REFRIGERATION AND AIR-CONDITIONING LAB MANUAL

GOVT. ENGG. COLLEGE, VALSAD.

MECHANICAL ENGG. DEPT. (FOR EVEN TERM - 2019)

GOVERNMENT ENGINEERING COLLEGE, VALSAD
MECHANICAL ENGINEERING DEPARTMENT

CERTIFICATE

This is to certify that Mr./Miss____ of Mechanical Branch, Sem-VI, Enrollment No.________________________, has satisfactorily completed his/her term work for the subject **Refrigeration and Air- Conditioning (2161908)** during even term-2019.

Date :

Sign of Faculty

Head of the Department

GOVERNMENT ENGINEERING COLLEGE, VALSAD
MECHANICAL ENGINEERING DEPARTMENT

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3	To understand construction and working of reciprocating, rotary and centrifugal compressor used for R&AC.			
4	To understand various tools used for refrigeration tubing and to perform various operations like flaring, swaging, bending, brazing etc.			
5	To perform different psychrometric processes and analyze the same using psychrometric chart.			
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PRACTICAL 1: TO UNDERSTAND DIFFERENT COMPONENTS OF VCR SYSTEM AND TO DETERMINE IT'S C.O.P.

Objective:

- To study different components of VCR system.
- To determine C.O.P. of VCR System.

Refrigeration:

Theory:

Refrigeration may be defined as an art of producing and maintaining a temperature in a space below the surrounding temperature. It also includes the process of removing heat from the substance under controlled conditions. It is used for the manufacturing of ice and similar products. This is widely used for cooling of storage chambers in which perishable foods, drinks and medicines are stored. The refrigeration has also wide application in submarine ships, aircrafts.

Standard Vapour Compression Cycle: - (SVCC)

This cycle consists of following four processes:

(1) Reversible adiabatic compression from the saturated vapour to a superheated condition.
(2) Reversible heat rejection at constant pressure (de-superheating and condensation of the refrigerant)
(3) Irreversible is enthalpy expansion from saturated liquid to a low pressure vapour.
(4) Reversible heat addition at constant pressure.

System components and its function: -

(1) **Compressor**: - Compressor is most important part of the system. The compressor raises the measure of incoming vapour from the evaporator to a high pressure. Different type of compressor are:

- Reciprocating compressor
- Rotary compressor
- Screw compressor
- Centrifugal compressor

The selection of the above mentioned compressor depends upon the usage. Usually domestic refrigerator are installed with reciprocating compressor. A hermetic type compressor is one in which the compressor and motor integral on one shaft and they are both contained in a pressure shield housing. It is compact in size, quite, low in cost and no problem of refrigerant gas leakage. The motor in a hermetic type compressor is cooled by refrigerant suction gas.

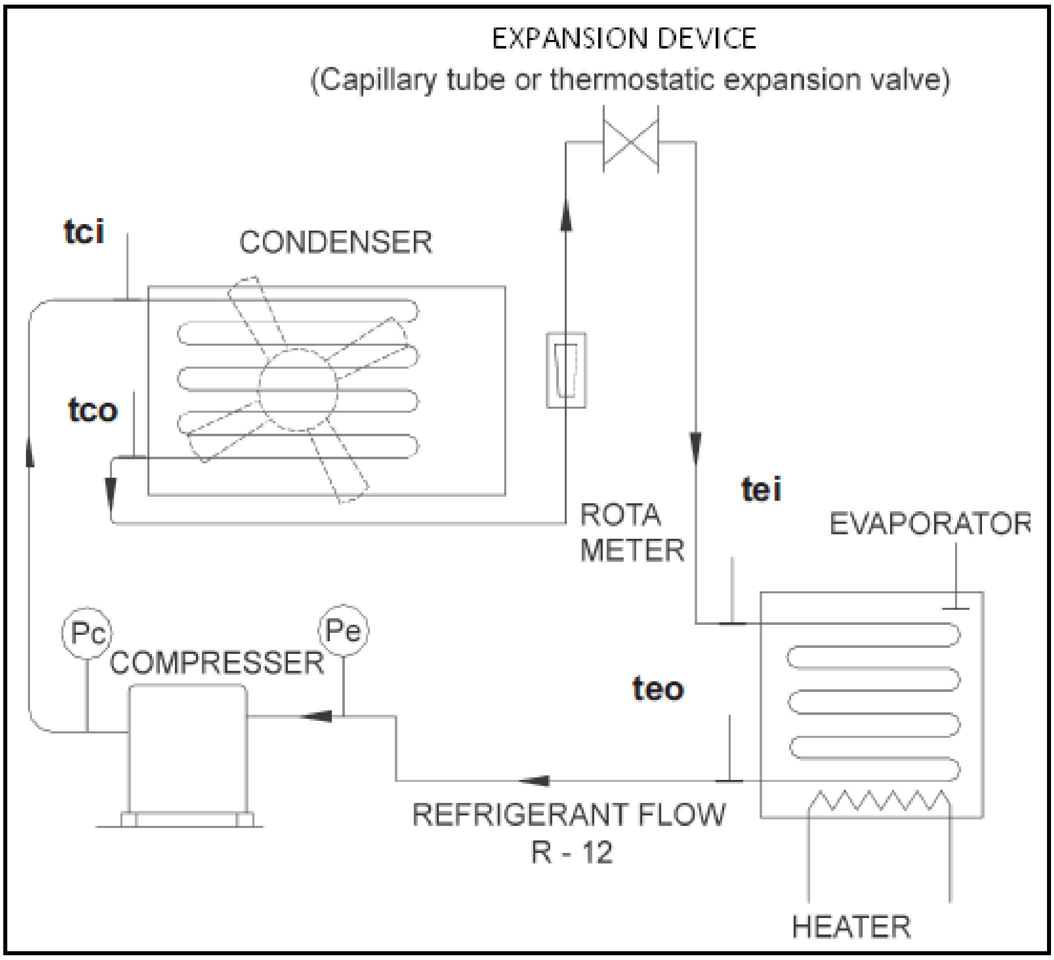


Fig. 1.1- Schematic diagram of Vapour Compression Refrigeration System

(2) **Condenser**: - The function of a condenser is to remove heat from the superheated high pressure refrigerant vapour and to condense the vapour into a sub cooled high pressure liquid. This is accomplished a cooling medium either air or water. The air cooled condenser may be of static cooled type where natural convective motion of air surrounding heat is enough to cool the condenser or they may be of fan cooled type. The static cooled condenser is used in domestic refrigerators. In commercial appliances and windows air-conditioners usually fan cooled condensers are used. The water condenser is normally used in large system firms 5 tons and above.

(3) **Expansion Devices**: -As the high pressure sub-cooled refrigerant liquid from the condenser passes through the expansion device its pressure and temperature is reduced. And outlet refrigerant, mostly in liquid stage.

Expansion device are of many types and are selected as per the requirement. For example, for constant evaporator pressure requirement automatic expansion valve are used. If variation in cooling load is high the thermostatic valves are best suited.
Hermetic compressor are almost invariably are used with capillary tube, through a few of them might also be used with thermostatic expansion valves.

(a) *Thermostatic expansion valve*: -

Thermostatic expansion valve controls the mass flow rate of refrigerant by sensing evaporator outlet temperature. Thus the valve is sensitive to the cooling load. If the load is more, the degree of super hit of refrigerant coming out of the evaporator increases. To maintain the degree of super heat to preset level, more liquid is fed to evaporator. When the load is low, valve closes and less liquid quantity is fed. Selection of thermostatic expansion is done on the basis of refrigerant used in capacity.

(b) *Capillary tube*: -

It is the simplest and cheapest form of expansion device. It does not include any moving parts hence no maintenance is required. Capillary tube is supposed to be a single point operation device in the sense that the best control is achieved only at a given set of operating parameters.

Under varying loads the capillary tube does not function satisfactorily. For example at lower loads than designed value capillary tube may overfeed the evaporator causing liquid to return to compressor. Under higher loads than designed the capillary tube starves the evaporator, causing excessive return gas superheat. Hence for variation in cooling loads, it is not suitable.

(4) **Evaporator**: -The function of evaporator is to remove heat from the product or the area to be cooled and maintain it at any desired temperature. The liquid refrigerant inside the evaporator evaporates by absorbing heat and converts into vapour refrigerant and then it returns back into the compressor. Various types of constructions of the evaporator used in refrigerant system e.g.

   a) Finned tube evaporator coil
   b) Bare tube soldered/clamped to the tank
   c) Bare tube dipped in the liquid to be cooled
   d) Shell & coil type evaporator

The choice of particular construction depends on the type of appliance. However in every case the heat capacity depends on these factors viz. temperature difference between the load and the refrigerant, heat transfer co-efficient and areas of the heat transfer.

(5) **Drier**: - If by chance refrigerant is containing any water particle then in low temperature region (i.e. at and after the expansion valve) it forms ice and chokes the valve or bends thereby preventing the smooth passage of refrigerant through it. To prevent this drier is used to remove any water particles carried into the refrigerant. It is used in between the evaporator and compressor.

(6) **Accumulator**: -It is fitted in between the evaporator and compressor. It prevents the liquid refrigerant from entering the compressor.

Description of Setup:

The unit is equipped with compressor operate on 220V AC supply and works on R-134 a. The unit is fitted on with compressor, air cooled condenser, condenser fan motor drier, thermostatic expansion valve, solenoid valve, capillary tube, expansion valve refrigerant flow motor water calorimeter (cooling coil), suction gauge, discharge gauge, digital temperature indicator with probe to measure different temperatures, heater inside the calorimeter, cooling thermostat, one number charging valve provided to charge the liquid refrigerant. The voltmeter and ampere meter for compressor have been provided which are duly interlocked type writing for safety point of view.

Technical Specifications:

- Compressor : Hermetically sealed make
- Agitator : Compatible capacity
- Condenser : Air cooled compatible to compressor
- Condenser cooling fan : Compatible capacity with permanent lubricating motor
- Evaporator : Made of Stainless steel insulated with ceramic wool/P.U.F
- Rotameter : Make Eureka
- Expansion device : Capillary tube solenoid & thermostatic valve
- Pressure gauges : 2 Nos.
- Safety control : Time delay circuit
- Temperature sensor : RTD PT-100 type
- Control panel : Digital voltmeter (0-300V) and ammeter (0-10A)
- Temp. Measurement : Digital temperature indicator with multi-channel switch

Experimental Procedure:

1. Switch in main board, check voltage. It should not be less than 180 V.
2. Start the condenser fan motor.
3. See that all the respective indication lights are on.
4. Put the water in the evaporative tank/calorimeter.
5. Switch on the compressor.
6. At the time of the start of the unit, note down the reading of voltage, ampere, suction and discharge gauge- pressures reading for compressor.
7. Check and note down the reading of various temperature through digital temp. Indicator.
8. Always close the door of the evaporator.
9. Note down the reading of the pressure gauge. Absence of any reading will indicate the blockage or leakage of gas.
10. After the gap of 15 minutes, start the agitator motor for two minute for equalization of water temperature and note down all the readings.
11. Now if you want to provide or test load on our compressor, switch on the heater.
12. Check and note don the readings of temperature, pressure and energy.
13. Now let the unit run for at least 10-20 minutes.
14. Switch on the agitator motor for 2 minutes for equalization of water temperature.
15. Check the water temperature through Digital Temp. Indicator. It must not go ahead of 350C.
16. After taking the required readings, switch off the heating process if the unit runs with compressor or cooling process.
17. While closing the unit, first switch-off the compressor, condenser, fan motor, and all the other valves and switches on the unit.
18. Always check the indication lights provided on the board for each component.

