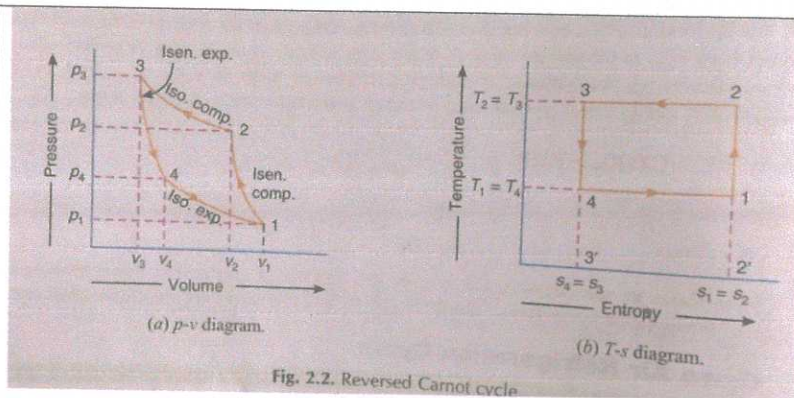


SCHEME OF VALUATION

(Scoring Indicators)

Revision : 2015		Course Code :TID(15) 6023		
Course Title : Refrigeration and air conditioning				
Qst.No.	Scoring Indicator	Split up score	Sub Total	Total
I(1)	<p style="text-align: center;">PART – A</p> <p>Define saturation temperature.</p> <p>Saturation temperature means boiling point. The saturation temperature is the temperature for a corresponding saturation pressure at which a liquid boils in to its vapour phase. The liquid can be said to be saturated with thermal energy.</p>			2
I(2)	<p>State the purpose of refrigeration.</p> <p>The main purpose of refrigeration is to manufacture ice and similar products. It is also widely used for the cooling of storage chambers in which perishable foods, drinks and medicines are stored. The refrigeration has also wide applications in submarine ships, air craft and rockets.</p>			
I(3)	<p>List the major components used in refrigeration system</p> <ol style="list-style-type: none">1. Compressor2. Condenser3. Receiver4. Expansion device5. Evaporator			2
I(4)	<p>State Dalton's law of partial pressure.</p> <p>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 constituent would exert, if it occupied the same space by itself." In other words, the total pressure exerted by air water vapour mixture is equal to the barometric pressure.</p>			2
I(5)	<p>Define air conditioning.</p>			2

	<p>The air conditioning is that branch of engineering science which deals with the study of conditioning of air. i.e supplying and maintaining desirable internal atmospheric conditions for human comfort, irrespective of external conditions.</p>			2
PART – B				
II (1)	<p>1. Define (i) Sensible heat (ii) Latent heat (iii) Enthalpy <u>Sensible heat :-</u> When a substance is heating or cooling, the amount of heat added or subtracted is called sensible heat. <u>Latent heat :-</u> The heat which brings about a change of state with no change in temperature is called latent heat. <u>Enthalpy :-</u> The sum of internal energy (U) and the product of pressure and volume (pv) is termed as enthalpy. $H = U + pv$</p>	2+2+2	6	6
II (2)	<p>Explain air refrigerator working on reversed Carnot cycle with p-v and T-s diagram</p> <p>A reversed Carnot cycle using air has working medium is shown on p-v and T-s diagrams. At point 1, let p_1, v_1, T_1 be the pressure, volume, and temperature of air respectively</p>			



The four process of cycle are as follows

1. Isentropic compression process :- The air is compressed isentropically as shown by the curve 1-2 on p-v and T-s diagrams. During this process , the pressure of air increases from p_1 to p_2 , sp
2. ecific volume decreases from v_1 to v_2 and temperature increases from T_1 to T_2 . During isentropic compression no heat is absorbed or rejected by the air.
3. Isothermal compression process :- The air is now compressed isothermally as shown by the curve 2-3 on p-v and T-s diagram. During this process the pressure of air increases from p_2 to p_3 and specific volume decreases from v_2 to v_3 . Heat rejected by the air during isothermal compression per kg of air
 $Q = T_3 (s_2 - s_3) = T_2 (s_2 - s_3)$
4. Isentropic expansion process :- The air is now expanded isentropically as shown by the curve 3-4. The pressure of air decreases from p_3 to p_4 , specific volume increases from v_3 to v_4 and temperature decreases from T_3 to T_4 . During isentropic expansion no heat is absorbed or rejected.
5. Isothermal expansion process :- The air is now expanded isothermally as shown by the curve 4-1. The pressure of air decreases from p_4 to p_1 and specific volume increases from v_4 to v_1 . Heat absorbed by the air during isothermal expansion per kg of air
 $Q = T_4 (s_1 - s_4) = T_4 (s_2 - s_3) = T_1 (s_2 - s_3)$

Explanation = 3
Diagrams = 3

6

6

II (3)

List the advantages of vapour absorption refrigeration system over vapour compression refrigeration system.

1. In the vapour absorption system, the only moving part is a pump. Thus the operation is quiet and is subjected to little wear

2. The vapour absorption system uses heat energy to change the condition of the refrigerant from the evaporator.
3. The vapour absorption system are usually designed to use steam, either at high pressure or low pressure. Thus the system can be used where the electric power is difficult to obtain or is very expensive.
4. The system can operate at reduced evaporator pressure and temperature by increasing the steam pressure to the generator with little decrease in capacity.
5. The load variation do not affect the performance of the system.
6. The system can be built in capacities well above 1000 tonnes of refrigeration each, which is the largest size for single compressor unit.

1 point = 1 mark

6 6

II (4)

Explain the working of flooded type evaporator.

