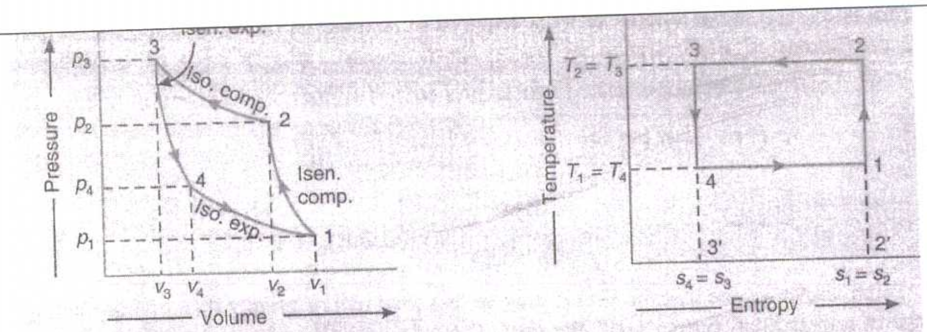
TED (15)6023

(Revision - 2015)

FIFTH SEMESTER DIPLOMA EXAMINATION IN ENGINEERING

REFRIGERATION AND AIRCONDITIONING

SCHEME OF VALUATION

I	**PART : A**			
1	COP of a refrigerating machine is defined as the ratio of refrigeration effect to the work supplied	2		
2	Refrigerant is a working medium employed in a refrigerating system.	2		
3	Specific humidity is the actual mass of water vapour to the mass of water vapour per unit volume of a mixture of water vapour and dry air.	2		
4	Air conditioning is defined as the simultaneous control of temperature , humidity, air circulation and cleanliness of air within an enclosed space.	2		10
5	HVAC is Heating,Ventilation and Airconditioning . It s defined as the mechanical system that provide thermal comfort and air quality in an indoor space are often grouped together and are generally interconnected.	2		
II	**PART B**			5*6=30
1	 (a) p-v diagram. (b) T-s diagram. The reversed Carnot cycle also consists of two isentropic and two isothermal processes. The process undergoes in direction 1-2-3-4-1 Process 1-2: Reversible Adiabatic Compression This process is isentropic. The engine is perfect insulated so that no heat is lost and absorbed. Gas is compressed slowly until the temperature rises from T1 to T2. Process 2-3: Reversible Isothermal Compression (TH=constant) During this process, heat is rejected. Gas is compressed reversibly at the constant temperature T2 Qr= Q2-3=area 2-3-3'-2'=T3(s2-s3) Process 3-4: Reversible Adiabatic Expansion This process is isentropic. The engine is	2 4	6	

	perfect insulated so that no heat is lost and absorbed. Gas expands slowly until the temperature drops from T3 to T4 Process 4-1: Reversible Isothermal Expansion (TL=constant) During this process, heat is absorbed. Gas is compressed reversibly at the constant temperature T1 $Q_a=Q_{4-1}=\text{Area } 4\text{-}1\text{-}2'\text{-}3' = T_4(s_1-s_4)=T_4(s_2-s_3)$ We know that workdone during the cycle per kg of air =Wr=Heat rejected-Heat absorbed$=Q_r-Q_a=T_2(s_2-s_3)-T_1(s_2-s_3)$ COP= Heat absorbed/Workdone $=Q_a/Q_r-Q_a$ $=T_1(s_2-s_3)/(T_2-T_1)(s_2-s_3)=T_1/(T_2-T_1)$.		
2	• Air is easily available • It is cheap • Weight per TR is low and hence ideal for aircraft refrigeration • No leakage problem • It is non-flammable and non-toxic refrigerant • Low maintenance cost **Demerits:** • It absorbs heat as sensible heat only, hence mass flow rate required is more as compared to other refrigerants • Low COP • Freezing of moisture at low temperature.	3 3	6
3	**The good properties of a refrigerant are as follows:** 1. High critical temperature to have large isothermal energy transfer. 2. The specific heat of liquid should be as small as possible and of vapour should be as high as possible to give less superheating of vapour. 3. High latent heat of vaporization to get more refrigeration effect. 4. Large conductivity to reduce size of condenser and evaporator. 5. Low specific volume of vapour 6. Low freezing point such that there is no blockage during flow through evaporator. 7. Non corrosive to metal and inert so as to not react with other materials and commodities of the refrigeration system. 8. Non-toxic 9. Low boiling point 10. Non-flammable and non-explosive 11. Low cost and easily available 12. Easy to liquefy at moderate pressure and temperature	6x1	6

13. Easy of locating leaks by odour or suitable indicator
14. Mixes well with oil.
15. Low viscosity so that pressure drop is small.

(write any six)

4

Vapour compression system	Vapour absorption system
The system has a main parts like Compressor, condenser receiver, refrigerant control device and evaporator	The system has a main parts like gene rectifier, condenser abs orber and evaporator
The system is noisy in operation	The system is quiet in operation
The system has so many moving parts, so there is a possibility of wear and tear	The system has no moving parts a nd no possibility of wear and tear stick
Energy supplied is mechanical	Energy input is mainly heat
Generally steel, copper tube is used to connect the parts	Steel tube is used to connect the parts
To reduce the high pressure control devices like expansion valve, front valve, capacity tube are used	To reduce the pressure hydrogen gas provided
The flow of gas depends upon the compressor	The flow of gas depends upon the gra working of the generator
This system is required to operate by prime movers like electric motor, diesel or petrol engine	This system is required to operate by h energy like gas kerosene or electric he
This system is more efficient and occupies more space	This system is poor efficient
Charging of refrigerant is quite simple	Charging of refrigerant to the system is
Energy supply is low	Energy supply is high

6x1 6

5 The **dry-bulb temperature** (DBT) is the **temperature** of air measured by a thermometer freely exposed to the air, but shielded from radiation and moisture. DBT is the temperature indicated by ordinary thermometer. 2