Observation Table:

ρ – Density of water = 1000 kg/m3

Cp_w – specific heat of water = 4.186 KJ/kg ^{0}C

Sr. No	P_1	P_2	T_1	T_2	T_3	T_4	T_5	T_6	Volume of water (W)	V	I
1											
2											
3											

Calculations:

(1) C.O.P. $_{theo}$:-

$COP_{th} = \frac{RE_{th}}{CW_{th}}$

$COP_{th} = \frac{H_1 - H_3}{H_2 - H_1}$ (H_3=H_4)

[Note: H1 at P_1-T_1 , H_2 at P_2-T_2 and H_3 at P_2-T_3 from P-H diagram of R-134a]

(2) C.O.P $_{act}$:-

Heat given away by water = Actual refrigerating effect

$CW_{act.}$ = V * I * cosΦ Watt (cosΦ = 0.7)

$RE_{act.}$ = m * C_p* (T_5 – T_7) Watt

$COP_{act} = \frac{RE_{act}}{CW_{act}}$

$COP_{relative} = \frac{COP_{act}}{COP_{th}}$

Nomenclature: -

T_1 – Temperature of compressor inlet (suction) (^{0}C)

T_2 – Temperature of compressor outlet (discharge) (^{0}C)

T_3 – Temperature of condenser outlet (^{0}C)

T_4 – Temperature of evaporator inlet (^{0}C)

T_5 – Temperature of water inlet (^{0}C)

T_6 – Temperature of water outlet (^{0}C)

H_1 – Enthalpy at compressor inlet (KJ/kg)

H_2 – Enthalpy at compressor outlet (KJ/kg)

H_3 – Enthalpy of sub-cooling at condenser outlet (KJ/kg)

H_4 - Enthalpy of refrigeration at evaporator inlet (KJ/kg)

P_1 & P_2– Pressure at compressor suction and discharge (kg/cm^2)

V & I – Voltmeter and ammeter reading

Conclusion:

Exercise:

<table>
<tr><td>1</td><td>Why in practice a throttle valve is used in vapour compression refrigerator rather than an expansion cylinder to reduce pressure between the condenser and the evaporator?</td></tr>
<tr><td>2</td><td>Explain Construction and working of simple vapour compression refrigeration system with P-V, T-S and P-H diagram and derive equation of COP for Bell-Coleman cycle.</td></tr>
<tr><td>3</td><td>A 5 Tonne R-12 refrigeration plant has saturated suction temperature of -5°C. The condensation takes place at 32°C and there is no undercooling of refrigerant liquid. Assuming isentropic compression, find (i) COP of the plant, (ii) Mass flow rate of refrigerant (iii) Power required to run the compressor in KW.
Take the following properties of R-12.
<table>
<tr><th>P (bar)</th><th>Sat. Temp.(°C)</th><th>hf (KJ/Kg)</th><th>hg (KJ/Kg)</th><th>Sg (KJ/Kg-K)</th></tr>
<tr><td>7.85</td><td>32°C</td><td>130.5</td><td>264.5</td><td>1.542</td></tr>
<tr><td>2.61</td><td>-5°C</td><td>95.4</td><td>249.3</td><td>1.557</td></tr>
</table></td></tr>
<tr><td>4</td><td>A vapor compression machine is used to maintain a temperature of - 230C in refrigerated space. The ambient temperature is 370C.The compressor takes in dry saturated vapor of F -12. Aminimum100C temperature difference is required at the evaporator as well as condenser. There is no sub-cooling of liquid. If refrigerant flow is rate is 1kg/min find (i) Tonnage of refrigeration. (ii) Power requirement (iii) Ratio of COP of this cycle to COP of Carnot cycle.</td></tr>
<tr><td>5</td><td>R-12 vapour compression system has saturated suction temperature of -5°C and saturated discharge temperature of 40°C. The refrigerant vapour is dry-saturated at the suction of compressor and becomes superheated after compression. For one ton of refrigeration capacity, Calculate (i) Refrigerating effect (ii) mass flow rate (iii) Power and (iv) COP of the system.</td></tr>
<tr><td>6</td><td>An air refrigerator working on Bell Coleman cycle takes in air at 1 bar and at a temperature of 100 C. The air is compressed to 5 bar abs. The same is cooled to 250 C in the cooler before expanding in the expansion cylinder to cold chamber pressure of 1 bar. The compression and expansion laws followed are pv1.35 = C and pv1.3 = C respectively. Determine C.O.P of the plant and net refrigeration effect per kg of air. Take Cp = 1.009 kJ/kg K and R = 0.287 kJ/kg K for air.</td></tr>
</table>

PRACTICAL 2: TO UNDERSTAND WORKING OF ELECTROLUX REFRIGERATOR AND TO DETERMINE IT'S COP.

Objective:

- To study different components of Electrolux VAR system.
- To determine C.O.P. of Electrolux VAR System.

Theory:

Electrolux refrigeration is an absorption type refrigeration system. In absorption refrigeration system, the vapour is drawn from the evaporator by absorption into liquid having high affinity for refrigerant. The refrigerant is expelled from the solution by application of heat and its temperature is increased. This refrigerant in the vapour form passes to the condenser gets liquefied where heat is rejected and the refrigerant gets liquefied. This liquid again flows to the evaporator at reduced pressure and the cycle is completed.

Absorber: -The main function of the absorber is the absorption of the refrigerant vapour by its weak or poor solution in a suitable absorbent, forming a strong or rich solution.

Condenser: -It condenses the vapour refrigerant into the liquid by condenser fan and passes it into the receiver tank for recirculation.

Evaporator: - It evaporates the liquid refrigerant by absorbing the heat into vapour refrigerant and sends back to next run.

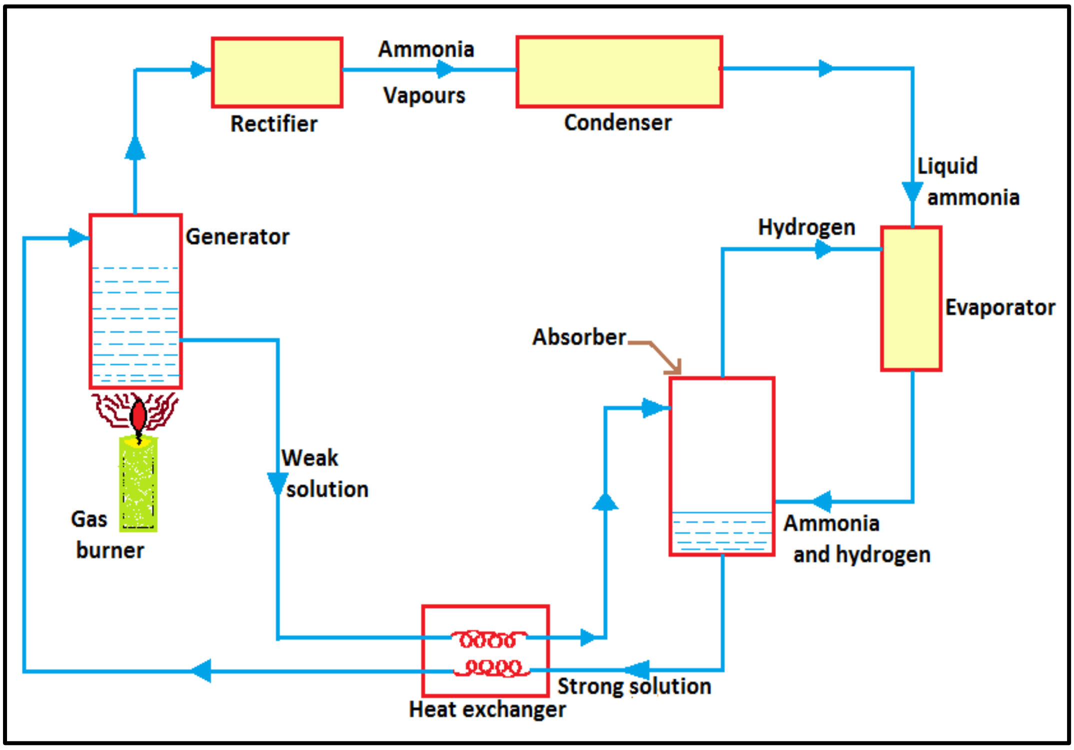


Fig. 2.1- Schematic Diagram of domestic Electrolux type refrigerator

The flow of fluids in the system has been shown in the diagram with different shadings and the index of these shadings also indicated in diagram.

Vertical generator in which an aqua solution of ammonia can range itself from distilled water at the bottom of the generator to strong ammonia vapour at the surface of liquid.

A water separator which is provided to remove water vapour so that they should not enter the condenser, get condensed there and pass on to evaporator where chocking might occur due to its freezing. The water vapour is formed in the boiler as some of the water may evaporator on application of heat to the boiler. The separator is jacked with liquid ammonia at pressure of about 14 bar gauge for which the saturation temperature is about 40^0C.

The dehydrate ammonia gas condensed to liquid in the condenser and gravitates to 'U' tube which acts as seal for the gas to enter the evaporator or any gas passing from evaporator to condenser.

In the evaporator, ammonia liquid comes across an atmosphere of hydrogen at about 12 bar pressure. The plant is charged to a pressure of about 14 bars. Hence due to Dalton's law of partial pressure. The pressure of ammonia gas should fall to about 2 bar gauge and the saturation temperature corresponding to about 2 gauges is about -10^0C. The temperature surrounding the evaporator is much high than this. Thus ammonia evaporates and produces the refrigerating effect i.e. absorbs the latent heat of vaporization at 2 bar gauge and about -10^0C from the space to be refrigerated.

In order to ensure continues action, hydrogen gas has to be removed from ammonia vapour. This is done in the absorber where a descending spray of very dilute ammonia liquid moseys the ascending mixture of ammonia vapour and hydrogen. Ammonia vapour is readily absorbed with evaluation of heat so that absorber has to be water jacketed or air cooled, otherwise evaporation may take place in this unit and the absorption may cease.

Heat exchanger: Liquid heat exchanger is placed between absorber and the generator. This weak liquid gets cooled and strong liquid gets heated. Thus is economized and better thermal efficiency is obtained. This heat exchanger is counter flow type. The strong solution from the absorber is preheated on its way to generator or boiler and the dilute solution on its way to absorber is cooled. This cooling of weak liquid also helps absorption and reduces the cooling of absorber by external source.

Working:

(1) Strong ammonia solution flows from the absorber vessel through heat exchanger to the generator.
(2) When the ammonia solution is heated in the generator by applying heat from the external source, bubbles of ammonia gas raises from the generator and passes to condenser through rectifier.
(3) The ammonia vapour is removed from the solution and passes into the condenser. Weak ammonia solution left behind in the generator flows to the absorber through the heat exchanger.
(4) Air circulating over the fins of the condenser, cool down the vapour, condensing it into liquid ammonia, which flows under gravity to the evaporator where it meets the hydrogen gas.
(5) The hydrogen in the evaporator lowers the ammonia vapour pressure and makes it evaporate.

(6) This process extracts heat from the evaporator, which in turn extracts heat from the food storage space. Thereby the temperature inside the refrigeration is lowered.

(7) The mixture of hydrogen and ammonia passes from the evaporator to the absorber. Weak ammonia solution is fed from the generator system through heat exchanger.

(8) As it returns to the absorber vessel, it absorbs the ammonia from the ammonia/hydrogen mixture and gets ready for another round in the generator.

Experimental Procedure:

1. Ensure that all ON/OFF switches given on the panel are at OFF position.
2. Switch On the main supply.
3. Switch On the refrigerator.
4. Record the temperature when the steady state is achieved.

Observation Table:

SR. No.	T1	T2	T3
1			
2			
3			
4			

Calculations:

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

Nomenclature: -

COP – Co-efficient of performance

T_1 – Temperature of generator, K

T_2 – Temperature of condenser, K

T_3 – Temperature of evaporator, K

Conclusion:

Exercise:

<table>
<tr><td>1</td><td>What is basic principle of Vapour absorption refrigeration system? Write brief note on Electrolux (NH3-H2) refrigerator.</td></tr>
<tr><td>2</td><td>Explain the significance of Hydrogen used in Electrolux Refrigerator system. In a 15 TR ammonia refrigeration plant, the condensing temperature is 250C and evaporating temperature -100C. The refrigerant ammonia is sub-cooled by 50 C before passing through the throttle valve. The vapour leaving the evaporator is 0.97 dry. Find (1) Coefficient of performance and (2) power required. Use the following properties of ammonia:-
<table>
<tr><td>Saturation temperature
0 C</td><td colspan="2">Enthalpy,
kJ/kg</td><td colspan="2">Entropy,
kJ/kg K</td><td colspan="2">Specific heat,
kJ/kg K</td></tr>
<tr><td></td><td>Liquid</td><td>Vapour</td><td>Liquid</td><td>Vapour</td><td>Liquid</td><td>Vapour</td></tr>
<tr><td>25</td><td>298.9</td><td>1465.84</td><td>1.1242</td><td>5.0391</td><td>4.6</td><td>2.8</td></tr>
<tr><td>-10</td><td>135.37</td><td>1433.05</td><td>0.5443</td><td>5.4770</td><td>--</td><td>--</td></tr>
</table></td></tr>
<tr><td>3</td><td>Discuss the advantages of vapour absorption refrigeration system over vapour compression refrigeration system.</td></tr>
<tr><td>4</td><td>What is the effect of sub-cooling on the performance of vapour compression refrigeration system?</td></tr>
</table>

PRACTICAL 3: TO UNDERSTAND CONSTRUCTION AND WORKING OF RECIPROCATING, ROTARY AND CENTRIFUGAL COMPRESSOR USED FOR R&AC.

