5th Sem. /MECH/DIP IN MECH/MECH(PROD)/MECH(MAINT)/
MECH(IND INTG)/MECH(SWITCH)/ 2021(W)

Th5 Refrigeration & Air Conditioning

Full Marks: 80 Time- 3 Hrs

Answer any five Questions including Q No.1& 2
Figures in the right hand margin indicates marks

1. Answer **All** questions 2 x 10

a. Define tonne of refrigeration.

b. What is the function of refrigerant?

c. Differentiate between open & closed air refrigeration system.

d. Draw schematic diagram of Bell-Coleman cycle.

e. Write the function of rectifier in VARS.

f. Why condenser is used in refrigeration cycle?

g. Write function of expansion valves with two examples.

h. What is the chemical formula of refrigerant dichloro-difluro methane?

i. Define relative humidity.

j. Write conditions of comfort air conditioning.

2. Answer **Any Six** Questions 6 x 5

a. Compare between VCRS and VARS.

b. Explain working of single acting reciprocating air compressor with suitable diagram.

c. What should be the desirable properties of an ideal refrigerant?

d. Describe Winter Air Conditioning system.

e. Explain Shell and tube type evaporator.

f. Write about the factors affecting comfort air conditioning.

g In a refrigeration system working on Joule cycle, air is compressed to 5bar from 7bar.Its initial temperature is 10°C.After compression, air is cooled upto 20°C in a cooler before expanding back to the pressure of 1 bar. Find COP of the system. Take C_P & C_v value for air as 1.005KJ/Kg-K & 0.718 KJ/Kg-K respectively.

3 Explain simple Vapour Absorption Refrigeration System with neat sketch. 10

4 A VCRS uses refrigerant R-40 and operates between temperature limits of -10°C & 45°C.At entry to the compressor, refrigerant is dry saturated & after compression it acquires a temperature of 60°C. Find COP of the refrigerating system. The properties of R-40 are 10

Temp in °C	h_f(KJ/Kg)	h_g(KJ/Kg)	S_f(KJ/Kg-k)	S_g(KJ/Kg-k)
-10	45.4	460.7	0.183	1.637
45	133	483.6	0.485	1.587

5 The atmospheric air at 25°C DBT and 12°C WBT is flowing at the rate of 100m^3/min through the duct. The dry saturated steam at 100°C is injected into the air stream at the rate of 72 Kg/Hour. Calculate specific humidity and enthalpy of the leaving air. Also determine DBT,WBT & relative humidity of leaving air. 10

6 Write short notes on 10

a) Automatic Expansion Valve

b)Cold storage plant

7 What is psychometric chart? write its uses. Explain different types of psychometric processes. 10

5th sem

Refrigeration and Air conditioning

1.(a) Define tonne of refrigeration.

Ans: Tonne of Refrigeration: A tonne of refrigeration is defined as the amount of refrigeration effect produced by the uniform melting of one tonne (1000 kg) of ice from and at 0°C in 24 hours.

$$\text{ITR} = 1000 \times 335 \text{ kJ in 24 hr.}$$

(∵ Latent heat of ice = 335 kJ/kg)

$$= \frac{1000 \times 335}{24 \times 60}$$

$$= 232.6 \text{ kJ/min.}$$

In actual practice, ITR = 210 kJ/min. or 3.5 kJ/sec or 3.5 kW.

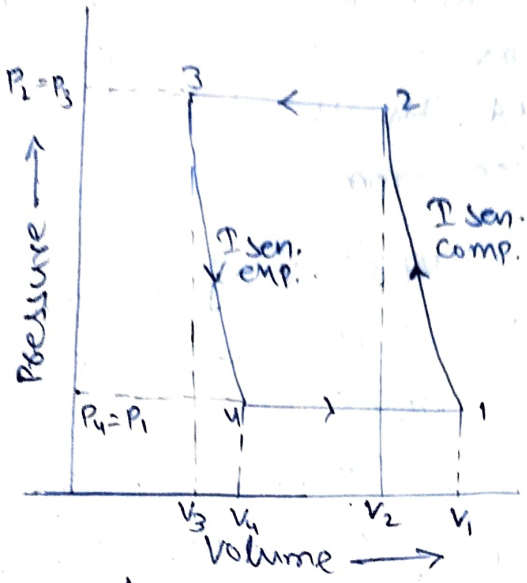
(b) What is the function of refrigerant?