11.16 Flooded Evaporators

In a flooded evaporator, as shown in Fig. 11.11, a constant liquid refrigerant level is always maintained. A float control valve is used as an expansion device which maintains constant liquid level in the evaporator. The liquid refrigerant from the receiver passes through a low side float control valve and accumulator before entering the evaporator coil. The accumulator (also called a surge drum or surge tank) serves as a storage tank for the liquid refrigerant. It maintains a constant liquid level in the evaporator and helps to separate the liquid refrigerant from the vapour returning to the compressor. Due to the heat supplied by the substance to be cooled, the liquid refrigerant in the evaporator coil vaporises and thus the liquid level falls down. The accumulator supplies more liquid to the evaporator in order to keep the liquid refrigerant in the evaporator at proper level. In this way, the level of liquid refrigerant in the accumulator also falls down. Since the float within the float chamber rests on liquid refrigerant at the same level as that in the accumulator, therefore the float also falls down and open the float valve. Now the liquid refrigerant from the receiver is admitted into the accumulator. As the liquid level in the accumulator rises and reaches to the constant level, the float also rises with it until the float control valve closes.

Since the evaporator is almost completely filled with liquid refrigerant, therefore the vapour refrigerant from the evaporator is not superheated but it is in a saturated condition. In order to prevent liquid refrigerant to enter into the compressor, an accumulator is generally used with the flooded evaporators. The liquid refrigerant trapped in the accumulator is re-circulated through the evaporator. The evaporator coil is connected to the accumulator and the liquid flow from the accumulator to the evaporator coil is generally by gravity. The vapour formed by vaporising the liquid in the coil being lighter, rises up and passes on to the top of the accumulator from where it is supplied to the suction side of the compressor. The baffle plate arrests any liquid present in the vapour.

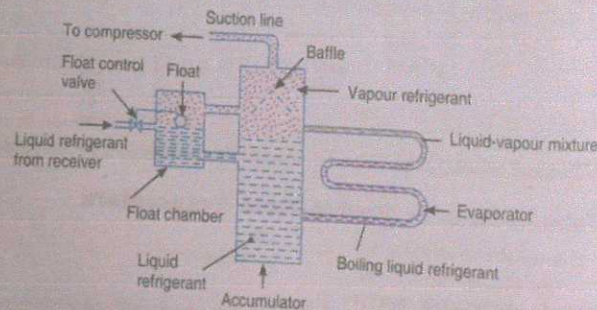


Fig. 11.11. Flooded evaporator.

6 6 6

II (5)

11 (5)

Define

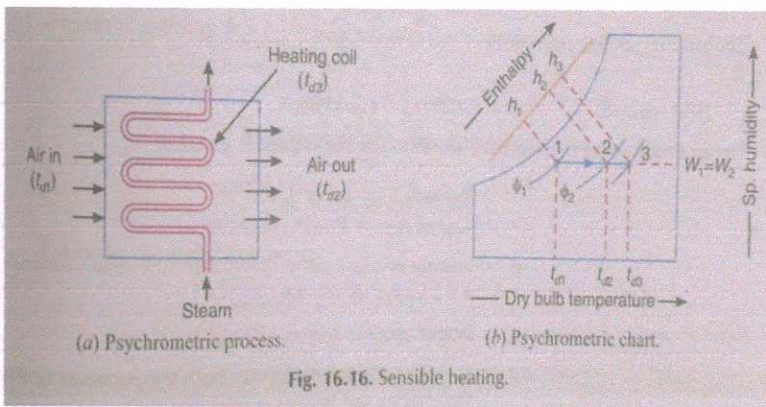
(i)Sensible heating

(ii)Cooling and Dehumidification

(iii)Sensible heat Factor

Sensible heating

The heating of air without any change in its specific humidity is known as sensible heating. Let air at temperature t_{d1} passes over a heating coil of temperature t_{d3} as shown in figure. It may be noted that the temperature of air leaving the heating coil t_{d2} will be less than t_{d3} . The process of sensible heating is shown by a horizontal line 1-2 as shown.



Each carries 2 marks

6

6

Cooling and dehumidification

16.16 Cooling and Dehumidification

This process is generally used in summer air conditioning to cool and dehumidify the air. The air is passed over a cooling coil or through a cold water spray. In this process, the dry bulb temperature as well as the specific humidity of air decreases. The final relative humidity of the air is generally higher than that of the entering air. The dehumidification of air is only possible when the effective surface temperature of the cooling coil (i.e. t_{ad}) is less than the dew point temperature of the air entering the coil (i.e. t_{dp1}). The effective surface temperature of the coil is known as *apparatus dew point* (briefly written as *ADP*). The cooling and dehumidification process is shown in Fig. 16.29.

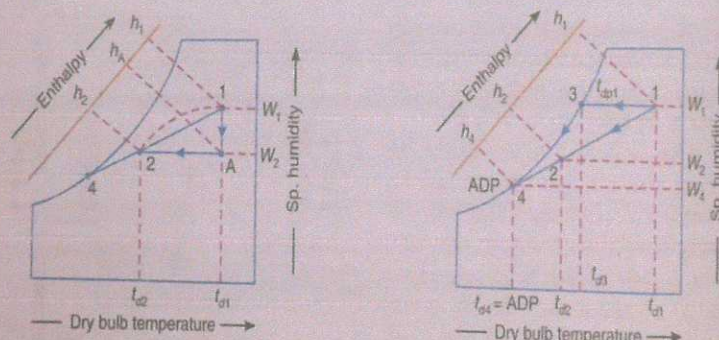


Fig. 16.29. Cooling and dehumidification.

