LAB MANUAL

REFRIGERATION AND CRYOGENICS

(MED 423)

G.S. Mandal's

MAHARASHTRA INSTITUTE OF TECHNOLOGY, AURANGABAD

DEPARTMENT OF MECHANICAL ENGINEERING

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Vision of Institute:

MIT aspires to be a leader in Techno-Managerial education at national level by developing students as technologically superior and ethically strong multidimensional personalities with a global mindset.

Mission of Institute:

We are committed to provide wholesome education in Technology and Management to enable aspiring students to utilize their fullest potential and become professionally competent and ethically strong by providing,

a) Well qualified, experienced and Professionally trained faculty

b) State-of-the-art infrastructural facilities and learning environment

c) Conducive environment for research and development.

d) Delight to all stakeholders.

Vision of Mechanical Engineering Department

To be a center of excellence in the field of Mechanical Engineering where the best of teaching, learning and research synergize and serve the society through innovation and excellence in teaching.

Mission of Mechanical Engineering Department

To provide world-class under-graduate and graduate education in Mechanical Engineering by imparting quality techno-managerial education and training to meet current and emerging needs of the industry and society at large.

Program Educational Objectives (PEOs):

PEO 1	Graduates will apply the tools and skills acquired during their undergraduate studies either in advanced studies or as employees in engineering industries.
PEO 2	Graduates of the program will have successful technical and professional career.
PEO 3	Graduates of the program will continue to learn to adopt constantly evolving technology.
PEO 4	Graduates will demonstrate sensitivity towards societal issues.

Program Outcomes:

POs		**Description**
PO 1	**Engineering Knowledge**	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO 2	**Problem Analysis**	Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3	**Design / Development of Solutions**	Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations
PO 4	**Conduct Investigations of Complex Problems**	Use research-based knowledge and search methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO 5	**Modern Tool Usage**	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO 6	**The Engineer and Society**	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO 7	**Environment and Sustainability**	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO 8	**Ethics**	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO 9	**Individual and Team Work**	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10	**Communication**	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO 11	**Project Management and Finance**	Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO 12	**Life-long Learning**	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes:

PSO 1	Ability to design & analyze components & systems for mechanical performance
PSO 2	Ability to apply and solve the problems of heat power and thermal systems
PSO 3	Ability to solve real life problems with the exposure to manufacturing industries

Course Objectives:

1. To study understand the fundamental working of various component of 'Refrigeration systems'
2. To study and understand the working of various compressors, controllers and tools used in 'Refrigeration systems'
3. To apply basic concept and analyze the performance of 'Refrigeration systems'

Course Outcomes:

CO No.	Statement
CO 1	State the basic refrigeration and liquefaction principles with respect to current low cooling technology.
CO 2	Explain thermodynamics property, processes carried out during refrigeration and cryogenics.
CO 3	Apply the knowledge for selection of refrigerant and cryogenic fluids for various refrigeration and cryogenics systems.
CO 4	Analyze various components of refrigeration and cryogenics systems.
CO 5	Evaluate the performance of refrigeration and cryogenics systems.
CO 6	Design the various components of refrigeration systems.

Dr. Babasaheb Ambedkar Marathwada University, Aurangabad

(Faculty of Science & Technology)

Syllabus of Final Year B. Tech. (MechanicalEngineering) Semester-VII

Course Code: MED423	**Course: Laboratory of Refrigeration and Cryogenics**
Teaching Scheme:	**Term Work: 25 marks**
Practical: 02 Hrs/week	**Practical Examination: 25 marks**
Credits: 01	

Prerequisite	1. 1.Basic knowledge and understanding of thermodynamics, heat transfer and fluid mechanics.
Objectives	1. To study understand the fundamental working of various component of 'Refrigeration systems' 2. To study and understand the working of various compressors, controllers and tools used in 'Refrigeration systems' 3. To apply basic concept and analyze the performance of 'Refrigeration systems'
List of Practical' s (Minimum 08)	**A] To study and demonstrate the of followings (minimum six)** 1. To study varies tools used in refrigeration and Air-conditioning 2. To study working of domestic refrigerator its wiring diagram and maintenance. 3. To study various compressors used in refrigeration 4. To study various controllers in refrigeration (at least ten) 5. To study leak detection and charging of refrigeration systems. 6. To study steam jet refrigeration system. 7. To study magnetic refrigeration system 8. To study construction, working of water cooler. 9. To study vapour absorption refrigeration system **B] To conduct trail on following system (minimum three)** 1. Trial on refrigeration system 2. Trail on ice plant 3. Trial on cascade refrigeration system 4. Trial on Heat pump 5. Trial on window air conditioner /air conditioning system/ water cooler. **C] Technical visit to at least one refrigeration establishment and report on the basic of observations.** **D] Technical report on current trend (at least one) of refrigeration such as greenhouse effect, global warming, alternative refrigerants etc.**

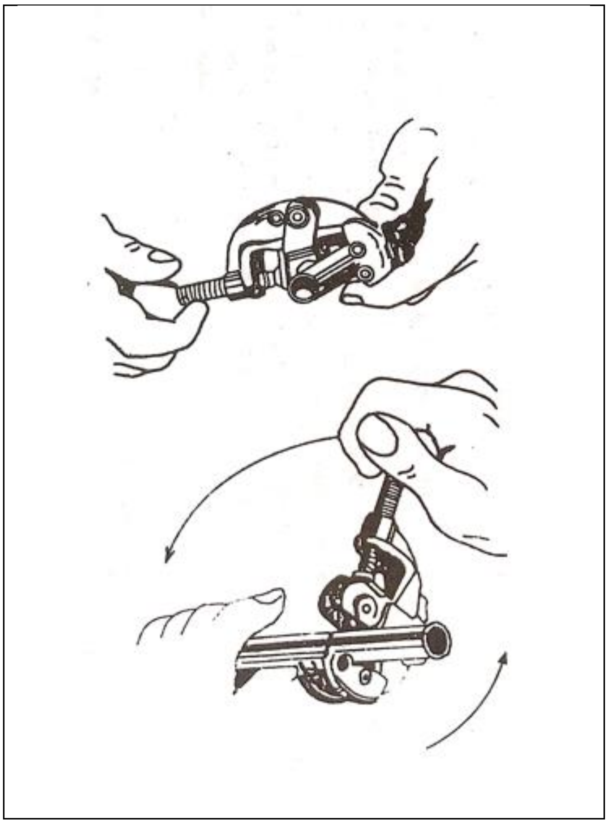
Lab Instructions:

1. All the students must wear college uniform, shoes and college identity card.
2. Make entry in logbook on reporting for the practical in the lab.
3. Don't sit in the lab by missing theory and practical classes.
4. Don't touch the lab equipments without permission of practical teacher or lab assistant.
5. Anemometer, psychrometer or thermometer, if required, will be issued by lab assistant. Return them after performing the experiment.
6. Before leaving the lab, please keep the stools in proper position.
7. Switch off the lights and fans, if not required.

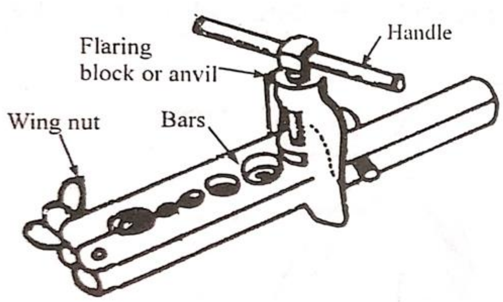
EXPERIMENT NO. 1

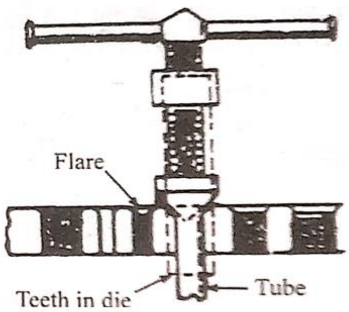
Objective: To study various tools used in refrigeration and Air-conditioning.

Tube Cutter – It is a refrigeration tool use to cut copper tubing from sizes 1/8" to 1/2" outside diameter. A larger tube cutter is also available for large tube diameters. Tubes are mark first before cutting. Slight pressure is applied to the copper tube during cutting. The burr inside the tube is cleaned with blade reamer.

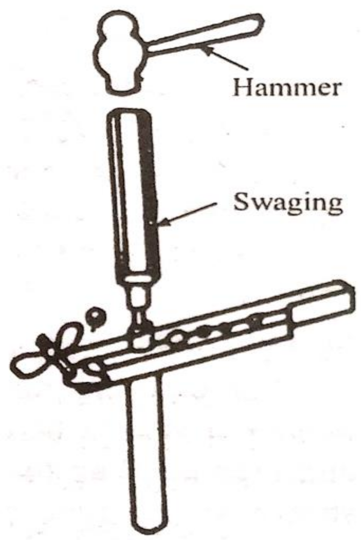


Flaring Tool – It is a refrigeration tool use to spread the copper end outward until a flare is formed. File and ream the copper tube before flaring. The copper tube is inserted into the flaring block with 30% of its diameter protruding. Turn the flaring yoke slowly until the flare is completed. Remove copper tube and inspect for defects.





