Scoring Indicators

Code :4029 R(10)

Version:A

Qn. No.	Scoring Indicators	Split score	Total score

Part-A

I	1	Refrigeration is a process of removing heat from a low-temperature reservoir and transferring it to a high-temperature reservoir.	2	
	2	Ammonia, air, carbon dioxide, sulphur dioxide, water (any two)	2	
	3	Branch of study of moist air or humidity	2	
	4	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, it occupied the same space by itself	2	10
	5	It is relating to or involving the branch of physics that deals with the production and effects of very low temperatures.	2	

Part-B

II 1 The Carnot refrigerator works on the reversed Carnot cycle. A reversed Carnot cycle using air as working medium is shown on p-v and t-s diagrams. The processes involved during the cycle are:

3 diagrams

3 exp

6

1. Isentropic compression process- Air is compressed is entropically as shown by curve 1-2 on diagrams. No heat is absorbed or rejected by the air.

2. Isothermal compression process- Air is now compressed isothermally (T_2=T_3) and the heat rejected per kg of air during the process is given by

$$q_{2-3}= \text{ area } 2-3-3'-2'=T_3(s_2-s_3)=T_2(s_2-s_3)$$

3. Isentropic expansion process- Air is now expanded is entropically as shown by curve 3-4.

4. Isothermal expansion process- Air is expanded isothermally and heat absorbed by air (or heat extracted from cold body) during this process per kg of air is given by

$$q_{4-1}=area \quad 4-1-2'-3'=T_4(s_1-s_4)=T_4(s_2-s_3)=T1(s2-s3)$$

Therefore, work done during cycle per kg of air

=heat rejected-heat absorbed=$(q_{2-3})-(q_{4-1})=T_2(s_2-s_3)-T_1(s_2-s_3)=(T_2-T_1)(s_2-s_3$

$C.O.P_R$=(Heat absorbed)/(Work done)

$$=q_{4-1}/(q_{2-3}-q_{4-1})=T_1(s_2-s_3)(T_2-T_1)(s_2-s_3)=T_{1/}(T_2-T_1)$$

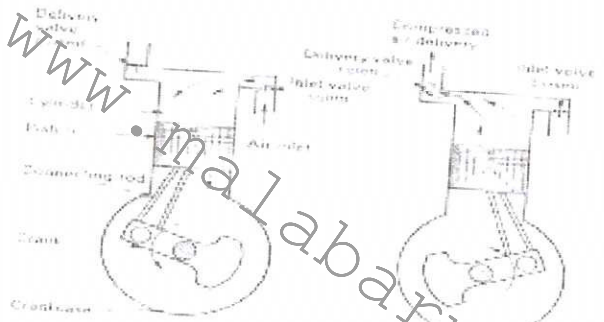
2

1. No cost of refrigerant
2. Easily available
3. Leakage is tolerable
4. Main compressor can be used as the system compressor therefore no extra compressor is required
5. Air is non toxic and non inflammable
6. The air is light weight per tonnage of refrigeration
7. Chilled air is directly used for cooling, there by eliminating the cost of separate evaporator
8. Since the pressure is low, piping design and fabrication is simple

1 mark for each point — 6

3

Reciprocating Compressor

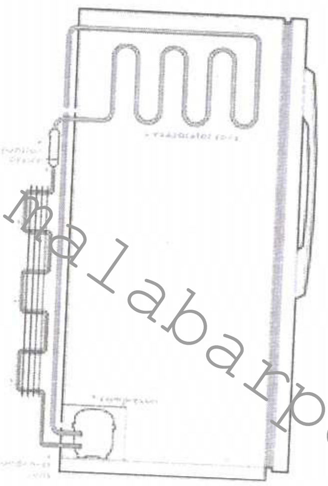


The compression of air is done by first drawing a volume of air into its cylinder through suction valves during suction stroke by the piston & then compressing & discharging it on the return stroke of the piston through delivery valves. This simple working is used in every Reciprocating Air Compressor. You will easily understand compressor engineering from below description. In single stage reciprocating air compressor, the entire compression is carried out in a single cylinder. If the compression is affected in one end of the piston & cylinder then it is known as single actin