Dry air: It is a mechanical mixture of constituent gases which comprise atmospheric air excluding water vapour. Or It is a mixture of nitrogen and oxygen neglecting the small percentage of other gases. 2

	The dew point depression : is the difference between the Dr Bulb temperature and dew point temperature at a certain height in the atmosphere. For a constant temperature, the smaller the difference, the more moisture there is, and the higher the relative humidity.	2	6	
6	Advantages 1. High energy per unit mass: Propellants like oxygen and hydrogen in liquid form give very high amounts of energy per unit mass due to which the amount of fuel to be carried aboard in the rocket decreases 2. clean fuels: Hydrogen and oxygen are extremely clean fuels Economical : The use of oxygen and hydrogen as fuels is very economical as liquid oxygen costs less than gasoline. Application: 1.Space technology application ; Cooling of IRsensors,Rocket propulsionetc. 2,Mechanical application: Crogeneic heat treatment of material,Recycling of materials , Mgnetic separation etc. 3. Medical application: Food preservation,cryosurgery,cellpreservation etc. 4. Gas industry application: Liquefaction of gases, separation of gases etc.; 5.High energy physics ITER,CERN etc. 6. Super conductivity: NMR,MRI etc.	1 1 1 1 1 1	6	
7	Environmental factors **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.

Personal factors

Clothing insulation

Thermal comfort is very much dependent on the insulating effect of clothing on the wearer.

Wearing too much clothing or PPE may be a primary cause of heat stress even if the environment is not considered warm or hot.

If clothing does not provide enough insulation, the wearer may be at risk from cold injuries such as frostbite or hypothermia in cold conditions.

Clothing is both a potential cause of thermal discomfort as well as a control for it as we adapt to the climate in which we work. You may add layers of clothing if you feel cold, or remove layers of clothing if you feel warm. Many companies inhibit this ability for employees to make reasonable adaptations to their clothing as they require them to wear a specific uniform or PPE.

It is important to identify how the clothing contributes to thermal comfort or discomfort. By periodically evaluating the level of protection provided by existing PPE and evaluating newer types of PPE you may be able to improve the level of thermal comfort.

Work rate/metabolic heat

The more physical work we do, the more heat we produce. The more heat we produce, the more heat needs to be lost so we don't overheat. The impact of metabolic rate on thermal comfort is critical.

A person's physical characteristics should always be borne in mind when considering their thermal comfort, as factors such as their size and weight, age, fitness level and sex can all

	have an impact on how they feel, even if other factors such as air temperature, humidity and air velocity are all constan (write any three)	3x2	6
	PART C		15 *4 =30

This cycle is also called as Joule Cycle. Fig. 1 (a) and (b) shows the schematic of a closed Bell-Coleman cycle and also the cycle on T-S diagram. As shown in the figure, the ideal cycle consists of the following four processes:

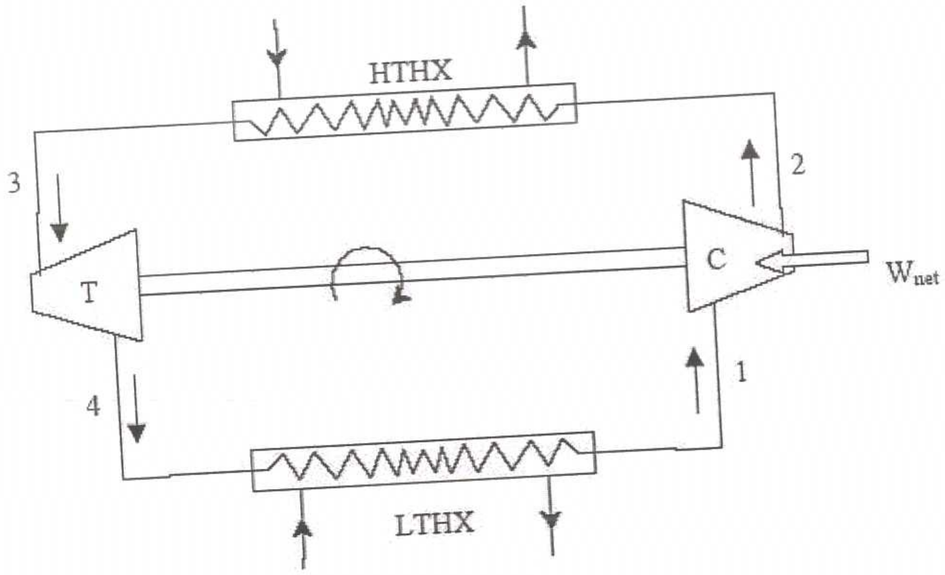


Fig. 1(a) Schematic of closed reverse Brayton cycle or Bell-Coleman cycle

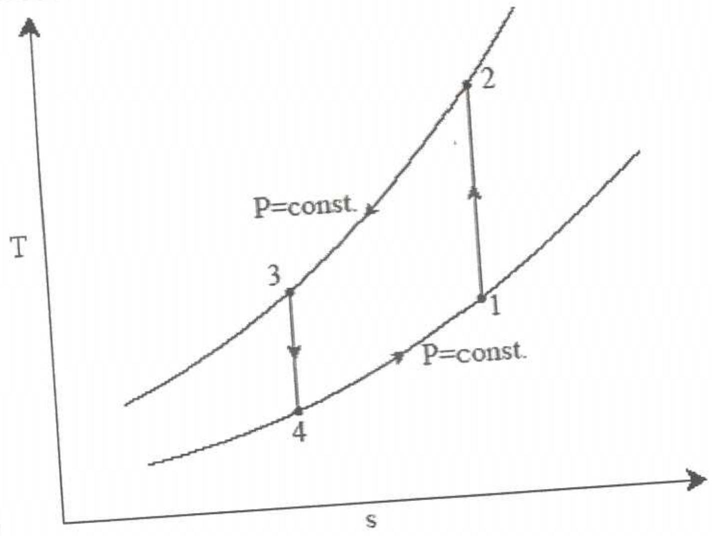


Fig 1(b) Bell-Coleman cycle in T-S plane

Process 1-2: Reversible, adiabatic compression in compressor.