Swagging Tool –It is a refrigeration tool use to expand the inside diameter of a copper tube so that the resulting diameter is the same as the outside diameter. It is used to join two copper tubes of the same diameter. Clamp the copper tube by the flaring block so that an 'equal to the outside diameter' of the copper tube length is to be swigged.



Brazing Torch – It is a refrigeration tool use in soldering the joints of two copper tubes together. 800 degrees Fahrenheit is required to solder copper tubing. Map gas is generally used in these application, although oxygen-acetylene is also popular except they are bulky and heavy. It can reach a temperature of 3600 degrees Fahrenheit. When brazing copper tube joints, do it in a well ventilated area. Prolong inhalation can cause cancer.

Copper Tube Bender – It is a copper tube bending refrigeration tool. It has a three-size molded half-round wheels. The most common sizes are from 1/4 of an inch diameter, to 5/16, then 3/8. Copper tubes are bent beautifully using this professional bending tool.

Adjustable wrench –It is a wrench with an adjustable jaw. A six inch adjustable wrench is very useful in the field of refrigeration repair. It can accommodate nuts and bolts' sizes from 1/8 of an inch to 1 inch. It can fit into the tool box easily.

Flat Edge Screw Driver – It is a screw driver with a flat driving end. An 8 inch screw driver with a blade width of 1/4" is the most useful size. It is always a good idea to have a 1/8" blade and a 3/16" blade around with you.

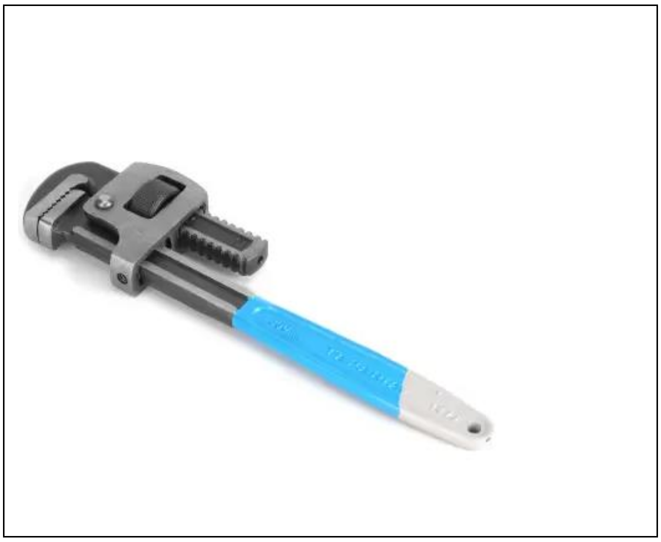
Philip Screw Driver –It is a screw driver with a cross driving end. It is a good idea to have three sizes of this type also. Buy only good quality philip screw driver because the teeth easily become blunt very slippery.

Allen Wrench – is an angle hexagonal driving wrench. They are made of hardened steel. You will need allen key when removing the squirrel caged fan of a window type air conditioner. The circular fan of an indoor unit is fastened with an allen screw.

Long Nose Plier – is a plier with a long pointed nose. A 7 inch long nose plier is very useful and is a good addition to your tool box. You will find the many uses of a long nose plier; from hard to-reach areas like removing a clip from a fan or holding the copper tube when brazing alone.

Electrical Plier – Insulated plier use by electrician. An 8 inch electrical plier is a must have in your tool box. There are time when it is necessary to remove a live fuse from a fuse box. Or arranging the stranded wires.

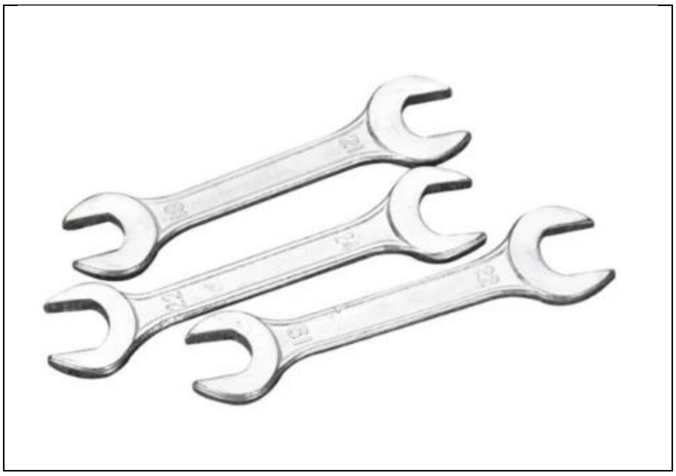
Pipe Wrench – is a wrench for fastening tubes and pipes. A 12 in pipe wrench must be in your tool box as well. Sometmes we have to remove a rounded hex nut.



Nut Drivers – Hand held driver to drive or remove hex nuts or bolts. Mostly applicable to deep down places where our hand is not able to reach. Straight hand grip type and the T-type drivers are available for you to choose.

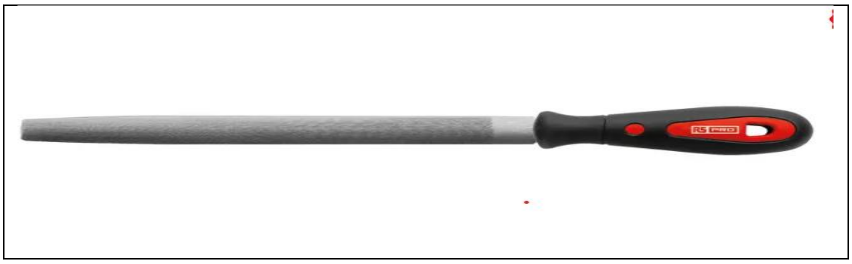
Box Wrench – Hand held box type wrenches. They came in from 1/4 of an inch to 1-1/4 inch size. Usually they are in combination as far as the size is concern. A practical tool for assembling and disassembling home air conditioner and automotive air conditioner compressors.

Open Wrench – Open end hand held wrench. Their sizes are from 1/8 of an inch to 1-1/4 of an inch. It is most useful when you are removing a machine bolt where access is only 50 to 75 percent, or the area is restricted that the wrench can make only one half turn.

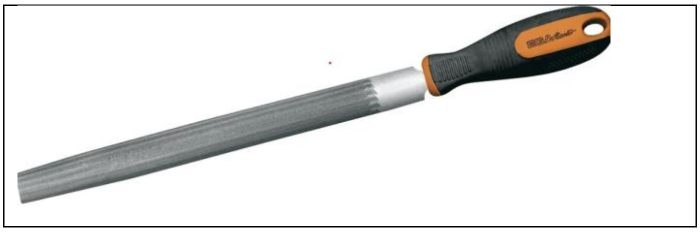


Flat File – flat hardened steel with cutting ridges. Used for filing a newly cut copper tube ends to square it. Or to remove burrs from steel brackets. File surface joints so that they can fit squarely.

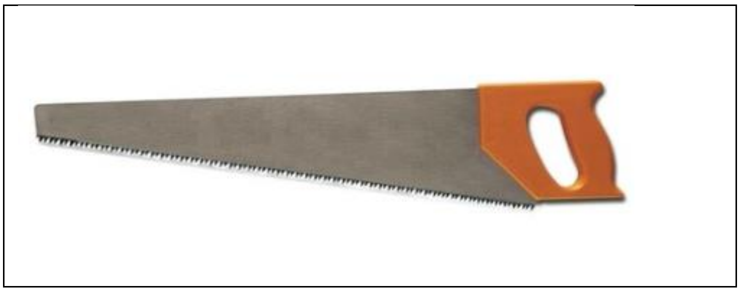
Round File – round long hardened steel with cutting ridges. Round file is very useful in enlarging a hole by filing. Cleaning a rusty steel tube, removing a clogged from a drain hole. Enlarging a flat washer hole to fit the larger bolt. Or to shape a certain parts through filing. Making prototype spare parts for hard-to-find spare.



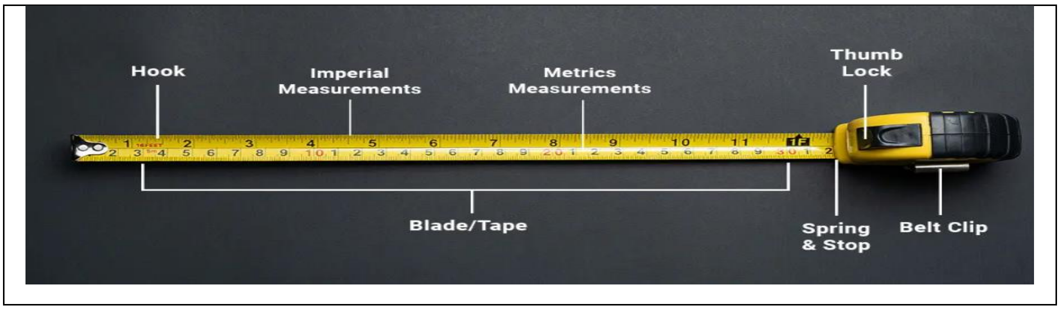
Half Round Files – Half round shaped long hardened steel with cutting ridges. When it is necessary to make a hole larger where the application of a round file is not practical. The half round side can finish a curve surface, and the flat side for the flat surface.



