WINTER– 14 EXAMINATION

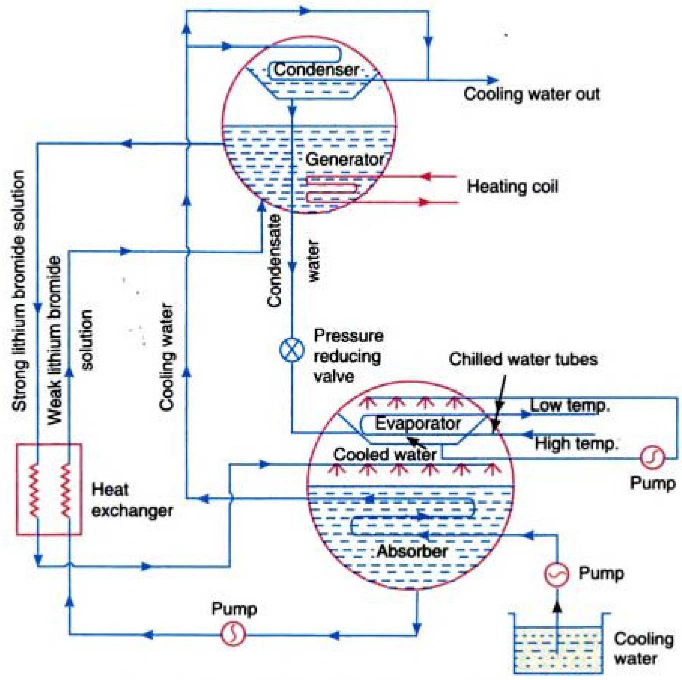
Subject Code: **12246 (RAC)** **Model Answer**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q1 a) Li-Br Vapour absorption system

(Sketch 04 marks, List of Components 02 Marks & working 02 marks)



Lithium-Bromide absorption refrigeration system.

It consists of conventional component of vapour absorption system:

Absorber

Generator

Heat exchanger,

Condenser,

Evaporator,

Expansion Device

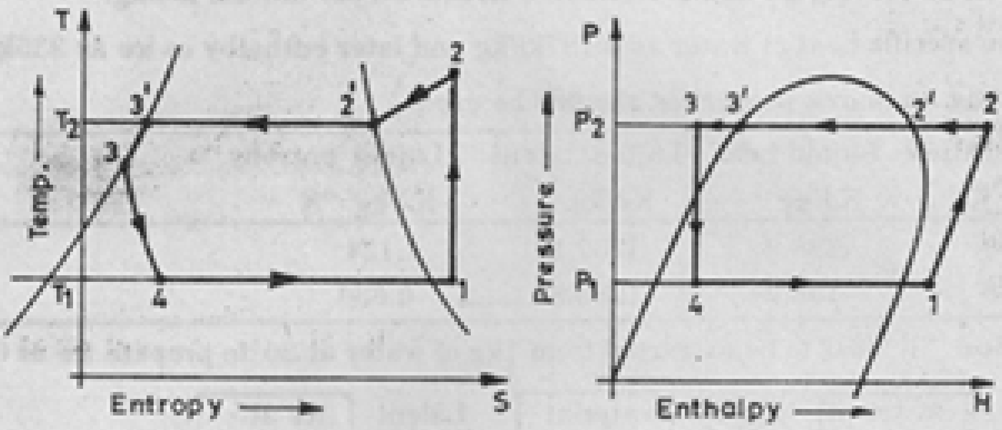
Pressure reducing valve

Pump

In evaporator refrigerant water evaporates absorbing latent heat from water to be chilled. The water vapors are drawn in absorber. In absorber weak solution of lithium bromide is spread which absorbs water vapour and gets converted in to strong solution. To increase the affinity for water vapour cooling coil is placed in absorber. Strong solution of lithium bromide is pumped to generator through heat exchanger. The function of heat exchanger is to transfer heat from weak solution to strong solution. In generator strong solution is heated by means of heating coil to realize water vapour. By realizing water vapour in strong solution converts in weak solution which is passed to absorber through heat exchanger. The generated water vapour from generator is further passed to condenser where it is condensed by condensing water supplied externally. This condensed water refrigerant is passed to evaporator to compensate the refrigerant evaporated in evaporator and cycle is completed.

Q1 b) (Representation of cycle on Ph & TS diagram – 04 marks, Calculation of COP 02 Marks & power required 02 marks)

The refrigerant is superheated by 15 degree C before entry to compressor and sub-cooled 3 degree C before entry to expansion valve. The cycle can be sketched on T-S & P-H diagrams as shown below noting, these 2 points.



Referring to T - S and P- H charts ,

1 is in superheated region as it is superheated by 15° C before entry to compressor.

1 - 2 Isentropic compression

2 - 2 Removal of superheat

2 - 3 Condensation

3 - 3 Subcooling by 3°C.