Objective:

- To study construction and working of reciprocating, rotary and centrifugal compressor

Theory:

The compressor is the heart of vapour compression system. The compressor is used to reclaim the refrigerant vapour leaving the evaporator. The refrigerant must be compressed to the pressure corresponding to a saturation temperature higher than the temperature of the naturally available air or water. The compressor is also used to circulate the refrigerant through the system. The capacity of compressor determines the capacity of refrigeration system as a whole. The refrigeration compressor and gas or air compressor differs very much because the refrigerating compressor is integral part of the cycle and it is coupled to other components.

Classification:

Classification of refrigeration compressors:

1. Reciprocating compressor.
2. Rotary compressor.
3. Centrifugal and scroll compressor.

1. Reciprocating Compressor:

The reciprocating compressors are available in sizes as small as 1/12 hp up to about 150 hp for large capacity installation. The reciprocating compressors are of three types.

a) Open type compressor.
b) Hermetically sealed compressor.

a) Open type of compressor:

A compressor whose crankshaft extends through the compressor housing so that a motor can be externally coupled to the shaft is called open type compressor.These types of compressors adopt a volumetric compression system using pistons and work much like an internal combustion engine. The pistons run up and down inside cylinders, producing suction and compression of the refrigerant gas. Each cylinder has a suction valve for the gas refrigerant and a discharge valve to deliver the gas to the condenser after having been compressed. A disadvantage of the open type of compressor is that the shaft seal is most vulnerable point for leakage of refrigerant.

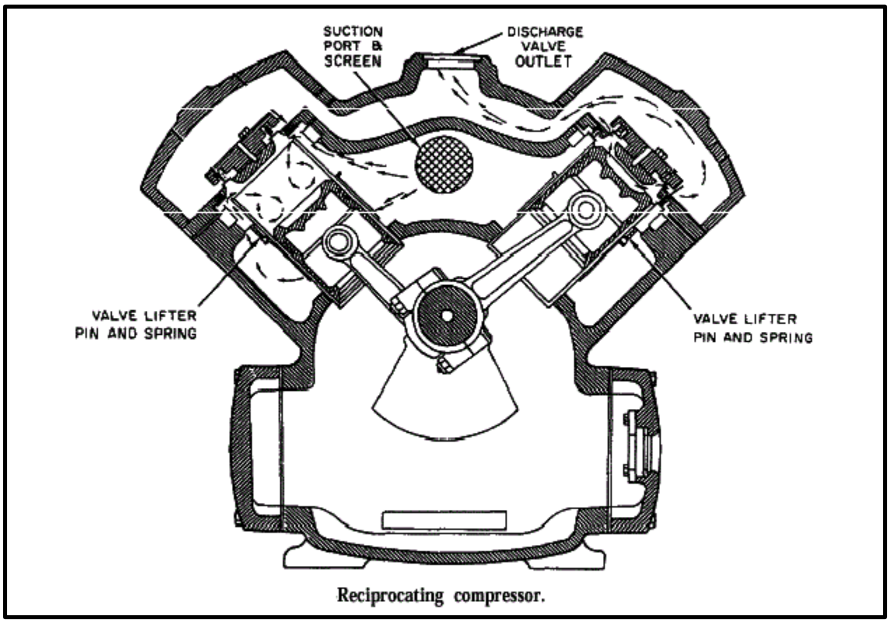


Fig 3.1- Cross-Section of Open Type compressor

b) Hermetically sealed compressor:

In hermetic compressor there is no need for shaft seal. The compressor and motor are mounted on single shaft and whole assembly is fixed in a steel shell, the joint of which are welded. The losses due to drive package and shaft seal friction are also eliminated i.e. the power required per tone of refrigeration is less then that of the open type.

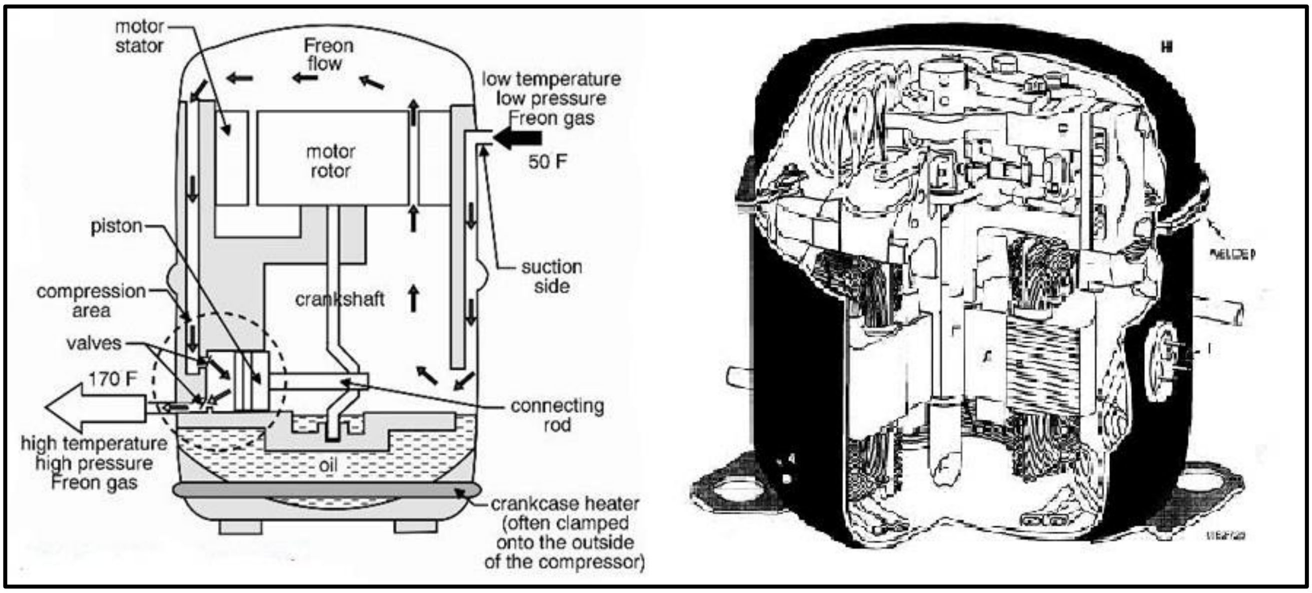


Fig3.2- Schematic Diagram of Hermetically sealed compressor

In a hermetic reciprocating compressor, as a result of the perfect hermetic sealing of the refrigeration circuit on the compressor body, unlike the two alternative variants – there are no refrigerant leaks possible. They are suitable for air conditioning, cold rooms or low temperature applications, the technology is very reliable, and they come in many different designs for all common refrigerants.

2. Rotary compressor:

As the name implies, the displacement and compression of the refrigerant vapour is achieved due to circular or rotary motion instead of reciprocating motion. These compressors are very efficient because the actions of taking in refrigerant and compressing refrigerant occur simultaneously. They have very few moving parts, low rotational speeds, low initial and maintenance costs, and are forgiving in dirty environments. However, they are limited to smaller volumes of the gas and produce less pressure than other types of compressors. There are two types of rotary compressor.

a) Rolling or Stationary Single Blade type rotary compressor:

The main components of rotary compressor are cylinder, roller mounted eccentrically on motor shaft and a spring loaded shaft. The roller moves eccentrically on the driver shaft inside a stationary cylinder. The vane moves up and down in the slot. This vane is dividing line between the suction and discharge of compressor.

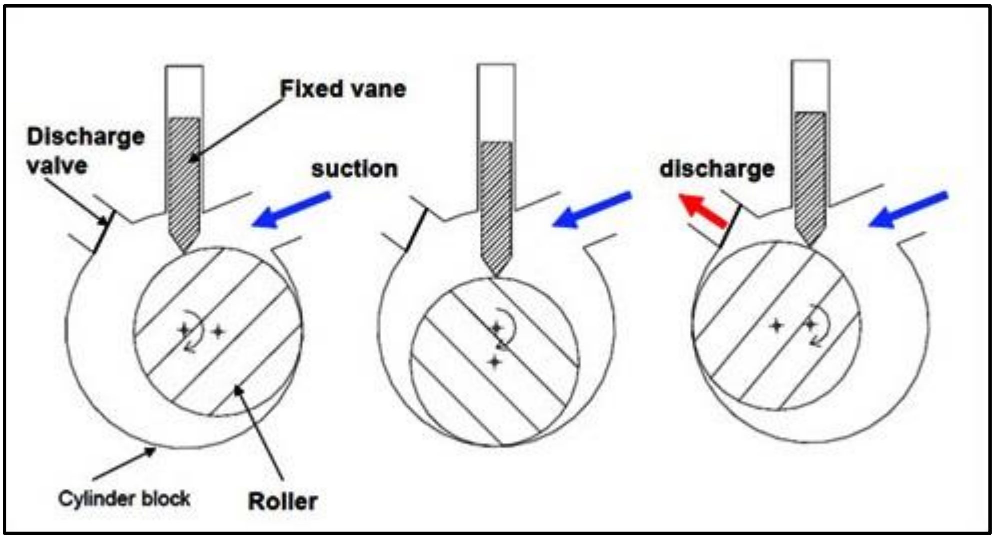


Fig3.3 – Schemaic diagram of Rolling type compressor

The suction and discharge ports of the compressor are located on either side of the vane. The suction vapour entering the cylinder gets compressed due to eccentric rotation of the rotor. It progressively reduces the volume of the annular space between cylinder and the rotor. The compressed vapor passes out of the discharge port.

b) Scroll type compressor:

Scroll compressors are in widespread use in air-conditioning systems (their classic application is chiller). In scroll compressors, the crankshaft is arranged vertically. The scroll set is located above it. This scroll set comprises one fixed and one orbiting spiral. These two spirals mesh with one another, compressing the refrigerant through an orbital motion from the outer part of the scroll set towards the middle.

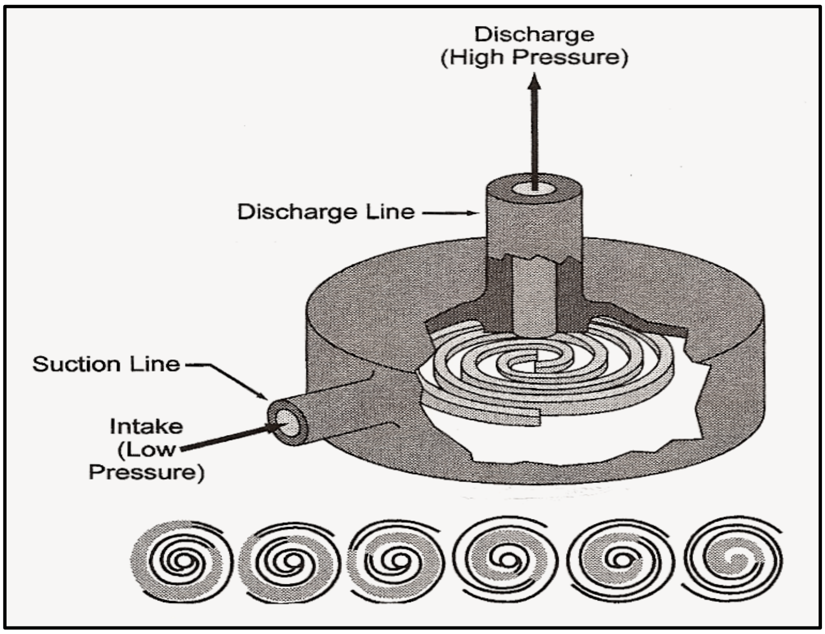


Fig 3.4 – scroll type of compressor

As a result of this principle, there are various stages of compression (differently sized “pockets” in which compression is currently occurring) at any point in the compression process. Compared to reciprocating compressors, scroll compressors expel smaller portions of refrigerant more frequently. This leads to smaller pulsations.

c) Screw type compressor

Screw compressor is also known as helical rotary compressor. It consists of two meshing multistory helical grooved rotors with vary close tolerance clearance within a housing. Suction and discharge ports are provided at the either ends of the housing.

