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) Define C.O.P and unit of refrigeration also explain heat engine. [4]

(A) Coefficient of performance (COP) is the ratio of heat extracted in the refrigerator to the work done on the refrigerant.

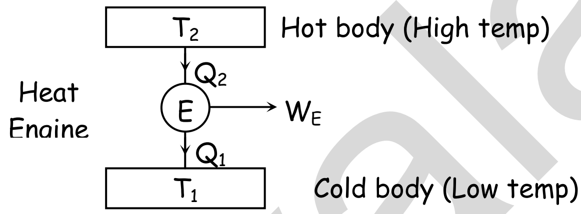
$$C.O.P = \frac{Q}{W}$$

- The practical unit of refrigeration is expressed in terms of "tonne of refrigeration" (written as TR).
  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.
  Taking latent heat of ice = 335 KJ / Kg
  $$1\ TR = 1000 \times 335 \text{ KJ in 24 hours}$$
  $$= \frac{1000 \times 335}{24 \times 60} = 232.6 \text{ KJ / min}$$

Heat engine

In a heat engine, the heat supplied to the engine is converted into useful work. If Q_2 is the heat supplied to the engine and Q_1 is the heat rejected from the engine then the net work done by the engine is given by

$W_E = Q_2 - Q_1$



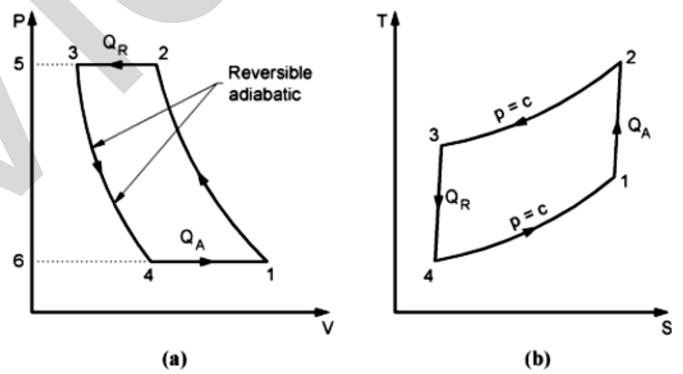
$T_1 > T_a$

$$\text{Efficiency} = \frac{\text{Net work output}}{\text{Heat added}} = \frac{Q_2 - Q_1}{Q_2} = 1 - \frac{Q_1}{Q_2}$$

Thus the efficiency of heat engine is always less than unity.

Q.1(a) (ii) Sketch Bell column cycle on P-V and T-S. List process involved. [4]

(A)



P – V and T – S diagram

Process 1 – 2 → The air is compressed isentropically
Process 2 – 3 → Heat rejected to atmosphere at constant pressure.
Process 3 – 4 → The air is expanded isentropically
Process 4 – 1 → Heat is absorbed at constant pressure.

Q.1(a) (iii) Draw a neat labelled symmetric diagram of a simple vapour compression refrigeration system. **[4]**

(A)

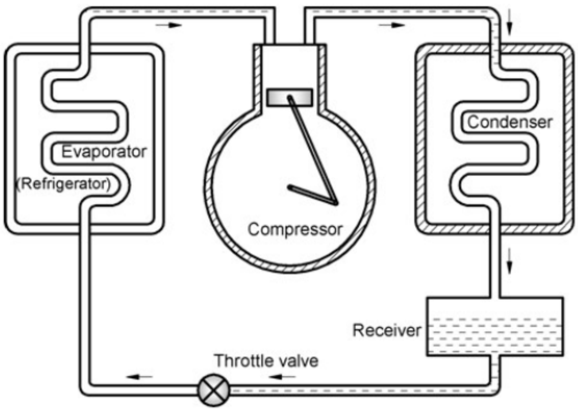
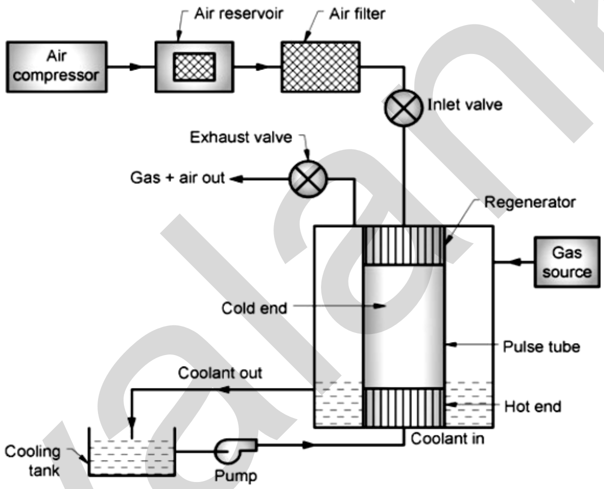


Fig.: Flow diagram of simple vapour compression refrigeration cycle

Q.1(a) (iv) Draw a neat labelled sketch and explain working of pulse tube refrigeration. **[4]**

(A) Pulse tube refrigeration uses the idea of sudden pressurization and depressurization are employed to get refrigeration effect.



Pulse Tube Refrigeration

Working of pulse tube refrigeration

- The main components are pulse tube refrigerator, valve mechanism and cooling system.
- A high pressure gas from gas source is supplied at temperature equal to ambient temperature to the base of the pulse tube.