The function of refrigerant is readily absorbs heat from the environment and can provide refrigeration or air conditioning when combined with other components such as compressors and evaporators.

(c) Differentiate both open and closed air refrigeration system.

Open Air refrigeration system.	Closed air refrigeration system.
(i) Air is directly led to the space to be cooled.	(i) Dense air passed through pipes all the time.
(ii) Since air is supplied to the refrigerator at atmospheric pressure, the volume of air handled by the compressor is large.	(ii) Suction pressure is higher than atmospheric pressure so a smaller volume of air is to be handled by the compressor.
(iii) Moisture leads to the formation of frost at the end of expansion.	(iii) pressure ratio can be reduced which results in higher COP.

(d) Draw schematic diagram of Bell-coleman cycle.



(P-V diagram)

(e) Write the function of rectifier in VARS.

The function of rectifier in VARS is to cool further the ammonia vapours leaving the analyser so that the remaining water vapours are condensed. Thus only dry and anhydrous ammonia vapours flow to the condenser. The condensate from the rectifier is returned to the top of the analyser by a drip return pipe.

(b) Why condenser is used in refrigeration cycle?

A condenser's function is to allow high pressure and temperature refrigerant vapor to condense and reject heat.

→ In a cooling cycle of a refrigeration system, heat is absorbed by the vapor refrigerant in the evaporator followed by the compression of the refrigerant by the compressor.

→ The higher pressure and high temp. state of the vapour refrigerant is then converted to liquid at the cond.

(g) write function of expansion valves with two examples.

→ The function of expansion valves removes pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapor in the evaporator.

→ Basically they have two important purpose:-

(i) Controlling the amount of refrigerant flowing to the evaporator.

(ii) Maintaining the pressure difference betn condenser and evaporator.

(h) what is the chemical formula of refrigerant dichloro-difluoro-methane?

Ans: CCl_2F_2 , R-12

(i) Define relative humidity.

It is the ratio of actual mass of water vapour is 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.

(j) Write conditions of comfort air conditioning.

Ans:- conditions of comfort air conditioning is to be

(i) Temperature of air

(ii) Humidity of air

(iii) Purity of air

(iv) Motion of air.

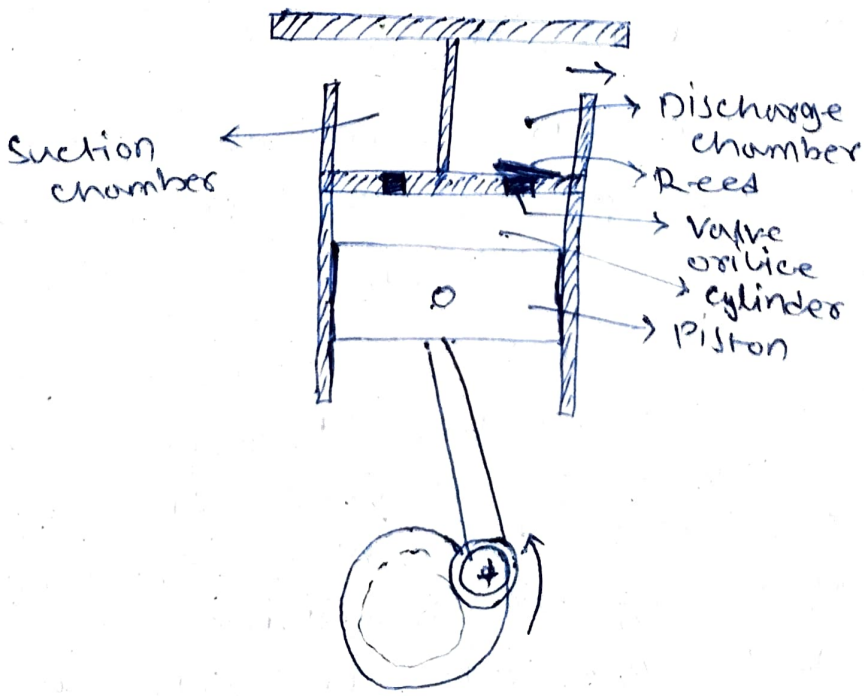
2.(a) Compare betn VCRS and VARS.