Sensible heat factor

16.15 Sensible Heat Factor

As a matter of fact, the heat added during a psychrometric process may be split up into sensible heat and latent heat. The ratio of the *sensible heat to the total heat is known as *sensible heat factor* (briefly written as *SHF*) or *sensible heat ratio* (briefly written as *SHR*). Mathematically,

$$SHF = \frac{\text{Sensible heat}}{\text{Total heat}} = \frac{SH}{SH + LH}$$

where

SH = Sensible heat, and

LH = Latent heat.

The sensible heat factor scale is shown on the right hand side of the psychrometric chart.

II (6)	<p>List the applications of cryogenic refrigeration.</p> <ol style="list-style-type: none"> 1. Liquefaction of gases 2. Separation of gases 3. Food preservation 4. Cryo 5. surgery 6. Cell preservation 7. Recycling of materials (PVC Rubbers) 8. Magnetic separation 9. Cryogenic heat treatment of materials 10. Rocket propulsion 	1 point = 1 mark	6	6
H(7)	<ol style="list-style-type: none"> 11. Space simulation chambers 			
II (7)	<p>List the factors affecting human comfort.</p> <ol style="list-style-type: none"> 1. Effective temperature 2. Heat production and regulation in human body 3. Heat and moisture losses from the human body 4. Moisture content of air 5. Quality and quantity of air 6. Air motion 7. Hot and cold surfaces 8. Air stratification 	1 point = 1 mark	6	6

III (a)

PART - C

Explain the working of air refrigerator based on Bell Coleman cycle with the help of flow diagram ,p-v and T-s diagrams

2.9 Air Refrigerator Working on a Bell-Coleman Cycle (or Reversed Brayton or Joule Cycle)

A Bell-Coleman air refrigeration machine was developed by Bell-Coleman and Light Foot by reversing the Joule's air cycle. It was one of the earliest types of refrigerators used in ships carrying frozen meat. Fig. 2.7 shows a schematic diagram of such a machine which consists of a compressor, a cooler, an expander and a refrigerator.

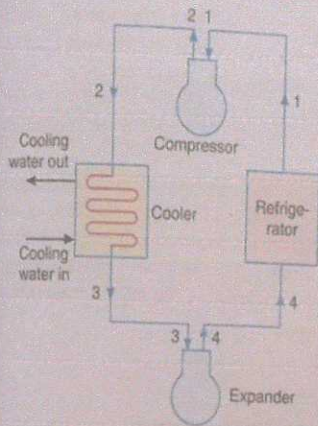


Fig. 2.7. Open cycle air Bell-Coleman Refrigerator.

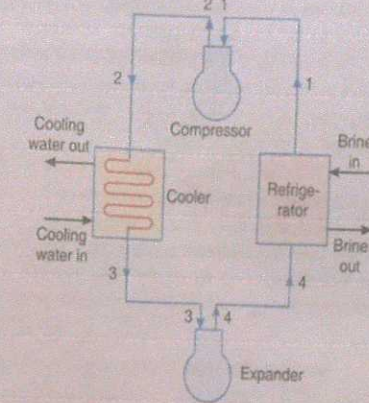


Fig. 2.8. Closed cycle or dense air Bell-Coleman Refrigerator.

The Bell-Coleman cycle (also known as reversed Brayton or Joule cycle) is a modification of reversed Carnot cycle. The cycle is shown on $p-v$ and $T-s$ diagrams in Fig. 2.9 (a) and (b). At point 1, let p_1 , v_1 and T_1 be the pressure, volume and temperature of air respectively. The four processes of the cycle are as follows :

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.

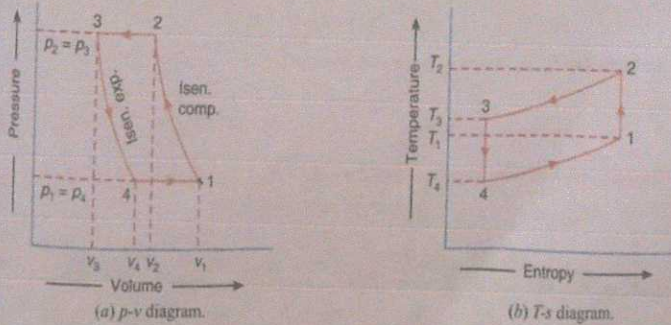


Fig. 2.9. Bell-Coleman cycle.

Explanation = 3 mark
 P-v diagram = 3 mark
 T-s diagram = 3 mark
 Flow diagram = 3 mark

9 9

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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_2 (equal to p_1), 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,

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

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 or the refrigerating effect produced) during constant pressure expansion per kg of air is

$$q_A = q_{4-1} = c_p(T_1 - T_4)$$

We know that work done during the cycle per kg of air

$$= \text{Heat rejected} - \text{Heat absorbed} = q_R - q_A$$

$$= c_p(T_2 - T_3) - c_p(T_1 - T_4)$$

∴ Coefficient of performance,

$$\begin{aligned} \text{C.O.P.} &= \frac{\text{Heat absorbed}}{\text{Work done}} = \frac{q_A}{q_R - q_A} = \frac{c_p(T_1 - T_4)}{c_p(T_2 - T_3) - c_p(T_1 - T_4)} \\ &= \frac{(T_1 - T_4)}{(T_2 - T_3) - (T_1 - T_4)} \end{aligned}$$

III (b)

List the advantages and disadvantages of air refrigeration system

Advantages

1. The air is easily available and there is no cost of the refrigerant.
2. The air is non-toxic and non-inflammable
3. The leakage of air in small amounts is tolerable.
4. Since the main compressor is employed for the compressed air source, therefore there is no problem of space for extra compressor.
5. The air is light in weight per tonne of refrigeration.
6. Since the pressure in the whole system is quite low,

Advantages = 4 marks
Disadvantages = 2 "

6

6

therefore the piping, ducting etc. are quite simple to design, fabricate and maintain.

