.
- Strong solution of aqua ammonia contains as much as ammonia as it can and weak solution contains less ammonia.

- The heat flow in the system at generator, and work is supplied to pump. Ammonia vapours coming out of evaporator are drawn in absorber. The weak solution containing very little ammonia is spread in absorber. The weak solution absorbs ammonia and gets converted into strong solution. This strong solution from absorber is pumped into generator.
- The addition of heat liberates ammonia vapor and solution gets converted into weak solution. The released vapor is passed to condenser and weak solution to absorber through a reducing valve.

- Thus, the function of a compressor is done by absorber, a generator, pump and reducing valve. The simple vapor Absoption system is used where there is scarcity of Electricity and it is very useful at partial and full load.

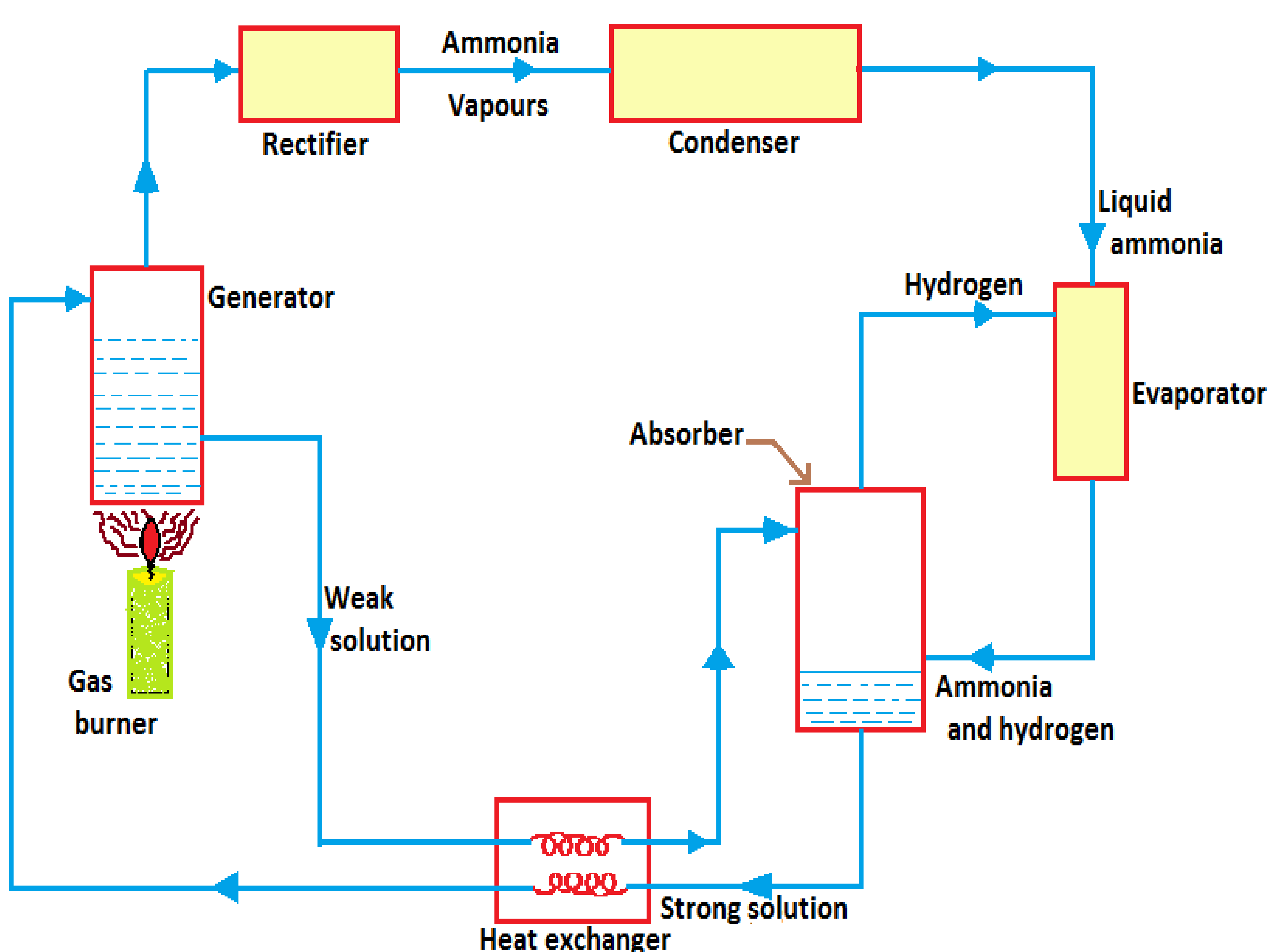
DOMESTIC ELECTROLUX REFRIGERATION SYSTEM

Principle :

If a liquid is exposed to an inert atmosphere, it will evaporate until atmosphere becomes saturated with the liquid vapours. Evaporation thus produces cooling effect.

Working :

- Liquid $NH3$ evaporates into $H2$ gas at low temperature in evaporator.
- $NH3$ + $H2$ mixture enters absorber where $NH3$ is absorbed in water, $H2$ returns back.
- Strong sol. $NH3$ in $H2O$ goes to generator, where it is heated and vapours then go to water


Ammonia
Vapours
Rectifier
Condenser
Liquid
ammonia
Hydrogen
Generator
Evaporator
Absorber
Weak
solution
Gas
burner
Ammonia
and hydrogen
Strong solution
Heat exchanger

ROLE OF HYDROGEN

- Helps in maintaining uniform total pressure throughout the system.
- Permits the refrigerant to evaporate at low temperature in evaporator, corresponding to its partial pressure.

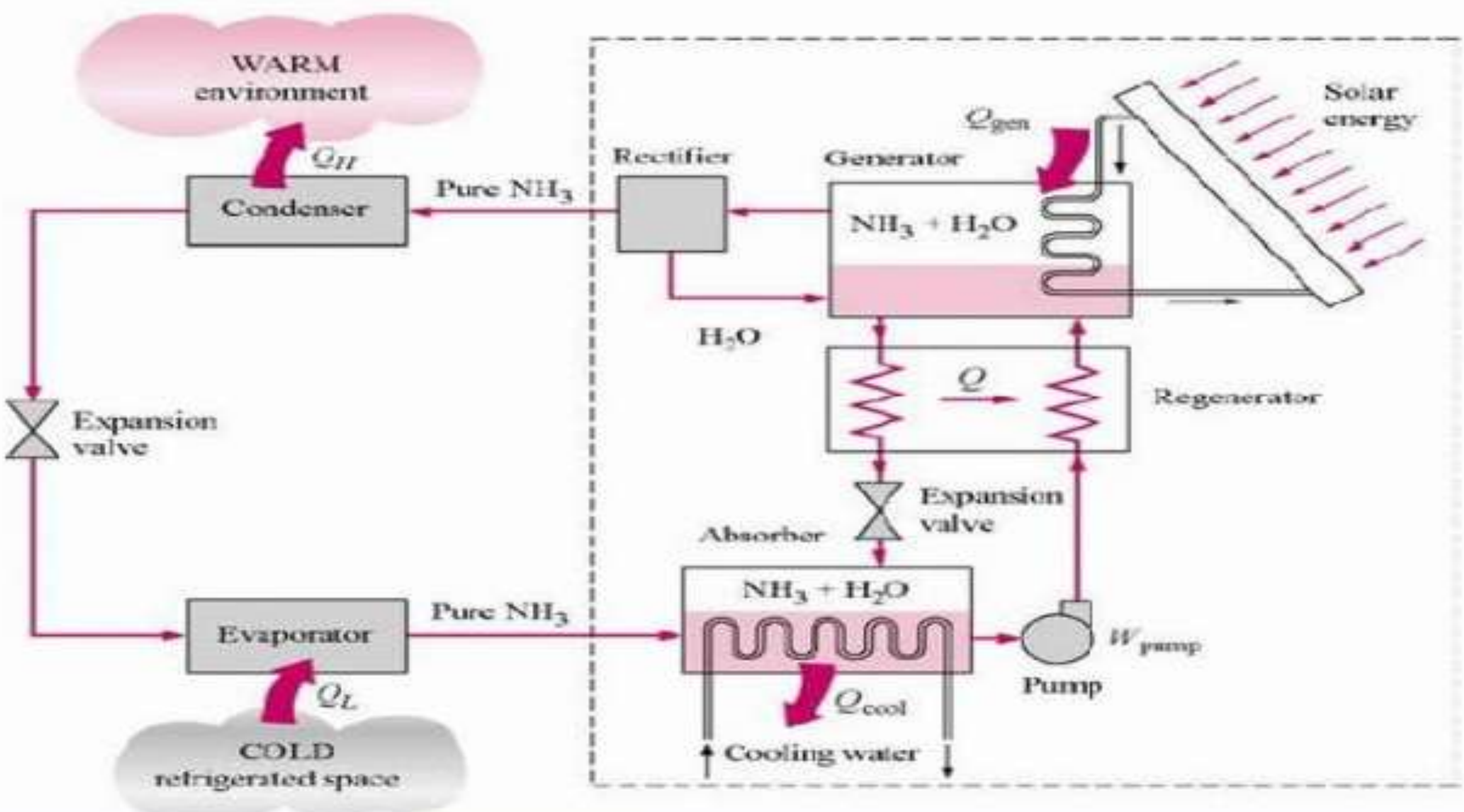
VAPOUR COMPRESSION V/S VAPOUR ABSORPTION SYSTEM

Vapour Compression System	Vapour Absorption System
1. Noisy in operation.	Quite in operation.
2. Energy supplied is a high grade energy.	Energy supplied is a low grade energy.
3. Energy supplied is Lower than Ref. Effect	Energy supplied is Higher than Ref. Effect
4. Poor performance at partial loads.	Performance is not affected by load variation.
5. Electricity requirement is must	Can be operated by any medium of heat like solar etc.
6. Charging of refrigerant is simple.	Charging of refrigerant is difficult.
7.Chances of leakage of refrigerant are more.	Chances of leakage of refrigerant are less.
8. Liquid particles in suction line may damage the compressor	Liquid particles does not cause any damage.

SOLAR POWER REFRIGERATION SYSTEM

- Solar refrigeration system is basically a vapour absorption system which utilizes solar energy as heat to produce refrigeration.
- It works on the same working principle as that of vapour absorption system.

$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Cooling effect}}{\text{Work input}} = \frac{Q_L}{Q_{gen} + W_{pump,in}} \cong \frac{Q_L}{Q_{gen}}$$



ADVANTAGES OF SOLAR REFRIGERATION SYSTEM

- Operating cost is very low.
- It has limited wear and tear.
- It is energy saving system as it uses natural energy
- It is eco-friendly
- Its performance is not affected by variation in load

DISADVANTAGES OF SOLAR REFRIGERATION SYSTEM

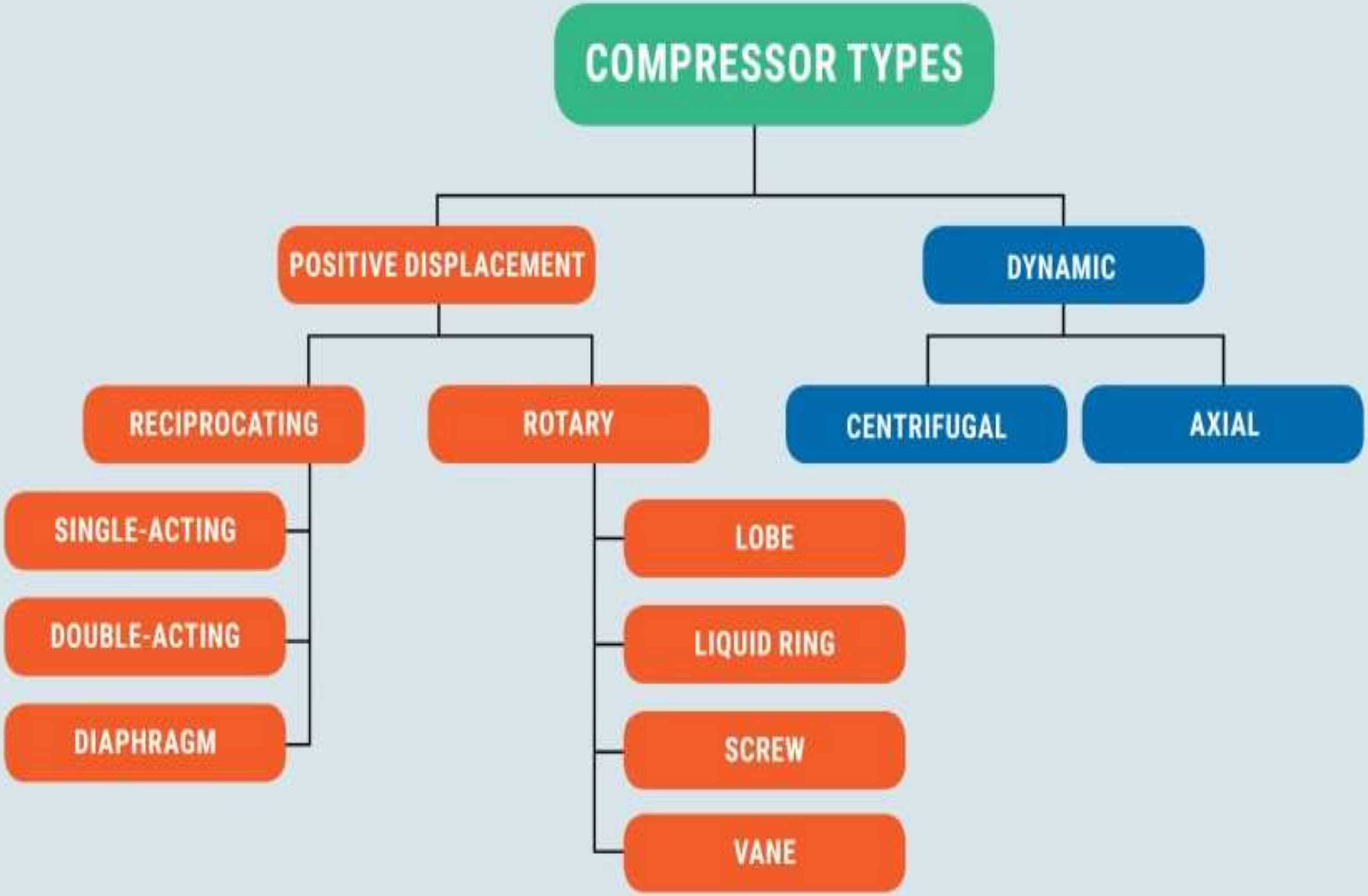
- It has low COP.
- Initial cost is high.
- It occupies more space.
- It’s not possible to achieve temperatures below 0 °C.
- Its performance is inconsistent as the system is dependent upon uncertain weather conditions.

CHAPTER -5

REFRIGERATION EQUIPMENT

COMPRESSOR

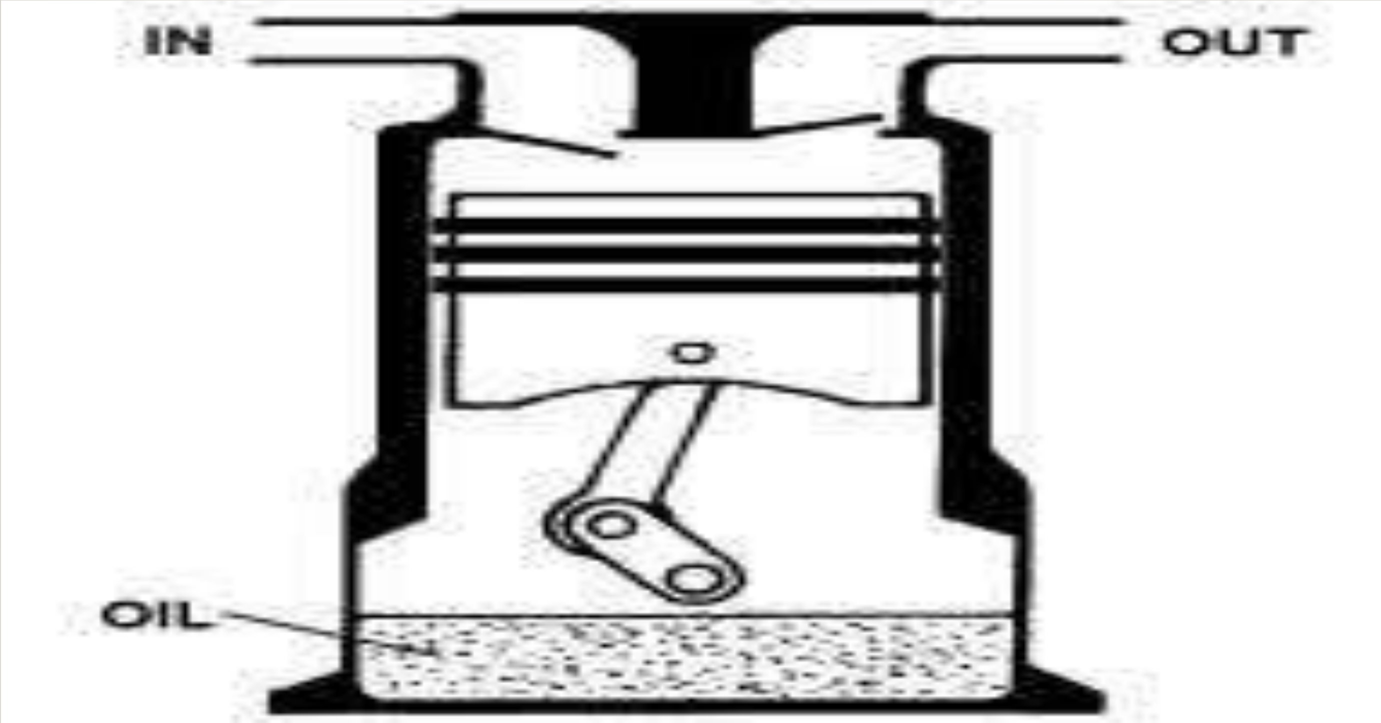
- The **compressor** is the heart of the air-conditioning system because it circulates or pumps refrigerant and oil through the system.
- The compressor is responsible for two main functions required by air-conditioning systems:
  - One is to raise the pressure of the refrigerant.
  - The second function is to create low pressure in the evaporator.



COMPRESSOR TYPES
POSITIVE DISPLACEMENT
DYNAMIC
RECIPROCATING
ROTARY
CENTRIFUGAL
AXIAL
SINGLE-ACTING
DOUBLE-ACTING
DIAPHRAGM
LOBE
LIQUID RING
SCREW
VANE

RECIPROCATING COMPRESSORS

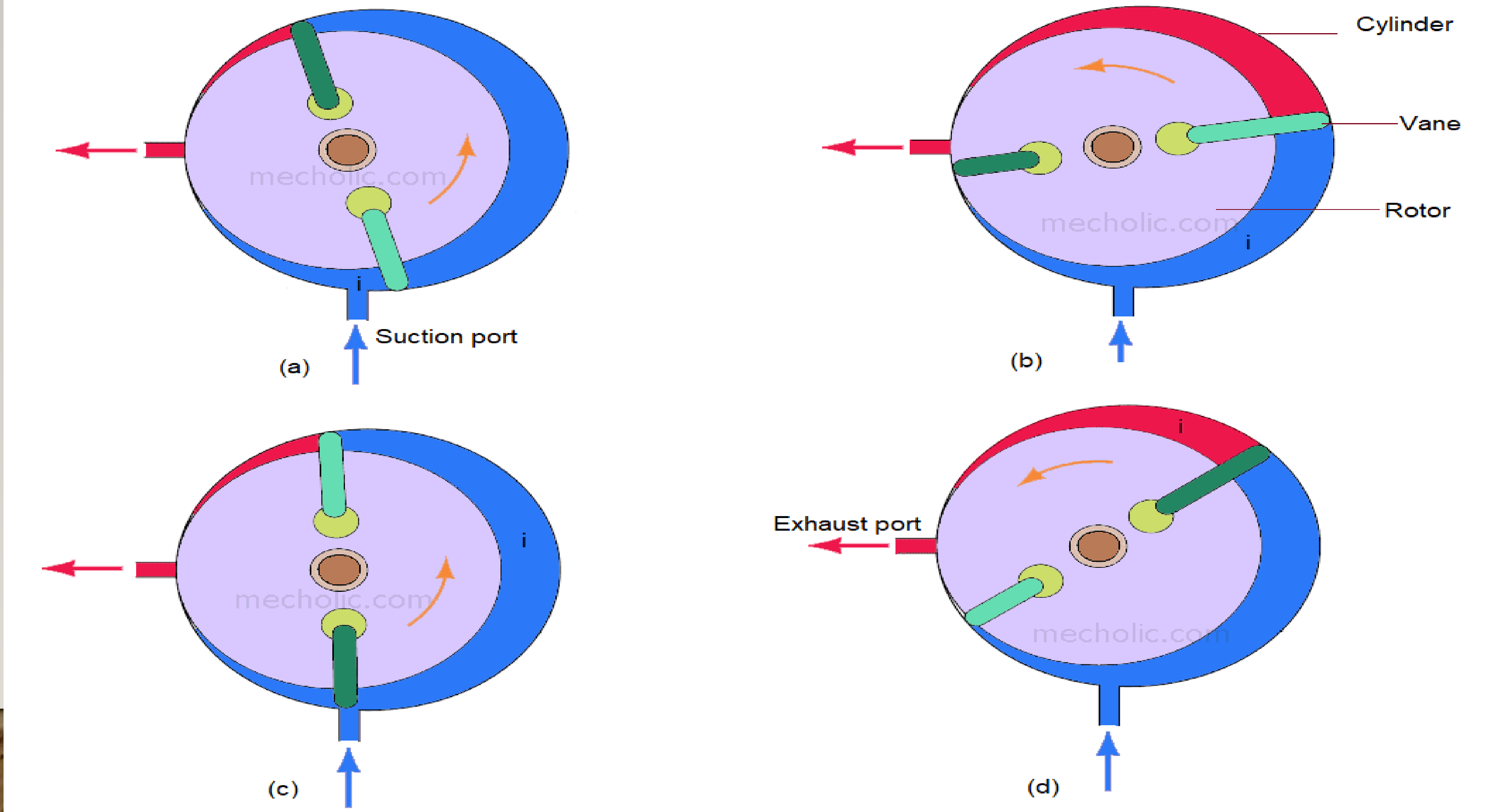
- The reciprocating compressors are one of the most widely used types of the refrigerating compressors.
- They have piston and cylinder arrangement like the automotive engine. The reciprocating motion of the piston due to external power compresses the refrigerant inside the cylinder.
- There are three types of reciprocating compressors: hermetically sealed, semi-hermetically sealed and open type. The open of reciprocating compressors can be of single cylinder type or multi-cylinder type.


IN
OUT
OIL

ROTARY COMPRESSOR

- The rotary compressors have two rotating elements, between which the refrigerant is compressed. These compressors can pump the refrigerant to lower or moderate condensing pressures.
- Since they can handle small volume of the gas and produce lesser pressure, they are used in fewer applications.