3 - 4 Expansion or throttling

4 - 1 Evaparation

Now , it is given H_1 = Enthalpy at compressor inlet = 1460 KJ/ kg.

H_2 = Enthalby at compressor outlet = 1796 KJ/ kg.

$H_3 = H_4$ = Enthalby at inlet to expassion valve = enthalby at outlet = 322 KJ/ kg.

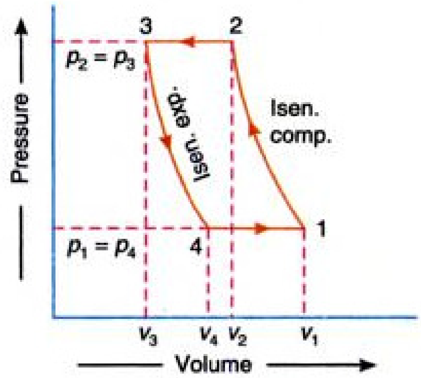
$$\text{Cop} = \frac{N}{W} = \frac{H_1 - H_4}{H_2 - H_1} = \frac{1460 - 322}{1796 - 1460} = \frac{1138}{336} = (3.36)$$

(2) Now power required = work of compression
$= H_2 - H_1 = 1796 - 1460 = 336$ KJ/kg.

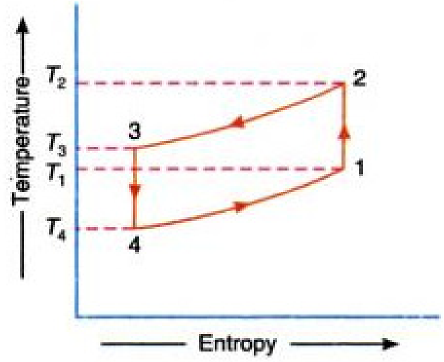
Since , 1 kg. of refrigerent is circulated /min.

so, Power/min = 336 KJ/min $= \frac{336}{60}$ = (5. 6 kw

Q1 c) (Representation of Bell Coleman cycle on Ph & TS diagram 04 Marks, Explanation of process 03 marks & formula COP 01 Marks)



(*a*) *p-v* diagram.



(*b*) *T-s* diagram.

1. *Isentropic compression process.* The cold air from the refrigerator is drawn into the compressor cylinder where it is compressed isentropically in the compressor as shown by the curve 1–2 on *p-v* and *T-s* diagrams. During the compression stroke, both the pressure and temperature increases and the specific volume of air at delivery from compressor reduces from v_1 to v_2. We know that during isentropic compression process, no heat is absorbed or rejected by the air.

2. *Constant pressure cooling process.* The warm air from the compressor is now passed into the cooler where it is cooled at constant pressure p_3 (equal to p_2), reducing the temperature from T_2 to T_3 (the temperature of cooling water) as shown by the curve 2-3 on *p-v* and *T-s* diagrams. The specific volume also reduces from v_2 to v_3. We know that heat rejected by the air during constant pressure per kg of air,

$$Q_{2-3} = c_p(T_2 - T_3)$$

3. *Isentropic expansion process.* The air from the cooler is now drawn into the expander cylinder where it is expanded isentropically from pressure p_3 to the refrigerator pressure p_4 which is equal to the atmospheric pressure. The temperature of air during expansion falls from T_3 to T_4 (*i.e.* the temperature much below the temperature of cooling water, T_3). The expansion process is shown by the curve 3-4 on the *p-v* and *T-s* diagrams. The specific volume of air at entry to the refrigerator increases from v_3 to v_4. We know that during isentropic expansion of air, no heat is absorbed or rejected by the air.

4. *Constant pressure expansion process.* The cold air from the expander is now passed to the refrigerator where it is expanded at constant pressure p_4 (equal to p_1). The temperature of air increases from T_4 to T_1. This process is shown by the curve 4-1 on the *p-v* and *T-s* diagrams. Due to heat from the refrigerator, the specific volume of the air changes from v_4 to v_1. We know that the heat absorbed by the air (or heat extracted from the refrigerator) during constant pressure expansion per kg of air is

$$\text{Coefficient of performance, C.O.P.} = \frac{\text{Heat absorbed}}{\text{Work done}}$$

$$= \frac{(T_1 - T_4)}{(T_2 - T_3) - (T_1 - T_4)}$$

Q2a) Refrigeration: **(Definition 02 marks & Its unit 02 marks)**

Refrigeration is a process of producing cold and maintaining temperature of confined space below atmosphere by continuously removing heat. It is process of removing heat from a body enclosed space and maintained at below surrounding temperature.

Unit of refrigeration: Tons of Refrigeration(TR)

A tons of refrigeration is defined as the amount of refrigerating effect produced by the melting of one tonne of ice from and at 0 ^oC in 24 hours.

