HEATING VENTILATION AND AIR CONDITIONING (R17A0331)

4^{th} Year B. Tech I- sem, Mechanical Engineering

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COURSE OBJECTIVES

UNIT - 1	**CO1:**To Explain in detail Basic Components of Air-Conditioning & Refrigeration machines, Basic Refrigeration cycle, Accessories & Refrigerants
UNIT - 2	**CO2:** To Know Detail classification of Air-Conditioning System
UNIT - 3	CO3: To Study Psychrometric Chart and various terminology
UNIT - 4	CO4:To Explain the Load calculations of Survey of Building, Ventilation requirement for IAQ, ESHF, ADP & Air Flow Rate(CFM)Calculation
UNIT - 5	CO5: Explain Hydronic System, Water Piping,Fittings used in the HVAC Piping System Function, CHW Pipe supports &Pump Head Calculation

UNIT 1

INTRODUCTION TO HVAC

CO1: To Explain in detail Basic Components of Air-Conditioning & Refrigeration machines, Basic Refrigeration cycle, Accessories & Refrigerants

UNIT – I (SYLLABUS)

INTRODUCTION TO HVAC:

- Fundamentals-Modes of Heat Transfer-Sensible Heat and Latent Heat
- Basic Refrigeration System or Vapor Compression

Basic Components of Air-Conditioning and Refrigeration machines

- Function & Types of Compressor
- Function & Types of Condenser-
- Function & Types of Expansion Valves,
- Function &Types of Evaporator.
- Refrigerant and Brines

COURSE OUTLINE

UNIT -1

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES
1	INTRODUCTION TO HVAC: Fundamentals-Modes of Heat Transfer-Sensible Heat and Latent Heat	Conduction, Convection& radiation, latent heat & Sensible Heat	Understand the basics of modes of Heat Transfer (B2). To remember the Sensible & latent Heat (B1)
2	Basic refrigeration System or Vapor Compression Cycle Pressure –Enthalpy Chart-Function	VCR CYCLE	Understand the working of cycles (B2) To analyze the cycle in enthalpy chart (B4)
3	Types of Compressor-Function	WORKING OF COMPRESSORS	To understand Function of compressor (B2) To Apply the compressors in hvac (B3)

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COURSE OUTLINE

UNIT -1

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES
4	**Types of Condenser-Function**	**WORKING OF CONDENSORS**	**To understand Function of condensors (B2)** **To Apply the compressors in hvac (B3)**
5	Types of Expansion Valves, Functions	WORKING OF EXPANSION VALVES	To understand Function of Expansion Values (B2) To Apply the compressors in hvac (B3)
6	Types of Evaporator functions	WORKING OF EVAPORATOR	To understand Function of Evaporators (B2) To Apply the compressors in hvac (B3)
7	Accessories used in the System-Refrigerant and Brines	REFRIGERANT TYPES	To able to understand which type of refrigerant is used in HVAC (B4)

LECTURE 1

INTRODUCTION TO HVAC:

TOPICS TO BE COVERED

- Introduction
- Conduction,
- Convection
- Radiation,
- Latent heat & Sensible Heat

LECTURE 1

INTRODUCTION TO HVAC:

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INTRODUCTION TO HVAC

- Heating ventilation & Air Conditioning involves heat transfer;
- Heat transfer is defined as energy-in-transit due to temperature difference.
- Heat transfer takes place whenever there is a temperature gradient within a system or whenever two systems at different temperatures are brought into thermal contact. Heat, which is energy-in-transit, cannot be measured or observed directly, but the effects produced by it can be observed and measured. Since heat transfer involves transfer and/or conversion of energy, all heat transfer processes must obey the first and second laws of thermodynamics

Generally heat transfer takes place in three different modes:

1. conduction,
2. convection and
3. radiation.

In most of the engineering problems heat transfer takes place by more than one mode simultaneously

CONDUCTION HEAT TRANSFER

- Conduction heat transfer takes place whenever a temperature gradient exists in a stationary medium. Conduction is one of the basic modes of heat transfer. On a microscopic level, conduction heat transfer is due to the elastic impact of molecules in fluids, due to molecular vibration and rotation about their lattice positions and due to free electron migration in solids.
- The fundamental law that governs conduction heat transfer is called Fourier's law of heat conduction, it is an empirical statement based on experimental observations and is given by:
- In the above equation, Qx is the rate of heat transfer by conduction in x-direction, (dT/dx) is the temperature gradient in x-direction, A is the cross-sectional area normal to the x-direction and k is proportionality constant and is a property of the conduction medium, called thermal conductivity.
- The '-' sign in the above equation is a consequence of 2^{nd} law of thermodynamics, which states that in spontaneous process heat must always flow from a high temperature to a low temperature (i.e., dT/dx must be negative).

- In Heating ventilation & Air Conditioning conductivity materials are used in the construction of heat exchangers, while low thermal conductivity materials are required for insulating refrigerant pipelines,refrigerated cabinets, building walls etc.

Material	**Thermal conductivity (W/m K)**
Copper (pure)	399
Gold (pure)	317
Aluminum (pure)	237
Iron (pure)	80.2
Carbon steel (1 %)	43
Stainless Steel (18/8)	15.1
Glass	0.81
Plastics	0.2 – 0.3
Wood (shredded/cemented)	0.087
Cork	0.039
Water (liquid)	0.6
Ethylene glycol (liquid)	0.26
Hydrogen (gas)	0.18
Benzene (liquid)	0.159
Air	0.026

GENERAL HEAT CONDUCTION EQUATION

- Fourier's law of heat conduction shows that to estimate the heat transfer through a given medium of known thermal conductivity and cross-sectional area, one needs the spatial variation of temperature.
- The heat conduction equation is obtained by applying first law of thermodynamics and Fourier's law to an elemental control volume of the conducting medium. In rectangular coordinates, the general heat conduction equation for a conducting media with constant thermo-physical properties is given by:

$$\frac{1}{\alpha}\frac{\partial T}{\partial \tau} = \left[\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right] + \frac{q_g}{k}$$

$$\alpha = \frac{k}{\rho c_p}$$

- In the above equation, is a property of the media and is called as thermal diffusivity,
- qg is the rate of heat generation per unit volume inside the control volume and τ is the time.

CONVECTION HEAT TRANSFER:

- Convection heat transfer takes place between a surface and a moving fluid, when they are at different temperatures.
- The fluid consists of two mechanisms operating simultaneously. The first one is energy transfer due to molecular motion (conduction) through a fluid layer adjacent to the surface, which remains stationary with respect to the solid surface due to no-slip condition.
- Superimposed upon this conductive mode is energy transfer by the macroscopic motion of fluid particles by virtue of an external force, which could be generated by a pump or fan (forced convection) or generated due to buoyancy, caused by density gradients.
- Similarly to the velocity gradient, there is a sharp temperature gradient in this vicinity of the surface if the temperature of the surface of the plate is different from that of the flow stream. This region is called thermal boundary layer, δt whose thickness is of the order of (ReLPr) , where Pr is the Prandtl number, given by:

$$Pr = \frac{c_{p,f}\mu_f}{k_f} = \frac{\nu_f}{\alpha_f}$$

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RADIATION HEAT TRANSFER:

- Radiation is another fundamental mode of heat transfer. Unlike conduction and convection, radiation heat transfer does not require a medium for transmission as energy transfer occurs due to the propagation of electromagnetic waves.
- The radiation energy emitted by a surface is obtained by integrating Planck's equation over all the wavelengths. For a real surface the radiation energy given by Stefan Boltzmann's law is:

$$Q_r = \varepsilon . \sigma . A . Ts$$

where Qr = Rate of thermal energy emission, W

ε = Emissivity of the surface

σ = Stefan-Boltzmann's constant, 5.669×10^{-8}

A=Surface area, m

Ts = Surface Temperature,

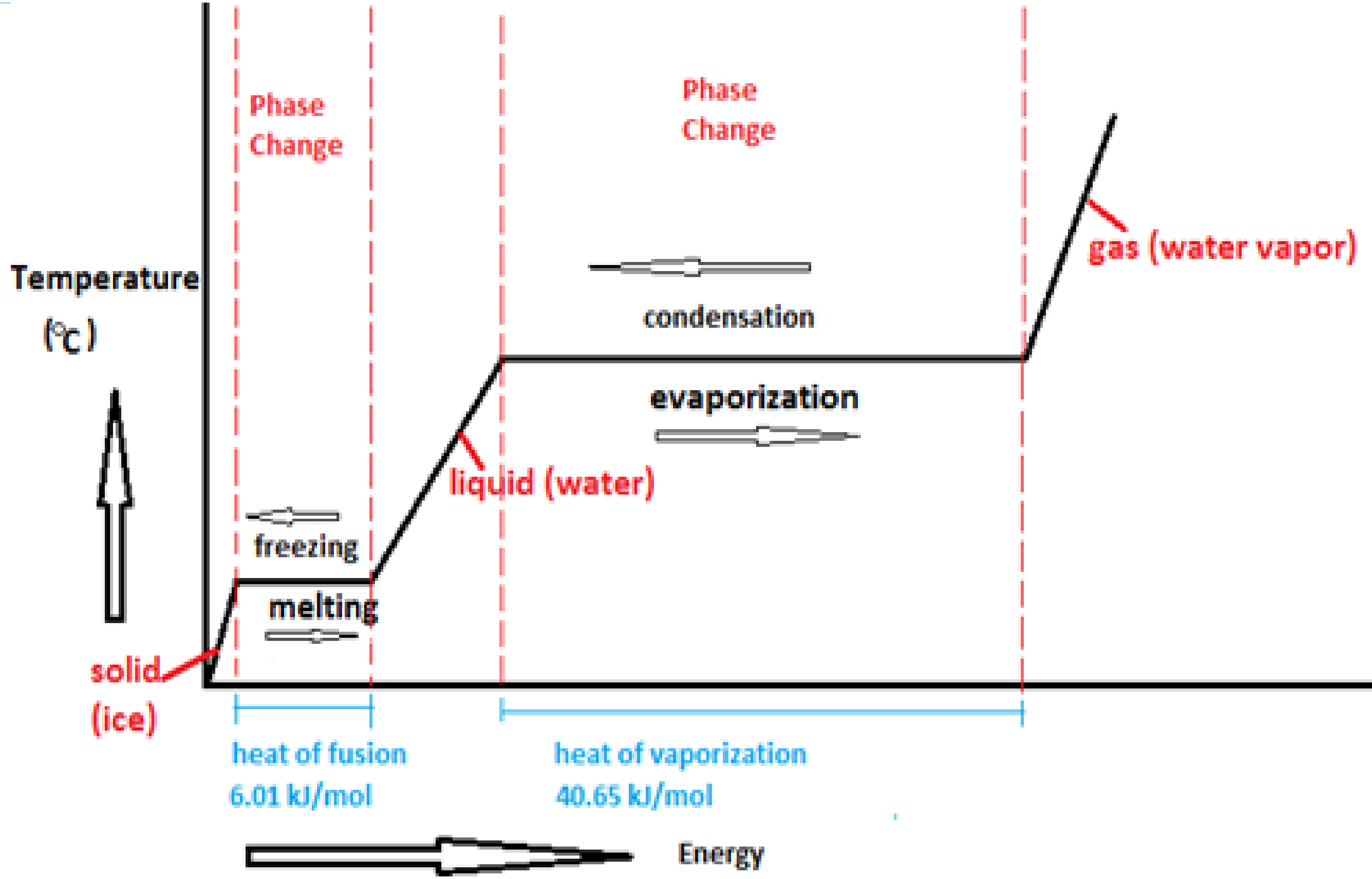
SENSIBLE HEAT

- Sensible heat is when energy is transferred as heat to an object, changing the temperature but not its state. If you can measure the temperature of the heat, it is sensible. A body (solid, liquid or gas) of mass m and specific heat c is heated to change its temperature from T1 to T2 without changing its state. Indeed, the volume or the pressure of the body is unchanged. The energy received by the body responsible for its risen temperature is given by the relation:
- Q=m*c*(T2-T1) in joules
- Q=m*c*(T2-T1)1055,06 in BTU

LATENT HEAT

- In contrast to sensible heat, latent heat is the energy released or absorbed that changes the state of a body during a constant temperature process. This process leaves temperature unaffected - it won't get higher or lower. The most common forms of latent heat are fusion and vaporization.
- **Fusion**
- Fusion is the passage of a body from solid state to liquid state. During the process of changing phasis, the temperature stays the same. Energy is supplied to a solid in order to melt it and energy is released from a liquid when it freezes. The best example is an ice cube melting at 32 °F (0°C).
- **Vaporization**
- Vaporization is the passage of a body from the liquid state to the vapor state. If conditions allow, the formation of vapor bubbles within a liquid, (known as boiling). Heat must be supplied to a liquid to effect vaporization. If there is not enough heat, it may come from the system itself as a reduction in temperature. The atoms or molecules of a liquid are held together by cohesive forces, and these forces must be overcome in separating the atoms or molecules to form the vapor. The heat of vaporization is a direct measure of these cohesive forces. The best example is a pot of water boiling at 212 °F (100°C).

LATENT HEAT & SENSIBLE HEAT



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LECTURE 2

BASIC COMPONENTS OF AIR-CONDITIONING AND REFRIGERATION MACHINES

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TOPICS TO BE COVERED

1. VCR
2. COMPONENTS OF VCR
3. COP of VCR

LECTURE 2

BASIC COMPONENTS OF AIR-CONDITIONING AND REFRIGERATION MACHINES

VAPOUR COMPRESSION REFRIGERATION

- vapour compression refrigeration systems are the most commonly used among all refrigeration systems. As the name implies, these systems belong to the general class of vapour cycles, wherein the working fluid (refrigerant) undergoes phase change at least during one process.

- Process 1-2: Isentropic compression of saturated vapour in compressor
- Process 2-3: Isobaric heat rejection in condenser
- Process 3-4: Isenthalpic expansion of saturated liquid in expansion device
- Process 4-1: Isobaric heat extraction in the evaporator

VCR

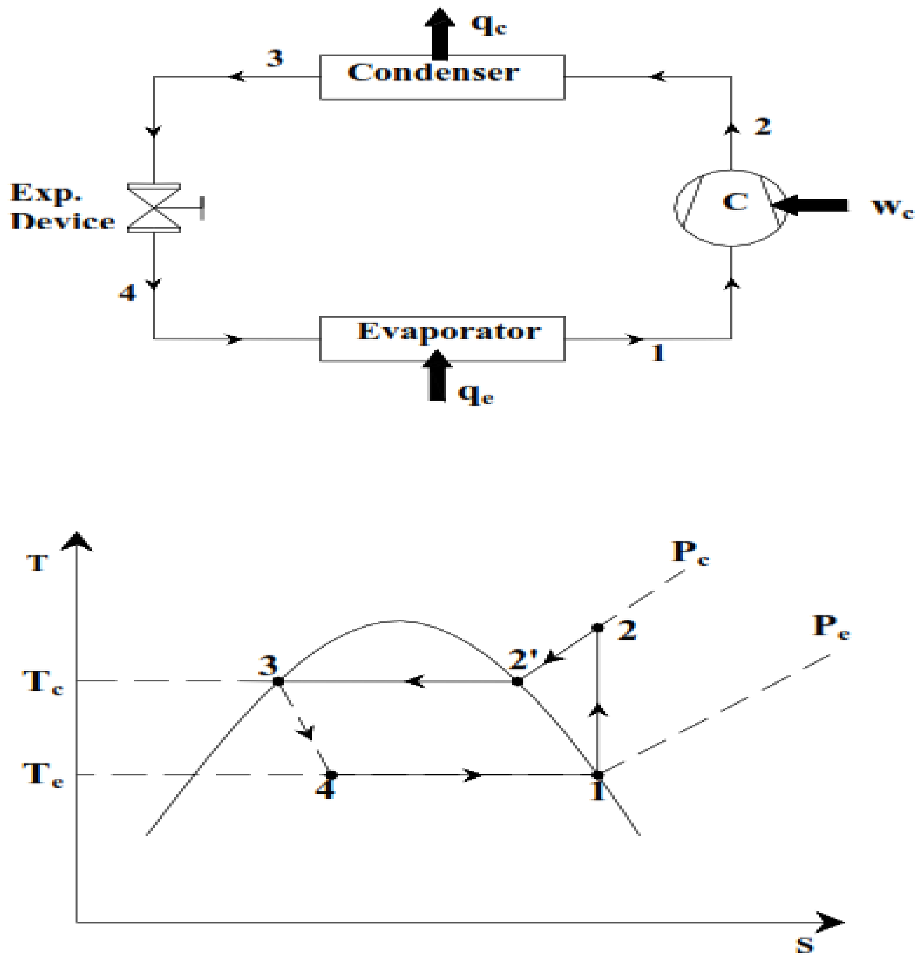

Fig.10.5. Standard Vapour compression refrigeration system

A simple analysis of standard vapour compression refrigeration system can be carried out

by assuming

a) Steady flow;

b) negligible kinetic and potential energy changes across

each component, and

c) no heat transfer in connecting pipe lines.

- The steady flow energy equation is applied to each of the four components.

- Evaporator: Heat transfer rate at evaporator or refrigeration capacity, Qe is given by:

$$\dot{Q}_e = \dot{m}_r (h_1 - h_4)$$

- where mr is the refrigerant mass flow rate in kg/s, h1 and h4 are the specific enthalpies (kJ/kg)at the exit and inlet to the evaporator, respectively.
- $(h_1 - h_4)$ known as specific refrigeration effect or simply refrigeration effect, which is equal to the heat transferred at the evaporator per kilogram of refrigerant. The evaporator pressure Pe is the saturation pressure corresponding to evaporator temperature Te, i.e.,

$$P_e = P_{sat}(T_e)$$

- Compressor: Power input to the compressor, W is given by:

$$\dot{W}_c = \dot{m}_r(h_2 - h_1)$$

- Where h2 and h1 are the specific enthalpies (kJ/kg) at the exit and inlet to the compressor, respectively.

 (h2-h1) is known as specific work of compression or simply work of compression, which is equal to the work input to the compressor per kilogram of refrigerant.

Condenser:

Heat transfer rate at condenser, Qc is given by:

$$\dot{Q}_c = \dot{m}_r(h_2 - h_3)$$

where h3 and h2 are the specific enthalpies (kJ/kg) at the exit and inlet to the condenser, respectively.

- The condenser pressure Pc is the saturation pressure corresponding to evaporator temperature T , i.e.,

$$P_c = P_{sat}(T_c)$$

- Expansion device:
- For the isenthalpic expansion process, the kinetic energy change across the expansion device could be considerable, however, if we take the control volume, well downstream of the expansion device, then the kinetic energy gets dissipated due to viscous effects, and

$$h_3 = h_4$$

- The exit condition of the expansion device lies in the two-phase region, hence applying definition of quality (or dryness fraction), we can write:

$$h_4 = (1 - x_4)h_{f,e} + x_4 h_{g,e} = h_f + x_4 h_{fg}$$

- where x4 is the quality of refrigerant at point 4, hf,e, hg,e, hfg enthalpy, are the saturated liquid saturated vapour enthalpy and latent heat of vaporization at evaporator pressure, respectively.

The COP of the system is given by:

$$COP = \left(\frac{\dot{Q}_e}{\dot{W}_c}\right) = \left(\frac{\dot{m}_r(h_1 - h_4)}{\dot{m}_r(h_2 - h_1)}\right) = \frac{(h_1 - h_4)}{(h_2 - h_1)}$$

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LECTURE 3

FUNCTIONS & TYPES OF COMPRESSORS

TOPICS TO BE COVERED

1. INTRODUCTION
2. CLASSIFICATION OF COMPRESSOR
3. FUNCTIONS

LECTURE 3

FUNCTIONS AND TYPES OF COMPRESSORS

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COMPRESSORS

- A compressor is the most important and often the costliest component (typically 30 to 40 percent of total cost) of any vapour compression refrigeration system (VCRS).
- The function of a compressor in a VCRS is to continuously draw the refrigerant vapour from the evaporator, so that a low pressure and low temperature can be maintained in the evaporator at which the refrigerant can boil extracting heat from the refrigerated space. The compressor then has to raise the pressure of the refrigerant to a level at which it can condense by rejecting heat to the cooling medium in the condenser.

CLASSIFICATION OF COMPRESSORS

Compressors used in refrigeration systems can be classified in several ways:

- **Based on the working principle:**
  i. Positive displacement type
  ii. Roto-dynamic type

Depending upon the construction, positive displacement type compressors used in refrigeration and air conditioning can be classified into:

i. Reciprocating type
ii. Rotary type with sliding vanes (rolling piston type or multiple vane type)
iii. Rotary screw type (single screw or twin-screw type)
iv. Orbital compressors, and
v. Acoustic compressors.

Depending upon the construction, roto-dynamic type compressors can be classified into:

i. Radial flow type, or

ii. Axial flow type.

Centrifugal compressors (also known as turbo-compressors) are radial flow type, roto-dynamic compressors.

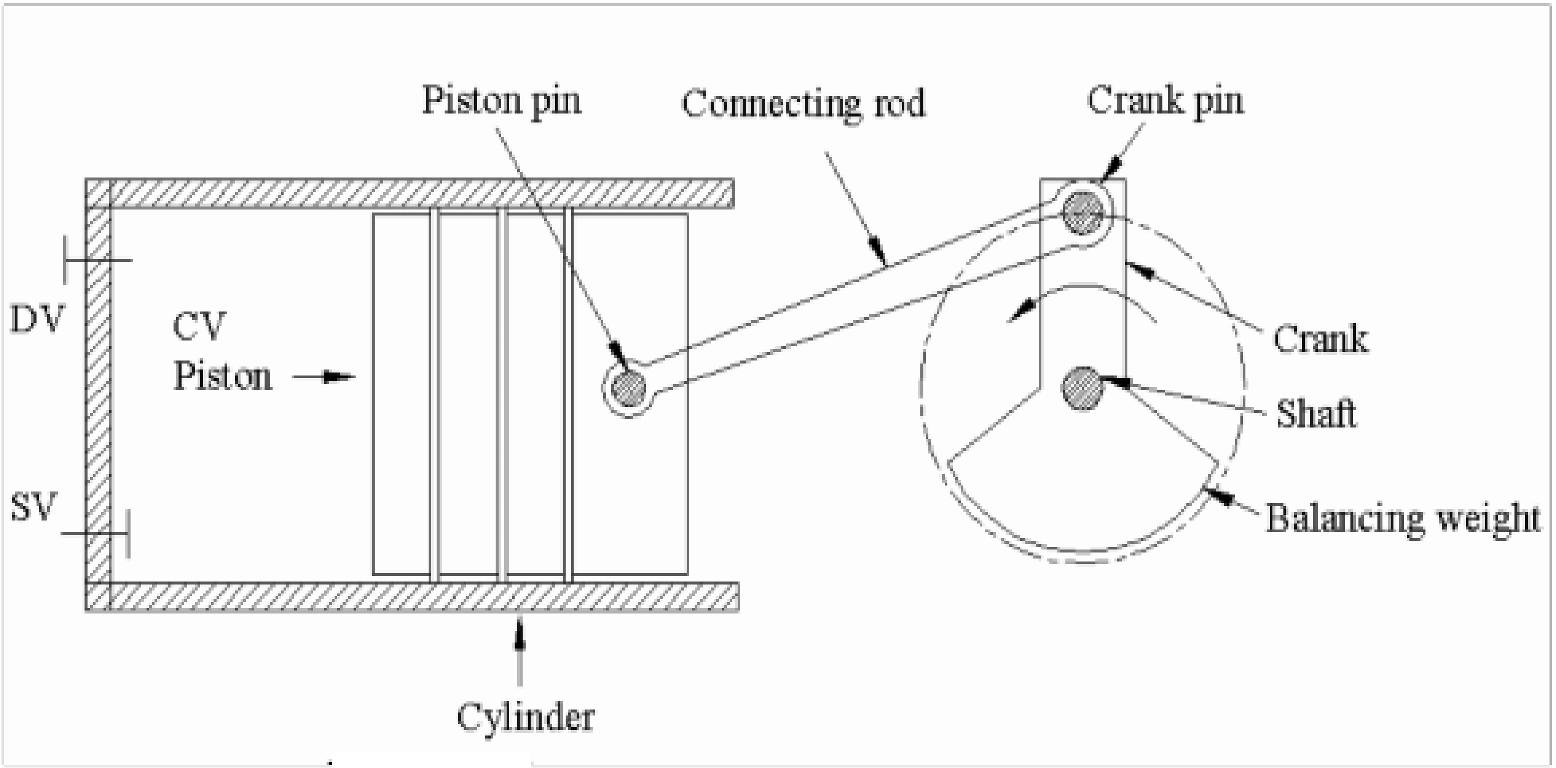
b) **Based on arrangement of compressor motor or external drive:**

i. Open type

ii. Hermetic (or sealed) type

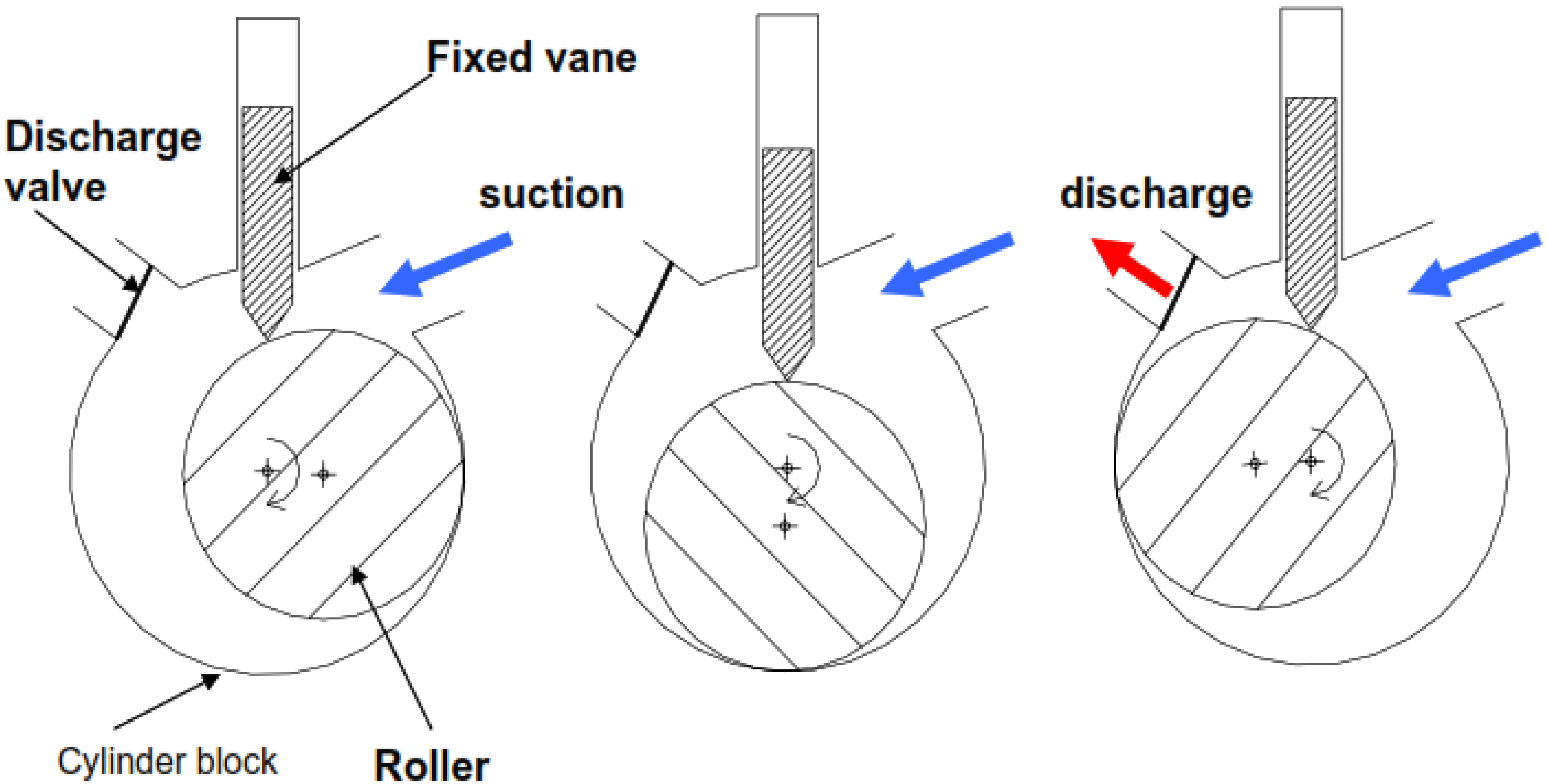
iii. Semi-hermetic (or semi-sealed) type

