T.Y. Diploma : Sem. VI

[ME/PG/PT/MH/MI/FE/FG]

Refrigeration and Air Conditioning

Time : 3 Hrs.] Prelim Question Paper Solution **[Marks : 100**

Q.1(a) Attempt any THREE of the following: [12]

Q.1(a) (i) Plot Reverse Carnot cycle on P–V and T–S diagram. Mention all the processes involved in the cycle. [4]

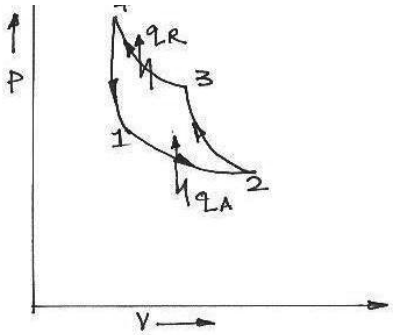
Ans.: Reversed carnot cycle on P-V and T-S plane [2+2 marks]

Processes :

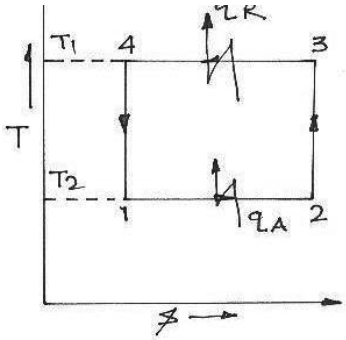
1-2- Reversible isothermal heat absorption

2-3 -Reversible adiabatic compression.

P –V Plane



T –S Plane



3-4 -Reversible isothermal heat rejection.

4-1- Reversible isothermal heat rejection.

Q.1(a) (ii) State desirable properties of ideal refrigerant. [4]

Ans.: Properties of ideal refrigerant [Any eight - 4 marks]

(1) Boiling point at atmospheric pressure should be low.
(2) Freezing point at atmospheric pressure should be low.
(3) Latent heat of vaporization of refrigerant must be high.
(4) Critical temperature should be high.
(5) It should not have corrosive action with system material.
(6) It should not be flammable & explosive.
(7) It should not be toxic.
(8) It leak should be easily detectable.
(9) It should have positive condensing pressure.
(10) It should have satisfactory heat transfer coefficient.
(11) It should have high thermal conductivity.
(12) It should have chemical stability.

Q.1(a) (iii) Compare primary and secondary refrigerant. [4]

Ans.: Primary Refrigerant: [4 marks]

(1) The refrigerants which directly take part in refrigeration system are called primary refrigerant.
(2) Primary refrigerants are used in domestic refrigerator and Air conditioning system etc.
(3) Primary refrigerants are R-11, R-12, R-21, R-143a etc.

Secondary Refrigerant:

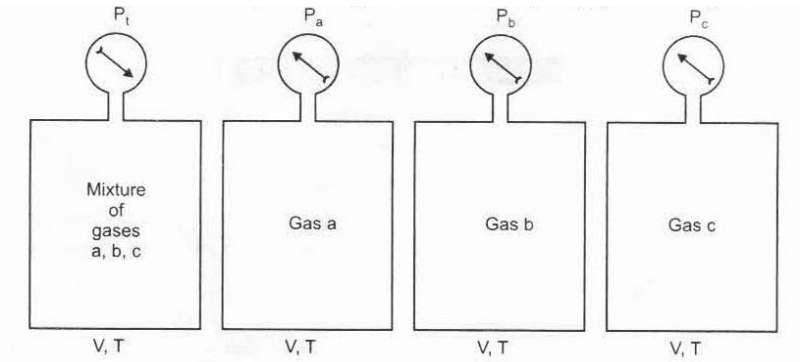
(1) The refrigerants which are first cooled by primary refrigerant and then used for cooling purpose are called as secondary refrigerant.
(2) It is used in ice plant and in big installation.
(3) Secondary refrigerants are water, brine, glycol etc.

Q.1(a) (iv) State Dalton's law of partial pressure. **[4]**

Ans.: Dalton's law of Partial Pressure [4 marks]

Dalton's law of partial pressure states that "the total pressure of mixture of gases equal to the sum of the partial pressures exerted by each gas when it occupies the mixture volume at the temperature of mixture".

Consider the mixture of gas having constituents of gas a, gas b and gas c.



Mixture of gas a, b, c at volume V and temperature T shows the total pressure P_t. if gas a, b, c is separated and kept at same volume V and temperature T it will show pressure P_a, P_b and P_c respectively.

Where P_a = Partial pressure of gas a.

P_b = Partial pressure of gas b.

P_c = Partial pressure of gas c.

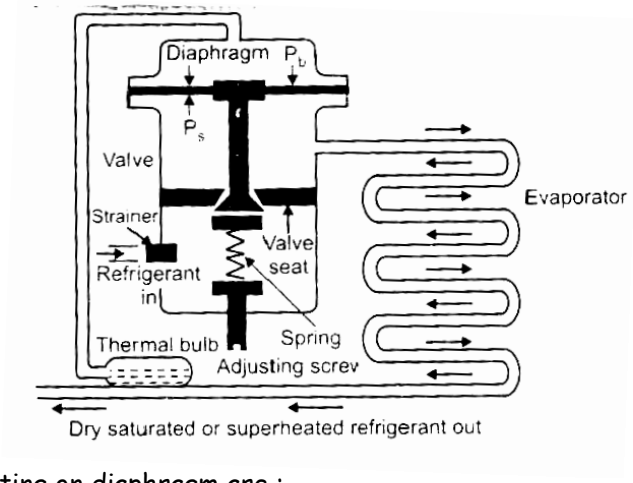
According to Dalton's law of partial pressure, $P_t = P_a + P_b + P_c$

Q.1(b) Attempt any ONE of the following: **[6]**

Q.1(b) (i) Explain with neat sketch 'Thermostatic expansion valve'. **[6]**

Ans.: Thermostatic expansion valve [Sketch & Explanation - 3 marks each]

Thermostatic expansion valve consists of diaphragm valve, valve seat, spring adjusting screw and thermal bulb. Thermal bulb is used to check temperature in evaporator. In thermal bulb same refrigerant can be used, which is filled in refrigeration system. The valve used in TEV open in downward direction by changing pressure on diaphragm.