Since the latent heat of ice is 335 kJ/kg, therefore one tonne of refrigeration,

$$1\text{TR} = 1000 \times 335 \text{ kJ in 24 hours}$$

$$= \frac{1000 \times 335}{24 \times 60} = 232.6 \text{ kJ/min}$$

In actual practice, one tonne of refrigeration is taken as equivalent to 210 kJ/min or 3.5 kW (*i.e.* 3.5 kJ/s).

1 Ton of refrigeration = 3.517 KJ/Sec or 3.517 kW

Q2b) **(Explanation 02 marks & List of any four refrigerant 02)**

Refrigerants directly contributing to global warming when released to the atmosphere. The refrigerants which does not affect environments and ozone layer are known as Eco friendly refrigerants.

- Domestic refrigeration-R134a,R152a,HC600a and blends
- Commercial refrigeration-R134a,R404A,R407C , HC blends,NH_3 ,CO_2
- Cold storage ,food processing- R404A,R407C , HC blends,NH_3 ,CO_2

List of Eco friendly refrigerants:

i) HCFC R22, R124
ii) HFC R134a , R152a
iii) Natural refrigerant Ammonia ,HC
iv) CO2

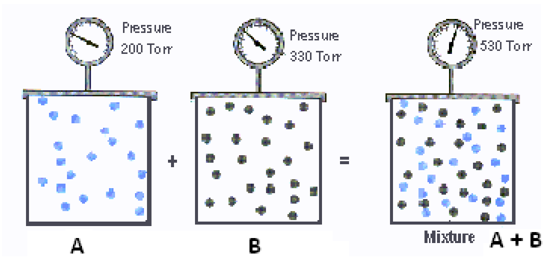
Q2c) **(Statement 02 marks & Sketch 02)**

Daltons law of partial pressures: It states that the total pressure exerted by the mixture of air and water vapour is equal to the sum of the pressures which each constituents would exert, if it occupies the same space by itself.

$$Pb = Pa + Pv$$

Pa = Partial pressure of dry air

Pv = Partial pressure of water vapour



Q2d) Heat exchange between human body and environment **(explanation 04 marks)**

-Sensible heat means a process of heat exchange where temperature measurement is physically sensed, whereas in latent heat transfer the temperature change cannot be sensed.

-During winter period the environment temperature is lesser as compared with body temperature and so there is a sensible heat transfer from body to environment. Due to this the temperature of body falls down and human body feels cold effect.

-In contrast to this during summer period outside temperature is higher as compared to body temperature. This leads to heat transfer from surrounding to human body and so there is a rise in temperature of human body. These are the cases of sensible heat exchange.

When during summer period due to hotness and wet conditions there could be lot of sweat coming from human body. If now there is any evaporation of sweat taking place that will take heat from the body and so body temperature is maintained. This is a case of latent heat exchange.

Q2e) Air conditioning systems are classified **(Classification 04 marks)**

1) According to the purpose:

i) Comfort air-conditioning ii) Commercial air-conditioning

iii) Industrial air-conditioning

2) According to season of the year

i) Summer air-conditioning ii) Winter air-conditioning

iii) Year round air-conditioning

3) According to Equipment Arrangement

i) Unitary air conditioning system ii) Central air conditioning system

iii) window air conditioning system iv) split air conditioning system

Q2 f) Desirable properties of insulating material**:** **(0ne mark for explanation of each property- 04)**

1. Low thermal conductivity: Thermal conductivity of insulating material should be as low as possible to reduce the thickness of material.
2. High permanence : Materials may disintegrate because of internal chemical activity, the material must have high resistance to such phenomenon.
3. It should have high strength in compression ,tension ,shear and impact as it is carrying some loads
4. It should be light weight.
5. It should be odorless
6. It should be fire proof.
7. Resistance to fungus and vermin
8. Low cost
9. Easy available

Q2 g) Applications of refrigeration any four points **(04)**

1. **Domestic Applications:** The domestic applications of refrigeration include the household refrigerators used for storing food, vegetables. Temperatures maintained in household refrigerator for storage has a range of 0 to 4 degrees centigrade's. A freezer compartment is also provided to maintain temperatures below zero degree centigrade which is used for storage of frozen food for a short duration. For storing of frozen food, Ice creams, meat, milk, for a long duration. House hold refrigerators works on Vapour Compression cycle as well as Vapour Absorption cycle. Generally R134a

is used as refrigerant. Other application includes Room air conditioners or Split air conditioners, Water coolers for cooling water.

2. Commercial Applications: Commercial Applications involves the Deep freezers. They are used to store frozen food, fish, cold drinks, Ice creams, milk for a long duration. Temperatures up to -15 degree centigrade's can be maintained here. These work on Vapour compression system and uses generally R134a, as refrigerant. Refrigerated trucks and railway wagons are also used for transportation of Gases, Milk and Food at a low temperature. Ice plants are used for manufacturing of Ice. They work on Vapour compression cycle with Ammonia as primary refrigerant and Brine as secondary refrigerant.