RECIPROCATING COMPRESSOR



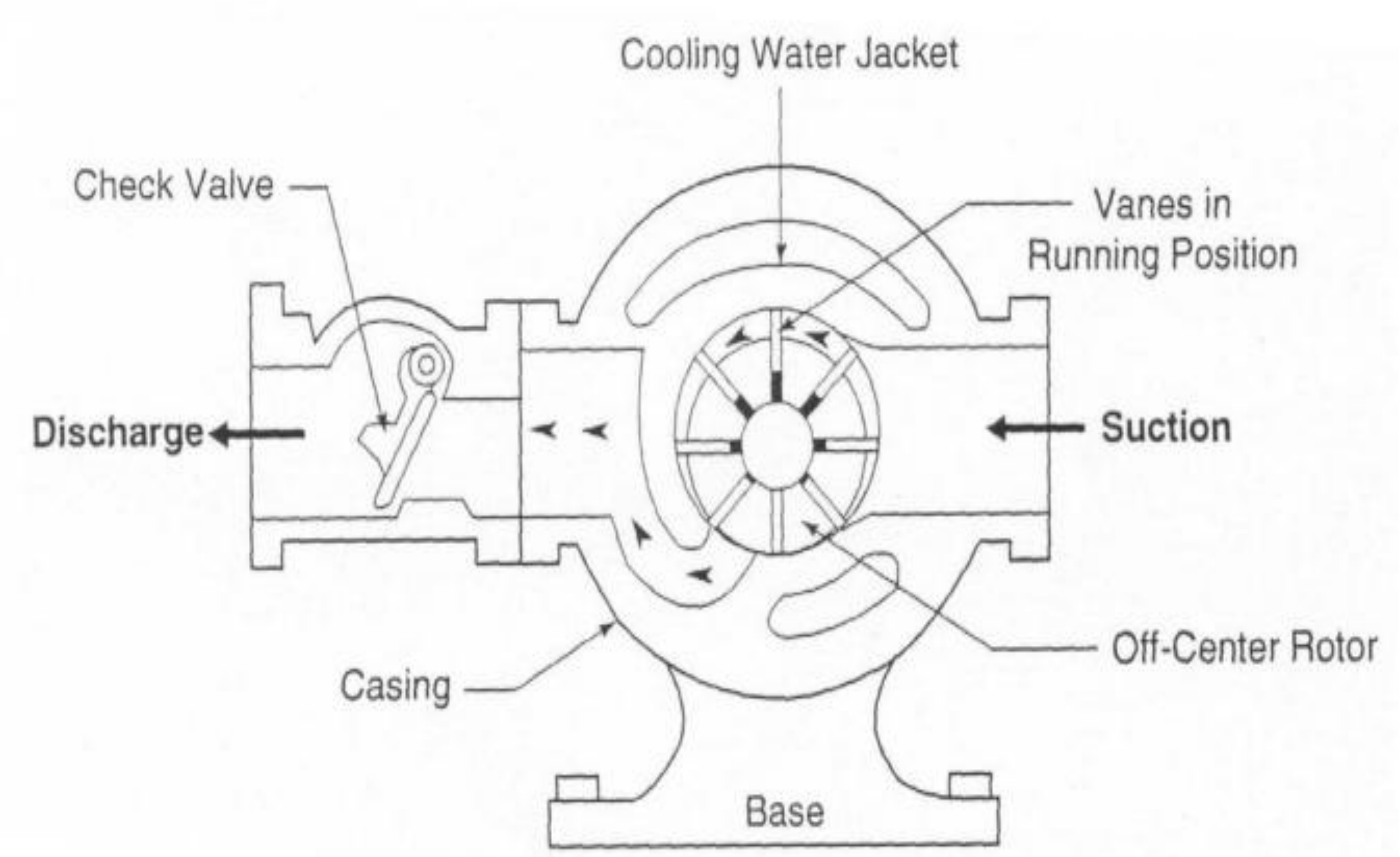
Schematic of a reciprocating compressor

ROLLING PISTON TYPE COMPRESSOR



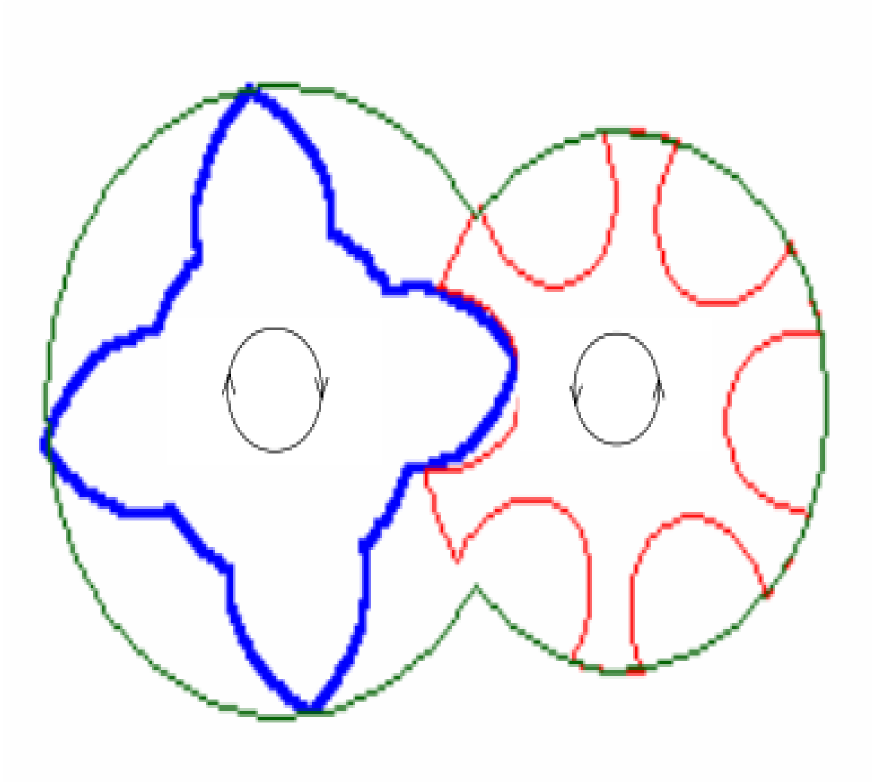
Working principle of a rolling piston type compressor

MULTIPLE VANE,ROTARY COMPRSSOR

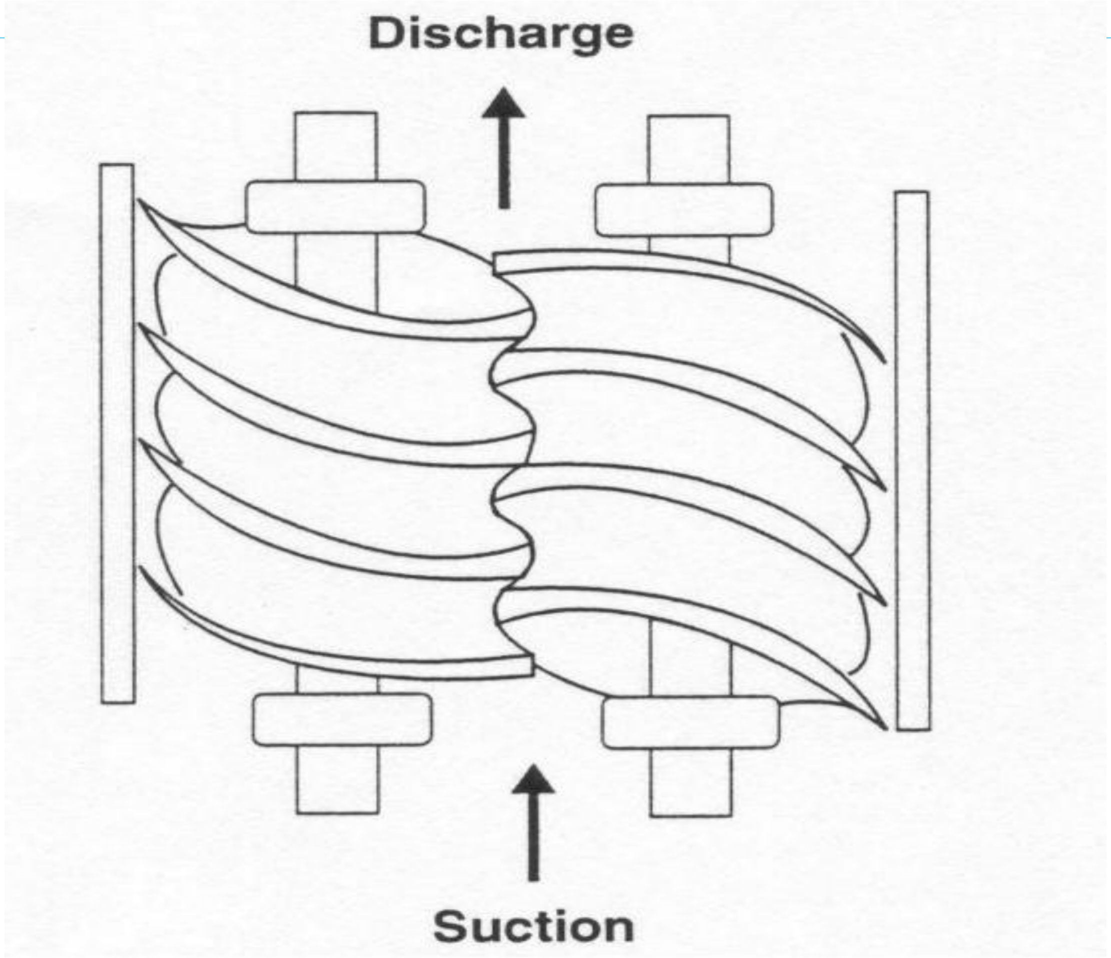


Sectional view of a multiple vane, rotary compressor

TWIN SCREW COMPRESSOR

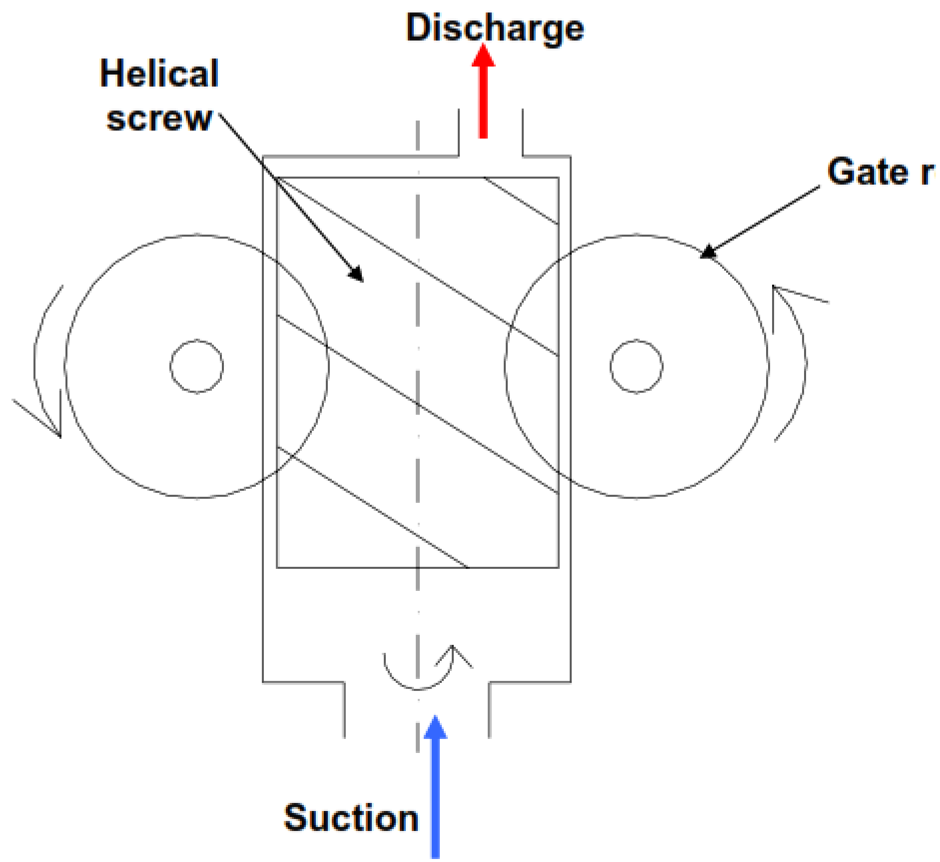


Twin-screw compressor with 4 male lobes and 6 female gullies

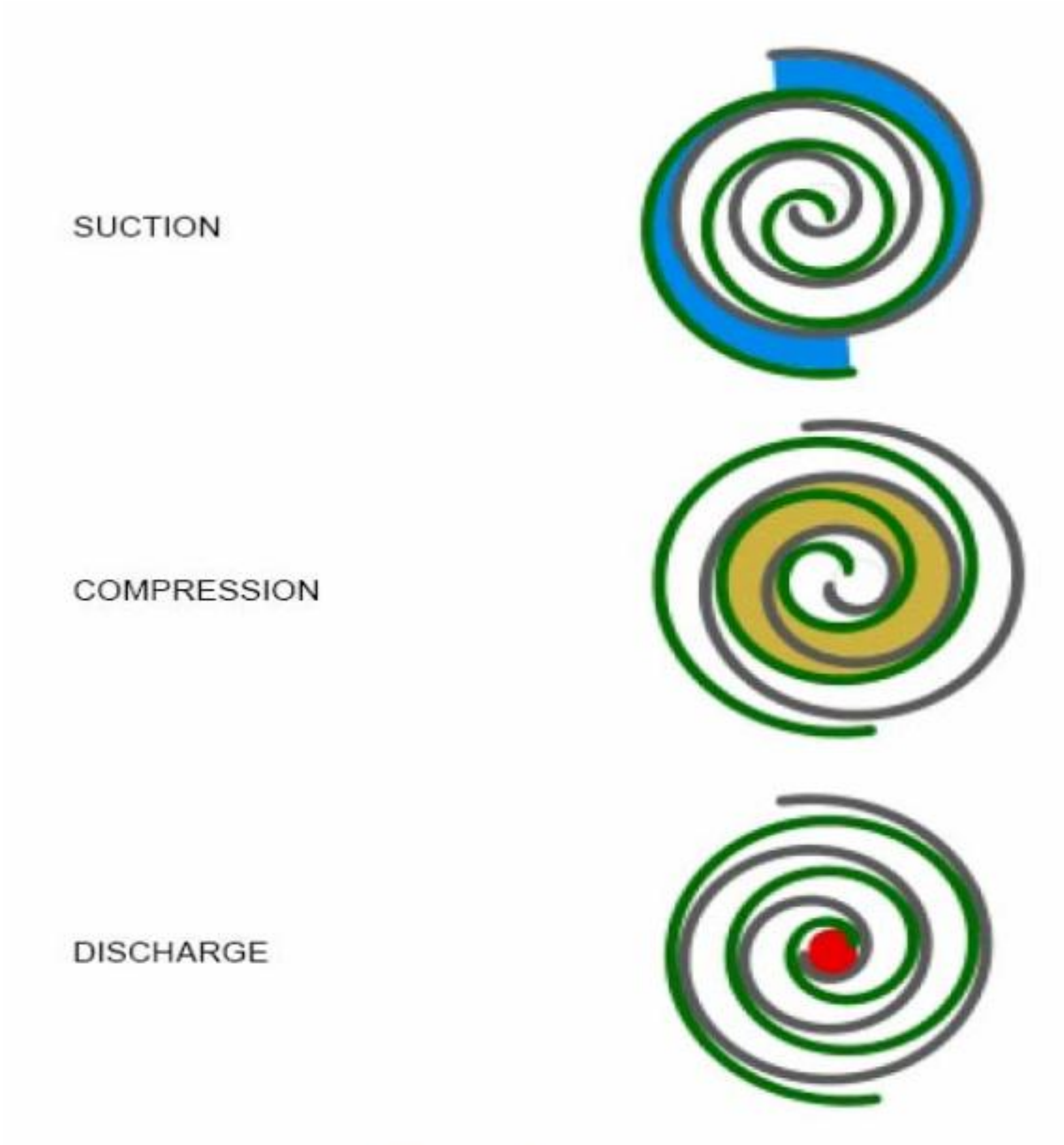


Direction of refrigerant flow in a twin-screw compressor

SINGLE SCREW COMPRESSOR

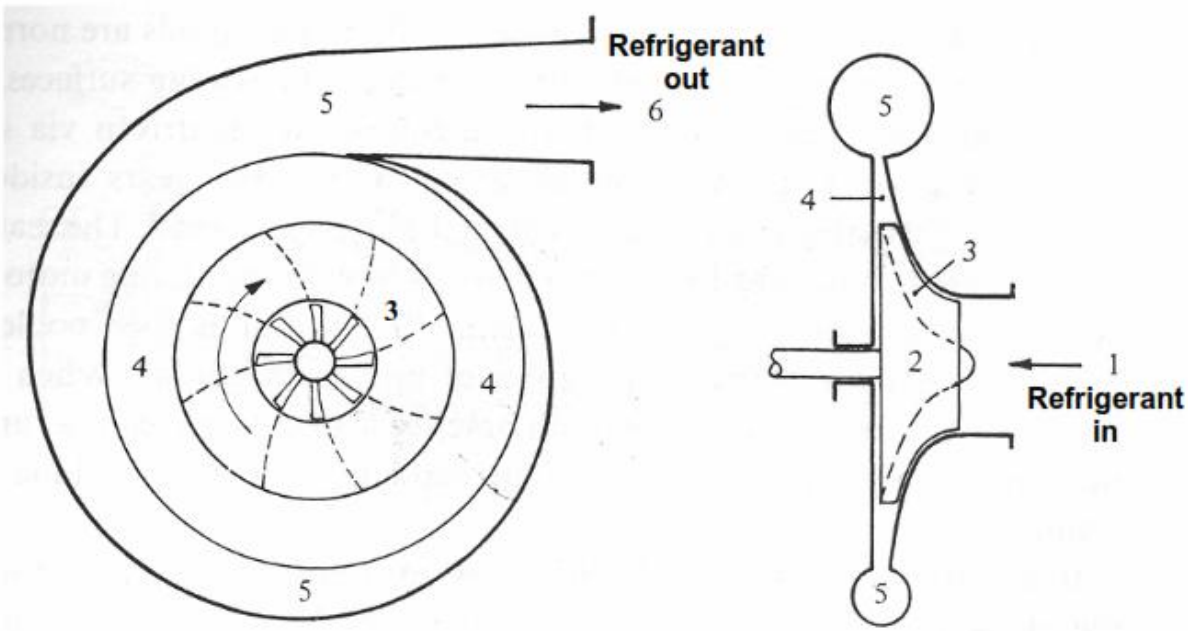


Working principle of a single-screw compressor



Working principle of a scroll compressor

CENTRIFUGAL COMPRESSOR



Centrifugal Compressor
1: Refrigerant inlet (eye); 2: Impeller; 3: Refrigerant passages
4: Vaneless diffuser; 5: Volute casing; 6: Refrigerant discharge

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LECTURE 4

FUNCTIONS & TYPES OF CONDENSORS

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TOPICS TO BE COVERED

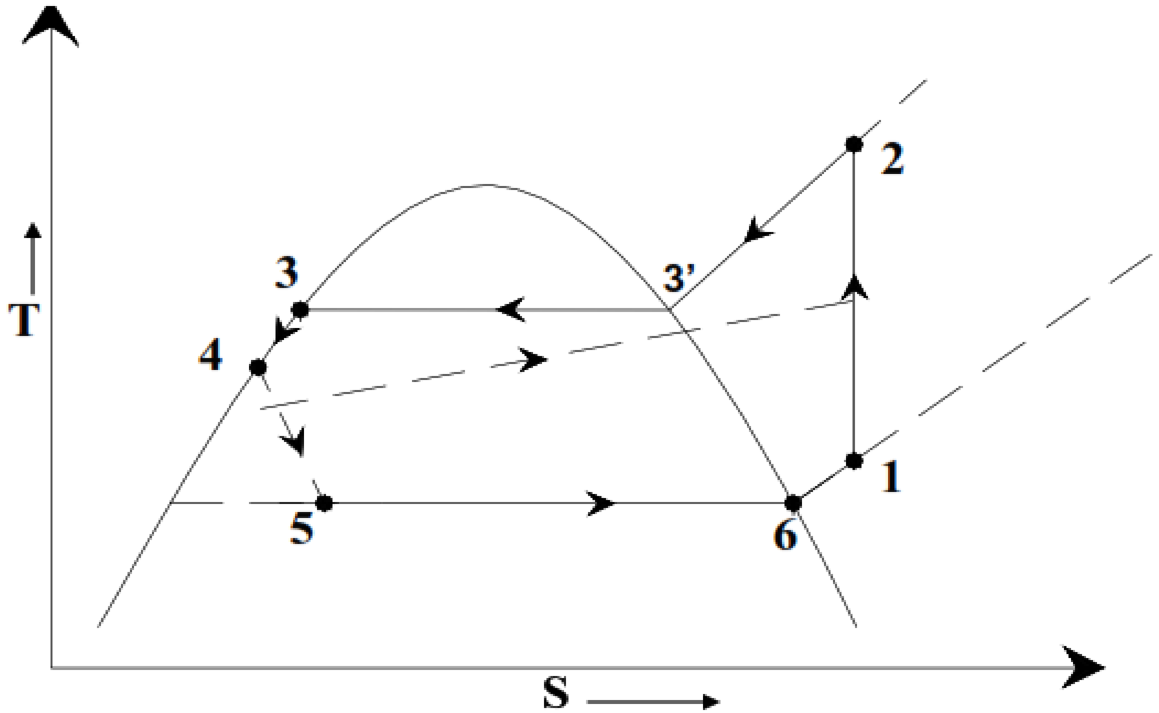
1. INTRODUCTION
2. CLASSIFICATION OF CONDENSORS
3. FUNCTIONS

LECTURE 4

FUNCTIONS AND TYPES OF CONDENSORS

CONDENSORS

- Condensers and evaporators are basically heat exchangers in which the refrigerant undergoes a phase change.
- In condensers the refrigerant vapour condenses by rejecting heat to an external fluid, which acts as a heat sink.
- Normally, the external fluid does not undergo any phase change, except in some special cases such as in cascade condensers, where the external fluid (another refrigerant) evaporates.
- . In a typical refrigerant condenser, the refrigerant enters the condenser in a superheated state.
- It is first de-superheated and then condensed by rejecting heat to an external medium. The refrigerant may leave the condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and design of the condenser.



Refrigeration cycle on T-s diagram

CLASSIFICATION OF CONDENSERS

- Based on the external fluid, condensers can be classified as:

a) Air cooled condensers

b) Water cooled condensers, and

c) Evaporative condensers

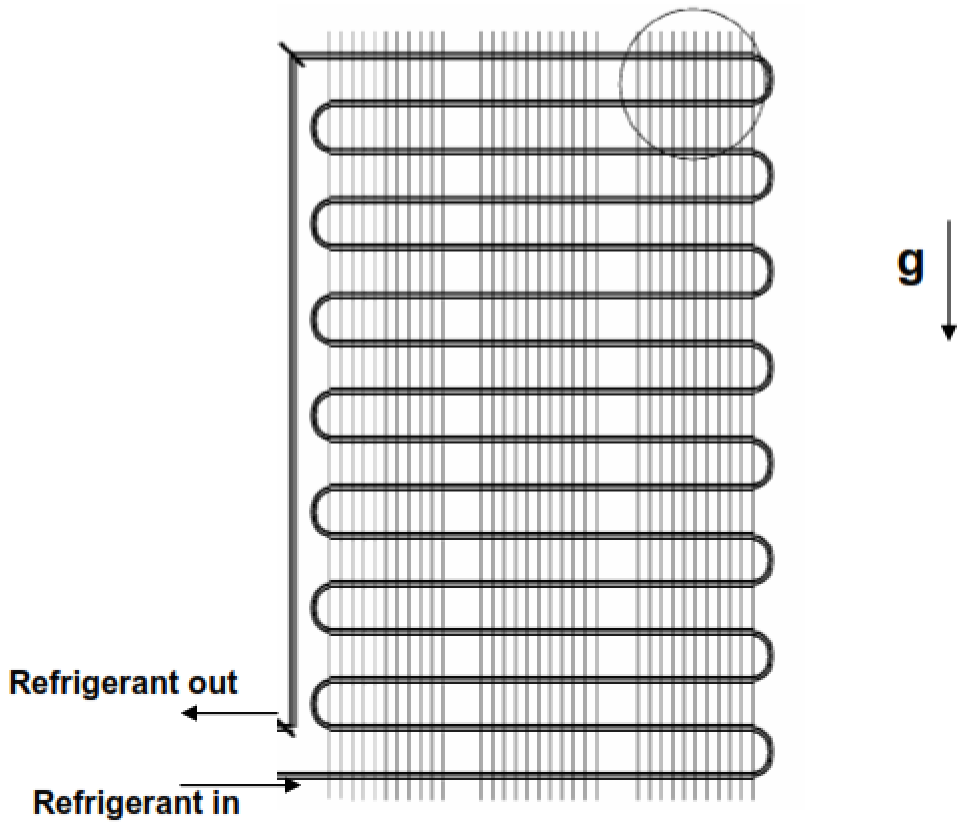
Air-cooled condensers can be further classified into

natural convection type or forced convection type.