VCRS	VARS
(i) Vapor compression Refrigeration system has high C.O.P	(i) Vapor absorption Refrigeration System has low C.O.P.
(ii) The charging of refrigerant is simple.	(ii) The charging of refrigerant is difficult.
(iii) A possibility of leakage of refrigerant is more.	(iii) A possibility of leakage of refrigerant is less.
(iv) Performance is adversely affected by part loads.	(iv) Reduced loads have no effect on its Performance.
(v) It can not be located outside without shelter.	(v) It can be located outside without shelter.
(vi) It is less bulky.	(vi) It is bulky.
(vii) wear and tear are high.	(vii) wear and tear are less.
(viii) Liquid traces in the suction line may damage the compressor.	(viii) Liquid traces in the refrigerant at the exit of the evaporator is not harmful to any component.
(ix) It has a compressor and a motor. Therefore, It is more noise in operation.	(ix) It has a pump only a moving part. hence it is quiet in operation.

2.(b) Explain working of single acting reciprocating air compressor with suitable diagram.

Ans:- In single stage reciprocating air compressor, the entire compression is carried out in a single cylinder. The opening & closing of a simple check valve depends upon the difference in pressure, if mechanically operated valves are

used for suction and discharge then their functioning is controlled by cams. The weight of air in the cylinder will be zero when the piston is at top dead centre. At this position, you have to neglect clearance volume. when piston starts moving downwards, the pressure inside the cylinder falls below atmospheric pressure and suction valve/inlet valve opens. The air is drawn into the cylinder through a suction filter element. This operation is known as suction stroke. when the piston moves upwards, compresses the air in cylinder and inlet valve closes when the pressure reaches atmospheric pressure. Further compression follows as the piston moves towards the top of its stroke. Until when the pressure in the cylinder exceed that in the receiver. This is compression stroke of a compressor. At the end of this stroke discharge / delivery valve opens and air is delivered to a receiver.



2.(c) What should be the desirable properties of an ideal refrigerant ?

Ans:-

→ Low boiling point.
→ High critical temperature.
→ High latent heat of vaporisation.
→ Non-corrosive to metal.
→ Low specific volume of vapours.
→ Low specific heat of liquid.
→ Non-flammable and non-explosive.
→ Non-toxic.
→ Low cost.
→ Mixes well with oil.
→ Easy of locating leaks by odour or suitable indicator.

(d) Describe winter Air conditioning system :-

Ans:

In winter air conditioning, the air is heated, which is generally accompanied by humidification. The schematic arrangement of the system.

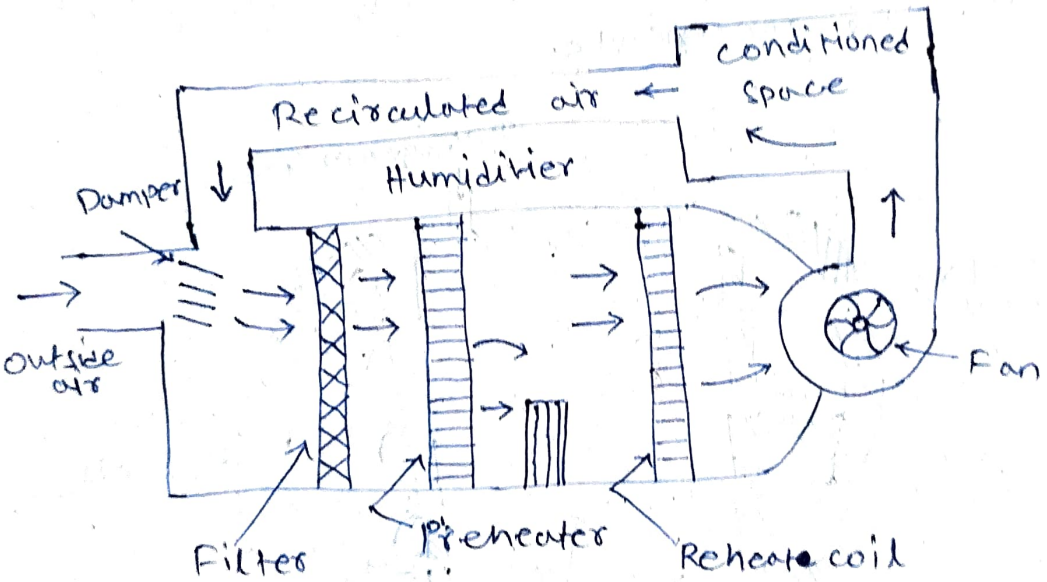
→ The outside air flows through a damper and mixes up with the recirculated air. The mixed air passes through a filter to remove dirt, dust and other impurities.
→ The air now passes through a preheat coil in order to prevent the possible breeze of water and to control the evaporation of water in the humidifier.
→ After that, the air is made to pass through a reheat coil to bring the air to the