ROLLING VANE TYPE ROTARY COMPRESSOR

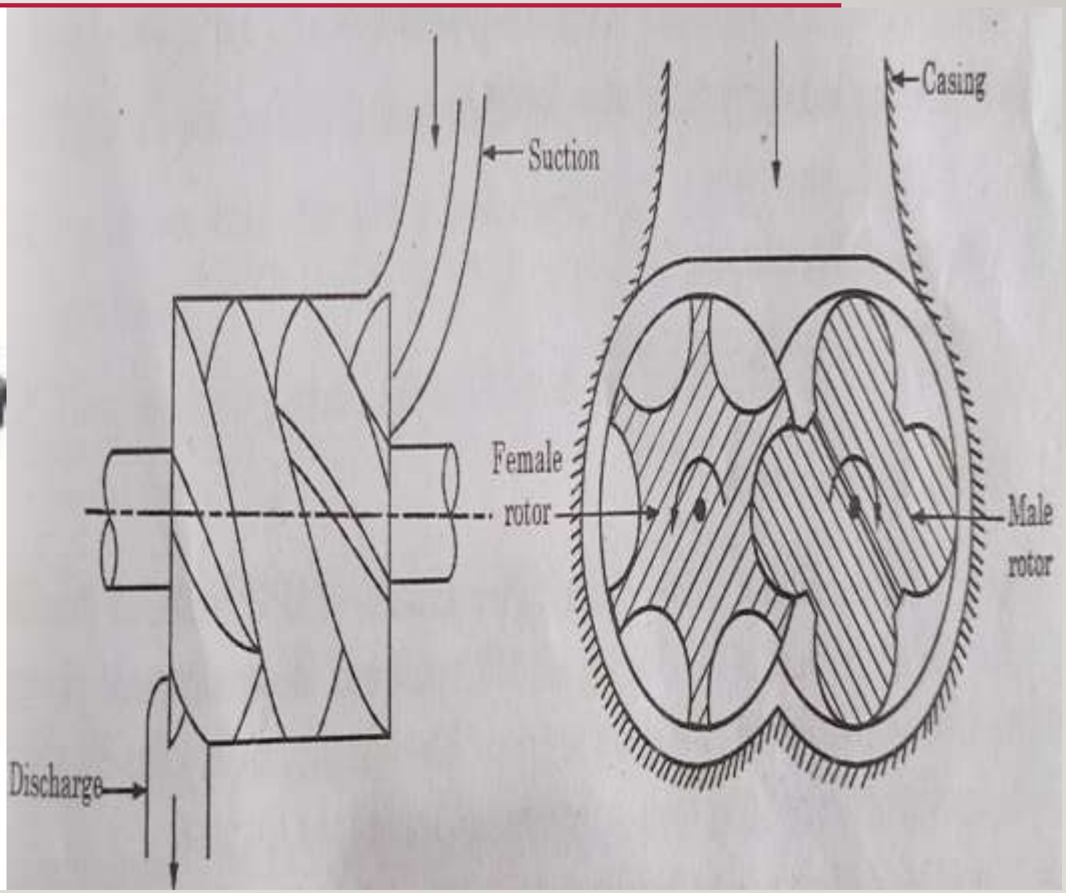


Rolling vane type compressor has a roller inside a stationary cylinder. Roller has two or more vanes positioned in the slots of the rotor. Vanes rotate with the roller and ride on the cylinder wall. The roller may have as many as eight vanes. The more the number of vanes it has the more the efficient compressor will be. A roller moves the vanes slides in and out of the roller to create a sealed space for compression. As roller continues to rotate this space get decreased, and causing compression of fluid (refrigerant) trapped inside this space during the suction.

SCREW COMPRESSOR

- These are positive displacement rotary compressors which have no suction and discharge valves.
- It consist of two rotors messing with each other and enclosed in a casing. The space between two rotors and the casing is called inter-lobel space. An increase in the inter- lobel space causes suction and a decrease causes compression

- The progressive plunges of the lobes into the gas filled flutes increases the pressure and decrease the volume of the gas. The gas is simultaneously propelled forward due to the helical profile of the rotor. The gas then discharges into the discharge port at constant pressure.

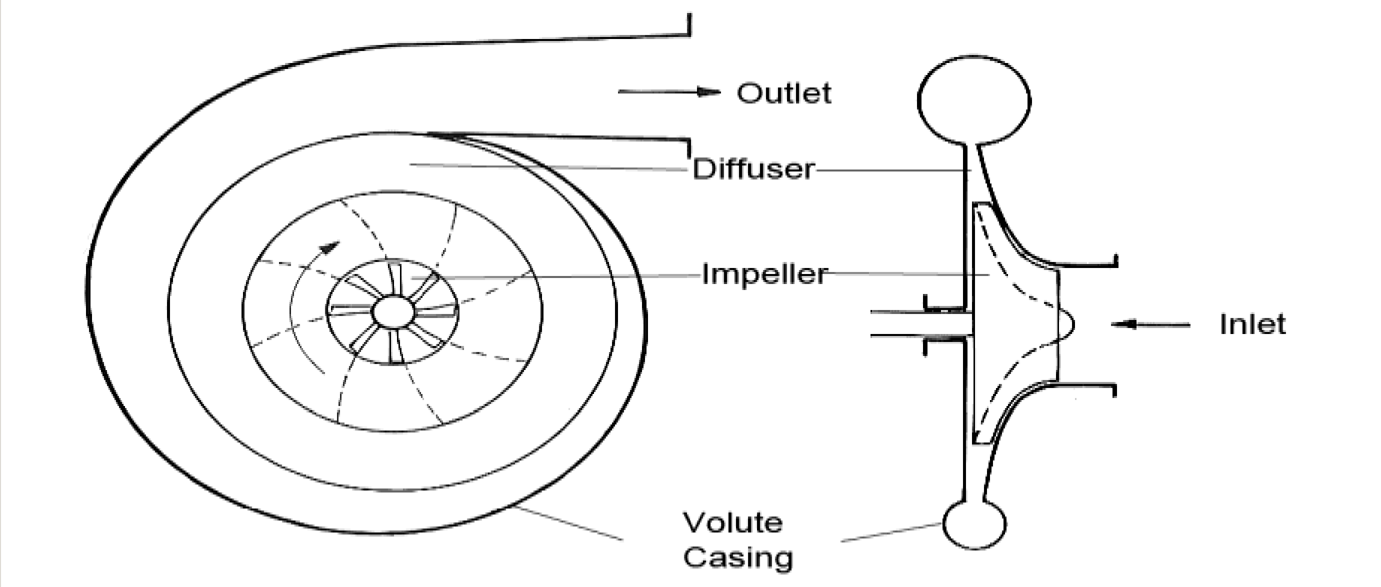

Casing
Suction
Female
rotor
Male
rotor
Discharge

CENTRIFUGAL COMPRESSOR

- A centrifugal compressor, unlike the reciprocating and rotary compressor, depends upon the centrifugal force and not on positive displacement for compression of the refrigerant (gas).
- It consists of an impeller on which a number of curved vanes are fitted symmetrically. The vanes may be radial or forward curved or backward curved.

- The impeller rotates in an air tight volute casing having inlet and outlet points.
- The incoming low pressure gas enters the eye of the impeller and is thrown to the periphery by centrifugal force.
- The high speed of the impeller imparts high velocity to the vapour at the vane tips of impeller.
- This kinetic energy is converted into pressure energy as the high velocity vapour passes over the vaneless diffuser

- Further the volute casing maintains the static pressure before discharging it to the outlet.



Centrifugal compressor schematic diagram

CONDENSERS

- a **condenser** is a device or unit used to condense a substance from its gaseous to its liquid state, by cooling it. In so doing, the latent heat is given up by the substance, and will transfer to the condenser coolant.
- It is used in systems involving heat transfer
- Condensers are typically heat exchangers, which have various designs and come in many sizes ranging from rather small (hand-held) to very large industrial-scale units used in plant processes.

- a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemicalprocesses such as distillation, heat-exchange steam power plants and other systems.
- Use of coolingwater or surrounding air as the coolant is common in many condensers.

FUNCTIONS OF CONDENSER:

- In the world of Heating, Ventilation, and Air Conditioning (HVAC), condensers happen to be a topic of great importance. Instead of confusing information, the goal is to provide some basic information on the different types of condensers and their applications.

TYPES OF CONDENSER

There are three other condensers used in HVAC systems

- **Water-cooled**
- **Air-cooled**
- **Evaporative**

AIR COOLED CONDENSER

- The Condenser uses air as cooling medium to condense refrigerant is called as **Air Cooled Condenser.**

- If the condenser is located on the outside of the unit, the air cooled condenser can provide the easiest arrangement. These types of condensers eject heat to the outdoors and are simple to install.

- Most common uses for this condenser are domestic refrigerators, upright freezers. A great feature of the air cooled condenser is they are very easy to clean. Since dirt can cause serious issues with the condensers performance, it is highly recommended that these be kept clear of dirt.
- Air cooled condenser requires large surface area because of low specific heat of air.
- Air cooled condenser is made of steel ,copper or aluminum.

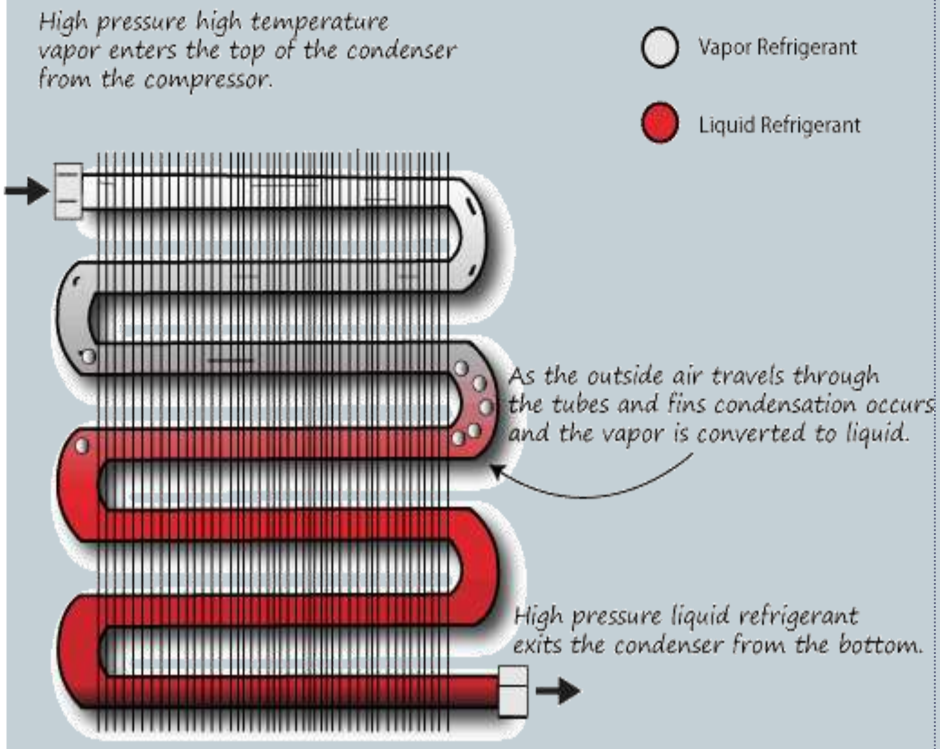
TYPES OF AIR COOLED CONDENSER

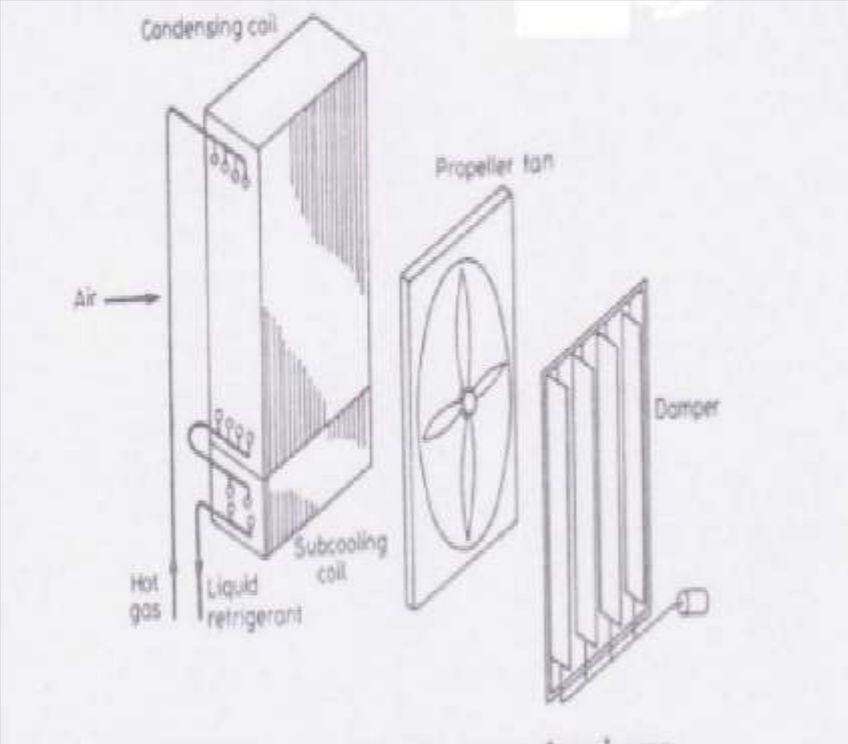
There are majorly two types of air cooled condenser.

- Natural Convection Condenser.
- Forced Convection Condenser.

Natural Convection

Forced Convection





Forced convection air cooled condenser.

Natural Convection	Forced Convection
• Needs large surface area .	• Need fan or blower to decrease surface area.
• Consumes larger space.	• Consumes less space.
• Simple in construction.	• Complex in construction.
• Low cost.	• High cost comparatively.

ADVANTAGES OF AIR COOLED CONDENSER

- Used in locations where water is difficult to use
- Very simple construction
- Low initial cost and maintenance cost
- Less piping work to do
- Less chances of fouling
- Very easy to clean

DISADVANTAGES OF AIR COOLED CONDENSER

- Low heat transfer rate
- Noisy operation while application
- Large surface area is required
- In hot weathered conditions it is less effective
- It is less efficient than water cooled condenser
- Air cooled condenser can not be used along with refrigerant having higher compression index

WATER COOLED CONDENSER

- **Water cooled condenser** uses water as a cooling medium it may be recirculated or fresh water depends upon availability
- Although a little more pricey to install, these condensers are the more efficient type and require regular service and maintenance.
- They also require a cooling tower to conserve water. To prevent corrosion and the forming of algae, water cooled condensers require a constant supply of makeup water along with water treatment.

- The selection of water cooled condenser depends upon cooling load in evaporator condenser temperature ,availability of water and water inlet and outlet temperature

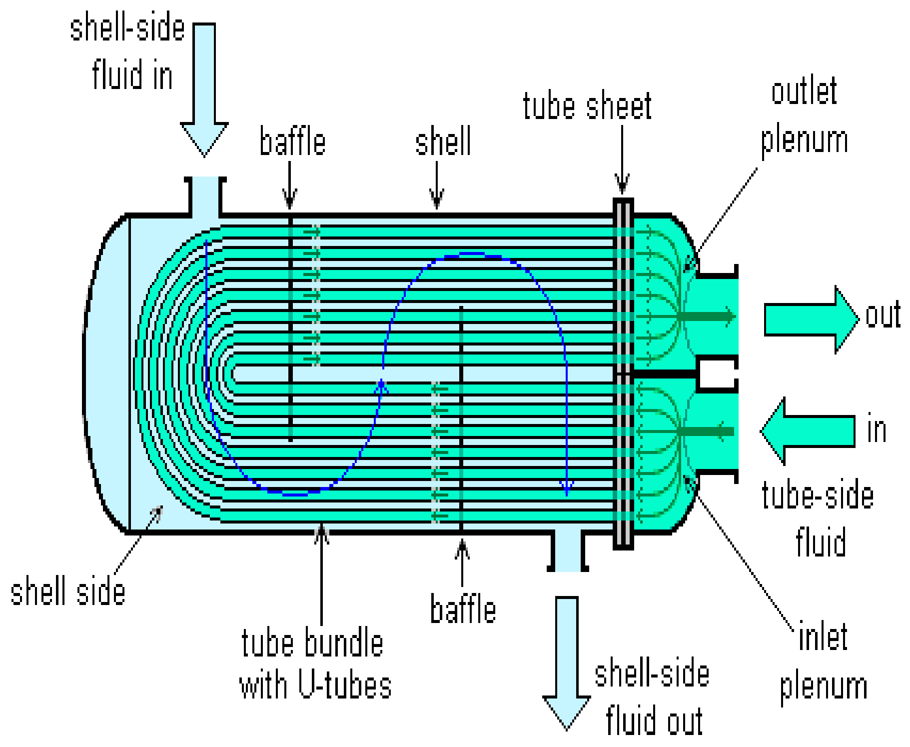
TYPES OF WATER COOL CONDENSER

There are mainly three types of condenser

- Shell & tube type condenser
- Shell & coil type condenser
- Tube & tube type condenser

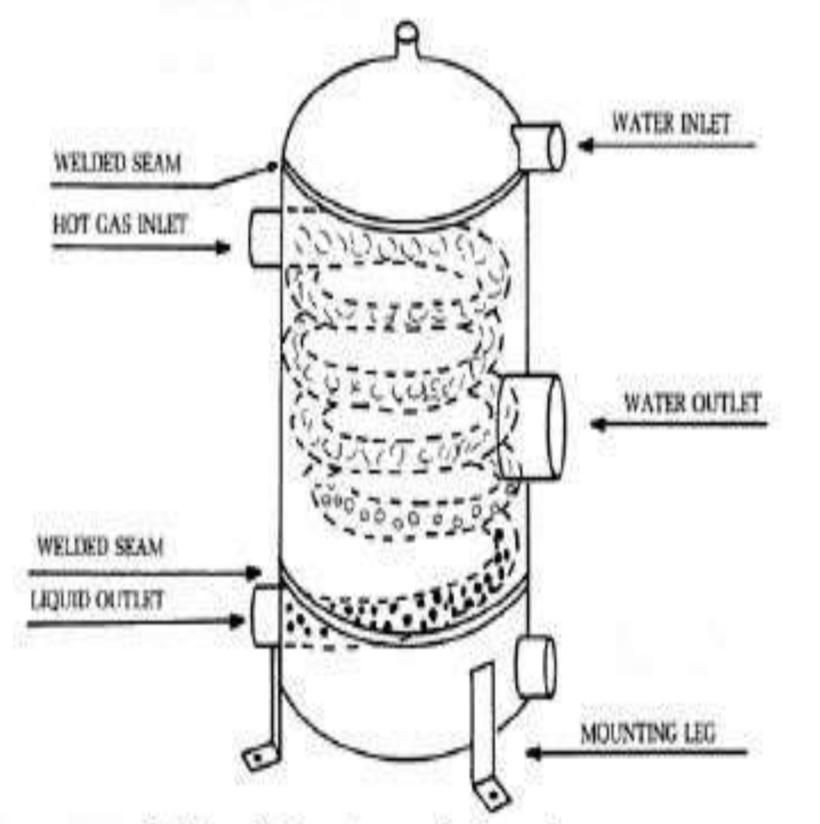
SHELL AND TUBE TYPE CONDENSER

- Compressor discharge gas flows through the tubes in the condenser
- Water is piped into the shell
- The shell acts as a receiver
- The ends of the shell are removed for cleaning
- Most expensive type of condenser



SHELL AND COIL TYPE CONDENSER

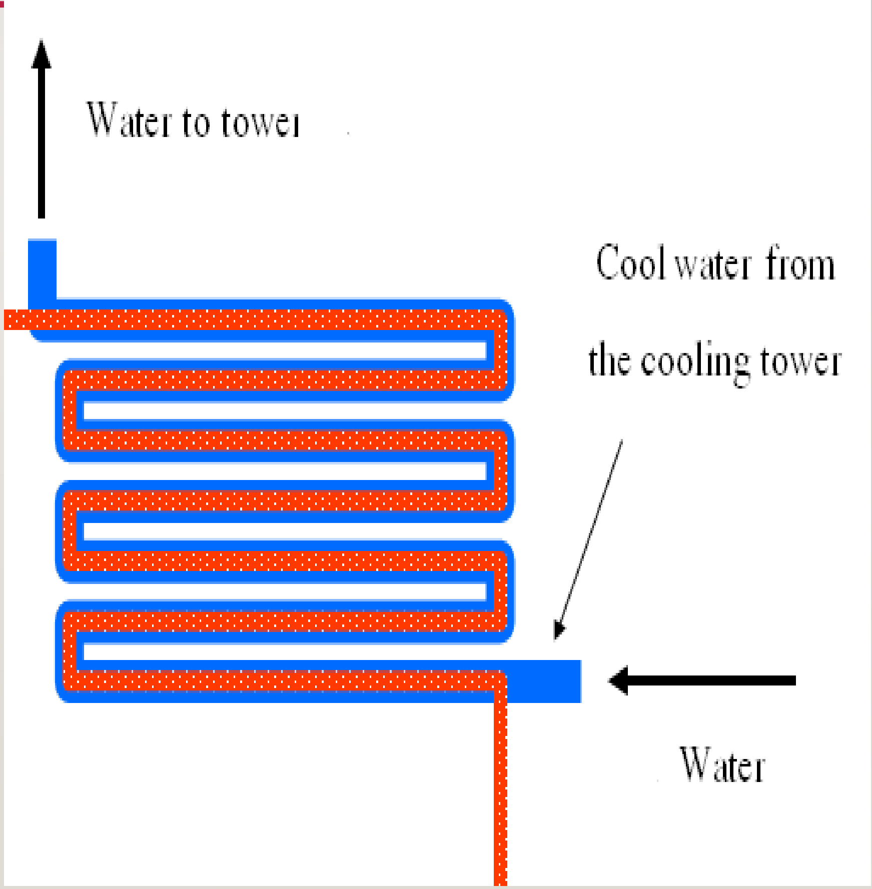
- Coil of tubing enclosed in a welded shell
- Refrigerant flows through the coil
- Water is discharged into the shell
- When refrigerant comes in contact with the cool water, it condenses anddischarged through outlet valve



Coil-in-shell water cooled condenser.

TUBE AND TUBE TYPE CONDENSER

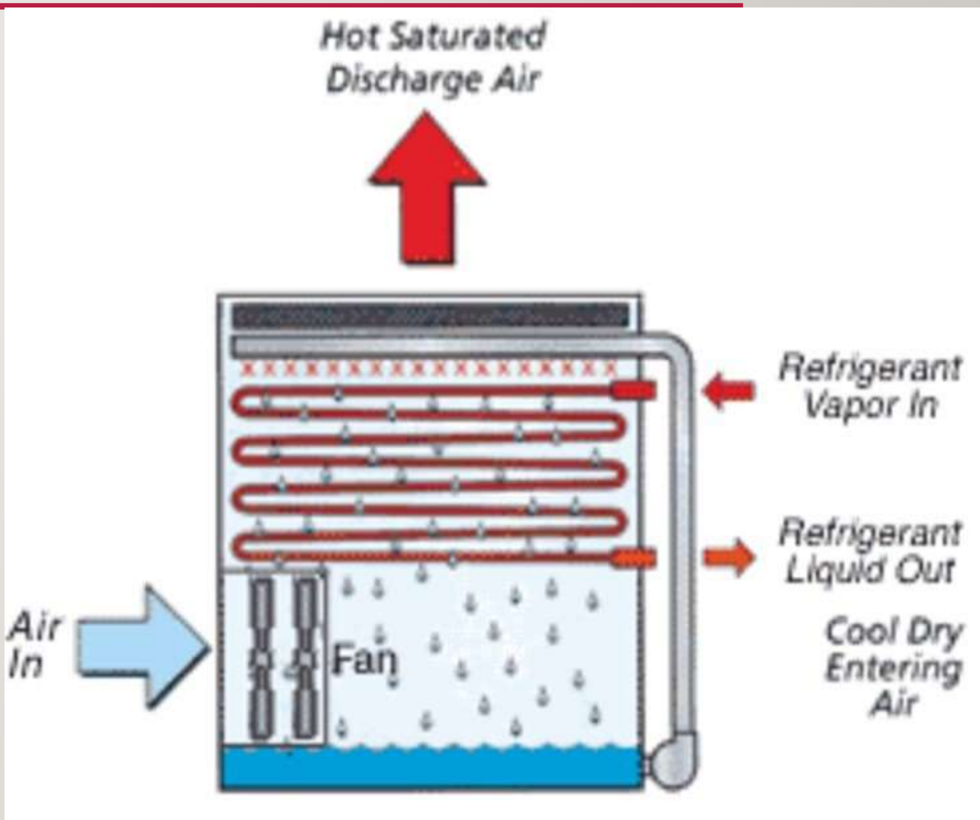
- Heat exchange takes place between the fluids in the inner and outer tubes
- Refrigerant flows in the outer tube
- Water flows in the inner tube
- Refrigerant and water flow in opposite directions to maximize the heat transfer rate



EVAPORATIVE CONDENSER

- While these remain the least popular choice, evaporative condensers can be used inside or outside of a building and under typical conditions, operate at a low condensing temperature.
- Typically these are used in large commercial air- conditioning units. Although effective, they are not necessarily the most efficient.