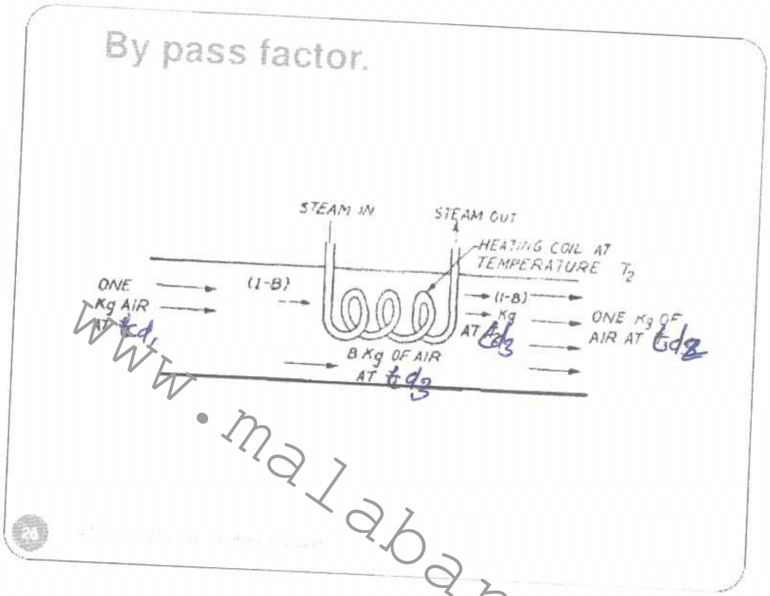
3+3 — 6

4

The function of the compressor is to raise the pressure of gaseous refrigerant coming from the evaporator. By raising the pressure, the boiling point of the refrigerant increases. This high pressure and high-temperature refrigerant while passing through the condenser changes the phase and condenses in high pressure and temperature liquid refrigerant. The room air is at the lower temperature than

	the refrigerant passing through the condenser, hence condensation takes place and vapor refrigerant converted to liquid refrigerant. Thus heat is thrown to the air at this point in the refrigerator. Now resultant liquid refrigerant which is at high pressure and temperature passes through the capillary tube which is made up of copper material and has the very small diameter and longer length. As the high-pressure liquid refrigerant passes through the capillary tube, due to throttling effect, temperature and pressure of the refrigerant decrease. Majority of the cooling is produced at this point in a refrigerator. This low temperature and low-pressure refrigerant now pass through the evaporator where refrigerant in liquid phase takes heat from foods and stuff. At this point, the boiling point of liquid refrigerant is very low (because of low pressure) in terms of -20 degree C. Thus anything above this temperature makes refrigerant to boil. This low-pressure vapor again circulated to compressor and cycle continuously as long as the compressor is in running condition. 	3+3	6
5	The process in which the air is cooled sensibly and at the same time the moisture is removed from it is called as cooling and dehumidification process. Cooling and dehumidification process is obtained when the air at the given dry bulb and dew point (DP) temperature is cooled below the dew point temperature. Let us understand the cooling and dehumidification process in more details. When the air comes in contact with the cooling coil that is maintained at the temperature below its dew point temperature, its DB temperature starts reducing. The process of cooling continues and at some point it reaches the value of dew point temperature of the air. At this point the water vapor within the air starts getting converted into the dew particles due to which the dew is formed on the surface of the cooling and the moisture content of the air reduces thereby reducing its humidity level. Thus when the air is cooled below its dew point temperature, there is cooling as well as dehumidification of air. The cooling and dehumidification process is most widely used air conditioning application. It is used in all types of window, split, packaged and central air conditioning systems for producing the comfort conditions inside the space to be cooled. In the window and split air conditioners the evaporator coil or cooling coil	3+3	6