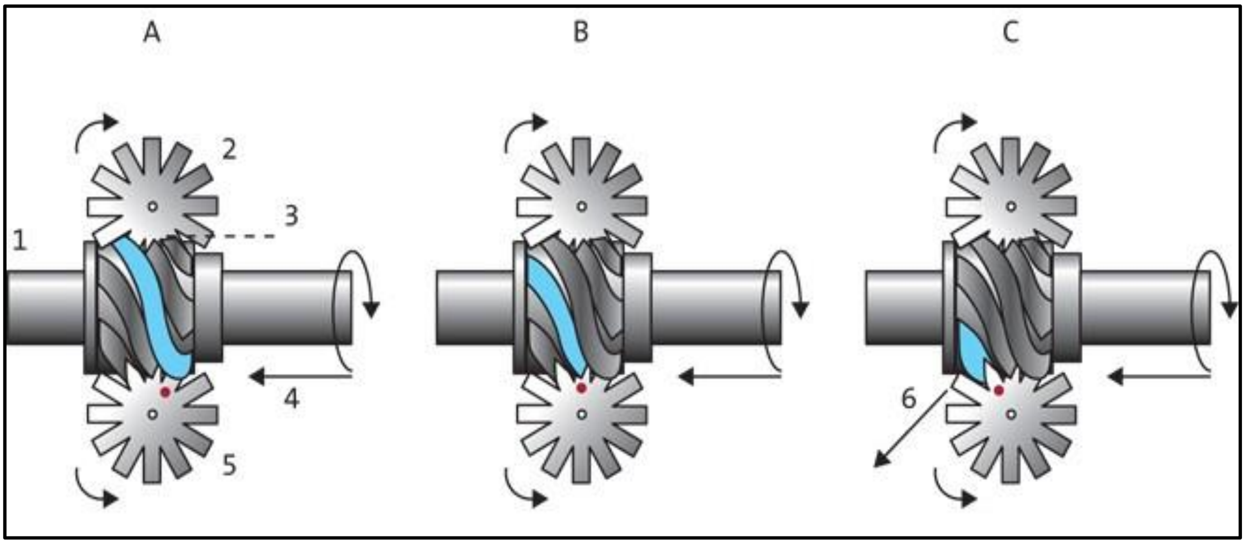
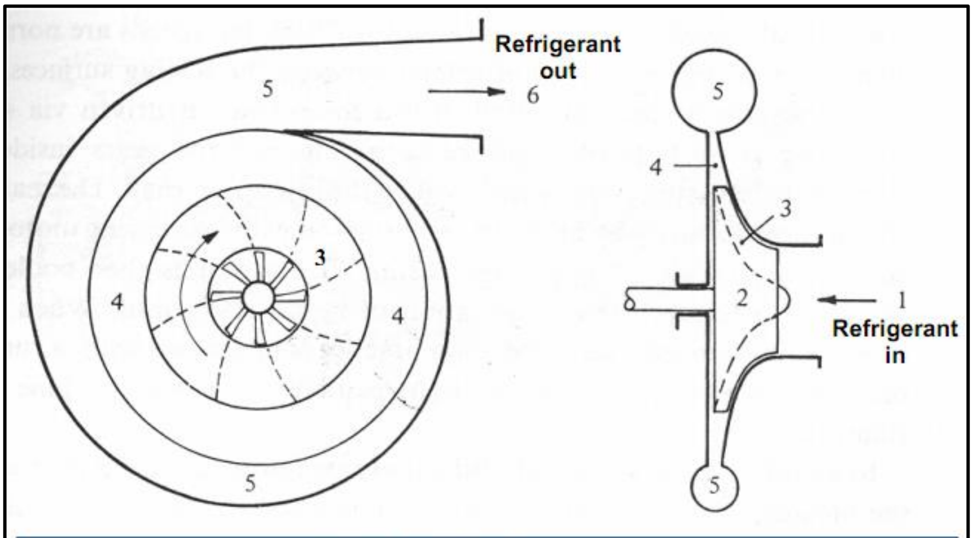


Fig 3.5 – working of Screw type compressor

The rotor whose shaft is connected to motor is called as male rotor and other as female. When the male rotor rotates, the female rotor in turn rotates, obviously in opposite direction.

3. centrifugal compressor

Centrifugal compressors are similar in construction to centrifugal pumps , the incoming fluid enters the eye of the spinning impeller and is thrown by centrifugal force to the periphery of the impeller. Thus the blades of the impeller imparts a high velocity to the gas and also build up the pressure. From the impeller the gas goes either into diffuser blades or into a volute casing, where some of the kinetic energy is converted into pressure.



21.1. Centrifugal Compressor
1: Refrigerant inlet (eye); 2: Impeller; 3: Refrigerant passages
4: Vaneless diffuser; 5: Volute casing; 6: Refrigerant discharge

Fig 3.6 – Centrifugal Compressor

The centrifugal compressors may be manufactured with only one wheel if the pressure ratio is low, although the machines are generally multistage. Centrifugal compressors operate with adiabatic compression efficiency of 70 to 80%.

Different protective devices used on compressors:

Protective devices are designed to protect the compressor against abnormal working conditions.

1. High pressure cutout switch.
2. Internal pressure relief value.
3. Low pressure switch
4. Motor winding thermal protector (Thermostat)
5. Time delay relays.

Exercise:

1	Write brief note on Hermetically sealed compressor also give advantages
2	What is a multi-stage compressor? Give its advantages
3	What are the advantages and disadvantages of centrifugal compressor over reciprocating compressors?
4	Explain working of screw type compressor.

PRACTICAL 4: TO UNDERSTAND VARIOUS TOOLS USED FOR REFRIGERATION TUBING AND TO PERFORM VARIOUS OPERATIONS LIKE FLARING, SWAGING, BENDING, BRAZING ETC.

Objective:

- To study various tools used for refrigeration.
- To perform various operations like flaring, swaging, bending, brazing etc.

Theory:

(1) Pipe Cutter

This instrument resembles wrench. It has a cutting wheel and two sliding wheels. The distance between the cutting wheel and sliding wheel can be altered by means of mechanism on the handle itself. The pipe is fixed in between the wheels and the instrument is given one rotation around the pipe. Then the distance between the wheels is decreased by rotation. Thus repeating the procedure, the pipe can be cut into two pieces.

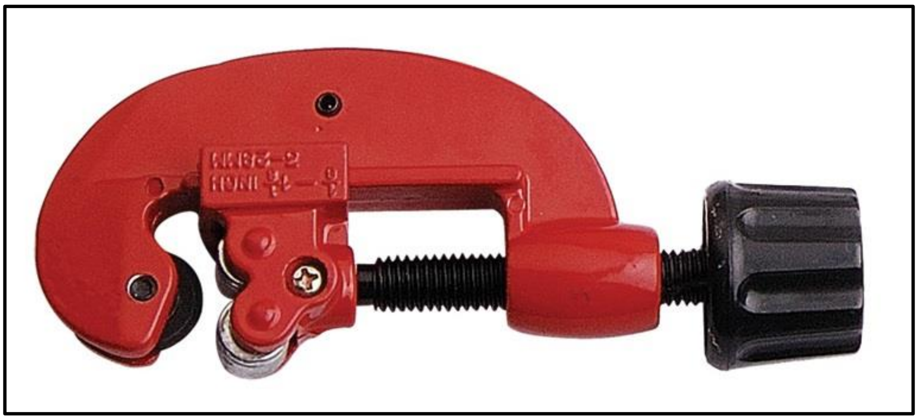


Fig 4.1- Pipe Cutter

(2) Wrench

This is commonly used to tight the bolt. It is also used for holding the parts tightly. These are available in different sizes depending upon the diameter of pipe. It is also available in adjustable form. By turning screw we get desire length between two ends.

Fig 4.2- Wrench

(3) Flaring Instruments

This instrument is a simple instrument of two pieces joined by means of two bolts operated by two wing nuts. When joined together, they form holes of different sizes in which different sizes of pipes are held tightly for flaring. The pipes do not slip because grips are provided in the inner side of the holes.

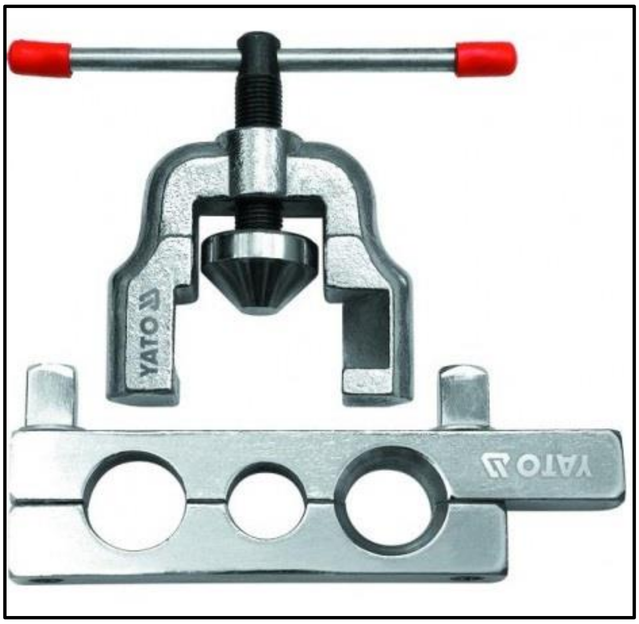


Fig 4.3– Flaring Instrument

(4) Pinch Off Tool

The pinch off tool has a similar constructional feature as a flarer. It consists of two parts assembled by two bolts as both ends. This is used for holding the pipes while working. Another use is that it pinches off the pipe line before the spot of leakage and helps the workman to work with damaged part.

Fig 4.4 - Pinch Off Tool

(5) Swaging Tool

This tool has a similar construction as the pinch off tool. One end of the tool is pointed which help in swaging the pipe held firmly with a pinch tool. Swaging means increasing the diameter of the pipe. This is done because bolt is not coming out. So after bolt is screwed, swaging operation is done.

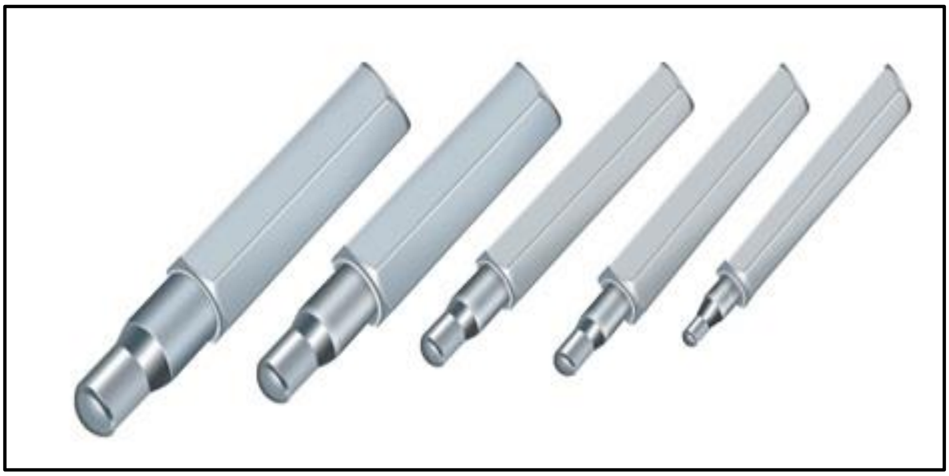


Fig 4.5– Swaging Tool

(6) Bender Tube

This is nothing but a spring given a special construction from general spring. One end of the spring is made wider to make it easy to push the pipe inside it. Then it is bended thereby giving the shape to the pipe. Then it is bended. Then the spring is removed. There are different sizes of bender tubes available.