- The refrigerant is flow through a pipe
- Through spray of water the refrigerant is condensed
- A latent heat transfer takes place throughout the pipe



Principle of Operation

ADVANTAGES AND DISADVANTAGES OF EVAPORATIVE CONDENSER

Advantages :-

- Evaporation is a part of heat transfer process heat absorption capacity of water is hire than air it needs less coil surface
- No need of cooling tower.

Disadvantages :-

- Needs separate system for water spray.
- Needs regular maintenance.
- This type of condenser can be used only for medium sized refrigeration plant.

EXPANSION DEVICE

Expansion valve is the term usually used in industry for any device that meters or regulates the flow of liquid refrigerant to an evaporator the expansion device performs the following functions :

- To reduce the pressure of liquid refrigerant coming from the condenser.
- To maintain the desire pressure difference between the high pressure and low pressure sides of the system.
- Capacity expansion devices are used to maintain the desired rate of flow and the pressure drop two the system.
- To control the flow of refrigerant according to variation of load on the evaporator.

LOW-SIDE FLOAT EXPANSION VALVE

- It is located between evaporator and compressor suction line. It maintains a constant level of liquid refrigerant in the evaporator and float chamber by controlling a needle valve with the help of a float ball. When the float ball rises, the valve opens and refrigerant is allowed to flow into evaporator. Reverse process occurs when float ball drops.

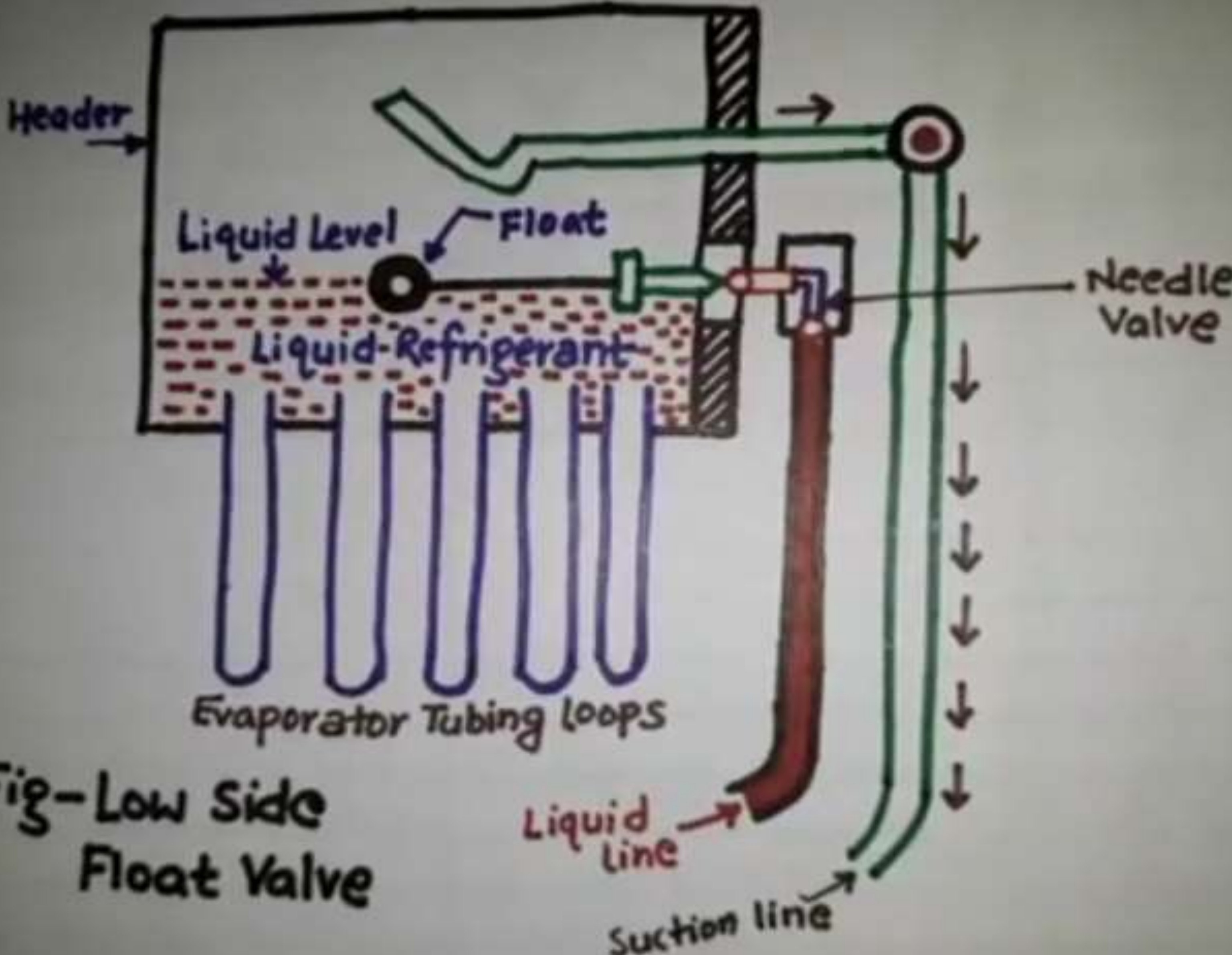


Fig-Low Side Float Valve

HIGH-SIDE FLOAT EXPANSION VALVE

- It is located between the condenser and evaporator. It controls the flow of refrigerant coming from condenser to the evaporator with operation similar to that of low-side float valve.

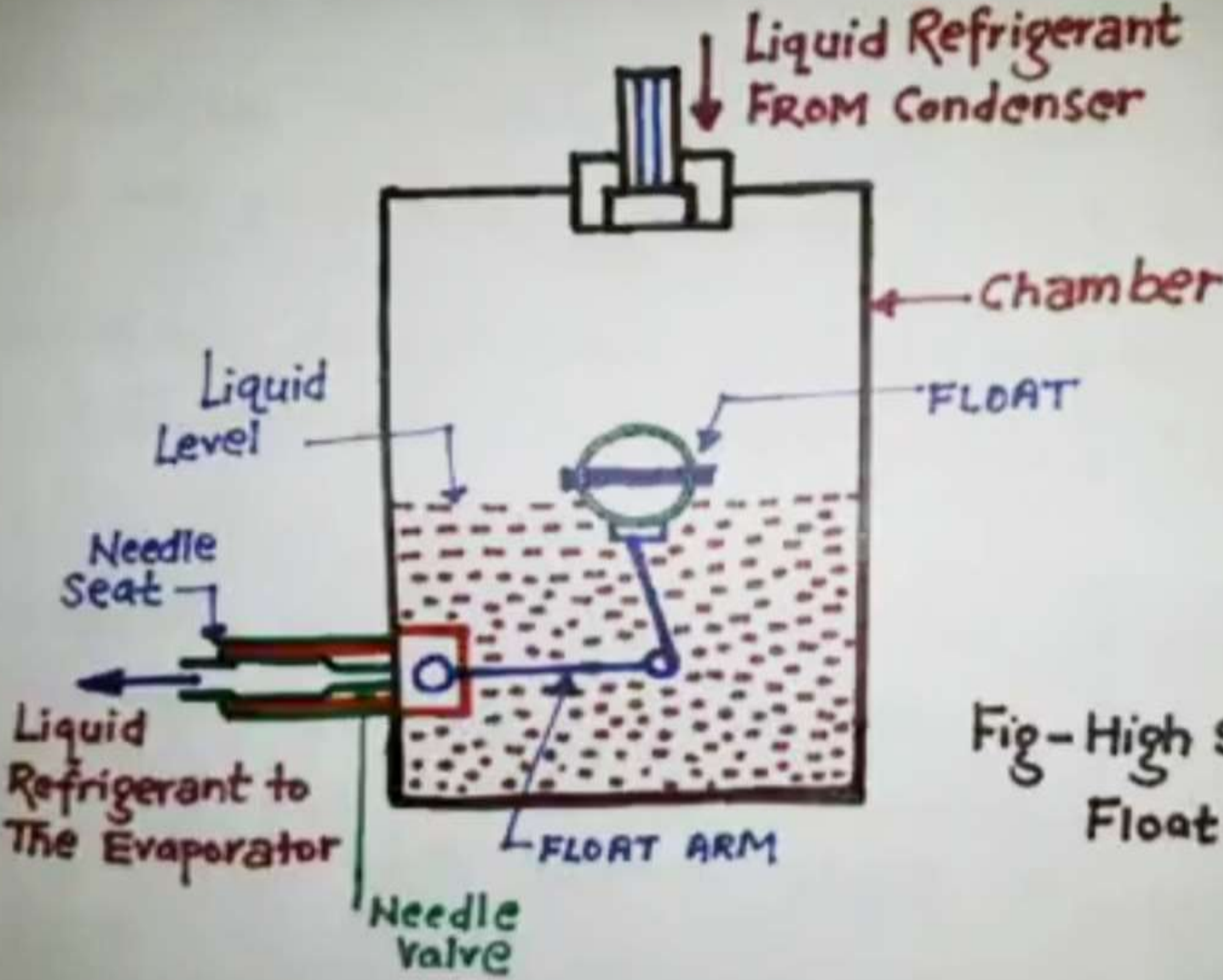


Fig - High Side
Float Valve

CAPILLARY TUBE

- A capillary tube is a long, narrow tube diameter. of constant.
- The refrigerant has to overcome the frictional resistance offered by tube walls. This leads to some pressure drop.

THERMOSTATIC EXPANSION VALVE

- Thermostatic expansion valve controls the flow of refrigerant through the evaporator in such a way that the quality of the vapour leaving the evaporator will always in superheated condition.
- Its operation is used for maintaining a constant degree of superheat at the evaporator outlet.

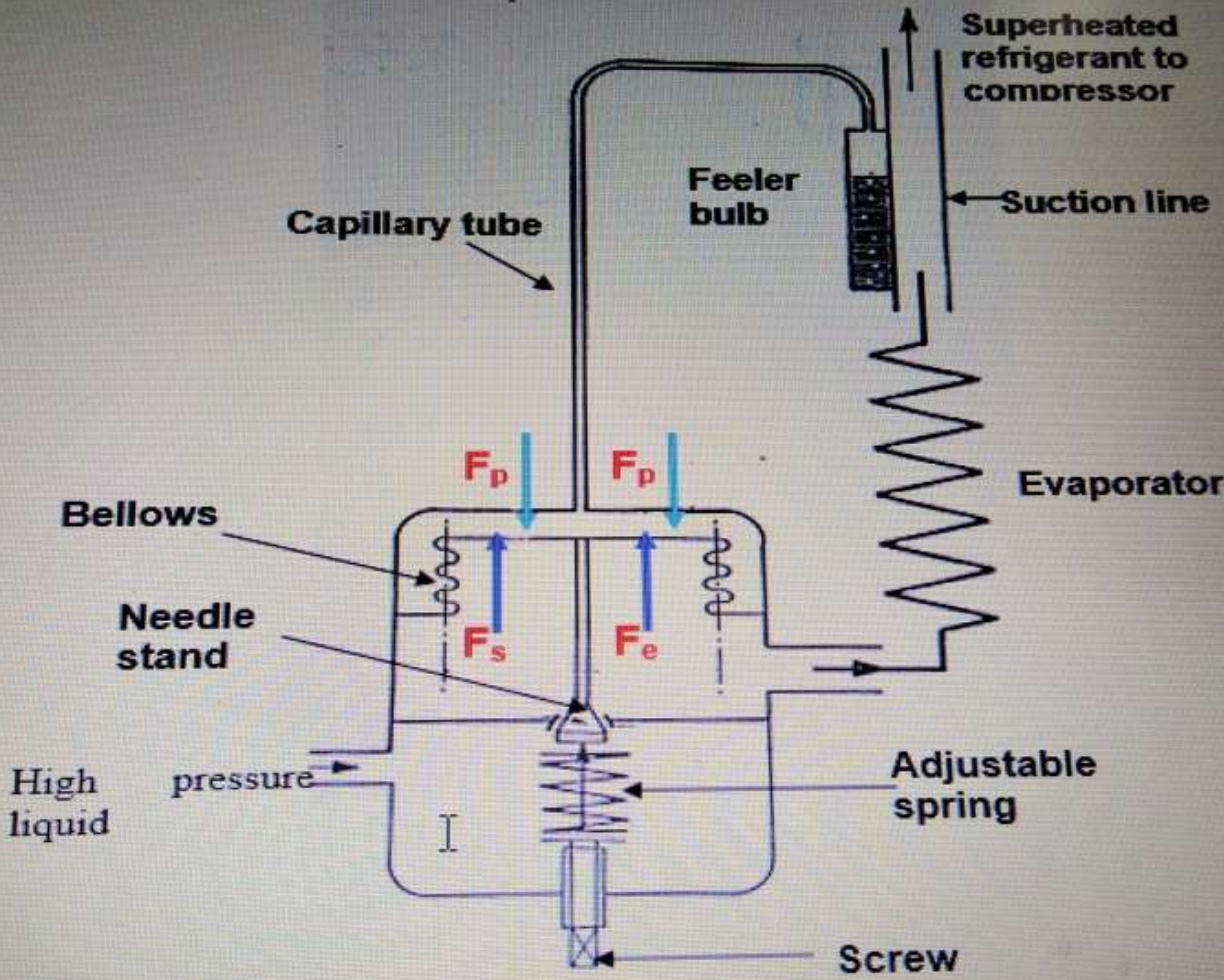


Fig 24.13: Schematic of a Thermostatic Expansion Valve (TEV)

EVAPORATOR

- The evaporator is a heat transfer system, and is that part of a refrigeration cycle in which liquid refrigerant is evaporated for the purpose of removing heat from the refrigerated space or product.
- Responsible for absorbing heat into the refrigeration system
- The evaporator is maintained at a temperature that is lower than the medium being cooled

TYPES OF EVAPORATORS

- According to type of construction

1. Bare tube coil evaporator
2. Finned tube evaporator
3. Plate evaporator
4. Shell and tube evaporator
5. Shell and coil evaporator
6. Tube in tube evaporator

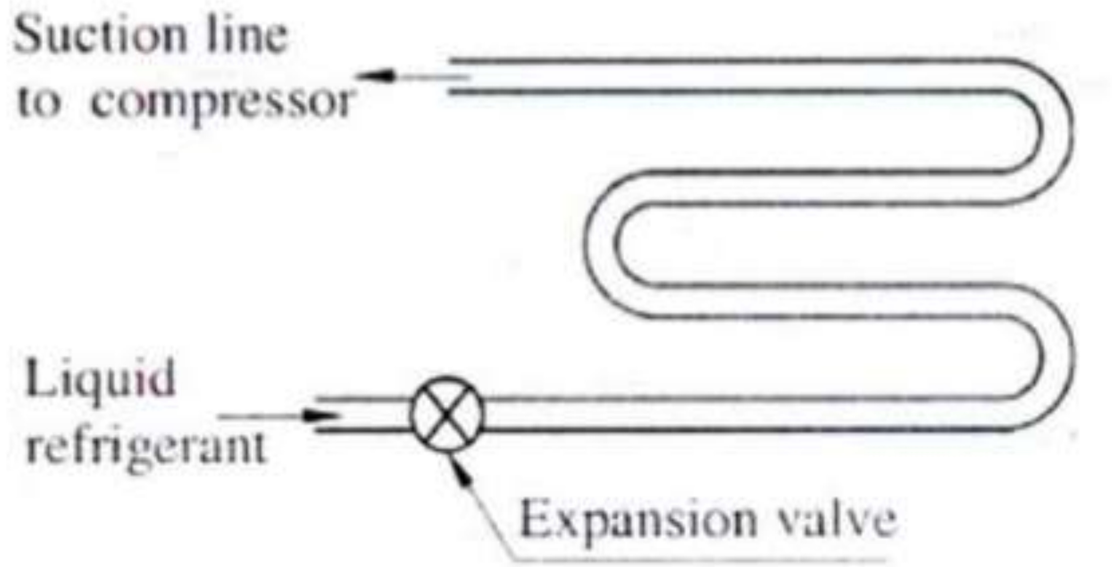
- According to the manner in which liquid refrigerant is fed

1. Flooded evaporator
2. Dry expansion evaporator

BARE TUBE EVAPORATORS

- The bare tube evaporators are made up of copper tubing or steel pipes
- The copper tubing is used for small evaporators where the refrigerant other than ammonia is used
- the steel pipes are used with the large evaporators where ammonia is used as the refrigerant.
- the atmospheric air flows over the bare tube evaporator and the chilled air leaving it used for the cooling purposes.
- The bare tube evaporators are usually used for liquid chilling

- **Bare tube coil evaporator**



FLOODED TYPE EVAPORATOR

- In the flooded evaporator , a constant liquid level is always maintained.
- A float control valve is used as an expansion device which maintain constant liquid level in the evaporator .
- The flooded evaporator are more expansive to operate because it require more refrigeration charge.
- The advantage of the flooded evaporator is that the whole surface of the evaporator coil is in contact with the liquid refrigerant under all the load conditions.
- These type of evaporator are used in chemical and food processing industry.

DRY EXPANSION EVAPORATOR

- Dry expansion evaporators are so called because liquid refrigerant enters the evaporator by an expansion valve and vaporizes by the time it reaches the end of the evaporator coil.
- There is always at least 20% vapor present within the evaporator pipe work.
- The amount of liquid present in dry expansion evaporators will depend upon the fixture load.

- At light load conditions, the amount of liquid will be small, and in high load conditions, the amount of liquid will be large.
- The larger the wetted surface, the greater the efficiency.

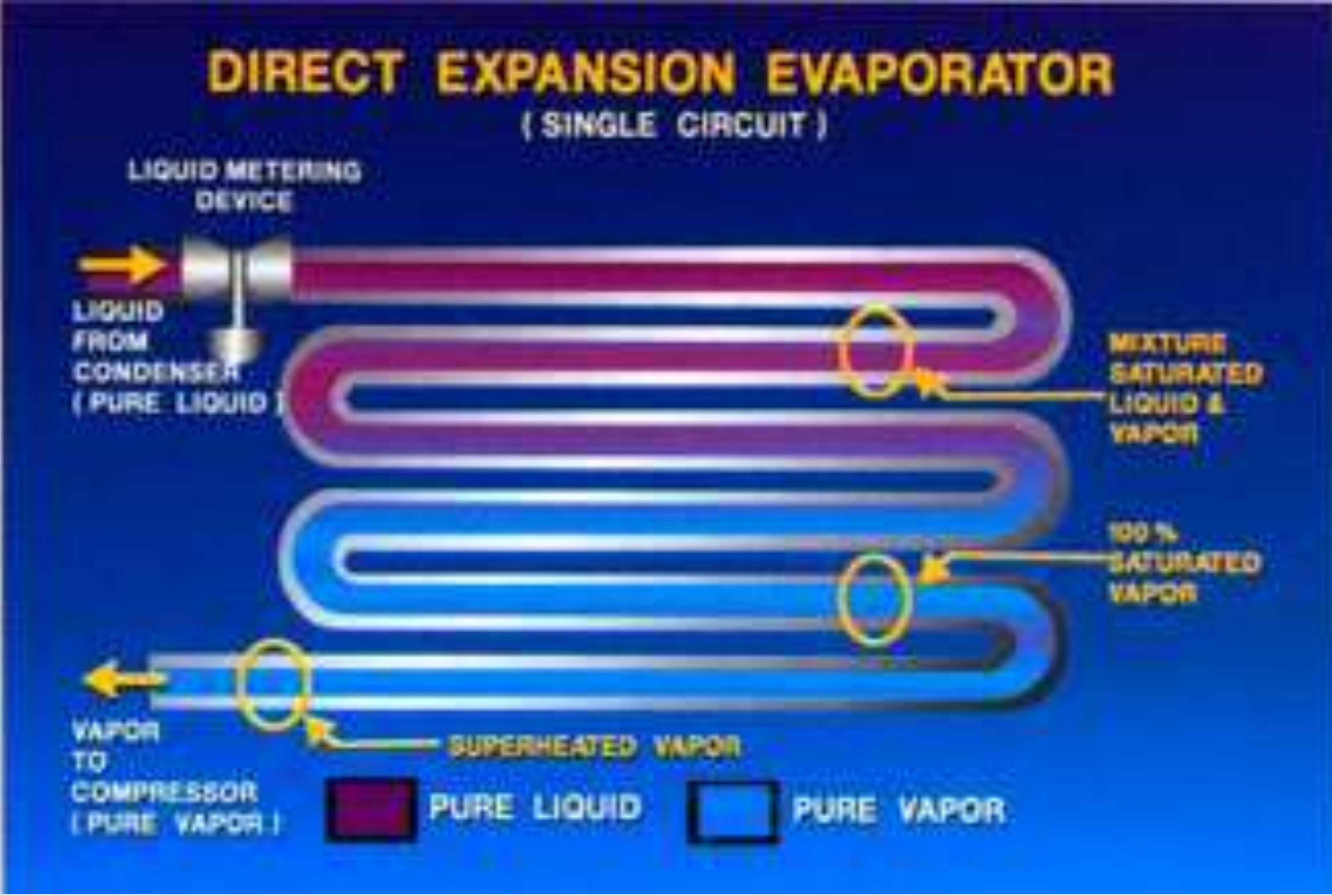

DIRECT EXPANSION EVAPORATOR
(SINGLE CIRCUIT)
LIQUID METERING DEVICE
LIQUID FROM CONDENSER (PURE LIQUID)
MIXTURE SATURATED LIQUID & VAPOR
100 % SATURATED VAPOR
SUPERHEATED VAPOR
VAPOR TO COMPRESSOR (PURE VAPOR)
PURE LIQUID
PURE VAPOR

PLATE SURFACE EVAPORATOR

- The refrigerant is contained between two plates to give a large cooling surface (aluminium corrugated and prefromed in a 'U' shape).
- This type of evaporator is widely used in domestic refrigeration.
- The only maintenance requirement is to keep the plate free from ice (See Figure 2)

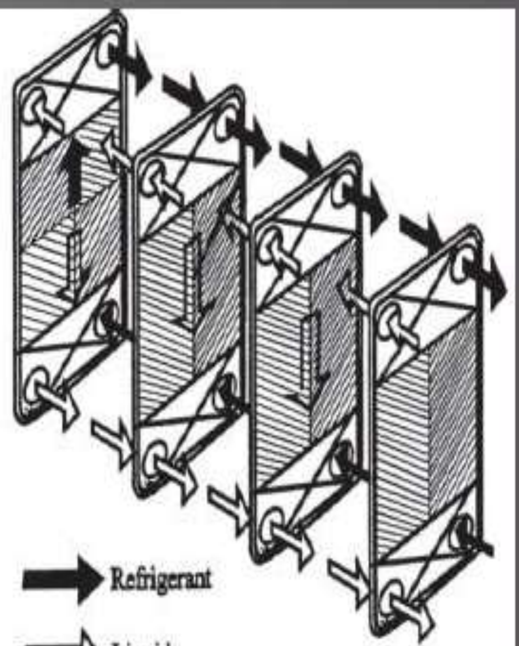


FIGURE 6.63
A plate-type liquid-chilling evaporator.

SHELL AND COIL EVAPORATOR

- Shell and Coil evaporators have one or more spiral shaped, bare tube coils enclosed in a welded steel shell.
- They are generally dry expansion type with refrigerant in coils and chilled liquid in the shell.
- They have thermal capacity for application for high but infrequent loads.
- They are used for chilling of drinking water and other aspects where cleanliness is a factor, e.g. Bakeries and Photographic Laboratories.