6 is maintained at temperature lower than the dew point temperature of the room air or the atmospheric air by the cool refrigerant passing through it. When the room air passes over this coil its DB temperature reduces and at the same time moisture is also removed since the air is cooled below its DP temperature. The dew formed on the cooling coil is removed out by small tubing. In the central air conditioning systems the cooling coil is cooled by the refrigerant or the chilled water. When the room air passes over this coil, it gets cooled and dehumidified. In the general the cooling and dehumidification process is obtained by passing the air over coil through which the cool refrigerant, chilled water or cooled gas is passed.



3+3 | 6

Balancing the enthalpies,

$$B \times C_{pm} \times t_{d1} + (1-B) Cpm \times t_{d3} = 1 \times Cpm \times t_{d2}$$

$$Cpm\ (B \times t_{d1} + (1-B) \times t_{d3} = Cpm \times t_{d2} \times 1$$

$$B(t_{d3}-t_{d1}) = t_{d3}-t_{d2}$$

By-pass factor, B= $t_{d3}-t_{d2}/(t_{d3}-t_{d1})$ For heating coil

B= $t_{d2}-t_{d3}/(t_{d1}-t_{d3})$ For cooling coil

7

Front Panel

The front panel is the one that is seen by the user from inside the room where it is installed and has a user interfaced control be it electronically or mechanically. Older unit usually are of mechanical control type with rotary knobs to control the temperature and fan speed of the air conditioner. The newer units come with electronic control system where the functions are controlled using remote control and touch panel with digital display. The front panel has adjustable horizontal and vertical(some models) louvers where the direction of air flow are adjustable to suit the comfort of the users. The fresh intake of air called VENT (ventilation) is provided at the panel in the event that user would like to have a certain amount of fresh air from the outside.

Indoor Side Components

The indoor parts of a window air conditioner include:

- **Cooling Coil** with a air filter mounted on it. The cooling coil is where the heat exchange happen between the refrigerant in the system and the air in the room.
- **Fan Blower** is a centrifugal evaporator blower to discharge the cool air to the room.
- **Capillary Tube** is used as an expansion device. It can be noisy during operation if installed too near the evaporator.
- **Operation Panel** is used to control the temperature and speed of the blower fan. A thermostat is used to sense the return air temperature and another one to monitor the temperature of the coil. Type of control can be mechanical or electronic type.
- **Filter Drier** is used to remove the moisture from the refrigerant.
- **Drain Pan** is used to contain the water that condensate from the cooling coil and is discharged out to the outdoor by gravity.

Outdoor Side Components; The outdoor side parts include:

- **Compressor** is used to compress the refrigerant.
- **Condenser Coil** is used to reject heat from the refrigeration to the outside air.
- **Propeller Fan** is used in air-cooled condenser to help move the air molecules over the surface of the condensing coil.
- **Fan Motor** is located here. It has a double shaft where the indoor blower and outdoor propeller fan are connected together.

6

III a

Part-C

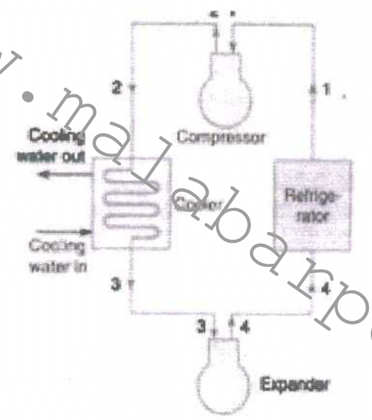
entropy at point 2, $s_2=s_2'+\ln C_p dT$