- Depending upon the construction, water cooled condensers can be further classified into:

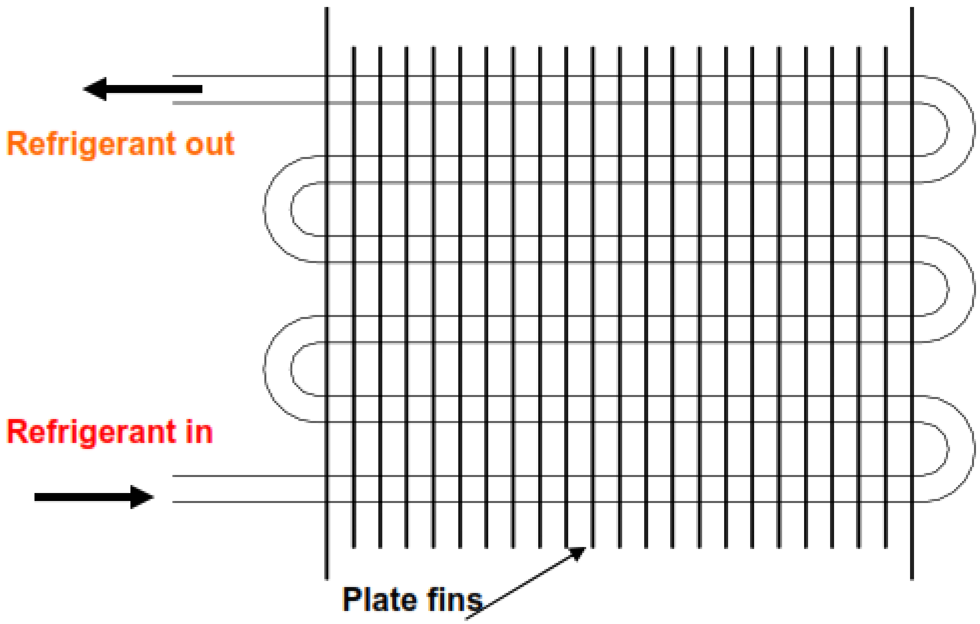
1. Double pipe or tube-in-tube type
2. Shell-and-coil type
3. Shell-and-tube type

NATURE CONVECTION TYPE



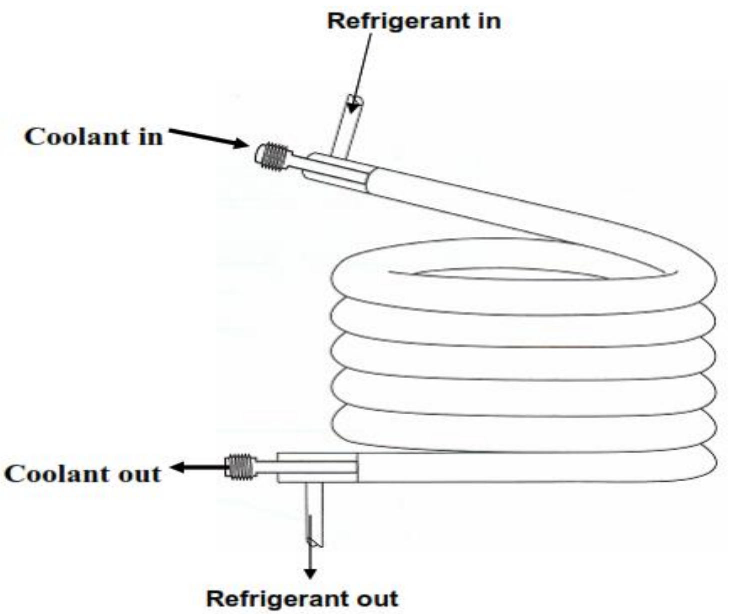
Schematic of a wire-and-tube type condenser used in small refrigeration systems

FORCED CONVECTION TYPE:



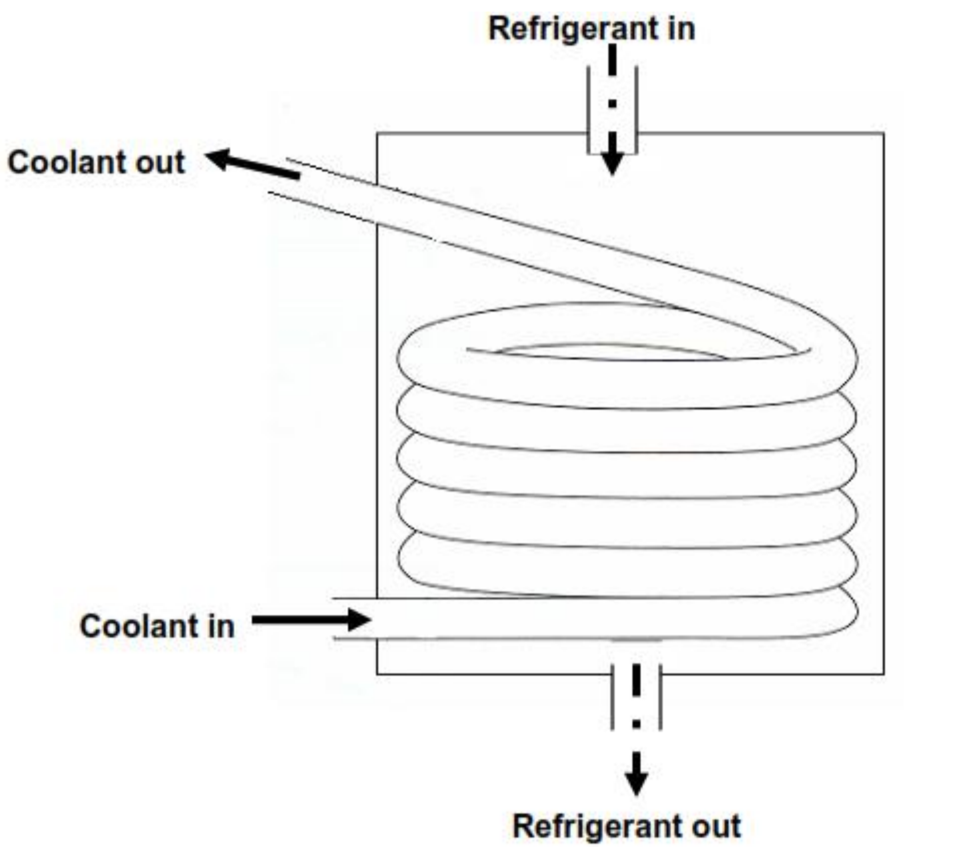
Forced convection, plate fin-and-tube type condenser

DOUBLE PIPE OR TUBE-IN-TUBE TYPE:



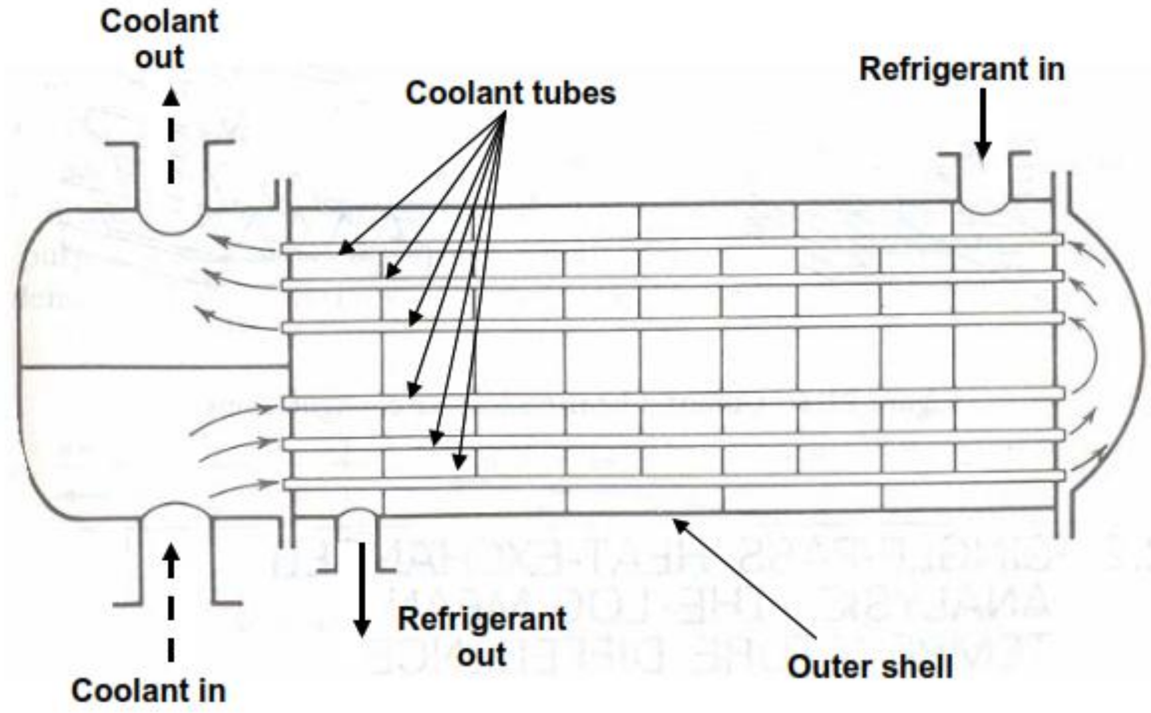
Double pipe (tube-in-tube) type condenser

SHELL-AND-COIL TYPE



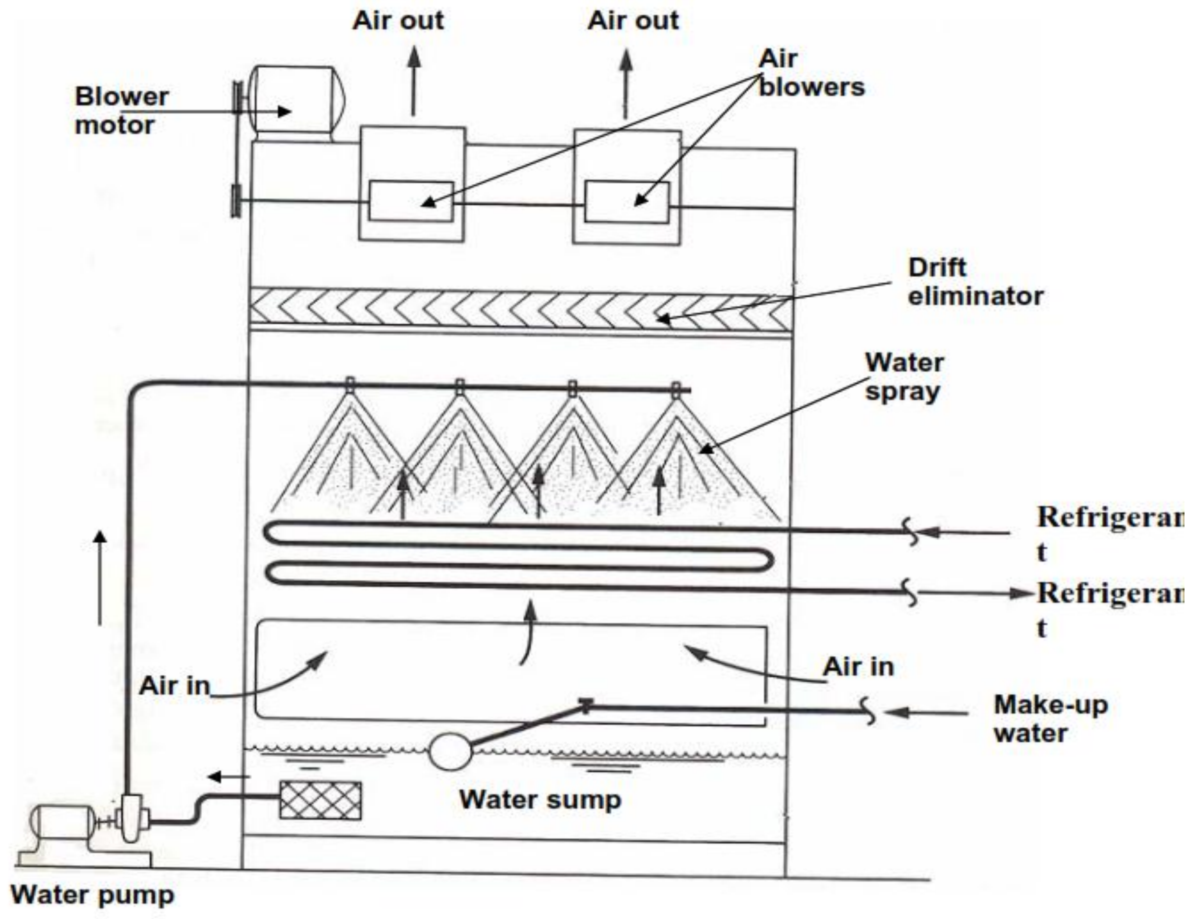
Shell-and-coil type condenser

SHELL-AND-TUBE TYPE



A two-pass, shell-and-tube type condenser

EVAPORATIVE TYPE



Schematic of an evaporative condenser

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LECTURE 5

FUNCTIONS & TYPES OF EVAPORATORS

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TOPICS TO BE COVERED

1. INTRODUCTION
2. CLASSIFICATION OF EVAPORATORS
3. FUNCTIONS

LECTURE 5

FUNCTIONS AND TYPES OF EVAPORATORS

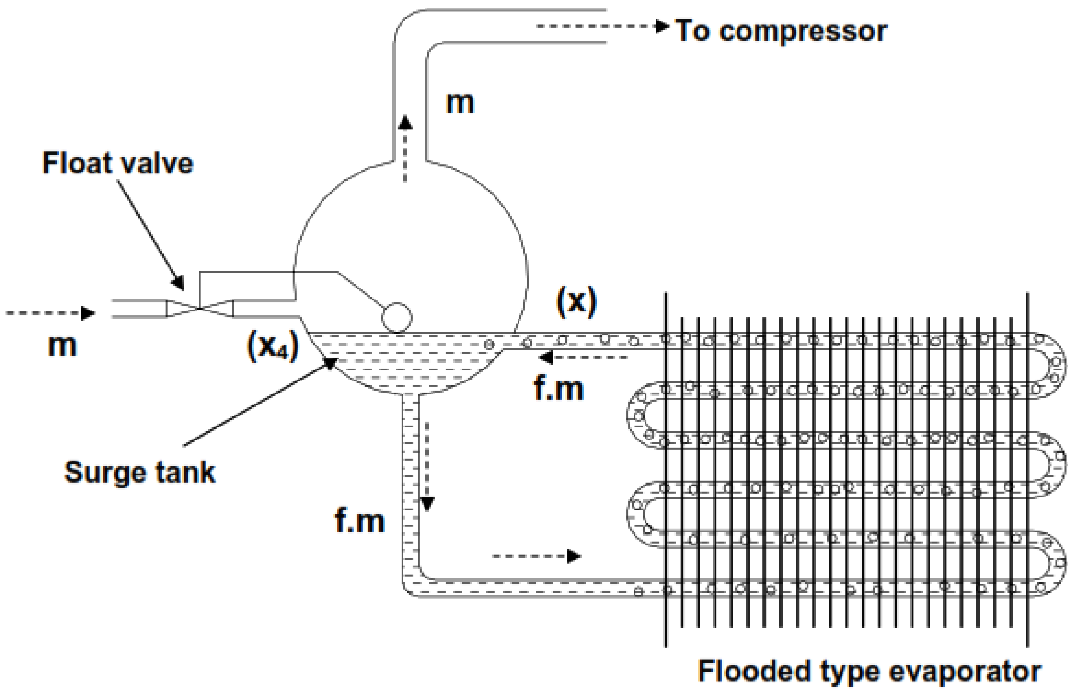
EVAPORATOR

- An evaporator, like condenser is also a heat exchanger. In an evaporator, the refrigerant boils or evaporates and in doing so absorbs heat from the substance being refrigerated. The name evaporator refers to the evaporation process occurring in the heat exchanger.

CLASSIICATION OF EVAPORATOR

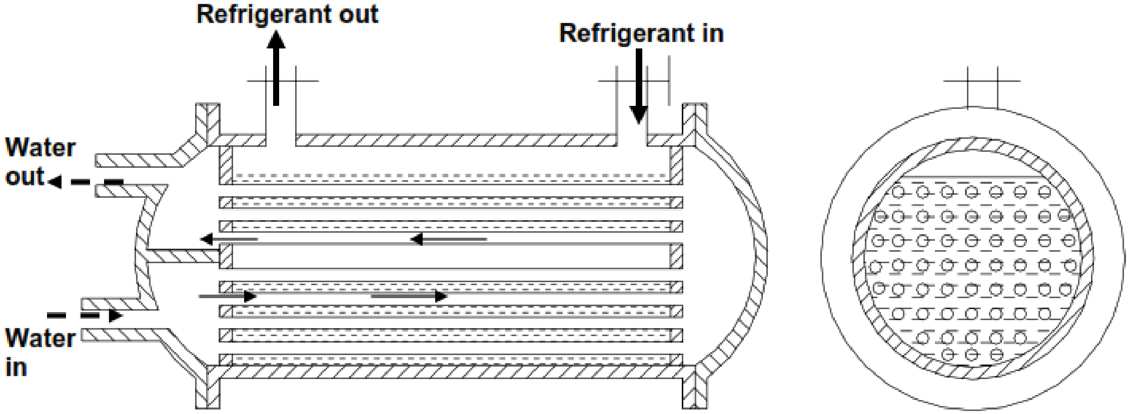
- There are several ways of classifying the evaporators depending upon the heat transfer process or refrigerant flow or condition of heat transfer surface.
- **Natural and Forced Convection Type**
- **Refrigerant Flow Inside or Outside Tubes**
- **Flooded and Dry Type**
- **Natural Convection type evaporator coils**

FLOODED EVAPORATOR



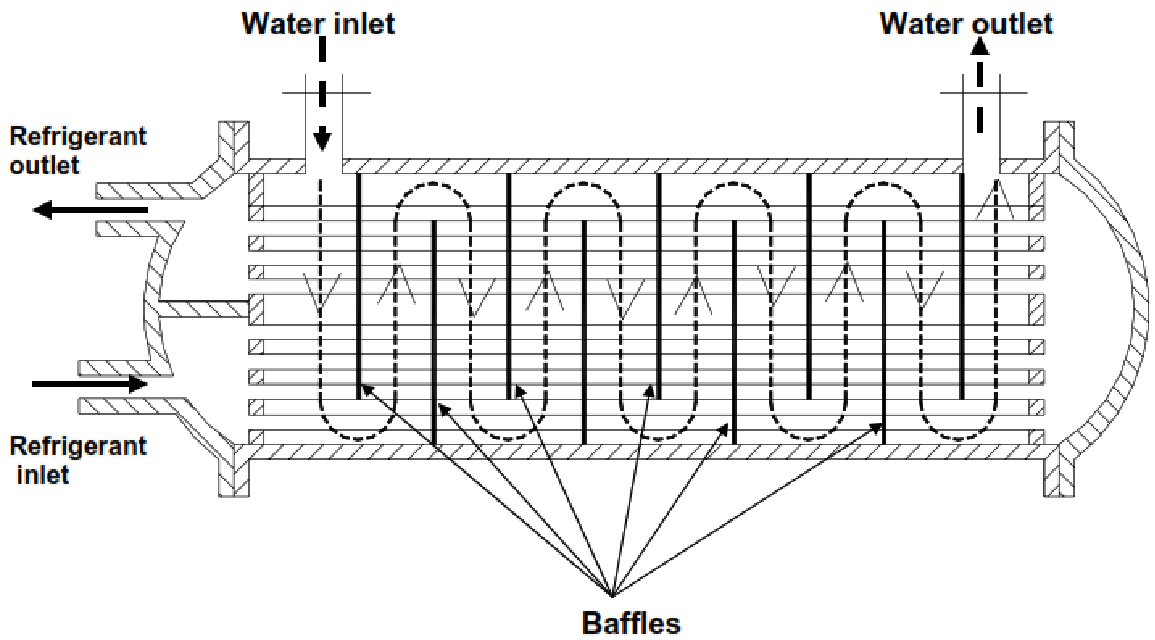
Schematic of a flooded evaporator

FLOODED TYPE SHELL AND TUBE EVAPORATOR



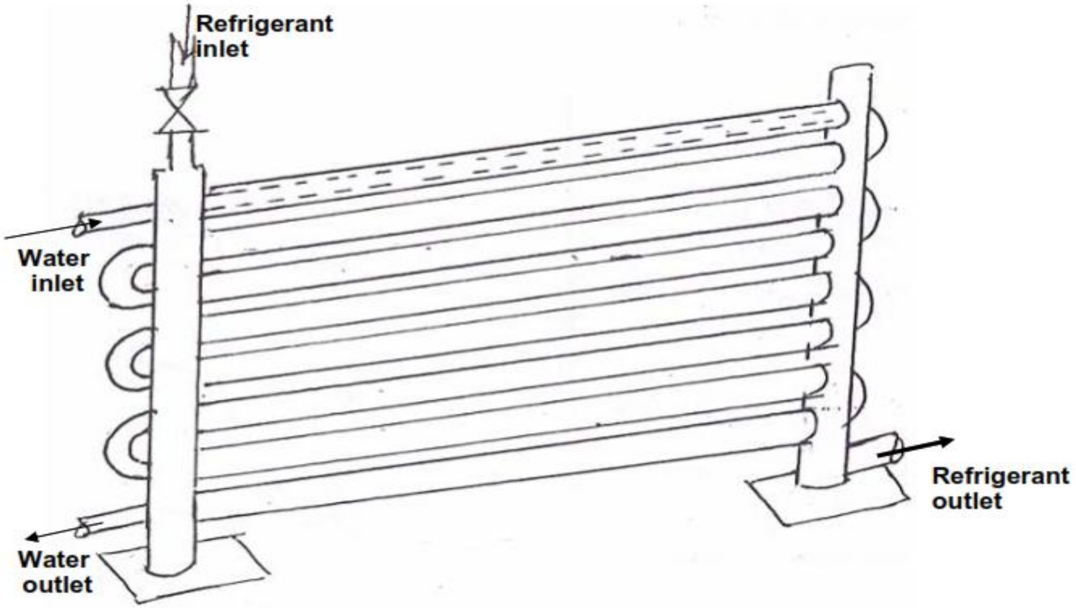
Schematic of a flooded type shell-and-tube evaporator

SHELL AND TUBE EVAPORATOR



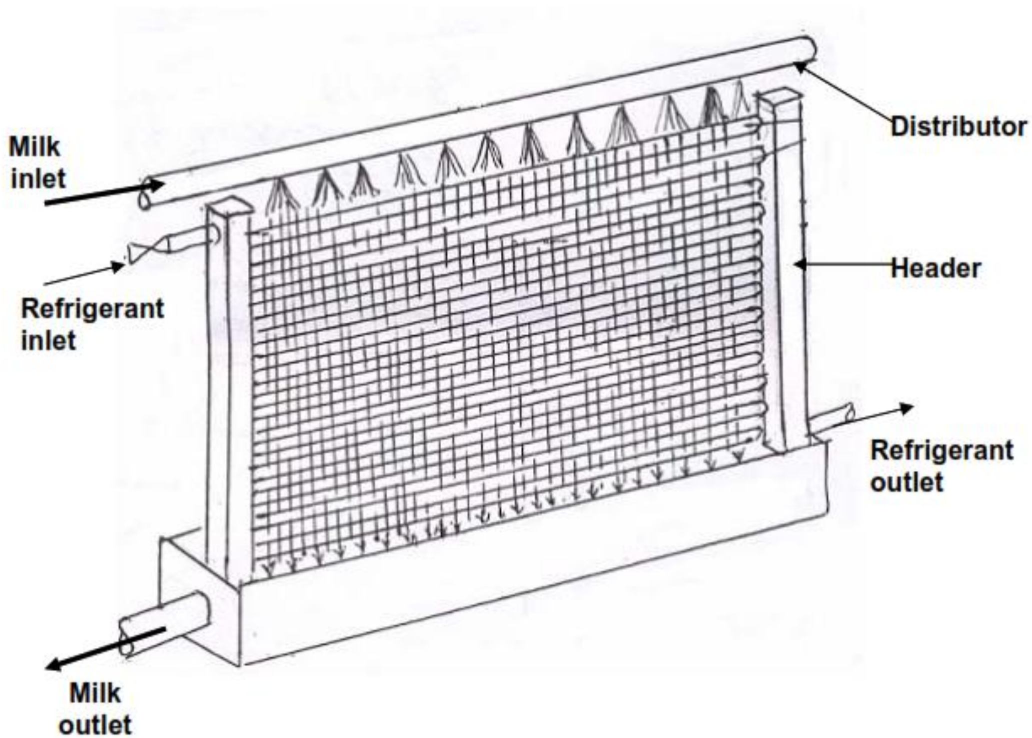
Schematic of a direct expansion type, Shell-and-Tube evaporator