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

Q.1(b) (i) Explain and draw Electrolux refrigeration system. **[6]**

(A)

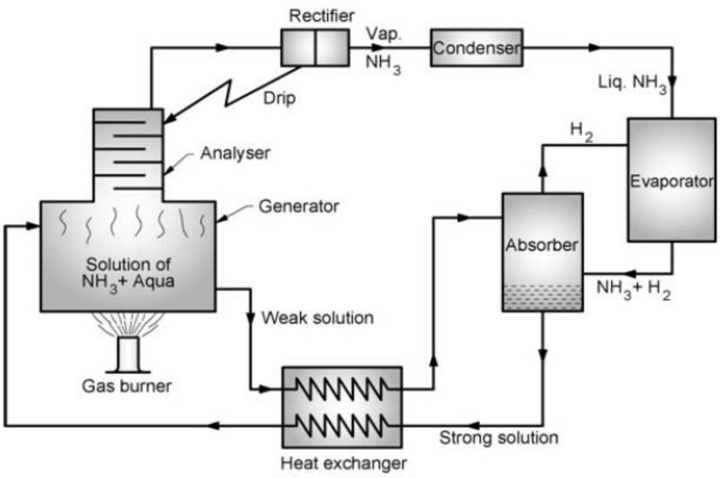


Fig. : Domestic electrolux type refrigerator

Operation or Working of Electrolux system :

- The strong aqua-ammonia solution is heated in the generator by external source usually a gas burner.
- During heating process aqua-ammonia vapour rises up through analyser where dehydration of aqua-takes places then it passes through a rectifier where complete water particles are removed and reback to generator and the strong ammonia vapour are sent to condenser.
- In condenser the ammonia vapour changes its phase from vapour to liquid. Condensation of ammonia vapour is done by external cooling source.
- The liquid refrigerant leaving the condenser flours under gravity to the evaporator where it meets with the hydrogen gas.
- The hydrogen gas which is in the evaporator increase the rate of evaporation. During the process of evaporation it absorbs latent heat from the refrigerated space and thus produces cooling effect.
- The mixture of ammonia vapour and hydrogen from evaporator is passed to the absorber where ammonia vapour is absorbed in water while the hydrogen rises to the top and flows back to the evaporator. Thus cycle is complete
- $\text{C.O.P.} = \dfrac{\text{Heat absorbed in the evaporator}}{\text{Heat supplied in the generator}}$

Q.1(b) (ii) What is the ultimate effect of under cooling (sub-cooling) on C.O.P.? Show on P-h and T-s diagram? **[6]**

(A) (1) Subcooling reduces flashing of the liquid during expansion and increases the refrigerating effect.

(2) Thus the piston displacement and power per ton are reduced for all refrigerant.

(3) The ultimate effect of undercooling or subcooling is to increase the value of co-efficient of performance under the same set of condition.

$$\text{Refrigerating effect (R.E)} = h_1 - h_4 = h_1 - h_3$$

$$W_C = \text{Work done} = h_2 - h_1$$

$$\therefore \quad \text{C.O.P.} = \frac{\text{R.E.}}{W_C} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{h_1 - h_3}{h_2 - h_1}$$

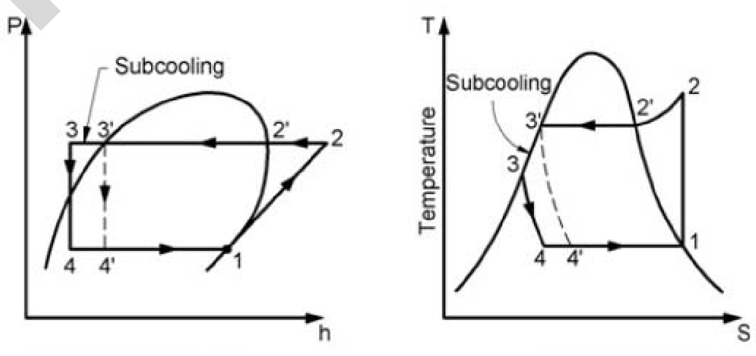


Fig. : Theoretical vapour compression cycle with subcooling or undercooling of the refrigerant

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

Q.2(a) A vapour compression refrigerator uses R-12 as a refrigerant and the liquid evaporates in the evaporator at −15°c. The temperature of this refrigerant at the delivery from the compressor is 15°C. When the vapour is condensed at 10°C; find the COP if [8]

(i) There is no under cooling

(ii) The liquid is subcooled by 5°C before expansion by throttling.

Take specific heat at constant pressure for the super heated vapour as 0.64 kJ/kg°k. and that of liquid as 0.94 kJ/kg°k.

The other properties of refrigerant are as follows.

Temp °C	Enthalpy (kJ/kg)		Specific Entropy (kJ/kg°k)	
	Liquid	Vapour	Liquid	Vapour
−15	22.3	0.88	0.0904	0.7051
10	45.4	191.76	0.1750	0.6921

Sketch the P−H and T−S diagram for both conditions.

(A) **(i)** COP if there is no undercooling.

Let x_1 = Dryness fraction of the refrigerant at point 1.