Process 2-3: Reversible, isobaric heat rejection in a heat exchanger.

Process 3-4: Reversible, adiabatic expansion in a turbine.

Process 4-1: Reversible, isobaric heat absorption in heat exchanger.

Process 1-2: Gas at low pressure is compressed isentropically from state 1 to state 2. Applying steady state flow energy equation and neglecting changes in kinetic and potential energy, we can write.

$$W_{1-2} = \dot{m}(h_2 - h_1) = \dot{m}c_p(T_2 - T_1)$$

$$s_2 = s_1$$

$$\text{and } T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = T_1 r_p^{\frac{\gamma-1}{\gamma}}$$

Where rp=(P2/P1)rp=(P2/P1)= Pressure ratio.
Process 2-3: Hot and high pressure gas flows through a heat exchanger and rejects heat sensibly and isobarically to a heat sink. The enthalpy and temperature of the gas drop during the process due to heat exchange, no work transfer takes place and the entropy of the gas decreases. Again applying steady flow energy equation and second T ds equation:

$$Q_{2-3} = \dot{m}(h_2 - h_3) = \dot{m}c_p(T_2 - T_3)$$

$$s_2 - s_3 = c_p \ln\frac{T_2}{T_3}$$

$$P_2 = P_3$$

Process 3-4: High pressure gas from the heat exchanger flows through a turbine, undergoes isentropic expansion and delivers net work output. The temperature of the gas drops during the process from T3T3 to T4T4. From steady flow energy equation:

$$W_{3-4} = m(h_3 - h_4) = mc_p(T_3 - T_4)$$

$$s_3 = s_4$$

$$\text{and } T_3 = T_4\left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = T_4 r_p^{\frac{\gamma-1}{\gamma}}$$ 1

Where rprp = (P3/P4)(P3/P4) = pressure ratio.
Process 4-1: Cold and low pressure gas from turbine flows through the low temperature heat exchanger and extracts heat sensibly and isobarically from a heat source, providing a useful refrigeration effect. The enthalpy and temperature of the gas rise during the process due to heat exchange, no work transfer takes place and the entropy of the gas increases. Again applying steady flow energy equation and second T ds equation: 1 8

$$Q_{4-1} = m(h_1 - h_4) = mc_p(T_1 - T_4)$$

$$s_4 - s_1 = c_p \ln\frac{T_4}{T_1}$$

$$P_4 = P_1$$

From the above equations, it can be easily shown that:

(T2/T1)=(T3/T4)(T2/T1)=(T3/T4)
`Applying 1st law of thermodynamics to the entire

$$\oint \delta q = (q_{4-1} - q_{2-3}) = \oint \delta w = (w_{3-4} - w_{1-2}) = -w_{net}$$

cycle:

The COP of the reverse Brayton or Bell-Coleman cycle is given 1

$$COP = \left|\frac{q_{4-1}}{w_{net}}\right| = \left(\frac{(T_1 - T_4)}{(T_2 - T_1) - (T_3 - T_4)}\right)$$

by:

Using the relation between temperatures and pressures, the COP can also be written as:

$$COP = \left(\frac{(T_1 - T_4)}{(T_2 - T_1) - (T_3 - T_4)}\right) = \left(\frac{T_4}{T_3 - T_4}\right) = \left(\frac{(T_1 - T_4)}{(T_1 - T_4)(r_p^{\frac{\gamma-1}{\gamma}} - 1)}\right) = (r_p^{\frac{\gamma-1}{\gamma}} - 1)^{-1}$$ 1

b. T2=35°C=35+273=308K,T1=-15°C=-15+273=258K,Q1=12TR=12*210=2520KJ/min

COP=T1/(T2-T1)=258/(308-258)=5.16 1

Heat rejected from the system per hour

Let Wr=Work or power required to drive the system

We know that COP=Q1/Wr 2

Wr=Q1/COP=2520/5.16=488.37 KJ/min

Heat rejected from the system Q2=Q1+Wr=2520+488.37=3008.37Kj/min 2

Power required 2 7

488.37/60=8.14KJ/s=8.14kW

1

IV (a)

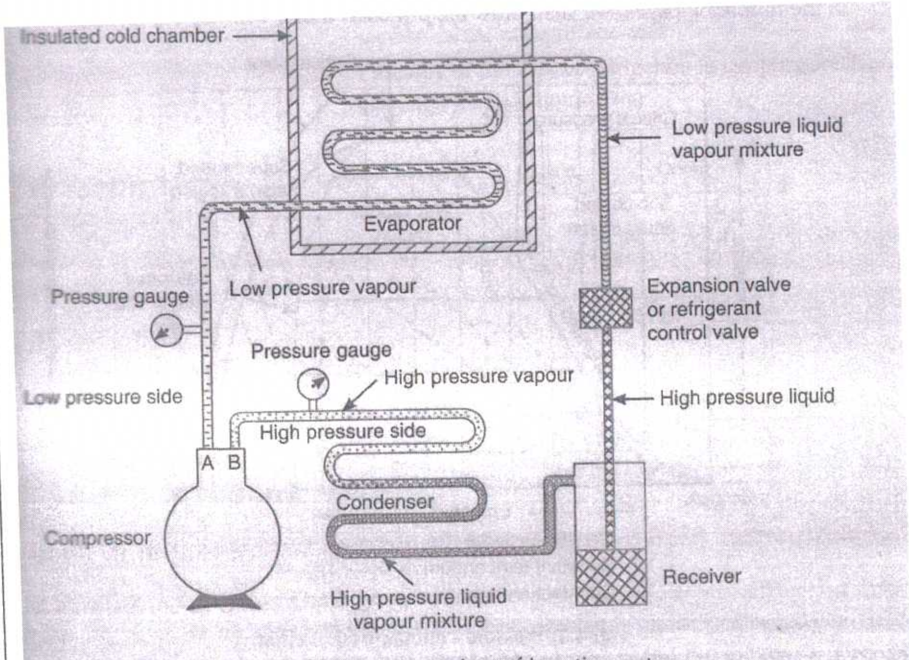


Fig. 4.1. Simple vapour compression refrigeration system.