DOUBLE PIPE TYPE EVAPORATOR



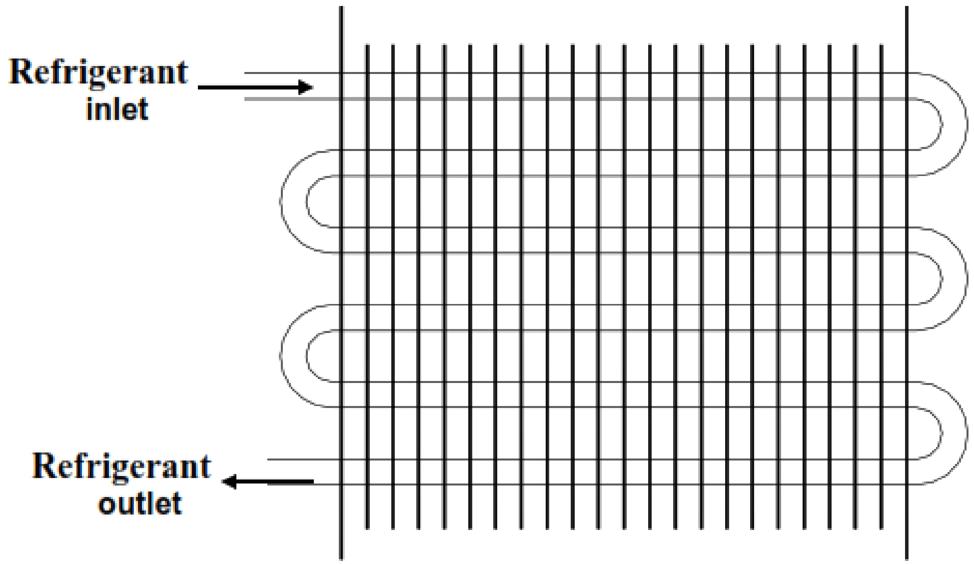
Schematic of a double pipe type evaporator

BAUDELOT TYPE EVAPORATOR FOR CHILLING OF MILK



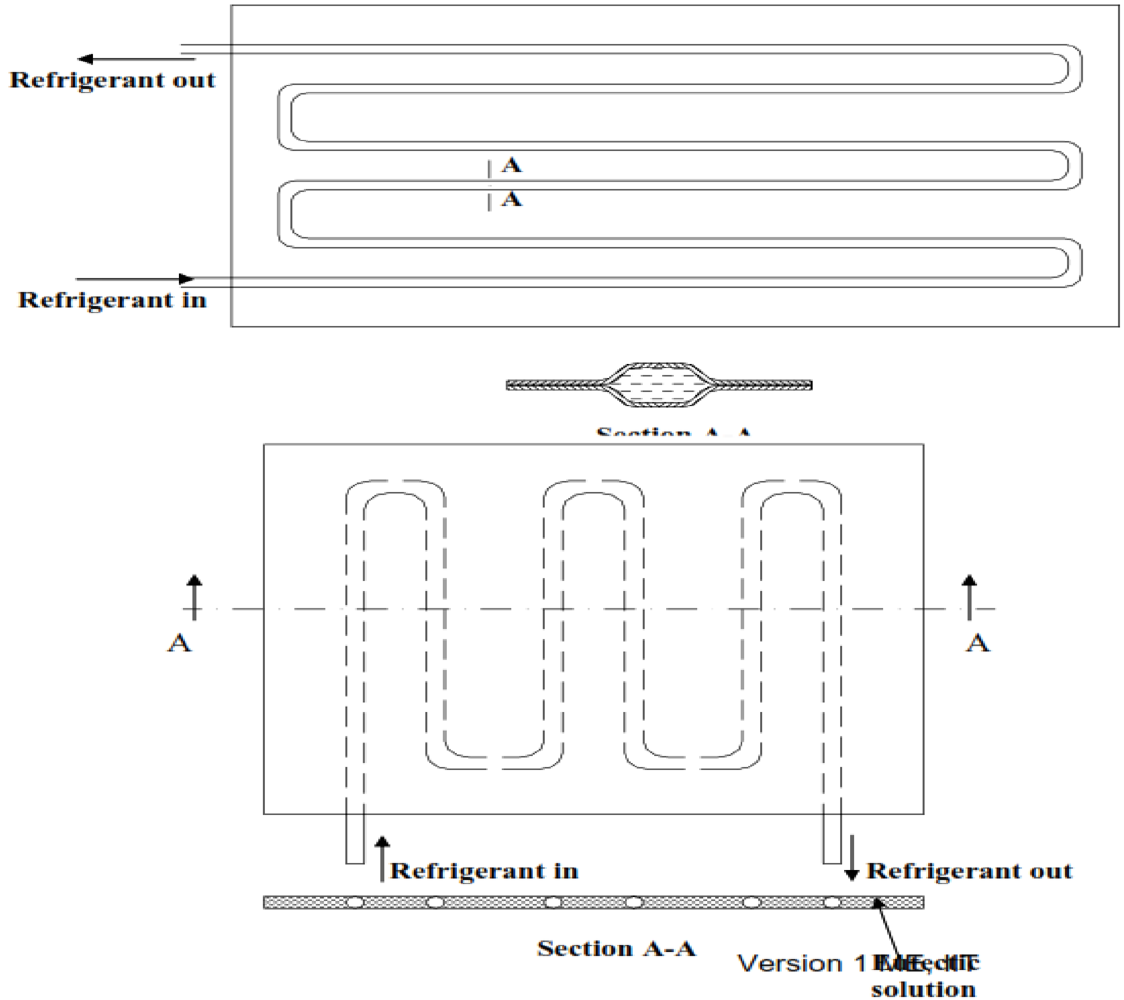
Schematic of a Baudelot type evaporator for chilling of milk

DIRECT EXPANSION FIN AND TUBE TYPE



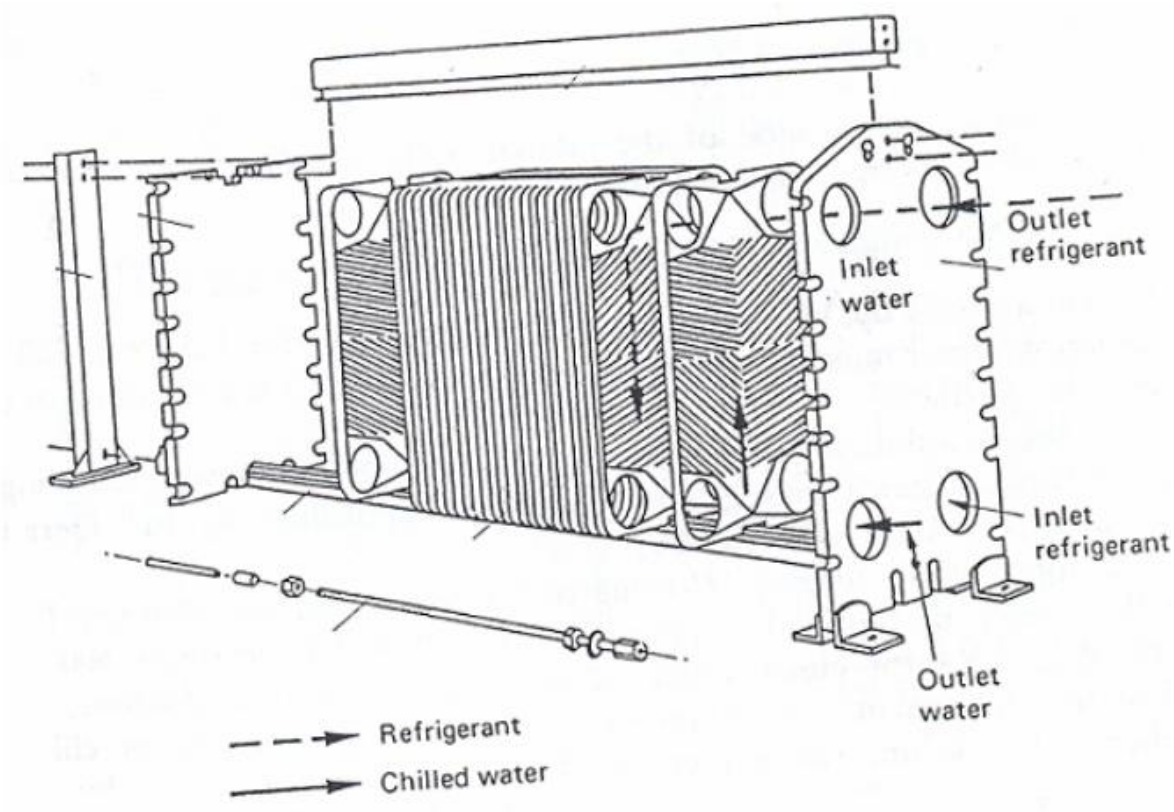
Schematic of a direct expansion fin-and-tube type

PLATE SURFACE EVAPORATOR



chematic of an embedded tube, plate surface evaporator

PLATE TYPE EVAPORATOR



Schematic of a plate type evaporator

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LECTURE 6

FUNCTIONS & TYPES OF EXPANSION DEVICES

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TOPICS TO BE COVERED

1. INTRODUCTION
2. CLASSIFICATION OF EXPANSION DEVICES
3. FUNCTIONS

LECTURE 6

FUNCTIONS AND TYPES OF EXPANSION DEVICES

DEPARTMENT OF MECHANICAL ENGINEERING

EXPANSION DEVICES

- An expansion device is another basic component of a refrigeration system. The basic functions of an expansion device used in refrigeration systems are to:
    1. Reduce pressure from condenser pressure to evaporator pressure, and
    2. Regulate the refrigerant flow from the high-pressure liquid line into the evaporator at a rate equal to the evaporation rate in the evaporator.
- Under ideal conditions, the mass flow rate of refrigerant in the system should be proportional to the cooling load. Sometimes, the product to be cooled is such that a constant evaporator temperature has to be maintained.

CLASSIFICATION OF EXPANSION DEVICES

The expansion devices used in refrigeration systems can be divided into fixed opening type or variable opening type.

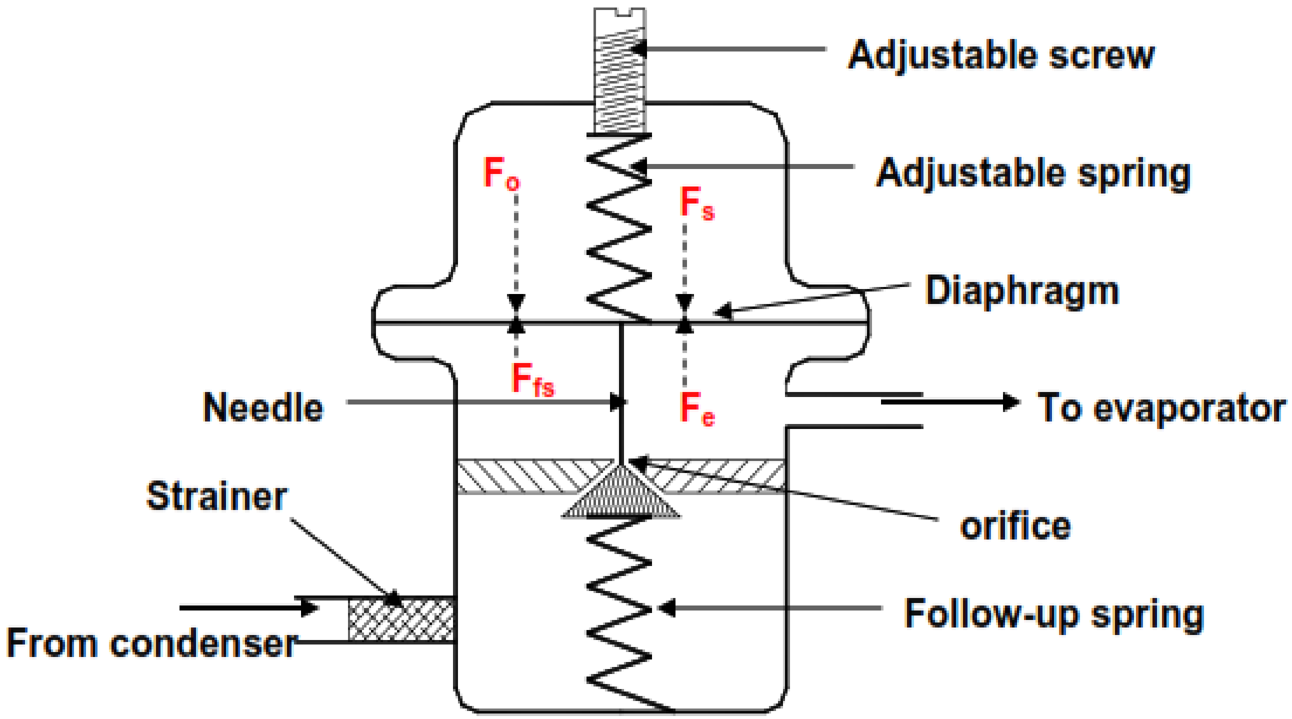
There are basically seven types of refrigerant expansion devices. These are:

1. Hand (manual) expansion valves
2. Capillary Tubes
3. Orifice
4. Constant pressure or Automatic Expansion Valve (AEV)
5. Thermostatic Expansion Valve (TEV)
6. Float type Expansion Valve
   - High Side Float Valve
   - Low Side Float Valve
7. Electronic Expansion Valve

. CAPILLARY TUBES

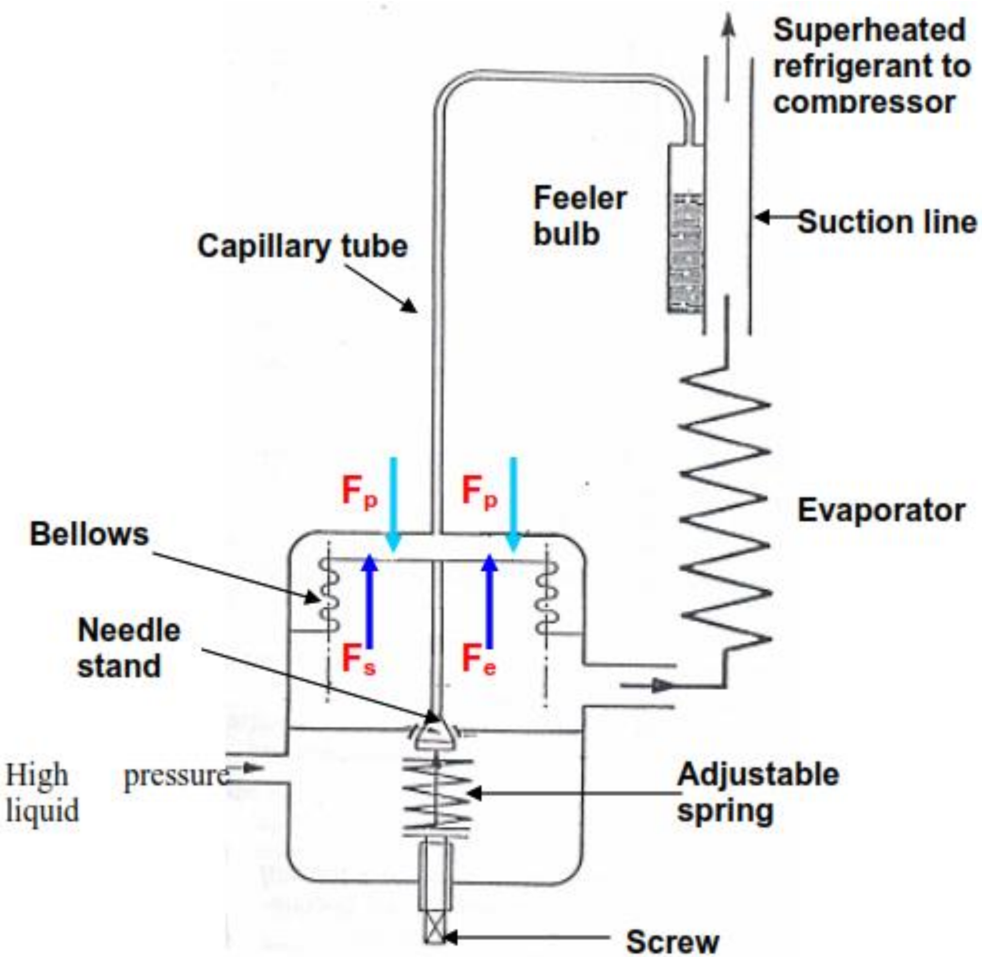
- A capillary tube is a long, narrow tube of constant diameter. The word “capillary” is a misnomer since surface tension is not important in refrigeration application of capillary tubes. Typical tube diameters of refrigerant capillary tubes range from 0.5 mm to 3 mm and the length ranges from 1.0 m to 6 m. The pressure reduction in a capillary tube occurs due to the following two factors:
- The refrigerant has to overcome the frictional resistance offered by tube walls. This leads to some pressure drop, and
- The liquid refrigerant flashes (evaporates) into mixture of liquid and vapour as its pressure reduces. The density of vapour is less than that of the liquid. Hence, the average density of refrigerant decreases as it flows in the tube. The mass flow rate and tube diameter (hence area) being constant, the velocity of refrigerant increases since $m = \rho VA$. The increase in velocity or acceleration of the refrigerant also requires pressure drop.

AUTOMATIC EXPANSION VALVE (AEV)



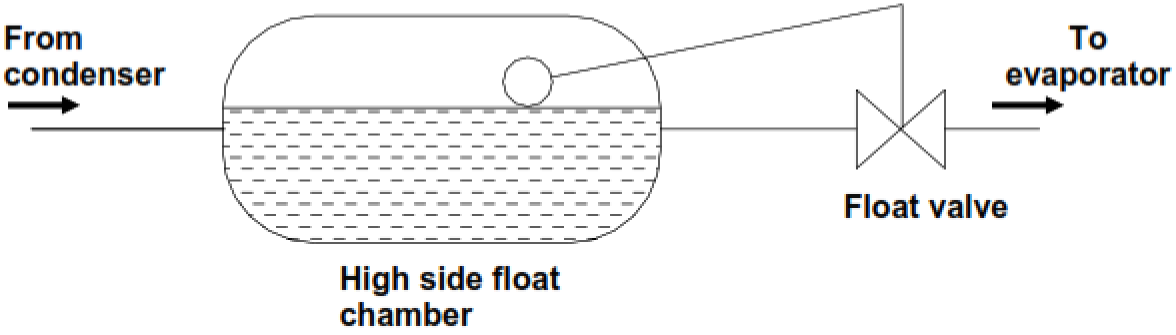
Schematic of an Automatic Expansion Valve

THERMOSTATIC EXPANSION VALVE (TEV)



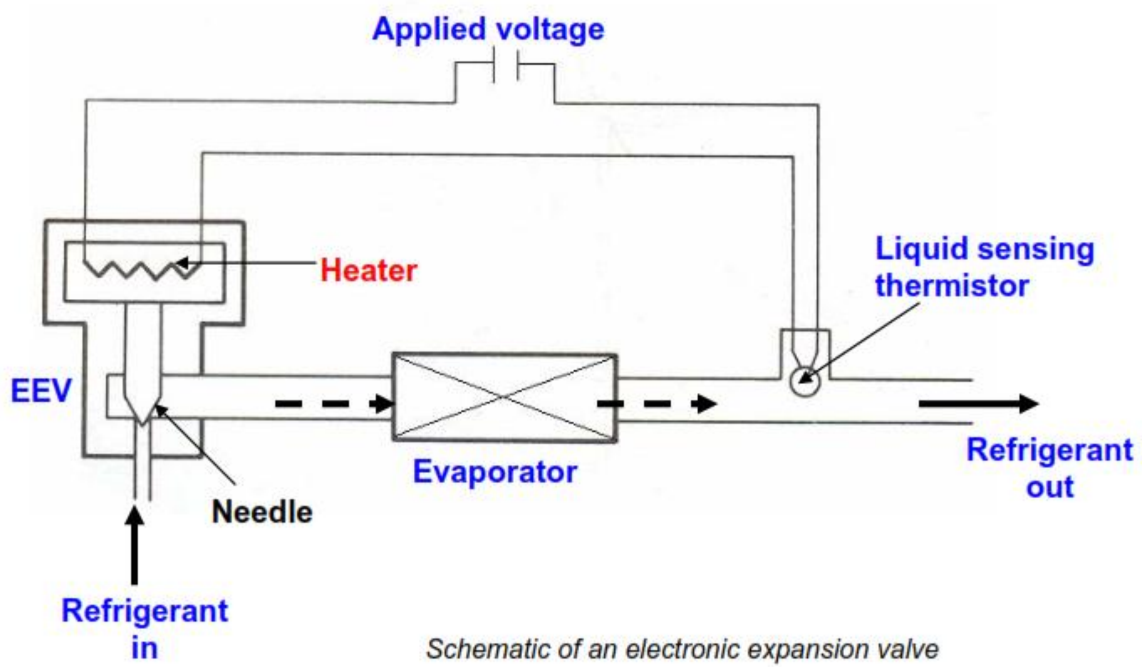
Schematic of a Thermostatic Expansion Valve (TEV)

HIGH SIDE FLOAT VALVE



Schematic of a high-side float valve

ELECTRONIC VALUE



Schematic of an electronic expansion valve

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LECTURE 7

REFRIGERANTS

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TOPICS TO BE COVERED

1. INTRODUCTION
2. CLASSIFICATION OF REFRIGERANTS
3. APPLICATIONS

LECTURE 7

REFRIGERANTS

REFRIGERANTS

- The thermodynamic efficiency of a refrigeration system depends mainly on its operating temperatures. However, important practical issues such as the system design, size, initial and operating costs, safety, reliability, and serviceability etc. depend very much on the type of refrigerant selected for a given application
- Fluids suitable for refrigeration purposes can be classified into primary and secondary refrigerants. Primary refrigerants are those fluids, which are used directly as working fluids, for example in vapour compression and vapour absorption refrigeration systems.
- secondary refrigerants are those liquids, which are used for transporting thermal energy from one location to other. Secondary refrigerants are also known under the name brines or antifreezes.

REFRIGERANT SELECTION CRITERIA

Selection of refrigerant for a particular application is based on the following requirements:

i. Thermodynamic and thermo-physical properties

ii.Environmental and safety properties, and

iii. Economics.

THERMODYNAMIC AND THERMO-PHYSICAL PROPERTIES:

The requirements are:

a) Suction pressure: At a given evaporator temperature, the saturation pressure should be above atmospheric for prevention of air or moisture ingress into the system and ease of leak detection. Higher suction pressure is better as it leads to smaller compressor displacement

b) Discharge pressure: At a given condenser temperature, the discharge pressure should be as small as possible to allow light-weight construction of compressor, condenser etc.

c) Pressure ratio: Should be as small as possible for high volumetric efficiency and low power consumption

d) Latent heat of vaporization: Should be as large as possible so that the required mass flow rate per unit cooling capacity will be small

In addition to the above properties; the following properties are also important:

e) Isentropic index of compression: Should be as small as possible so that the temperature rise during compression will be small

f) Liquid specific heat: Should be small so that degree of subcooling will be large leading to smaller amount of flash gas at evaporator inlet

g) Vapour specific heat: Should be large so that the degree of superheating will be small

h) Thermal conductivity: Thermal conductivity in both liquid as well as vapour phase should be high for higher heat transfer coefficients

i) Viscosity: Viscosity should be small in both liquid and vapour phases for smaller frictional pressure drops

ENVIRONMENTAL AND SAFETY PROPERTIES:

a) Ozone Depletion Potential (ODP)
b) Global Warming Potential (GWP)
c) Total Equivalent Warming Index (TEWI)
d) Toxicity
e) Flammability
f) Chemical stability
g) Compatibility with common materials of construction
h) Miscibility with lubricating oils

Economic properties:

- The refrigerant used should preferably be inexpensive and easily available.

CLASSIFICATION OF REFRIGERANTS

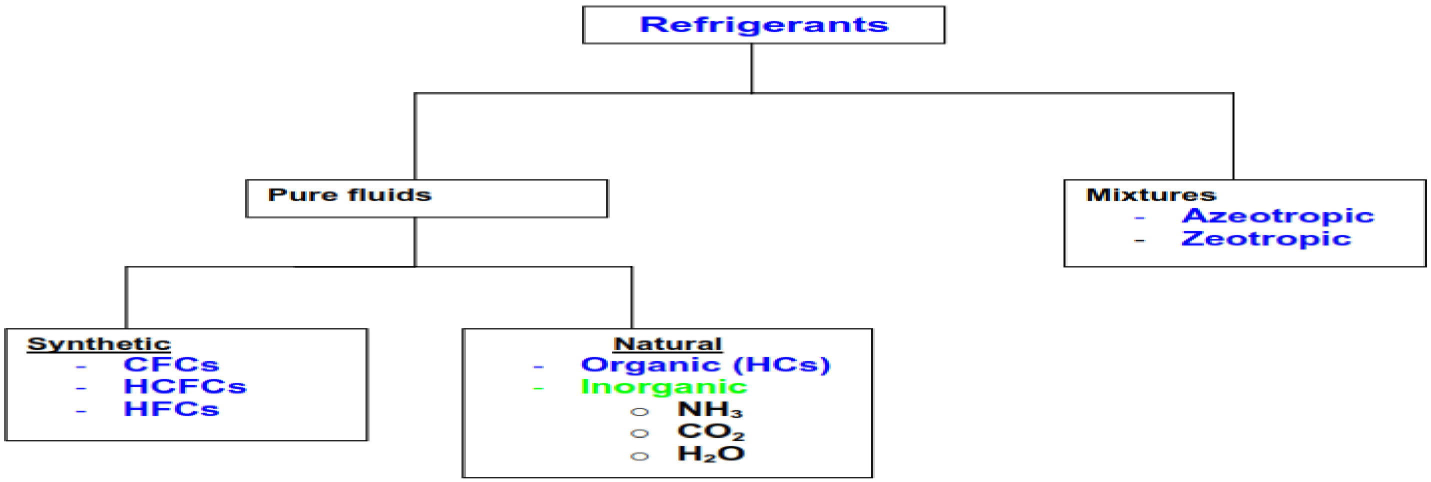

***Fig.26.1**: Classification of fluids used as refrigerants*

iii) Mixtures: Azeotropic mixtures are designated by 500 series, where as zeotropic refrigerants (e.g. non-azeotropic mixtures) are designated by 400 series.