designed dry bulb temperature.

→ Now, the conditioned air is supplied to the conditioned space by a fan from the conditioned space. a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators.

→ The remaining part of the used air is again conditioned.

→ The outside air is sucked and made to mix with recirculated air, in order to make up for the loss of conditioned air through exhaust fans or ventilation from the conditioned space.



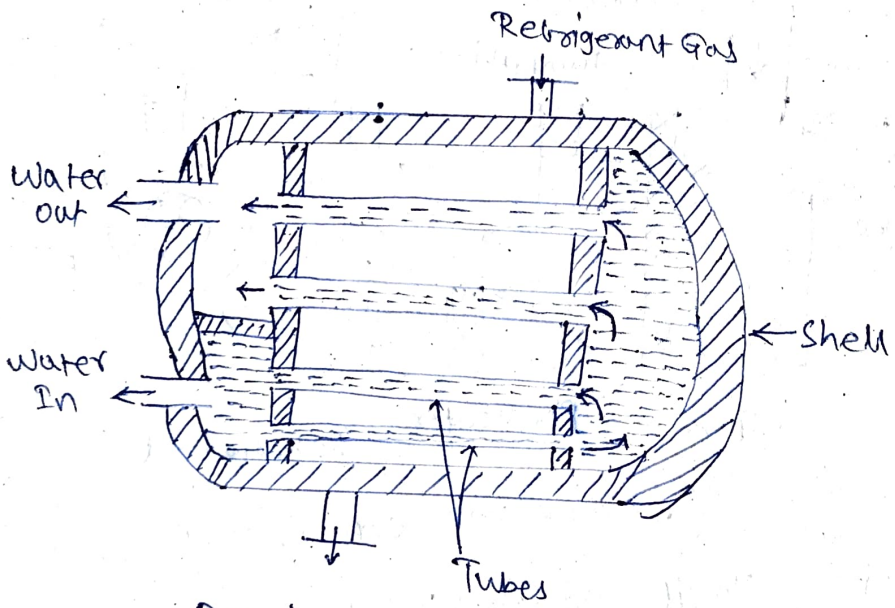
(winter air conditioning system.)

2.(e) Explain shell and tube type evaporator.

A shell and tube condenser consists of a cylindrical shell in which a number of straight tubes are arranged in parallel and held in place at the ends by tube sheets. The condensing water is circulated through the tubes, which may be either steel or copper, bare or extended surface. The refrigerant is contained in the steel shell betn the tube sheets.

water circulates in the annular spaces betn the tube sheets and the end plates, the end plates being baffled to act as manifolds to guide water flow through the tubes. The arrangement of the end-plate baffling determines the number of passes the water makes through the condenser from one end to the other before leaving the condenser. The number of passes may vary from 2 to 20.

→ In such condensers, the upper tubes act as desuper heaters while the tubes at the bottom yield subcooled condensate. If there is any oil associated with refrigerant, it flows with the condensate.



(Shell and Tube condenser)

2(b) Write about the factors affecting comfort air conditioning.

Ans: The factors affecting the comfort of a air conditioning.

→ Effective temperature.

→ Heat production and regulation in human body.

→ Heat and moisture losses from the human body.
→ Moisture content of air.
→ Quality and quantity of air.
→ Air motion.
→ Hot and cold surfaces.
→ Air stratification.