3. Industrial Applications: Industrial air conditioning involves following,

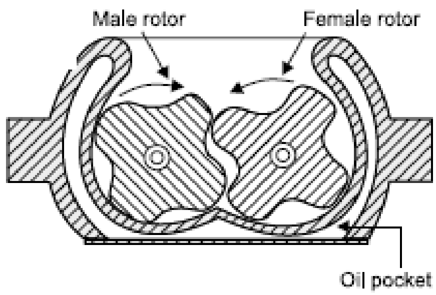
- Air-conditioning for comfort of workers
- For textile industries for production of quality textile products.
- For manufacturing process in photographic industry.
- In printing industries for quality printing.
- In paper industries for production of paper.
- For preservation of food in food industries.

4. Marine Applications: Air conditioning of passenger ships is done for comfort of passengers. Air-conditioning of cargo ships is done for preservation of food and perishable products. Temperature in the range of -23 to 12 ^{o} C is maintained in the atmosphere.

Q.3 a) Classification of air compressor: **(Any four points 04 mark)**

1) According to number of stages:
   i.) Single stage :- Delivery pressure up to 10 bar
   ii.) Multistage:- Delivery pressure above 10 bar.
2) According to number of cylinder: i) Single cylinder ii) Multi cylinder.
3) According to method of cooling: i) Air cooled ii) Water cooled.
4) According to action of air**:** i) Single acting ii) Double acting.
5) According to capacity: i) Low capacity ii) Medium capacity iii) High capacity.
6) According to drive: i) Steam engine drive ii) Steam turbine drive
   iii) Electric motor drive iv) Internal combustion drive.

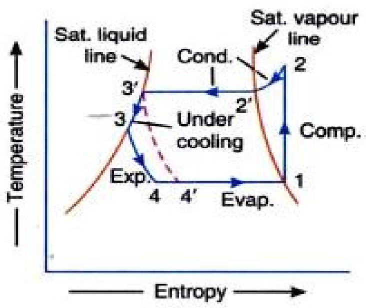
Screw Type compressor **(Sketch 02 marks & Working 02 marks)**



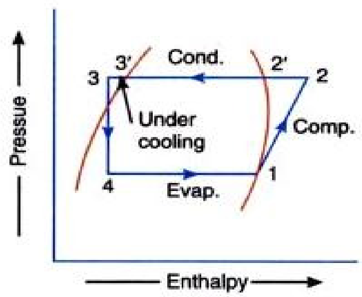
These may have two spiral lobed rotors, out of which one may be called male rotor having3–4 lobes and other female rotor having 4–6 lobes which intermesh with small clearance. Meshing is such that lobes jutting out of male rotor get placed in matching hollow portion in female rotors. Initially, before this intermeshing the hollows remain filled with gaseous fluid at inlet port. As rotation begins the surface in contact move parallel to the axis of rotors toward the outlet end gradually compressing the fluid till the trapped volume reaches up to outlet port for getting discharged out at designed pressure. Since the number of lobes is different so the rotors operate at different speed. Two rotors are brought into synchronization by the screw gears. Thrust upon rotors is taken care of by oil lubricated thrust bearings. These compressors are capable of handling gas flows ranging from 200 to 20000 m3/h under discharge pressures of 3 bar gauge in single stage and up to 13 bar gauge in two stages. Even with increase in number of stages pressures up to 100 bar absolute have been obtained with stage pressure ratio of 2.Mechanical efficiency of these compressors is quite high and their isothermal efficiencies are even more than vane blowers and may be compared with centrifugal and axial compressors. But these are very noisy, sensitive to dust and fragile due to small clearances.

Q3 b) Superheating **(for Ph diagram 02 marks & Its effects 02 marks)**

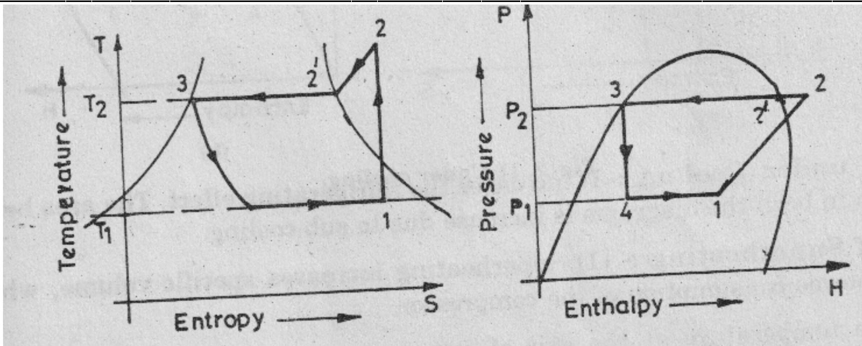
Sub cooling **(for Ph diagram 02 marks & Its effects 02 marks)**



(a) T-s diagram.



(b) p-h diagram.



Superheated Compression.