4

8

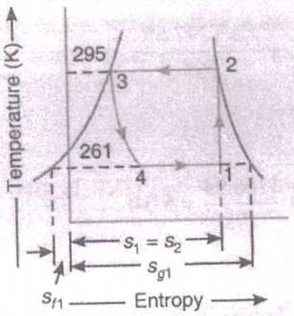
Simple Vapour Compression Refrigeration System: A simple vapour compression refrigeration system consists of the following equipments: i) Compressor ii) Condenser iii) Expansion valve iv) Evaporator. 4

The schematic diagram of the arrangement is as shown in Fig.. The low temperature, low pressure vapour from the evaporator is goes to the compressor were it is compressed to high temperature and pressure vapour . This vapour is condensed into high pressure vapour at in the condenser and then passes through the expansion valve. Here, the vapour is throttled down to a low pressure liquid and passed on to an evaporator, where it absorbs heat from the surroundings from the circulating fluid (being refrigerated) and vaporizes into low pressure low temperature vapour

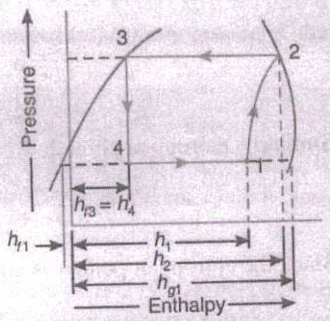
(b)	**Solution.** Given : $p_2 = p_3 = 60$ bar ; $p_1 = p_4 = 25$ bar ; $T_2 = T_3 = 295$ K ; $T_1 = T_4 = 261$ K ; $h_{f3} = h_4 = 151.96$ kJ/kg ; $h_{f1} = 56.32$ kJ/kg ; $h_{g2} = h_2 = 293.29$ kJ/kg ; $h_{g1} = 322.58$ kJ/kg ; $*s_{f2} = 0.554$ kJ/kg K ; $s_{f1} = 0.226$ kJ/kg K ; $s_{g2} = s_2 = 1.0332$ kJ/kg K ; $s_{g1} = 1.2464$ kJ/kg K		7

1. *C.O.P. of the cycle*

The *T-s* and *p-h* diagrams are shown in Fig. 4.5 (*a*) and (*b*) respectively. 3



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



(*b*) *p-h* diagram.

Fig. 4.5

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

We know that entropy at point 1,

$$s_1 = s_{f1} + x_1 s_{fg1} = s_{f1} + x_1(s_{g1} - s_{f1}) \quad \ldots (\because s_{g1} = s_{f1} + s_{fg1})$$

$$= 0.226 + x_1 (1.2464 - 0.226) = 0.226 + 1.0204\, x_1 \quad \ldots (i)$$ 2

and entropy at point 2, $s_2 = s_{g2} = 1.0332$ kJ/kg K ... (Given) ... (*ii*)

Since the entropy at point 1 is equal to entropy at point 2, therefore equating equations (*i*) and (*ii*),

$$0.226 + 1.0204\, x_1 = 1.0332 \quad \text{or} \quad x_1 = 0.791$$

We know that enthalpy at point 1,

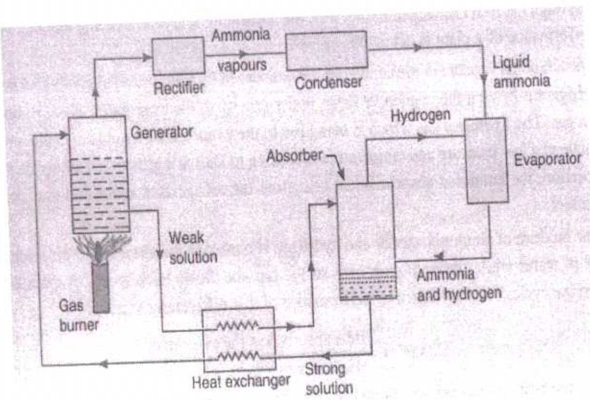
$$h_1 = h_{f1} + x_1 h_{fg1} = h_{f1} + x_1 (h_{g1} - h_{f1}) \ldots (\because h_{g1} = h_{f1} + h_{fg1})$$

$$= 56.32 + 0.791\,(322.58 - 56.32) = 266.93 \text{ kJ/kg}$$ 2

∴ C.O.P. of the cycle

$$= \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{266.93 - 151.96}{293.29 - 266.93} = 4.36 \text{ Ans.}$$

V



ELECTROLUX REFRIGERATOR . This type of refrigerator is also called

Three-fluids absorption system". The three fluids used in this• system are

ammonia, hydrogen and water Principle and Working of Electrolux Refrigerators. Fig. 5.6