$1.637=1.587+0.046\ C_p$

$C_p=1.09$ — C_p -2

Enthalpy at point2, $h_2=h_{2'}+c_p(T_2-T_{2'})$ — h_2- 3 — 8

COP-3

	COP=h1-hf3/h2-h1=460.7-133/500-460.7=8.34		
b	1. preservation of medicines, 2.ice production , 3.photographic material processing , 4.Processing of chemical products, 5.computer functioning , 6.treatment of air for blast furnace, 7.preservation of blood and human tissues, 8.cooling of concrete for dams, 9.comfort air conditioning, 10.production of rocket fuels , 11.temperature control machining	Each one mark (Any seven)	7
	OR		
IV a	In this system, air is taken into the compressor from atmosphere and compressed. The hot compressed air is cooled in heat exchanger upto the atmospheric temperature (in ideal conditions). The cooled air is then expanded in an expander. The temperature of the air coming out from the expander is below the atmospheric temperature due to isentropic expansion. The low temperature air coming out from the expander enters into the evaporator and absorbs the heat. The cycle is repeated again. The working of airrefrigeration cycle is represented on p-v and T-s diagrams.  Process 1-2 represents the suction of air into the compressor. Process 2-3 represents the isentropic compression of air by the compressor. Process 3-5 represents the discharge of high pressure air from the compressor into the heat exchanger. The reduction in volume of air from v3 to v5 is due to the cooling of air in the heat exchanger. Process 5-6 represents the isentropic expansion of air in the expander. Process 6-2 represents the absorption of heat from the evaporator at constant pressure.	4 fig 4 exp	8
b	heat removed from the fruits in 10 hrs,$Q_1=mc_f(T_2-T_1)$ =500x1.256(293-268) =15700kJ total latent heat of freezing Q_2= mxh_{fg}=500x105 =52500kJ total heat removed in 10 hrs=Q_1+Q_2 = 15700+52500=68200kJ total heat removed in one minute=68200/60=113.7kJ/min	Q1-2 Q2-2 Total heat	7

total heat removed in one minute=68200/60=113.7kJ/min

Refrigeration capacity =113.7/210=0.541TR

Refri. capa-2 | 7

V a

Vapour absorption	Vapour compression
Requires heat energy	Mechanical energy requires
Low COP	Relatively high COP
No compressor , no electric power, low maintenance	Motor driven compressor, high maintenance
Not affected load variation	Poor performance at partial loads
Less refrigerant leakage	More chance of refrigerant leakage
Charging is difficult	Charing is simple
Low pressure, so less chance to burst the pipes	Liquid traces in suction line may damage the compressor
Exhaust steam can be used for other purpose	No such facility
Reduced evaporator temperature	Capacity of system drops at lower evaporator temperature
High capacity units are possible	Not possible with single compressor

Any 8 Each 1 | 8

b

Ice plant basically contains of three main circuits.

1. Refrigeration Circuit (Working fluid. Ammonia, Primary refrigerant)
2. Cooling Water Circuit (Cooling water)
3. Brine Circuit (Brine solution)

In Refrigeration Circuit, compressor increases the boiling point of *low pressure vapor*refrigerant i.e. Ammonia to *high pressure boiling point ammonia* (so that it can be easily condensed at room temperature) and sends it to condenser via discharge line.

Here, room temperature water coming out from the cooling water circuit/cooling tower condenses the high pressure vapor and converts it to *high pressure liquid ammonia*.

High pressure liquid ammonia is stored in reservoir or receiver and forwarded to throttle valve or flow control valve where, high pressure refrigerant is converted to *low pressure liquid refrigerant* (to decrease the boiling point) so that at low pressure condition in evaporator, it can be easily vaporized from the heat of stuffs to be cooled. This process is called throttling.