Disadvantages

1. It has low coefficient of performance.
2. The rate of air circulation is relatively large.

IV (a)

Example 4.1. In an ammonia vapour compression system, the pressure in the evaporator is 2 bar. Ammonia at exit is 0.85 dry and at entry its dryness fraction is 0.19. During compression, the work done per kg of ammonia is 150 kJ. Calculate the C.O.P. and the volume of vapour entering the compressor per minute, if the rate of ammonia circulation is 4.5 kg/min. The latent heat and specific volume at 2 bar are 1325 kJ/kg and 0.58 m³/kg respectively.

Solution. Given : $p_1 = p_2 = 2 \text{ bar}$; $x_1 = 0.85$; $x_2 = 0.19$; $w = 150 \text{ kJ/kg}$; $m_a = 4.5 \text{ kg/min}$; $h_{fg} = 1325 \text{ kJ/kg}$; $v_g = 0.58 \text{ m}^3/\text{kg}$

C.O.P.

The $T-s$ and $p-h$ diagrams are shown in Fig. 4.3 (a) and (b) respectively. Since the ammonia vapour at entry to the evaporator (i.e. at point 4) has dryness fraction (x_2) equal to 0.19, therefore enthalpy at point 4,

$$h_4 = x_2 \times h_{fg} = 0.19 \times 1325 = 251.75 \text{ kJ/kg}$$

Similarly, enthalpy of ammonia vapour at exit i.e. at point 1,

$$h_1 = x_1 \times h_{fg} = 0.85 \times 1325 = 1126.25 \text{ kJ/kg}$$

∴ Heat extracted from the evaporator or refrigerating effect,

$$R_E = h_1 - h_4 = 1126.25 - 251.75 = 874.5 \text{ kJ/kg}$$

We know that work done during compression,

$$w = 150 \text{ kJ/kg}$$

∴ C.O.P. = $R_E / w = 874.5 / 150 = 5.83 \text{ Ans.}$

Volume of vapour entering the compressor per minute

We know that volume of vapour entering the compressor per minute

$$= \text{Mass of refrigerant / min} \times \text{Specific volume}$$

$$= m_a \times v_g = 4.5 \times 0.58 = 2.61 \text{ m}^3/\text{min} \text{ Ans.}$$

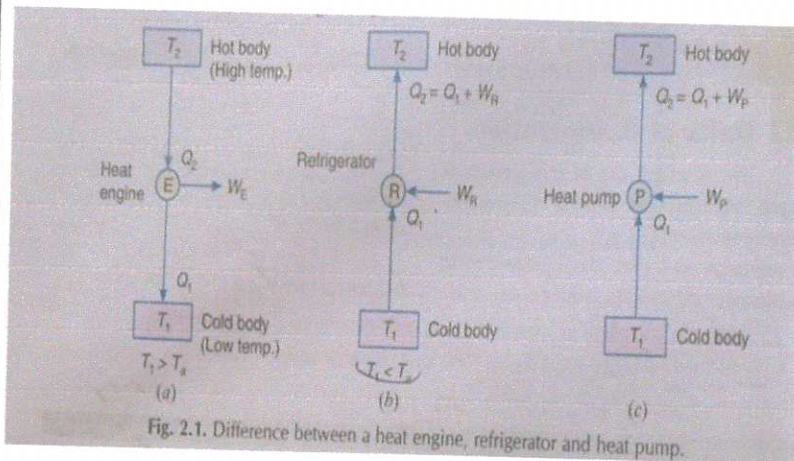
Calculation = 5
Given data = 2
Equation = 2

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IV (b)

Differentiate heat engine, refrigerator and heat pump.



Each carries 2 marks.

6

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

$$W = Q_2 - Q_1$$

Refrigerator :- It is a reversed heat engine which either cool or maintain the temperature of a body (T_1) lower than the atmospheric temperature (T_a). This is done by extracting the heat (Q_1) from a cold body and delivering it to a hot body (Q_2).

Heat pump :- A heat pump which extracts heat (Q_1) from a cold body and delivers it to a hot body. Thus there is no difference between the cycle of operation of a heat pump and a refrigerator. A refrigerator used for cooling in summer can be used as a heat pump for heating in winter.

Explain the working of simple vapour absorption system with a flow diagram

V (a)

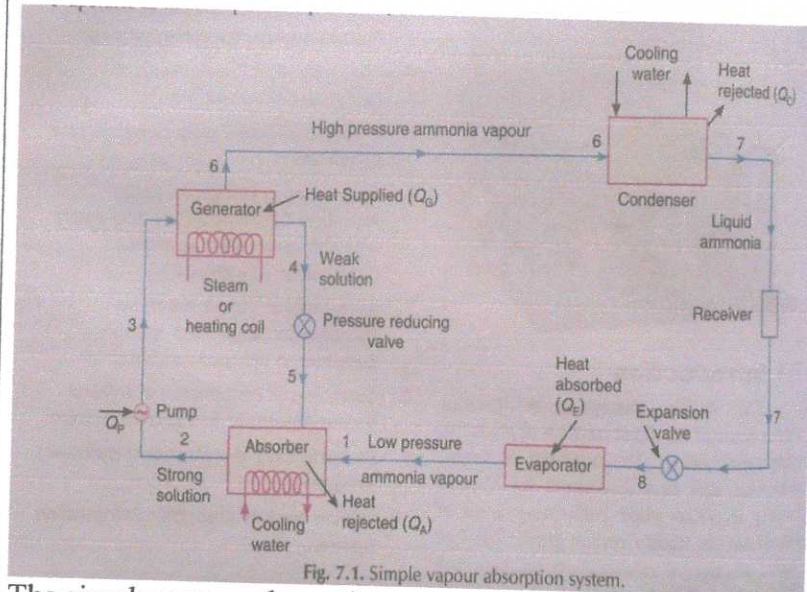


Fig. 7.1. Simple vapour absorption system.