Evaporators:

- **Shell and Coil**

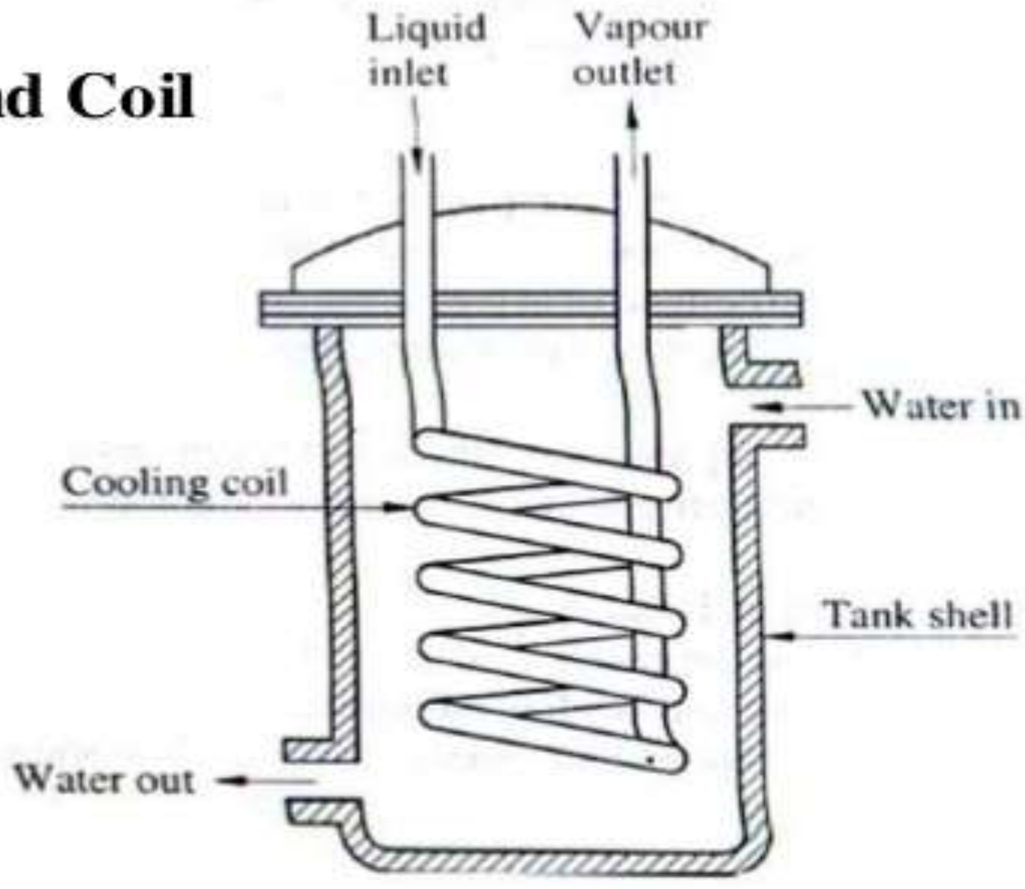
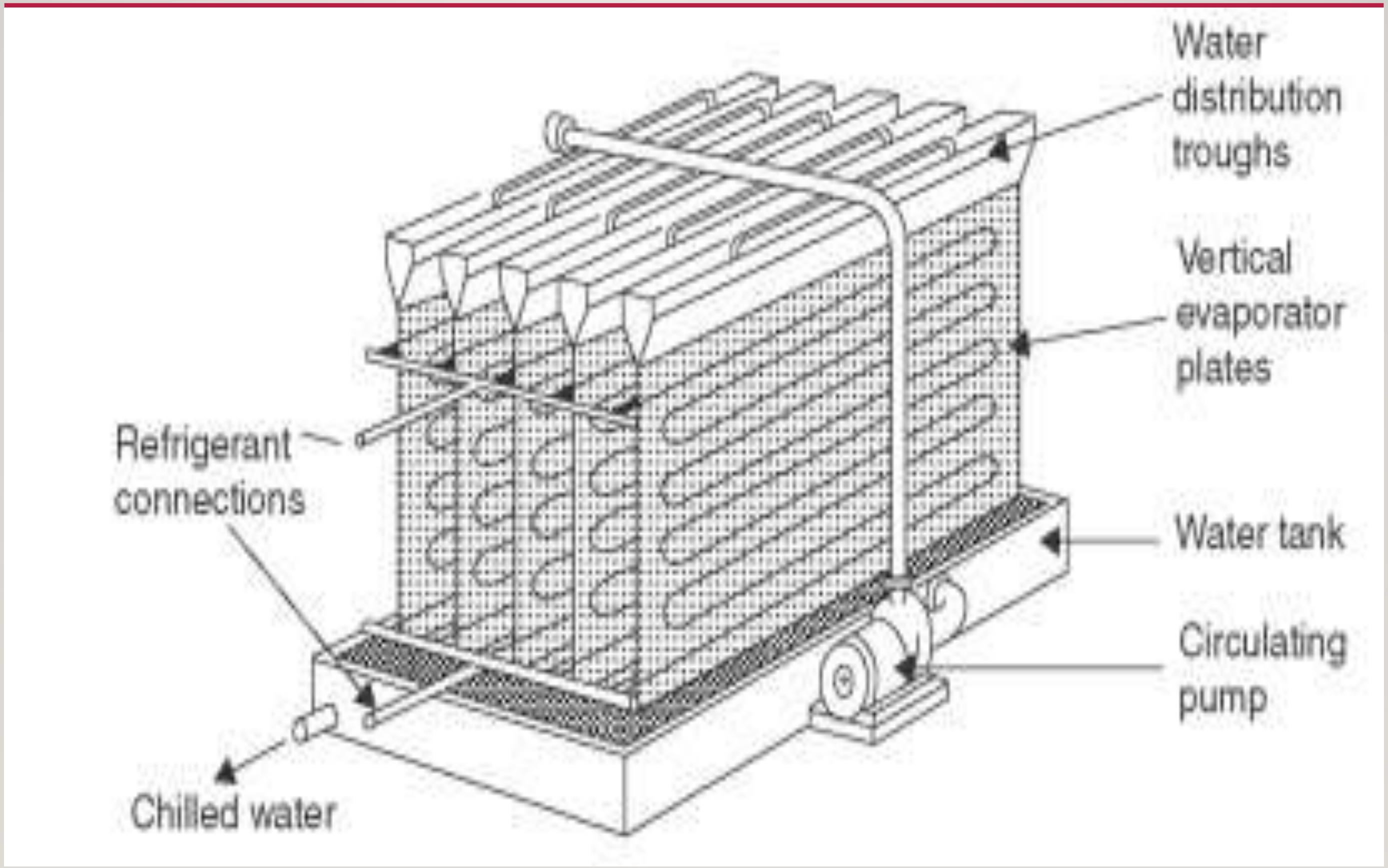


Fig. Shell and coil evaporator

BAUDELOT COOLER

- The Baudelot Cooler consists of a series of horizontal pipes, one under another, connected to form a circuit.
- They can be either dry or flooded.
- Refrigerant flows through the tubes, while chilled liquid flows in a thin film over the outside, (in a counter flow direction).
- This is then collected in a trough at the bottom of the cooler.
- They were used for cooling milk (prior to the introduction of the E.E.C. Regulations) wine and water, since it is possible to chill to very nearly freezing point without damaging equipment


Water distribution troughs
Vertical evaporator plates
Refrigerant connections
Water tank
Circulating pump
Chilled water

FINNED EVAPORATOR

- The finned evaporators are the bare tube type of evaporators covered with the fins. When the fluid (air or water) to be chilled flows over the bare tube evaporator lots of cooling effect from the refrigerant goes wasted since there is less surface for the transfer of heat from the fluid to the refrigerant.
- The fluid tends to move between the open spaces of the tubing and does not come in contact with the surface of the coil, thus the bare tube evaporators are less effective.
- The fins on the external surface of the bare tube evaporators increases the contact surface of the of the metallic tubing with the fluid and increase the heat transfer rate, thus the finned evaporators are more effective than the bare tube evaporators

- **Finned tube evaporator**

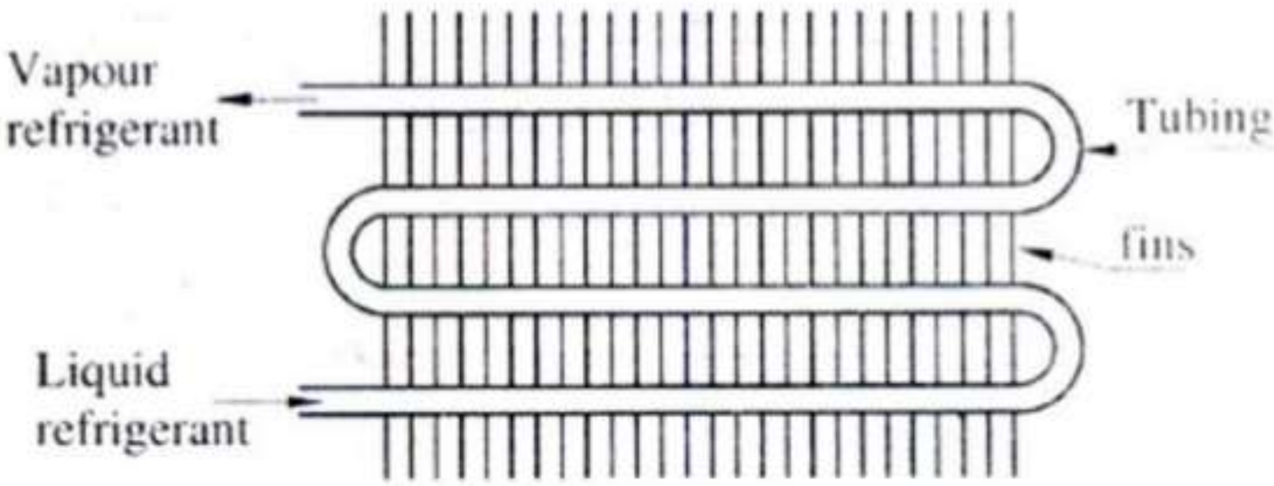


Fig. Finned tube evaporator

SAFETY DEVICES

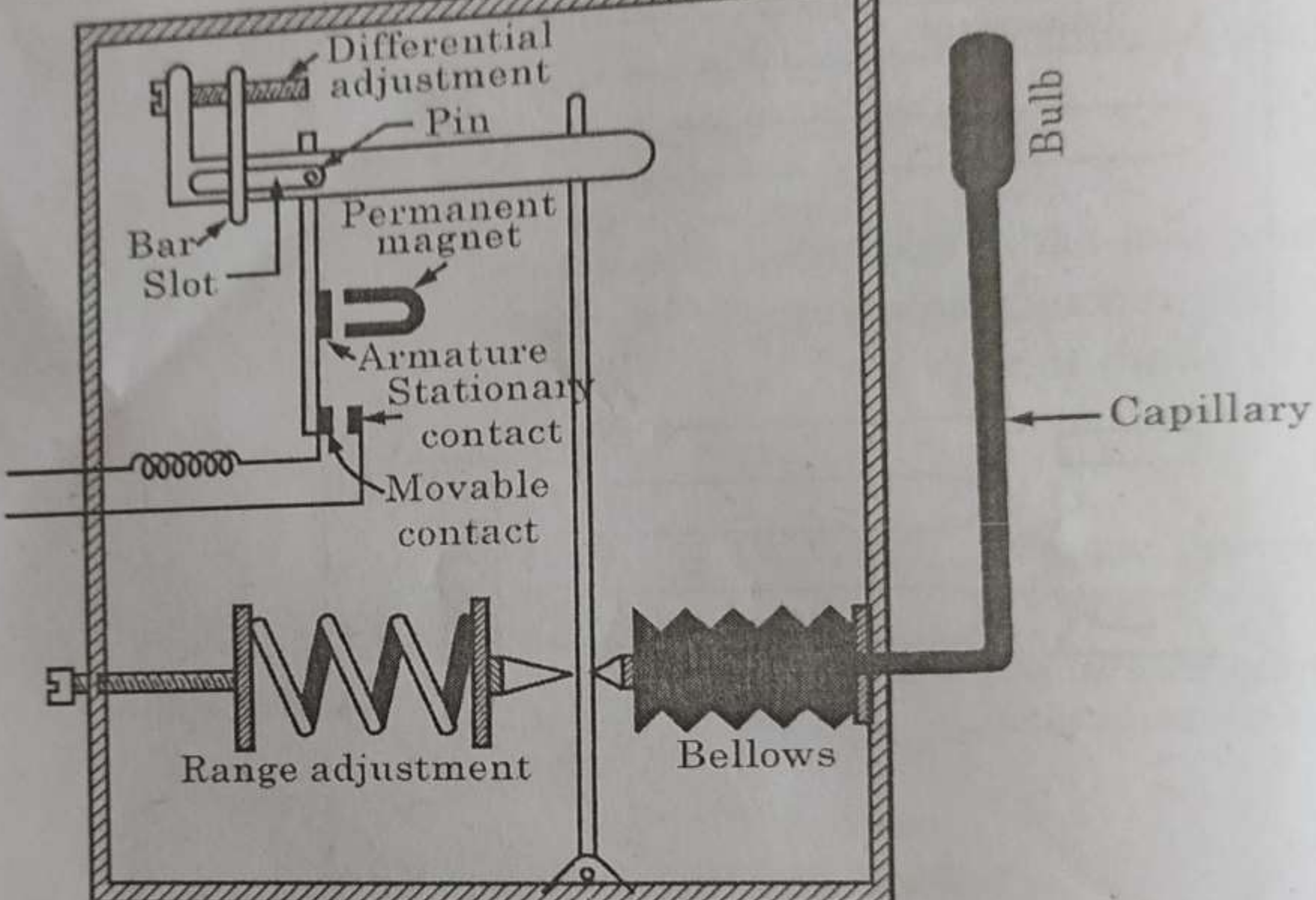
1. **Thermostat Switch:-**

- it is a temperature control device. It cuts-in (makes) or cuts out (breaks) the compressor motor circuit as the temperature in the refrigeration space rises above or falls below the pre-set value.

Construction :

- The bulb is connected to the bellows by means of the capillary tube and both the bellows and the bulb are charged with volatile liquid refrigerant.

, a capillary tube,



- The bulb is attached to the evaporator and makes tight contact with it. the differential and temperature range can be adjusted with the adjustment screw provided.
- A permanent magnet and armature are provide to avoid arc formation between the movable and stationary contacts.

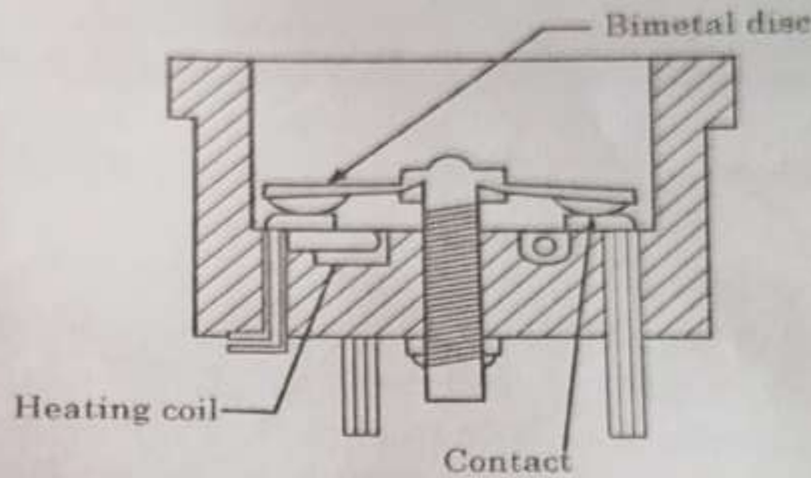
Working:-

- As the temp. in the evaporator rises above the cut-in temp. the bulb temp. and the pressure of fluid in it also rises causing the bellows to expand. This further causes the movable contact point to travel towards the stationary contact point. The opposing spring tension, the armature is quickly pulled towards the magnet and makes a contact to start the compressor.

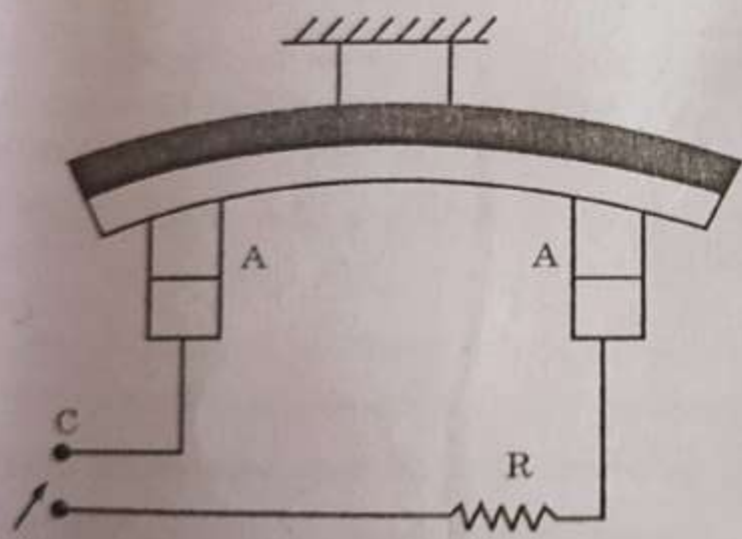
- When the evaporator temp. In the evaporator decreases below the cut-out temp., the bulb becomes colder, the pressure decreases and bellows contract sufficiently to open the electrical contact. The compressor motor stop.

2. Over-load protector :-

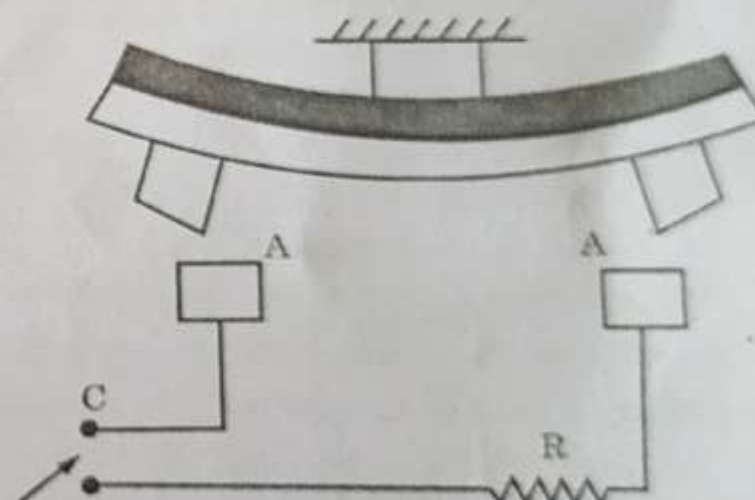
- It saves the compressor from burn-out due to over current and overheating.
- The overload protector consist of a bimetallic disc and a series of heating coil or thermistor.
- The metals of the disc have different coefficients of linear expansion, in normal operation condition, the contact point (A) remain in contact with each other, but when the overloading due to excessive current flowing through the resistance R takes place, the points are separated and the contact is broken.



(a)



(b) **Motor winding connections, normal condition**

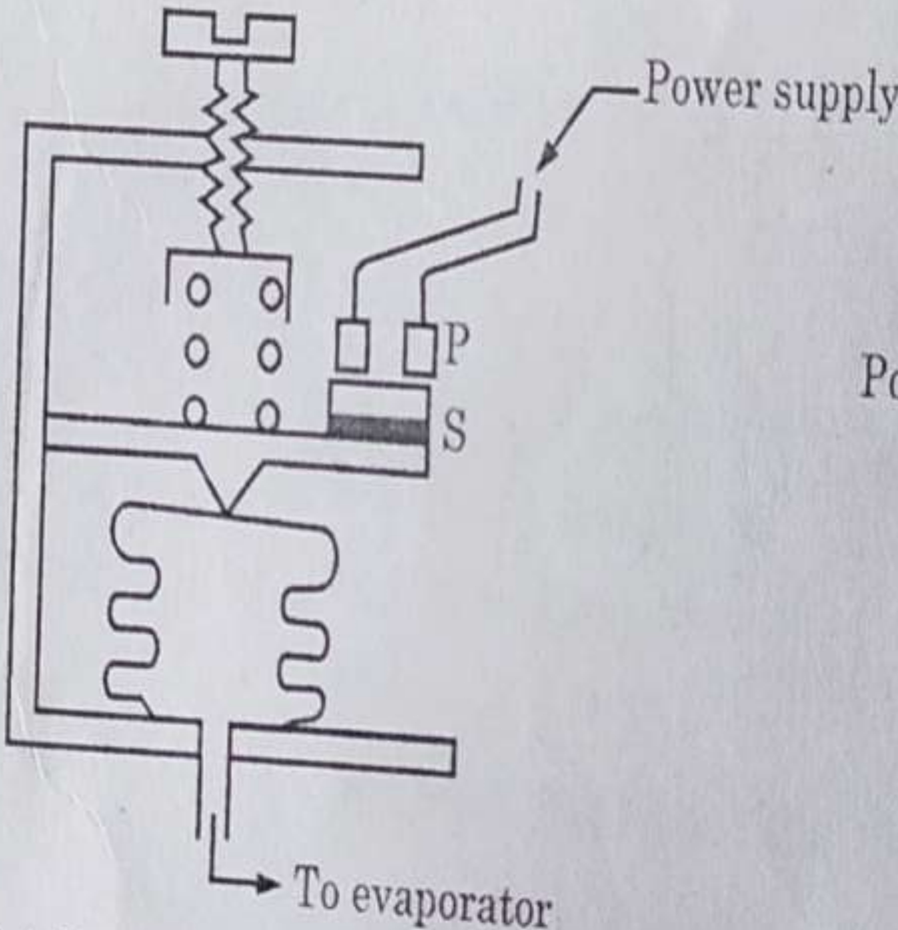


(c) Motor winding connections, hot condition

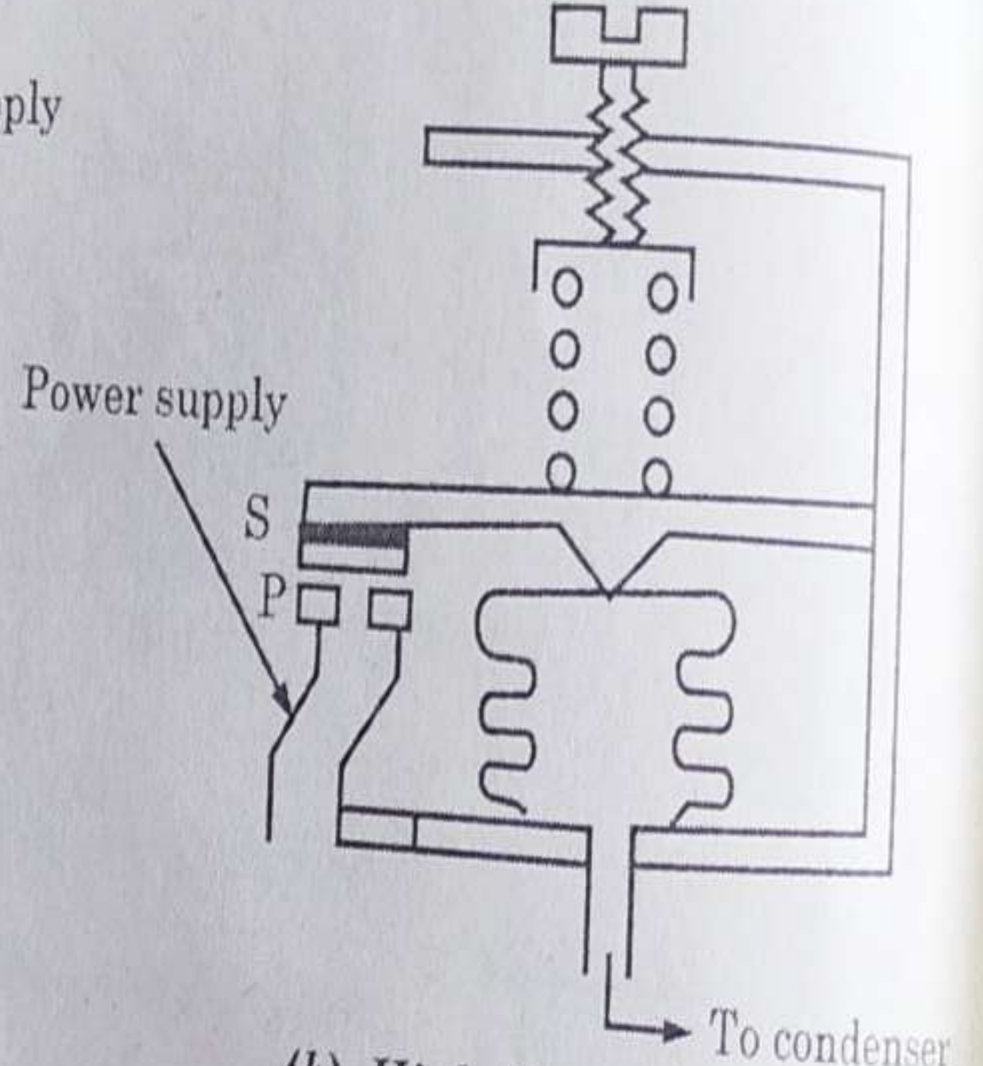
3. low pressure cut-out switch :-

- It consists of bellows connected to evaporator side. A screw and spring arrangements is used to change the cut-out range of the mechanism. The electric circuit is made or broken by the contacts P and S. A graduated scale is usually provided with a pointer in order to indicate the desired lower pressure below which the system is switched off.