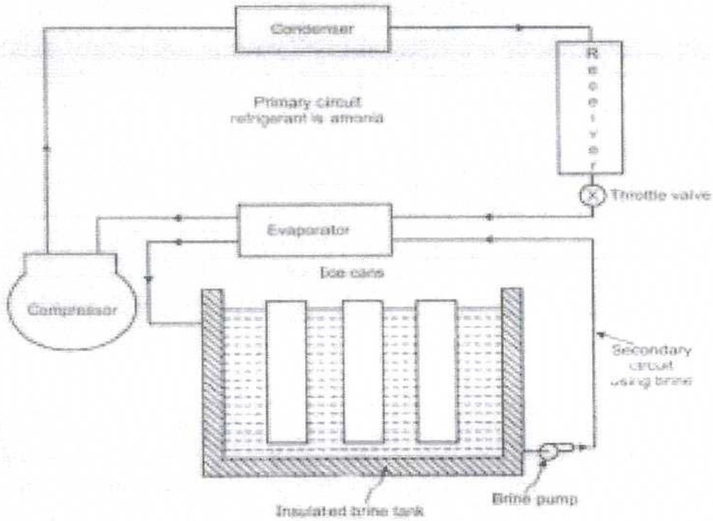


fig-3 exp-4 7

Now, low pressure liquid ammonia passes through evaporator (a heat exchanger) where it is converted to the *low pressure vapor* by heat obtained from brine solution. Brine solution circulates itself from brine tank to evaporator and cools the water kept in ice can below zero degree centigrade to make it in ice form. Here, brine solution is also a refrigerant but as it does change the phase during heat transfer between water and evaporator, it is called *secondary refrigerant*. On the other hand, Ammonia is *primary refrigerant* as it undergoes phase change during cooling process.

OR

VI a

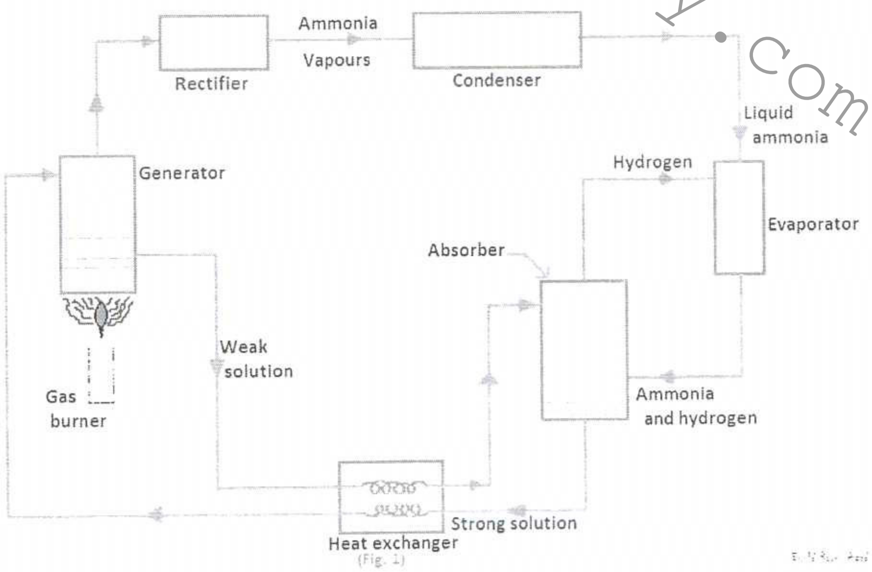


Fig-4 Exp-4 8

The ammonia liquid leaving the condenser enters the evaporator and evaporates into the hydrogen at the low temperature corresponding to its low partial pressure.

admitted water from the separator. The water absorbs the ammonia and the hydrogen returns to the evaporator. In the absorber the ammonia therefore passes from the ammonia circuit into water circuit as ammonia in water solution. This strong solution passes to the generator where it is heated and the vapor given off rises to the separator. The water with the vapor is separated out and a weak solution of ammonia is passed back to the absorber, thus completing the water circuit. The ammonia vapor rises from the separator to the condenser where it is condensed and then returned to the evaporator.

The actual plant includes refinements and practical modifications (which are not included here). The following points are worth noting:

The complete cycle is carried out entirely by gravity flow of the refrigerant.