We know that entropy at point 1

$$S_1 = Sf_1 + x_1 \, . \, Sf_{g1}$$
$$= Sf_1 + x_1 \, . \, (S_{g1} - Sf_1)$$
$$= 0.0904 + x_1 \, (0.7051 - 0.0904)$$
$$= 0.0904 + 0.6147 \, x_1 \qquad \ldots (1)$$

and entropy at point 2

$$S_2 = S_2' + 2.3 \, C_{pv} \log\left(\frac{T_2}{T_2^1}\right)$$
$$= 0.6921 + 2.3 \times 0.64 \log\left(\frac{288}{283}\right)$$
$$= 0.6921 + 2.3 \times 0.64 \times 0.0077$$
$$= 0.7034 \qquad \ldots (2)$$

Since the entropy at 1 is equal to entropy at z, therefore equating equations (1) + (2)

$$= 0.0904 + 0.6147 \, x_1$$
$$= 0.7034$$
$$x_1 = 0.997$$

We know that the enthalpy at point 1

$$h_1 = hf_1 + x_1 \, . \, hf_{g1}$$
$$= hf_1 + x_1 \, (hg_1 - hf_1)$$
$$= 22.3 + 0.997 \, (180.88 - 22.3)$$
$$= 180.4 \text{ kJ/kg}$$

$$\text{and } h_2 = h_2' + C_{pv} \, (T_2 - T_2')$$
$$= 191.76 + 0.6 + (2.88 - 2.83)$$
$$= 194.96 \text{ kJ/kg}$$

$$\text{C.O.P.} = \frac{h_1 - hf_3'}{h_3 - h_1}$$
$$= \frac{180.4 - 45.4}{194.96 - 180.4}$$
$$= 9.27$$

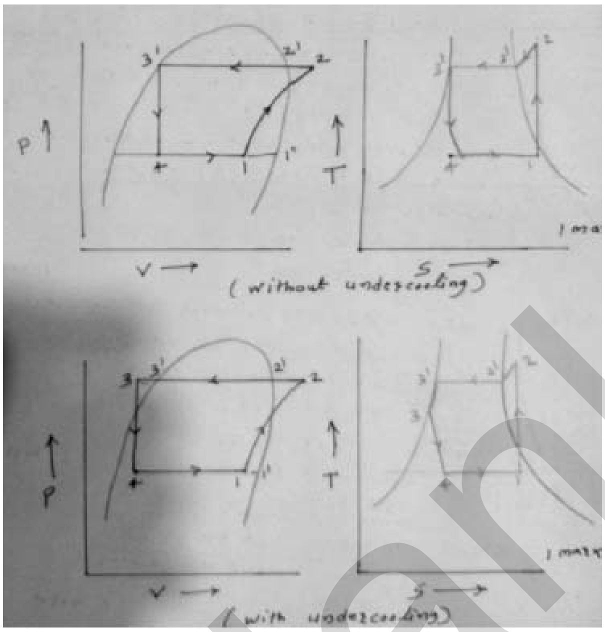
(ii) C.O.P. when there is undercooling at 5°C

$hf_3 = hf_3' + Cp_1 \times \text{Degree of undercooling}$

$= 4.54 - 0.94 \times 5$

$= 40.7$ kg/kJ

$$\text{C.O.P.} = \frac{h_1 - hf_3}{h_2 - h_1} = \frac{180.4 - 40.7}{194.96 - 180.4} = 9.59$$



Q.2(b) State functions of expansion devices and give classification of same. Explain construction and working of thermostatic expansion valve with neat sketch. **[8]**

(A) An expansion valve is a component in refrigeration and air conditioning systems that controls the amount of refrigerant flow into the evaporator thereby controlling the superheat at the outlet of the evaporator.

Types of Expansion devices

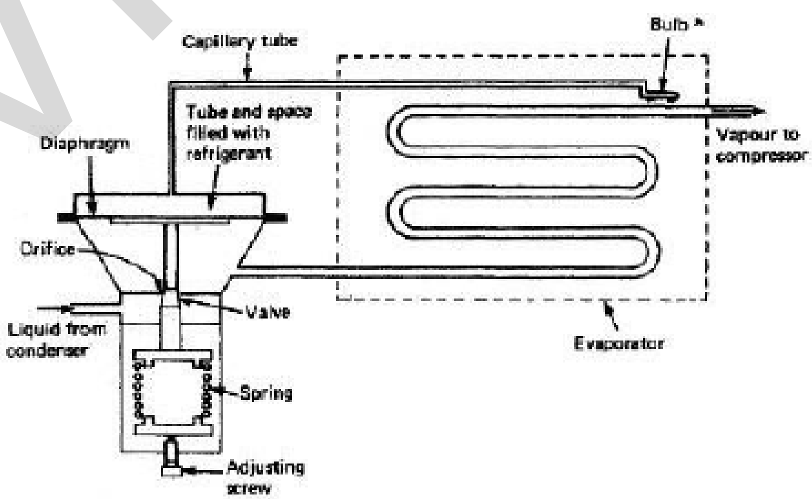
Thermostatic EV

Capillary tube

Hand operated EV

Automatic or Constant Pressure EV Float expansion

Explanation of Thermostatic expansion valve:



Thermostatic expansion valve or TEV is one of the most commonly used throttling devices in the refrigerator and air conditioning systems. The thermostatic expansion valve is the automatic valve that maintains proper flow of the refrigerant in the evaporator as per the load inside the evaporator. If the load inside the evaporator is higher it allows the increase in flow of the refrigerant and when the load reduces it allows the reduction in the flow of the refrigerant. This leads to highly efficient working of the compressor and the whole refrigeration and the air conditioning plant.