The pressures acting on diaphragm are :

(1) Bulb pressure from thermal bulb acting in downward direction.

(2) Spring pressure acting in upward direction.

(3) Evaporator pressure from evaporator.

Thermostatic expansion valve is fitted in liquid line just ahead of evaporator in direction of arrow provided on it and thermal bulb is clamped with exit line of evaporator.

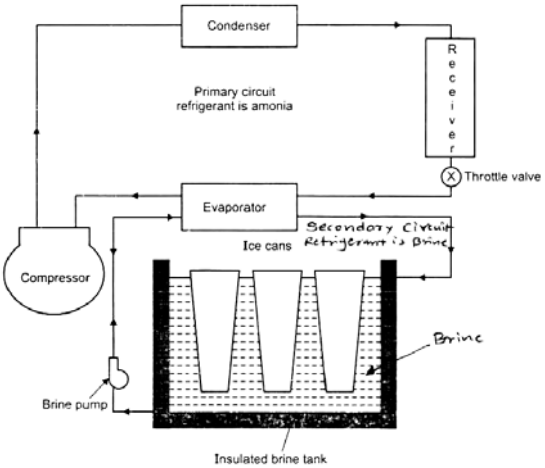
For constant load operation adjusting screw is adjusted such that it allows constant mass flow rate of refrigerant to evaporator.

The valve responds to change in temperature in evaporator. When there is load on evaporator, superheated vapours are coming at exit of evaporator, which transfers its heat to thermal bulb. Due to this, refrigerant filled in thermal bulb vaporizes and increases the bulb pressure to open up valve allowing more liquid refrigerant into evaporator.

When there is decrease in load on evaporator, vapours at the exit of evaporator absorbs heat from thermal bulb and reduces the pressure on diaphragm to reduce opening of valve resulting in reduction in mass flow rate of refrigerant entering in evaporator.

Q.1(b) (ii) Explain with neat sketch 'Ice Plant'. **[6]**

Ans.: Ice Plant [Sketch & Explanation - 3 marks each]



The ice plant is shown in Fig. The cycle used for the ice plant is vapour compression cycle with ammonia as the refrigerant in primary circuit and brine solution in secondary circuit. Brine solution takes heat from water in secondary circuit and delivers the heat to ammonia in primary circuit. Thus, the indirect method of cooling is used in ice plant. In secondary circuit brine is cooled first in evaporator and then it is circulated around the can which contains water. The heat is extracted from the water through the can and is given to brine. The brine is continuously circulated around the can and is given to brine. The brine is circulated around the can with the help of pump till entire water in can is converted into ice.

In primary circuit, ammonia is used as refrigerant. Ammonia vapour coming out of evaporator is compressed to high pressure and then vapours are condensed in condenser. Open type of compressor is generally used for ice plant. Evaporative condenser is used, in which same cooling water can be used again and again. High pressure liquid ammonia is collected in receiver and then it is passed through the expansion valve. The throttled ammonia at low temperature and low pressure enters in evaporator, which is coil dipped in brine. The liquid ammonia absorbs heat from brine and converts into vapours, which are drawn by compressor. The ice can after removing from brine solution is dipped into thawing tank for few minutes, which helps for easy removal of ice slab from can. The temperature of brine circulated is about 10°c and the ice formation is continued fill its temperature is 6°c.

Q.2 Attempt any TWO of the following : **[16]**

Q.2(a) What is sensible and latent heat gain? List the sources of sensible and latent heat gain in a restaurant. **[8]**

Ans.: Sensible heat gain-When there is direct addition of heat to the enclosed space, a gain in sensible heat is said to be occur. [1 mark]

Latent heat gain-When there is addition of water vapour to the air of enclosed space, a gain in latent heat is said to be occur. [1 mark]

List of Heat sources in Restaurant- (Here assume a large restaurant for air conditioning)

Two main components of heat load are [Any Six source - 1 mark each]

1. Sensible heat load and 2. Latent heat load.

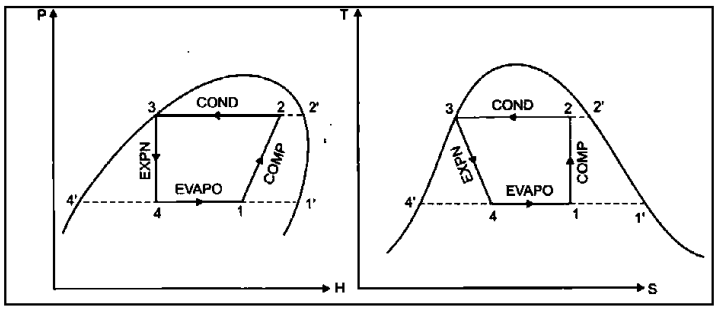
1. **Sensible heat gain through structure by conduction :**
   Q=U* A*(to-ti)
   Where-Q=Total heat transfer,
   A=Outside area of wall,
   to= Outside air temperature,
   ti = Inside air temperature,
2. **Sensible heat gain from solar radiation through walls and roof :**
   Q=U*A*te
   Where Q=Total heat transfer,
   A=area of roof or wall,
   te=Equivalent temperature differential.
3. **Heat gain due to infiltration :** (using air change method)
   Amount of infiltrated air through windows and wall is
   = (L*W*H*Ac)/60 m3/min. Both sensible and latent heat load gain.
4. **Heat gain through ventilation :**
   The ventilation (supply of outside air) is provided to the conditioned space in order to minimise smoke concentration, carbon dioxide and other undesirable gases.
   1/2 air should be change per hour in buildings in normal ceiling heights. The outside air adds sensible as well as latent heat load.
5. **Heat gain from appliances/Lighting Equipment's :**
   Appliances used may be coffee braver, egg boiler, grinder, food warmer ,toaster etc.
   Appliances may be gas fire or steam heated.
   Heat gain can be calculated as-
   Q = (Total Wattage *use factor*Allowance Factor).
6. **Heat gain from power equipment's :**
   Such as motor, fan or other equipment of this type also add heat in the air conditioned space- Ex-Electric motor used ,then heat added in KW
   Q = (rating of motor (KW)* Load Factor)/Motor Efficiency.
7. **Heat gain from Occupants :**
   The human body in cooled space constitutes cooling load of sensible and latent heat. Heat gain depends on average number of people present in restaurant and activity of person.