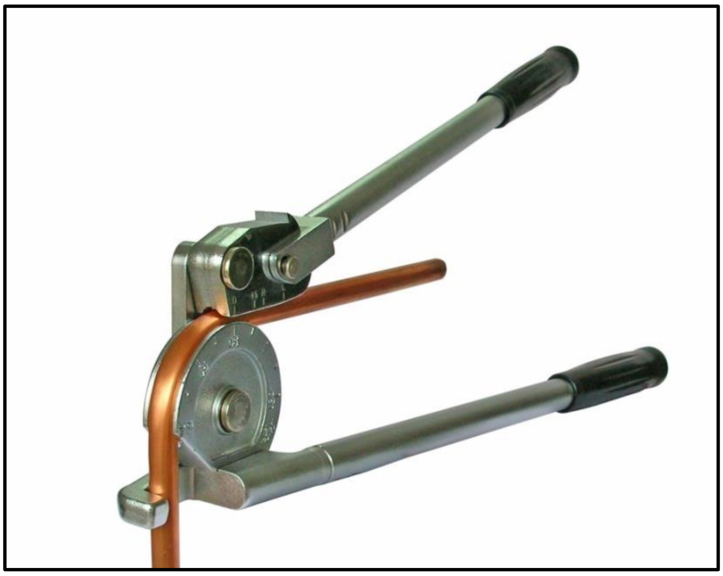


Fig 4.6– Tube Bender

(7) Yoke

The yokes are the complete part of the flaring instruments. It has got a movable in operated thread mechanism. The yoke is gripped with the flare and the pipe is moved to make flaring of the pipe.

Fig 4.7- Yoke

(8) Vacuum Pump

This pump is used to make vacuum into the system. The pipe is connected to suction line. Then start motor so all refrigerant will be sucked from the system. We can see the reading dial.

Exercise:

1	Explain flaring operation.
2	Explain swaging operation.
3	Explain bending operation.
4	Explain brazing operation.

PRACTICAL 5: TO PERFORM DIFFERENT PSYCHROMETRIC PROCESSES AND ANALYZE THE SAME USING PSYCHROMETRIC CHART.

Objective:

- To study psychrometric chart.
- To analyze the psychrometric processes using psychrometric chart.

Theory:

Psychrometer:

The word 'PSYCHROMETERY' means study of properties of atmospheric moist air. Therefore the device which measures the property of moist air is known as psychrometer.

The types of psychrometer which will be studied under this experiment are:

1. Sling psychrometer
2. Wet-bulb & Dry bulb thermometers
3. Hair type hygrometer
4. Barometer

1. Sling psychrometer:

It is used to measure the thermodynamic wet bulb temperature of the air. Thermodynamic wet bulb temperature is the temperature at which water by evaporating into air, may bring the air to saturation adiabatically at the same temperature. In construction, a wet bulb thermometer is attached at two points along length of the wooden sick & the thermometer whirl around it. When the thermodynamic temperature is to be measured,

a) Wet the wick
b) Whirl the thermometer around the wooden stick for some time
c) Then immediately measure the temperature

2. Wet bulb & Dry bulb thermometer:

It is mounted on a wooden piece. As the name indicates they are used to measure the wet bulb and dry bulb temperature respectively. In case of wet bulb thermometer, the bulb of the thermometer is always covered with a wet wick. But in case of dry bulb thermometer, bulb of the thermometer is not covered with wet wick; rather it is always kept dry.

3. Hair type hygrometer:

It directly measures the relative humidity of the air in terms of percentage. Relative humidity is the rate of mole fraction of water vapour in a given sample of moist air to the mole fraction of water vapour if the same air is brought to saturation a t constant pressure and temperature.

Volume of the hair and Biological matter changes in humidity. This is the working principle of it. The scale also gives the idea of weather viz. dry, normal or humid.

4. Barometer:

It measures the pressure of the moist air. There are two scales provided on it. The outer scale gives the pressure of the air in terms of inches of mercury whereas the inner scale gives the pressure of air in terms of mili bars.

There are two equations by which we can calculate psychrometric properties. They are as follows:

a) Dr. Carrier's Equation:

$$p_w = p_{wb} - \frac{(p - p_{wb})(T_{db} - T_{wb})}{1940 - 1.44T_{wb}}$$

b) $h_a = 1.004T_{db} + W[(h_{dp} + 1.884(T_{db} - T_{dp}))]$ kJ/kg of dry air

where,

p_w = Existing partial pressure of water vapour in bar

p_{wb} = Saturation pressure in bar corresponding to wet bulb temperature, T_{wb}

p = Total pressure of the environment in bar

T_{db} = Dry bulb temperature

T_{dp} = Dew point temperature

Psychometric Properties:

A. By Observation:

All reading are taken on date ____________ at ________ pm

1) Dry bulb temperature T_{db} = __________ ˚C
2) Wet bulb temperature T_{wb} = __________ ˚C
3) Relative humidity by hair hygrometer RH = __________%
4) Barometric pressure p = __________ bar

B. By calculation:

1) Dew Point Temperature Tdp = __________ ˚C
2) Relative Humidity RH = __________%
3) Partial pressure of water vapour by Dr. Carrier's Eq. = __________bar
4) Specific Humidity = __________kg/kg of dry air
5) Absolute Humidity = __________for 100m3 of air
6) Enthalpy of air ha = __________ KJ/kg of dry air
7) Specific volume of air = __________ m3/kg of dry air
8) Amount of dry present in 100m3 of air = __________ kg

C. By psychrometric chart:

1) Relative Humidity RH = ____________ %
2) Work done w = ____________ KJ/kg of dry air
3) Enthalpy of air h_a = ____________ KJ/kg of dry air
4) Specific volume v_a = ____________ m^3/kg
5) Dew point temperature T_{dp} = ____________ ˚C

Exercise:

1	Define following terms: (i) Saturated air (ii) Specific humidity (iii) Relative humidity (iv) Absolute humidity (v) Dry bulb temperature (vi) Dew point temperature (vii) Wet bulb depression.
2	The sling- psychrometer reads 35°C DBT and 25°C WBT calculate followings: (i) Specific humidity (ii) Relative humidity (iii) Absolute humidity in air (iv) Dew point temperature (v) Enthalpy of the mixture per kg of dry air. Assume atmospheric pressure to be 1.01 bar.
3	40 m^3 of air at 35°C DBT and 50% R.H. is cooled to 25°C DBT maintaining its specific humidity constant. Determine: (i) Relative humidity (R.H.) of cooled air ; (ii) Heat removed from air.
4	The atmospheric air at 300C dry bulb temperature and 75 % relative humidity enters a cooling coil at the rate of 200 m3/min. The coil dew point temperature is 140C and the by-pass factor of the coil is 0.1. Determine: 1. The temperature of air leaving the cooling coil; 2. The capacity of the cooling coil in tonnes of refrigeration 3. The sensible heat factor for the process.

PRACTICAL 6: TO DETERMINE C.O.P. AND APPARATUS DEW POINT OF AN AIR CONDITIONING TEST RIG.

Objective:

- To determine C.O.P. of air-conditioning test rig.
- To determine apparatus dew point of air-conditioning test rig.

Theory:

Previously the air conditioning for human comfort was considered luxury in most of the countries but now a days it is a necessity. Therefore air conditioning industry is growing fastly throughout the world. Due to increase in population and industrialization the uncomfort may be due to the inadequate supply of oxygen or unbearable temperature. Full air conditioning does the automatic control of an atmospheric environment either for comfort of human being or animals or for the proper performance of some industrial or scientific processes. The purpose of air conditioning is to supply sufficient volume of clean air containing a specific amount of water vapour and at a temperature capable of maintaining predetermined atmospheric conditions.

In brief the air conditioning the space signifies.

1. Temperature Control: You can enjoy a perfect constant temperature because of the control of not only cooling but also heating.
2. Humidity Control: The room can be humidified or dehumidified.
3. Air Filtering, Cleaning and Purification: The room is cleaned by removing dust and dirt from the air.
4. Air movement and Circulation: Air which is cleaned and controlled in temperature and humidity is distributed throughout the room. As a result, room air can be maintained evenly.

Description of Setup:

The equipment consists of a hermetically sealed compressor, air cooled condenser, blower for air circulation through a duct mounted on a frame, an evaporator is placed in the duct, also there are heaters of suitable capacity in the duct. The refrigerant used in the system is R22. The mass flow rate of air through duct can be varied by arrangement provided on the blower unit. The humidity of air is increased by introducing steam generated in small boiler. The relative humidity of air at inlet and outlet can be measured by noting dry / wet bulb temperatures. The duct is insulated from outside to avoid heat loss. The control panel consists of switches, voltmeter, ammeter etc. as well as energy meter for measuring the power consumption of compressor. The refrigeration circuit and duct are mounted on a fabricated frame.

Technical Specifications:

1. Compressor : Hermetically sealed type.
2. Condenser : Air cooled type, cooling fan driven by motor.
3. Rotameter : Eureka make, range 6.1-61 LPH, calibrated for R22
4. Thermostatic Expansion valve : Danfos make no
5. Evaporator : Evaporator fitted in the duct size 10” x 10” x 3 row.
6. Blower unit : To force air through the duct 1HP 3 phase motor.
7. Heater fitted in the duct after the evaporator: 2kw
8. Steam generator to generate steam with suitable piping for introducing steam in the duct- 8 litre capacity, with 2 kw heater.

a) Pressure gauges for measurement of pressures.

b) HP & LP cut outs:

c) Energy meter for compressor with EMC ______ R/kwh.

Experimental Procedure:

The demonstration of the following processes can be done on the test rig.

1. Cooling process.
2. Heating process.
3. Cooling with dehumidification process.
4. Heating with humidification. Process.

Cooling Process: (Sensible cooling)

It is cooling with out subtraction of moisture is termed as sensible cooling. The cooling can be achieved by parsing the air over cooling coil like evaporating coil of refrigeration cycle.

Heating Process:

Heating of air without addition of moisture is termed sensible heating. The heating can be achieved by passing air over heater in the duct. The process is represented as below in psychometric chart:

Cooling with Dehumidification:

In this process cooling along with humidification is carried out it is represented as below:

Heating with Humidification:

It is represented as given below.

for starting the test rig. Put ‘ON” the air condenser fan and run it for 2-3 minutes.

1. Then start blower with suction full open.
2. Now put ‘ON’ the compressor switch, so that refrigeration cycle may produce refrigeration effect.
3. Run the plant for achieving steady temperature at condenser and Evaporator.
4. Measure the air velocity in the duct by using anemometer.
5. Note down the following observations.

Observation Table:

Conducting Trials and Measured Reading:

1. Condenser pressure = ____________kg/cm^2
2. Evaporator pressure = ____________kg/ cm^2
3. (a) Temperature of gas at inlet to condenser T_{c1} = ________________ ˚C

   (b) Temperature of gas at outlet to condenser T_{co} = _______________ ˚C

   (c) Temperature of gas at inlet to evaporator T_{ei} = ________________ ˚C

   (d) Temperature of gas at outlet = to evaporator T_{eo} = ____________ ˚C

4 (a) Refrigerant flow rate = _____________LPH.