2(g) In a refrigeration system working on Joule cycle, air is compressed to 5 bar from 1 bar. Its initial temperature is 10°C. After compression air is cooled upto 20°C in a cooler before expanding back to the pressure of 1 bar. Find COP of the system. Take C_p & C_v value for air as 1.005 kJ/kg-K & 0.718 kJ/kg-K respectively.

Solution: Given Data,

$P_2 = P_3 = 5$ bar

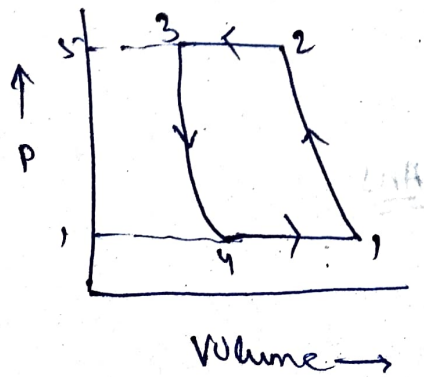
$P_1 = P_4 = 1$ bar

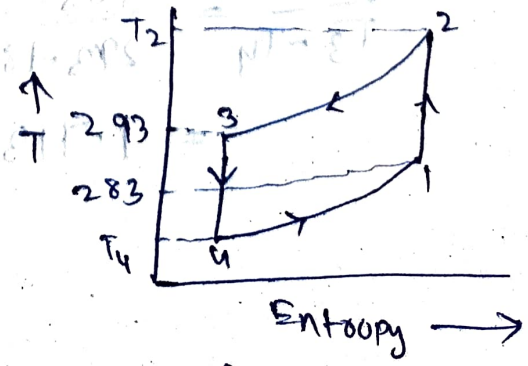
$T_1 = 10°C = 10 + 273 = 283$ K

$T_3 = 20°C = 20 + 273 = 293$ K

$C_p = 1.005$ kJ/kg K

$C_v = 0.718$ kJ/kg K





we know that isentropic index for compression and expansion process,

$$\gamma = c_p/c_v$$
$$= \frac{1.005}{0.718}$$
$$= 1.4$$

For isentropic compression process 1-2,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$
$$= \left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}}$$
$$= (5)^{0.286}$$
$$= 1.584$$

and for isentropic expansion process 3-4

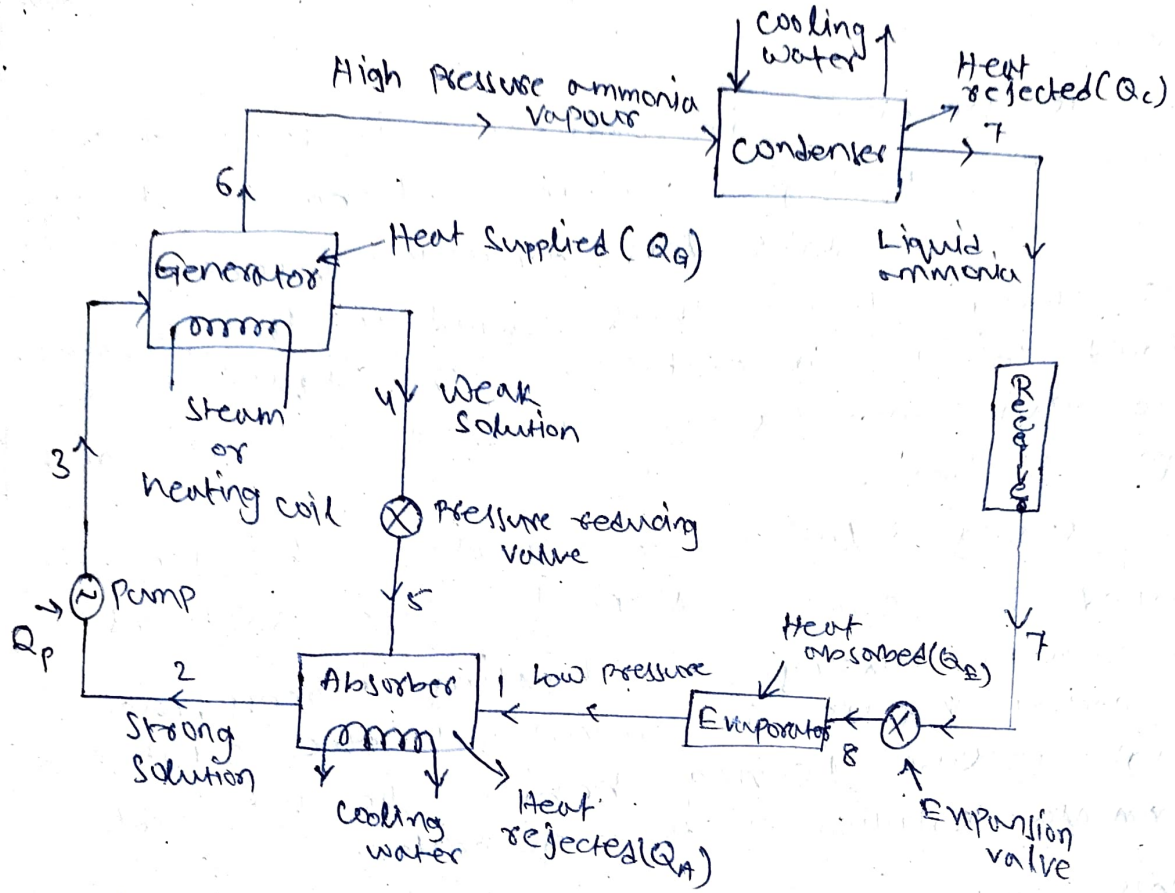
$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$
$$= \left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}} = (5)^{0.286} = 1.584$$