Q.2 (b) Represent a neat labelled T-S & P-H diagram for the following : [8]

(i) Wet refrigerant at the end of compression

(ii) Dry and saturated refrigerant at the end of compression, also write C.O.P. equations for the both conditions.

Ans.: (i) Wet refrigerant at the end of compression: [4 marks]



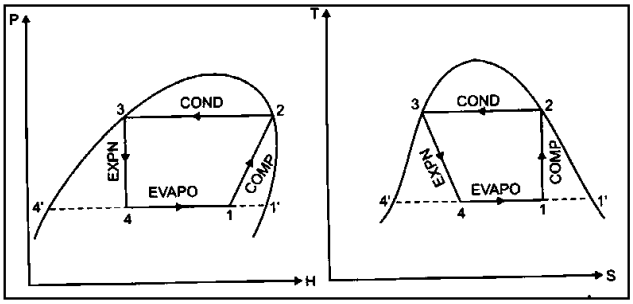
$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP = \frac{\left[h'_4 + x_1\left(h'_1 - h'_4\right)\right] - h_4}{\left[h_3 + x_2\left(h'_2 - h_3\right)\right] - \left[h'_4 + x_1\left(h'_1 - h'_4\right)\right]}$$

Where $h_1 = h'_4 + x_1 (h'_1 - h'_4)$

$h_2 = h'_3 + x_2 (h'_2 - h'_3)$

(ii) Dry and saturated refrigerant at the end of compression: [4 marks]



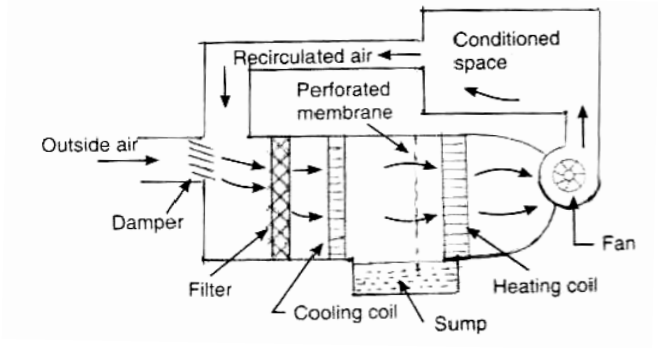
$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP = \frac{\left[h'_4 + x_1\left(h'_1 - h'_4\right)\right] - h_4}{h_2 - \left[h'_4 + x_1\left(h'_1 - h'_4\right)\right]}$$

Where $h_1 = h'_4 + x_1 (h'_1 - h'_4)$

Q.2 (c) Explain with neat sketch summer and winter Air-conditioning system. **[8]**

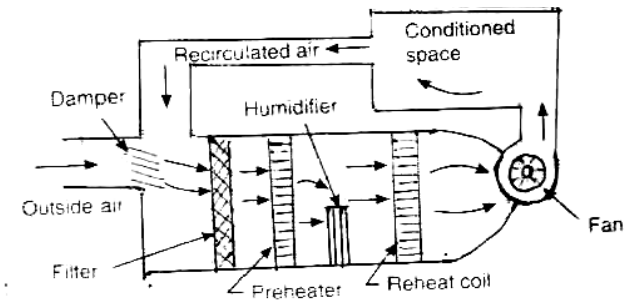
Ans.: Summer Air-conditioning system : [Sketch & Explanation - 2 marks]



Summer air conditioning system is used to provide human comfort in summer season. In summer season outdoor temperature is high and occupant feel comfortable at relatively low temperature. Air is passed over cooling coil where it reduces its temperature but relative humidity exceeds human comfort range. The air is passed over heating coil which restores humidity within comfort zone and observe slight increase in temperature. Thus, the measure problem in summer air conditioning is to cool air and remove excess moisture from it.

In summer air conditioning re-circulated air and fresh air are mixed together. The stream of air is passed to cooling coil through filter.

Winter Air-conditioning system : [Sketch & Explanation - 2 marks]



Winter air conditioning system is used where outdoor temperature is considerably low (5°c to 10°c). This system can be used in cities like Delhi, Chandigarh during winter season to get comfort condition. The comfort condition commonly used is 20°c to 23°c temperatures and 60% relative humidity.

In winter air conditioning system, recirculated air and outdoor fresh air are mixed. The stream of air is passed to spray chamber through filter and preheating coil. The function of filter is to remove dust, dirt and harmful bacteria from air to make it clean and pure.

Q.3 Attempt any FOUR of the following : [16]

Q.3(a) Classify compressor. [4]

Ans.: 1. According to the method of compression : [Any four points - 1 mark each]

(i) Reciprocating compressor (ii) Rotary compressor (iii) Centrifugal compressor

2. According to number of stages :

(i) Single stage compressor : Delivery pressure up to 10 bar

(ii) Multistage compressor: Delivery pressure above 10 bar

3. According to number of cylinder :

(i) Single cylinder compressor (ii) Multi cylinder compressor

4. According to method of cooling :

(i) Air cooled compressor (ii) Water cooled compressor

5. According to action of air :

(i) Single acting compressor (ii) Double acting compressor

6. According to capacity :

(i) Low capacity (ii) Medium capacity (iii) High capacity

7. According to the method of drive employed :

(i) Direct drive compressor (ii) Belt drive compressor

Q.3 (b) State advantages of multistaging in vapour compression system. [4]

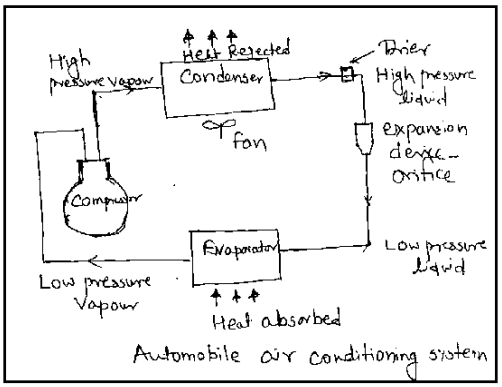
Ans.: Advantages of multi-staging in vapor compression system are : [4 marks]

1. Work done per kg of refrigerant is reduces by using an intercooler.
2. Volumetric efficiency of compressor increases.
3. It reduces leakage of refrigerant.
4. It gives uniform torque therefore smaller flywheel may be used.
5. Effective lubrication can be done.
6. Cost of compressor reduces.