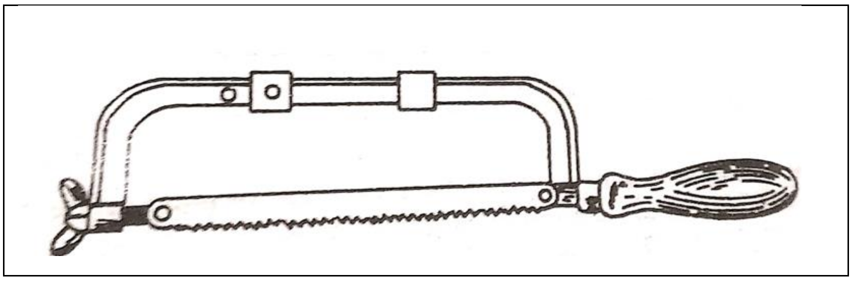
Carpenter's Saw – a hand tool with tooth blade used to cut wood. Fabricating wooden frame for a window type air conditioner, cutting wooden sticks to be used to elevate an air conditioner unit. Fabricating elevated stand for a split type stand alone indoor unit.



Tape measure -Steel tape measuring device. Put one in your pocket whenever you are going out into the field. Either you are going to make measurement for the length of the copper tubing you will need for a certain project, or measuring the volume of a room.

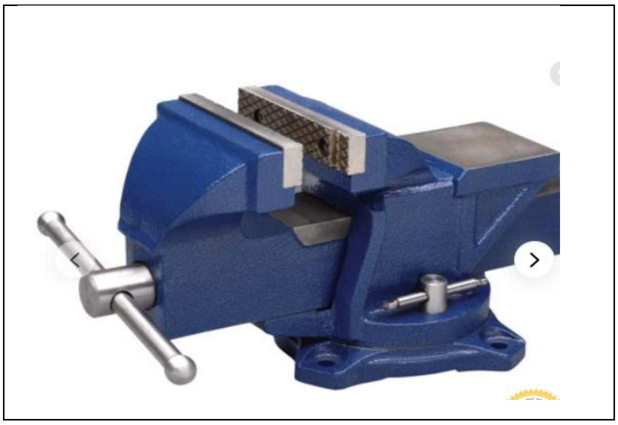


Hack Saw – a hand tool with tooth blade used to cut iron pipes or iron bars, maybe you need to shorten the length of a certain PVC pipe, or fabricating a bracket for a new air conditioner. Making a new home air conditioner installation. Cutting the window frame so that the new air conditioner will fit.



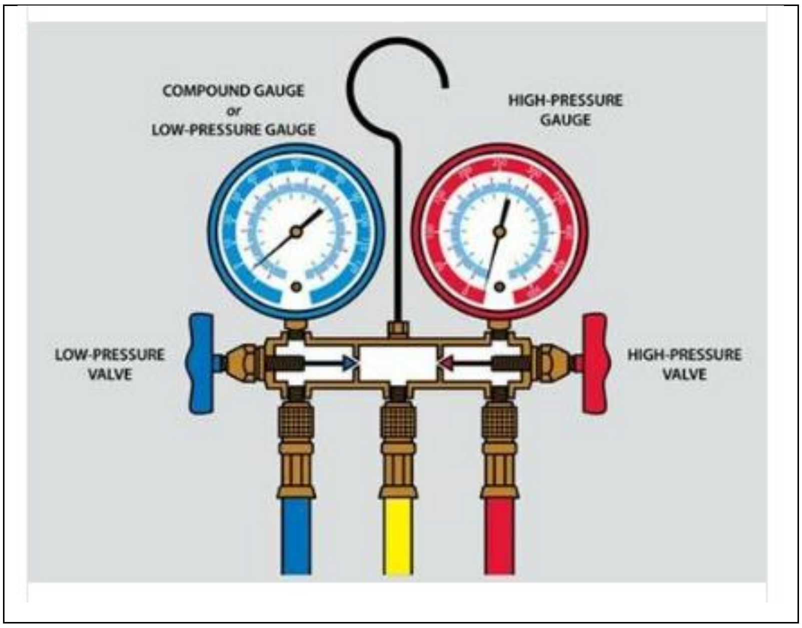
Electric Drill Gun –It is also a good refrigeration tool a refrigeration mechanic should have. We measure the size of a drill gun by the size of the chuck. I have with me a 1/2 inch chuck, and it is all I need in doing different things, like installing a new compressor and I need to make new holes for the anchor bolts.

Bench Vise – a refrigeration tool with two jaws for holding works. Most of the time we need a vise to hold the copper tube so that we can braze the joints correctly. Or we must clamp the machine bolt so that we can remove the hex nut. Or simply clamp a piece of steel bar so that we can cut it into the size we need.



Yoke Vise – a pipe vise. It is good to have a yoke vise in your working bench. Yoke vise is a common refrigeration tool a mechanic should have. Either you are lengthening your water pipes or removing electrical conduit pipes, a yoke vise clamps the tubing without deforming them.

Gauge Manifold – refrigeration tool pressure gauges. Whenever you are reprocessing a refrigerator, or replacing a new compressor for a freezer, or charging refrigerant to your automotive air conditioner, you need a gauge manifold to tell you if you are doing it right.



Conclusion: Thus we have studied various tools used in refrigeration and Air-conditioning.

EXPERIMENT NO. 2

Objective: To study construction and working of domestic refrigerator.

Apparatus: Capacity 175 Ltrs, Refrigerator Haier make, storage shelves, shelf of eggs, crisper, glass shelf, energy meter for compressor, energy meter for heater ,temperature indicator, refrigerant R-134a.

Theory: Refrigeration is defined as the process of extracting heat from a lower-temperature heat source, substance, or cooling medium and transferring it to a higher-temperature heat sink. Refrigeration maintains the temperature of the heat source below that of its surroundings while transferring the extracted heat, and any required energy input, to a heat sink, atmospheric air, or surface water. A refrigeration system is a combination of components and equipment connected in a sequential order to produce the refrigeration effect. The refrigeration systems commonly used for air conditioning can be classified by the type of input energy and the refrigeration process as follows: 1. Vapor compression systems. In vapor compression systems, compressors activate the refrigerant by compressing it to a higher pressure and higher temperature level after it has produced its refrigeration effect. The compressed refrigerant transfers its heat to the sink and is condensed to liquid form. This liquid refrigerant is then throttled to a low-pressure, low temperature vapor to produce refrigerating effect during evaporation.

- **Internal Parts of the Domestic Refrigerator**

The internal parts of the refrigerator are ones that carry out actual working of the refrigerator. Some of the internal parts are located at the back of the refrigerator, and some inside the main compartment of the refrigerator. Some internal parts of the domestic refrigerator are (please refer the figure above):

1) Refrigerant: The refrigerant flows through all the internal parts of the refrigerator. It is the refrigerant that carries out the cooling effect in the evaporator. It absorbs the heat from the substance to be cooled in the evaporator (chiller or freezer) and throws it to the atmosphere via condenser. The refrigerant keeps on recirculating through all the internal parts of the refrigerator in cycle.

2) Compressor: The compressor is located at the back of the refrigerator and in the bottom area. The compressor sucks the refrigerant from the evaporator and discharges it at high pressure and temperature. The compressor is driven by the electric motor and it is the major power consuming devise of the refrigerator.

3) Condenser: The condenser is the thin coil of copper tubing located at the back of the refrigerator. The refrigerant from the compressor enters the condenser where it is cooled by the atmospheric air thus losing heat absorbed by it in the evaporator and the compressor. To increase the heat transfer rate of the condenser, it is finned externally.

4) Expansive valve or the capillary: The refrigerant leaving the condenser enters the expansion devise, which is the capillary tube in case of the domestic refrigerators. The capillary is the thin copper tubing made up of number of turns of the copper coil. When the refrigerant is passed through the capillary its pressure and temperature drops down suddenly.