The hydrogen gas circulates only from the absorber to the evaporator and back. With this type of machine efficiency is not important since the energy input is small.

It has not been used for industrial applications as the C.O.P. of the system is very low.

b

1) The refrigerant should have low boiling point and low freezing point.

2) It must have low specific heat and high latent heat. Because high specific heat decreases the refrigerating effect per kg of refrigerant and high latent heat at low temperature increases the refrigerating effect per kg of refrigerant.

3) The pressures required to be maintained in the evaporator and condenser should be low enough to reduce the material cost and must be positive to avoid leakage of air into the system.

4) It must have high critical pressure and temperature to avoid large power requirements.

5) It should have low specific volume to reduce the size of the compressor.

6) It must have high thermal conductivity to reduce the area of heat transfer in evaporator and condenser.

7) It should be non-flammable, non-explosive, non-toxic and non-corrosive.

8) It should not have any bad effects on the stored material or food, when any leak develops in the system. Any7 Each -1 7

9) It must have high miscibility with lubricating oil and it should not have reacting properly with lubricating oil in the temperature range of the system.

10) It should give high COP in the working temperature range. This is necessary to

reduce the running cost of the system.

11) It must be readily available and it must be cheap also.

VII a Relative humidity, $\Phi = P_v/P_s$

$0.3 = P_v/0.02642$

1. Vapour pressure, $P_v = 0.3 \times 0.02624 = 0.007926$ bar

2. humidity ratio, $W = 0.622P_v/(P_b - P_v) = 0.622 \times 0.007926/(1.01308 - 0.007926)$

$= 0.0049$ kg/kg of dry air

3. Vapour density, $\rho_v = W(P_b - P_v)/ R_a x T_d$

$= 0.0049(1.01308 - 0.007926)10^5/287(273+22)$ 4x2 8

$= 0.00582$ kg/m^3 of dry air

4. Enthalpy, $h = 1.022t_d + W(h_{fgdp} + 2.3td_p)$

$= 1.022 \times 22 + 0.0049(2492.6 + 2.3 \times 3.8)$

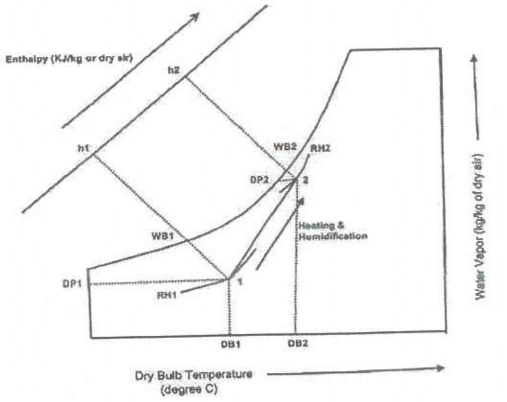
b $= 34.74$ kJ/kg of dry air

In heating and humidification psychrometric process of the air, the dry bulb temperature as well as the humidity of the air increases. The heating and humidification process is carried out by passing the air over spray of water, which is maintained at temperature higher than the dry bulb temperature of air or by mixing air and the steam.