Q.3 (c) Explain automobile air-conditioning systems. [4]

Ans.: Automobile air conditioning system : [Sketch & Working - 2 marks]

Air conditioners work on the principle that "liquids absorb heat when they become a vapour (evaporate). Low pressure R134a vapor entering the compressor is compressed to become high pressure/temperature R134a vapor. This is then circulated along with lubricant oil to the condenser. As the high pressure/temperature vapor travels through the condenser, heat is released to the cooler ambient air passing over the condenser tubes condensing the vapor into a liquid. This high pressure/temperature liquid then travels through the filter drier onto the expansion valve where a small variable orifice provides a restriction against which compressor pushes.



Automobile air conditioning system

Suction from the compressor pulls the high pressure/temperature liquid R134a through small variable orifice of the TX valve and into the low-pressure side of the A/C system. The R134a is now under low pressure/temperature vapor where heat from the cabin being blown over the evaporator coil surface is absorbed into the colder low pressure refrigerant The R134a is then pulled through the evaporator and into the compressor.

The A/C cycle begins again as the R134a vapor is compressed and discharged under pressure. Heat transfer R134a in the LOW-PRESSURE side is COLD and can absorb large quantities of heat from the air moving over the evaporator. R134a in HIGH-PRESSURE side is HOT and the cooler ambient air moving over the condenser can absorb the heat from it.

Q.3(d) Differentiate 'Open type' and 'Hermetically sealed type' compressors. [4]

Ans.: Open type compressors : [Any four - 2 marks]

- Most common problem is failure of shaft seal assembly and leakage of refrigerant.
- Due to leakage of refrigerant, the recurring cost for open type compressor is quite high.
- Motors used for Open compressors are air-cooled.
- Reduces the efficiency and reliability of the motors.
- Motors of Open compressors have to be erected and assembled at site. This requires precise alignment of the motor and compressor.
- Motors of Open compressors reject heat in the plant room.
- Open type compressor requires heavy foundations and grouting to be done at site.
- Simple construction
- Application for capacity of plants ex. Cold storage .central air conditioning.

Hermetically sealed type compressors. [Any four - 2 marks]

- Do not need any shaft seal assembly, because the compressor and the motor are mounted on a common shaft and in a common housing.
- There is no chance of leakage of costly refrigerant gas through the seals is less costly
- Semi-hermetic compressor motors are refrigerant gas cooled.
- High efficiency and reliability of the compressor motor.
- Motor is enclosed under shell. Problem does not arise in case of hermetic compressors.
- The motor heat is rejected directly into the cooling tower.
- Hermetic compressors are factory assembled and mounted on the structure/skid and do not require any foundation or grouting.
- With many redundant safety features built in the system like overheat and overload protection, hermetic motors do not face serious problems.
- Application for smaller capacity plant like refrigerator, air conditioning unit

Q.3(e) Name the refrigerant used in following : [4]

(i) Air-conditioner **(ii) Ice Plant**
(iii) Domestic refrigerator **(iv) Water cooler**

Ans.: Name the refrigerant used :

(i) Air Conditioner – R-22, R-114 [1 mark]
(ii) Ice Plant – In primary circuit Ammonia and secondary circuit Brine solution. [1 mark]
(iii) Domestic Refrigerator – R-12, R-134a [1 mark]
(iv) Water cooler – R-12, R-134a [1 mark]

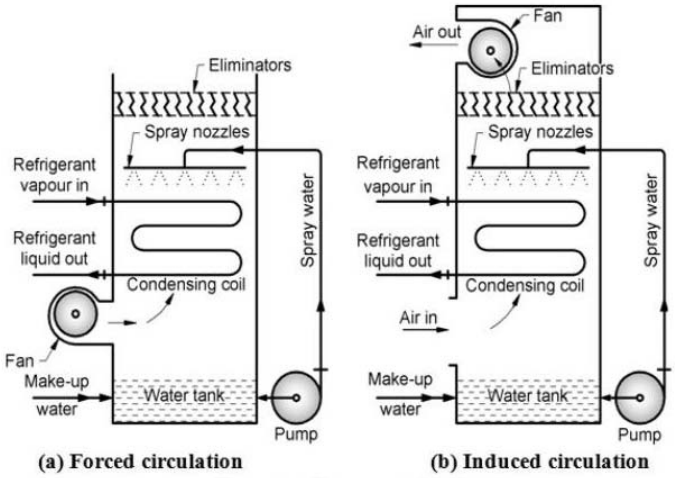
Q.4 Attempt any FOUR of the following : [16]

Q.4(a) Explain working principle of evaporative condenser with neat sketch. [4]

Ans.: Principle of evaporative condenser [Working principle & Sketch - 2 marks each]

- The evaporative condenser perform both the combined function of a water-cooled condenser and a cooling tower.

- In it's operation the water is pumped from sump to spray header and sprayed through nozzles over the condenser coil through which hot refrigerant from compressor is passing.
- Heat is transferred from refrigerant in the condenser into the water that is outside the surface of tuber.
- A fan is also used which draws air from the bottom side of condenser and discharges out at the top of condenser.
- The air causes the water from the surface of the condenser coils to evaporate and absorb the latent heat of evaporation from the remaining water to cool it.
- Since heat for vaporizing the water is taken from the refrigerant, therefore the vapour refrigerant condenses into liquid refrigerant.
- The cold water that drops down into a sump is recirculated. A float valve keeps a check of water level.
- The eliminator is provided above the spray header to stop particles of water escaping along with the discharge air.