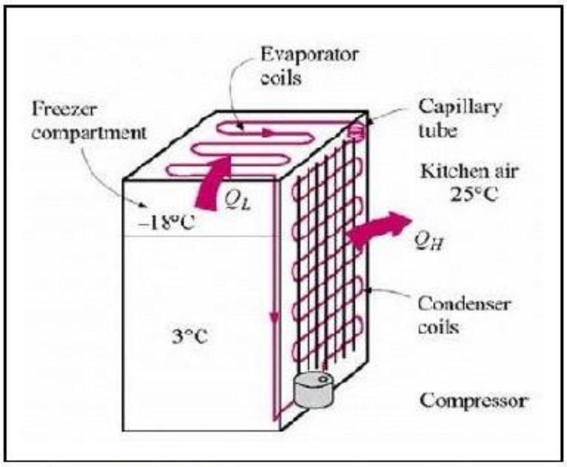
5) Evaporator or chiller or freezer: The refrigerant at very low pressure and temperature enters the evaporator or the freezer. The evaporator is the heat exchanger made up of several turns of copper or aluminum tubing. In domestic refrigerators the plate types of evaporator is used as shown in the figure above. The refrigerant absorbs the heat from the substance to be cooled in the evaporator, gets evaporated and it then sucked by the compressor. This cycle keeps on repeating.

6) Temperature control devise or thermostat: To control the temperature inside the refrigerator there is thermostat, whose sensor is connected to the evaporator. The thermostat setting can be done by the round knob inside the refrigerator compartment. When the set temperature is reached inside the refrigerator the thermostat stops the electric supply to the compressor and compressor stops and when the temperature falls below certain level it restarts the supply to the compressor.

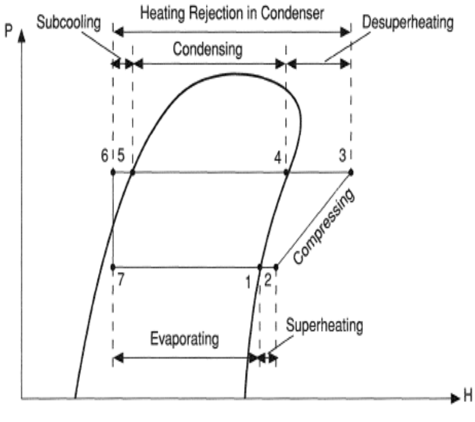
7) Defrost system: The defrost system of the refrigerator helps removing the excess ice from the surface of the evaporator. The defrost system can be operated manually by the thermostat button or there is automatic system comprising of the electric heater and the timer.

Those were the some internal parts of the domestic refrigerator; now let us see the external parts of the refrigerator.

- The external parts of the refrigerator are: freezer compartment, thermostat control, refrigerator compartment, crisper, refrigerator door compartment, light switch etc.



Household Refrigerator Cooling Cycle



External Visible Parts of the Refrigerator

The external parts of the compressor are the parts that are visible externally and used for the various purposes. The figure below shows the common parts of the domestic refrigerator and some them are described below:

1) Freezer compartment: The food items that are to be kept at the freezing temperature are stored in the freezer compartment. The temperature here is below zero degree Celsius so the water and many other fluids freeze in this compartment. If you want to make ice cream, ice, freeze the food etc. they have to be kept in the freezer compartment.

2) Thermostat control: The thermostat control comprises of the round knob with the temperature scale that help setting the required temperature inside the refrigerator. Proper setting of the thermostat as per the requirements can help saving lots of refrigerator electricity bills.

3) Refrigerator compartment: The refrigerator compartment is the biggest part of the refrigerator. Here all the food items that are to be maintained at temperature above zero degree Celsius but in cooled condition are kept. The refrigerator compartment can be divided into number of smaller shelves like meat keeper, and others as per the requirement.

4) Crisper: The highest temperature in the refrigerator compartment is maintained in the crisper. Here one can keep the food items that can remain fresh even at the medium temperature like fruits, vegetables, etc.

5) Refrigerator door compartment: There are number of smaller subsections in the refrigerator main door compartment. Some of these are egg compartment, butter, dairy, etc.

6) Switch: This is the small button that operates the small light inside the refrigerator. As soon the door of the refrigerator opens, this switch supplies electricity to the bulb and it starts, while when the door is closed the light from the bulb stops. This helps in starting the internal bulb only when required.

Figure2. Photographic view of domestic refrigerator.

Conclusion: Thus we have studied the working of domestic refrigerator.

Questions:

1. **Explain the on which cycle domestic refrigerator works?**
2. **What are the main parts of domestic refrigerator?**
3. **Which refrigerant used in domestic refrigerator?**
4. **What is the role of compressor in domestic refrigerator?**
5. **What are the temperature range in different compartment of domestic refrigerator?**

EXPERIMENT NO. 3

Objective: To study construction and working of hermetically sealed compressor.

Apparatus: Hermetically sealed compressor cut section.

Theory:

The hermetically sealed compressor is widely used for the refrigeration and air conditioning applications. You can find it in all the household refrigerators, deep freezers, window air conditioners, split air conditioners, most of the packaged air conditioners. In hermetically sealed compressor, the compressor and the motor are enclosed in the welded steel casing and the two are connected by a common shaft. This makes the whole compressor and the motor a single compact and portable unit that can be handled easily. The hermetically sealed compressor is very different from the traditional open type of compressors in which the compressor and the motor are different entities and the compressor is connected to the motor by coupling or belt.

Types of Hermetic compressors:

One of the most popular types of hermetically compressors are the reciprocating compressors. They were the first to be used as the hermetically sealed compressors and still being widely used. The days the vane type of rotary compressor has become more popular. It is considered that the rotary type of hermetically compressor consumes less electricity, makes lesser noise, requires lesser maintenance, and is cheaper than the reciprocating type of compressor. This is because the rotary compressors has less frictional parts and have only a rotor. The centrifugal types of hermetically sealed compressors are used for the larger units.

Construction of Hermetically sealed reciprocating compressor:

In hermetically sealed compressor, in one side of the enclosed casing the various parts of the compressor like cylinder, piston, connecting rod , and the crank shaft are located. If it is multi-cylinder compressor, there are more than two cylinders inside the casing. On the other side of the casing is the electric winding inside which the shaft of the motor rotates. This motor can be single speed or multi-speed motor. In hermetically sealed compressor the crank shaft of the reciprocating compressor and the rotating shaft of the motor are common. The rotating shaft of the motor extends beyond the motor and forms the crankshaft of the hermetically reciprocating compressor.

All these parts of the hermetically sealed compressor are assembled and enclosed in a strong and rigid casing made up of welded steel shell. The steel shell comprises of two half rounded steel bodies that are welded together to form the casing for the hermetically sealed compressor. In some cases the two halves of the shell can be bolted together instead of welding, which permits easy opening of the casing in case of compressor burnout.

The hermetically sealed compressors have inbuilt lubrication system for the lubrication of the piston and cylinder and crank shaft. The lubricant also acts as the coolant for the piston and cylinder. Additionally, the cool suction refrigerant also offers cooling effect.

Externally , the casing has refrigerant suction and discharge connections that are connected to the evaporator and condenser respectively. There is also socket for the electrical connection. The typical condenser unit with the hermetically sealed compressor is shown in fig. Such condenser units are called s hermetic condenser units.

Working of Hermetically sealed compressor:

In hermetically sealed compressor, the motor and the compressor are enclosed in the same housing to prevent leakage. The housing has welded connections for refrigerant inlet and outlet and for power input socket as shown in figure 1. As a result of this there is virtually no possibility of refrigerant leakage from compressor. All motors reject a part of the power supplied to it due to eddy current and friction. Similarly, compressor also gets heated up due to friction and due to temperature rise of the refrigerant during compression. In open type both the compressor and the motor reject heat to the surrounding air for efficient operation. In hermetic compressor heat cannot be rejected to the surrounding air since both are enclosed in a shell. Hence, the cold suction gas is made to flow over the motor and compressor before entering the compressor. This keeps the motor cool. The motor winding is in direct contact with the refrigerant, hence only those refrigerants which have dielectric strength, can be used in hermetically sealed compressor.

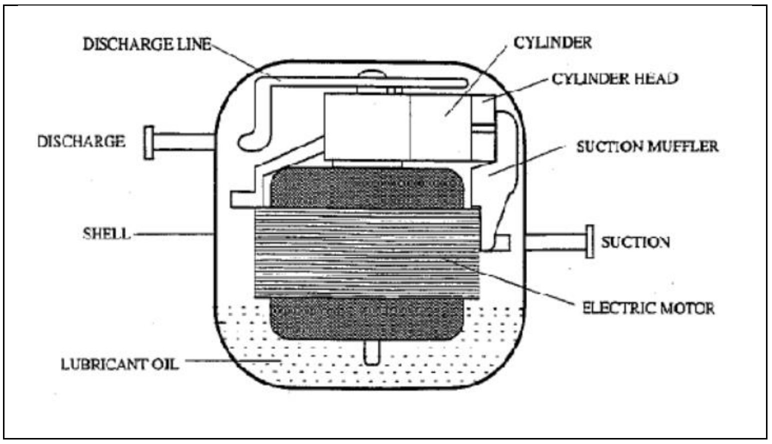


Figure1. Hermetically sealed compressor

The cooling rate depends upon the flow rate of the refrigerant, its temperature and the thermal properties of the refrigerant. If flow rate is not sufficient of if the temperature is not low enough the insulation on the winding of the motor can burn out and short circuiting may occur. Hence, hermetically sealed compressor give satisfactory and safe performance over a very narrow range of design temperature and should not be used for off-design conditions.