. Shows a schematic diagram of an „Electrolux refrigerator". It is a domestic refrigerator and is the best known ab type of refrigerator.
. The principle involved makes use of the properties of gas-vapor mixtures. If a liquid is exposed to an inert atmo will evaporate until the atmosphere is saturated with the vapor of the liquid. This evaporation requires heat which from the surroundings in which the evaporation takes place. A cooling effect is thus produced. The partial pressu refrigerant vapor (in this case ammonia) must be low in the evaporator, and higher in the condenser. The total pre throughout the circuit must be constant so that the only movement of the working fluid is by convection currents. pressure of ammonia is kept low in requisite parts of the circuit by concentrating hydrogen in those parts. **Workin** ammonia liquid leaving the condenser enters the evaporator and evaporates into the hydrogen at the low temper corresponding to its low partial pressure. The mixture of ammonia and hydrogen passes to the absorber into whic admitted water from the separator. The water absorbs the ammonia and the hydrogen returns to the evaporator. absorber the ammonia therefore passes from the ammonia circuit into water circuit as ammonia in water solution. strong solution passes to the generator where it is heated and the vapor given off rises to the separator. The wate vapor is separated out and a weak solution of ammonia is passed back to the absorber, thus completing the wate The ammonia vapor rises from the separator to the condenser where it is condensed and then returned to the ev The complete cycle is carried out entirely by gravity flow of the refrigerant.• The hydrogen gas circulates only fro absorber to the evaporator and back.• With this type of machine efficiency is not important since the energy inpu It has not been used for industrial applications as the C.O.P. of the system is very low.• Role of Hydrogen. By the of hydrogen it is possible to maintain uniform total pressure throughout the system and at the same time permit th refrigerant to evaporate at low temperature in the evaporator corresponding to its partial pressure. Thus the cond evaporator pressures of the refrigerant are maintained as below: (i) In the condenser only ammonia is present, ar pressure is the condensing pressure. (ii) In the evaporator hydrogen and ammonia are present; their relative mas adjusted such that the partial pressure of ammonia is the required evaporator pressure. These are achieved with of pumps or valves

b.

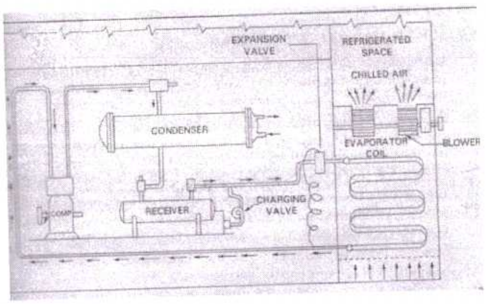
The cold storage is specially designed and built of concrete, stone or brick in order to prevent the leakage or cold leakage. Its floors and ceilings, walls and doors are properl insulated with special insulating materials with low thermal conductivity.

There are various refrigeration mechanism and processes but Vapour Compression Refrigeration System is the common one because of higher coefficient of performance compared to Vapour Absorption System. Cold storage plant also works on the 'Vapor Compression Refrigeration' cycle. As per the second law, in order to transfer heat from low-temperature body to high-temperature body, one needs to put extra energy. Compressor power is work or energy needed for cooling process continuation.

Construction of cold storage plant

- Compressor: Compressor is the heart of the cold storage plant and only power consuming device or machine of the cold storage plant. The majority of power is consumed by the compressor. It raises the temperature and pressure of refrigerant (the working medium, Ammonia) vapor coming out from an evaporator. Due to high pressure, the refrigerant boiling point gets increased and thus it can be now easily condensed at condenser temperature.

- Condenser: It is a heat exchanger device which exchanges the heat from vapor refrigerant and water being circulated. The condenser is not powered consuming device. It condenses (meaning 'phase change') the high-pressure and high-temperature refrigerant to the high-pressure and high-temperature liquid. One can say, a condenser is a heat sink where heat is rejected. The efficiency of plant is dependent on the effectiveness of heat transfer at condenser.
- Receiver: It receives the high-pressure liquid condensate from the condenser and collects it.
- Expansion Valve: It reduces the pressure and temperature of refrigerant from receiver pressure and temperature to evaporator pressure and temperature. The throttling process makes the pressure and temperature reduction. Due to friction, throttling process occurs and pressure along with temperature decreases. This is the location where cooling is produced.
- Evaporator: The heat exchanger where actual cooling takes place. It evaporates (vaporize) the low-pressure, low-temperature liquid refrigerant (with low boiling point) by taking/utilizing heat from atmosphere/storage compartment to be cooled, thus heat content of fruits or vegetable decrease and it cool due to this cyclic process (Chilled air is produced due to convection current)
- Blowers: It circulates chilled air in the refrigerated space to cool the fruits and vegetables by convection process.

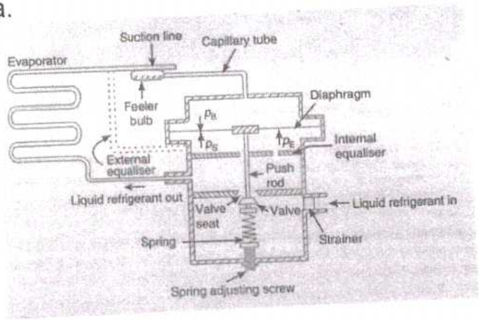


Working of cold storage plant

- The compressor compresses vaporized refrigerant(Ammonia) to high pressure and high temperature to raise the boiling point of refrigerant.
- The condenser then liquefies the vaporized refrigerant to high-pressure and high-temperature state. Thus, heat rejection takes place
- The condensate from the condenser is collected in reservoir and allow to pass through expansion valve where its pressure and temperature decrease from earlier state.
- The low-pressure liquid refrigerant then allow passing through refrigerated space whereby the heat of hot air of refrigerated space starts evaporating the liquid refrigerant hence, heat in the atmosphere decrease and cooling is produced.
- Blowers circulates the chilled air to stored fruits and

VI

a.