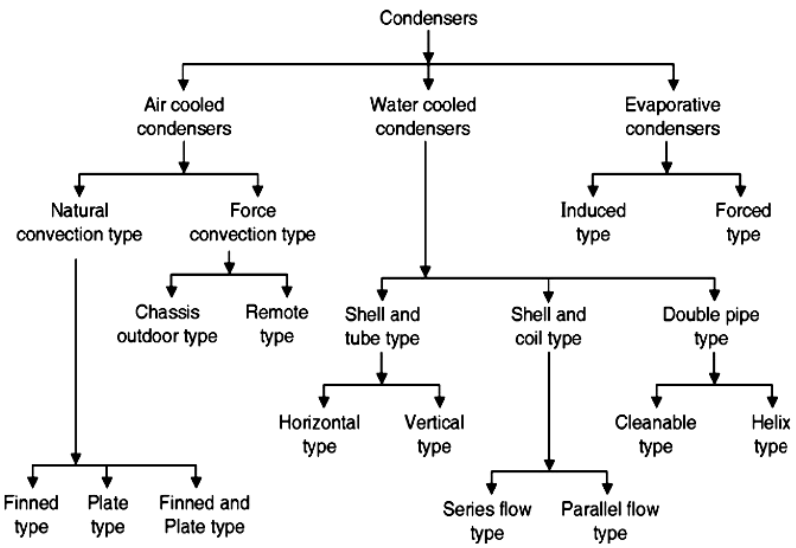


Evaporative condensers

Note : For exam student must draw any one figure.

Q.4 (b) State the classification of condenser used in refrigeration system. **[4]**

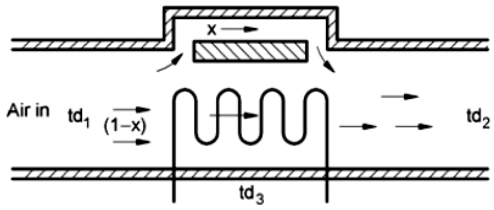
Ans.: [4 marks]



Q.4(c) Explain the concept of sensible heat factor and bypass factor with suitable sketches. **[4]**

Ans.: By-pass factor [Explanation & Sketch - 1 mark each]

When air passes over a coil, some of it say "x" just by-passes unaffected while the remaining (1 – x) kg comes in direct contact with the coil. This by-pass process of air is measured in terms of by-pass factor.



Balancing the enthalpies, we get

$xC_{pm}\ td_1 + (1 - x)\ C_{pm}\ td_3$

$= 1 \times C_{pm}\ td_2$ (C_{pm} = specific humid heat)

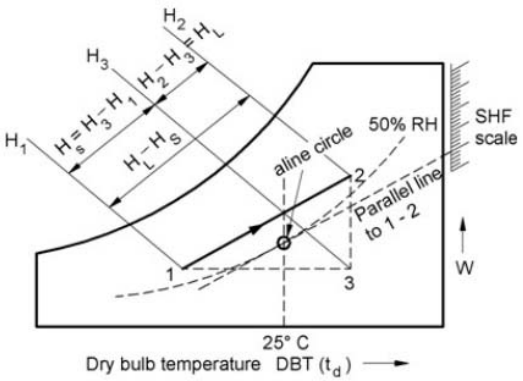
$x\ (td_3 - td_1) \quad = td_3 - td_2$

$$x = \frac{td_3 - td_2}{td_3 - td_1}$$, where x is by pass air

Sensible Heat Factor : [Explanation & Sketch - 1 mark each]

The ratio of sensible heat to total heat added is known as sensible heat factor (SHF) process of sensible heating on the psychromatic chart is shown by a horizontal line 1 – 2 extending from left to right.

$$\text{Sensible heat factor} = \frac{\text{Sensible heat}}{\text{Sensible heat} + \text{Latent heat}}$$



Q.4(d) Explain working principle of evaporative condenser with neat sketch. **[4]**

Ans.: Evaporative condenser [Working principle & Sketch - 2 marks each]

- The evaporative condenser perform both the combined function of a water-cooled condenser and a cooling tower.
- In it's operation the water is pumped from sump to spray header and sprayed through nozzles over the condenser coil through which hot refrigerant from compressor is passing.
- Heat is transferred from refrigerant in the condenser into the water that is outside the surface of tuber.
- A fan is also used which draws air from the bottom side of condenser and discharges out at the top of condenser.
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- Since heat for vaporizing the water is taken from the refrigerant, therefore the vapour refrigerant condenses into liquid refrigerant.
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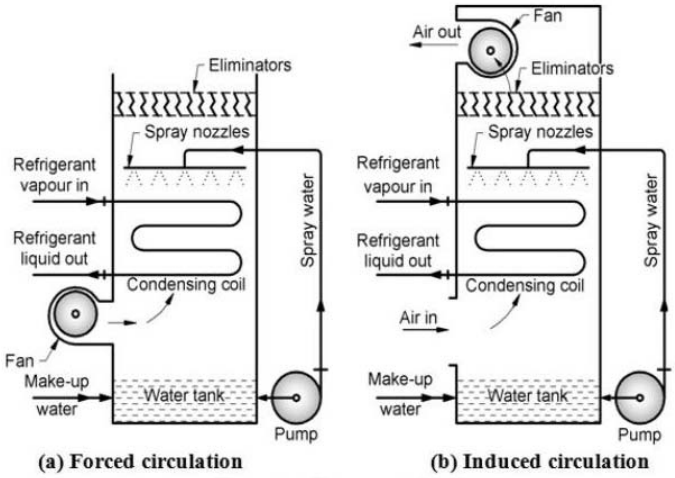


Evaporative condensers

Note : For exam student must draw any one figure.