Azeotropic mixtures:

R 500: Mixture of R 12 (73.8 %) and R 152a (26.2%)
R 502: Mixture of R 22 (48.8 %) and R 115 (51.2%)
R503: Mixture of R 23 (40.1 %) and R 13 (59.9%)
R507A: Mixture of R 125 (50%) and R 143a (50%)

Zeotropic mixtures:

R404A : Mixture of R 125 (44%), R 143a (52%) and R 134a (4%)
R407A : Mixture of R 32 (20%), R 125 (40%) and R 134a (40%)
R407B : Mixture of R 32 (10%), R 125 (70%) and R 134a (20%)
R410A : Mixture of R 32 (50%) and R 125 (50%)

APPLICATIONS

Refrigerant	Application	Substitute suggested Retrofit(R)/New (N)
R 11(CFC) NBP = 23.7°C h_{fg} at NBP=182.5 kJ/kg T_{cr} =197.98°C Cp/Cv = 1.13 ODP = 1.0 GWP = 3500	Large air conditioning systems Industrial heat pumps As foam blowing agent	R 123 (R,N) R 141b (N) R 245fa (N) n-pentane (R,N)
R 12 (CFC) NBP = -29.8°C h_{fg} at NBP=165.8 kJ/kg T_{cr} =112.04°C Cp/Cv = 1.126 ODP = 1.0 GWP = 7300	Domestic refrigerators Small air conditioners Water coolers Small cold storages	R 22 (R,N) R 134a (R,N) R 227ea (N) R 401A,R 401B (R,N) R 411A,R 411B (R,N) R 717 (N)
R 22 (HCFC) NBP = -40.8°C h_{fg} at NBP=233.2 kJ/kg T_{cr} =96.02°C Cp/Cv = 1.166 ODP = 0.05 GWP = 1500	Air conditioning systems Cold storages	R 410A, R 410B (N) R 417A (R,N) R 407C (R,N) R 507,R 507A (R,N) R 404A (R,N) R 717 (N)
R 134a (HFC) NBP = -26.15°C h_{fg} at NBP=222.5 kJ/kg T_{cr} =101.06°C Cp/Cv = 1.102 ODP = 0.0 GWP = 1200	Used as replacement for R 12 in domestic refrigerators, water coolers, automobile A/Cs etc	**No replacement required** * Immiscible in mineral oils * Highly hygroscopic
R 717 (NH_3) NBP = -33.35°C h_{fg} at NBP=1368.9 kJ/kg T_{cr} =133.0°C Cp/Cv = 1.31 ODP = 0.0 GWP = 0.0	Cold storages Ice plants Food processing Frozen food cabinets	**No replacement required** * Toxic and flammable * Incompatible with copper * Highly efficient * Inexpensive and available
R 744 (CO_2) NBP = -78.4°C h_{fg} at 40°C=321.3 kJ/kg T_{cr} =31.1°C Cp/Cv = 1.3 ODP = 0.0 GWP = 1.0	Cold storages Air conditioning systems Simultaneous cooling and heating (Transcritical cycle)	**No replacement required** * Very low critical temperature * Eco-friendly * Inexpensive and available

Refrigerants, their applications and substitutes

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APPLICATIONS

Vapour compression refrigeration cycle finds it place in following applications:

- Domestic refrigerator
- Domestic Air conditioner
- Chiller for cold water around 5 to 6 degree centigrade
- Central air conditioning system
- Cold storage to cool vegetables and fruits
- Ice plant to make ice
- Industry application like process industry
- And many applications where cooling is desired.
- Refrigerated trucks and railroad cars.
- large-scale warehouses for chilled or frozen storage of foods and meats
- Oil refineries, petrochemical and chemical processing plants,
- Natural gas processing plants are among the many types of industrial plants that often utilize large vapor-compression refrigeration systems.
-

ASSINGMENT QUESTIONS

1. List important components of a vapour compression refrigeration system
2. Classify refrigerant compressors based on their working principle and based on the arrangement of compressor motor/external drive?
3. Draw the schematic of a reciprocating compressor and explain its working principle
4. Compare air-cooled condensers with water-cooled condensers
5. Explain the basic functions of expansion devices in refrigeration systems
6. Describe advantages, disadvantages and applications of different types of expansion valves,
7. Classify refrigerant evaporators and discuss the salient features of different types of evaporators
8. List important thermodynamic and environmental properties influencing refrigerant selection?
9. What are the applications of refrigeration?
10. Write the desirable properties of the Refrigerents and Classification of Refrigerants?.
11. Explain with the neat sketch the working of vapour compression refrigeration system?
12. Explain different modes of heat transfer? explain latent heat and Sensible Heat?

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HEATING VENTILATION AND AIR CONDITIONING (R17A0331)

4th Year B. Tech I- sem, Mechanical Engineering

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COURSE OBJECTIVES

UNIT - 1	**CO1:**To Explain in detail Basic Components of Air-Conditioning & Refrigeration machines, Basic Refrigeration cycle, Accessories & Refrigerants
UNIT - 2	**CO2:** To Know Detail classification of Air-Conditioning System
UNIT - 3	CO3: To Study Psychrometric Chart and various terminology
UNIT - 4	CO4:To Explain the Load calculations of Survey of Building, Ventilation requirement for IAQ, ESHF, ADP & Air Flow Rate(CFM)Calculation
UNIT - 5	CO5: Explain Hydronic System, Water Piping,Fittings used in the HVAC Piping System Function, CHW Pipe supports &Pump Head Calculation

UNIT 2

CLASSIFICATION OF AIR-CONDITIONING SYSTEM

CO1: To Explain in detail Basic Components of Air-Conditioning & Refrigeration machines, Basic Refrigeration cycle, Accessories & Refrigerants

UNIT – I (SYLLABUS)

CLASSIFICATION OF AIR-CONDITIONING SYSTEM

- Window A/C
- Split A/C-Types
- Ductable Split A/C
- Variable Refrigerant Volume (VRV)/ Variable Refrigerant Flow (VRF)
- Ductable Package A/C

COURSE OUTLINE

UNIT -2

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES (2 to 3 objectives)
1	CLASSIFICATION OF AIR-CONDITIONING SYSTEM	Classifications	To understand Classification of Air Conditioning System(B2)
2	Window A/C-Working of Window A/C with Line Diagrams	Working of A/C Systems	To understand of Window A/C Systems (B2) To analyze the Each Component (B4)
3	Split A/C-Types - Working of Split A/C with Line Diagrams-	Working of Split A/C Systems	To understand of Split A/C Systems (B2) To analyze the Each Component (B4)
4	Ductable Split A/C- Working of Ductable Split A/C with Line Diagrams	Working of Ductable A/C	To understand of Ductable A/C Systems (B2) To analyze the Each Component (B4)
5	Variable Refrigerant Volume (VRV)/ Variable Refrigerant Flow (VRF)-	Working of (VRV)/VRF	To understand of VRV /VRF (B2) To analyze the Each Component (B4)

LECTURE 1

CLASSIFICATION OF AIR-CONDITIONING SYSTEM

TOPICS TO BE COVERED

- Introduction
- Classification
- Applications

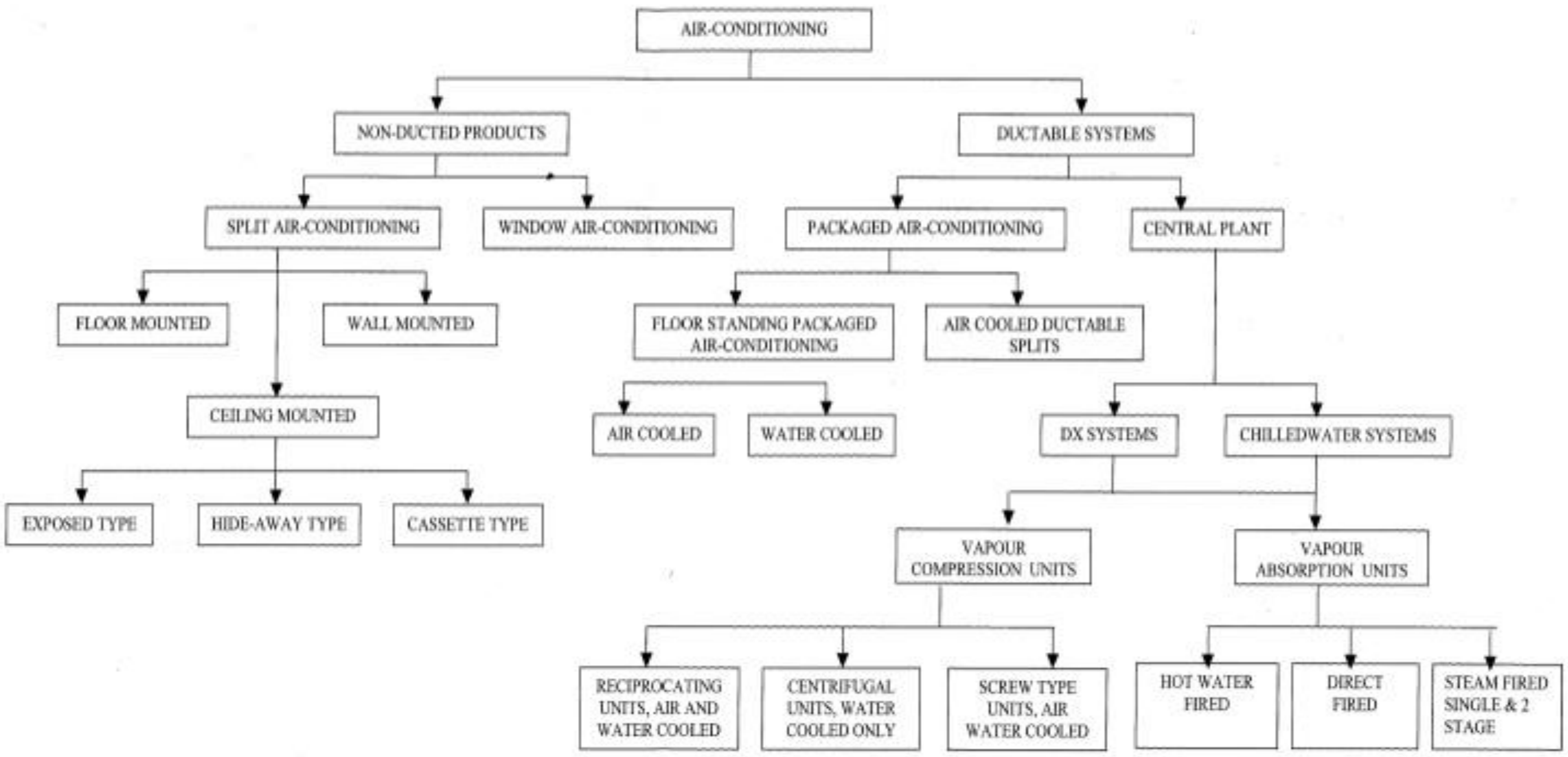
LECTURE 1

CLASSIFICATION OF AIR-CONDITIONING SYSTEM

INTRODUCTION

- Definition - Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favorable conditions.
- The control of these conditions may be desirable to maintain the health and comfort of the occupants, or to meet the requirements of industrial processes irrespective of the external climatic conditions

VARIOUS AC SYSTEMS



TYPE OF AIR-CONDITIONING

1. Window air-conditioning system
2. Split air-conditioning system
3. Centralised air-conditioning system
4. Package air-conditioning system

APPLICATIONS

Air conditioning is required for

- ❖ Providing thermal comfort to humans and other living beings - Comfort air conditioning.
- ❖ Providing conditions required for various products and processes in industries - Industrial air conditioning.

Comfort Air Conditioning -

The objective of this is to provide thermal comfort to the occupants.

Thermal comfort may be defined as the state of mind that expresses satisfaction with its surroundings. The requirement of thermal comfort is that human body core temperature to be maintained about 37 degrees.

Classification of comfort air conditioning systems :

1. Air conditioning systems for residences.
2. Commercial air conditioning system.
3. Air conditioning system for hospitals.
4. Laptop, mobile air conditioning systems.

Industrial Air Conditioning -

- The objective of this is to provide favorable surrounding conditions so that the required processes can be carried out and required products can be produced.
- It should also provide at least a partial measure of comfort to the people working in the industries.

Industrial air conditioning examples -

- Textile industries
- Printing industries
- Manufacturing of precision parts
- Semi-conductor industries
- Pharmaceutics
- Photographic materials
- Computer rooms
- Mines, power plants, etc.

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SPLIT AC SYSTEM

LECTURE 2

WINDOW TYPE AIR CONDITIONER

TOPICS TO BE COVERED

- Introduction
- Classification
- various parts of the window air conditioner
- Working
- Merits & Demerits

LECTURE 1

Window Type Air Conditioner

WINDOW AC SYSTEM

- Windows air conditioners are one of the most widely used types of air conditioners because they are the simplest form of the air conditioning systems. Window air conditioner comprises of the rigid base on which all the parts of the window air conditioner are assembled. The base is assembled inside the casing which is fitted into the wall or the window of the room in which the air conditioner is fitted.

The whole assembly of the window air conditioner can be divided into two compartments:

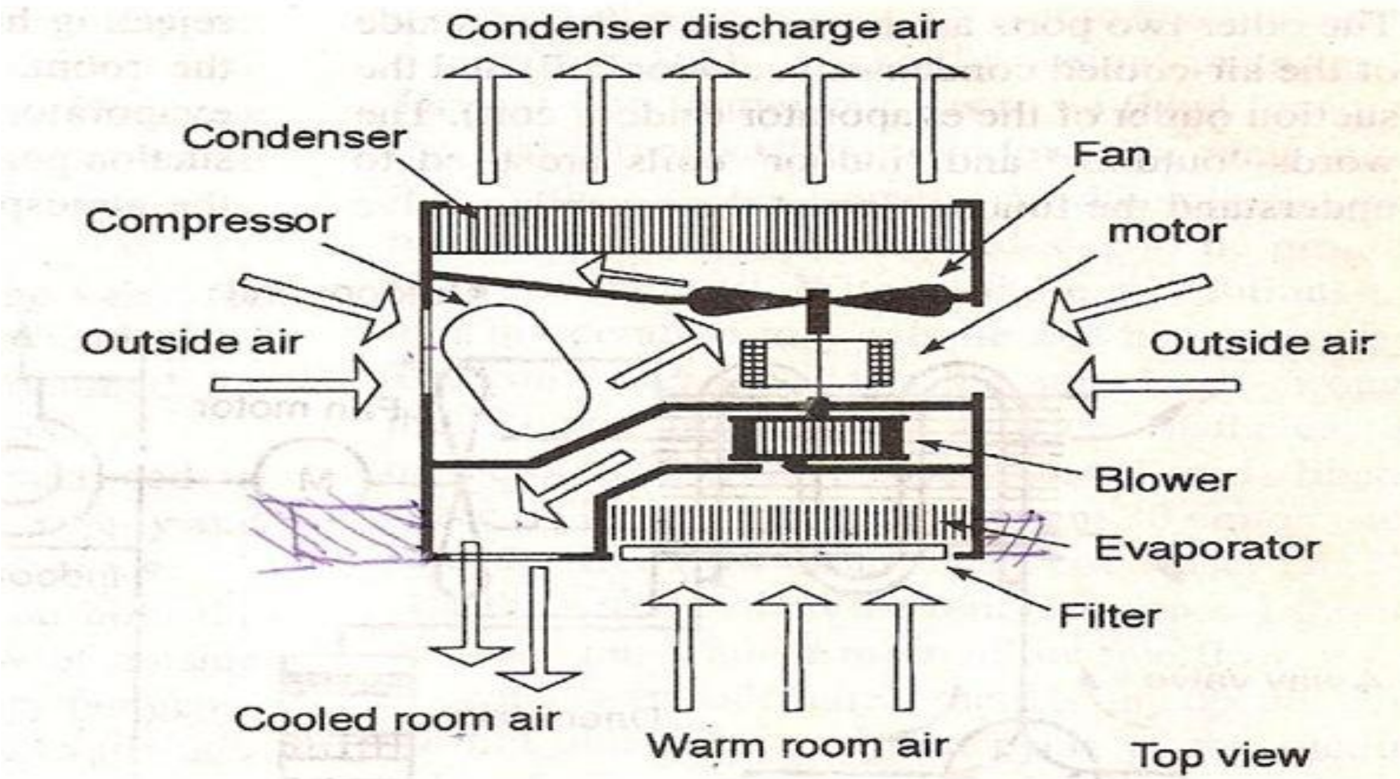
1. The room side, which is also the cooling side
2. The outdoor side from where the heat absorbed by the room air is liberated to the atmosphere.

VARIOUS PARTS OF THE WINDOW AIR CONDITIONER

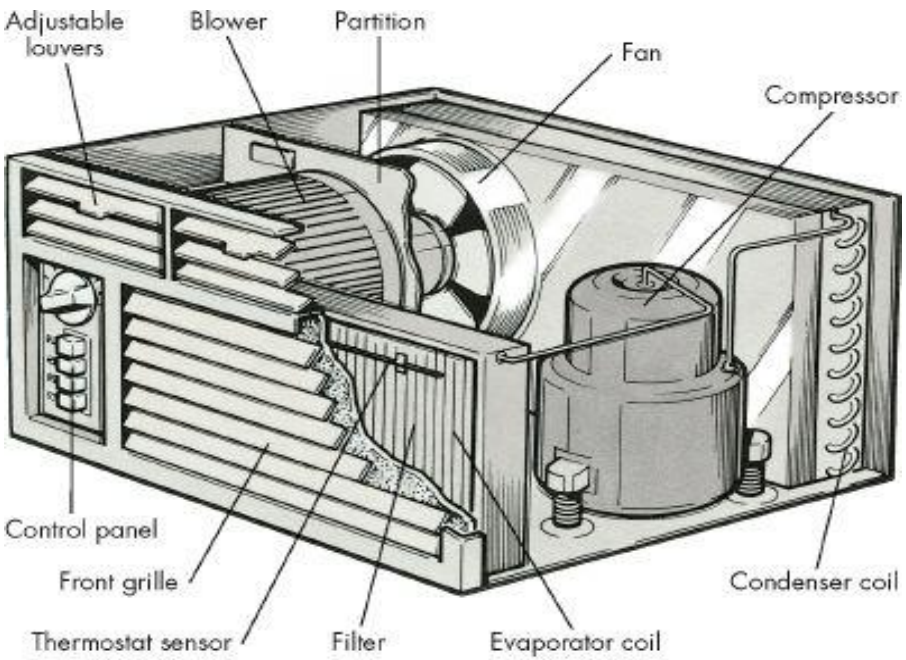
- The various parts of the window air conditioner can be divided into following categories:

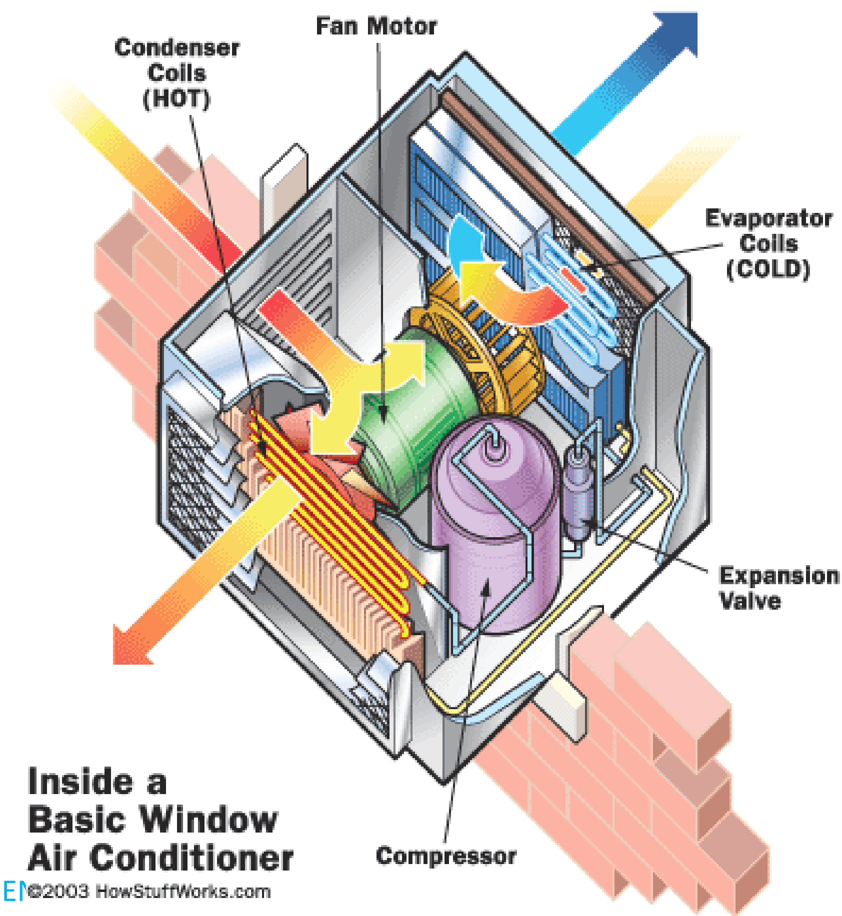
1. The refrigeration system,
2. Air circulation system,
3. ventilation system, control system, and
4. the electrical protection system.

AIR CIRCULATION SYSTEM

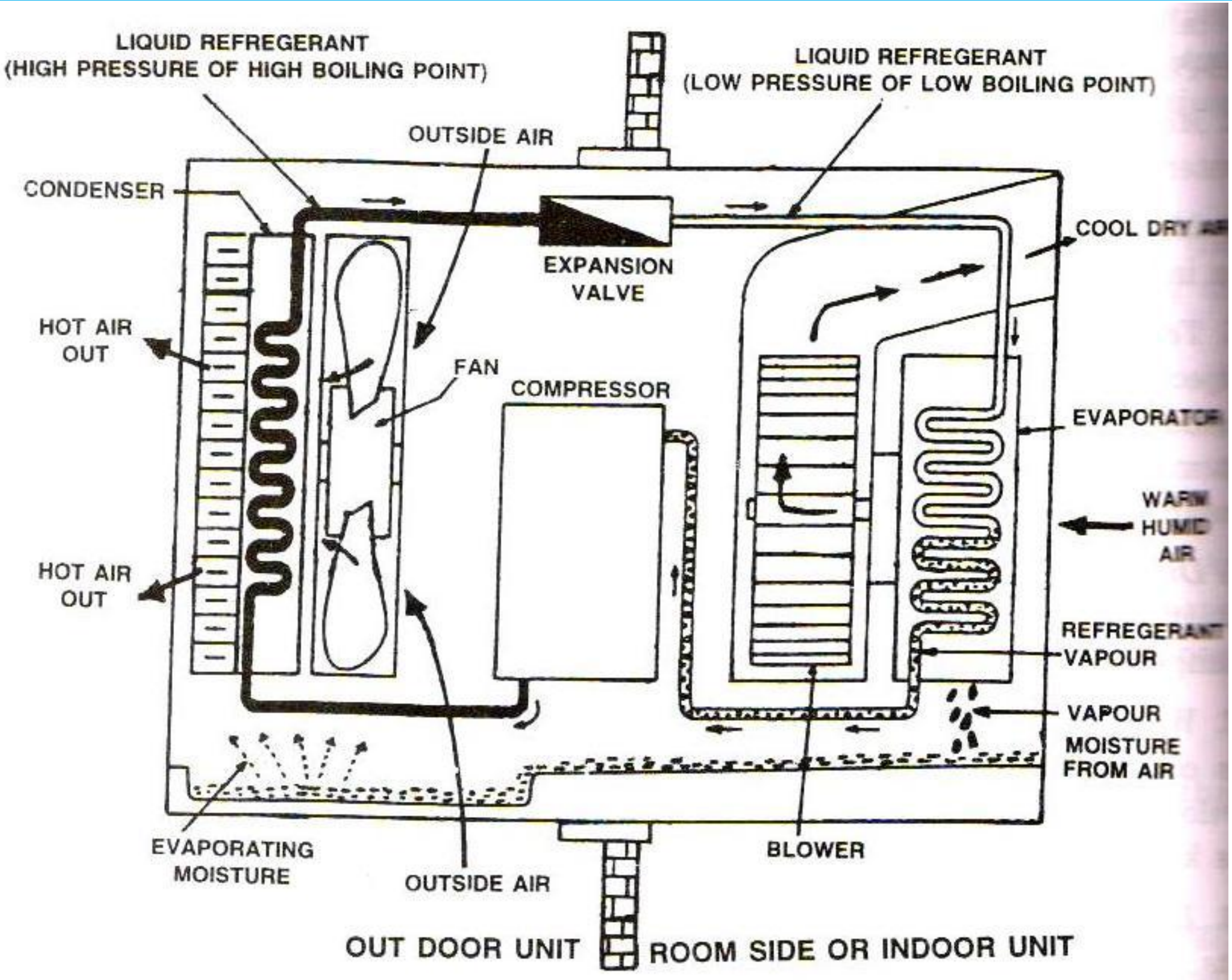


WINDOW TYPE AIR CONDITIONER





WINDOW TYPE AIR CONDITIONER



WINDOW TYPE AIR CONDITIONER - WORKING

- The low pressure vapour refigerant from the evaporator is sucked by compressor through the open inlet valve.
- The compressor compresses the vapour refrigerant.
- The high pressure and high temperature vapour refrigerant then flows to the condenser through the open outlet valve.
- In the condenser, the outside atmospheric temperature in summer being around 42o C, air is circulated by fan.
- After condensation, the high pressure liquid refrigerant formed passes through an expansion valve which reduces its pressure

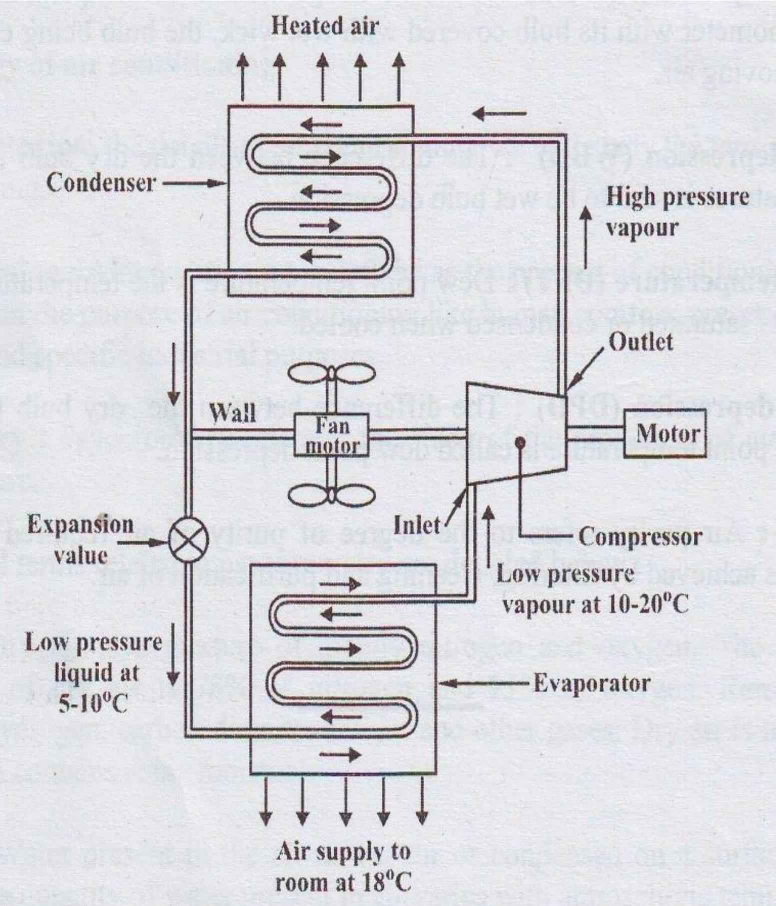


Fig.1 Window room air conditioner

WINDOW TYPE AIR CONDITIONER - WORKING

- The low pressure refrigerant then enters the evaporator and evaporates, thus absorbing latent heat of vapourisation from the room air.
- The equipment which is used for evaporating the refrigerant is called evaporator.
- After evaporation, the refrigerant becomes vapour.
- The low pressure vapour is again passed to the compressor. Thus the cycle is repeated.
- A partition separates high temperature side of condenser, compressor and low temperature side of evaporator
- The quantity of air circulated can be controlled by the dampers.
- The moisture in the air passing over the evaporator coil is dehumidified and drips into the trays.
- The unit automatically stops when the required temperature is reached in the room. This is accomplished by the thermostat and control panel.
- Generally, the refrigerant monochloro difluro methane ($CHCLF2$) is used in air conditioner. It is called Freon 22

MERITS AND DEMERITS OF WINDOW TYPE AIR CONDITIONER

Merits :

1. A separate temperature control is provided in each room.
2. Ducts are not required for distribution.
3. Cost is less.
4. Skilled technician is required for installation.