Effect of sub cooling: It increases the refrigerating effect. Thus COP will increase

Effect of superheating: It increases specific volume which increases power consumption of the compressor. The temperature at the compressor is raised. The refrigerating effect slightly increased, but increase in work done required is more and hence COP will decrease.

Q3 c) Classification of refrigerants: **(classification 04 marks & any four properties 04 marks)**

It is classified into two categories:

i) Primary Refrigerant: The refrigerant which directly extracts or carries the heat from heat generating source in the refrigeration system in the evaporator of refrigeration system is called as the primary refrigerant.

Ex- R134a , R22

The primary refrigerant are further classified:

i) Halo-carbon refrigerant
ii) Azeotropic refrigerant
iii) Inorganic refrigerant
iv) Hydro-carbon refrigerant

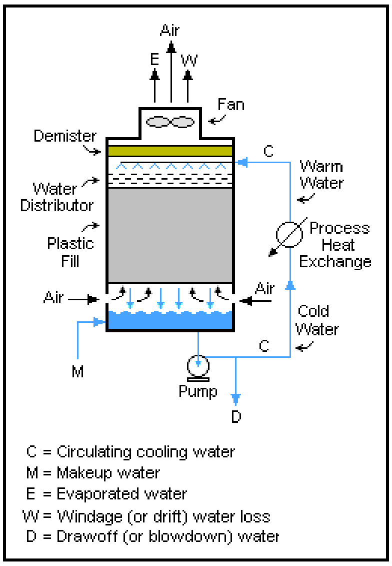
ii) Secondary Refrigerant: In many applications it is not desirable to carry the heat from place which is to be cooled directly by refrigerant, and then it is carried by using the secondary refrigerant such as Air, Water, or Brine. The heat carried away by secondary refrigerant is given to primary refrigerant in evaporator and secondary refrigerant is circulated again and again. Ex- Brine, water

Thermodynamic Properties of refrigerant:

1. **Boiling point**: for ideal refrigerant boiling point should be low.
2. **Freezing point**: Low freezing point of refrigerant is necessary because refrigerant should not freeze under required evaporator temperature.
3. **Evaporator and condenser pressure**: it is desired to have positive pressure in evaporator and condenser. But high pressure requires robust construction.

4. **Critical temperature and pressure**; It is a temperature above which vapor cannot be condensed irrespective of any high pressure. Therefore critical temperature of refrigerant must be higher than condenser temperature.
5. **Latent heat of refrigerant:** It should be high so that for required capacity, mass of refrigerant circulated will be less and this also reduces cost of refrigerant.

Q4 a) Induced draft cooling: **(Sketch 04 marks & Explanation 04 marks)**



In the Induced draft cooling tower, the fan sucks the air through the tower. In its operation the warm water from the condenser is spread at the top of the tower through the spray nozzle. The air is induced from the tower , pulls this warm water by means of evaporation. The effectiveness of the cooling tower is increased by increasing the height of tower and area of water surface exposed to air or the velocity of air

4 b) **Name of any four devices 04 marks, sketch 02 marks & explanation 02 marks)**

List of expansion devices used

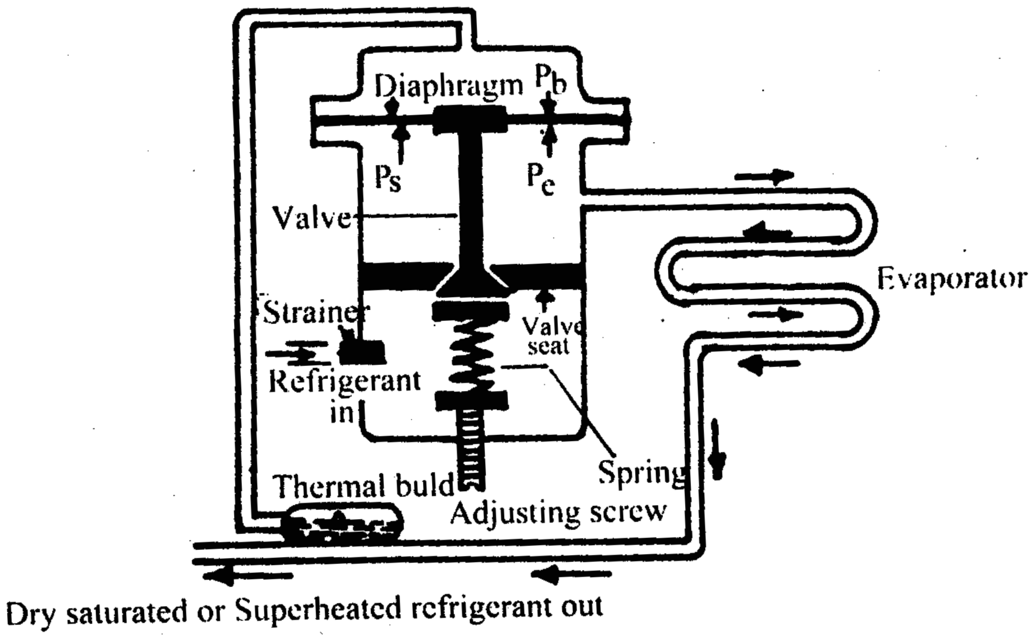
1. Capillary tube
2. Thermostatic expansion valve
3. Automatic expansion valve
4. Solenoid valve
5. Low and high side float valve.