Q.4(e) Explain the thermal exchange mechanism of human body with environment? [4]

Ans.: Thermal exchange mechanism [4 marks]

- The human body works best at a certain temperature, like any other machine, but it cannot tolerate wide range of variation in their environmental temperature like machines.
- Human body tries to maintain its thermal equilibrium with the environment by means of three modes of heat transfer i.e. Evaporation, radiation and convection.
- A human body feels comfortable when the heat produced by metabolism is equal to sum of heat dissipated to surrounding and stored in human body by increasing the temperature of body tissues.

  $Q_M - W = Q_E \pm Q_R \pm Q_C \pm Q_S$

  Q_M = Metabolic heat produced within the body
  W = Useful rate of working
  Q_R, Q_C is heat test or gained by radiation and convection respectively.
  + when heat is lost to surrounding.
  – when heat is gained from surrounding.
- In summer the energy stored 'Q_S' increases and temperature of body increases. This leads to increase in blood flow rate through the extremities and body starts perspiring and thus reduces body temperature. This condition is called vasodilation.
- In winter stored energy may become negative because of decrease in temperature. Thus reducing the blood flow rate through extremities which results in shivering. Such a condition is called as vasoconstriction.
- For comfort feeling thermal neutrality is required and in order to achieve that there should be no stored energy and hence no change in temperature.
- Any variation in the body temperature acts as a stress to the brain which ultimately results in either perspiration or shivering.

Q.4(f) Explain factors affecting human comfort. [4]

Ans.: Following are the factors affecting human comfort : [$\frac{1}{2}$ mark each]

(i) Effective temperature
(ii) Moisture content of air
(iii) Heat production and regulation in human body
(iv) Heat and Moisture losses from the human body
(v) Quality and Quantity of air
(vi) Air motion
(vii) Air stratification
(viii) Hot and Cold surfaces

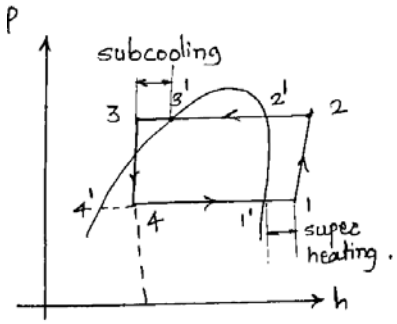
Q.5 Attempt any TWO of the following : [16]

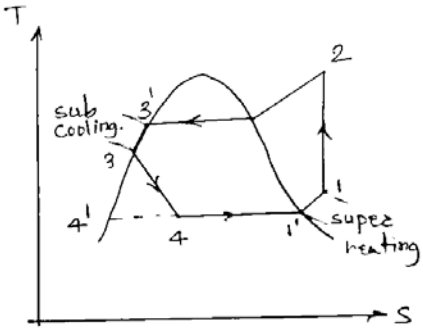
Q.5(a) Refrigeration system works on VCR system. [8]

Enthalpies at various points are given below :
Compressor inlet = 1460 kJ/kg
Compressor outlet = 1796 kJ/kg
Inlet to expansion valve = 322 kJ/kg
The refrigerant is superheated by 15 °C before it enters the compressor and subcooled by 3 °C before expansion. Show the cycle on PH and T-S chart.
Find : (i) COP (ii) Power required for 1 kg of refrigerant circulated/min.

Ans.: Given data :
h1 = 1460 kJ/kg
h2 = 1796 kJ/kg
h3 = 322 kJ/kg
Mass of refrigerant circulate, m=1 kg/min.

[2 marks for each figure]





(i) $COP = \frac{(h_1 - h_4)}{(h_2 - h_1)} = \frac{(1460 - 322)}{(1796 - 1460)} = 3.386$ [2 marks]

(ii) Power required per kg refrigerant circulated per minute is, [2 marks]

W.D. = m(h2-h1)
= 1*(1796 – 1460) Unit conversion-(kg/min)*(kJ/kg) = kJ/min
= 336 kJ/min
= 336/60 kJ/sec
= 5.6 kJ/sec
= 5.6 kW. As .....J/s = W

Q.5(b) Explain with neat sketch the various losses in the duct? [8]

Ans.: (i) Surface Frictional Loss: [Explanation with sketch (Any Four) - 2 marks each]

The frictional resistance of a duct of any cross-section is given by Darey's equation,

$$h_f = \frac{flv^2}{2gD}$$

D = Diameter of circular duct.
V = Velocity of the fluid flowing in m/sec.
f = Friction factor.
L = Length of the duct in meters.

The friction factor f is depend on Reynold number,

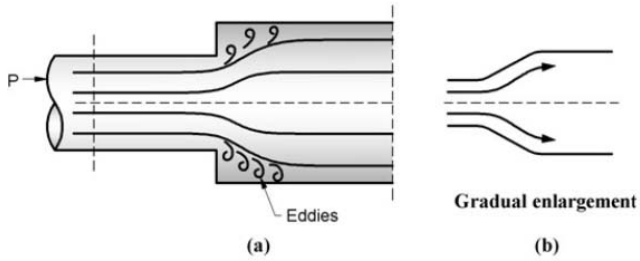
$$f = \frac{64}{R_e} \text{ when } R_e < 2300$$

(ii) Dynamic Losses in Ducts:

- Whenever there is change in direction or velocity in the flow through duct, the pressure loss is inevitable. The additional loss called dynamic loss.
- The change in magnitude of velocity occurs when the area of duct changes.
- The change in magnitude or direction which cause accelerating and decelerating force which may be internal or external.

- The pressure loss due to the change of direction of velocity at elbow is known as velocity pressure head.

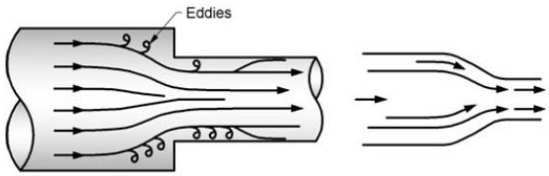
(iii) Loss due to Enlargement:



When the area of duct changes, the velocity of air flowing through the duct changes, when area increase, the velocity decrease with rise in pressure which form eddies at the corner thus sudden or abrupt change is neglected.