The COP of the hermetically sealed compressor based systems is lower than that of the pen compressor based systems since a part of the refrigeration effect is lost in cooling the motor and the compressor. However hermetically sealed compressor are almost universally used in small systems such as domestic refrigerators, water coolers, air conditioners, etc where efficiency is not as important as customer convenience. In addition to this the use of hermetically sealed compressors is ideal in the systems which uses capillary tube as expansion devices. Hermetically sealed compressors are normally not serviceable.

Application:

The hermetically sealed compressor is widely used for the refrigeration and air conditioning applications because of several advantages like:

1) The hermetically sealed compressor can be moved easily from one place to the other place, they are highly portable. One does not have to dissemble the compressor form the motor and no coupling, belt and pulley arrangement is involved.

2) The whole condenser unit of the refrigeration and air conditioning unit comprising of the condenser and the compressor can be moved easily from one place to the other.

3) Since no coupling, belt or pulley is involved, the maintenance is lesser.

4) The lubrication system of the hermetically sealed compressor is inherent and no external lubrication is required, unless the fresh gas charge is done.

5) The installation of the hermetically sealed compressor is very easy. The suction and discharge connections and the electrical connections are available externally.

6) Hermetically sealed compressor have very long life , the companies offer warranty period upto seven years for these compressors.

Conclusion: Thus we have studied the working of hermetically compressor.

EXPERIMENT NO. 4

Objective: To study varies controllers in refrigeration.

1. Refrigerant controls:
   Refrigerant controls are devices used to control the flow of refrigerant at varies points throughout the refrigeration cycle. Following are some points where refrigerant controls are used in a system.
   I. Expansion valves used to regulate the flow of refrigerant liquid to the evaporator.
   II. Suction line regulators used to control the flow of refrigerant gas from the evaporator coil.
2. **Hand Expansion Valve**
   It is hand operated needle valve as shown in figure 1. The rate of liquid flow through the valve depends upon the pressure differential across the valve orifice and the degree of valve opening, he latter being manually adjustable.

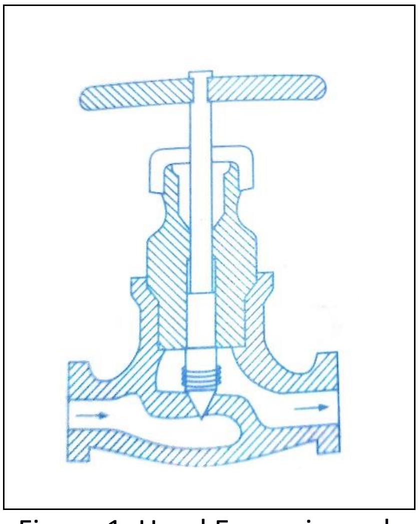


Figure 1. Hand Expansion valve

3. **Automatic Expansion Valve**
   It is activated by evaporator pressure and which keeps constant since the pressure of the refrigerant in the evaporator determines evaporator temperature. Figure2 shows the schematic diagram of an automatic expansion valve.

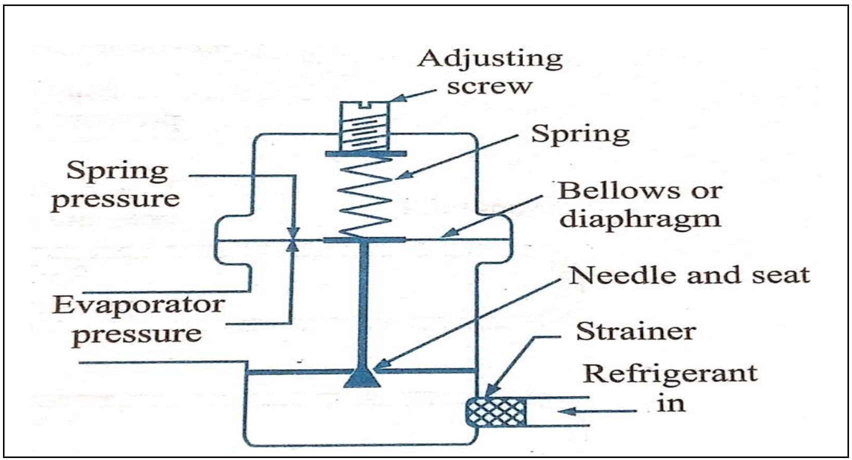


Figure 2. Automatic Expansion Valve

4. **Thermostatic Expansion Valve**
   It is throttling device which works automatically, maintaining proper and correct liquid flow as per the requirements of the load on evaporator as shown in figure3.

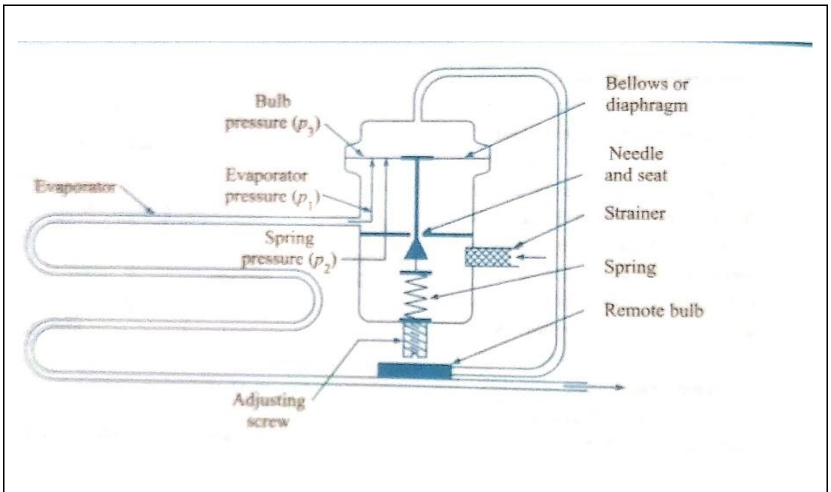


Figure 3. Thermostatic Expansion Valve

5. **Capillary Tube:**
   A capillary tube is a fixed restriction-type device. It is the simplest of the refrigerant flow controls, consisting merely of fixed length (from 0.5 m to 5 m) of diameter (0.5 mm to 2.25 mm) tubing installed between the condenser and evaporator.
6. **Low Side Float Valve**
   Low-side float valve is essentially a hallow ball, pan or inverted bucket connected through linkages and pivots to open or close needle valve as shown in figure 4. It maintains a predetermined liquid level in an evaporator.

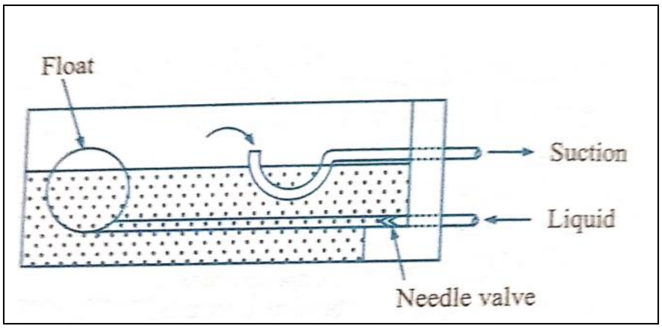


Figure 4. Low Side Float Valve

7. **High Side Float valve**
   It is the same element as a low-side float: a hallow ball, linkages, and a needle valve. It differs from the low-side float in that it is on the high side of the system and that rising liquid level opens the valve as shown in figure 5.

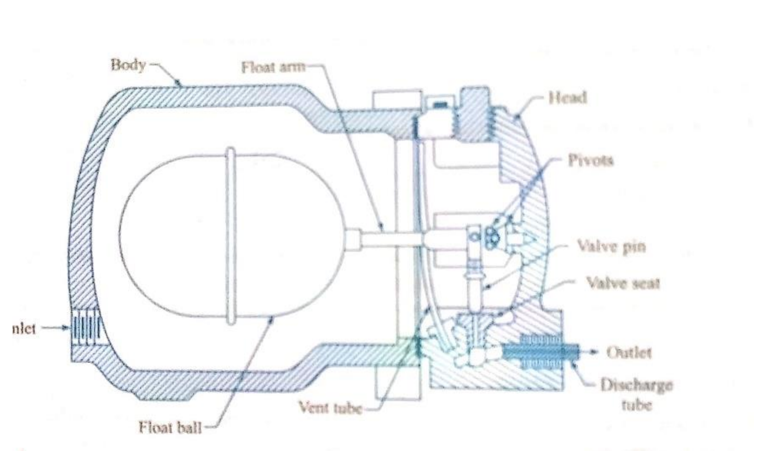


Figure 5. High Side Float Valve

8. **Pressure Relief Valve**
   These are the safety valves designed to relieve the pressure in the system to the atmosphere, or to outdoors through a vent line, in the event that the pressure in the system rises to unsafe level for any reason.
9. **Fusible Plug**
   A fusible plug is sometimes substituted for the pressure relief valve. A fusible plug is simply a pipe plug which has been drilled and filled with a mental alloy designed to melt at some pressure determined fixed temperatures.