Thermostatic Expansion Valve: It consists of diaphragm, valve, valve seat, spring, adjusting screw and thermal bulb. Thermal bulb is used to check temperature in evaporator. The pressure acting on diaphragm are

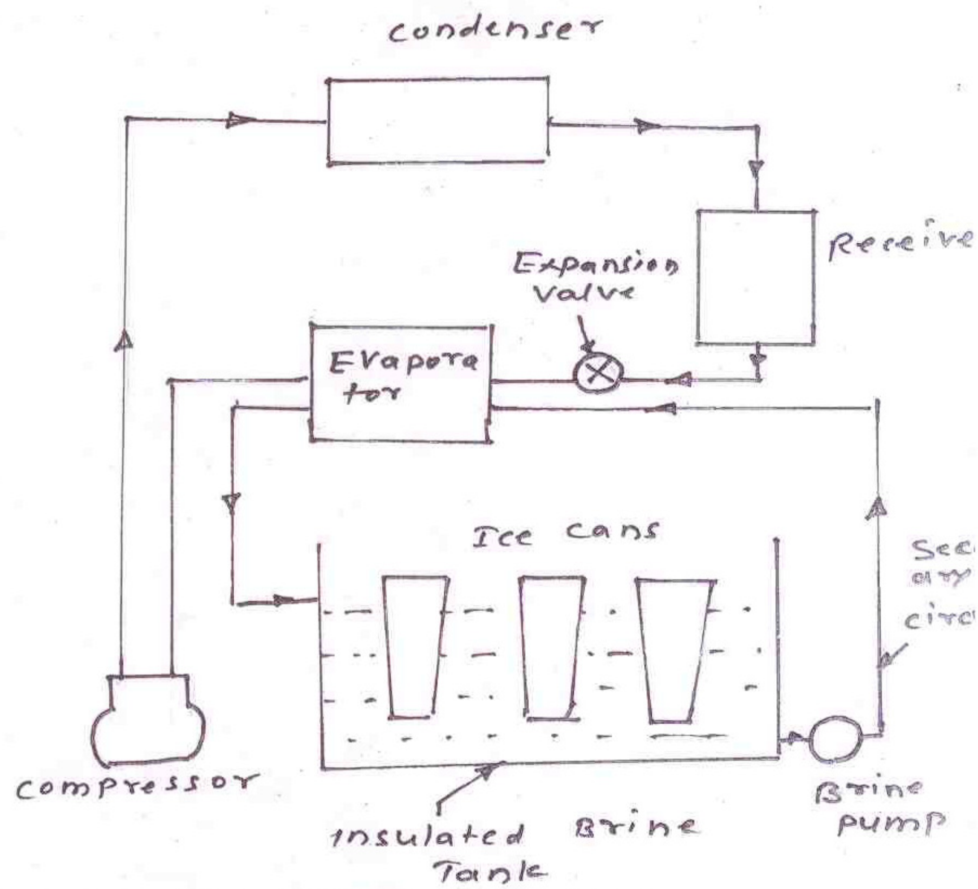
1. Bulb pressure from thermal bulb acting in downward direction
2. Spring pressure acting in upward direction
3. Evaporator pressure from evaporator

It is fitted in liquid line just before evaporator in direction of arrow provided on it and thermal bulb is clamped with exit line of evaporator. For constant load of pressure, 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 vapors are coming at exit of evaporator which transfers heat to thermal bulb. Due to this refrigerant field in bulb vaporized and increases the bulb pressure to open up valve allowing more liquid refrigerant into evaporator. When there is decrease in load on evaporator, vapor at the exit of evaporator absorbs heat from 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 4 c)



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

- 4 marks for neat labeled sketch

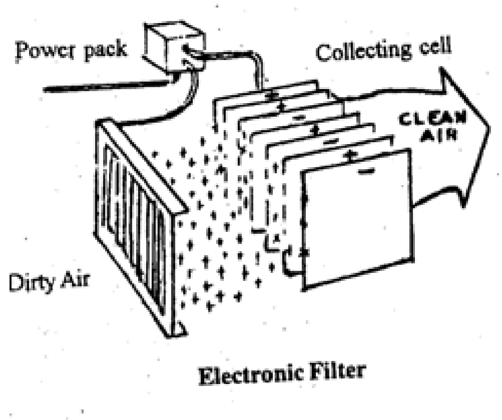
  4 marks for explaination.