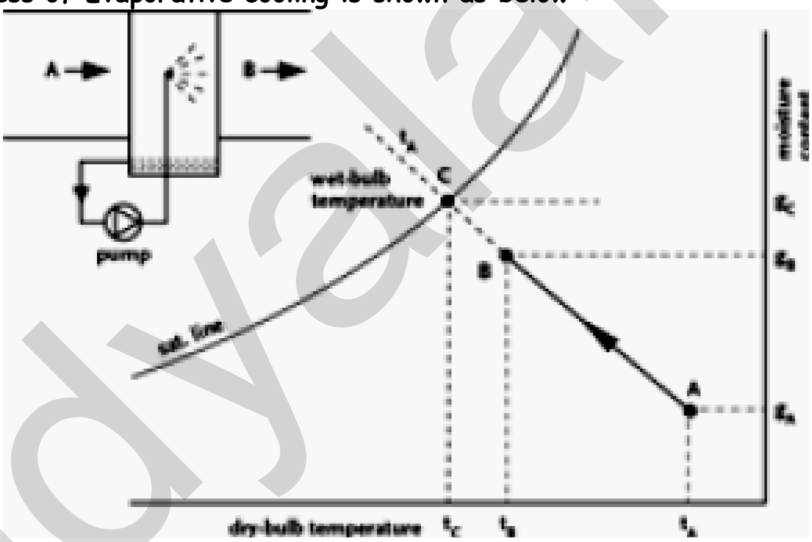
The thermostatic expansion valve also prevents the flooding of the refrigerant to the compressor ensuring that the plant would run safely without any risk of breakage of the compressor due to compression of the liquid. The thermostatic expansion valve does not controls the temperature inside the evaporator and it does not vary the temperature inside the evaporator as its name may suggest.

Q.2(c) List psychometric processes and explain evaporative cooling process with sketch. [8]

(A) Various psychrometric processes are as follows :

(i) Sensible cooling and heating.
(ii) Latent heating and cooling.
(iii) Cooling and dehumidification.
(iv) Cooling and humidification.
(v) Heating and humidification.
(vi) Chemical dehumidification.

The process of Evaporative cooling is shown as below :



It is the process in which cooling is achieved by evaporating water without transfer of heat from or to the surrounding. Thus, enthalpy remains constant during process and process takes place along constant WBT.

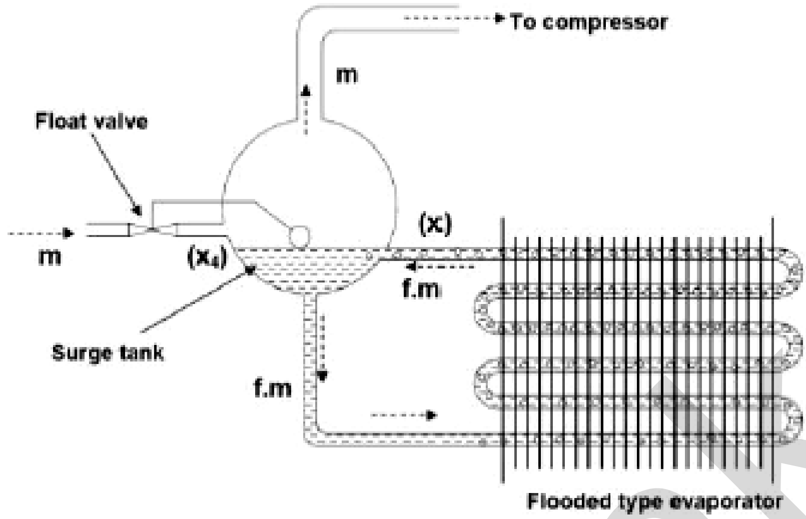
It is achieved by direct contact of water particles and moving air stream. It can be shown on psychrometric chart as above.

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

Q.3(a) Explain working of ''Flooded type evaporator' with a neat sketch. [4]

(A) Working of Flooded type evaporator :

This is typically used in large ammonia systems. The refrigerant enters a surge drum through a float type expansion valve. The compressor directly draws the flash vapour formed during expansion. This vapour does not take part in refrigeration hence its removal makes the evaporator more compact and pressured drop due to this is also avoided. The liquid refrigerant enters the evaporator from the bottom of the surge drum. This boils inside the tubes as heat is absorbed. The mixture of liquid and vapour bubbles rises up along the evaporator tubes. The vapour is separated as it enters the surge drum. The remaining unevaporated liquid circulates again in the tubes along with the constant supply of liquid refrigerant from the expansion valve. The mass flow rate through the evaporator is three times that through the compressor.



Since, liquid refrigerant is in contact with whole of evaporator surface, the refrigerant side heat transfer coefficient will be very high. The lubricating oil tends to accumulate in the flooded evaporator hence an effective oil separator must be used immediately after the compressor.

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

(A) Open type compressors :

- 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 :

- 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(c) Classify ducts used in air-conditioning systems. [4]

(A) Classify ducts used in air-conditioning system :

The ducts may be classified as follows :

(i) Supply duct – conditioned air from the air conditioning equipment to the space to be conditioned.
(ii) Return air duct- carry the recirculating air from the conditioning space back to the air conditioning equipment.
(iii) Fresh air duct – carry the outside air.
(iv) Low pressure duct- static pressure in the duct is less than 50mm of water gauge.
(v) Medium pressure duct- static pressure in the duct is upto 150mm of water gauge.
(vi) High pressure duct- static pressure in the duct is from 150 to 250mm of water gauge.
(vii) Low velocity duct-velocity of air in the duct is upto 600 m/min.
(viii) High velocity duct- velocity of air in the duct is more than 600m/min.

Q.3(d) Write four industrial applications of refrigeration and A/C system. [4]

(A) Industrial applications of refrigeration :

- Air-conditioning for comfort of workers.
- For textile industries for production of quality textile products.
- For manufacturing process in photographic industry.
- In printing industries for quality printing.
- In paper industries for production of paper.
- For preservation of food in food industries.