- As the pressure in the evaporator decreases, the bello get supressed causing the contact point P to separate from contact point S. this cause the electric circuit to break and the compressor to stop. When the pressure returns to normal, the bellows expand and the point makes contact with point P. this restores the power supply and the compressor restart.



(a) Low-Pressure Cut-Out Switch



(b) High Pressure Cut-Out Switch

4. High pressure cut-out switch :-

- Its operation is similar as that of low pressure cut-out switch except that the connection is reversed and bellows are connected to the condenser side.
- In this case, the electric circuit remains operative as long as the condensing pressure remains below the upper set value.

AIR CONDITIONING

CHAPTER -6

PSYCHROMETRY

INTRODUCTION

Psychrometry

- The Science which deals with the study of the behaviour of air and water vapour mixture (or moist air) is known as **Psychrometry**.
- The properties of water vapour and air mixture are known as **Psychrometric Properties**.

IMPORTANCE OF PSYCHROMETRY

Study of psychrometry is important because it deals with

- Various properties of air
- Methods of controlling air temperature
- Humidity (moisture content) as its affects human beings and materials

PSYCHROMETRIC TERMS

Dry Air

- Air without moisture content is known as dry air.
- The pure dry air is a mixture of number of gases such as nitrogen, oxygen, and hydrogen and carbon dioxide. Density of air is 1.293kg/m3 at 1.01325 bar 273 K.
- Pure dry air does not exist in nature as it contains some impurities and some moisture all the time.

Moist Air

- It is a mixture of dry air and water vapour. The amount of water vapour present in air depends on the pressure and temperature of the mixture.

Saturated Air

- It is the mixture of dry air and water vapour when air has diffused maximum amount of water vapour into it. This means air has reached its moisture carrying capacity to the fullest and no more addition is possible.

Unsaturated Air

- Moist air which contains less amount of water vapour than required to saturate it at the given temperature is called unsaturated air.

Superheated Air

- When the temperature of the mixture of air and water vapour is above its saturation temperature , it is called superheated vapour.

Specific Humidity or Humidity Ratio (ω)

- The mass of water vapour present per unit of mass of dry air in certain volume of water vapour-air mixture is called specific humidity or humidity ratio. It is expressed in Kg of water vapour / Kg of dry air.

Let m_a = mass of dry air ,

m_v = mass of water vapour associated with $'m_a'$ mass of dry air in a sample of moist air of mass ($m_a + m_v$).

$$\text{Then specific humidity, } \omega = \frac{m_v}{m_a}$$

Relative Humidity ($\emptyset$)

- It is the ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure. It is a unitless and expressed in percentage.

Degree of Saturation (μ)

- It is the ratio of actual mass of water vapour in a unit mass of dry air to the mass of water vapour in the same mass of dry air when it is saturated at same temperature and pressure.

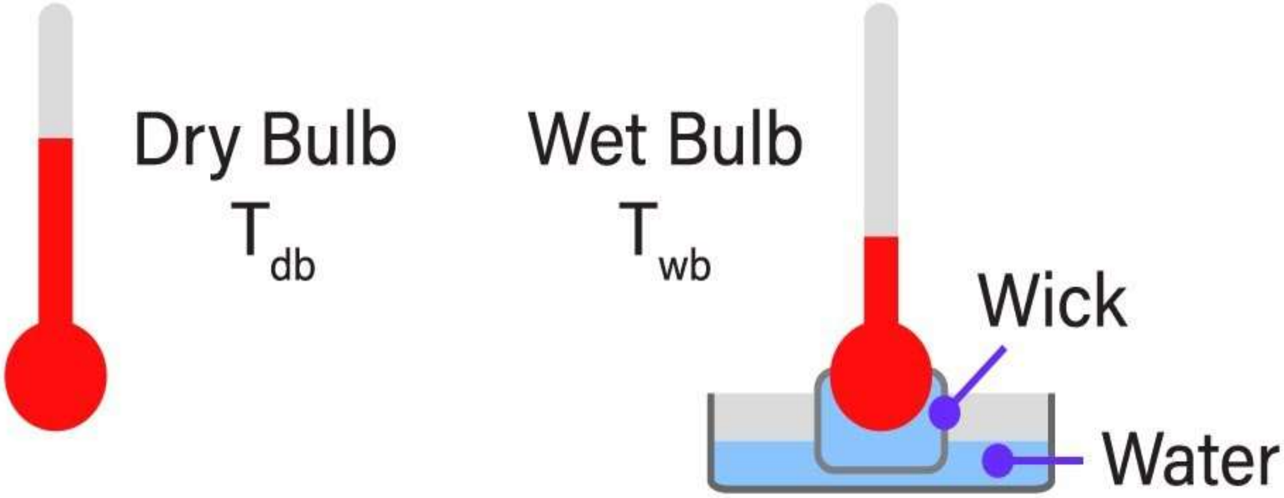
Dry Bulb Temperature (DBT) or t_d

It is the temperature of air recorded by a thermometer when its bulb is not surrounded by a wet cloth exposed to air. It is measured in °C.

Wet Bulb Temperature (WBT) or t_w

- It is the temperature of moist air measured by a thermometer whose bulb is covered with the wet cloth or wick. it is measured in °C.

DRY-BULB & WET-BULB TEMPERATURE



Wet Bulb Depression (WBD)

- It is the difference between dry bulb temperature and wet bulb temperature at any point. it is measured in °C.

$$WBD = DBT - WBT$$

Dew Point Temperature (DPT) or t_{dp}

- It is the temperature of air recorded by a thermometer when water vapour in air begins to condense or dew is formed. it is measured in °C.

Dew Point Depression (DPD)

it is measured in °C.

$$DPD = DBT - DPT$$

Sensible Heat

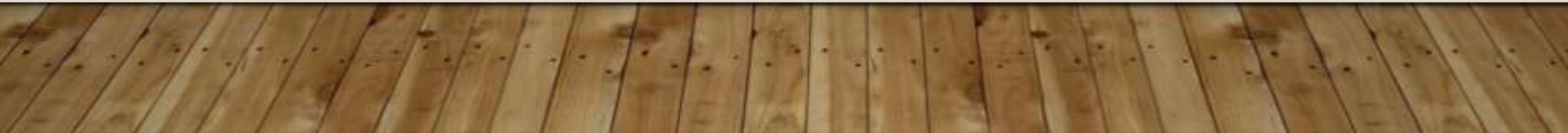
The amount of heat that can be measured by DBT is known as sensible heat.

Latent Heat

The amount of heat required to change liquid phase into vapour phase without changing its temperature.

Total Enthalpy of Moist Air

- The sum of sensible heat of the dry air and sensible heat plus latent heat of water vapour associated with this dry air is called the total enthalpy or total heat of the moist air.

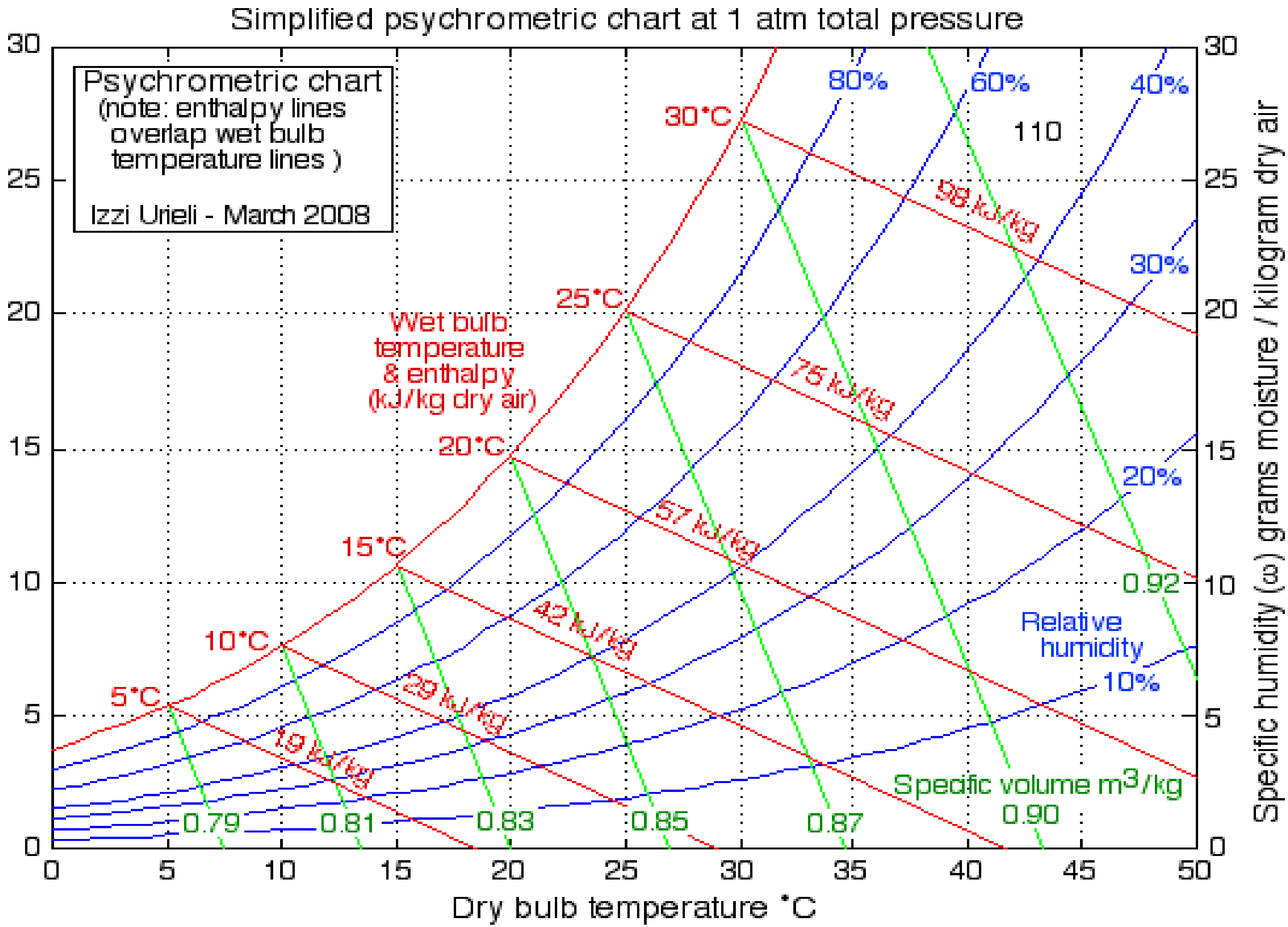


CHAPTER -7

APPLIED PSYCHROMETRY AND HEAT LOAD ESTIMATION

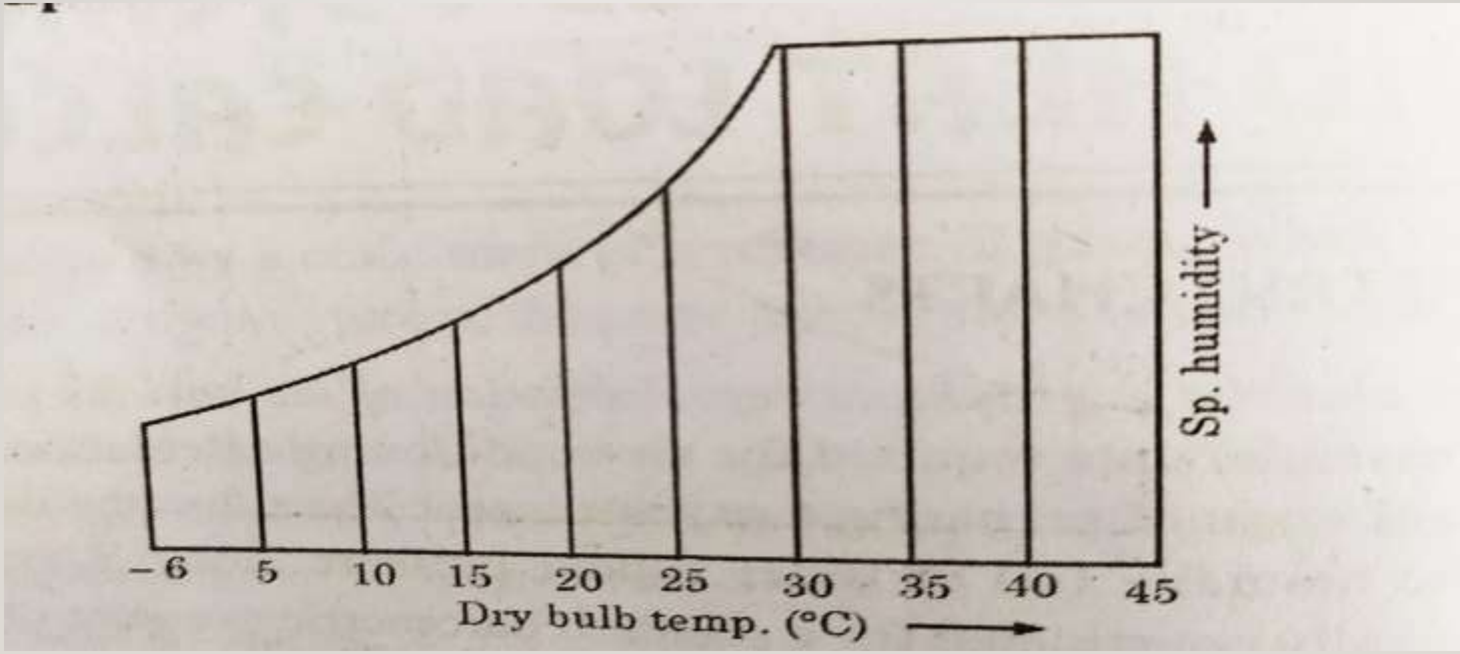
PSYCHROMETRIC CHART

- it is a graphical representation of the various properties of moist air.
- This chart is used for air conditioning calculations and it helps to easily measure the various thermodynamic properties of air and eliminates many time consuming and tedious calculations.

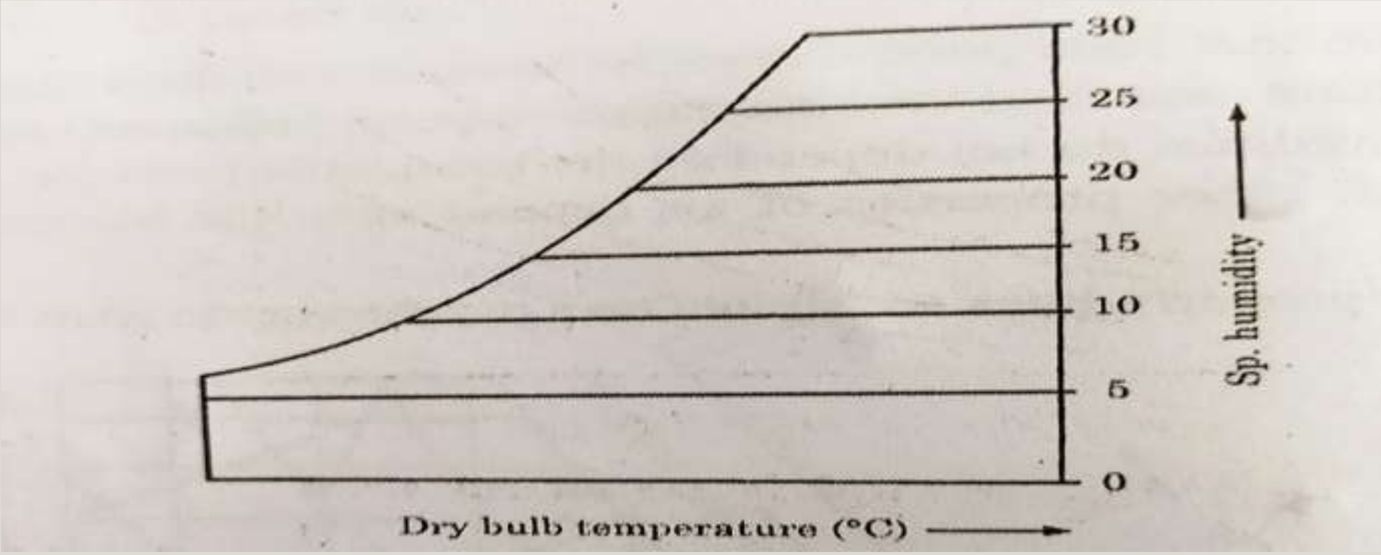

Simplified psychrometric chart at 1 atm total pressure
Psychrometric chart
(note: enthalpy lines
overlap wet bulb
temperature lines)
Izzi Urieli - March 2008
Wet bulb
temperature
& enthalpy
(kJ/kg dry air)
5°C
10°C
15°C
20°C
25°C
30°C
19 kJ/kg
29 kJ/kg
42 kJ/kg
57 kJ/kg
75 kJ/kg
98 kJ/kg
110
80%
60%
40%
30%
20%
10%
Relative
humidity
0.79
0.81
0.83
0.85
0.87
0.90
0.92
Specific volume m3/kg
Dry bulb temperature °C
Specific humidity (ω) grams moisture / kilogram dry air
0
5
10
15
20
25
30
35
40
45
50

VARIOUS LINES ON PSYCHROMETRIC CHART

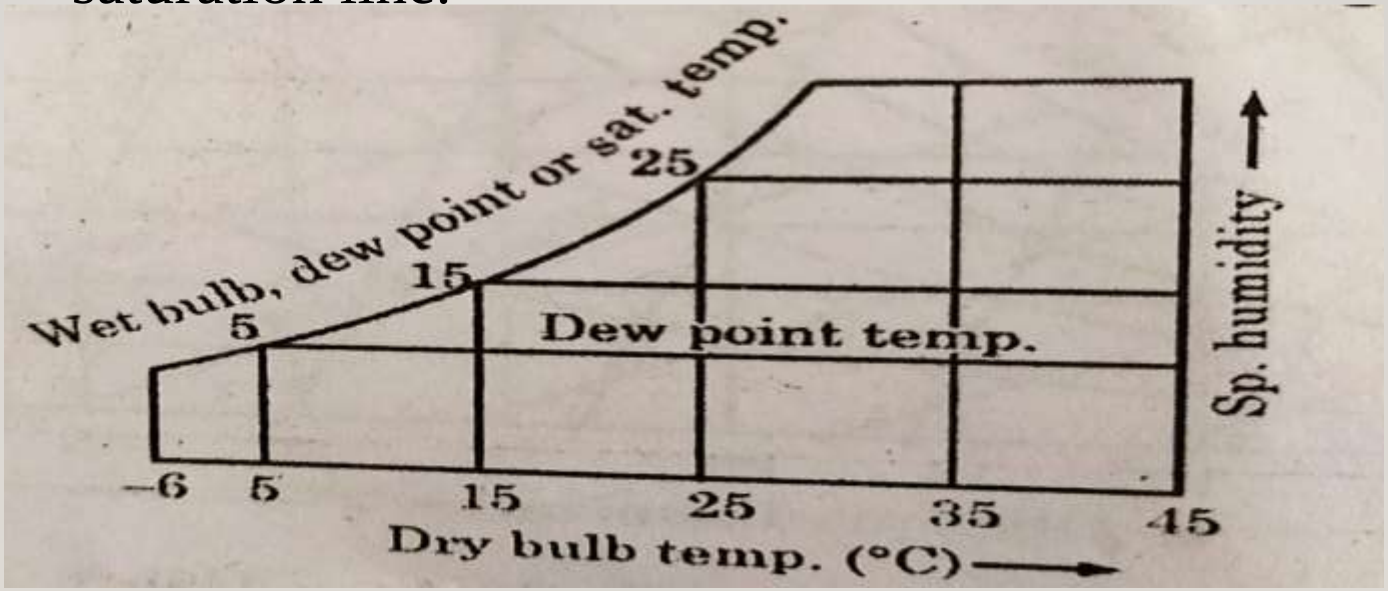
- **Dry bulb temperature lines** – these are straight vertical lines drawn parallel to the ordinate(Y axis).



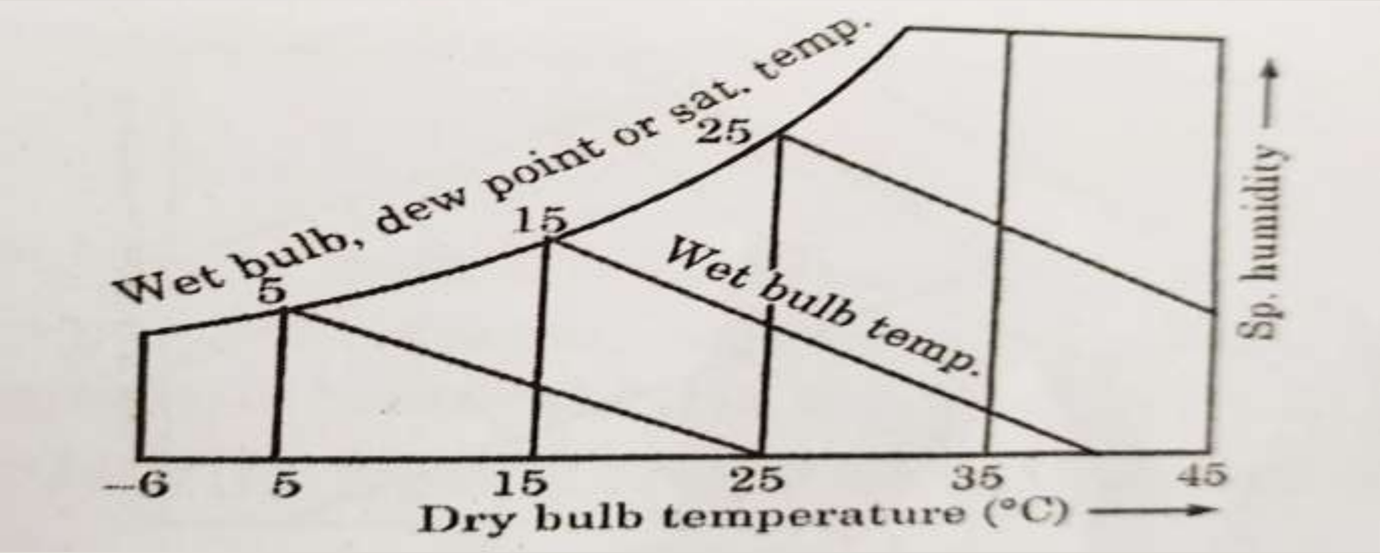
- **Specific humidity lines** – these are straight Horizontal lines drawn parallel to the abscissa (X axis).