10. **Oil Safety Switches**
    In large compressors forced lubrication is done for which an oil pump is employed. If the pump does not work due to some reason the parts will not be lubricated and these parts will get damaged. Therefore, some means must be provided to stop the compressor in case the pressure of lubricating oil falls below a pre-determined minimum level. This is achieved by using an oil pressure failure control in the control circuit of refrigeration equipment.

EXPERIMENT NO. 5

Objective: To study leak detection and charging of refrigerant in a vapour compression system.

Apparatus: Vacuum pump, four-way manifold guage,90 degree shut off valve, process stub Schrader valve, dye-drier with Schrader valve, 134a recovery cylinder, 134a charging cylinder and charging hose.

Refrigerant Charging Procedure:

A: Operation

Caution:

- During operation, be sure to wear safety goggles and protective gloves.
- Before charging the refrigerant, evacuate the system to remove small amounts of moisture remaining in the system.

The moisture in the system can be completely evacuated only under the minimum vacuum level. The minimum vacuum level affects the temperature in the system.

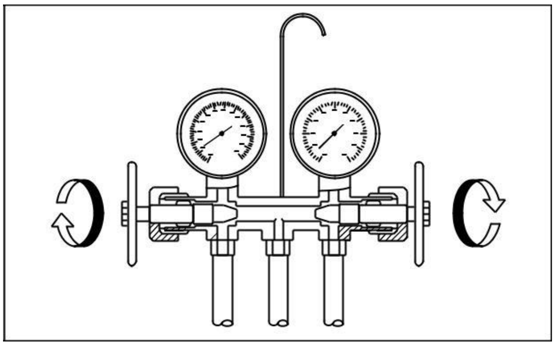
- The list below shows the vacuum values necessary to boil water in various temperatures. In addition, the vacuum levels indicated on the gauge are approx. 3.3 kPa (25 mmHg, 0.98 in Hg) lower than those measured at 304.8 m (1,000 ft) above sea level.

Temperature	Vacuum
1.7°C (35°F)	100.9 kPa (757 mmHg, 29.8 inHg)
7.2°C (45°F)	100.5 kPa (754 mmHg, 29.7 inHg)
12.8°C (55°F)	99.8 kPa (749 mmHg, 29.5 inHg)

18.3°C (65°F)	99.2 kPa (744 mmHg, 29.3 inHg)
23.9°C (75°F)	98.5 kPa (739 mmHg, 29.1 inHg)
29.4°C (85°F)	97.2 kPa (729 mmHg, 28.7 inHg)
35°C (95°F)	95.8 kPa (719 mmHg, 28.3 inHg)

Vacuum level required to boil water (at sea level)

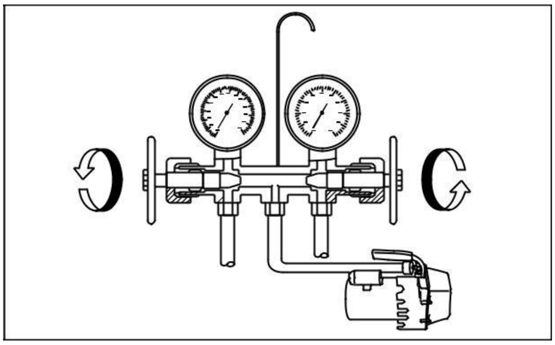
1) Close the valves on low-/high-pressure sides of the manifold gauge.



A) Low-pressure gauge (Compound pressure gauge)

B) High-pressure gauge

C) Close



2)Install the low-/high-pressure hoses to the corresponding service ports on the vehicle respectively.

3)Connect the center hose of the manifold gauge set with the vacuum pump.

4) Carefully open the valves on the low-/high-pres-sure sides to activate the vacuum pum

(A) Low-pressure gauge (Compound pressure gauge)

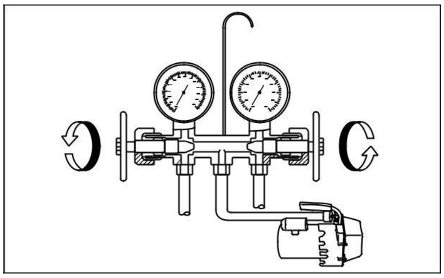
(B) High-pressure gauge

(C) Slowly open

(D) Vacuum pump turn on

5) After the low-pressure gauge reaches 100.0 kPa (750 mmHg, 29.5 inHg) or higher, evacuate the system for approx. 15 minutes (Continue evacuation)

6) After 15 minutes of evacuation, if the reading shows 100.0 kPa (750 mmHg, 29.5 inHg) or higher, close the valves on the both sides to stop the vacuum pump.



(A) Low-pressure gauge (Compound pressure gauge)

(B) High-pressure gauge

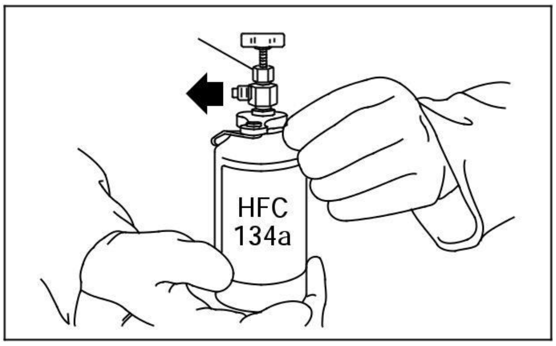
(C) Close

(D) Vacuum pump turn off

7) Note the low-pressure gauge reading.

8) Leave it at least 5 minutes, and then check the low-pressure gauge reading for any changes. When a gauge indicator shows near to zero point, this is a sign of leakage. Check pipe connector points, repair them, and make sure there is no leakage by air bleeding.

9) Following the can tap operation manual instructions, install it to the refrigerant can.



(A) Tap valve

(B) Center manifold hose

10) Disconnect the center manifold hose from the vacuum pump, and connect the hose to the tap valve.

11) When a 13.6 kg (30 lb) refrigerant container is used, measure the refrigerant amount in use using a weighting scale.

12) Confirm that all the 3 hoses are tightly connect-ed to the manifold gauge set.

13) Open the valve on the HFC-134a source.

14) Loosen the center hose connection on the manifold gauge set (if applicable, press a purge valve on the manifold gauge set) only for a couple of seconds to allow the air in the center hose to es-cape by the refrigerant.

15) Carefully open the high-pressure valve with the engine stopping.

CAUTION:

Do not open the low-pressure valve.

16) Close the high-pressure valve when the low-pressure gauge reaches 98 kPa (1 kg/cm^2, 14 psi).

Using a leak tester, check the system for leaks.

17) If any leakage is found after the refrigerant recovery is completed, repair the applicable area.

17) After confirming that there are no leaks with the leak test, charge the required amount of refrigerant.

18) Close the high-pressure valve when; the readings of low-/high-pressure gauges become almost equal, after the charging speed is reduced,

the HFC-134a source becomes empty, or the system is filled with the gas

19) If the HFC-134a source is empty, close the high-pressure valve, close the valve on the can tap, and replace the HFC-134a source with a new one to restart the operation.

20) Confirm that both the low-/high-pressure valves can be closed. Start the engine with the A/C switch OFF.

21) Quickly repeat ON-OFF cycles a few times to prevent initial compressor damage.

22) Set up the system to on condition.

23) While reading the low-pressure gauge, careful-ly open the low-pressure valve with the refrigerant source connected and the service hose purged.

24) Adjust the refrigerant flow to maintain the pres-sure on the low-pressure side at 276 kPa (2.81 kg/ cm^2, 40 psi) max.

25) After the system is fully charged, close the low –pressure valve.

26) Close the valve on the refrigerant source.

27) Disconnect the hose from the service port, and install the service port cap.

Conclusion: Thus we have studied the charging of refrigerant in a vapour compression refrigeration system.

EXPERIMENT NO. 6

Objective: To study steam jet refrigeration system

Steam jet or Ejector refrigeration system uses water as refrigerant. It uses the basic principle of boiling of liquid at lower temperature by reducing pressure on its surface.

This system employs a steam ejector or booster instead of mechanical compressor. The main components as shown in figure are flash chamber or evaporator, steam nozzles, ejector and condenser.

The flash chamber is heavily insulated and is fitted with perforated pipes which spray warm water coming out of refrigerated space. Some of this water is converted into vapours after absorbing latent heat from the rest of the water, thereby cooling it. Loss of water through vapours is made up from make-up water line.

High pressure steam from boiler is passed through steam nozzle thereby increasing its velocity. This entrains water vapours from flash chamber and results in further formation of vapours.

The mixture of steam and water vapour passes through venturi-tube of ejector and gets compressed. This leads to rise in temperature and pressure of the mixture and then it is fed to the water cooled condenser as shown in figure1.

The condensate is again fed to boiler as feed water.Steam jet refrigeration system is widely used in paper mills, breweries, food processing plants, gas plants etc. Since water is the refrigerant, it cannot be used for applications below 0°C.