Industrial applications of A/C system :

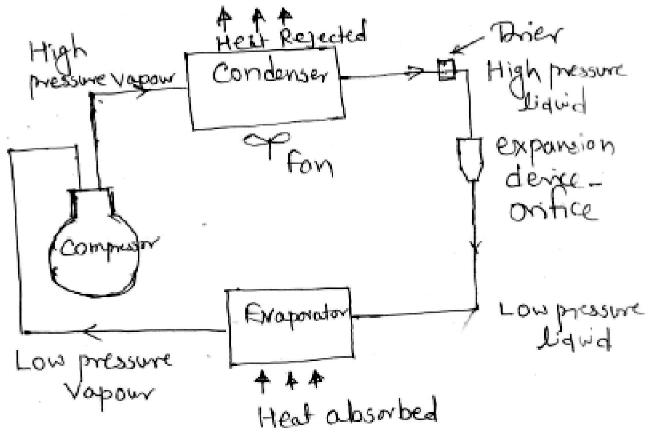
- Laboratories: to make precise measurements.
- Printing : to control temperature and humidity.
- Textile manufacture :greatly depends on moisture control.
- Pharmaceutical: industry needs refrigeration to reduce air borne bacteria and dirt to preserve products.
- Photographic: products deteriorate rapidly at high temperatures and high humidity.
- Manufacture of Precision Parts:
  - Farm Animals
  - Computer Rooms
  - Power Plants

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

(A) Automobile air conditioning system

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.

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.



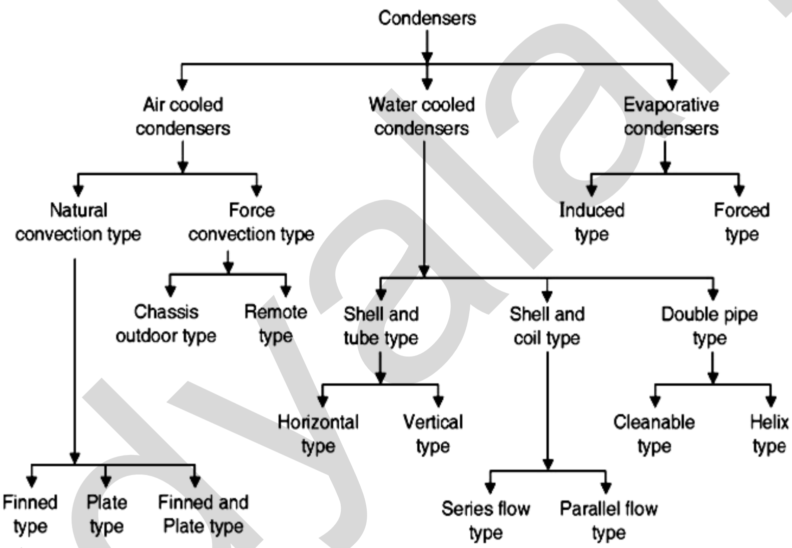
Automobile air conditioning system

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

Q.4(a) (i) State the classification of condenser used in refrigeration system ? [4]

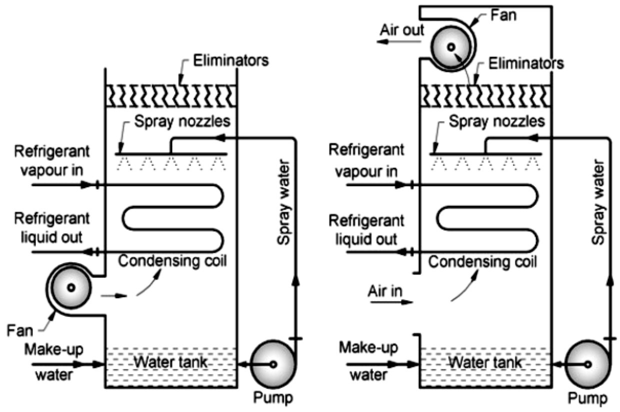
(A)



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

(A)
- 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.



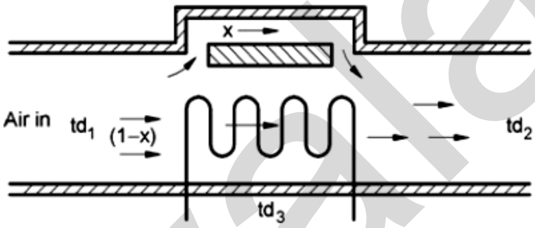
(a) Forced circulation **(b) Induced circulation**

Evaporative Condensers

Note : For exam student must draw any one figure.

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

(A) **By-pass factor :** 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

$$xC_{pm}\,td_1 + (1 - x)\,C_{pm}\,td_3 = 1 \times C_{pm}\,td_2 \quad (C_{pm} = \text{specific humid heat})$$

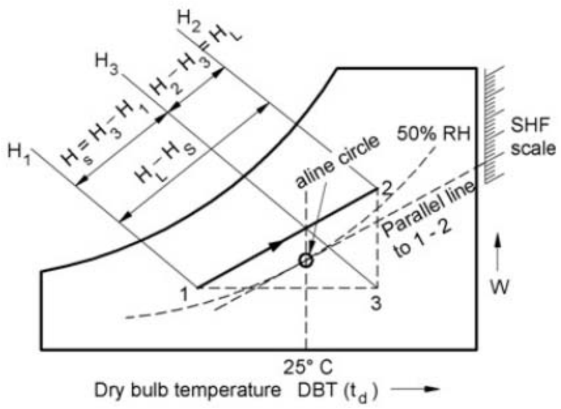
$$x\,(td_3 - td_1) = td_3 - td_2$$

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

Sensible Heat Factor :

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 lin 1 – 2 extending from left to right.