$$T_4 = T_3/1.584 = 293/1.584$$
$$= 185\ K.$$

C.O.P. of the plant

$$= \frac{T_4}{T_3 - T_4} = \frac{185}{293-185}$$
$$= 1.713$$ Ans

3. Explain simple vapour Absorption Refrigeration System with net sketch.



→ The simple vapour absorption system, consists of an absorber, a pump, a generator and a pressure reducing valve to replace the compressor of vapour compression system.

→ The other components of the system are condenser, reciver, expansion valve and evaporator as in the vapour compression system.

→ In this system, the low pressure ammonia vapour leaving the evaporator enters the absorber where it is absorbed by the cold water in the absorber. The water has the ability to absorb very large quantities of ammonia vapour and the solution, thus formed is known as aqua - ammonia.

→ The absorption of ammonia vapour in water lowers the pressure in the absorber which is turn drawn more ammonia vapour from the evaporator

and thus raises the temperature of solution. Some form of cooling arrangement is employed in the absorber to remove the heat of solution evolved there.

→ This is necessary in order to increase the absorption capacity of water, because at higher temp. water absorbs less ammonia vapour.

→ The strong solution thus formed in the absorber is pumped to the generator by the liquid pump. The pump increases the pressure of the solution upto 10 bar.

→ The strong solution of ammonia in the generator is heated by some external source such as gas or steam. During the heating process, the ammonia vapour is driven off the solution at high pressure leaving behind the hot weak ammonia solution in the generator.

→ This weak ammonia solution flows back to the absorber at low pressure after passing through the pressure reducing valve. The high pressure ammonia vapour from the generator is condensed in the condenser to a high pressure liquid ammonia. This liquid ammonia is passed to the expansion valve through the reciver and then to the evaporator. This completes the simple vapour absorption cycle.

Q. A VCRS uses Refrigerant R-40 and operates between temperature limits of -10°C & 45°C. At entry to the compressor, refrigerant is dry saturated and after compression it acquires a temp. 60°C. Find COP of the refrigerating system. The properties of R-40 are.

Temp in °C	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kg-k)	s_g (kJ/kg-k)
-10	45.4	460.7	0.183	1.637
45	133	483.6	0.485	1.587.