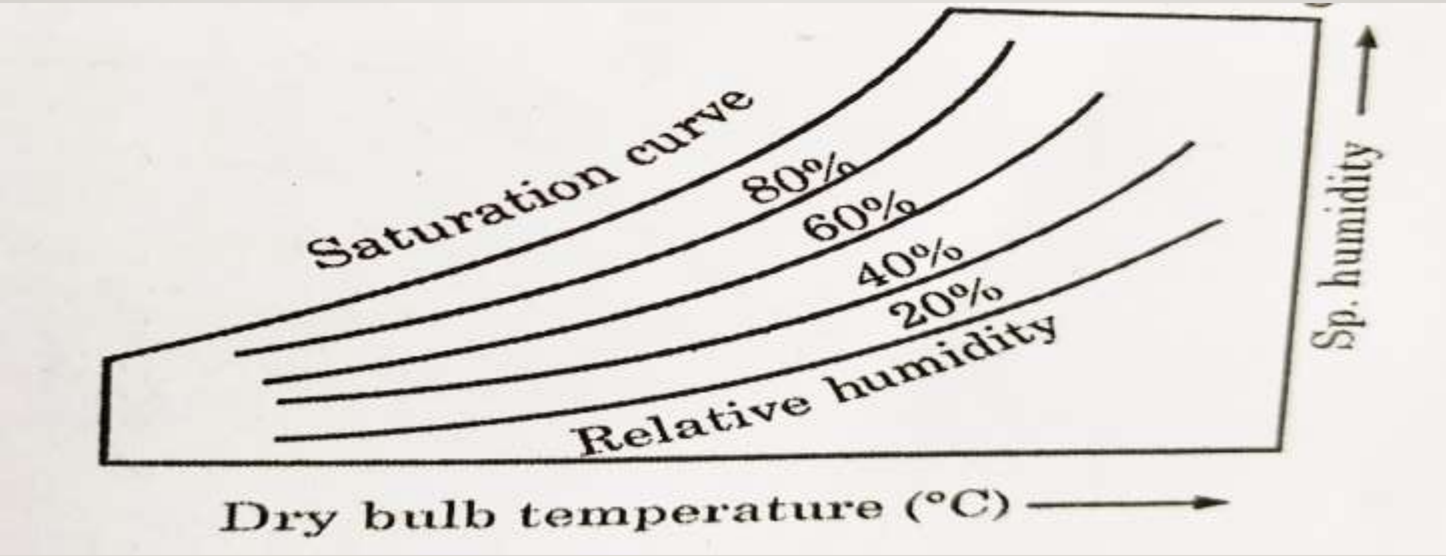
- **DPT lines** – these are straight horizontal and parallel lines. The DPT scale is shown on the saturation line.



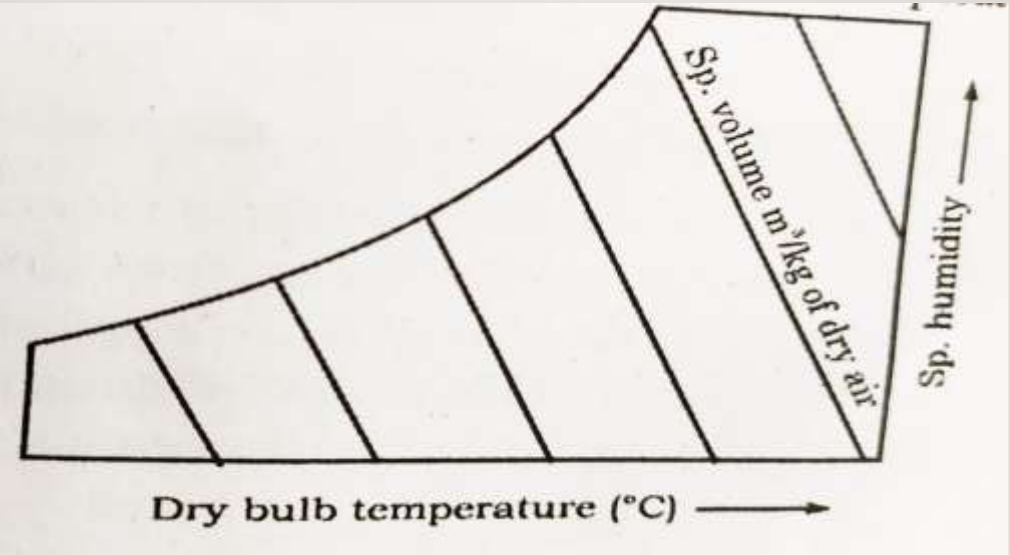
- **WBT lines –** these are straight inclined lines extended diagonally. The WBT scale is also shown on the saturation line.



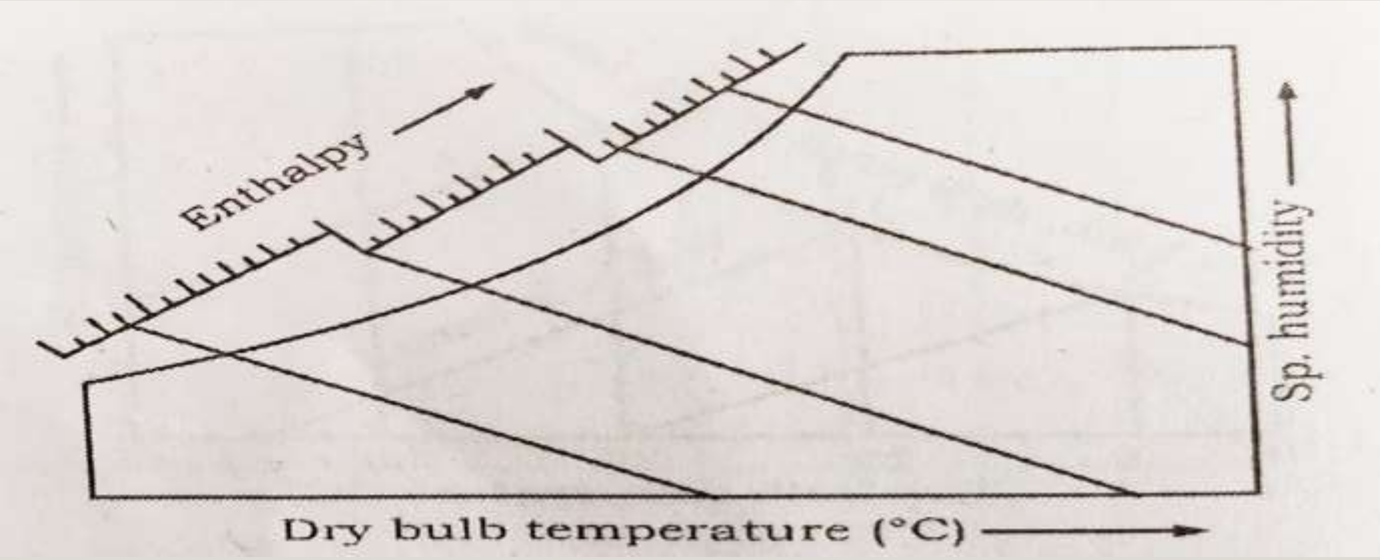
- **Relative humidity (∅) lines-** these are curved lines running in the shape of saturation curve.the saturation curve has the value of ∅ = 1 or 100 %



- **Specific volume lines –**these are straight, inclined and widely spaced lines there inclination with the horizontal is more than those of WBT lines.



- **Enthalpy lines** – these are the same as WBT lines. The scale of enthalpy is shown on a diagonal line above the saturation curve.



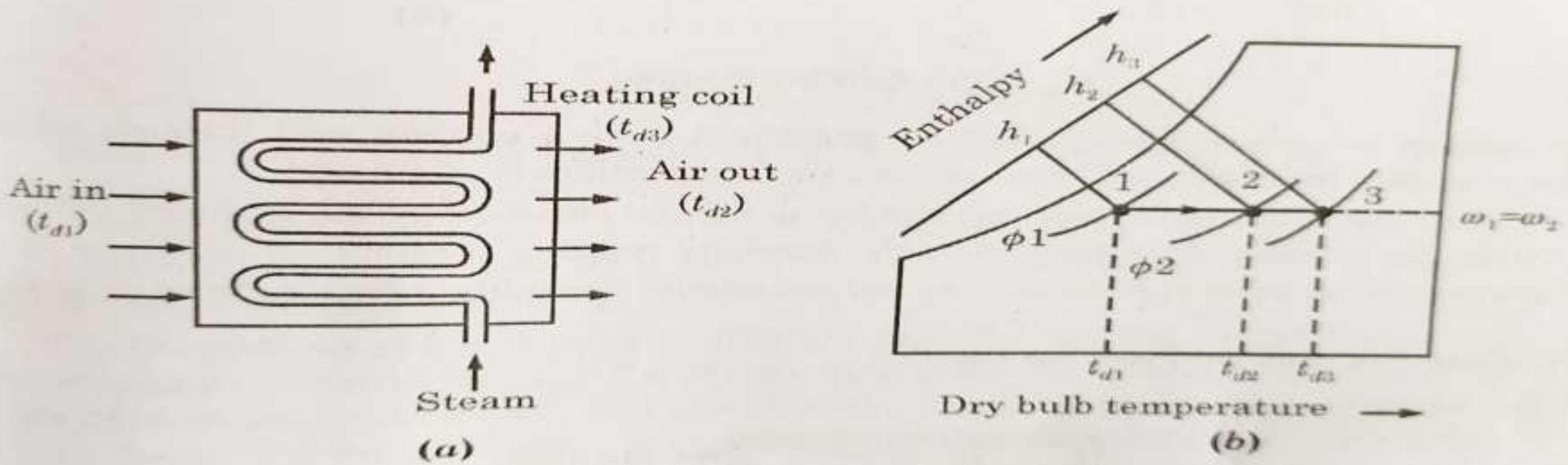
PSYCHROMETRIC PROCESSES

- The processes which affect the psychrometric properties of air according to the requirement are called psychrometric processes.

1. Sensible heating
2. Sensible cooling
3. Humidification
4. Dehumidification
5. Heating and humidification
6. Heating and dehumidification
7. Cooling and humidification
8. Cooling and dehumidification
9. Adiabatic chemical dehumidification

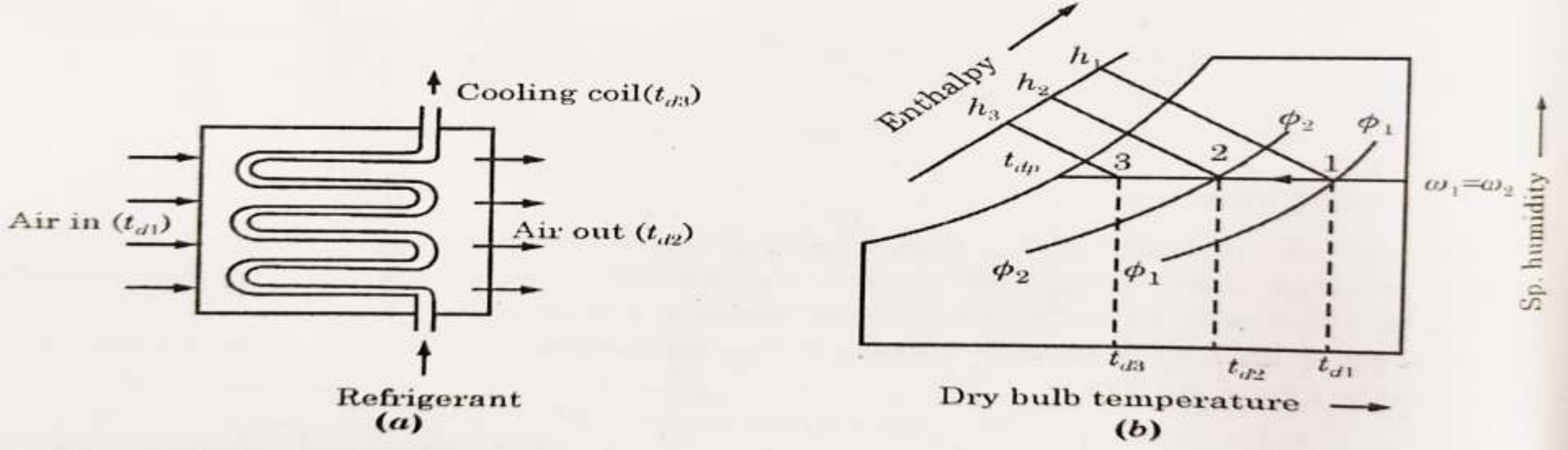
SENSIBLE HEATING

The process in which air is heated without changing its moisture content (specific humidity) is known as sensible heating.



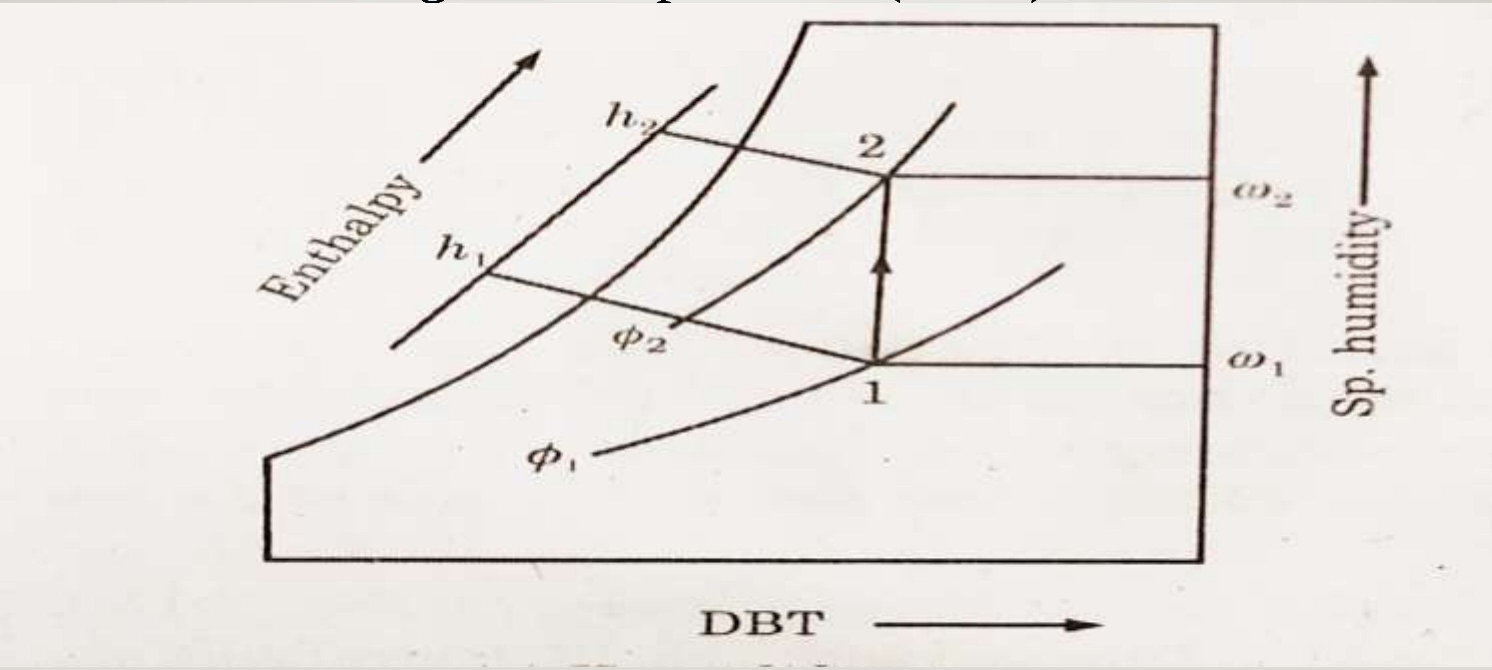
SENSIBLE COOLING

The process in which air is cooling without changing its moisture content (specific humidity) is known as sensible cooling.



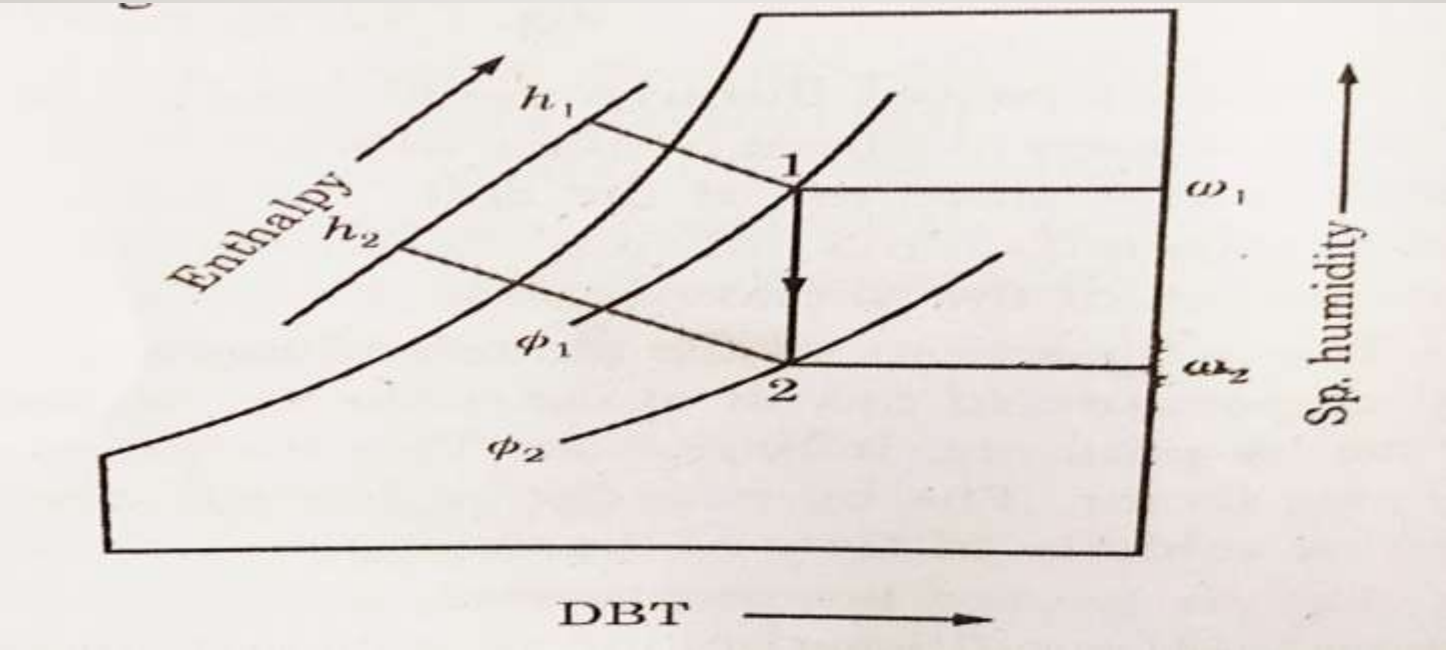
HUMIDIFICATION

It is the process of adding moisture to the air without change in temperature (DBT).



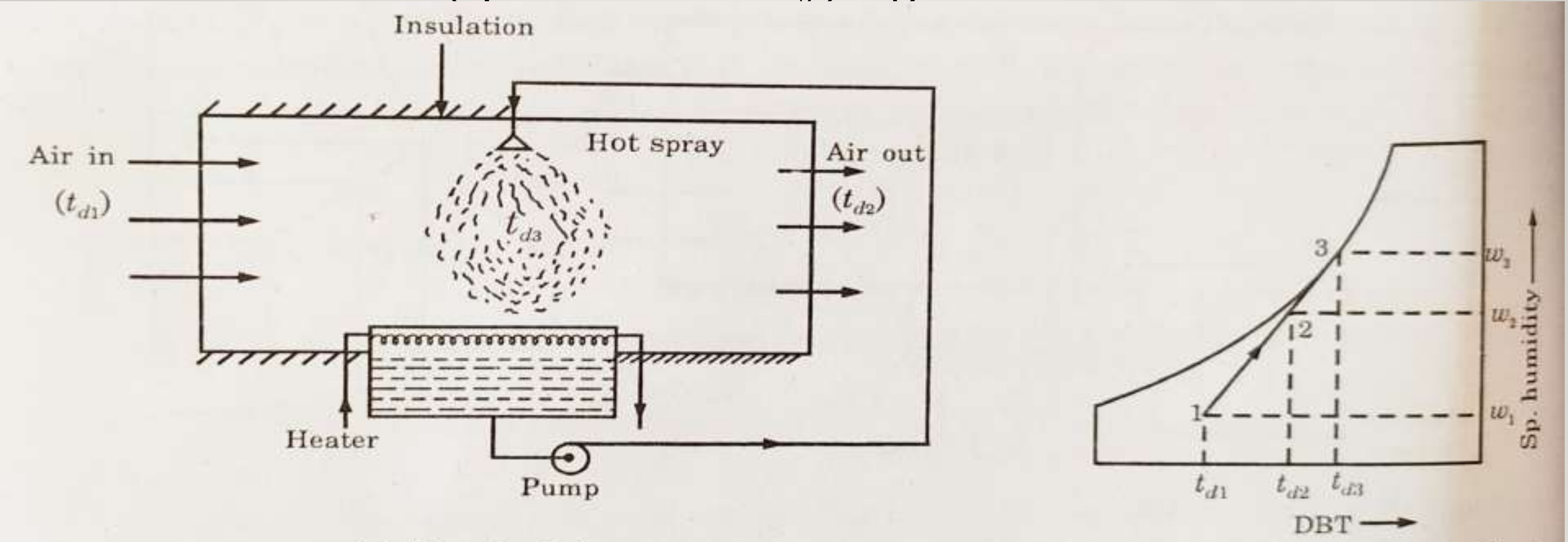
DEHUMIDIFICATION

It is the process of removing moisture to the air without change in temperature (DBT).



HEATING AND HUMIDIFICATION

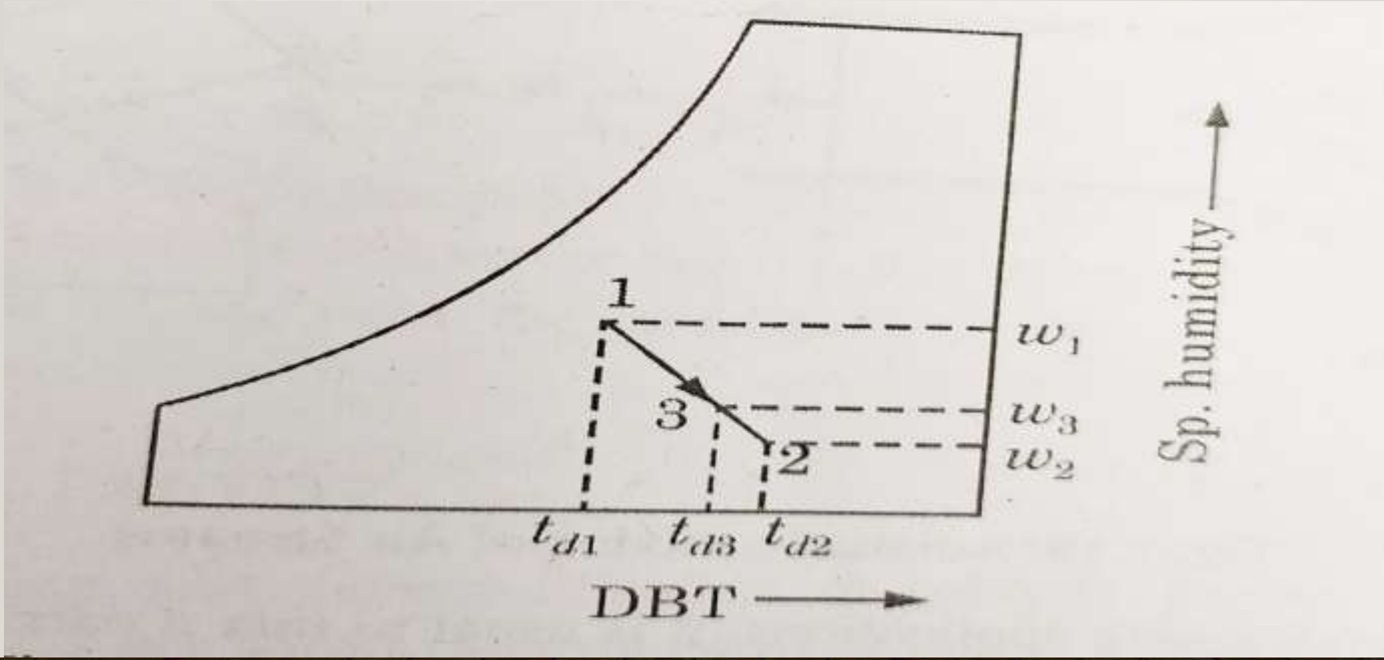
It is the process of increasing DBT and the moisture content (specific humidity). eg winter AC



(*a*) Physical Arrangement (*b*) Process on Psychrometric Chart

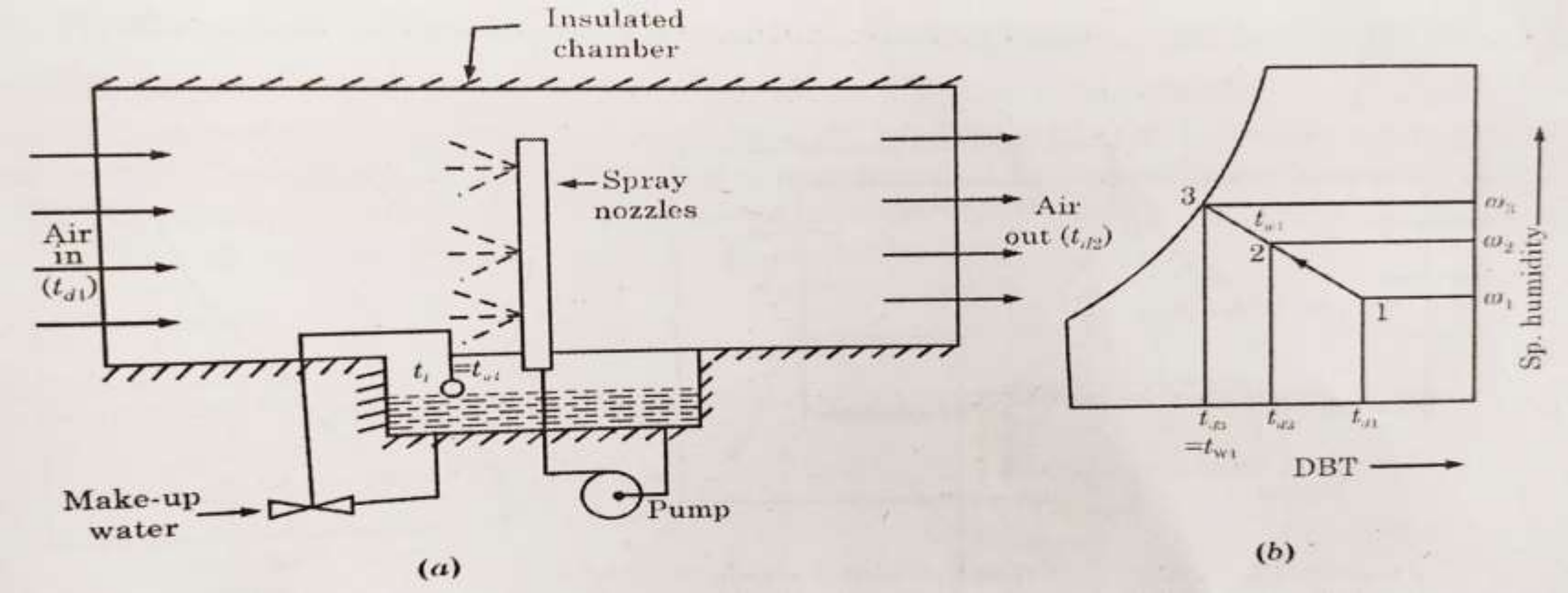
HEATING AND DEHUMIDIFICATION

- It is the process of increasing DBT and decreasing the moisture content (specific humidity).