The simple vapour absorption system consists of an absorber, a pump, a generator and a pressure reducing valve to replace the compressor of vapour compression system. The other components of the system are condenser, receiver, expansion valve and evaporator as in the vapour compression system.

In this system the low pressure ammonia vapour leaving the evaporator enters the absorber where it is absorbed by the cold water in the absorber. The water has ability to absorb very large quantities of ammonia vapour and the solution, thus formed is known as aqua-ammonia. The absorption of ammonia vapour from the evaporator and thus raises the temperature of the solution. Some form of cooling arrangement (usually water cooling) is employed in the absorber to remove the heat of

Explanation = 5 marks
Flow diagram = 4 "

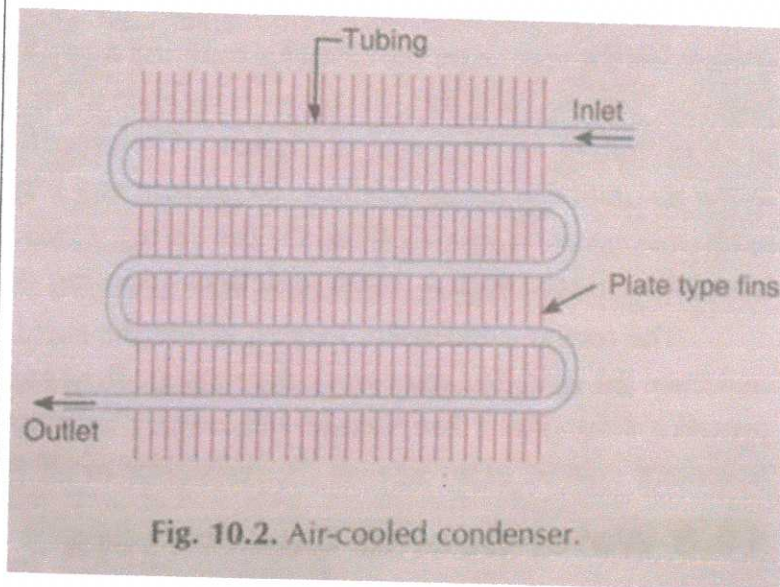
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solution evolved there. The strong solution thus formed in the absorber is pumped to the generator by the liquid pump. The pump increases the pressure of the solution up to 10bar. The strong solution of ammonia in the generator is heated by some external source such as gas or steam. During the heating process the ammonia vapour is driven off the solution at high pressure leaving behind the hot weak ammonia solution in the generator which flows back to the absorber. The high pressure ammonia vapour from the generator is condensed in the condenser to a high pressure liquid ammonia. This liquid ammonia is passed to the expansion valve through the receiver and to the evaporator. This completes the simple vapour absorption cycle.

V(b) Explain the working of air cooled condenser.

V(b)



The air cooled condensers is one in which the removal of heat is done by air. It consist of steel or copper tubing through which the refrigerant flows. The condensers with single row of tubing provides the most efficient heat transfer. This is because the air temperature rises as it passes through each row of tubing. The temperature difference between the air and the vapour refrigerant decreases in each row of tubing and therefore each row becomes less effective. However single row condensers requires more space than multi row condensers.

V1(a) Explain with sketch the working of centrifugal compressor.

b b b

VI (a)

9.22 Centrifugal Compressors

The centrifugal compressor for refrigeration systems was designed and developed by Dr. Willis H. Carrier in 1922. This compressor increases the pressure of low pressure vapour refrigerant to a high pressure by centrifugal force. The centrifugal compressor is generally used for refrigerants that require large displacement and low condensing pressure, such as R-11 and R-113. However, the refrigerant R-12 is also employed for large capacity applications and low-temperature applications.

A single stage centrifugal compressor, in its simplest form, consists of an impeller to which a number of curved vanes are fitted symmetrically, as shown in Fig. 9.16. The impeller rotates in an airtight volute casing with inlet and outlet points.

The impeller draws in low pressure vapour refrigerant from the evaporator. When the impeller rotates, it pushes the vapour refrigerant from the centre of the impeller to its periphery by centrifugal force. The high speed of the impeller leaves the vapour refrigerant at a high velocity at the vane tips of the impeller. The kinetic energy thus attained at the impeller outlet is converted into pressure energy when the high velocity vapour refrigerant passes over the diffuser. The diffuser is normally a vaneless type as it permits more efficient part load operation which is quite usual in any air-conditioning plant. The volute casing collects the refrigerant from the diffuser and it further converts the kinetic energy into pressure energy before it leaves the refrigerant to the evaporator.

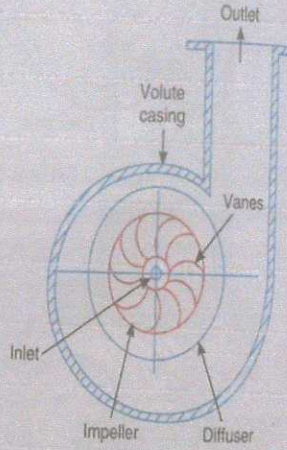


Fig. 9.16. Centrifugal compressor.