Solution: Given Data,

$T_1 = T_4 = -10°C = -10 + 273 = 263K$

$T_2' = T_3 = 45°C = 45 + 273 = 318K$

$T_2 = 60°C = 60 + 273 = 333K$

$h_{f1} = 45.4$ kJ/kg

$h_{f3} = 133$ kJ/kg

$h_1 = 460.7$ kJ/kg

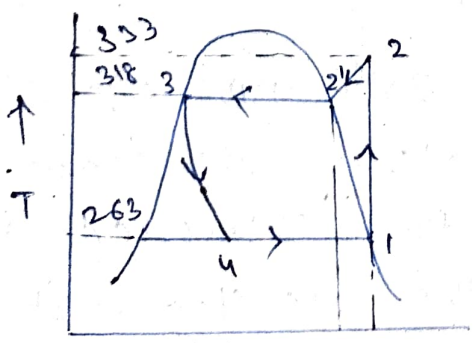
$h_2' = 483.6$ kJ/kg

$s_{f1} = 0.183$ kJ/kg K

$s_{f3} = 0.485$ kJ/kg K

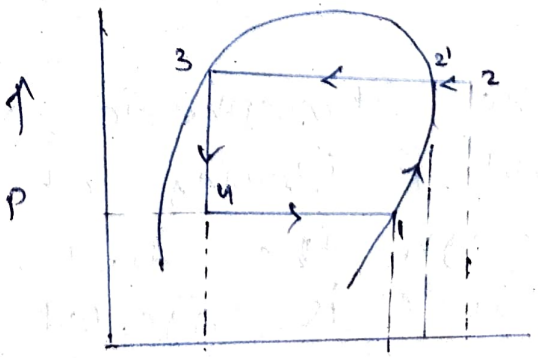
$s_1 = s_2 = 1.637$ kJ/kg K

$s_2' = 1.587$ kJ/kg K.



$s_1 = s_2$

Entropy →



Enthalpy →

(p-h diagram)

Let c_p = Specific heat at constant pressure for superheated vapour.

We know that entropy at point 2,

$$s_2 = s_2' + 2.3\, c_p \log\left(\frac{T_2}{T_2'}\right)$$

$$\Rightarrow 1.637 = 1.587 + 2.3\, c_p \log\left(\frac{333}{318}\right)$$

$$= 1.587 + 2.3\, c_p \times 0.02$$

$$= 1.587 + 0.046\, c_p$$

$$c_p = 1.09$$

$$h_2 = h_2' + c_p \times \text{Degree of superheat}$$

$$= h_2' + c_p (T_2 - T_2')$$

$$= 483.6 + 1.09 (333 - 318)$$

$$= 500 \text{ kJ/kg}.$$

∴ COP of the refrigerator.

$$= \frac{h_1 - h_{f3}}{h_2 - h_1}$$

$$= \frac{460.7 - 133}{500 - 460.7}$$

$$= 8.34 \quad \underline{\text{Ans}}$$

5. The atmospheric air at 25°C DBT and 12°C WBT is blowing at the rate of 100 m³/min through the duct. The dry saturated steam at 100°C is injected into the air steam at the rate of 72 kg/Hour. Calculate specific humidity and enthelpy of the leaving air. Also determine DBT, WBT, & relative humidity of leaving air

Solution: Given Data

$t_{d_1} = 25°C$, $t_{w_1} = 12°C$, $V_1 = 100\ m^3/min$

$t_s = 100°C$

$m_s = 72\ kg/h = 1.2\ kg/min$

Specific humidity of the leaving air.

$V_{s_1} = 0.844\ m^3/kg$ of dry air

Specific humidity of air at point 1,

$w_1 = 0.0034\ kg/kg$ of dry air

Enthalpy of air at point 1,

$h_1 = 34.2\ kJ/kg$ of dry air

we know that mass of air blowing,

$$m_a = \frac{V_1}{V_{s_1}} = \frac{100}{0.844}$$

$$= 118.5\ kg/min.$$

$$w_2 = w_1 + \frac{m_s}{m_a}$$

$$= 0.0034 + \frac{1.2}{118.5}$$

$$\boxed{w_2 = 0.0135\ kg/kg}$$ of dry air. Ans

Enthalpy of leaving air

$$h_2 = h_1 + \frac{m_s}{m_a} \times h_s$$

$$= 34.2 + \frac{1.2}{118.5} \times 2676$$

$$\boxed{h_2 = 61.3\ kJ/kg}$$ of dry air Ans

Dry bulb temperature, WBT and relative humidity of the leaving air.