Demerits:

1. It makes noise.
2. Large hole is made in the external wall or a large opening to be created in the window panel. This leads to insecurity to inmates.
3. Air quantity cannot be varied.

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LECTURE 3

SPLIT AIR CONDITIONER

TOPICS TO BE COVERED

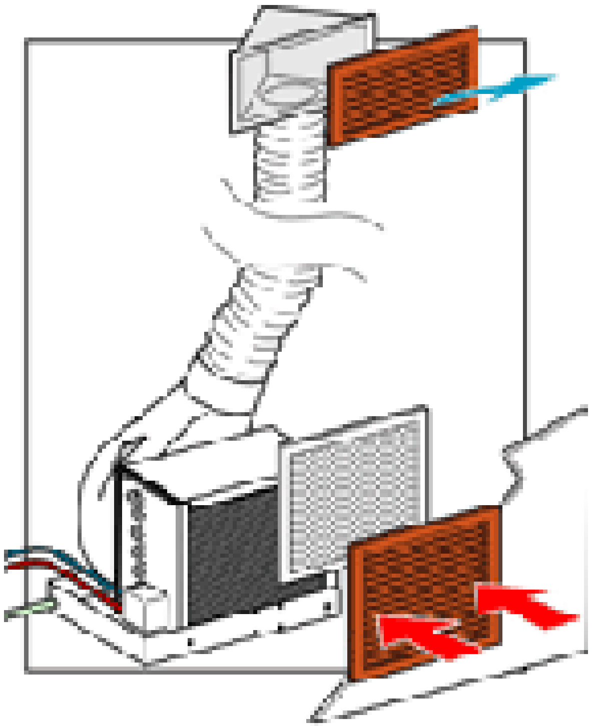
- Introduction
- Classification
- Working
- Merits & Demerits
- Applications

LECTURE 3

SPLIT AIR CONDITIONER

SPLIT TYPE AIR CONDITIONER - CONSTRUCTION

SPLIT TYPE AIR CONDITIONER - CONSTRUCTION



SPLIT TYPE AIR CONDITIONER WORKING

- In split air type air conditioner noise making components like compressor and condenser are mounted outside or away from room.
- Split type air conditioning system has two main components.

  (i) Outdoor Unit (ii) Indoor unit.
- The outdoor unit consists of compressor and condenser.
- The indoor unit consists of power cables, refrigerant tube and an evaporator mounted inside the room.
- Compressor is used to compress the refrigerant.
- The refrigerant moves between the evaporator and condenser through the circuit of tubing and fins in the coils.
- The evaporator and condenser are usually made of coil of copper tubes and surrounded by aluminium fins.
- The liquid refrigerant coming from the condenser evaporates in the indoor evaporator coil.
- During this process the heat is removed from the indoor unit air and thus, the room is cooled.

- Air return grid takes in the indoor air.
- Water is dehumidified out of air is drained through the drain pipe.
- The hot refrigerant vapour is passed to the compressor and then to the condenser where it becomes liquid.
- Thus the cycle is repeated.
- A thermostat is used to keep the room at a constant, comfortable temperature avoiding the frequent turning on off.

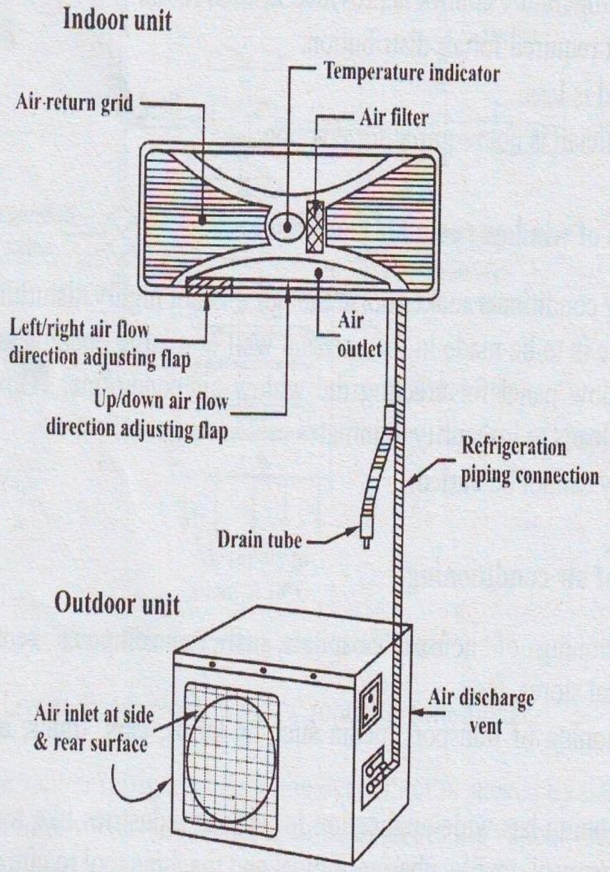


Fig.1 Split type room air conditioner

Fig.1 shows the layout diagram of a split type room air conditioner.

MERITS AND DEMERITS OF SPLIT TYPE AIR CONDITIONER

Merits :

- It is compact
- It is energy and money saving.
- Duct is not used.
- Easier to install.
- It is noiseless, because rotary air compressor used is, kept outside.
- It is more efficient and powerful.
- It has the flexibility for zoning.
- It is energy and money saving.

DeMerits :

- Initial cost is higher than window air conditioner
- Skilled technician is required for installation.
- Each zone or room requires thermostat to control the air cooling.

APPLICATIONS OF AIR CONDITIONING

- Used in houses, hospitals, offices, computer centres, theatres, departmental stores etc.,
- Air-conditioning of transport media such as buses, cars trains, aeroplanes and ships.
- Wide application in food processing, printing, chemical, pharmaceutical and machine tool, etc.,

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LECTURE 4

DUCTABLE SPLIT A/C

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TOPICS TO BE COVERED

- Introduction
- Classification
- Working
- Merits & Demerits
- Applications

LECTURE 3

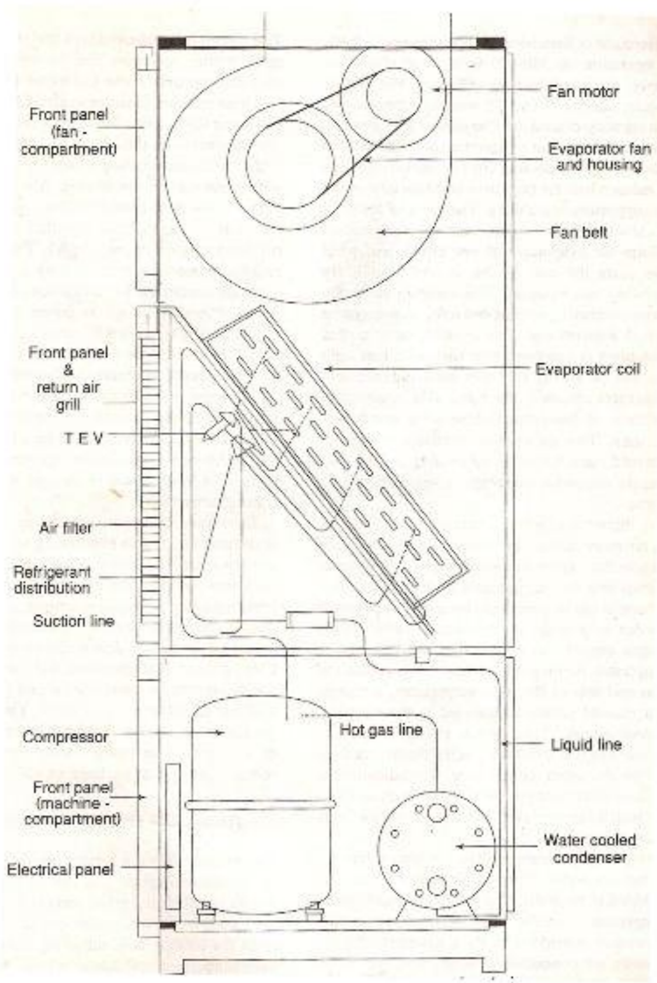
DUCTABLE SPLIT AIR CONDITIONER

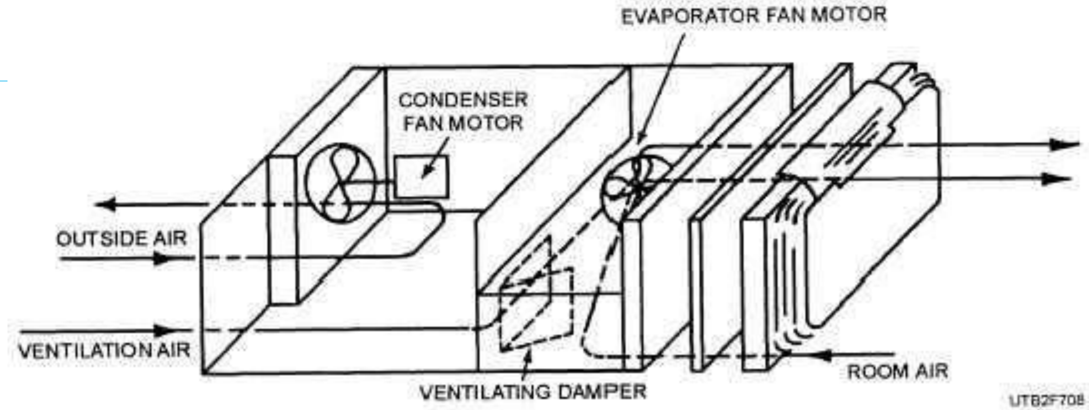
DUCTABLE SPLIT A/C

- The window and split air conditioners are usually used for the small air conditioning capacities up to 5 tons.
- The central air conditioning systems are used for where the cooling loads extend beyond 20 tons.
- The packaged air conditioners are used for the cooling capacities in between these two extremes.
- The packaged air conditioners are available in the fixed rated capacities of 3,5, 7, 10 and 15 tons.
- These units are used commonly in places like restaurants, telephone exchanges, homes, small halls, etc.

- Depending on the type of the cooling system used in these systems, the packaged air conditioners are divided into two types:
  - water cooled condenser.
  - air cooled condensers.

PACKAGED AIR CONDITIONERS




EVAPORATOR FAN MOTOR
CONDENSER FAN MOTOR
OUTSIDE AIR
VENTILATION AIR
VENTILATING DAMPER
ROOM AIR
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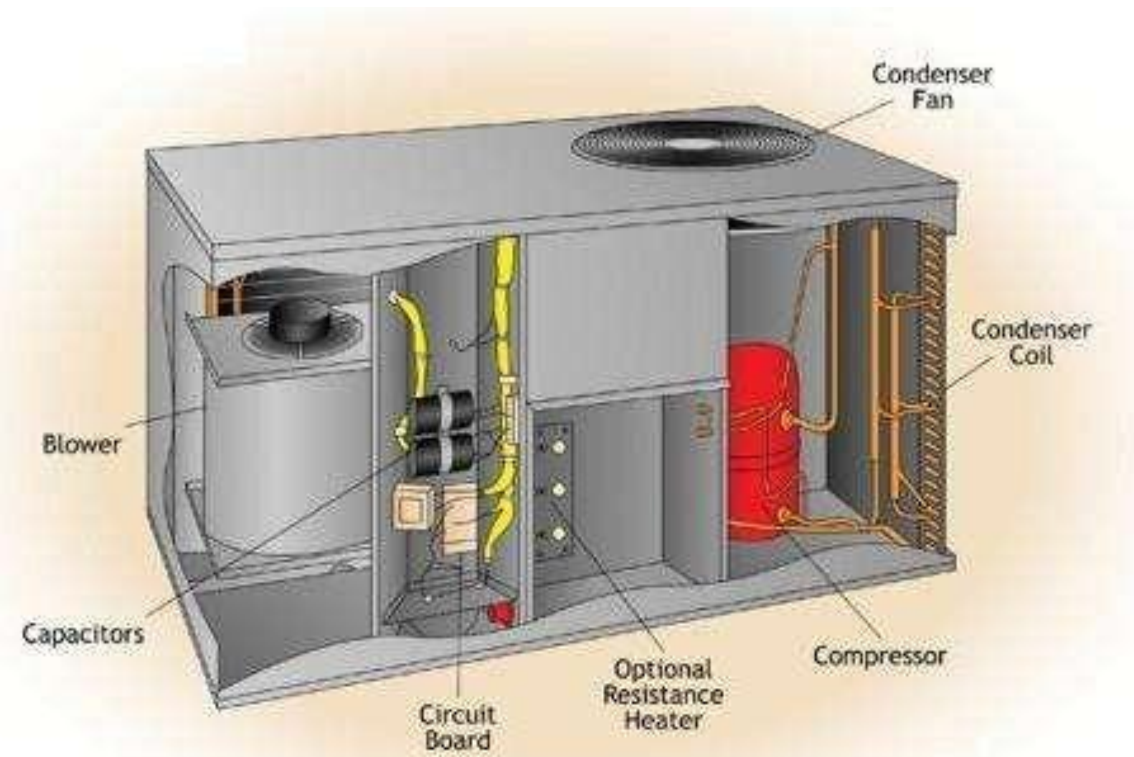
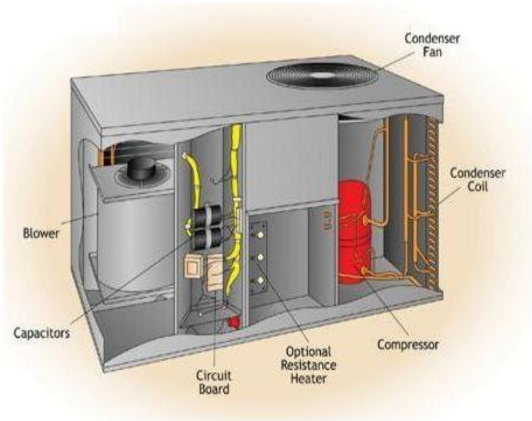

Condenser Fan
Condenser Coil
Blower
Capacitors
Circuit Board
Optional Resistance Heater
Compressor

PACKAGED AIR CONDITIONERS WITH WATER COOLED CONDENSER

- The condenser is of shell and tube type, with refrigerant flowing along the tube side and the cooling water flo along the shell side. The water has be supplied continuously in these systems to maintain functioning of air conditioning system
- The shell and tube type of condens is compact in shape and it is enclo in a single casing along with the compressor, expansion valve, and air handling unit including the cooli coil or the evaporator.

PACKAGE AIR CONDITIONER AIR COOLED CONDENSER

- In this packaged air conditioners the condenser of the refrigeration system is cooled by the atmospheric air. There is an outdoor unit th comprises of the important components like compressor, condenser and in some cases expansion valve
- The outdoor unit can be kept on the terrace any other open place where the free flow of atmospheric air is available. The fan locate inside this unit sucks the outside air and blo it over the condenser coil cooling it in the process. The condenser coil is made up of several turns of the copper tubing and it is finned externally.



VARIABLE REFRIGERANT VOLUME (VRV)/ VARIABLE REFRIGERANT FLOW (VRF)

- Variable refrigerant flow (VRF), also known as variable refrigerant volume (VRV).
- VRFs are typically installed with an air conditioner inverter which adds a DC inverter to the compressor in order to support variable motor speed and thus variable refrigerant flow rather than simply perform on/off operation.
- By operating at varying speeds, VRF units work only at the needed rate allowing for substantial energy savings at load conditions.
- Heat recovery VRF technology allows individual indoor units to heat or cool as required, while the compressor load benefits from the internal heat recovery.
- Energy savings of up to 55% are predicted over comparable unitary equipment. This also results in greater control of the building's interior temperature by the building's occupants.

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LECTURE 5

Central Air-Conditioning

TOPICS TO BE COVERED

- Introduction
- Classification
- Working

LECTURE 5

Central Air-Conditioning

CENTRAL AIR-CONDITIONING PLANTS

- The central air conditioning plants or the systems are used when large buildings, hotels, theaters, airports, shopping malls etc. are to be air conditioned completely.
- The window and split air conditioners are used for single rooms or small office spaces.
- If the whole building is to be cooled it is not economically viable to put window or split air conditioner in each and every room.
- Further, these small units cannot satisfactorily cool the large halls, auditoriums, receptions areas etc.

CENTRAL AIR-CONDITIONING PLANTS

CLASSIFICATION

There are two types of central air conditioning plants or systems.

1. Direct expansion or DX central air conditioning plant.
2. Chilled water central air conditioning plant:

WORKING

- In the central air conditioning systems there is a plant room where large compressor, condenser, thermostatic expansion valve and the evaporator are kept in the large plant room.
- They perform all the functions as usual similar to a typical refrigeration system. However, all these parts are larger in size and have higher capacities.
- The compressor is of open reciprocating type with multiple cylinders and is cooled by the water just like the automobile engine.
- The compressor and the condenser are of shell and tube type.
- While in the small air conditioning system capillary is used as the expansion valve, in the central air conditioning systems thermostatic expansion valve is used.

WORKING

- The chilled is passed via the ducts to all the rooms, halls and other spaces that are to be air conditioned.
- Thus in all the rooms there is only the duct passing the chilled air and there are no individual cooling coils, and other parts of the refrigeration system in the rooms. What is we get in each room is the completely silent and highly effective air conditions system in the room.
- Further, the amount of chilled air that is needed in the room can be controlled by the openings depending on the total heat load inside the room.

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APPLICATIONS

Air-conditioning is an important part of human society. Day by day its the environment that we live-in is in verge of pullution overtake. It's important to us that we breath good conditioned air. Air conditioners have following applications.

1. Air conditioning can be defined as conditioning the air for a natural and comfortable atmosphere within the living area particularly in our home or office.
2. Filtering air for dust particles, mould, insects, and much other micro organism living in air.
3. Employed in large super computer halls to small desktops rooms for keeping them their cool and for their prolonged working.
4. Constant temperature is to be maintained in tool room as you know metal are not so trusted with changing temperature for their dimensions.
5. Air conditioning helps the shop owners for a good sale. Or may be that is why we hang out in malls more often in college days.
6. Air conditioner keeps the boss cool in office. Just imagine what it would like a sweaty red boss.
7. Air conditioner can keep your food fresh for a little longer. Some times even for 2 year in cold rooms.
8. Air conditioner is used in Operation theatre so that patients could get well soon other than getting his wounds septic due to the micro organisms present in air, which as stated, in a condition without AC.
9. Air conditioning keeps your office toilet smell free its 80% fresh air for every intake air.

ASSINGNMENT QUESTIONS

1. Explain detail classification of Air Conditioning System?
2. Explain with neat sketch working of window air-conditioning?
3. Difference between the window and split air-conditioning?
4. Explain with neat sketch working of packaged Air Conditioning System ?
5. Explian the working of Split A/c System with neat diagram?
6. Write the Merits and Demerits of Split a/c?
7. Describe briefly about Variable Refrigerant Volume (VRV)/ Variable Refrigerant Flow (VRF)?
8. Write Down the applications of ductable ac

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HEATING VENTILATION AND AIR CONDITIONING (R17A0331)

4th Year B. Tech I- sem, Mechanical Engineering

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COURSE OBJECTIVES

UNIT - 1	**CO1:**To Explain in detail Basic Components of Air-Conditioning & Refrigeration machines, Basic Refrigeration cycle, Accessories & Refrigerants
UNIT - 2	**CO2:** To Know Detail classification of Air-Conditioning System
UNIT - 3	CO3: To Study Psychrometric Chart and various terminology
UNIT - 4	CO4:To Explain the Load calculations of Survey of Building, Ventilation requirement for IAQ, ESHF, ADP & Air Flow Rate(CFM)Calculation
UNIT - 5	CO5: Explain Hydronic System, Water Piping,Fittings used in the HVAC Piping System Function, CHW Pipe supports &Pump Head Calculation

UNIT 3

STUDY OF PSYCHROMETRIC CHARTS:

CO1: **To Study Psychrometric Chart and various terminology.**

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UNIT – I (SYLLABUS)

STUDY OF PSYCHROMETRIC CHARTS

- Dry Bulb Temperature
- Wet Bulb Temperature
- Dew Point Temperature
- Relative Humidity
- Humidity Ratio

PSYCHROMETRIC PROCESSES

- Heating
- Cooling
- Cooling and Dehumidification
- Heating and Humidification

COURSE OUTLINE

UNIT - 3

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES (2 to 3 objectives)
1	STUDY OF PSYCHROMETRIC CHARTS	To learn what is PSYCHROMETRIC CHARTS	To understand & apply the PSYCHROMETRIC CHARTS (B2),(B3).
2	Dry Bulb Temperature-Wet Bulb Temperature-	DBT & WBT Definations	
3	Dew Point Temperature-Relative Humidity-Humidity Ratio-Processes,	DPT	
4	Heating, Cooling, Cooling and Dehumidification, Heating and Humidification	TO MARK IN PSYCHROMETRIC CHARTS CURVES	To Able to Analyze in HVAC systems.(B4)

LECTURE 1

STUDY OF PSYCHROMETRIC CHARTS

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TOPICS TO BE COVERED

- Introduction
- Psychrometric Chart
- Dry Bulb Temperature
- Wet Bulb Temperature

LECTURE 1

STUDY OF
PSYCHROMETRIC CHARTS

PSYCHROMETRICS

- Psychrometrics is the science of studying the thermodynamic properties of moist air. The amount of moisture vapour in the air varies quite significantly under different conditions.
- When the air is hot, it can contain a large amount of moisture vapour,sometimes as much as 5% by volume.
- When it is cold, its capacity to hold the moisture is reduced. When the temperature of warm air begins to fall, the vapour also cools and,
- if cooling continues, it will condense into tiny moisture droplets. In the atmosphere this results in the formation of clouds and eventually rain.

Three basic definitions

1. **Atmospheric air** - contains nitrogen, oxygen, carbon dioxide, water vapor, other gases, and miscellaneous contaminants such as dust, pollen, and smoke. This is the air we breathe and use for ventilation.

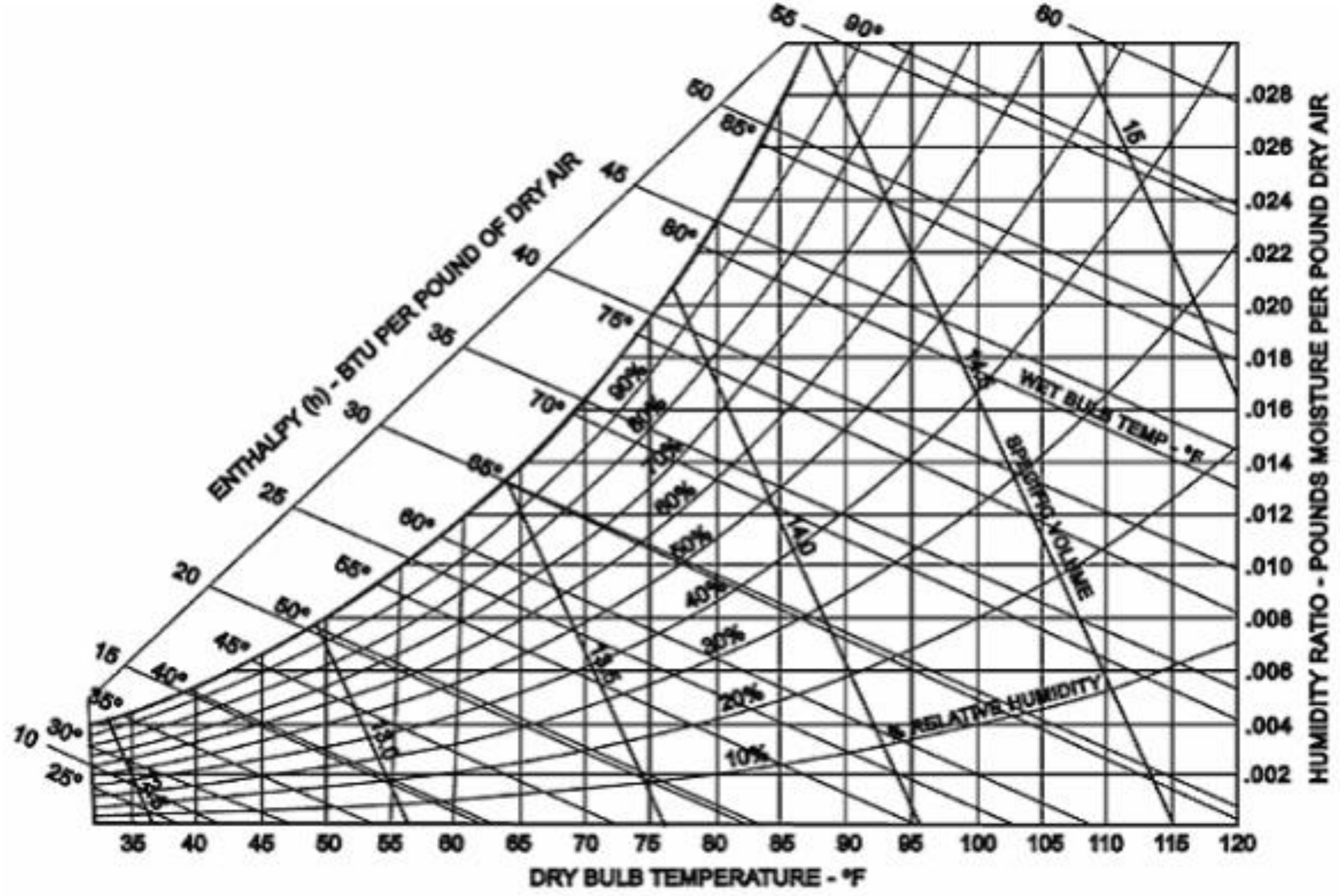
2. **Dry air** - exists when all of the contaminants and water vapor have been removed from atmospheric air. By volume, dry air contains about 78 percent nitrogen, 21 percent oxygen, and 1 percent other gases. Dry air is used as the reference in psychrometrics.