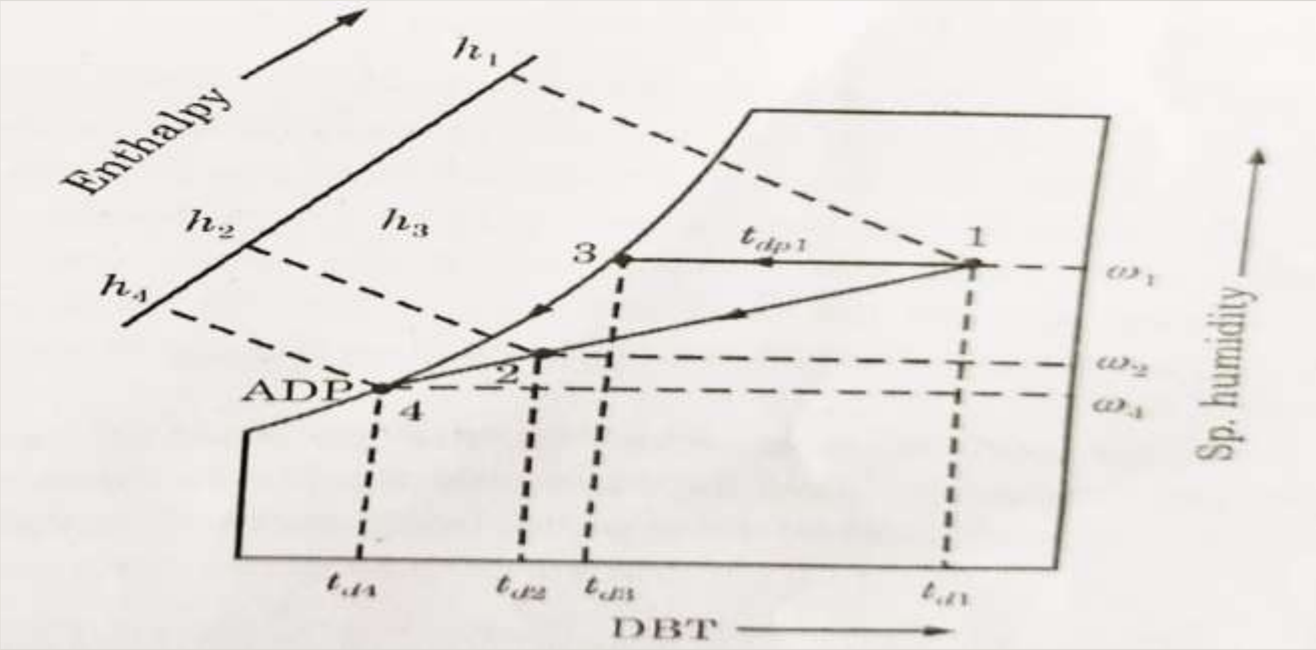
COOLING AND HUMIDIFICATION

It is the process of decreasing DBT and increasing the moisture content (specific humidity).



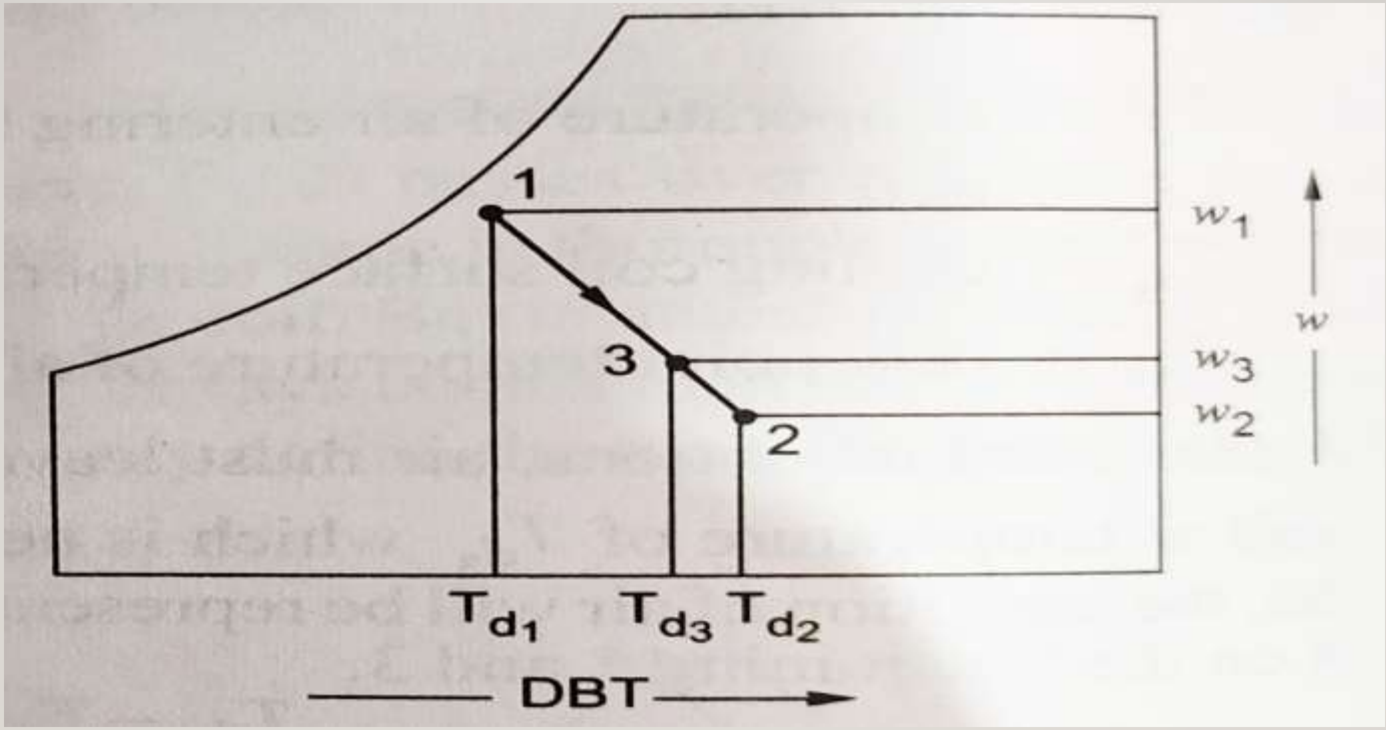
COOLING AND DEHUMIDIFICATION

- It is the process of decreasing DBT and the moisture content (specific humidity). e.g. Summer AC



ADIABATIC CHEMICAL DEHUMIDIFICATION

- Adiabatic chemical dehumidification is a process in which moisture present in the air is absorbed by a hygroscopic material i.e. a liquid or solid chemical moisture absorbing agent, when the air is passed over it. During condensation, the latent heat released by water vapour is absorbed by the air and hence the DBT increases and specific humidity decreases. since the total heat of air remain constant, the process is known as adiabatic chemical dehumidification.



1
3
2
w_1
w_3
w_2
w
T_{d_1}
T_{d_3}
T_{d_2}
DBT

BY- PASS FACTOR (BPF)

- When some of the air flowing through the coil remains unaffected then this air is known as by-pass air. This inefficiency of the coil for the process (heating or cooling) is expressed as by- pass factor of the coil.

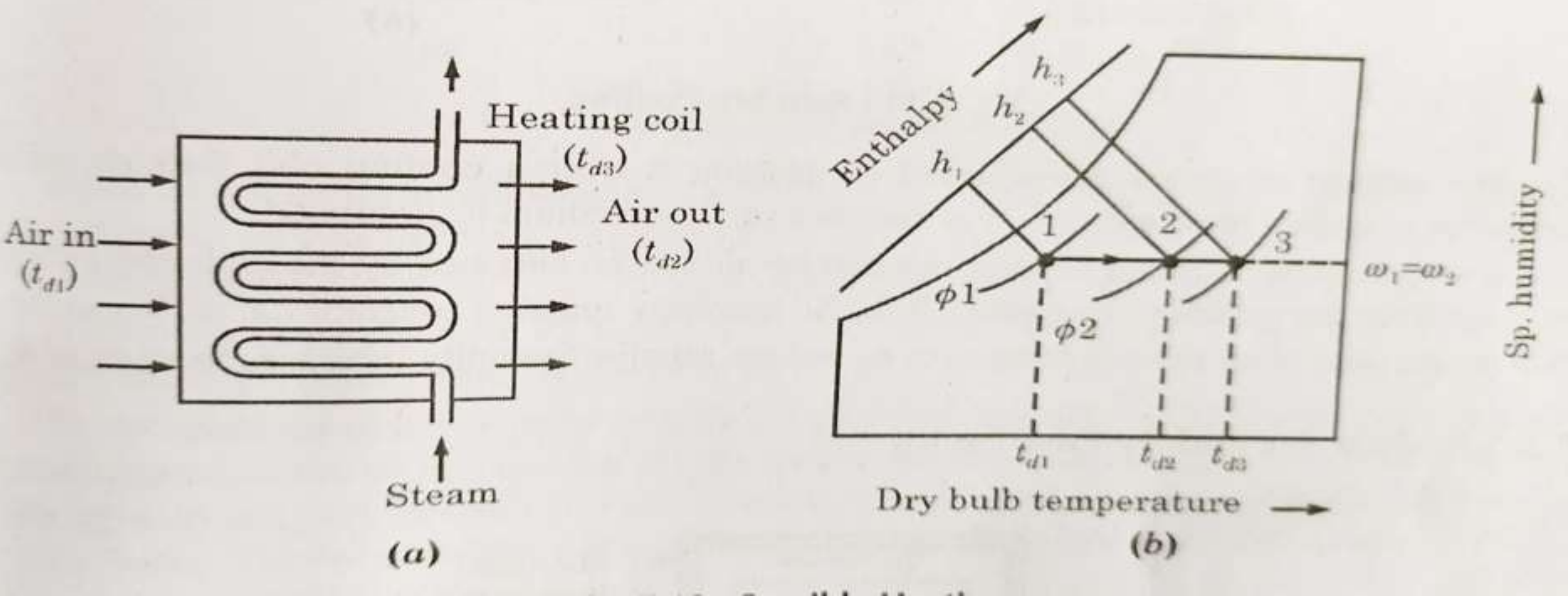
BPF depends upon

- construction of the coil
- Surface area of the coil
- Velocity of flow of the air

Efficiency or effectiveness of the coil = 1- BPF

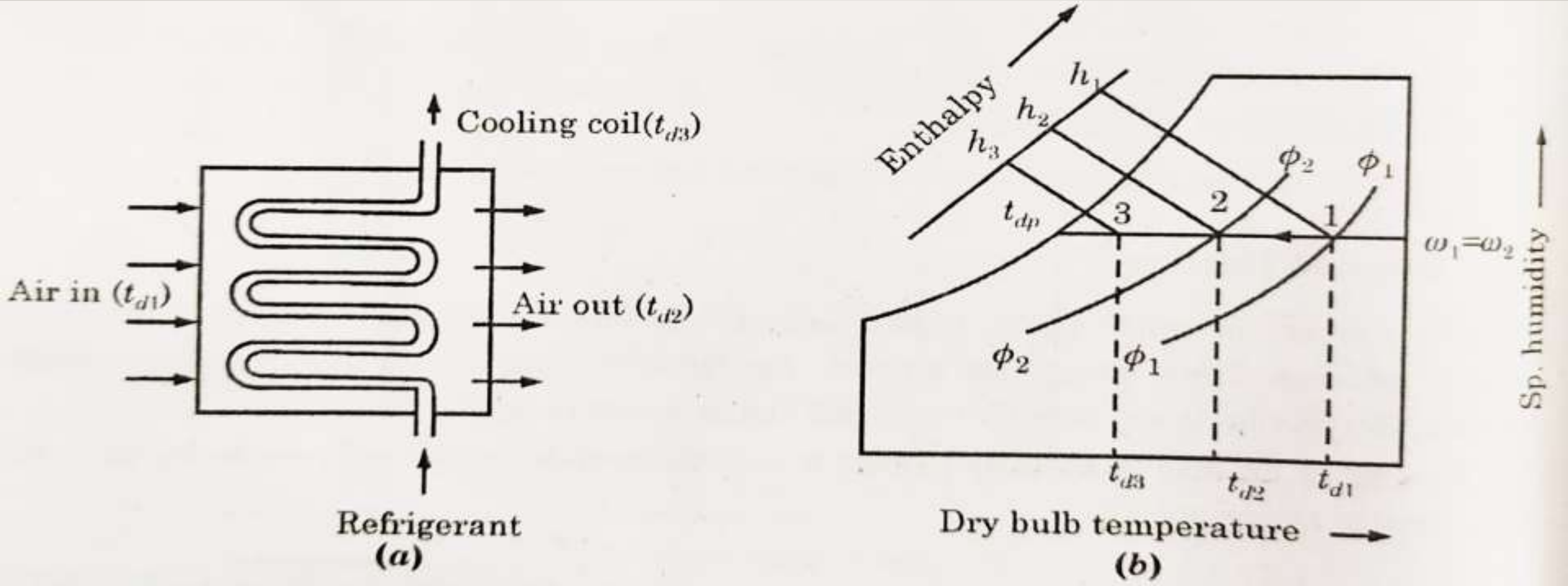
- **BPF for heating coil-**

$$\text{BPF} = \frac{t_{d3} - t_{d2}}{t_{d3} - t_{d1}}$$



- **BPF for cooling coil-**

$$\text{BPF} = \frac{t_{d2} - t_{d3}}{t_{d1} - t_{d3}}$$



SENSIBLE HEAT FACTOR (SHF)

- The process of cooling and dehumidification is frequent in air conditioning. The line representing this process on the psychrometric chart is called as sensible heat factor line. This line represent the changes in latent heat and sensible heat during the process.

- SHF may be defined as the ratio of sensible heat to the total heat where total heat of the air is the sum of its latent heat and sensible heat.

$$\text{SHF} = \frac{Sensible\ heat}{Total\ heat} = \frac{SH}{SH+LH}$$

ROOM SENSIBLE HEAT FACTOR (RSHF)

- It may be defined as the ratio of room sensible heat to the room total heat. Room total heat(RTH) is the sum of room sensible heat(RSH) and the room latent heat(RLH).

$$\text{RSHF} = \frac{RSH}{RTH} = \frac{RSH}{RSH+RLH}$$

GRAND SENSIBLE HEAT FACTOR (GSHF)

- It may be defined as the ratio of total sensible heat to grand total heat which the conditioning apparatus or the cooling coil is required to handle.
- GSHF line is also known as apparatus sensible heat line
- The intersection of RSHF line and GSHF line is the ideal condition for supply air to the room

EFFECTIVE SENSIBLE HEAT FACTOR (ESHF)

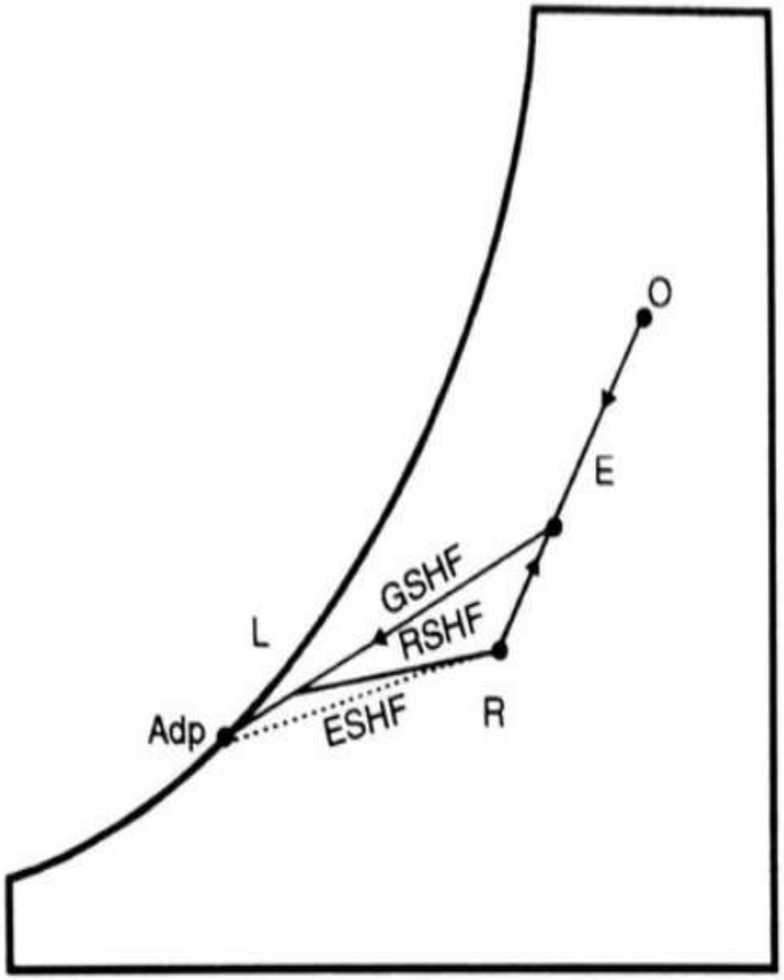
- It may be defined as the ratio of effective room sensible heat (ERSH) to the effective room total heat (ERTH). Where effective RTH is the sum of effective RSH and effective RLH.

$$\text{ESHF} = \frac{EFFECTIVE\ ROOM\ SENSIBLE\ HEAT}{EFFECTIVE\ ROOM\ TOTAL\ HEAT}$$

$$= \frac{ERSH}{ERTH} = \frac{ERSH}{ERSH+ERLH}$$

RSHF, ESHF, GSHF

- The outside air after mixing with return air gives condition E as shown in figure. This is then passed over the cooling coil.
- The cooling coil and dehumidification process then proceeds from the mixture condition 'E' to Adp as shown in figure.
- The condition of air leaving the coil is 'L' on GSHF line.
- The line joining L to R is RSHF line as shown in figure.
- It could be seen that GSHF and RSHF lines are actual processes taking place in coil and room respectively.
- The ESHF line is a conceptual line and hence represented as dotted line.



RSHF, ESHF, GSHF

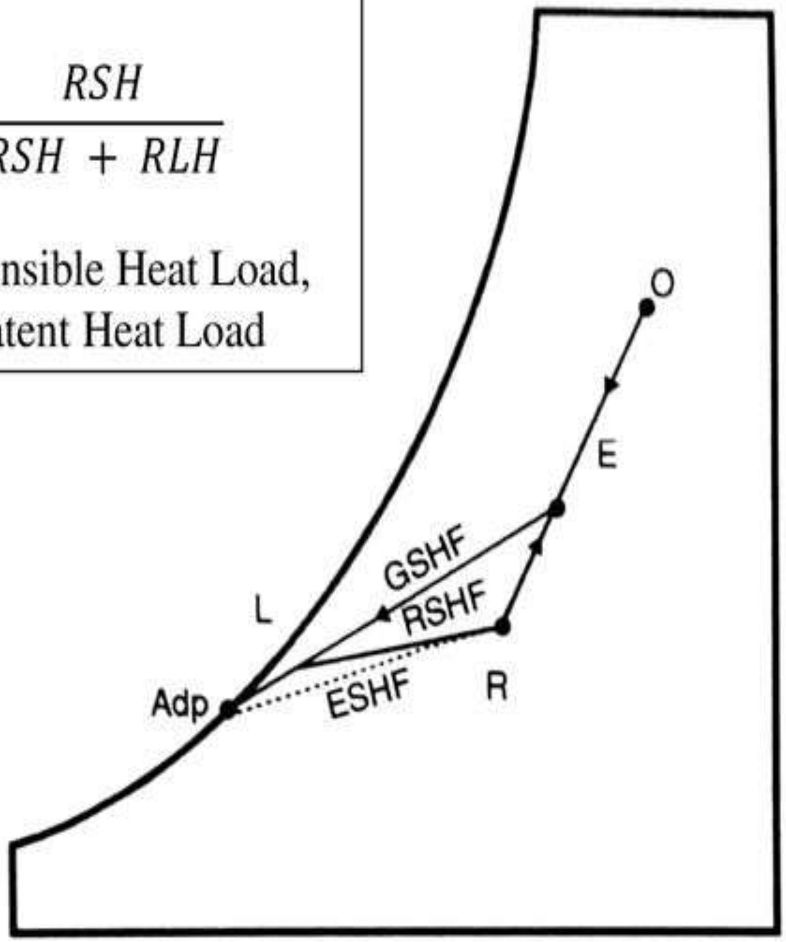
Room Sensible Heat Factor (RSHF):

$$RSHF = \frac{RSH}{RSH + RLH}$$

Where,

RSHL = Room Sensible Heat Load,

RLHL = Room Latent Heat Load



Then,

Effective Room Sensible Heat Load (ERSH)
= RSH + (BF) x (Outside air SH)