Notes : 1. In case of a single stage centrifugal compressor, the compression ratio that an impeller can develop is limited to about 4.5. But when high compression ratio is desired, multi-stage centrifugal compressors with intercoolers are employed.

2. The centrifugal compressors have no valves, pistons and cylinders. The only wearing parts are the main bearings.

Explanation = 5
Sketch = 4.

9

9

List the desirable properties of refrigerants.

VI (b)

1. Low boiling and freezing point
2. High critical pressure and temperature
3. High latent heat of vaporization
4. Low specific heat of liquid and high specific heat of vapour.
5. Low specific volume of vapour
6. High thermal conductivity.
7. Non- corrosive to metal.
8. Non-flammable and non-explosive
9. Non-toxic
10. Low cost
11. Easily available
12. High coefficient of performance.

Each point 1 mark

6x1 = 6

6.

VII(a)

Given $v_1 = 300 \text{ m}^3$, $t_{d1} = 30^\circ\text{C}$, $t_{w1} = 25^\circ\text{C}$,
 $t_{d2} = 40^\circ\text{C}$, $P_b = 1.01325 \text{ bar}$

Amount of heat added,

From the psychrometric chart, we find that specific volume of air at point 1,

$$v_{s1} = 0.883 \text{ m}^3/\text{kg of dry air}$$

Enthalpy at point 1,

$$h_1 = 76 \text{ kJ/kg of dry air}$$

and enthalpy at point 2,

$$h_2 = 86.4 \text{ kJ/kg of dry air}$$

\therefore Amount of air supplied,

$$m_a = \frac{v_1}{v_{s1}} = \frac{300}{0.883}$$

$$= \underline{\underline{339.75 \text{ kg}}}$$

\therefore Amount of heat added = $m_a (h_2 - h_1)$

$$= 339.75 (86.4 - 76)$$

$$= \underline{\underline{3533.4 \text{ kJ}}}$$

Fresh relative humidity

From the psychrometric chart, the relative humidity at point 2 is

$$\phi_2 = \underline{\underline{39\%}}$$

Wet bulb temperature

From the psychrometric chart, wet bulb temp. at point 2 is $t_{w2} = \underline{\underline{27.5^\circ\text{C}}}$

Given data = 2 marks
 Calculations = 3 marks
 Equations = 4 "

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VII(b)

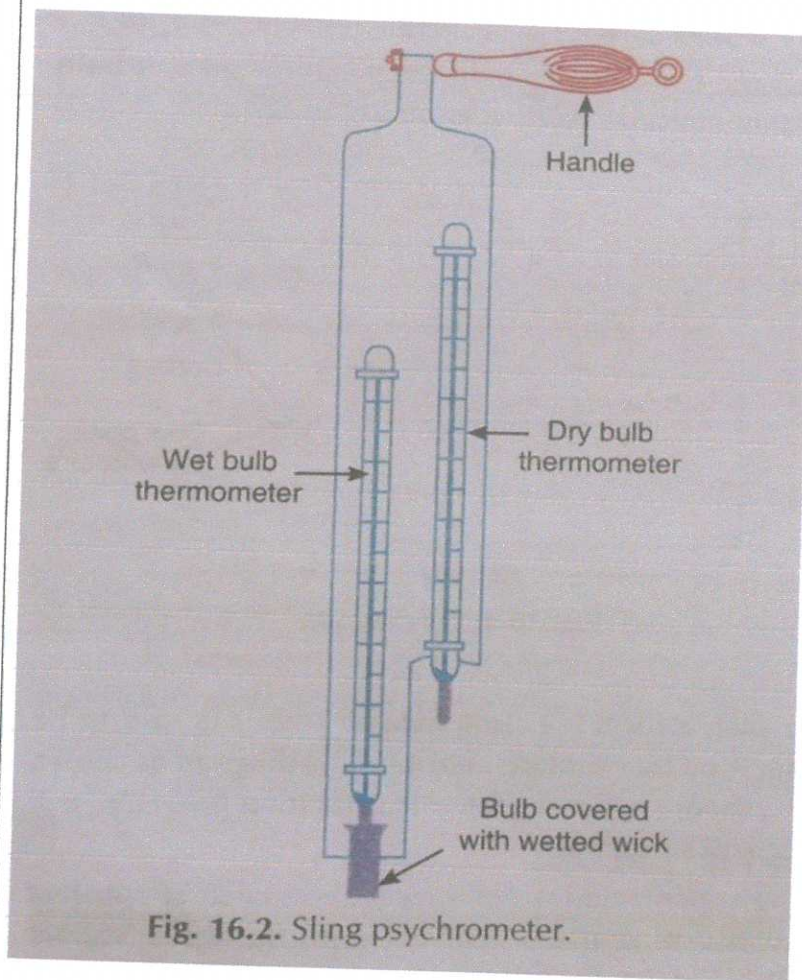
Explain the construction and use of a psychrometer.

VIII(b)

There are many types of psychrometers but the sling psychrometer is widely used. It consists of a dry bulb

thermometer and a wet bulb thermometer mounted side by side in a protective case can be easily rotated. The dry bulb thermometer is directly exposed to air and measure the actual temperature of air. The bulb of the wet bulb thermometer is covered by a wick thoroughly wetted by distilled water. The temperature measured by this wick covered bulb of a thermometer is the temperature of liquid water in the wick and is called wet bulb temperature.