3**. Moist air** - is a mixture of dry air and water vapor.

PSYCHROMETRIC CHART

- The Psychrometric Chart provides a graphic relationship of the state or condition of the air at any particular time. It displays the properties of air:
- dry bulb temperature (vertical lines),
- wet bulb temperature (lines sloping gently downward to the right),
- dew point temperature (horizontal lines),
- relative humidity (the curves on the chart).
- Given any two of these properties, the other two can be determined using the chart.

PSYCHROMETRIC CHART

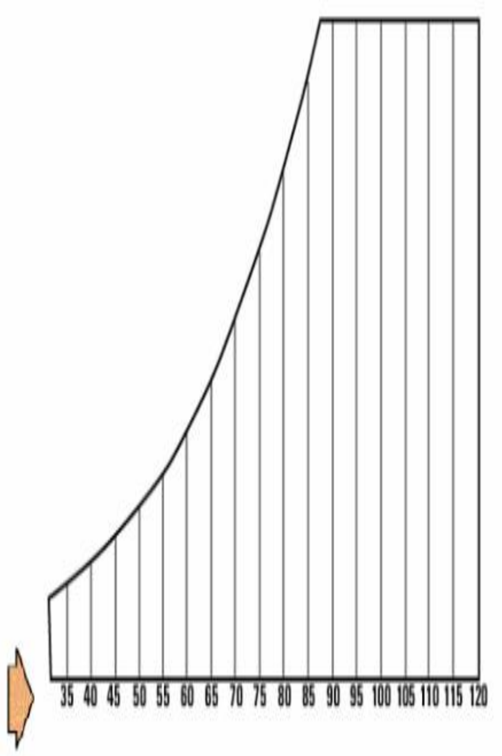


USES OF PSYCHROMETRIC CHART

- The psychrometric chart conveys an amazing amount of information about air.
- To predict whether or not moisture condensation will occur on a given surface you need three pieces of information; the temperature of the air, the relative humidity of the air, and the surface temperature.
- The psychrometric chart explains that by raising the surface temperature or by lowering the moisture content of the air or employ some combination of both can avoid surface condensation.
- A psychrometric chart also helps in calculating and analyzing the work and energytransfer of various air-conditioning processes.
- In practical applications, the most common psychrometric analysis made by HVAC contractors involves measuring the dry and wet bulb temperatures of air entering and leaving a cooling coil.

DRY BULB TEMPERATURE

- Dry Bulb Temperature (DBT) is the temperature that we measure with a standard thermometer that has no water on its surface. When people refer to the temperature of the air, they are commonly referring to its dry bulb temperature.
- Dry-bulb temperature is located on the X-axis, of the psychrometric chart and lines of constant temperature are represented by vertical chart lines.



Dry bulb temperature lines shown on the Psychrometric Chart

WET BULB TEMPERATURE

- Radiation is another fundamental mode of heat transfer. Unlike conduction and convection, radiation heat transfer does not require a medium for transmission as energy transfer occurs due to the propagation of electromagnetic waves.
- The radiation energy emitted by a surface is obtained by integrating Planck's equation over all the wavelengths. For a real surface the radiation energy given by Stefan Boltzmann's law is:

$$Q_r = \varepsilon.\sigma.A.Ts$$

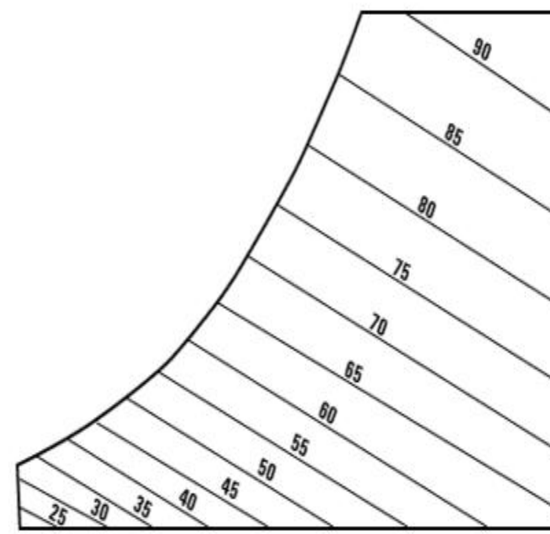
where Qr = Rate of thermal energy emission, W

ε = Emissivity of the surface

σ = Stefan-Boltzmann's constant, 5.669×10^{-8}

A=Surface area, m

Ts = Surface Temperature,



Lines of constant wet-bulb temperature on the Psychrometri

WET BULB TEMPERATURE

- Wet bulb temperature is easily measured with a standard thermometer which has its sensing bulb encased in a wetted wick that is subjected to rapid air motion across its surface.
- Such devices, called sling or whirled psychrometers, have a frame that can be whirled in the air by hand.
- When the sling psychrometer whirls through the air, water from the wetted sack evaporates, causing it to cool to the wet-bulb temperature.
- The amount of cooling that occurs depends on the relative humidity. The lower the humidity, the faster will be the evaporation, and the more the bulb will cool.
- High humidity will cause less evaporation, slowing the cooling process.

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LECTURE 2

PSYCHROMETRIC PROPERTIES

TOPICS TO BE COVERED

Dew Point Temperature

Relative Humidity

Humidity Ratio

LECTURE 2

PSYCHROMETRIC PROPERTIES

PSYCHROMETRIC CHART

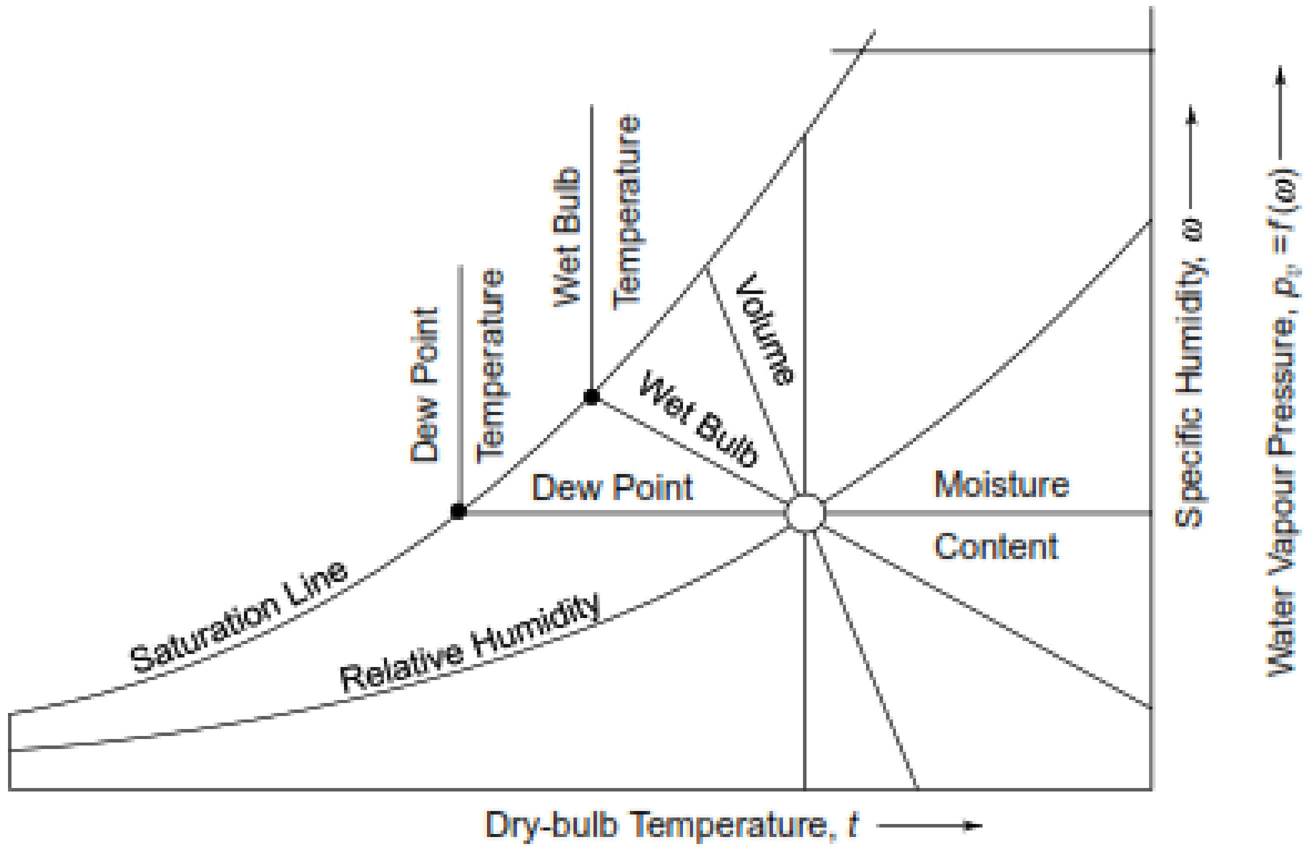


Fig. 14.9 Constant property lines on a psychrometric chart

Adiabatic saturation temperature. It is the temperature at which the water or ice can saturate air by evaporating adiabatically into it. It is numerically equivalent to the measured wet bulb temperature (as corrected, if necessary for radiation and conduction) (tdb– twb).

Wet bulb depression. It is the difference between dry-bulb and wet bulb temperatures.

Dew point temperature (DPT). It is the temperature to which air must be cooled at constant pressure in order to cause condensation of any of its water vapour. It is equal to steam table saturation temperature corresponding to the actual partial pressure of water vapour in the air (tdp).

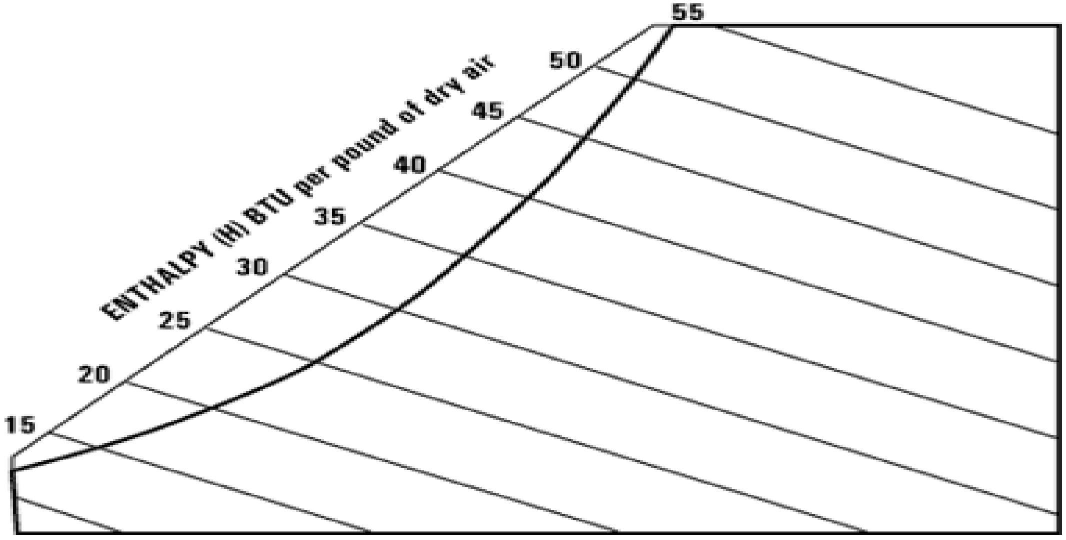
Dew point depression. It is the difference between the dry bulb and dew point temperatures (tdb – tdp).

- **Specific humidity (Humidity ratio).** It is the ratio of the mass of water vapour per unit mass of dry air in the mixture of vapour and air, it is generally expressed as grams of water per kg of dry air. For a given barometric pressure it is a function of dew point temperature alone.
- **Relative humidity (RH), ().** It is the ratio of the partial pressure of water vapour in the mixture to the saturated partial pressure at the dry bulb temperature, expressed as percentage.
- **Sensible heat.** It is the heat that changes the temperature of a substance when added to or abstracted from it.
- **Latent heat.** It is the heat that does not affect the temperature but changes the state of substance when added to or abstracted from it.
- **Enthalpy.** It is the combination energy which represents the sum of internal and flow energy in a steady flow process. It is determined from an arbitrary datum point for the air mixture and is expressed as kJ per kg of dry air (h).

ENTHALPY

- Enthalpy is the measure of heat energy in the air due to sensible heat or latent heat
- Sensible heat is the heat (energy) in the air due to the temperature of the air
- The latent heat is the heat (energy) in the air due to the moisture of the air.
- The sum of the latent energy and the sensible energy is called the air enthalpy.
- Enthalpy is expressed in Btu per pound of dry air (Btu/lb of dry air) or kilojoules per kilogram (kJ/kg).
- Enthalpy is useful in air heating and cooling applications.

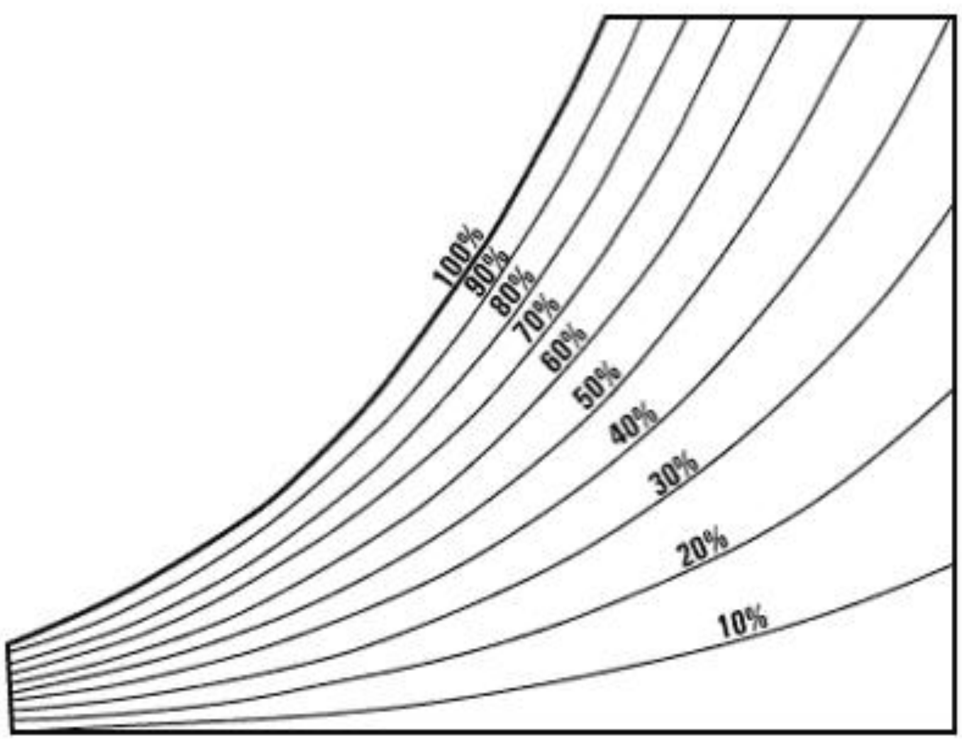
- The enthalpy scale is located above the saturation, upper boundary of the chart. Lines of constant enthalpy run diagonally downward from left to right across the chart; follow almost exactly the line of constant wet bulb temperature.



Enthalpy lines shown on Psychrometric Chart

RELATIVE HUMIDITY (RH)

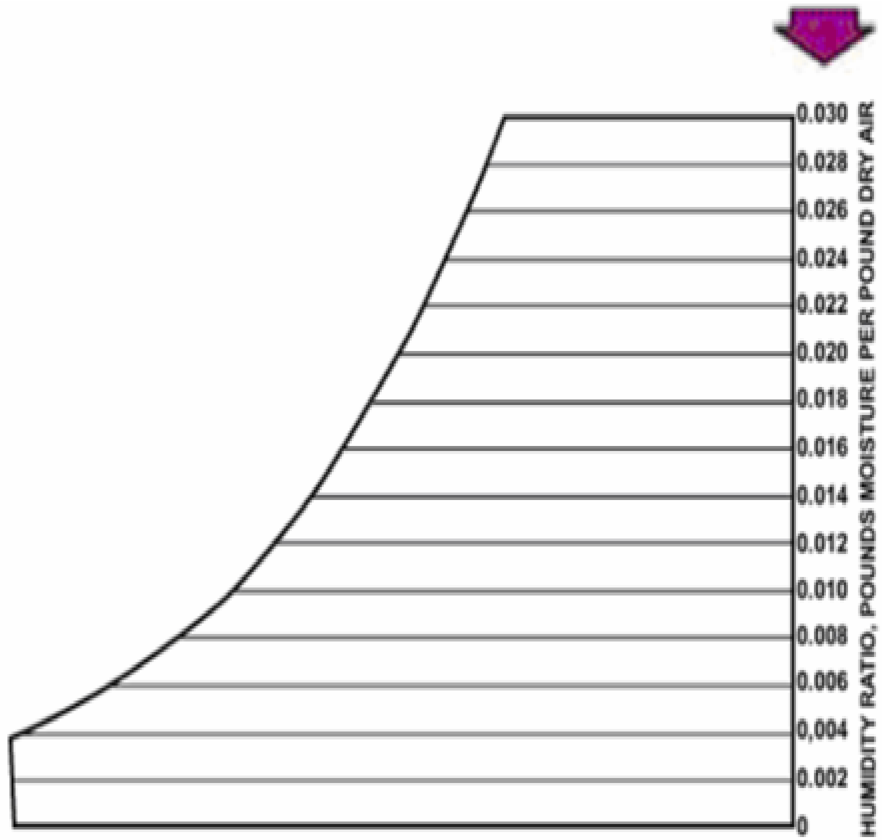
- Relative humidity (RH) is a measure of the amount of water air can hold at a certain temperature.
- Air temperature (dry-bulb) is important because warmer air can hold more moisture than cold air.
- Lines of constant relative humidity are represented by the curved lines running from the bottom left and sweeping up through to the top right of the chart.
- The line for 100 percent relative humidity, or saturation, is the upper, left boundary of the chart.
- The 100 % RH (saturation) line corresponds to the wet bulb and the dew-point temperature scale line and the line for zero percent RH falls along the dry-bulb temperature scale line



Relative humidity lines shown on Psychrometric Chart

ABSOLUTE HUMIDITY OR HUMIDITY RATIO

Absolute Humidity is the vapor content of air, given in grams or lb of water vapor per lb of dry air (i.e., lb of moisture/lb of d.a).
It is also known as moisture content or humidity ratio.
Air at a given temperature can support only a certain amount of moisture and no more.
This is referred to as the saturation humidity.
Humidity ratio is represented on the chart by lines that run horizontally and the values are on the right hand side (Y-axis) of the chart increasing from bottom to top.



Humidity Ratio lines shown on Psychrometric Chart

DEW POINT TEMPERATURE

Dew point temperature indicates the temperature at which water will begin to condense out of moist air. When air is cooled, the relative humidity increases until saturation is reached and condensation occurs.

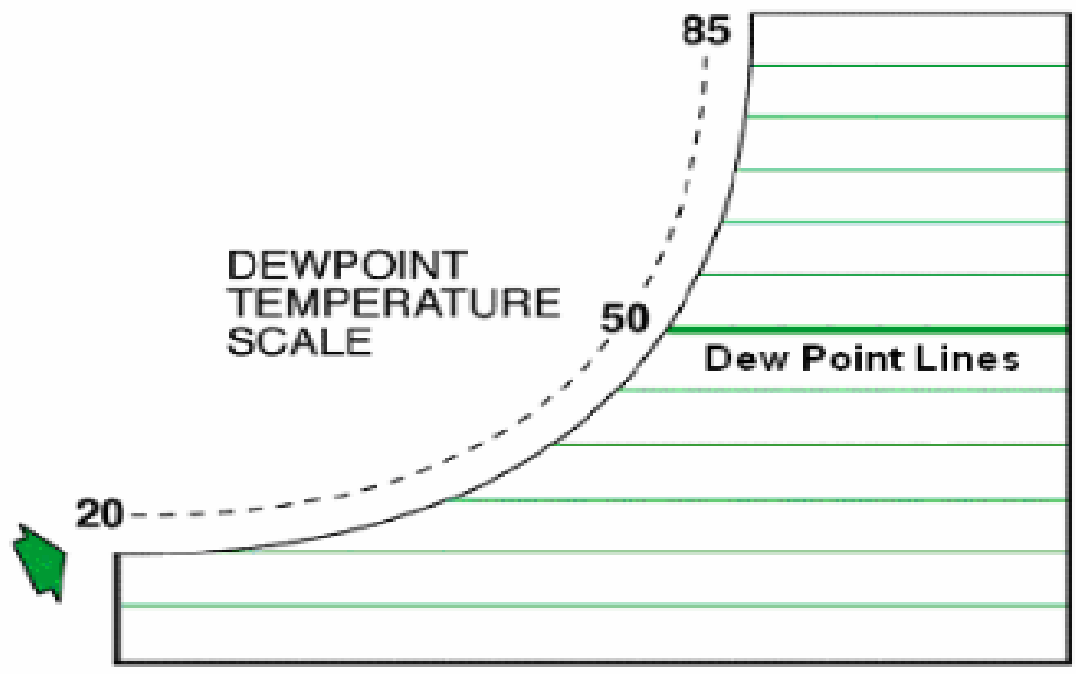
Condensation occurs on surfaces which are at or below the dew point temperature.

Dew point is represented along the 100% relative humidity line on the psychrometric chart.

Dew point temperature is determined by moving from a state point horizontally to the left along lines of constant humidity ratio until the upper, curved, saturation temperature boundary is reached.

At dew point, dry bulb temperature and wet bulb temperature are exactly the same.

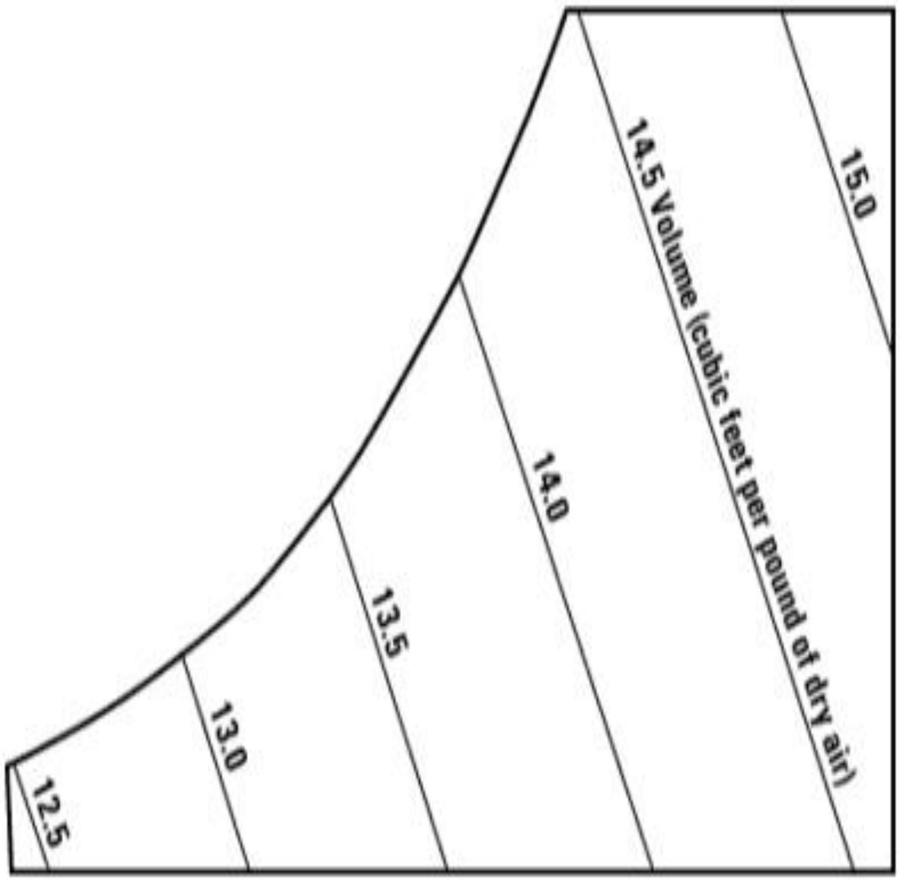
DEW POINT LINES



Dew Point lines shown on Psychrometric Chart

SPECIFIC AIR VOLUME

- Specific Volume is the volume that a certain weight of air occupies at a specific set of conditions. The specific volume of air is basically the reciprocal of air density.
- As the temperature of the air increases, its density will decrease as its molecules vibrate more and take up more space (as per Boyle's law).
- Specific volume is represented on Psychrometric Chart by lines that slant from the lower right hand corner towards the upper left hand corner at a steeper angle than the lines of wet bulb temperature and enthalpy.