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



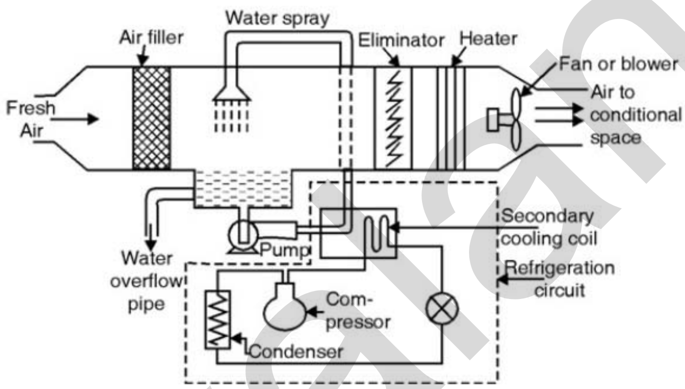
Q.4(a) (iv) List different types of dehumidifiers. Describe most commonly used type with sketch ? [4]

(A) Different types of dehumidifiers :

(i) Spray type dehumidifier (ii) Cooling coil type dehumidifier

(i) Spray type dehumidifier :

- This type of dehumidifier is similar with humidifier with an exception that the water used for spraying purpose is having temperature below the dew point temperature of air.
- The outside fresh air enters through filter which removes the dust particle.
- This air is then passed through cold water having temperature below dew point temperature of the room air.
- By this the outside air is cooled below it's dew point temperature (DPT) and thus excess moisture is removed.
- However, the dry bulb temperature of air leaving the eliminator is much below the DBT of desired condition space.
- Hence an heater is used to maintain the temperature through which air is passed to condition space.
- A refrigeration system is used to cool the water supply the and an overflow pipe is required to drain the added water.



Spray type Dehumidifier

Q.4(b) Attempt any ONE of the following : [6]

Q.4(b) (i) Explain the thermal exchange mechanism of human body with environment? [6]

(A)

- 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(b) (ii) Explain factors affecting human comfort? [6]

(A) Following are the factors affecting human comfort :

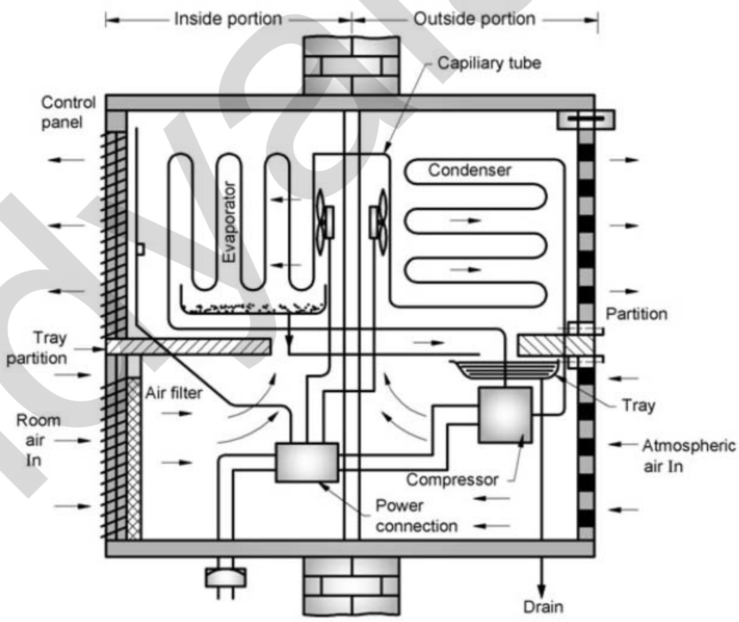
(i) Effective temperature
(ii) Moisture content of air
(iii) Heat production and regulation in human body
(iv) Heat and Moisture losses from the human body
(v) Quality and Quantity of air
(vi) Air motion
(vii) Air stratification
(viii) Hot and Cold surfaces

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

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

(A) Working :

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

(A) (i) Surface Frictional Loss:

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.

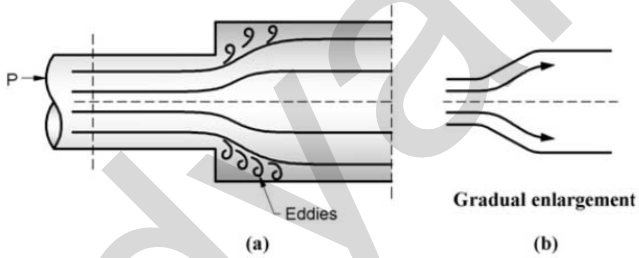
The friction factor f is depend on Reynold number,

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

(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.

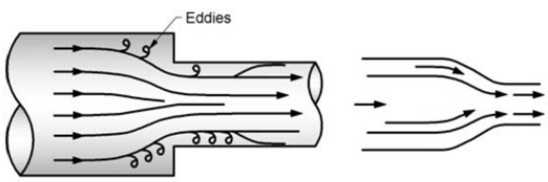
(iii) Loss due to Enlargement:



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

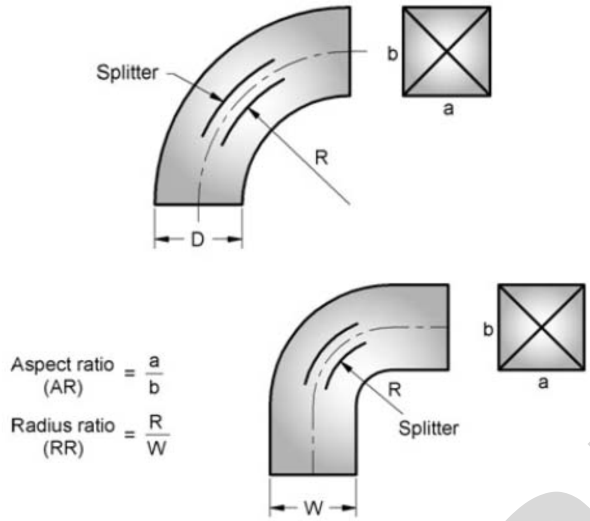
- The loss of pressure due to sudden contraction is not due to contraction itself but it is due to sudden enlargement of flow area from vena-contracta to the section of smaller duct.