There are three pressures acting inside the thermostatic expansion valve. PB is the pressure at the top of the thermostatic expansion valve acting inside the power element above the diaphragm. Due to this pressure the diaphragm tends to move down due which the needle also moves down and the valve tends to open. When the evaporator temperature becomes higher the gas in the feeler bulb expands due to which the gas pressure inside the power element increases. This causes the downward movement of the needle to open the valve

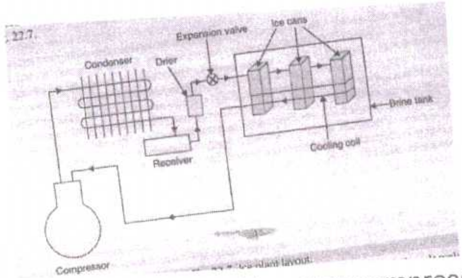
The pressure PE is the pressure acting on the lower side of the diaphragm due to the refrigerant pressure inside the evaporator. This pressure tends to move the diaphragm upwards and close the opening of the valve.

The pressure PSis the spring pressure that tends to close the opening of the valve. This pressure remains constant.During the normal working of the refrigeration plant the thermostatic expansion valve remains opened in certain position. When the refrigeration load increases, the temperature inside the evaporator also increases. In such cases there is need of the more refrigerant to take care of the increased load. The increased temperature in the evaporator is sensed by the feeler bulb of the thermostatic expansion valve. This leads to the expansion of the gas in the feeler bulb and also in the power element of the TEV leading to the increase in pressure PB. Due to this the diaphragm of the TEV moves down and tends to open the valve further to increase the flow of the refrigerant to the evaporator.

At the same time the pressure PE below the diaphragm also increases due to superheating of the refrigerant inside the evaporator. This pressure tends to close the valve. There is also spring pressure PSbelow the diaphragm that opposes the opening of the valve. If the increase in the refrigeration load is much higher the pressure PB overcomes pressure P2Eand PS leading to the further opening of the thermostatic expansion valve. This allows for the increased flow of the refrigerant to the evaporator to take care of the extra load.

When the refrigeration load reduces, the magnitude of pressure PB reduces and the combined pressures PS and PE overcome pressure PB that allows for partial closing of the valve so the flow of the refrigerant to the evaporator reduces. Thus the TEV maintains the flow of the refrigerant inside the evaporator as per the refrigeration or air conditioning load. The TEV constantly modulates the flow to maintain the superheat for which it has been adjusted by the spring.

b.



The main cycle used for ice plant is vapor compression cycle with ammonia as the refrigerant in primary circuit and brine solution in secondary circuit. Brine solution takes heat from water in secondary circuit and delivers the heat to ammonia in primary circuit. Thus, the indirect method of cooling is used in ice plant. In secondary circuit brine is cooled in evaporator and then it is circulated around the can which contains water. The heat is extracted from the water in the can and is given to the brine. The brine is contentiously circulated around the can with the help of brine pump till entire water in the can is converted into ice at -6 0 C. Ammonia vapor coming out of evaporator is compressed to high pressure and then these vapors are condensed in the condenser. High pressure liquid ammonia is collected in the receiver and it is passed through the expansion valve to reduce its pressure and temperature as per requirement. The throttle liquid ammonia at low temperature & low pressure enters in evaporator, which are the coils dipped in brine tank. The liquid ammonia absorbs heat from brine and gets converted into vapors, which are drawn by suction line of compressor.

VI I

Two Stage Cascade Refrigerating System

A two-stage cascade system employs two vapor-compression units working separately with different refrigerants, and interconnected in such a way that the evaporator of one system is used to serve as condenser to a lower temperature system (i.e. the evaporator from the first unit cools the condenser of the second unit). In practice, an alternative arrangement utilizes a common condenser with a booster circuit to provide two separate evaporator temperatures.
In fact, the cascade arrangement allows one of the units to be operated at a lower temperature and pressure than would otherwise be possible with the same type and size of single-stage system. It also allows two different refrigerants to be used, and it can produce temperatures below -150°C. Figure shows a two-stage cascade refrigeration system, where condenser B of system 1 is being cooled by evaporator C of system 2. This arrangement enables to reach ultralow temperatures in evaporator A of the system.

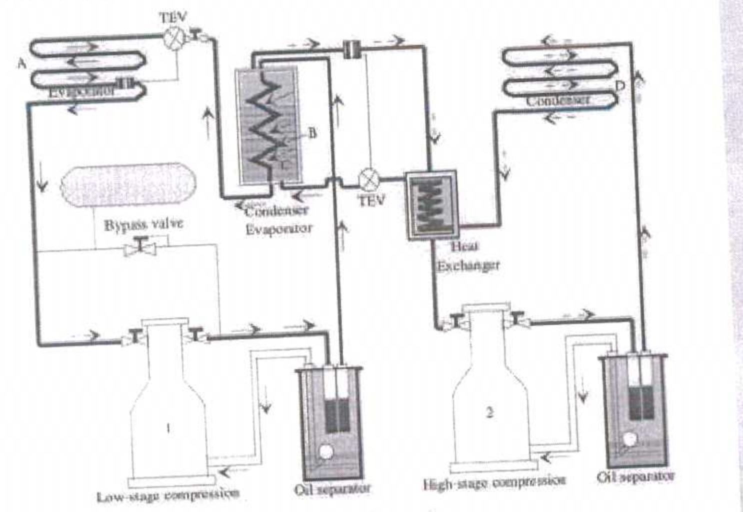


Figure 3.38 A practical two-stage cascade refrigeration system.

A practical two-stage cascade refrigeration system.

For a schematic system shown in Figure 3.39, the condenser of system I, called the first or high-pressure stage, is usually fan cooled by the ambient air. In some cases a water supply may be used but air-cooling is much more common. The evaporator of system I is used to cool the condenser of system II called the second or low-pressure stage. The unit that makes up the evaporator of system I and the condenser of system II is often referred to as the inter-stage or cascade condenser. As stated earlier, cascade systems generally use two different refrigerants (i.e. one in each stage). One type is used for the low stage and a different one for the high stage. The reason why two refrigeration systems are used is that a single system cannot economically achieve the high compression ratios necessary to obtain the proper evaporating and condensingtemperatures.

b.