Q5 a) **(List of Filters 02 marks , Sketch 03 marks & Explanation 3 marks)**

. **Filters**

- Dry Filters
- Viscous Filters
- Wet Filters
- Electric Filters
- Electronic Filters

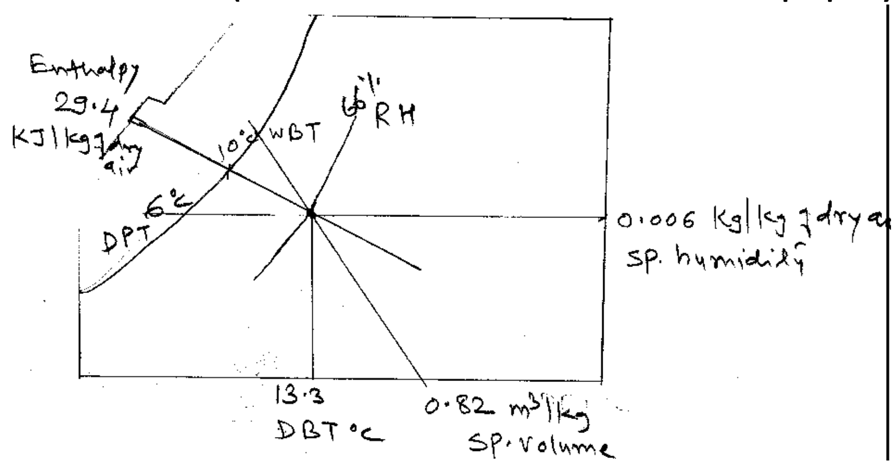
Electronic Filter



Electronic Filter

Electronic filter: This type of filter operates on the principle that unlike electrical charges attracts one another. The dirty air stream passes through a series of charging plates so that dirt particles in the air acquire a strong charge 20% negatively and 80% positively. The air stream then passes to the collector plates which have an electrical charge opposite to that of particle. The charged dust particles are attracted to the collector plates.

Q5 b) Solution **(chart drawn 03 marks & 0ne marks each property- 05 marks)**



From the psychrometric chart having 6^0 C DPT and Specific Volume 0.82 m^3 /kg ,

i) DBT = 13.3 ^{0} c

ii) WBT = 10 ^{0} C

iii) Relative Humidity = 66 %

iv) Enthalpy= 29.4 kJ/kg of dry air

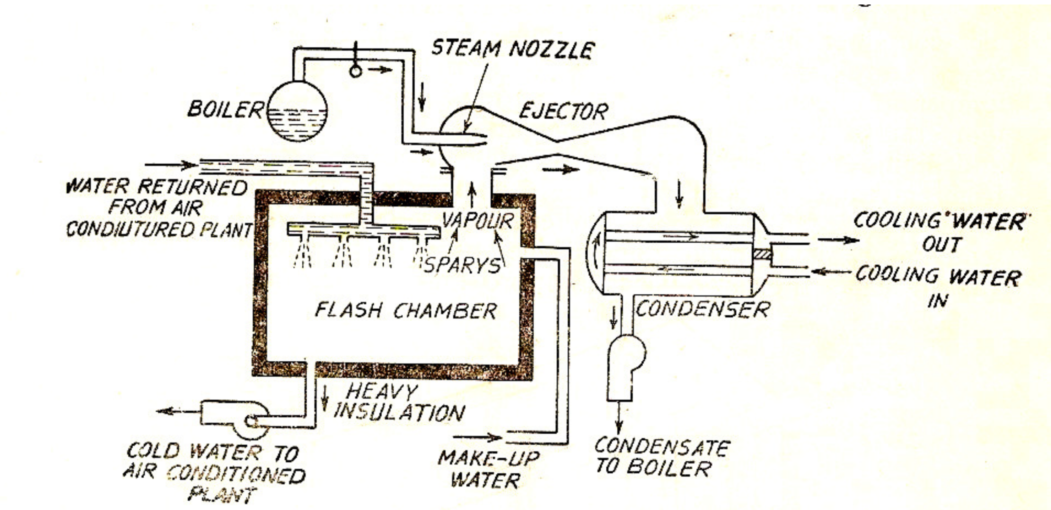
v) Specific Humidity= 0.006 kg/kg of dry air

Q5 c) Non conventional refrigeration system:

(List any four 02 marks ,Sketch 03 marks & explanation 3 marks)

1. Vortex tube refrigeration
2. Pulse tube refrigeration
3. Solar refrigeration
4. Steam jet refrigeration
5. Thermoelectric refrigeration

Steam jet refrigeration: Figure shows the arrangement for steam jet refrigeration. At atmospheric pressure water boils at 100 ^{o} C. If this boiling temperature is reduced to 5 cm of water column, the temperature of evaporation is 6 ^{O} C. This principle of boiling water at low temperature is adopted in stem jet refrigeration. Water at low pressure is maintained in flash chamber by means of steam jet and ejector system. The steam passing through the nozzle acquires high velocity and pressure reduced to required level. The condensate in the condenser is thrown out.