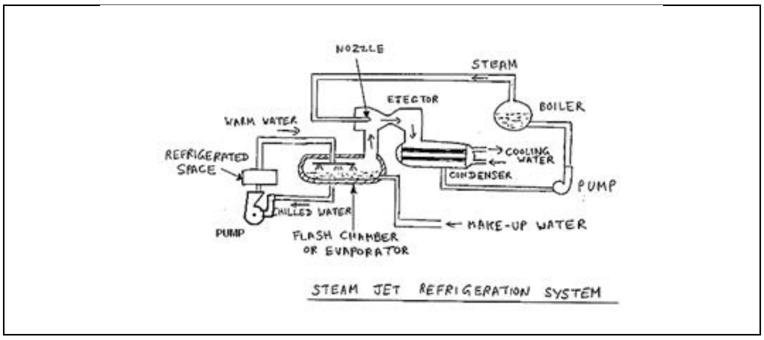


Figure1. Steam Jet Refrigeration System

EXPERIMENT NO. 7

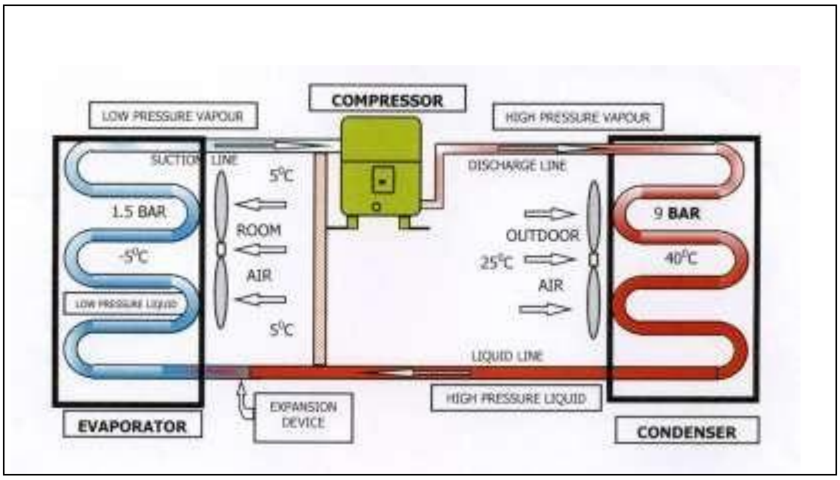
Objective: To study construction and working of water cooler.

Theory:

In 1906 Halsey Willard Taylor and Luther Haws invented the first drinking water fountain, with the primary motivation being to provide safer drinking water and avoid the risk of typhoid fever caused by contaminated water. (Luther Haws' father had died of typhoid fever precipitated by contaminated water. Early drinking fountains provided room temperature drinking water, but demand led to the development of fountains that could provide cooler water thereby killing the micro-organisms responsible for pollution and disease. But early water coolers did not have a discrete water treatment method for purifying the dispensed H2O.As the years went by, water coolers further evolved into smaller, lighter, and more efficient units. They also varied in shape and size, depending on the needs of the consuming. Water cooler is one piece of equipment that we find in our day to day life. Water coolers are used to reduce the temperature of drinking water and to maintain the temperature of the water in a particular range. In this article we will discuss the working and most common types of water coolers made by us. The purpose of water cooler is to make water available at a constant temperature respective of room temperature.

WORKING PRINCIPLE

The process of refrigeration occurs in a system which encompasses of a compressor, a condenser, expansion device and an evaporator. VCR system functions based on reversed Brayton cycle. The VCR system consists of four main components which are compressor, condenser, expansion device and evaporator. Compressor is used to compress the low temperature and pressure refrigerant from the evaporator to high temperature and pressure. After compression the high temperature and pressure refrigerant is discharged into the condenser though the delivery or discharge. The Condenser consists of coils of pipe in which the high temperature and pressure refrigerant is cooled and condensed. There refrigerant, which passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water. The condensed liquid refrigerant from the condenser is stored in the vessel known as receiver from where it is supplied to evaporator through the expansion valve (i.e. capillary) or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high temperature and pressure to pass at a controlled rate after reducing its temperature and pressure. Some of the liquid refrigerant evaporates as it passes though the expansion valve, but the greater portion is vaporized anthem evaporator at low temperature and pressure. Next it travels to the evaporator. An Evaporator consists of coils of pipes in which the liquid vapour refrigerant at low temperature and pressure is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (water) which is to be cooled. The performance of the water cooler system is to be evaluated by using experimental methods which is carried out by using the specially developed test rig. The test rig can be modified and upgraded if required. The work explains some of the technical modification and evaluation of the refrigeration system under varying load condition. The refrigeration system used to test the concept has a low pressure with single hermetically sealed compressor.



Conclusion: Thus we have studied construction and working of water cooler.

EXPERIMENT NO. 8

Objective: To study working of Electrolux Refrigerator.

Apparatus: Gross volume 41 litres , refrigerant water, ammonia, hydrogen , electrically heated generator, natural convection type condenser, natural evaporator, energy consumption 1.07KWH per 24 Hrs.

Theory:

Absorption refrigerators are often used for food storage in recreational vehicles. The principle can also be used to air-condition buildings using the waste heat from a gas turbine or water heater. Using waste heat from a gas turbine makes the turbine very efficient because it first produces electricity, then hot water, and finally, air-conditioning (called cogeneration/trigeneration). Absorption refrigerators are a popular alternative to regular compressor refrigerators where electricity is unreliable, costly, or unavailable, where noise from the compressor is problematic, or where surplus heat is available.

The domestic absorption type refrigerator was developed from an invention by Carl Munters and Baltzer Von Platen. This system is often called "Munters Platen System".

This type of refrigerator is also called "Three-fluid absorption system". The three fluids used in this system are ammonia, hydrogen and water.

- The "ammonia" is used as a refrigerant because it possesses most of the desirable properties.

  Though it is toxic, and not otherwise preferred in domestic appliances, it is very safe in this system due to absence of any moving parts in the system and , therefore, there is the least chance of any leakage.
- The "hydrogen" being the lightest gas, is used to increase the rate of evaporation (the lighter the gas, faster is the evaporation) of the liquid ammonia passing through the

evaporator. The hydrogen is also non-corrosive and insoluble in water. This is used in the low-pressure side of the system.

- The "water" is used as a solvent because it has the ability to absorb ammonia readily.

Principle and Working of Electrolux Refrigerators.

Figure drawn below shows a schematic diagram of an „Electrolux refrigerator‟. It is a domestic refrigerator and is the best known absorption type of refrigerator. Here pump is dispensed with. The small energy supply is by means of a heater which may be electric or gas as shown figure1.

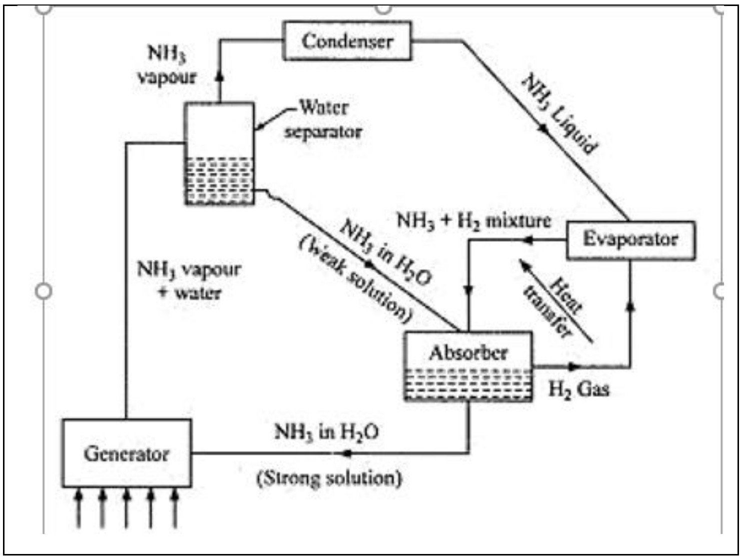


Figure1. Electrolux Refrigerator

Principle. The principle involved makes use of the properties of gas-vapor mixtures. If a liquid is exposed to an inert atmosphere, it will evaporate until the atmosphere is saturated with the vapor of the liquid. This evaporation requires heat which is taken from the surroundings in which the evaporation takes place. A cooling effect is thus produced. The partial pressures of the refrigerant vapor (in this case ammonia) must be low in the evaporator, and higher in the condenser. The total pressure throughout the circuit must be constant so that the only movement of the working fluid is by convection currents. The partial pressure of ammonia is kept low in requisite parts of the circuit by concentrating hydrogen in those parts.