Given V1=250m^3 ,td1=25˚C tw1=20˚C td2=35˚C

From the psychrometric chart: vs1=0.886m^3/kg of dry air.

enathalpy at point h1=57kJ/kg of dry air.

Enthalpy at point h2=68 kJ/kg of dry air.

We know that amount of air supplied ma=V/v1=250/.886=282.16kg

Amount of heat added= ma(h2-h1)=282.16(68-57)=3103.1kJ

Final relative humidity=37%

WBT=23˚C

Final DPT=19˚C

VIII

11.4 LIQUEFACTION OF HYDROGEN :

It is most difficult to liquefy hydrogen gas because of its extreamly liquefaction temperature. More over, all substances at such low temperat solidify and therefore the hydrogen used should be absolutely pure.

The schematic arrangement of equipment for liquefying hydrogen is show the figure. The working of the system is as follows.

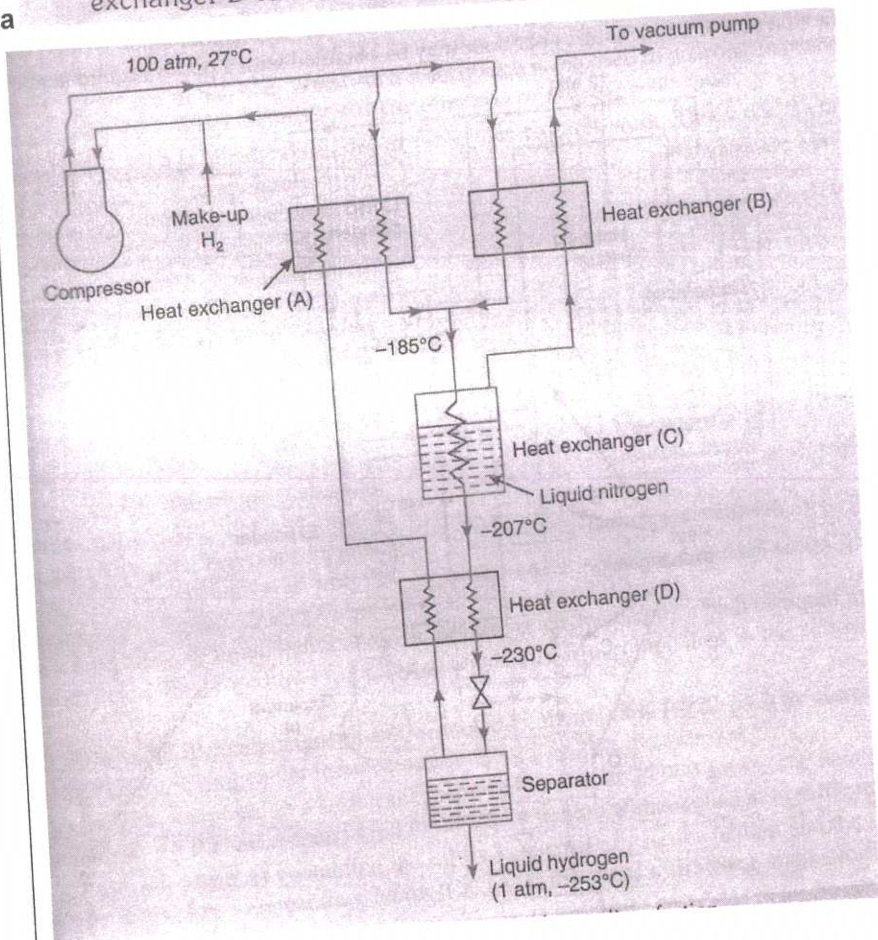
Pure hydrogen gas at a pressure about 100 atmospheres and 27^{0}C from compressor is precooled in two heat exchangers A and B. In heat exchange the incoming high pressure hydrogen is cooled by the out going low press hydrogen. In the heat exchanger B, it is cooled by nitrogen.

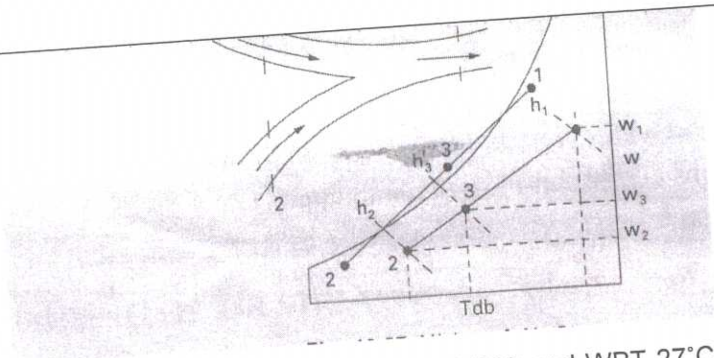
The high pressure hydrogen gas from both the heat exchangers is passed thro a third heat exchanger C, where the hydrogen gas is further cooled to ab -207^{0}C by nitrogen boiling under reduced pressure.

The hydrogen gas is further cooled to around -230^{0}C in the fourth h exchanger D, by the low pressure hydrogen gas returning from the separat

The liquid hydrogen is produced by throthting the hydrogen gas from the h exchanger D to atmospheric pressure.

a





b. Locate the point 1 on psychrometrichart corresponding to DBT40˚C and WBT 27˚C Mark point 2 on the chart which indicates DBT 23˚Cand RH 50%

m1=V1/vs1=100/.913=109.53 kg/min.