Steam Jet Refrigeration System

Q6 a) 1) Sensible Heat Gain : (any four point 04 marks)

Sensible heat is the heat as it flows into conditioned space or produced in the conditioned space, which will tend to cause rise in temperature of conditioned space.

Sensible heat gain from class room includes.

a) Heat deception through the building structure as a result of conduction, convection and radiation.
b) Sensible heat brought in with the outside air by ventilation.
c) Sensible heat produced by student.
d) Sensible heat produced in conditioned space by lights, fans etc.
e) Sensible heat coming by solar radiation.

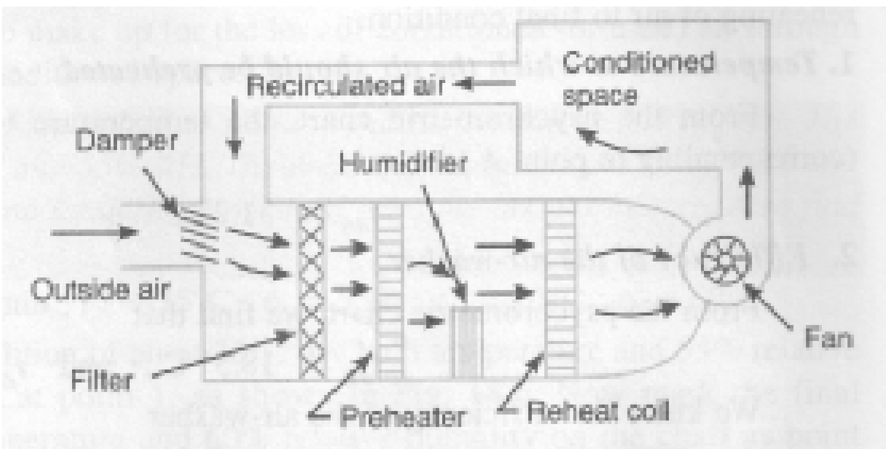
2) Latent Heat Gain: (any Two point 04 marks)

Latent heat is transferred whenever there is change of phase. It is in the form of moisture change (change in relative humidity) taking place at constant temperature.

Latent heat gain includes.

a) Latent heat gain due to moisture in outside air entering by infiltration.
b) Latent heat gain due to condensation of moisture from students.
c) Latent heat gain due to condensation of moisture from any activity of students
d) Latent heat of ventilation air coming in conditioned space.
e) Latent heat by student respiration.

Q6 b) Winter air conditioning: (Sketch 04 marks & Description 04 marks)

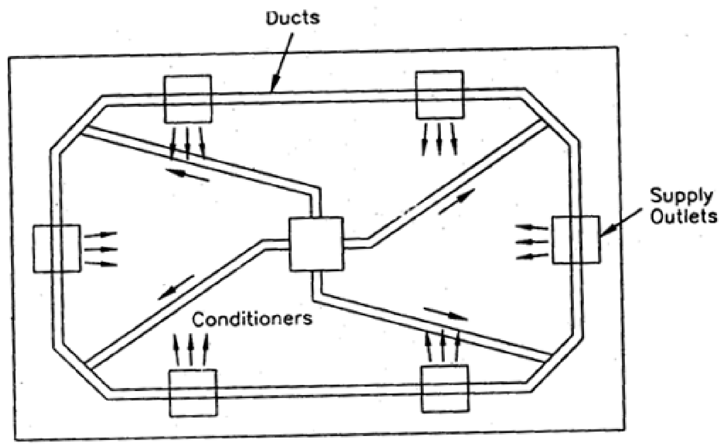


It is mainly used where outdoor temperature is considerably low (5^0C to 10 ^{0} C) . In winter air-conditioning system re circulated air and outdoor fresh air is mixed. The stream of air is passed to spray chamber through filter and preheating coil. The function of filter is to remove dust, dirt and harmful bacteria from air to make it clean and pure. In preheating coil sensible heating of air takes place. Heating of air increases temperature but relative humidity decreases. The decrease in relative humidity is increased by humidifier. Water eliminator is provided to remove heavy moisture particles. Before passing air to condition space it is reheated to adjust temperature and humidity.

Q6 c) Type of duct systems: (Type any four 02 marks , Sketch 03 marks & Explanation 03 marks)

1. Extended plenum system
2. Radial perimeter duct system
3. Loop perimeter duct system
4. Graduated trunk duct system
5. Overhead trunk duct system

Closed perimeter duct system: The perimeter duct system may be of closed loop or radial type. The figure shows closed Perimeter duct system. In this system the conditioner is usually placed in the basement and it is located near the geometric centre of all outlets. The supply outlets are placed close to the ceiling level. The ducts runs through the basement building foundation slab, the floor and connect the air conditioner to the outlet grills are generally located on the bottom side of the inside wall. This arrangement is commonly used for the residential systems.



Perimeter loop system