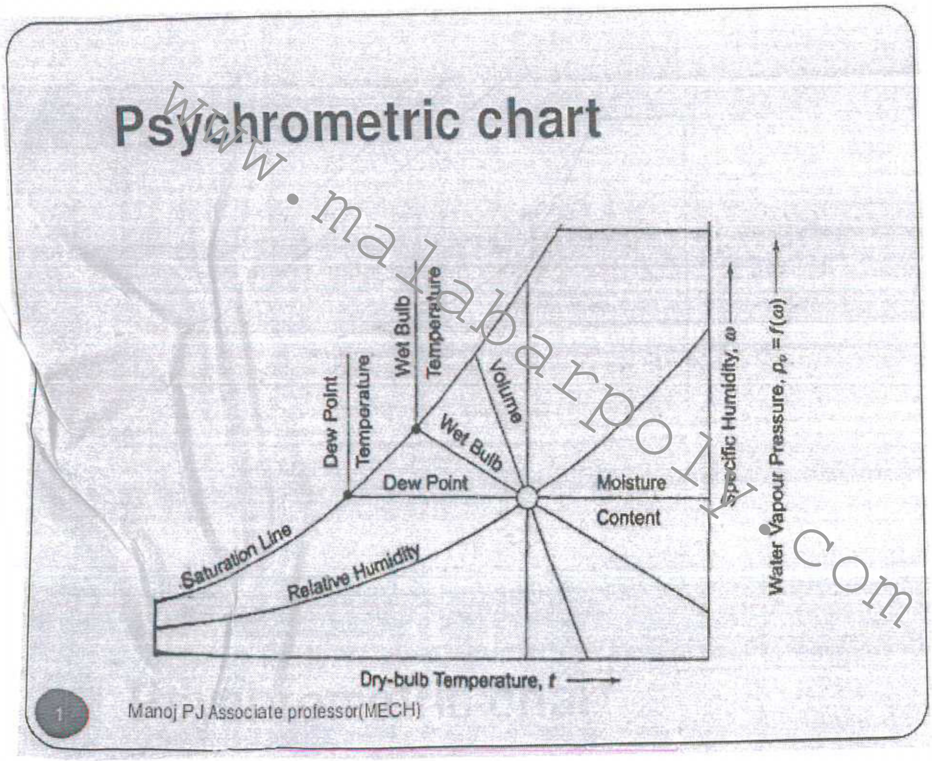
When the ordinary air is passed over the spray of water maintained at temperature higher than the dry bulb temperature of the air, the moisture particles from the spray tend to get evaporated and get absorbed in the air due to which the moisture content of the air increase. At the same time, since the temperature of the moisture is greater than the dry bulb temperature of the air, there is overall increase in its temperature. Fig-3 7

Exp-4

During heating and humidification process the dry bulb, wet bulb, and dew point temperature of the air increases along with its relative humidity. The heating and humidification process is represented on the psychrometric chart by an angular line that starts from the given value of the dry bulb temperature and extends upwards towards right (see the figure below)



VIII a



8

Using Chart

b

DBT	25	35
WBT	15	20.6
DPT	7	7
RH	34	20
h	42	52

7

IX a	**Air temperature** :This is the temperature of the air surrounding the body. It is usually given in degrees Celsius (°C). Radiant temperature: Thermal radiation is the heat that radiates from a warm object. Radiant heat may be present if there are heat sources in an environment. Radiant temperature has a greater influence than air temperature on how we lose or gain heat to the environment. Examples of radiant heat sources include: the sun; fire; electric fires; ovens; kiln walls; cookers; dryers; hot surfaces and machinery, molten metals etc. **Air velocity**:This describes the speed of air moving across the employee and may help cool them if the air is cooler than the environment. Air velocity is an important factor in thermal comfort for example: still or stagnant air in indoor environments that are artificially heated may cause people to feel stuffy. It may also lead to a build-up in odour • moving air in warm or humid conditions can increase heat loss through convection without any change in air temperature • physical activity also increases air movement, so air velocity may be corrected to account for a person's level of physical activity • small air movements in cool or cold environments may be perceived as a draught as people are particularly sensitive to these movements **Humidity**:If water is heated and it evaporates to the surrounding environment, the resulting amount of water in the air will provide humidity. Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature. Relative humidity between 40% and 70% does not have a major impact on thermal comfort. In workplaces which are not air conditioned, or where the weather conditions outdoors may influence the indoor thermal environment, relative humidity may be higher than 70%. Humidity in indoor environments can vary greatly, and may be dependent on whether there are drying processes (paper mills, laundry etc) where steam is given off. High humidity environments have a lot of vapour in the air, which prevents the evaporation of sweat from the skin. In hot environments, humidity is important because less sweat evaporates when humidity is high (80%+). The evaporation of sweat is the main method of heat reduction. When non-breathable vapour-impermeable personal protective equipment (PPE) is worn, the humidity inside the garment increases as the wearer sweats because the sweat cannot evaporate. If an employee is wearing this type of PPE (eg asbestos or	2x4	8

chemical protection suits etc) the humidity within the PPE will be high.