(iv) Loss due to Sudden Contraction:

- When the air is flowing and having a sudden or abrupt contraction, the eddies are formed at the shoulders of the large section and beyond the entry at the smaller section forming a vena–contracta.



(a) Sudden contraction (b) Gradual contraction

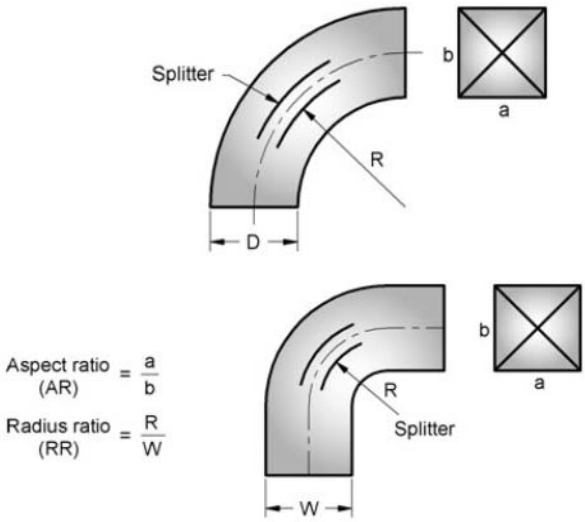
- The loss of pressure due to sudden contraction is not due to contraction itself but it is due to sudden enlargement of flow area from vena-contracta to the section of smaller duct.

(v) Pressure Losses in Elbow and Bend:

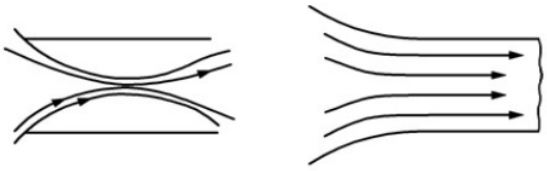
L_e = Equivalent length of duct.

K_d = Dynamic loss coefficient.

- The value of (L_e / K_d) is different for different elbow. The value of (L_e/K_d) is mostly affected by the geometry of elbow and surface roughness of duct wall and remains unaffected by the air velocity.
- To minimize the pressure loss in the bend, the splitters are generally used, aspect ratio is small.



(vi) Losses at Suction and Discharged Opening:



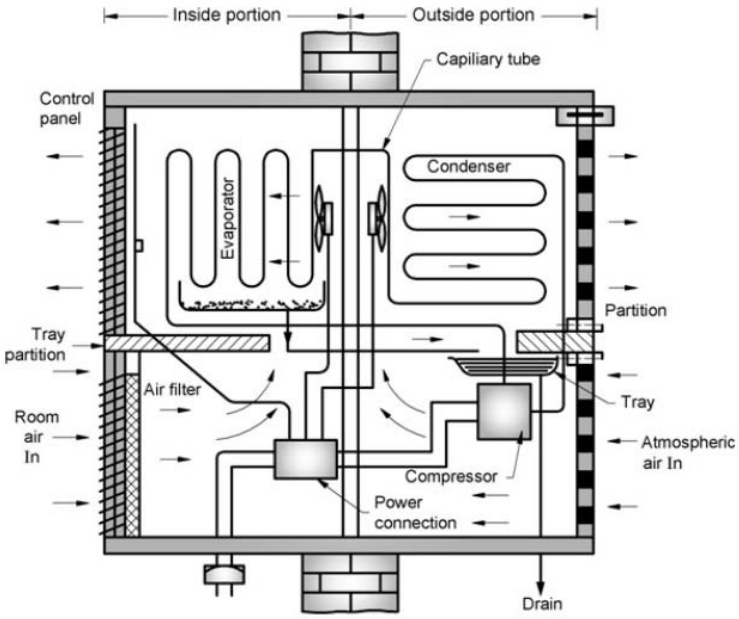
(a) Abrupt entrance (b) Formed entrance

When an abrupt suction opening is provided the air is accelerated at the opening, forming a vena-contracta inside the duct. In this case sudden changes from infinity to duct area and dynamic loss coefficient.

Q.5(c) Draw a labeled sketch and explain working of window air conditioning system? [8]

Ans.: Working : [Diagram & Working - 4 marks each]

- First the low pressure, low temperature refrigerant vapour is sucked by hermitically sealed compressor and compressed to high pressure, high temperature and it is then discharged to condenser to reject the latent heat.
- The liquid refrigerant passes through the filter into the capillary tube where it is throttled and the flows to the evaporator coil at lower pressure.
- This liquid refrigerant than rapidly boils at low pressure and picks up evaporation enthalpy from the evaporator surface.