M2=V2/vs2=600/0.852=705.9kg/min

We know that m1/m2=(W3-W2)/(W1-W3)

From psychrometric chart at point 1 W1=0.0175 kg/kg of dry air

At point 2 W2=0.009kg/kg of dry air

From ean 109.53/705.9=(W3-.09)/(0.0175-W3)

W3=0.0102kg/kg of dry air

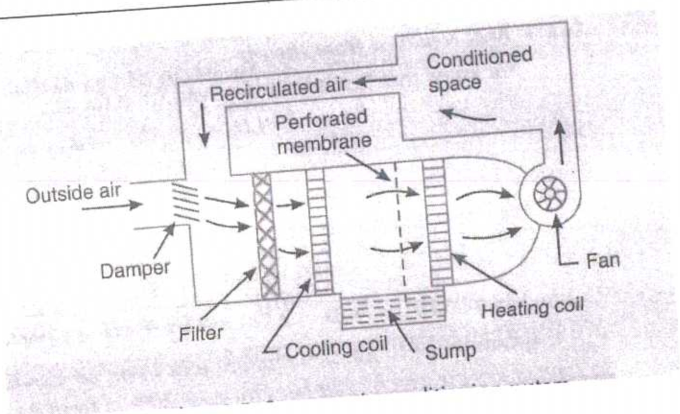
Mark point 3 is located from the chart **DBT= 25.5˚C**

WBT=18.2˚C

Specific humidity=0.012kg/kg of dry air

Relative humidity = 47%

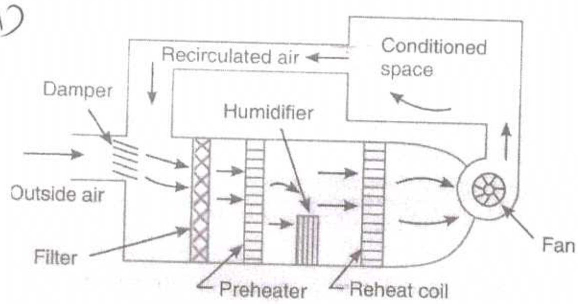
IX a



summer air conditioning: In most of the places the summer season is hot and humid. Hence, in order to provide comfortable conditions to the occupants during summer, it is required to supply cold and dry air to the occupied space. This requires systems wherein the hot and humid air can be cooled to temperatures lower than the dew point temperature, so that the water vapour in air can be removed by condensation, and the resulting cold and dehumidified air supplied to the conditioned space in required quantity for providing thermal comfort. Thus it can be seen that a typical summer air

	conditioning system requires a refrigeration system that reduces the temperature of the air to temperatures much lower than the surroundings. Of course, in some areas such as deserts, the summer is hot and dry. Air conditioning systems for these hot and dry climates also require cooling of air below the ambient temperatures, however, in stead of removing water vapour it may be required to add water to the air supplied to the conditioned space b. The heat is generated in the air-conditioned space from various sources. To maintain the comfort conditions inside the room the total heat generated inside the room per hour should be removed completely. Here are various sources of heat 1) **Heat gained by the walls**: The walls of the room gain heat from the sun by way of conduction. The amount of heat depends on the wall material and its alignment with respect to sun. If the wall of the room is exposed to the west direction, it will gain maximum heat between 2 to 5 pm. The southern wall will gain maximum heat in the mid-day between 12 to 2 pm. The heat gained by the wall facing north direction is the least. The heat gained by the walls in day-time gets stored in them, and it is released into the rooms at the night time thus causing excessive heating of the room. If the walls of the room are insulated the amount of heat gained by them reduces drastically. 2) **Heat gained by the roof and partitions**: If the roof is exposed directly to the sun, it absorbs maximum heat. If there is other room above the air-conditioned room, then the amount of heat gained by the roof reduces. The heat gained by the partitions of the room depends upon the type of partition. 3) **Heat gained by the windows**: Windows of the room are exposed directly to the surrounding and the heat from the sun enters the room by radiation. As in the case of the walls, the heat gained by the rooms through windows depends on their alignment. If there are sufficient curtains on the windows and the external awning the amount of heat gained by radiation reduces. The type of glass doors on the windows also affects the amount of heat gained through the windows by radiation. 4) **Heat generated by the people**: The people inside the room generate lots of heat. The heat dissipated by working people is more than from sitting people. 5) **Heat generated by the electrical appliances**: Heat is generated by electrical appliances like lights, motors, coffeemakers, electronic equipments, etc. should also be considered for heat load calculations, which is also called cooling load calculations. 6) **Heat gain from outside air**: Outside air is normally at a greater temperature than the room temperature. When this air comes inside the room, it brings certain amount of heat along with it.		7	

X (a)



Winter Air Conditioning System In winter air conditioning, the air is heated which is generally followed by humidification. The schematic arrangement of the system is shown in Fig. The outside air flows through a damper and mixes up with the re-circulated 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 preheat coil in order to prevent the possible freezing of water and to control the evaporation of water in the humidifier. After that, the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature. Now, the conditioned air is supplied to the conditioned space by a fan.

(b)

he degree of warmth or cold felt by a human body depends mainly on following three factors: (a) Dry bulb temperature (b) Relative humidity (c) Air velocity.

Effective temperature is used to evaluate the combined effect of all these factors. It is defined as that index which correlates the combined effects of air temperature, air velocity and relative humidity on human body.

The numerical value of effective temperature is made equal to temperature of still saturated air (i.e. 5 to 8 m/min air velocity) which produces same sensation of warmth or coolness as produced under the given conditions.

Factors affecting 'Effective Temperature' are:

a) Climatic and seasonal differences: There is a relationship between optimum indoor effective temperature and outdoor temperature which changes with seasons.

b) Clothing: Person with light clothing needs less optimum temperature than person with heavy clothing.

c) Age and sex: Women of all ages require higher effective temperature than men. Children also need higher ET than adults.

d) Duration of stay: If the stay in a room is shorter then higher ET is required than that needed for long stay.

e) Kind of activity: When activity of person is heavy such as people working in factory then low ET is needed than for people sitting in cinema hall or auditorium.

f) Density of occupants: The effect of body radiant heat particularly in a densely occupied space like auditorium is large enough which requires little lower ET.