Make the condition of leaving air on the Psychrometric chart as point 2 corresponding to $\omega_2 = 0.0135$ kg/kg of dry air and $h_2 = 61.3$ kJ/kg of dry air air.

Now from the Psychrometric chart corresponding to point 2,

Dry bulb temperature of the leaving air

$$t_{d2} = 26.1^\circ C. \quad \text{Ans}$$

WBT of the leaving air

$$t_{w2} = 21.1^\circ C \quad \text{Ans}$$

Relative humidity of the leaving air,

$$\phi_2 = 62\% \quad \text{Ans}$$

6) a) Automatic Expansive valve:-

i) The automatic expansion valve is also known as constant pressure expansion valve, because It maintains constant evaporator pressure regardless of the load on the evaporator, Its main moving force is the evaporator pressure It is used with dry expansion evaporators where the load is relatively constant.

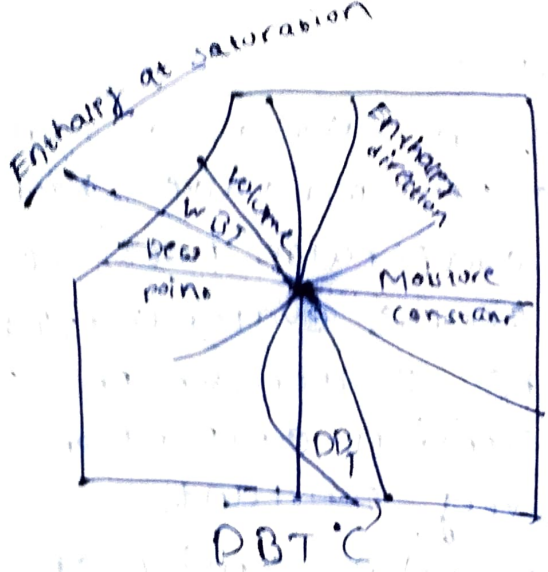
ii) The automatic expansion valve, consist of a needle valve and a seat (which forms on office), a metallic diaphragm or bellows, spring and an adjusting screw. The opening and closing of the valve with respect to the seat depends upon the forces.

(b) : Cold storage Plant:-

i) An installation intended for the cooling, freezing and cold storage of perishable food products and other perishables. A large cold storage facility, which operates as an independent enterprise, comprises a cold-storage warehouse with truck and rail road plat forms, compressor and condensor rooms for a refrigerating system, a cooling tower, reservoirs and a pumping station for a circulating water supply, administration and residential boilings and other building and installation

ii) cold storage facilities are often found at plants that make ice cream, dry ice, or liquid carbon dioxide or at plants that, for example package butter. complexes of this type are called cold storage plants.

7)



Psychometric Process :- The process affecting the psychometric properties of air are called psychometric process. There are:

(i) Mixing of air streams
(ii) sensible heating
(iii) sensible cooling
(iv) cooling and dehumidification
(v) cooling and humidification
(vi) Heating and dehumidification
(vii) Heating and humidification.

(i) 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 adiabatically and at constant total moisture content.

(ii) sensible Heating :- when air passes over a dry surface which is at a temperature greater than its (air) dry bulb temperature (DBT), it undergoes sensible heating.

iii) 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

iv) 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 vapoor in air will occur simultaneously with the sensible cooling process.

v) Cooling and humidification :-

If unsaturated air is passed through a spray of continuously recirculated water, the specific humidity will increase while dry bulb temperature decreases. This is the process of adiabatic saturation or evaporative cooling. This process is one of the constant adiabatic saturation or evaporative cooling

vi) Heating and Dehumidification :-

If air is passed over a solid adsorbent or through a liquid absorbent spray simultaneous heating and dehumidification results from adsorbent or absorbent having a lower water vapour pressure than air

vii) Heating and Humidification:

If air is passed through a humidifier which has heated water sprays instead of simply recirculated spray, the air is dehumidified and may be heated, cooled or unchanged in temperature. The air increases in specific humidity and the enthalpy and the DBT will increase or decrease according to the initial temperature of the air and that of the spray.