The sling psychrometer is rotated in the air for approximately one minute after which the readings from both the thermometers are taken. This process is repeated several times to assure that the lower possible wet bulb temperature is recorded.



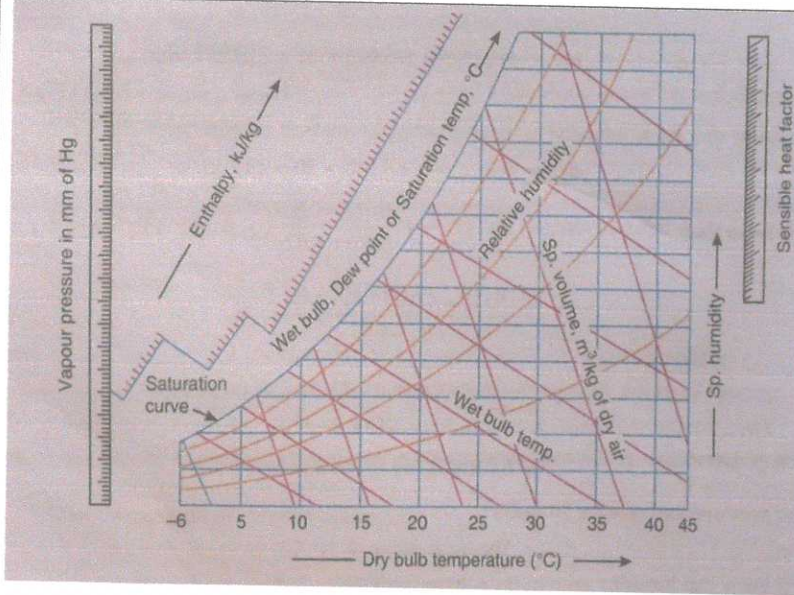
Construction = 4 marks
Use = 2 's

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6

VIII (9) Draw a typical psychrometric chart and explain various lines in the chart.

VIII(a)



The different types of lines in psychrometric chart are follows.

1. **Dry bulb temperature lines** :- These lines are vertical (parallel to the ordinate and uniformly spaced as shown). Generally the temperature range of these lines on psychrometric chart is from -6° to 45° .
2. **Specific humidity lines** :- The specific humidity (moisture content) lines are horizontal i.e parallel to the abscissa and are also uniformly spaced. Generally moisture content range is from 0 to 30 g/Kg of dry air.
3. **Dew point temperature lines** :- These lines are horizontal i.e. parallel to the abscissa and non-uniformly spaced as shown. At any point on the saturation curve the dry bulb and dew point temperature are equal.
4. **Wet bulb temperature lines** :- These lines are inclined straight lines and non-uniformly spaced. At any point on the saturation curve, the dry bulb and wet bulb temperatures are equal.
5. **Enthalpy (total heat) lines** :- These lines are inclined straight lines and uniformly spaced as shown. These lines are parallel to the wet bulb temperature lines and are drawn up to the saturation curve.
6. **Specific volume lines** :- These lines are obliquely inclined straight lines and uniformly spaced. These lines are drawn up to the saturation curve.
7. **Vapour pressure lines** :- These are horizontal and uniformly spaced. Generally these lines are not drawn in the main chart. But a scale showing on the extreme left side of the chart as shown.
8. **Relative humidity lines** :- These lines are curved lines and

Psychrometric chart = 5 marks
Explanation = 4 "

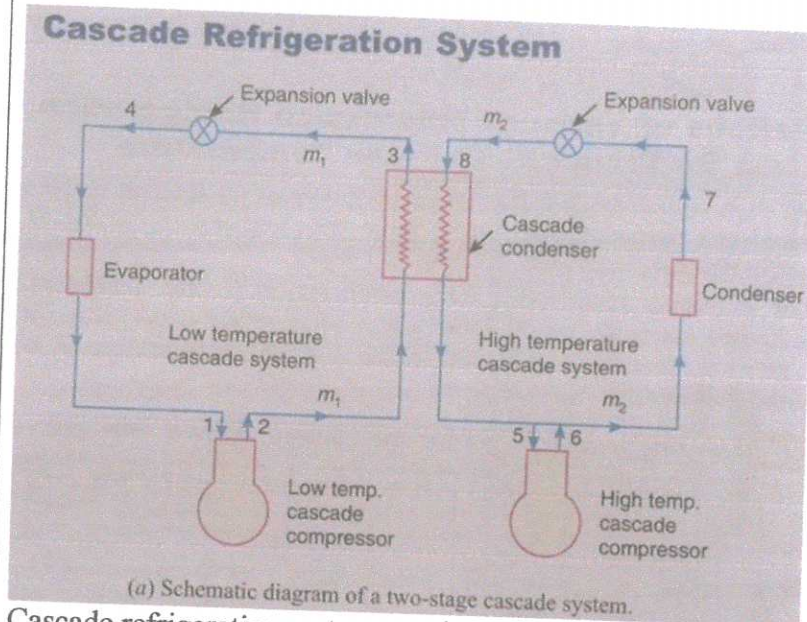
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follow the saturation curve. Generally these lines are drawn with values 10%, 20%, 30% etc. and up to 100%. The saturation curve represents 100% relative humidity.

VIII (b) Explain cascade refrigeration system.

VIII(b)



Cascade refrigeration system consists of two or more vapour compression refrigeration system in series which use refrigerants with progressively lower boiling temperatures. A two stage cascade system using two refrigerants is shown in fig. In this system a cascade condenser serves as an evaporator for high temperature cascade system and a condenser for the low temperature cascade system. The only useful refrigerating effect is produced in the evaporator of the low temperature cascade system. The principal advantage of the cascade system is that it permits the use of two refrigerants. The high temperature cascade system uses a refrigerant with high boiling temperature such as R12 or R-22. The low temperature cascade system uses a refrigerant with low boiling temperature such as R-13 R-13 BI. These low boiling temperature refrigerants have extremely high pressure which ensures a smaller compressor displacement in the low pressure cascade system and a higher coefficient of performance.