Effective Room Latent Heat Load (ERLH)
= RLH + (BF) x (Outside air LH)

$$ESHF = \frac{ERSH}{ERSH + ERLH}$$

$$GSHF = \frac{TSH}{GTH} = \frac{TSH}{TSH + TLH}$$

$$= \frac{RSH + OASH}{(RSH + OASH) + (RLH + OALH)}$$

TSH = Total sensible heat

TLH = Total latent heat

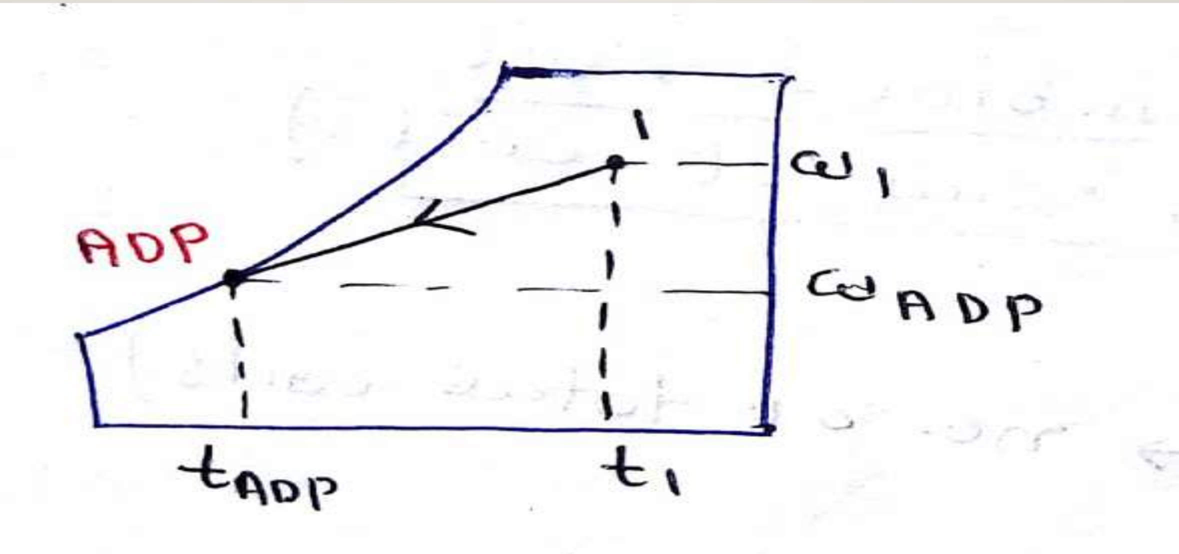
GTH = Grand total heat

OASH = outside air sensible heat

OALH = outside latent heat

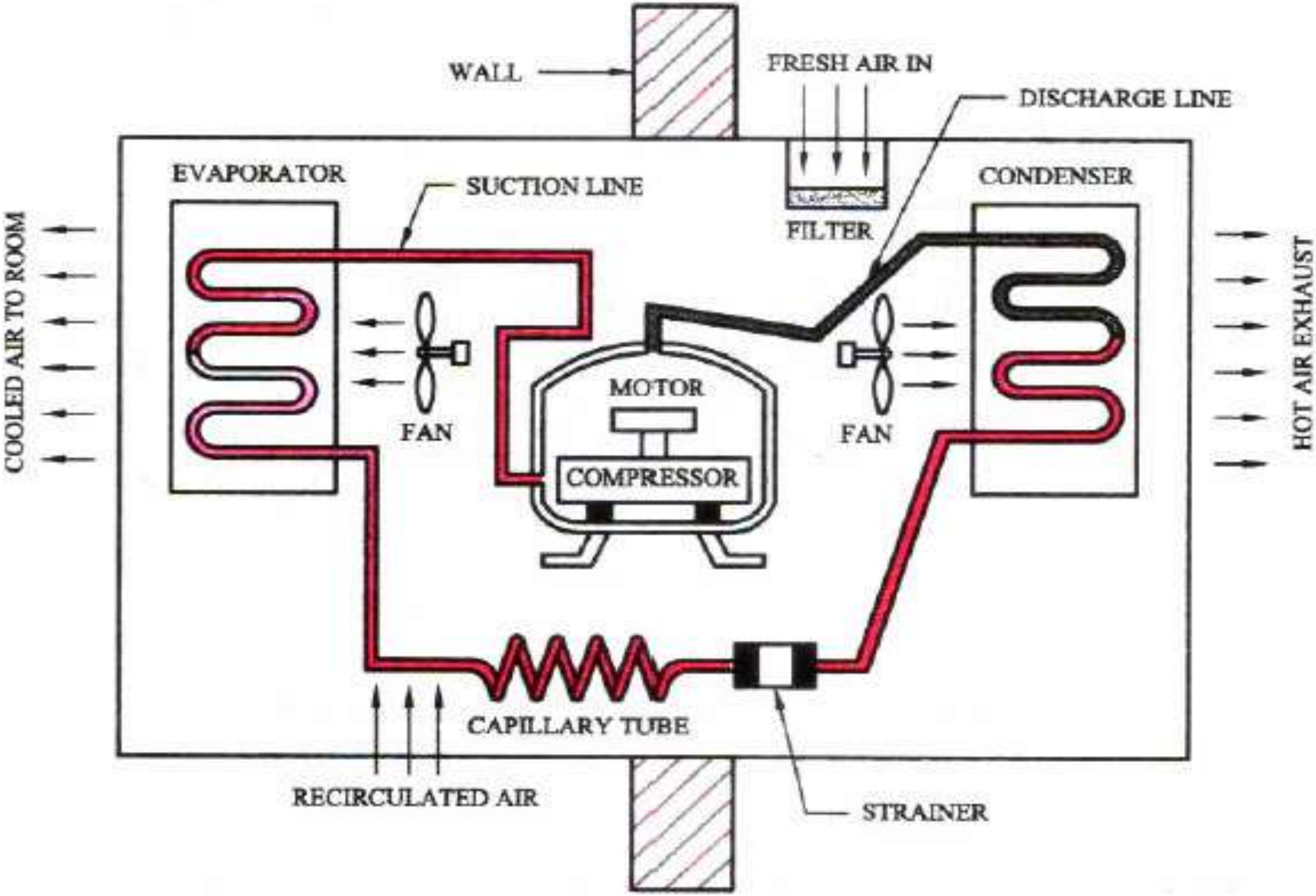
APPARATUS DEW POINT (ADP)

- It is the temperature at a point that is obtained by intersection of cooling and dehumidification line with the saturation curve.



WINDOW AIR- CONDITIONER

- Figure shows the schematic diagram of a window air-conditioner. The window air conditioner works on the vapour compression refrigeration cycle.
- The basic components of the system are compressor, condenser, a capillary tube and an evaporator, in addition, filters, accumulators, motors, fan and electrical controls from the rest of components.

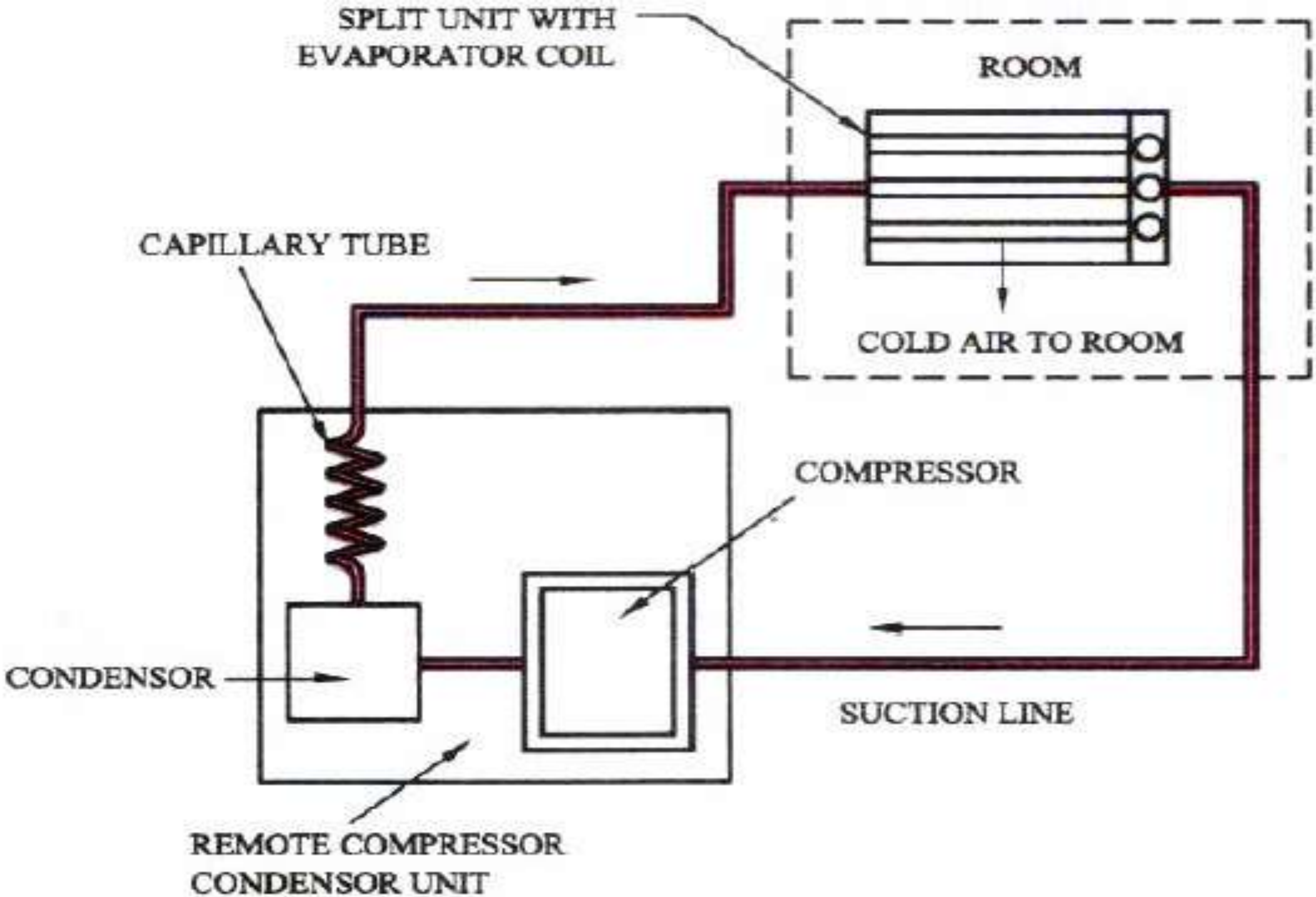

WALL
FRESH AIR IN
DISCHARGE LINE
EVAPORATOR
SUCTION LINE
CONDENSER
FILTER
COOLED AIR TO ROOM
HOT AIR EXHAUST
MOTOR
FAN
FAN
COMPRESSOR
CAPILLARY TUBE
RECIRCULATED AIR
STRAINER

- The high pressure gas (refrigerant), which comes out of the compressor, is condensed in the condenser using ambient air as a coolant. The liquid refrigerant is expanded in a capillary tube and then enters the evaporator. Here, it evaporates and causes the refrigerating effect.
- Then fan blows the fresh air over the evaporator coil, which cools the air. The cool air is supplied the room. Meanwhile, refrigerant from the evaporator enters the compressor to be compressed and the cycle repeats itself.

- The compressor used in a window air-conditioner is hermetic type, which is sealed in a casing with a motor.
- The condenser and evaporator fans are both propeller type. The condenser coil is a continuous copper coil with aluminium fins.
- The capillary tube is 40cm long, usually with 0.75mm diameter.
- Evaporator coil is also made of copper with aluminium fins.

SPLIT TYPE AIR-CONDITIONING

- Split ACs are preferred for offices, schools, auditoriums, etc. The idea of split units came from the fact that air-conditioning system operation was noisy. In order to eliminate the noise, compressor and condenser were located at remote location and only evaporator coil and a fan were located near the application. This division or splitting of the air- conditioning unit gave the equipment its name.

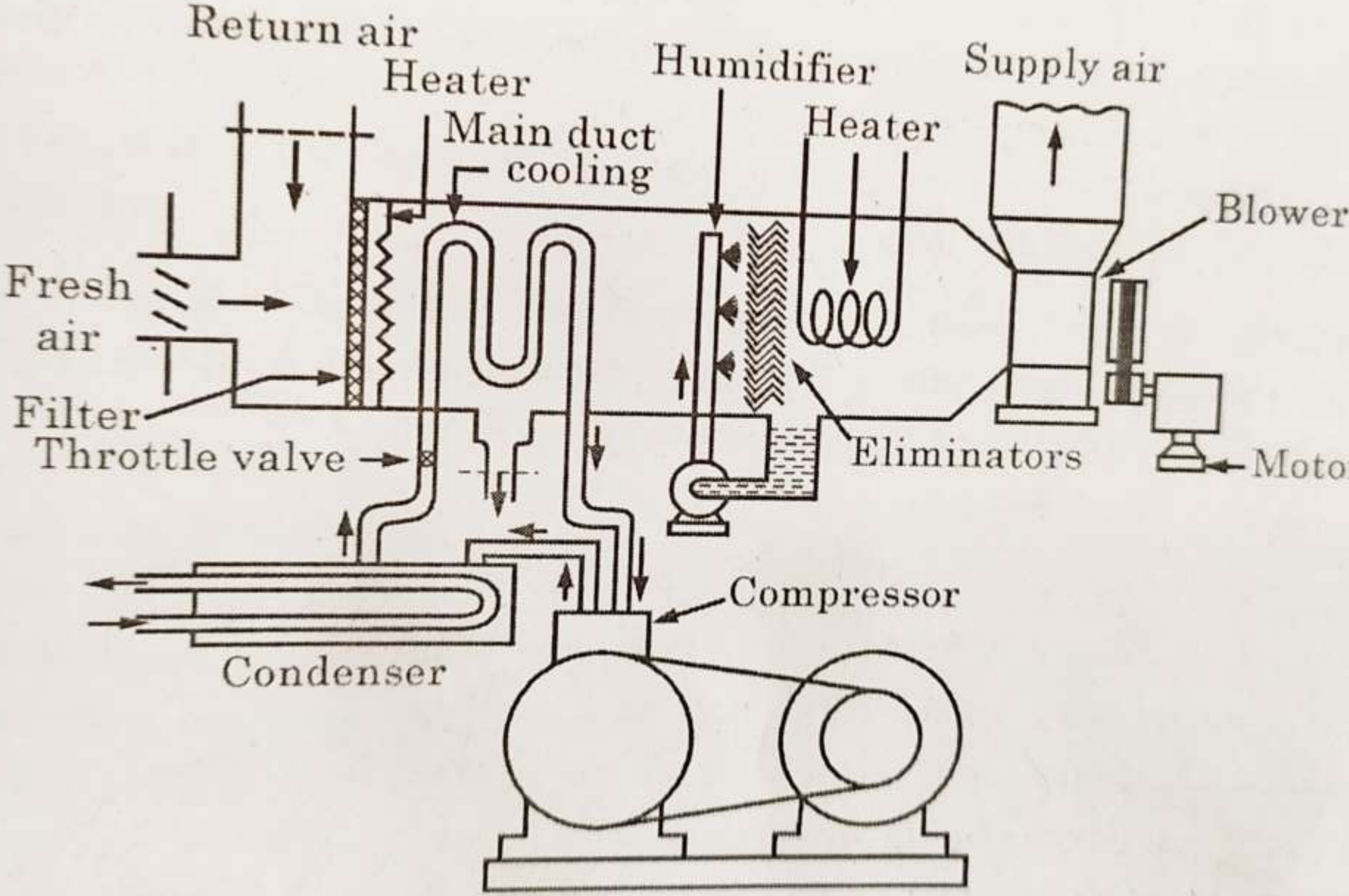

SPLIT UNIT WITH
EVAPORATOR COIL
ROOM
CAPILLARY TUBE
COLD AIR TO ROOM
COMPRESSOR
CONDENSOR
SUCTION LINE
REMOTE COMPRESSOR
CONDENSOR UNIT

- This operation is similar to the window air-conditioner as the basic cycle of operation is vapour compression refrigeration. The refrigerant is compressed, condensed, expanded at the remote site and evaporated only in the room evaporator. The air is blown over the evaporator coil and that causes cooling.

Advantages	Disadvantages
• Noiseless operation • Easy Maintenance • Less Vibration • Compact unit • Aesthetic quality of unit is high	• High cost of unit • Longer refrigerant lines and thus more leakage • COP of unit is poor • Control over operation is difficult

CENTRAL AIR CONDITIONING SYSTEM

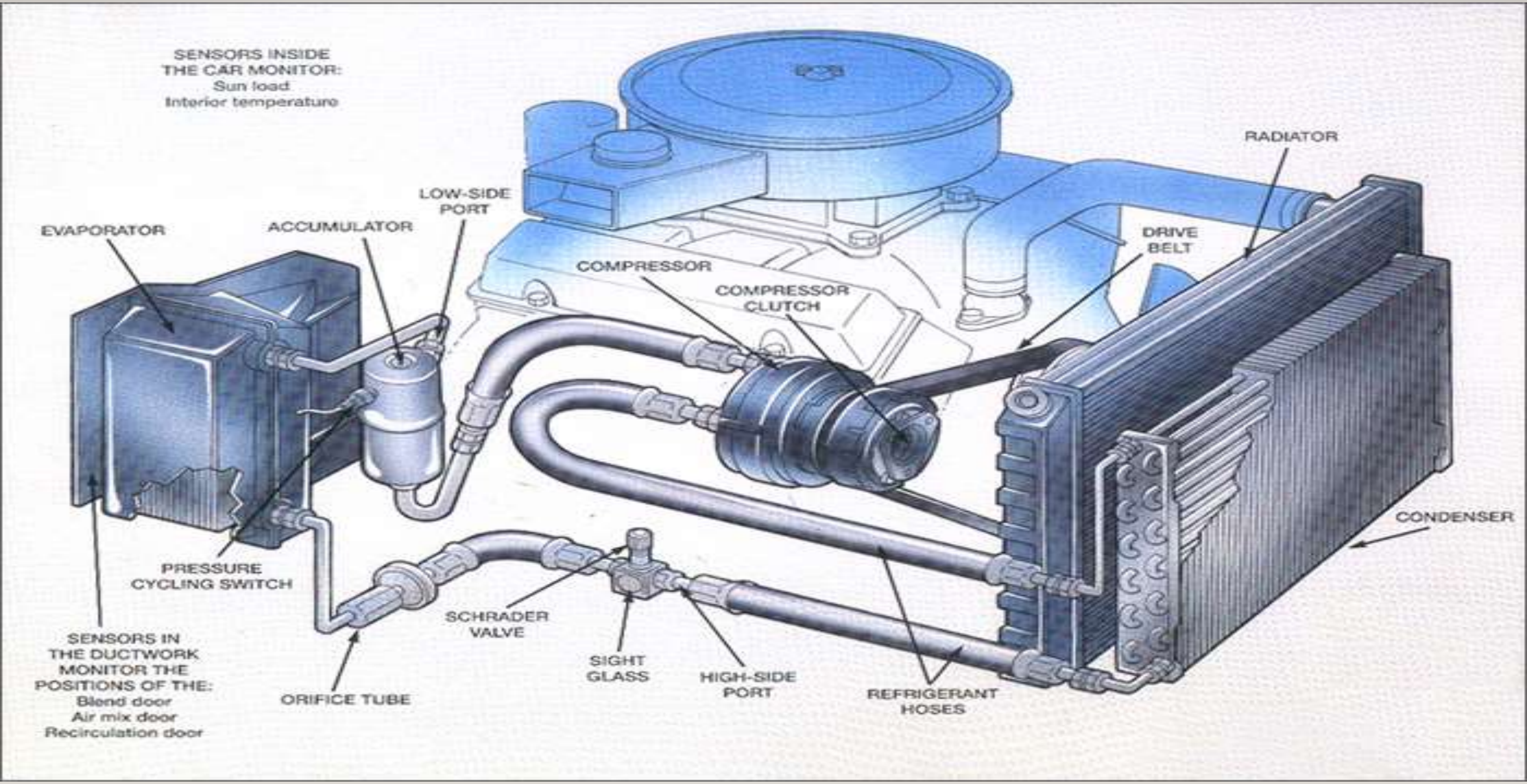
- Central ACs are generally used where the required cooling capacity is 25 TR or more or where the air flow is more than 300 m^3/ min or different zones in a building are to be air conditioned.
- The cooling plant is located at the central place and the conditioned air is supplied to various compartments through ducts or pipings.


Return air
Heater
Main duct
cooling
Humidifier
Heater
Supply air
Blower
Fresh
air
Filter
Throttle valve
Eliminators
Moto
Compressor
Condenser

A mixture of return air and fresh air entering through the air filter is sucked or forced over the cooling coil. The air is heated by a pre-heater before it is cooled over the cooling coil. In addition to cooling, the air may be dehumidified also, if required, by maintaining the coil temperature below the dew point temperature of the air. On the other hand, the air can be humidifed, if needed, by means of a water spray. Larger water droplets are separated by the eliminator. A reheater coil provided before the fan or blower finally heats up the air to the desired room conditions.

In case chilled water is to be supplied to various rooms of a building, the water is chilled in the central conditioned room and is supplied to the individual rooms with individual flow controls.

CAR AIR-CONDITIONING



- Car or Automobile ACs are meant for human comfort. Due to moving nature of the car, the equipment used should be light , compact quickly serviceable and unaffected by vibrations.
- Total heat load depends upon many factors such as outdoor temperature, humidity, number of occupants, and fresh air quantity etc.

WORKING OF CAR AC

- The open reciprocating compressor is driven by the main engine by means of a belt drive system. A fin and tube air cooled condenser is fitted in front of the radiator and is cooled by the radiator fan of the car.
- The heater and the assembly of cooling coil, air filter and blower is fitted either behind the dashboard or in the rear of the car.

- Air is conditioned over the cooling by using a fan and is distributed in the car through the grill.
- A temperature of about 21 °C to 24 °C is maintained in the car during summer when the car is running and the system is operated.
- In the winter season when the cooling cycle of the ac is shut, heating inside the car can be done. Air is forced through the coils by the blower. Thus warm air is distributed through the grills inside the car.

CHAPTER -8

LATEST DEVELOPMENT IN REFRIGERATION AND AIR CONDITIONING

INVERTER TECHNOLOGY

- An inverter AC controls the speed of the compressor motor so as to regulate the temperature continuously. It is more effective and uses less power than a normal AC.
- It runs at full load until the fixed temperature achieved and runs at part load (generally half load) to maintain that temperature.
- An inverter Ac never turns off the motor or compressor.

Advantages of inverter AC

- Energy saving
- Less noisy
- Lower operational cost
- Requires no reset after a power cut
- Includes filtration process
- Comfortable

AUTO DEFROSTING

- It is the automatically defrosting the ice which may block the vents that allows air into the refrigerator compartment.

Advantages of Auto defrosting

- No need to manually defrost
- Most frozen food will not stick together
- Smells are limited because the air always circulate.
- Better temperature managements

Disadvantages of the Auto defrosting

- More expensive
- Thermal cut-out safety device is required to prevent overheating of the elements
- May cause freezer burn on articles placed in the freezer from partially defrosting then re-freezing.
- Increased electrical and mechanical complexity, making it more prone to component failure.

BLAST COOLING

- *Blast Cooling* (also *Blast Chilling*) is a precooling method where air is forced (blasted) out at relatively high velocities in order to cool food to a low temperature suitable for storage. Blast Cooling is also called forced-air cooling.
- Blast Cooling rapidly lowers the "pulp temperature" of product to preserve quality, extend shelf-life, and inhibit microbial growth.

BENEFITS OF BLAST COOLING

- Maintaining food quality
- Prevent food shrinkage
- Increase menu and service
- Achieve food safety standards

STAR RATING

- The **star rating** is a measure of energy efficiency of an appliance, it is a five-point scale where the higher the **rating**, the lower is the energy consumption and, hence, better savings. For each product, BEE decides a period of two to three years for which a **rating** table is valid.

BEE (BUREAU OF ENERGY EFFICIENCY)

- BEE is an agency of Government of India established in March 2002 under the Ministry of power. It is an autonomous Government agency which introduced conservation and efficient use of energy in certain electrical appliances in India. Bee star rating means the capacity of the appliance according to the volume, storage volume, and electricity it consumes per unit.

STAR RATING IN REFRIGERATORS

- The BEE star rating of the top refrigerators in India starts from a minimum of 1-star to a maximum of 5-star. The expense also increases with the stars and the quality of the Refrigerator as well. You must notice that these star ratings are only available for single door and frost-free refrigerators. These refrigerators are more expensive due to star ratings. But a 5-star refrigerator is more expensive than a 1-star. But in long run, it will save your money by saving your electricity bill.

POWER CONSUMPTION

- According to the calculation of annual electricity consumption, a no star Refrigerator consumes 1000 units per year. But a 3-star rating Refrigerator uses only 626 units of electricity consumption per year. A 3-star rated Refrigerator saves 44% of your electricity consumption and obviously your electricity bill.


THANK
YOU