b

The cascade refrigeration system is a freezing system that uses two kinds of refrigerants having different boiling points, which run through their own independent freezing cycle and are joined by a heat exchanger. The schematic view and the P-h diagram of this system are shown below.

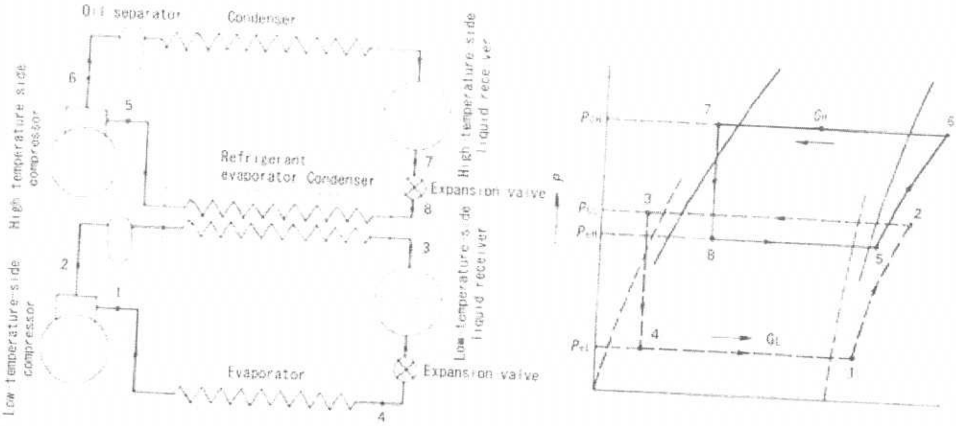


Fig-4

Exp-3

7

This system is employed to obtain temperatures of -40 to -80°C or ultra-low temperatures lower than them.

At such ultra-low temperatures, a common single-refrigerant two-stage compression system limits the low-temperature characteristics of the refrigerant to a considerably poor level, making the system significantly inefficient. The efficiency is improved by combining two kinds of refrigerants having different temperature characteristics.

X	*Note:Mark points 1 and 2 on psychrometric chart –draw horizontal and vertical lines to find point 3* From chart: h_1=76.8 kJ/kg, h_2 = 53.6 kJ/kg h_3 = 62 kJ.kg Sp.Vol at 1, V_{s1} = 0.895 Mass of infiltration air = V/V_{s1} = 360/0.895 = 402 kg/hr Sensible heat load of infiltration = $m(h_3-h_2)$ = 402 (62-53.8) =3295 kJ/hr Latent heat load of infiltration = $m(h_1-h_3)$ = 402(76.8-62) = 5950 kJ/hr Sensible heat gain from occupants, servicing persons and food = 210x30+210x3+12.5x30 =7305 kJ/hr Latent heat gain from occupants, servicing persons and food = 168x30+270x3+20x30 =6450 kJ/hr	Marking-2 Mass of air-1 Total SH -4 Total LH -4 Total load- 1 SHF-3	15

No	Total heat gain	Sensible heat Kj/hr	Latent heat kJ/hr
1	From solar radiation	6700	-
2	From other sources	20000	-
3	From equipment	8500	2000
4	From people and food	7305	6450
5	From infiltration	3295	5950
	Total	45800	14400

1. Total heat load = 45800+14400 =60200 kJ/hr
2. Room sensible heat factor, SHF = SH/(SH+LH) =45800/60200 =0.76