   (b) Dry bulb temperature of inlet air DBT1 = __________ ˚C

   (c) Wet bulb temperature of inlet air WBT1= __________ ˚C

   (d) Dry bulb temp. after evaporator DBT2 = ___________ ˚C

   (e) Wet bulb temp. after evaporator WBT2 = __________ ˚C

5 Time for 10 revolutions of energy meter = _________sec.

6 Air velocity in duct = _________m/sec

7 Voltmeter reading = __________volts

8 Ammeter reading = ___________Amp.

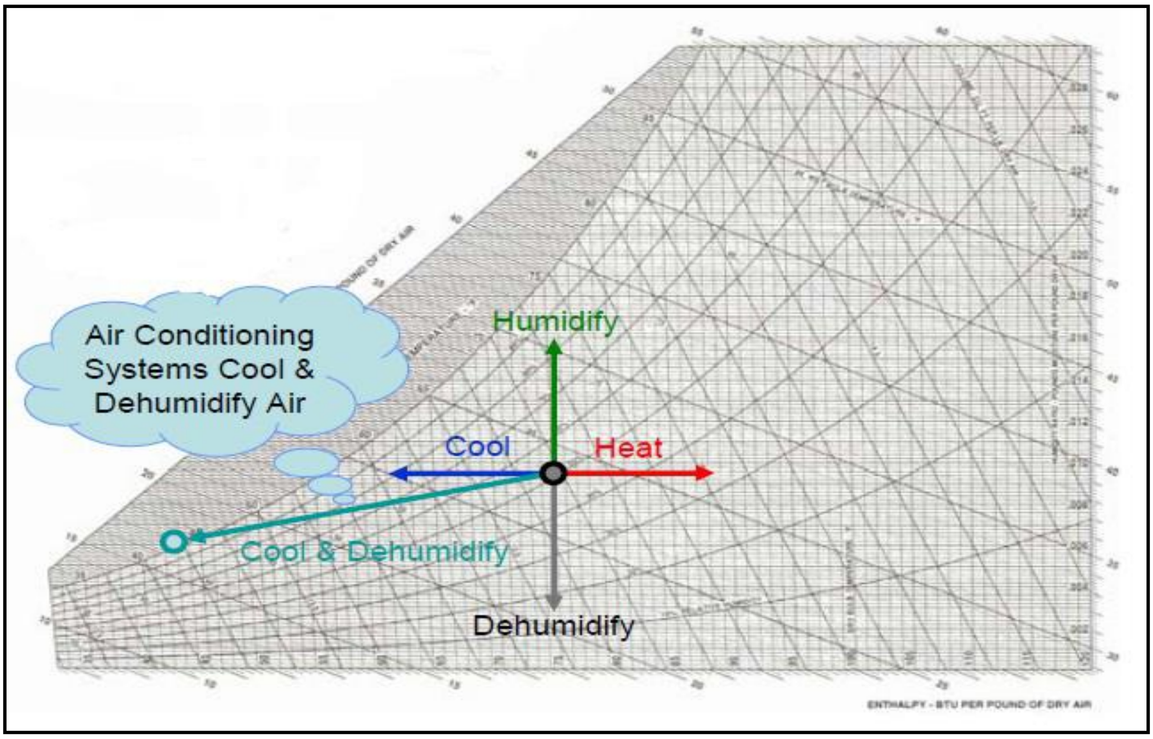


Fig 6.1 - Psychometric Chart

Calculations:

1. Theoretical COP = $\frac{\text{Heo} - \text{Hei}}{\text{Hcl} - \text{Heo}}$ (Hco = Hei)

2. Actual COP = $\frac{\text{Refrigeration effect produced}}{\text{Work done}}$

3. Refrigeration effect produced = Ma x (h1 – h2).

4. Mass of air (ma) = density x volume of air

5. h1 and h2 can be calculated from psychometric chart

6. Work done by compressor = $\frac{\text{rev x 3600}}{\text{T x EMC}}$ watt .

7 . Relative COP = $\frac{\text{Actual COP}}{\text{Theoretical COP}}$

8. Carnot COP = $\frac{TL}{TH - TL}$ T_H & T_L = Saturation temperature of condenser and evaporator in K

Conclusion:

Exercise:

1	Define Air-conditioning. Explain Central air conditioning system.
2	Classify air conditioning systems and enlist factors affecting comfort air conditioning.
3	An air refrigeration open system operating between 100 kPa and 1 MPa is required to produce a cooling effect of 2000 kJ/min. Temperature of the air leaving the cold chamber is (– 5)°C and at leaving the cooler is 30°C. Neglect losses and clearance in the compressor and expander. Determine : (i) Mass of air circulated per min, (ii) Compressor work, expander work, cycle work , (iii) COP and power in kW required.
4	A Refrigerator working on Bell-Coleman cycle takes air into the compressor at 1 bar and –50C. It is compressed in compressor to a 5 bar and cooled to 250C at the same pressure. It is further expanded in the expander to 1 bar and discharged to take cooling load. The isentropic efficiency of the compressor = 85% and the isentropic efficiency of the Expander = 90% find the following: (i) Refrigerating capacity of the system if air circulation is 40kg/min. (ii) KW capacity of motor required to run the compressor (iii) COP of the system. Take γ =1.4 Cp =1kJ/kg Cv = 0.7 kJ/kg for air.
5	An air refrigerator working on Bell coleman cycle takes in air at 1 bar and at a temperature of 100 C. The air is compressed to 5 bar abs. The same is cooled to 250 C in the cooler before expanding in the expansion cylinder to cold chamber pressure of 1 bar. The compression and expansion laws followed are $pv^{1.35} = C$ and $pv^{1.3} = C$ respectively. Determine C.O.P of the plant and net refrigeration effect per kg of air. Take Cp = 1.009 kJ/kg K and R = 0.287 kJ/kg K for air.

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PRACTICAL 7: TO STUDY DIFFERENT CONTROLS USED IN REFRIGERATION AND AIRCONDITIONING EQUIPMENTS FOR BETTER PERFORMANCE.

Objective:

- To study different controls used in refrigeration and air conditioning.

Theory:

1. **Flow control devices :**

The major devices under this category air the expansion devices. The purpose of the expansion devices is two fold : it must reduce the pressure of the liquid refrigerant, and it must regulate the flow of refrigerant to the Evaporator. An expansion device offers a resistance to flow so that the pressure drops Resulting in a throttling process. Basically there are two types of expansion devices.

I. Variable restriction type

II. Constant Restriction Type

I. Variable restriction type

In the variable restriction type the extent of opening or area of flow keeps on changing depending on the type of control. There are two common types of such control devices viz,

A. Thermostatic expansion valve.

B. Automatic expansion valve.

A. Thermostatic Expansion value (TEV):

The name may give an impression that it is a temperature control device. It is not a temperature control device and it cannot be adjusted and used to vary evaporator temperature. Actually TEV is a throttling device which works automatically maintaining proper and correct liquid flow as per the dictates of the load on the evaporator. Because of automatic operation, high efficiency and ability to prevent liquid flood backs this value is extensively used.

P1 = Thermostatic Elements Pressure

P2 = Evaporator Pressure

P3 = Pressure Equivalent of the Superheat Spring Force

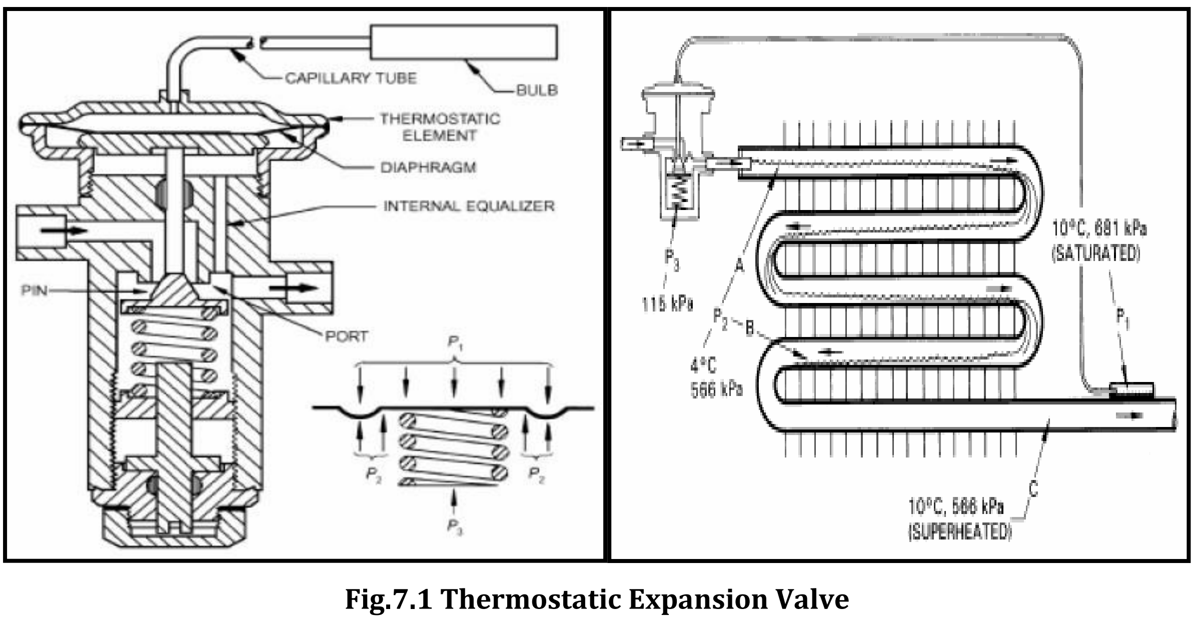

Fig.7.1 Thermostatic Expansion Valve

The functions of thermostatic expansion value are:

1. To reduce the pressure of the liquid from the condenser pressure to evaporator pressure.
2. To keep the evaporator fully active.
3. To modulate the flow of liquid to the evaporator according to the load requirement of the evaporator so as to prevent flood back of liquid refrigerant to the compressor.
4. Pressure P1 in the power element acts to open the valve i.e. to move the value needle away from its seat.
5. The evaporator pressure P2 acts an the bottom side of the diaphragm of the power element tending to close the value.
6. Pressure P3 of the superheat spring also assist in the closing action. Therefore if the power element pressure P1 is greater then the constrained pressure of P2 and P3, the value will open. It does last two functions by maintaining a constant superheat of the refrigerant at the outlet of the evaporator it would be more appropriate to call it a "constant superheat valve". The important parts of the valve are power element with feeler bulb, value seat, needle and a superheat adjustment spring. The power element is charged with a refrigerant. The operation of the valve i.e. the closing and opening of the value is controlled by their basic forces. The force balance is shown in figure

B. Automatic Expansion Valve:

AEV is also called as constant pressure expansion value. As name implies it maintains a constant pressure in the evaporator. It works on the same principle as the pressure reducing valves used in compressed air lines, oxyacetylene cylinders etc. A schematic diagram of the constant pressure Expansion. Valve is shown in figure

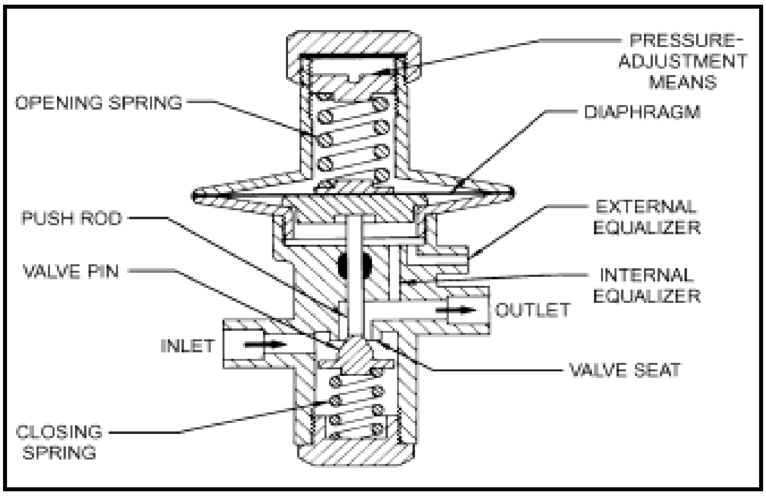

Fig.7.2 Automatic Expansion Valve

The valve consists of seat and needle- which forms the orifice, a metallic diaphragm or bellow, spring and an adjusting screw. The spring pressure and the atmospheric pressure acts on top of the diaphragm, thereby moving the needle a way from it seat that is moving the needle valve in the opening direction. The evaporator pressure acts below the diaphragm moving the needle valve towards the closing position. Thus the evaporator pressure and spring pressure oppose each other and whichever is greater will determine the position of the needle with respect to the seat.