(v) Pressure Losses in Elbow and Bend:

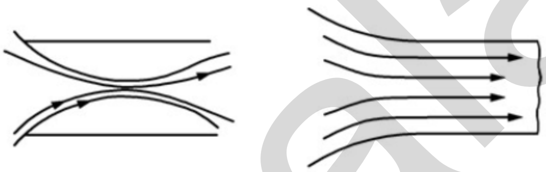
L_e = Equivalent length of duct.

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:

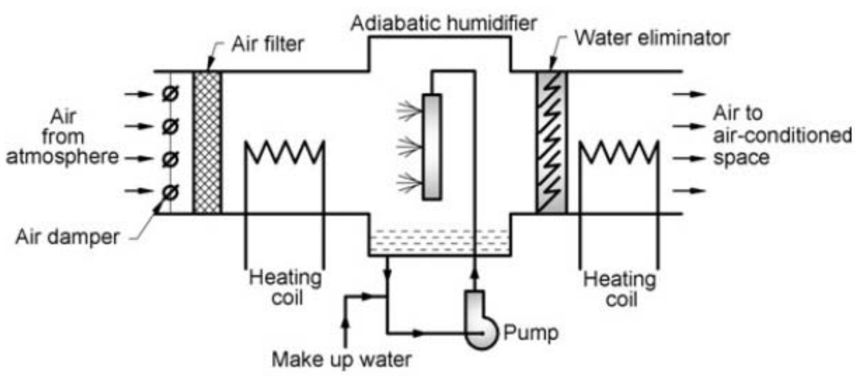


(a) Abrupt entrance (b) Formed entrance

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) A cold storage room has walls made of 0.23 m of brick on the outside, 0.08 m of plastic foam and finally 15 mm of wood on the inside. The outside and inside temperature are 22°C and −2°C respectively. If the inside and outside heat transfer coefficient are 29 and 12 W/m^2 °K respectively the thermal conductivities of bricks, foam and wood are 0.98, 0.02 and 0.17 W/m °K respectively. Determine rate of heat removal by refrigeration per unit area of wall. **[8]**

(A)



Inside heat transfer coefficient = h_i = 29 W/m^2 °K
Outside heat transfer coefficient = h_o = 12 W/m^2 °K

U = Overall heat transfer coefficient

$$\frac{1}{U} = \frac{1}{h_0} + \frac{X_1}{K_1} + \frac{X_2}{K_2} + \frac{X_3}{K_3} + \frac{1}{hi}$$

$$= \frac{1}{12} + \frac{15}{1000 \times 0.17} + \frac{0.08}{0.02} + \frac{0.23}{0.98} + \frac{1}{29}$$

$$\frac{1}{U} = 4.4407$$

$$U = 0.225 \text{ W/m}^2 \text{ °K}$$

$\therefore$ The rate of heat removed by refrigeration per unit area of wall,

$$Q = UA\,(To - Ti)$$

$$\frac{Q}{A} = U(T_o - T_i)$$

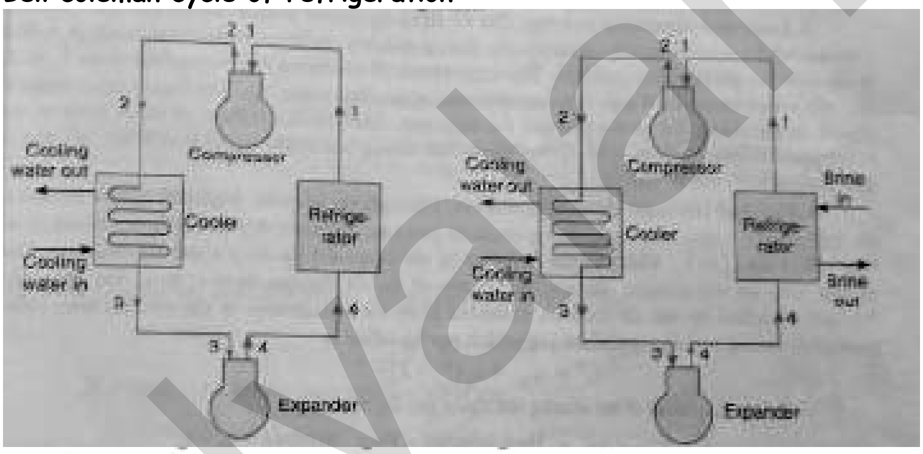
$$= 0.225\,(295 - 271)$$

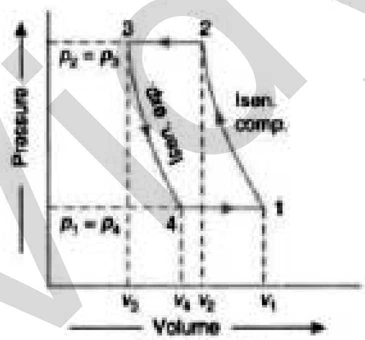
$$= 5.40 \text{ kJ/m}^2$$

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

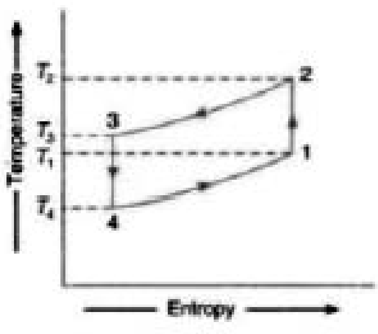
Q.6(a) Draw schematic diagram of Bell-Coleman air refrigeration cycle with P-V and T-S diagram. [4]

(A) Bell coleman cycle of refrigeration:





(a) p-v diagram.