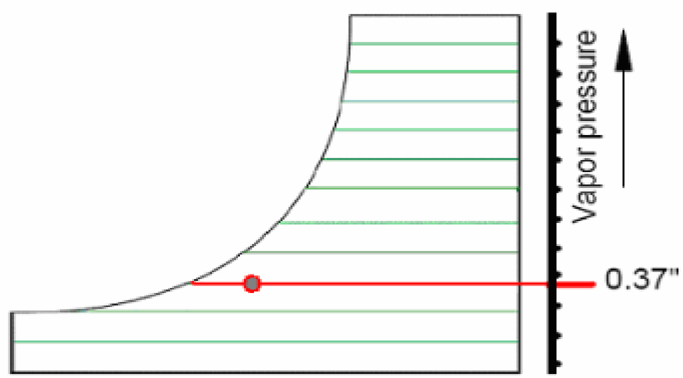


Specific Volume lines shown on Psychrometric Chart

VAPOUR PRESSURE

•Water vapour is one of several gaseous constituents of air, the other principal ones being nitrogen, oxygen and carbon dioxide. Each exerts its own partial pressure on the surrounding environment in proportion to the amount of gas present, the sum of the pressures making up the total or barometric pressure of the air

•Vapour pressure directly affects evaporation rate. If the vapour pressure in the air is already very high, it is more difficult for water molecules to break free from a liquid surface and enter the air as vapour. That is why there is very little evaporation in humid environments. The point at which absolutely no more evaporation will occur because the air is already saturated is called, interestingly enough, saturation pressure and coincides with the saturation point.



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LECTURE 3

PSYCHROMETRIC PROCESSES

TOPICS TO BE COVERED

1. INTRODUCTION
2. Mixing of air streams
3. Sensible heating
4. Sensible cooling
5. Cooling and dehumidification

LECTURE 3

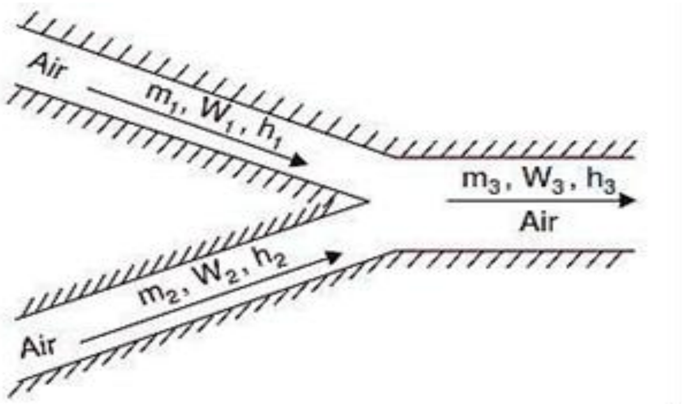
PSYCHROMETRIC PROCESSES

INTRODUCTION

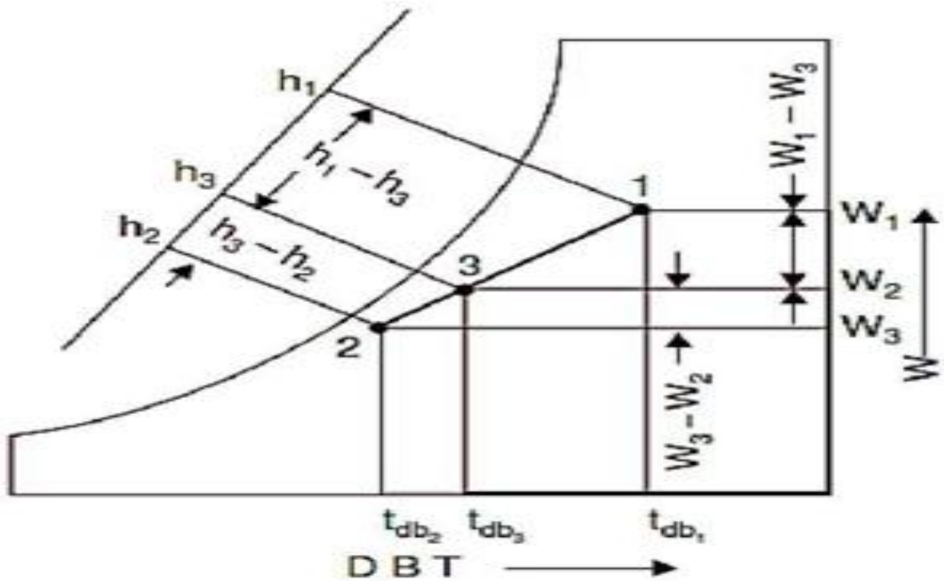
- In order to condition air to the conditions of human comfort or of the optimum control of an industrial process required, certain processes are to be carried out on the outside air available. The processes affecting the psychrometric properties of air are called **psychrometric processes.**
- The important psychrometric processes are enumerated and explained in the following text:
    1. Mixing of air streams
    2. Sensible heating
    3. Sensible cooling
    4. Cooling and dehumidification
    5. Cooling and humidification
    6. Heating and dehumidification
    7. Heating and humidification.

MIXING OF AIR STREAMS

- Mixing of several air streams is the process which is very frequently used in air conditioning. This mixing normally takes place without the addition or rejection of either heat or moisture, i.e., adiabatically and at constant total moisture content. Thus we can write the following equations :



$$m_1 + m_2 = m_3$$
$$m_1W_1 + m_2W_2 = m_3W_3$$
$$m_1h_1 + m_2h_2 = m_3h_3$$



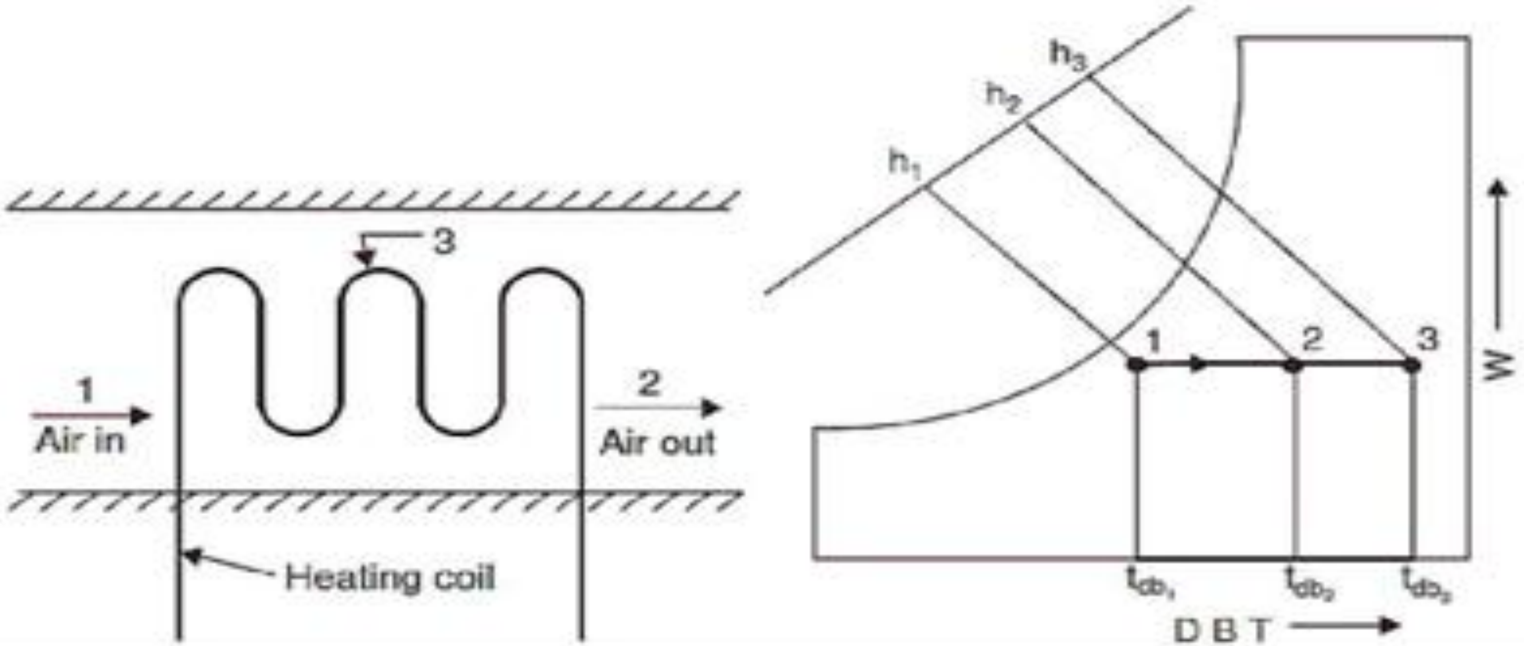
$$\frac{m_1}{m_2} = \frac{W_3 - W_2}{W_1 - W_3} = \frac{h_3 - h_2}{h_1 - h_3}$$

$$m_1(W_1 - W_3) = m_2(W_3 - W_2)$$
$$m_1(h_1 - h_3) = m_2(h_3 - h_2)$$
$$\frac{m_1}{m_2} = \frac{W_3 - W_2}{W_1 - W_3} = \frac{h_3 - h_2}{h_1 - h_3}$$

SENSIBLE HEATING

- When air passes over a dry surface which is at a temperature greater than its (air) dry bulb temperature, it undergoes sensible heating. Thus the heating can be achieved by passing the air over heating coil like electric resistance heating coils or steam coils. During such a process, the specific humidity remains constant but the dry bulb temperature rises and approaches that of the surface.
- The extent to which it approaches the mean effective surface temperature of the coil is conveniently expressed in terms of the equivalent **by-pass factor.**
- The by-pass factor (BF) for the process is defined as the ratio of the difference between the mean surface temperature of the coil and leaving air temperature to the difference between the mean surface temperature and the entering air temperature.

$$BF = \frac{t_{db_3} - t_{db_2}}{t_{db_3} - t_{db_1}}$$



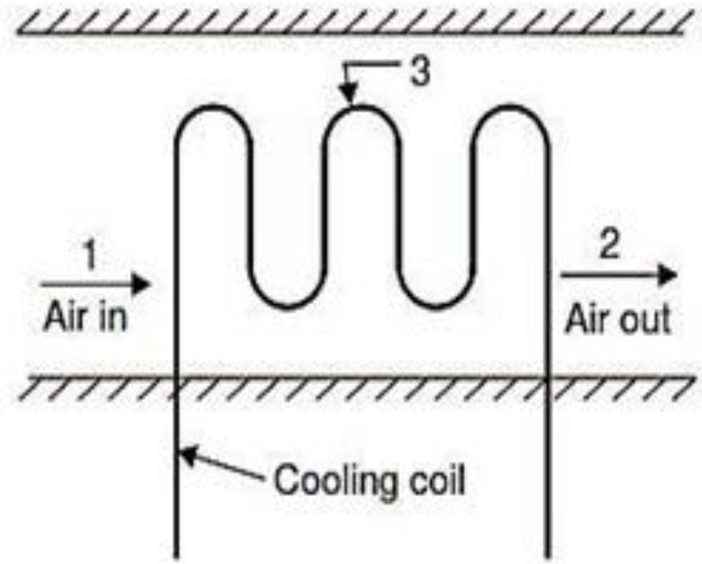
The value of the by-pass factor is a function of coil design and velocity. The heat added to the air can be obtained directly from the entering and leaving enthalpies (h2-h1) or it can be obtained from the humid specific heat multiplied by the temperature difference (tdb2-tdb1). In a complete air conditioning system the preheating and reheating of air are among the familiar examples of sensible heating.

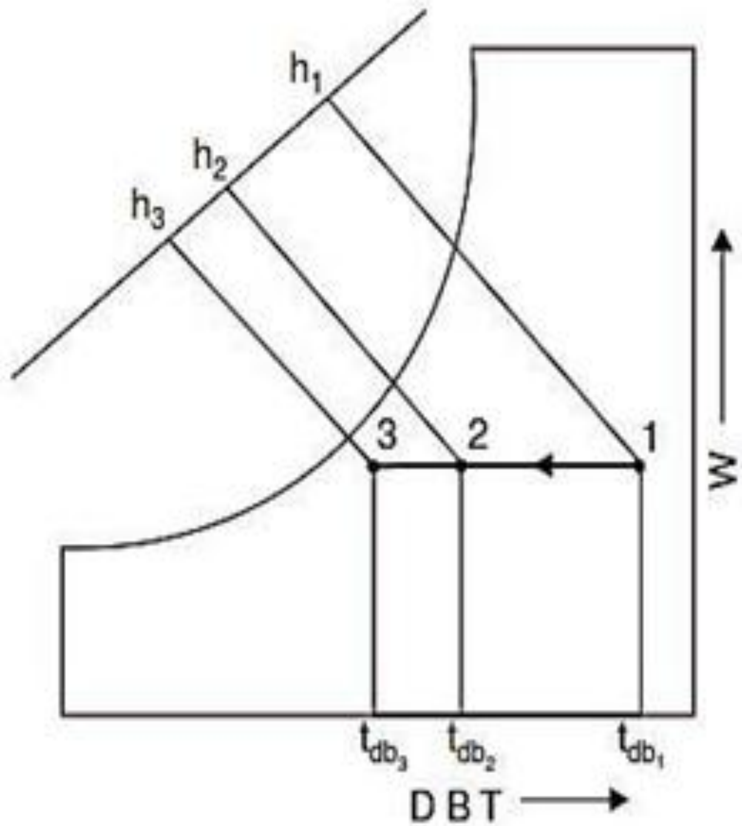
SENSIBLE COOLING

- Air undergoes *sensible cooling* whenever it passes over a surface that is at a temperature less than the *dry bulb* temperature of the *air but greater than the dew point temperature.* Thus sensible cooling can be achieved by passing the air over cooling coil like *evaporating coil of the refrigeration cycle or secondary brine coil.* During the process, *the specific humidity remains constant* and *dry bulb temperature decreases*, approaching the mean effective surface temperature. On a psychrometric chart the process will appear as a horizontal line 1–2, where point 3 represents the effective surface temperature.

$$\text{By-pass factor BF} = \frac{t_{db_2} - t_{db_3}}{t_{db_1} - t_{db_3}}$$

SENSIBLE COOLING





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LECTURE 4

FUNCTIONS & TYPES OF CONDENSORS

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TOPICS TO BE COVERED

1. **Cooling and Dehumidification**
2. **Cooling and Humidification**
3. **Heating and Dehumidification**
4. **Heating and Humidification**

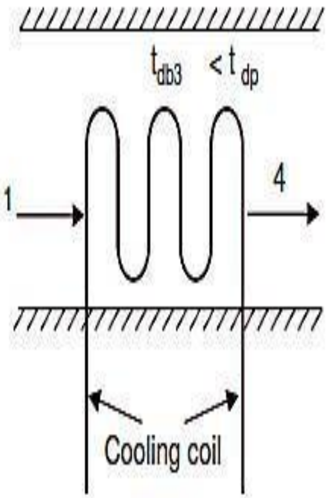
LECTURE 4

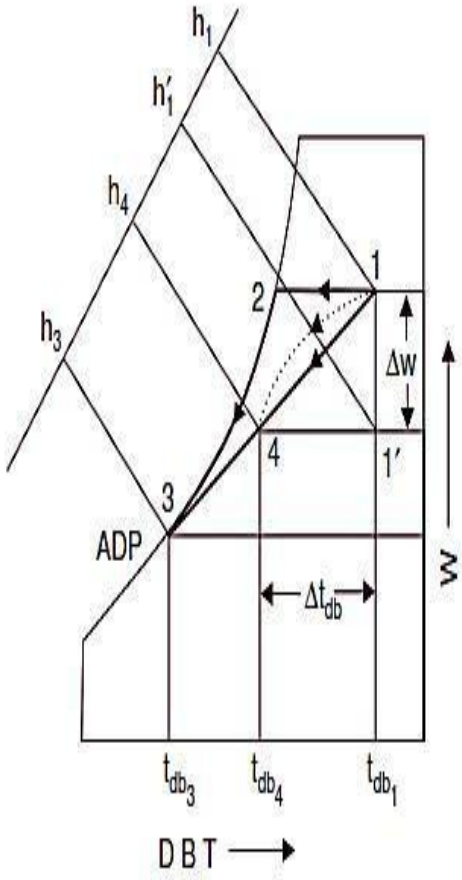
PSYCHROMETRIC PROCESSES

COOLING AND DEHUMIDIFICATION

- Whenever air is made to pass over a surface or through a spray of water that is at a temperature less than the dew point temperature of the air, condensation of some of the water vapour in air will occur simultaneously with the sensible cooling process.
- Any air that comes into sufficient contact with the cooling surface will be reduced in temperature to the mean surface temperature along a path such as 1-2-3 in Fig. I, with condensation and therefore dehumidification occurring between points 2 and 3.
- The air that does not contact the surface will be finally cooled by mixing with the portion that did, and the final state point will somewhere on the straight line connecting points 1 and 3.

COOLING AND DEHUMIDIFICATION





$$Q_t = h_1 - h_4 = (h_1 - h_1') + (h_1' - h_4)$$
$$= Q_L + Q_S$$

where, W_L = Latent heat removed $(h_1 - h_1')$, and

Q_S = Sensible heat removed $(h_1' - h_4)$

The ratio $\frac{Q_S}{Q_L}$ *is called sensible heat factor* (SHF) Or

sensible heat ratio (SHR)

$$SHF = \frac{Q_S}{Q_L + Q_S}$$

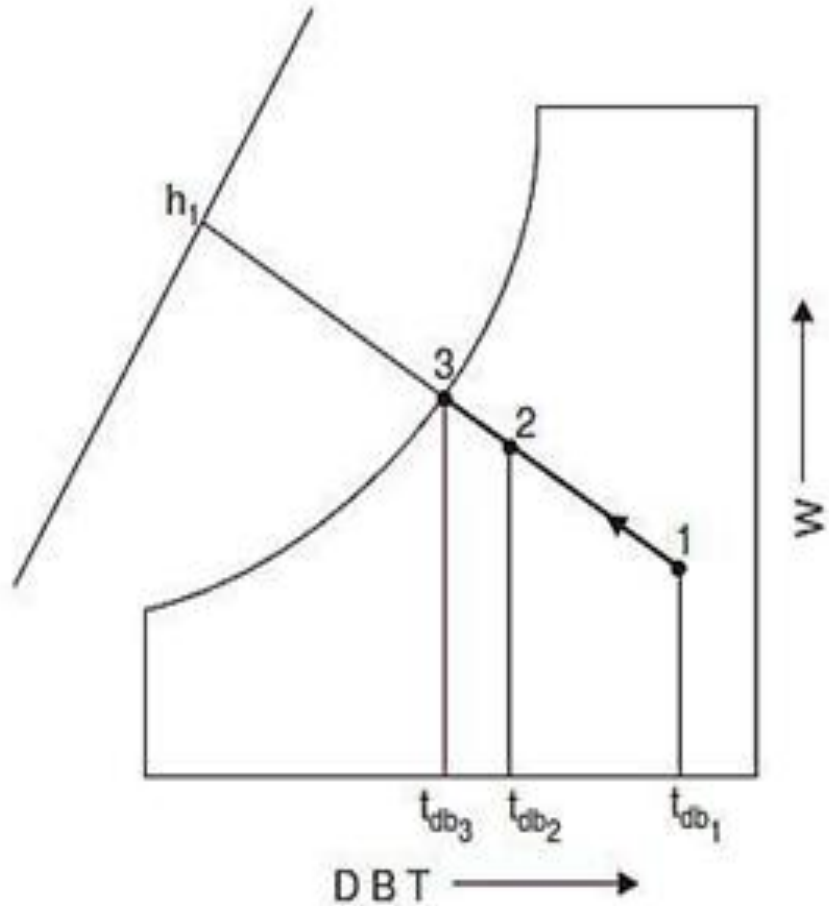
$$\text{Capacity in TR} = \frac{m_a(h_1 - h_4) \times 60}{14000},$$

COOLING AND HUMIDIFICATION

- If unsaturated air is passed through a spray of continuously recirculated water, the specific humidity will increase while the dry bulb temperature decreases.
- This is the process of **adiabatic saturation or evaporative cooling.** This process is one of constant adiabatic- saturation temperature and for all practical purposes, one of constant wet bulb temperature.
- The process is illustrated as path 1-2 on Fig. J, with wet bulb temperature of air being that of point 3, which is also equilibrium temperature of the recirculated water if there is sufficient contact between air and spray, the air will leave at a condition very close to that of point 3
- The concept of equivalent by pass can be applied to this process but another term is more used to describe the performance of a humidifying apparatus. It is the **'saturating'** or **'humidifying efficiency'** which is defined as the ratio of dry-bulb temperature decrease to the entering wet bulb depression usually expressed as percentage.

COOLING AND HUMIDIFICATION

$$\% \eta_{sat} = \left(\frac{t_{db_1} - t_{db_2}}{t_{db_1} - t_{db_3}} \right) \times 100$$

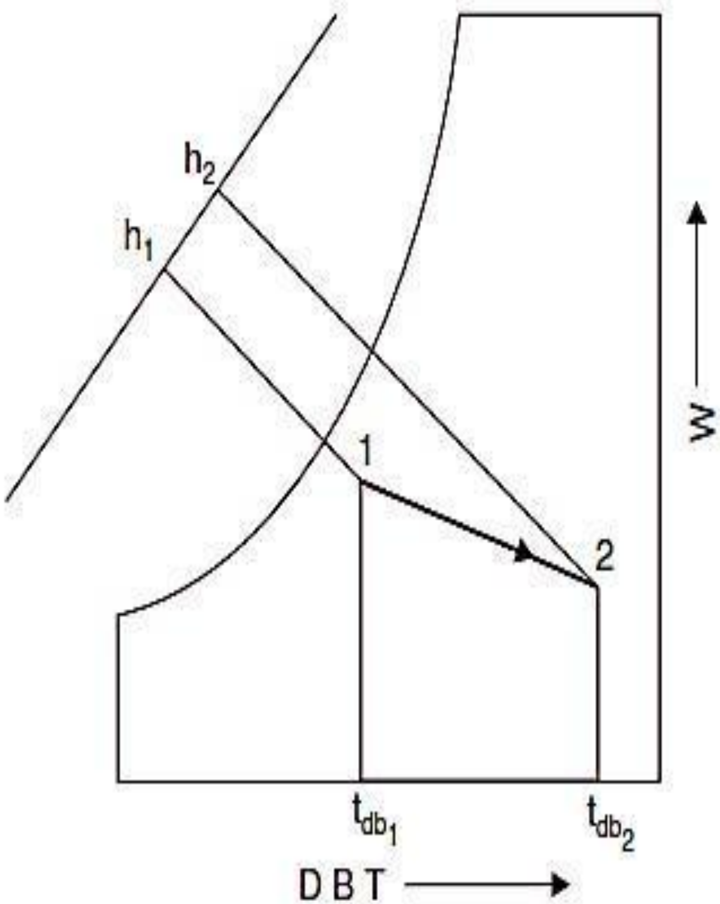


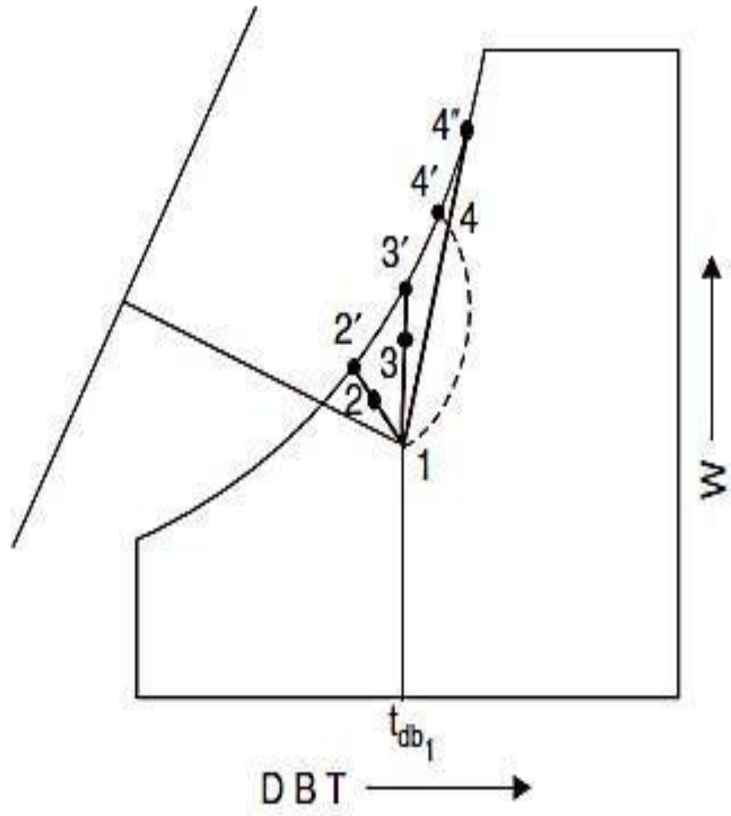
HEATING AND DEHUMIDIFICATION

- If air is passed over a solid absorbent surface or through a liquid absorbent spray simultaneous heating and dehumidification is accompanied.
- In either case the dehumidification results from adsorbent or absorbent having a lower water vapour pressure than air.
- Moisture is condensed out of the air, and consequently the latent heat of condensation is liberated, causing sensible heating of air. If these were the only energies involved, the process would be the inverse of the adiabatic saturation process.
- There is, however, an additional energy absorbed or liberated by the active material, termed the heat of adsorption or absorption. For the solid adsorbents used commercially, such as silica gel or activated alumina, and for the more common liquid absorbents, such as solutions of organic salts or inorganic compounds like ethylene, glycol, heat is involved and results in additional sensible heating

HEATING AND HUMIDIFICATION

- If air is passed through a humidifier which has heated water sprays instead of simply recirculated spray, the air is humidified and may be heated, cooled or unchanged in temperature. In such a process the air increases in specific humidity and the enthalpy, and the dry bulb temperature will increase or decrease according to the initial temperature of the air and that of the spray. If sufficient water is supplied relative to the mass flow of air, the air





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INDUSTRIAL APPLICATION

- The psychrometric chart plays a vital role in the design, analyses and optimization of various food engineering systems and processing equipments.
- The most common food processes where there is heat and moisture transfer between the food and the surrounding air. These processes are food drying, chilling, storage of grains and frozen storage of foods to draw the attention of industry in the overall understanding of the psychrometrics in food production and provide a positive insight to the literature of psychrometrics in those processes

ASSIGNMENT QUESTIONS

1. Explain the various psychrometric process in detail with the psychrometric chart.
2. The values obtained from a sling psychrometer are Tdb=30 degree celsius and Twb=20 degree celsius. The barometric readings are 740 mm of Hg. Calculate (i) dew point temp and relative humidity (ii) degree of saturation (iii) specific humidity (iv) specific volume (v) specific enthalpy.
3. Define the following psychrometric terms a. Dry Bulb temperature b.Wet bulb temperature. c. Dew point temperature d. humidity ratio
4. Explain briefly about sensible heating and Sensible cooling?
5. Explain the Heating and Humidification process with neat diagram?
6. Explain the process Cooling and Dehumidification?

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