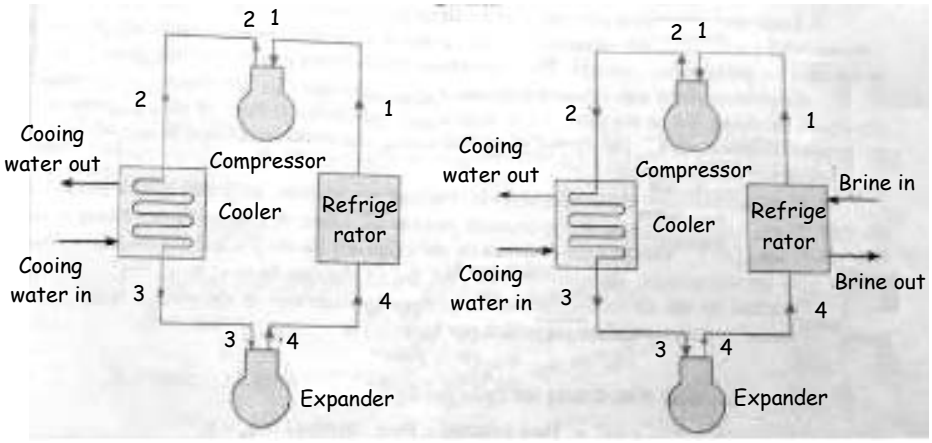


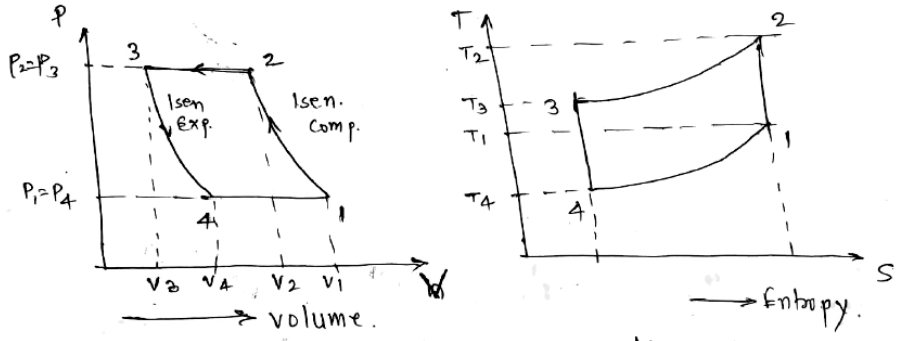
- A fan or blower is used to drive the air from room through air filter from the lower part of the unit and forces it to flow over the evaporator coil.
- The temperature of the cooling coil absorbs the heat from the air and is circulated back into the conditioned room.
- Due to this the temperature of room air is reduced hence air becomes chilled and circulated back into the conditioned room.
- But due to reduction in the temperature of the air dew is formed on the surface of the cooling coil. For this purpose the temperature of the cooling coil is lower than then the dew point temperature of the air.
- This moisture present in circulating air is removed and flows from coil surface and drips in the tray at the bottom. This moisture in the tray (pan) evaporates to some extent which helps in cooling the compressor and condensor.
- This type of air conditioning is used for office, bed room, drawing office etc.

Q.6 Attempt any FOUR of the following : Compressor **[16]**

Q.6(a) Draw schematic diagram of Bell-Coleman air refrigeration cycle with P-V and T-S diagram. **[4]**

Ans.: Bell coleman cycle of refrigeration: [Diagram - 2 marks each]





Q.6(b) What are the factors which need to be considered during design of car air conditioning? **[4]**

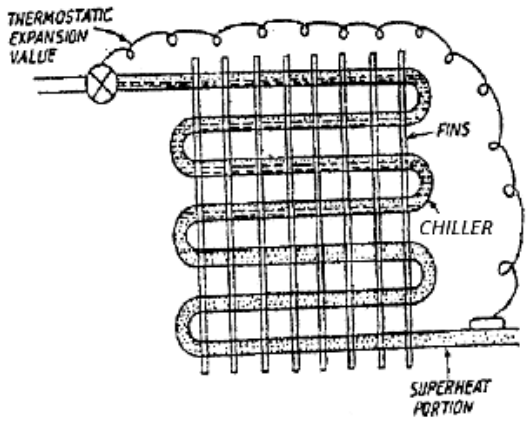
Ans.: The automobile compartment is designed by considering several factors to achieve the required conditions for all weather such as : [Any four factor - 1 mark each]

(i) Higher outside temperature
(ii) Dissipation of heat by engine.
(iii) Colour of vehicle is also considered
(iv) Infiltration of air and ventilation
(v) Solar radiations through glass, window and roof depending upon the position of sun and intensity of solar radiation, cleanness of sky.
(vi) Vehicle speed and wind direction and velocity of air.

Q.6(c) Explain working of dry expansion type chillers with sketch. **[4]**

Ans.: Dry expansion chiller: [Explanation & Diagram - 2 marks]

Dry expansion chiller is a simple tube type chiller. In dry expansion chiller the liquid refrigerant from the receiver is fed by expansion valve to the chiller. The expansion valve controls the rate of flow of liquid refrigerant in such a way that all the liquid refrigerant is vaporized by the time it reaches at the end of the chiller coil or the suction line of the compressor. The vapor is also superheated to some extent. The rate of refrigerant flow depends on load, it increases when load increases and vice versa.



Dry Expansion Chiller

Q.6(d) What is need of multistaging? State limitations of it. **[4]**

Ans.: Need of multistaging: [2 marks]

In case of a Refrigeration system very low pressure refrigerant vapors (Evaporator pressure) are to be compressed to very high pressure refrigerant vapors (Condenser pressure). As this pressure ratio is very high the size and work done required in case of single stage is more, thus COP decreases TO increase COP and reduce work done multistaging is needed.

Limitations of multistage vapor compression system: [2 marks]

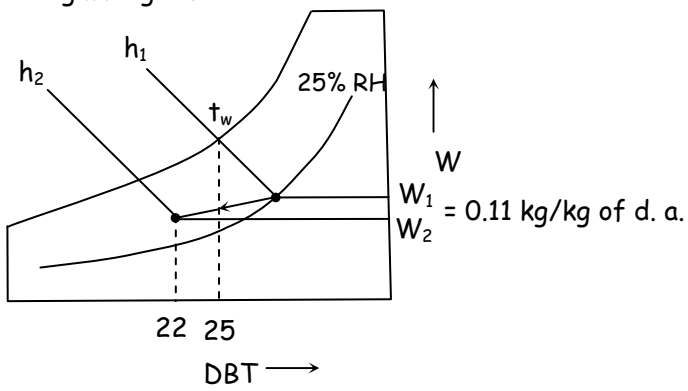
(i) More than one compression is used.
(ii) Inter-cooling system is required.
(iii) System is complicated.

Q.6(e) Air at 25°C WBT 25% RH is to be conditioned to 22°C. DBT and 11 gm / kg d.a. specific humidity. Determine heat transfer per kg of dry air referring the psychrometric chart. Represent the process on chart by sketch. **[4]**

Ans.: Given :

t_w = 25°C WBT, 25% RH, t_d = 22°C DBT,

W = 11 gm / kg d.a



[2 marks]

From Chart W_1 = 0.0128 kg of d.a
h_1 = 77.5 KJ / Kg
h_2 = 49 KJ / Kg
W_2 = 0.011 Kg / Kg of d.a.

Heat transfer per kg of d.a. = $h_1 - h_2$
= 77.5 – 49
= 28.5 kJ / Kg [2 marks]

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