(b) T-s diagram.

Q.6(b) Give classification of refrigerants and state at least one refrigerant name in each refrigerant type. [4]

(A) Classification of refrigerants:

Refrigerants are broadly classified as

(i) Primary refrigerants
(ii) Secondary refrigerants

Primary refrigerants further classified into four groups
(i) Hallo-carbon or organic refrigerants
Example – R-11, R-12, R-13, R-22 R134a etc.

(ii) Azeotropes refrigerants
Example – R-500, R-502,R-503,R-504 etc.

(iii) In organic refrigerants
R-717, R-729, R-744, R-764 etc.

(iv) Hydro-carbon refrigerants
Example – R-170, R-290, R-600, R-600a, R-1130, R-1150, R-1270 etc.

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

(A) Need of multistaging:

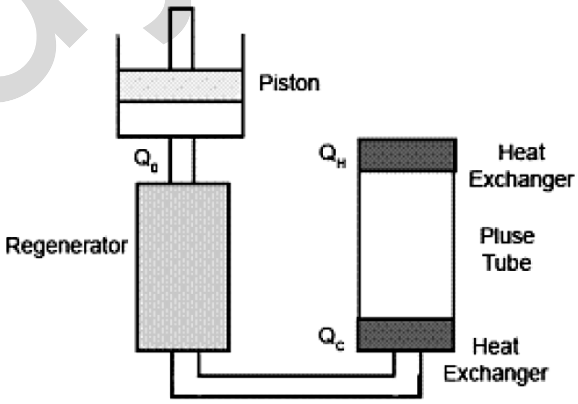
In case of a Refrigeration system very low pressure refrigerant vapors (Evaporator pressure) are to be compressed to very high pressure refrigerant vapors (Condenser pressure). As this pressure ratio is very high the size and work done required in case of single stage is more, thus COP decreases TO increase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

Advantages of multistage vapor compression system:
(i) Work done per kg of refrigerant is reduces by using an intercooler.
(ii) Volumetric efficiency of compressor increases.
(iii) It reduces leakage of refrigerant.
(iv) It gives uniform torque therefore smaller flywheel may be used.
(v) Effective lubrication can be done.
(vi) Cost of compressor reduces.

Limitations of multistage vapor compression system:
(i) More than one compression is used.
(ii) Inter-cooling system is required.
(iii) System is complicated.

Q.6(d) Explain pulse tube refrigeration system. **[4]**

(A)

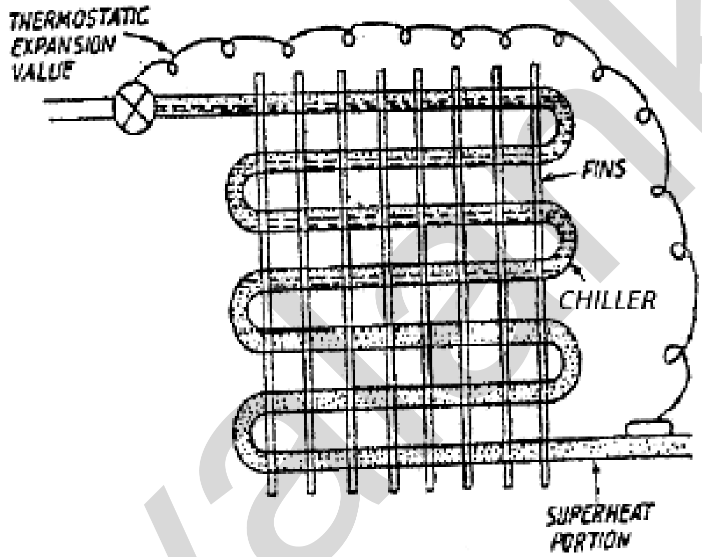


The first pulse tube was built in 1963 by Gifford and Longsworth. Its basic components include a pulse tube, a regenerator, a pressure wave generator, and two heat exchangers as shown in Fig. 1. The pulse tube is a simple tube with one open end and one closed end. The closed end is the hot end and is capped with a heat exchanger that cools it to the ambient temperature. The open end is the cold end. It is connected to the regenerator and a cold stage by a second heat exchanger. The regenerator is a periodic flow heat exchanger. It absorbs heat from gas pumped into the pulse tube precooling it, and stores the heat for half a cycle then transfers it back to outgoing cold gas in the second half of the cycle cooling the regenerator. The interior of the regenerator tube is filled with either stacked fine mesh screens or packed spheres to increase its heat capacity. A piston, compressor or similar pressure wave generator is attached to the warm end of the regenerator and provides the pressure oscillations that drive the refrigeration. Helium is used as the working gas due to its monotonic ideal gas properties and low condensation temperature. In systems with a base temperature below 2K the He3 isotope is used.

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

(A) Dry expansion chiller:

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

❑ ❑ ❑ ❑ ❑