6 6 6

IX (a) Illustrate the working of summer air conditioning system with a line diagram.

IX (a)

18.9 Summer Air Conditioning System

It is the most important type of air conditioning, in which the air is cooled and generally dehumidified. The schematic arrangement of a typical summer air conditioning system is shown in Fig. 18.5.

The outside air flows through the damper, and mixes up with recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove dirt, dust and other impurities. The air now passes through a cooling coil. The coil has a temperature much below the required dry bulb temperature of the air in the conditioned space. The cooled air passes through a perforated membrane and loses its moisture in the condensed form which is collected in a sump. After that, the air is made to pass through a heating coil which heats up the air slightly. This is done to bring the air to the designed dry bulb temperature and relative humidity.

Now the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators. The remaining part of the used air (known as recirculated air) is again conditioned as shown in Fig. 18.5. The outside air is sucked and made to mix with the recirculated air in order to make up for the loss of conditioned (or used) air through exhaust fans or ventilation from the conditioned space.



Summer air-conditioning system.

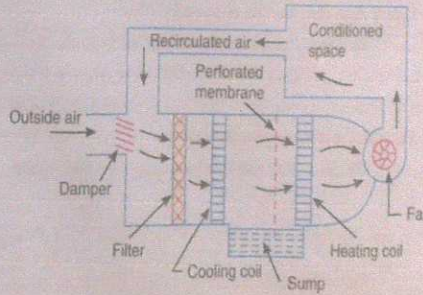


Fig. 18.5. Summer air conditioning system.

Explanation = 5 mark
line diagram = 4 "

9

9.

IX (b)

List the equipments used in air conditioning system.

IX (b)

Following are the main equipments used in an air conditioning system

1. Circulation fan
2. Air conditioning unit
3. Supply duct
4. Supply outlets
5. Return outlets
6. Filters.

Each point 1 mark

1 x 6 = 6

6.

X(a)

Given, Section capacity = 60, $t_{d2} = 22^\circ\text{C}$,
 $\phi_2 = 55\%$, $t_{d1} = 32^\circ\text{C}$, $t_{m1} = 22^\circ\text{C}$, $V_1 = 0.5 \text{ m}^3/\text{min}$
 $\text{min/person} = 0.5 \times 60 = 30 \text{ m}^3/\text{min}$, BPF = 0.3

1. Dry bulb temp. of air at exit of dehumidifier

From psychrometric chart, DBT of air at exit of dehumidifier, w at point 3,

$$\underline{t_{d3} = 41^\circ\text{C}}$$

2. Capacity of dehumidifier

From chart, enthalpy at point 1

$$h_1 = h_3 = 64.5 \text{ kJ/kg of dry air}$$

Enthalpy at 2, $h_2 = 45 \text{ kJ/kg of dry air}$

Sp humidity at 1, $W_1 = 0.0123 \text{ kg/kg of dry air}$
 at point 3, $W_3 = W_2 = 0.0084 \text{ kg/kg}$ "

Sp. volume of air at point 1

$$V_{s1} = 0.881 \text{ m}^3/\text{kg of dry air}$$

\therefore Mass of air supplied

$$m_a = \frac{V_1}{V_{s1}} = \frac{30}{0.881} = 34.05 \text{ kg/min}$$

\therefore Capacity of dehumidifier = $m_a(W_1 - W_2)$

$$= 34.05(0.0123 - 0.0084)$$

$$= 0.1328 \text{ kg/min}$$

$$= 0.1328 \times 60 = \underline{7.968 \text{ kg/hr}}$$

3. Capacity and surface temp. of cooling coil,

Capacity of cooling coil = $m_a(h_3 - h_2)$

$$= 34.05(64.5 - 45) = 664 \text{ kJ/min}$$

$$= \frac{664}{210} = \underline{3.16 \text{ TR}}$$

t_{d4} = Surface temp. of cooling coil

$$\text{We know that } \text{BPF} = \frac{t_{d2} - t_{d4}}{t_{d3} - t_{d4}}$$

Calculation = 3 marks

Given data = 2 mark

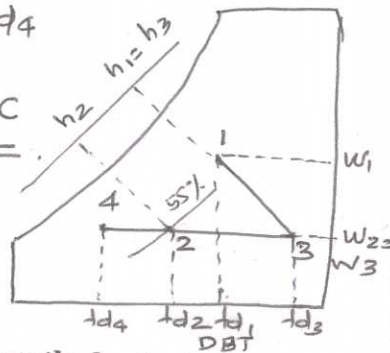
Equation = 4 "

9

9

$$0:3 = \frac{22 - t_{d4}}{41 - t_{d4}}$$

$$t_{d4} = \underline{\underline{13.86^\circ\text{C}}}$$



Classify air conditioning system on the basis of major function, season of the year and equipment arrangement

X (b)

The air condition systems may be broadly classified as follows

1. According to the purpose
 - (a) Comfort air conditioning system
 - (b) Industrial air conditioning system
2. According to season of the year
 - (a) Winter air conditioning system
 - (b) Summer air conditioning system
 - (c) Year-round air conditioning system
3. According to the arrangement of equipment
 - (a) Unitary air conditioning system
 - (b) Central air conditioning system.

Each point 1 mark.

6x1 = 6.

6.