When the plant is running the value maintain an evaporator pressure in equilibrium with the spring pressure plus atmospheric pressure. The tension of the spring can be varied by the spring adjusting screw. The value operates automatically to maintain a constant evaporator pressure as per the setting of the spring pressure. By adjusting the tension of the spring, the evaporator pressure can be varied. Once a setting is made, the valve functions to maintain a constant evaporator pressure. Hence it is called the constant pressure expansion valve". Once the plant stops, the evaporator pressure increases due to the vaporization of the liquid left in the evaporator. This increase in pressure acts on the diaphragm against the spring pressure and closes the valve tightly. It remains closed until the compressor start again and reduces the pressure in the evaporator which is advantageous.

II. Constant Restriction Type

The capillary tube, a long tube with very small bore comes under constant restriction type expansion devices. The capillary tube is a fixed restriction type device. It is a long narrow tube connecting the condenser directly to the evaporator. The pressure drop through the capillary tube is due to the following reasons:

1. Friction due to fluid viscosity, resulting in frictional pressure drop.
2. Acceleration, due to the flashing of the liquid refrigerant into vapour resulting in momentum pressure drop.

The mass flow through the capillary tube will, therefore be adjusted so that the pressure drop through the tube just equals the difference in pressure between the condenser and evaporator. For a given state of the refrigerant, the pressure drop is directly proportioned to the length and inversely proportional to the bore diameter of the tube. A number of combinations of length and bore are possible for a capillary tube to obtain the desired flow and pressure drop. However, once a capillary tube has been selected, it will be suitable only for the designed pressure drop and flow. It cannot satisfy the flow requirements with changing condenser and evaporator pressures. Even then it is most commonly used expansion device in small refrigeration units such as domestic refrigerators, window A/C, water coolers, etc. The advantages of a capillary tube are its quite working, simplicity, low cost and absence of any moving part. Also it is found most suitable with on-off control because of its unloading characteristics. Thus when compressor stops it allow high and low pressure to equalize, thereby enabling the compressor motor to restart on no load. Accordingly lower starting torque motors can be used.

2. Safety Devices:

a) High pressure and low pressure cut-out:

Refrigerant compressors are provided with high pressure (HP) and low pressure (LP) cut outs. High pressure cut-out is merely a safety control. When the head pressure increases beyond a set point, the HP cutout cycles off the compressor in order to avoid the possible damage to the compressor. When the head pressure subsequently drops, the circuit is one again closed and the compressor starts. Because of the possibility of scale formation in condenser tubes and the failure of water supply high pressure cutout are essential in the system with water cooled condensers. These cutouts require manual setting. The low-pressure cutout is used both as safety control as well as temperature control. The evaporator governs the suction pressure. A low-pressure cutout is actuated by change in suction pressure and can be indirectly used to control the evaporator temperature.

b) Starting relays:

The relays are generally used in hermetic type units. It allows the flow of electricity through the starting winding of the motor and disconnects the starting winding or starting capacitor from the circuit when the motor reaches 75% of its rated speed. There are two types starting relays.

i. Current relay

ii. Voltage relay.

i. Current Relay:

The current relay is used primarily with capacitor start induction motors for disconnecting the starting winding and starting capacitor from the circuit. It is a Magnetic type relay and actuated by the change of current flow in running winding during starting and running periods of motor. It consists of few turns of copper wire in which soft iron plunger is free to more up and down. This soft iron plunger is free to more up and down. This soft iron plunger may be called electronic net. It is connected in series with the running winding and the contact points, which are fitted near the electromagnet, are connected in series with the current relays with the starting winding.

When the motor is energized, the current flow through the relay in the running winding. In the starting, the magnetic field produces around the relay and attracts the plunger to close the contact thus energizing the stating winding. The speed of the motor increases gradually and when it reaches 75% of its rated speed, the motor current and magnetic field of the relay decreases. Permitting the contact points to open. Then motor runs on running winding alone.

ii. Voltage Relay:

The voltage relay is growing in popularity, especially in the larger units. Its operation depends on the increase in voltage as a unit approaches and reaches its rated speed. In construction, the voltage coil made of many turns of wire as compared with current coil which is made of few turns of heavy wire and is connected parallel with starting winding.

A set of content points are connected in series with the starting capacitor and closed when the motor is at rest. When the supply is connected to the motor, the motor starts up and increases its speed then the voltage in the starting winding increases along the line voltage because of capacitor in service with this winding. The higher voltage creates more in magnetism in the relay coil, which attracts the plunger, the contact point opens and disconnect the starting capacitor from the circuit.

Exercise:

1	State the name of Different types evaporative devices used in refrigeration system Explain Automatic expansion valve.
2	Explain construction, working, advantages and disadvantages of Thermostatic Expansion valve with neat sketch

PRACTICAL 8: TO DETERMINE $(COP)_C$ AND $(COP)_H$ OF HEAT PUMP.

Objective:

- To determine C.O.P. of Heat pump.

Theory:

Now-a-days, energy conservation is becoming very important. Hence engineers have started using heat pump systems for commercial and industrial buildings to save energy. The heat pump is a machine that absorbs heat at one location and transfers it to another location at a different temperature. Heat pump is the modern expression for a refrigeration system In which heat discharged at the condenser is of prime importance. Thus heat pump is device which collects heat from one source and delivers it to another source using refrigeration cycle. The medium being, cooled serves as heat source.

Heat is picked up by the refrigerant, which is pumped to another higher level by the compressor and given to the medium cooling condenser so that it can be used practically. The heat pumps can be operated on low temperature heat energy using winter air, a body of water or the ground as a reservoir and rejecting heat at a higher temperature, not enough to energize heating systems.

Thus the basic heat sources that are normally used are air, water and earth. When heat pumps are installed frequently provision is made for both heating and cooling services to be supplied simultaneously to the separate zones of buildings.

Description of Setup:

Mechanical Heat Pump is a table mounted model which uses water as well as air as a heat source and sink for both cooling and heating purposes. The experiments can be done as water to water heat pump i.e. using water condenser and water evaporator and water to air heat pump i.e. using water condenser and air evaporator.

On the unit, compressor is mounted centrally and both the water and air condensers are mounted on either sides of the compressor. All the components are mounted on the main unit and the schematic layout of the Mechanical Heat Pump Is sell-explanatory.

Technical Specifications:

1. Compressor : hermetically sealed, using R-12 refrigerant.
2. Condenser : Water cooled copper tube, Shell & Coil type.
3. Rotameter : Eureka make, range 6.1-61 LPH, calibrated for R22
4. Thermostatic Expansion valve : Thermostatic expansion valve having 1/2 ton of Refrigerating Capacity.
5. Evaporator: (a) Water circulated copper tube, Shell and Coil type.
   (b) Air circulated copper tube type.
6. Multichannel Digital temperature indicator with thermocouples: 0-3000 C. with 10 C least count
7. Pressure gauges: Two Nos. for delivery and suction for measurement of pressures.
8. HP & LP cutouts: of suitable range.
9. Energy meter for compressor with EMC ______ R/kwh.

Experimental Procedure:

This experiment is performed by using water condenser and water evaporator. -

a) Start the water supply to both condenser and evaporator and adjust the flow rate to predetermine value.
b) See that pressures in both the gauges are equal.
c) Put 'ON' the main switch.
d) Check the valve positions as per given diagram.
e) Now, start the compressor cooling fan first and then start the compressor. Within a short period, clear liquid refrigerant flow will be seen in the rotameter.
f) After sometime the pressure of refrigeration cycle will become stable. Allow the plant to run for at least half an hour.
g) During testing see that water flow rates are constant and not varying.
h) Allow the plant to attain steady state. Check tor steady state by taking the readings periodically.
i) Take all readings as mentioned in the observation table. Complete one set of observations.

By varying the water flow rate of condenser, effect of sub- cooling can be studied. Similarly by varying water flow rate of evaporator, load on the plant can be varied.

Observation Table:

Conducting Trials and Measured Reading:

1. Condenser pressure = ___________ kg/cm^2
2. Evaporator pressure = ___________ kg/cm^2
3. Tempratures

a) Condenser Inlet T_{ci} = ______________ ˚C

b) Condenser Outlet T_{co} = ____________ ˚C

c) Evaporator Inlet T_{ei} = ______________ ˚C

d) Evaporator Outlet T_{eo} = ___________ ˚C

4) a) Refrigerant flow rate = ____________ LPH.

5) Time for 10 revolutions of Compressor energy meter = _________ sec.

Condenser Side

1) Water Temperature

a) Inlet = ______________ ˚C

a) Outlet = _____________ ˚C

2) Water flow rate = __________ LPH

Evaporator Side

1) Water Temperature

a) Inlet = ___________ ˚C

a) Outlet = __________ ˚C

2) Water flow rate = __________ LPH

Calculations:

1. Theoretical COP = $\frac{\text{Heo} - \text{Hei}}{\text{Hcl} - \text{Heo}}$ (Hco = Hei)

2. Actual COP = $\frac{\text{Heat absorbed in evaporator from water}}{\text{Compressor Work}}$

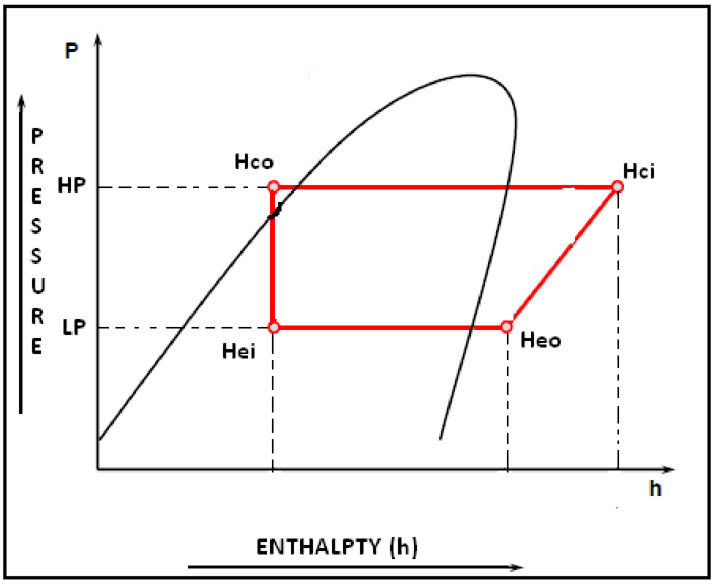

Fig 8.1- Plot the operating cycle on p-h chart

3. Heat absorbed in evaporator from water = m_e x Cp x Te

Where, m_e = Mass flow rate of water in evaporator Kg / hr

Cp = Specific heat of water 1 Kcal / Kg °C

Te = Temp. difference of water in Evaporator

4. Work done by compressor = $\frac{860 \times 10 \times 3600}{\text{Tc} \times \text{EMC}}$ watt

Where,

Tc = Time for 10 revolutions of energymeter disc sec.

5. Relative COP = $\frac{\text{Actual COP}}{\text{Theoretical COP}}$

6. Carnot COP = $\frac{\text{TL}}{\text{TH} - \text{TL}}$

T_H = Saturation temperature of condenser pressure in °K

T_L = Saturation temperature of evaporator pressure in °K

Conclusion:

Exercise:

1	Explain Heat pump.
2	Differentiate between heat pump and refrigerator.

PRACTICAL 9: TO STUDY THE CHARGING, TESTING, EVACUATING, PUMPING DOWN AND LEAK DETECTION TECHNIQUES IN A REFRIGERATION PLANT.

Objective:

- To study the charging, testing, evacuating, and pumping down in a refrigeration plant.
- To study leak detection techniques in a refrigeration plant.

Theory:

Charging and Evacuating Techniques:

Charging and evacuating techniques are the method of charging the plant with refrigeration. The detailed procedure of charging the plant is as under:

Initially there may be air entrapped in the piping circuit of the plant. Thus before charging the plant with the refrigerant, it is essential to remove entrapped air. For removing this air and thereby to create a vacuum, a vacuum pump is used, which sucks the air.

A vacuum pump fitted with a compound gauge is connected to the suction line. As the air is sucked the pointer on the compound gauge keeps on falling steady and vacuum is created. The pump is run for a while till the compound gauge reads. The system is left as it is for some hours at a stretch and the compound gauge reading is observed. If the pointer starts climbing towards zero there, it would be ascertained that there is a leakage and if there is no change in the reading, then we can conclude that the piping is leak proof.

If there is any leakage i.e. if the compound gauge reading slowly rises to higher values, then this leakage has to be detected and plugged properly. For this the plant is pressurized with the air at high pressure, so that the leakage may be removed. This completes the evacuating process.

Now the vacuum pump is disconnected and the suction line is connected to the cylinder containing the refrigerant. There is a valve, provided at the suction line, which is closed before disconnecting the vacuum pump. After connecting the cylinder to the suction line of the compressor, the cylinder valve is opened and the nut joining the pipe to the suction is kept slightly loose. So that when the valve is opened the refrigerant rushes out and forces the air entrapped in the pipe to the atmosphere. Now the suction line is opened. There is vacuum inside, it sucks the refrigerant from the refrigerant cylinder very rapidly. At the same time a pressure gauge indicates the pressure developed in the compressors due to a charging of pipe attached to the suction line is disconnected and back pressure is measured. The correct charging pressure is 175 to 200 lb/in^2 and the back pressure is about 20-25 Ib/in^2. The correct charging pressure is of importance because if the pressure is more i.e. more refrigerant is charged, then the handling of the refrigerant is not proper, thereby affecting the performance of the plant.

Once the charging is over the plant is ready for service.

Testing :

When the refrigerant plant is newly set-up, the pipe joints and other connections of the system have to be tested for leakage. For that in beginning CO_2 and N_2 is passed through the system and pressure gauge reading is noted. Then at the joint, some soap solution is applied. If no bubbles are formed at the joint and pressure remains constants then we can conclude that the joints are free from any leakage and if bubbles are formed then the joint has to be tightened more. The second method is used to detect the leakage.

The system is completely evacuated after performing leakage test and this is done with the help of a vacuum pump. Whether the system is completely evacuated or not is determined by the pressure gauge readings. Then the plant will be evacuated and charged with refrigerant.

Pumping Down:

Pumping down means collecting all the refrigerant of the plant into its receiver tank. It is useful when there is some minor repair of the plant is to be done. So refrigerant is not required to be removed of the plant which is otherwise necessitates recharging.

For this the delivery valve of the receiver tank is closed and the plant is run for few minutes. After some time all the refrigerant will be collected in the receiver tank and after rectifying the fault, by opening the delivery valve of the plant refrigerant is charged in the line. If necessary, extra amount of refrigerant should be added from the refrigerant cylinder.

Leak Detection:

If there is any leakage i.e. if the compound gauge reading slowly rises to higher values, then this leakage has to be detected and plugged properly

Leak Test Methods :

Different leak testing methods one employed for different types of refrigerants.

1. Ammonia, R12, R22:

A. Sulphur Test Method:

Burning sulphur stick shows a dense white smoke if ammonia is present. The burning sulphur stick is passed around all the joints and suspected leaky points for the appearance of smoke. This test is applicable for tracing minute leaks only.

B. Soap Bubble Test:

This test may not be very effective to trace very minute ammonia leak as it is soluble in water. Fortunately, ammonia is having plungent odor, a heavy leak can be easily detectable.

C. Litmus Test:

Wet litmus paper (Phenolpthalene paper) which turns red in contact with ammonia can also be used to detect leaks.

2. Halogenated Refrigerants:

Soap solution, Halogen leak detector, Halide torch and Electronic leak detectors are the methods used to trace leaks in halogenated refrigerants

A. Halogen Torch:

A halogen torch can detect minute leaks, which are not possible to trace with soap solution. The presence of trace of refrigerant can change the light blue colour of the detector flame to green or deep blue. The end of the explorer tube of the detector is carefully passed over the joints and suspected leakage points. If there is a leak, the refrigerant can be drained in with the suction effect at the end of the explorer tube to the hot copper or brass portion of the burning torch. The refrigerant reacts with the metal to form copper chloride, which produces the color change in the flame. A well maintained halogen torch is claimed to detect leaks of the order of about 15 gram per year.

B. Electronic Leak Detector:

This is an electrical instrument. In this also an explorer tube is used to suck the refrigerant from the leaky points to an instrument. A vibrator is provided to suck the refrigerant through the explorer tube. A filter is also provided at the tip of the tube to prevent atmospheric dert entering the instrument. A heating element in the tube heats the refrigerant drawn in and the refrigerant creates a variation in the current flow of the instrument. The extent of variation of the current is an indication of the amount of leak. The current variation is read on the dial of the instrument. The change of current actuates a relay which operates an indicating light. These detectors are capable of detecting refrigerant leaks of the order of about 0.3 gm per year. The electronic leak detector is a very sensitive instrument and should be handled and stored carefully.

Exercise:

1	Explain charging, testing in refrigeration system.
2	Explain evacuating, and pumping down in refrigeration system.
3	Explain leak detection techniques in a refrigeration plant.

PRACTICAL 10: STUDY OF PACKAGED PLANT.

Objective:

- To determine C.O.P. of an Ice-plant.

Theory:

Natural ice was used for preservation purpose for a very long time. But it has been replaced to a large extent by manufactured ice since the beginning of twentieth century because of the uncertainly of the natural supply and also because of the cost of transportation to the retail trade.

The manufacturer of ice is one of the principal needs of refrigeration and it will continue, as ice is the cheapest means for short time preservation of food. A vast amount of research has been put in developing a least expensive means of manufacture.

The quantity of ice required for different purpose is very large so that the manufacture of ice is one of the principal applications of refrigeration. Ice factories are commonly installed now a day in every small town of India to fulfill day-to-day requirements of the people.

The appearance of the ice plays important role for the sale in the retail trade. Therefore, preliminary chemical treatment and filtration of water, agitation of water during freezing to issue transparency, core sucking to remove impurities in the water supply and scoring of ice cakes in size required for retail trade are important features of ice manufacturing.

In present day ice factories, all the operations mentioned above are automatically done to keep the speed of production and distribution.

The vapour compression refrigeration cycle is based on a circulating fluid media viz. a refrigerant having special properties of vaporizing at temperatures lower than the ambient and condensing back to the liquid form, at slightly higher than ambient conditions by controlling the saturation temperature and pressure.

When the refrigerant evaporates or boils at temperature lowers then ambient it extracts or removes heat from the load and lowers the temperature consequently providing cooling.

The superheated vapour is increased to a level by the compressor to reach a saturation pressure so that heat added to vapour is dissipated / rejected into the atmosphere, using operational ambient conditions with cooling medians such as air or water. The vapour is condensed to liquid form and recycled gain to form the refrigeration cycle.

Main components of refrigeration cycle: -

1. Compressor
2. Condenser
3. Throttling device
4. Evaporator

Compressor:

The compressor is known as the heart of the refrigeration system. It pumps the refrigerant vapour in refrigeration cycle as the heart pumps blood in the body. The low temperature, pressure, superheated vapour from the evaporator is conveyed through suction line and compressed by compressor to a high pressure, without any change of gaseous state and the same is discharged into condenser. During this process, heat is added to the refrigerant and is known as heat compression. The compressor should have a compression ratio to raise the pressure of the refrigerant to such a level that the saturation temperature of the discharged refrigerant is higher than the temperature of the available cooling medium, to enable the superheated refrigerant to condenser at normal ambient condition.

Condenser:

The heat is added in the evaporator and compressor to the refrigerant is rejected in condenser at high temperature. This superheated refrigerant vapors enters the condenser to dissipate its heat in three stages. First on entering the refrigerant loses its superheat, it then loses its latent heat at which the refrigerant is liquefied at saturation temperature pressure. This liquid loses its sensible heat, further and the refrigerant leaves the condenser as a sub-cooled liquid.

The heat transfer from refrigerant to cooling medium takes place in the condenser. The sub-cooled liquid from condenser is collected in a reservoir and is then fed through the throttling device by liquid line to the evaporator.

There are several methods of dissipating the rejected heat into the atmosphere by condenser. These are water-cooled, air cooled and evaporative cooled condensers.

Throttling device:

Throttling device is design to pass maximum possible liquid refrigerant to obtain a good refrigeration effect. The line should be properly designed to have minimum pressure drop.The throttling device is a pressure reducing device and a regulator for controlling the refrigerant flow. It also reduces the pressure from the discharge pressure to the evaporator pressure without any change of state to the liquid refrigerant.

Various types of throttling devices are:

a) Capillary tubes
b) Thermostatic valves
c) Hand expansion valves
d) Hand valves

Evaporator:

The liquid refrigerant from the condenser at high pressure is fed through a throttling device to an evaporator at a low pressure. On absorbing the heat to be extracted from media to be cooled, the liquid refrigerant boils actively in the evaporator and changes state. The refrigerant gains latent heat to vaporize at saturation temperature /pressure and further absorbs sensible heat from media to be cooled and gets fully vaporized and superheated.

Technical Specifications:

Compressor	: Hermetically sealed along with its std. accessories
Condenser	: Fins and tube type air cooled condenser
Condenser fan motor	: one no.
Cooling coil	: Water immersed type
Agitator with motor	: Provided to circulate the brine
Brine tank cabinet	: Inner and Outer surface of brine tank fabricated with S.S
Temperature measurement	: RTD PT-100 type
Control panel	: Digital voltmeter (0-300V) and ammeter (0-10A)
Temperature Indicator	: Digital temperature indicator with multi channel switch

Description of Setup:

Primary refrigerant	: R-22 refrigerant gas
Secondary refrigerant	: Brine solution
Measuring controls	: Suction pressure gauge for low pressure measurement
	: Discharge pressure gauge for high pressure measurement
	: Filter, drier, capillary tube type expansion device
	: Main switch, Voltmeter, Amp-meter for compressor I/p
	: Switches and indication lights
Temperature indicator	: Digital temperature indicator provided with RTD sensors
Chemical Required	: Sodium chloride (Nacl) – 15 kg

Experimental Procedure:

Starting procedure :

1. Give supply of 220V on the main switch of the rig.
2. Check the voltage.
3. Switch on the condenser fan switch.
4. After 2 minutes, switch on the compressor.
5. Check the compound and pressure gauge and note the readings.
6. Note down the pressure and temperature readings.
7. Put brine solution in the ice tank.
8. Note down the temperature of the brine tank from digital temperature indicator.
9. At the time of starting the apparatus note down the ampere & voltage reading.
10. Note down the reading of gauges, temperatures, ampere meter & voltmeter after running of the rig at least 20 to 30 min. take 2 to 3 readings.
11. Start the agitator motor for 5 minutes only, after the gap of every 15 minutes.
12. Run the unit continuing at least 2-3 hours and note down the brine solution temperature, if the brine temperature reaches up to 4^0C then put water in the ice can for freezing.
13. Now again check the temperature of suction pressure and discharge pressure.
14. Always close the door of ice tank and the door should be open at he time of putting ice cans of lifting the same.

Closing procedure:

1. While closing the rig, first switch off the compressor.
2. Then close the condenser fan motor.
3. Then close all the other valves.
4. At last switch off the units.
5. After closing the unit, drain the brine solution from the tank in order to avoid the rusting of the tank.

Observation Table:

Sr. no	Pressure (kg/cm^2)		Temperatures (^{o}C)						V	I
	P_1	P_2	T_1	T_2	T_3	T_4	T_5	T_6		
1										
2										
3										
4										

Calculations:

Theoretical COP = $\dfrac{Heat\ extracted\ in\ evaporator}{Workdone\ by\ compressor} = \dfrac{H_1 - H_3}{H_2 - H_1}$

[Note: H1 at P_1-T_1 , H_2 at P_2-T_2 and H_3 at P_2-T_3 from P-H diagram of R-134a]

Actual COP= $\dfrac{net\ cooling\ effect(\ Actual)}{power\ consumed\ by\ compressor}$

Net Cooling Effect= $m * C_{pb} * (T_1 - T_4)$ $\qquad$ C_{pb} = 3.20 KJ/kg^{o}C

Power consumed by compressor= V*I*cosϕ watt $\qquad$ *cosΦ = 0.8*

Relative COP= $\dfrac{Theoretical\ COP}{Actual\ COP}$

Conclusion:

Exercise:

1	State important applications of refrigeration system.
2	Explain construction and working of an Ice plant.