Working:

The ammonia liquid leaving the condenser enters the evaporator and evaporates into the hydrogen at the low temperature corresponding to its low partial pressure. The mixture of ammonia and hydrogen passes to the absorber into which is also admitted water from the separator. The water absorbs the ammonia and the hydrogen returns to the evaporator. In the absorber the ammonia therefore passes from the ammonia circuit into water circuit as ammonia in water solution. This strong solution passes to the generator where it is heated and the vapor given off rises to the separator. The water with the vapor is separated out and a weak solution of ammonia is passed back to the absorber, thus completing the water circuit. The ammonia vapor rises from the separator to the condenser where it is condensed and then returned to the evaporator. The photographic view shown in figure2.

Figure2. Photographic view of vapour absorption refrigerator

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

1. The complete cycle is carried out entirely by gravity flow of the refrigerant.
2. The hydrogen gas circulates only from the absorber to the evaporator and back.
3. With this type of machine efficiency is not important since the energy input is small.
4. It has not been used for industrial applications as the C.O.P. of the system is very low.

Role of Hydrogen. By the presence of hydrogen it is possible to maintain uniform total pressure throughout the system and at the same time permit the refrigerant to evaporate at low temperature in the evaporator corresponding to its partial pressure. Thus the condenser and evaporator pressures of the refrigerant are maintained as below

(ii) In the condenser only ammonia is present, and the total pressure is the condensing pressure.

(iii) In the evaporator hydrogen and ammonia are present; their relative masses are adjusted such that the partial pressure of ammonia is the required evaporator pressure.

These are achieved without the use of pumps or valves.

Advantages and Disadvantages of Electrolux Refrigerator over Conventional Refrigerators:

Advantages:

1. No pump or compressor is required.
2. No mechanical troubles, maintenance cost is low.
3. No lubrication problem; no wear and tear.
4. Completely leak proof.
5. Noiseless.
6. No chance of pressure unbalancing and no need of valves.
7. System may be designed to use any available source of thermal energy-process steam, exhaust from engines or turbines, solar energy etc.
8. Easy control, simply by controlling heat input.

Disadvantages:

1. More complicated in construction and working.
2. C.O.P. very low.
3. The major disadvantages of this type of refrigerator are that if it is spoiled once, it cannot be repaired and has to be replaced fully.

Conclusion: Thus we have studied the working of a vapour absorption refrigeration system (Electrolux Refrigerator).

B. To conduct Trial on Following Refrigeration Systems

Experiment No.09

Name of Experiment: To conduct trial on refrigeration test rig.

Objectives;

1. To understand principle of operation and working of vapour compression system.
2. To calculate theoretical, actual and relative C.O.P. of the system

Working:

The refrigeration system works on vapour compression cycle. The refrigeration is the process of (maintaining a closed space temperature below the surrounding temperature) is accomplished continuously circulating, evaporating and condensing a fixed supply of refrigerant in a closed system. Evaporation occurs at a low temperature and low pressure while condensation occurs at a high temperature and pressure. Thus it is possible to transfer heat from an area of low temperature to an area of high temperature. (the surrounding).

The compressor pumps the low pressure vapour refrigerant from evaporator, increases pressure and discharge high pressure vapour refrigerant to the condenser. In the condenser heat rejected to the surrounding by passing air over it.

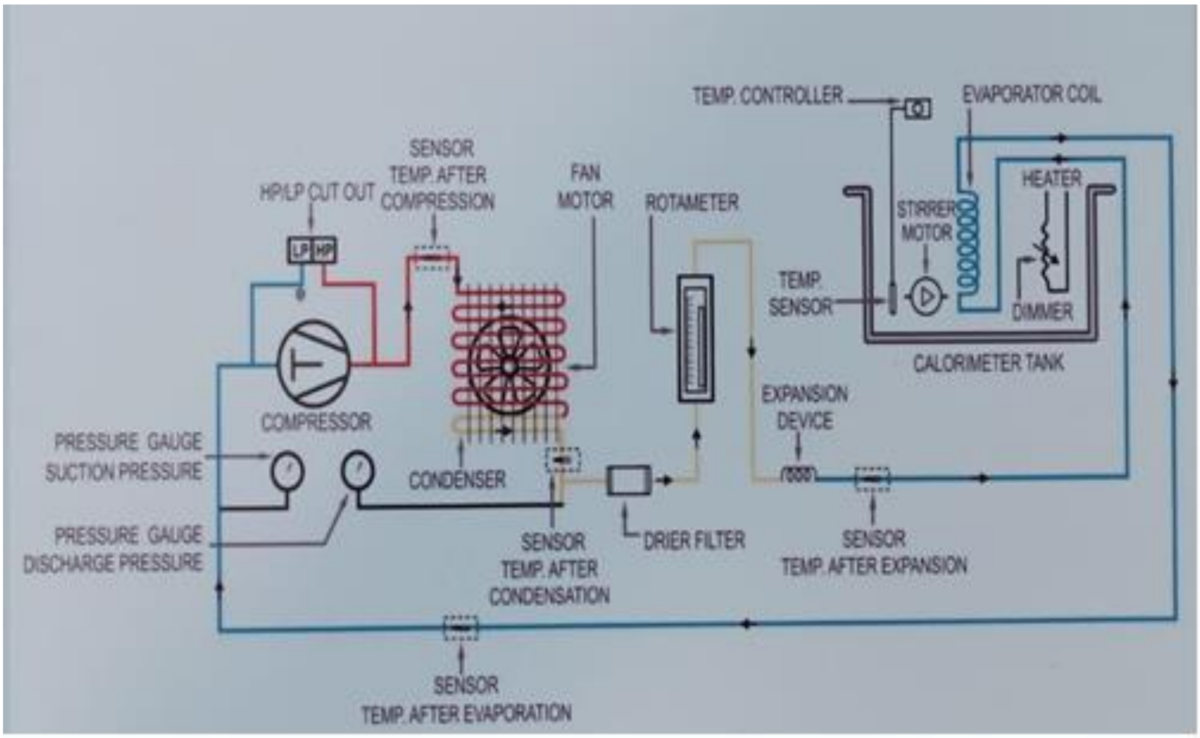


Figure1. Schematic diagram of refrigeration system.

At that pressure refrigerant losses its latent heat and liquefies. Then the refrigerant passes through the drier/filter where any residual moisture or foreign particles present, these are plugged the flow rate of refrigerant into the evaporator is controlled by the expansion device. Where its pressure and consequently temperature is lowered to the saturation temperature at the corresponding pressure. The low temperature vapour enters evaporator where it absorbs heat from the surrounding medium and evaporators. The compressor draws the cold vapour and the cycle repeats. The schematic diagram of experimental setup is shown in figure1 and photographic view in figure 2.

Operating Instructions:

- Place the machine in the proper positon where its level is horizontal and it is well ventilated.
- Give 230 volts, 50 Hz and single phase electric supply to the unit.
- Fill the colorimeter or isothermal bath with clean water.

- Start the compressor by putting the switch ON
- The pump in the calorimeter will equalize the temperature in the tank.
- Put ON the supply of heater.
- Refrigerant circulated through the tube absorb heat from the water and equal amount of heat supplied from the heater to maintain the temperature of the bath practically constant.
- Load = Refrigeration effect.
- Record all the readings as per the observation table
- Allow at least ½ hours running time for the correct results
- Calculate the results as per the procedure mentioned.

CAUTION:

- Always start the machine only after ensuring adequate water level in the tank.
- Do-not switch on the heater in the dry tank
- Do-not tamper with the temperature as well as the pressure settings.

Technical Specifications:

Component	Specifications
Compressor	Hermetically sealed. Emerson make
Capacity	500 watts @ rated test condition
Condenser	Forced convection air cooled
Drier/Filter	Molecular sleeve type
Expansion Device	Capillary tube and Thermostatic expansion valve
Evaporator	Shell and coil type
HP/LP cut out	Provided
Pressure gauges	2 numbers, (Bourdon tube)
Temperature indicator	Provided (As well as wells are provided to measure temperature at varies point using ordinary thermometer)
Energy meter	Provided for compressor and heater
Refrigerant	R-134 a

Figure2. Photographic view of refrigeration system

Standard Values and Formulas:

Standard Barometric Pressure	**=**	**1.013 bar = 1.013 x 10^5 N /m^2**
Density of Water	**=**	**1000 kg / m^3 = 1 kg / liter**
Specific heat of water	**=**	**4.18 kJ/kg K**
Gas Constant for Air	**=**	**287 J / kg K**
Specific Gravity of R-134a at 40^0 C	**=**	**1.2**
1 Ton of Refrigeration effect	**=**	**3500 Watts = 3.5 kJ / s**
Density of air at 25^0 C	**=**	**1.1 kg/m^3**
1 kWHr (kilowatt-hour)	**=**	**3600 kJ**
1 bar	**=**	**14.5 psig**

Observation Table

(Note-Take first reading when heater starts.)

Time	Refrigerant temp. (°C)				Water temperature °C	Energy meter (kWhr) compressor.	Energy meter (kWhr) heater.	Refrigerant Pressure Psig		Refrigerant flow lph
						E1 – time for 10 pulses	E2 – time for 10 pulses	Suction	Discharge	
Hrs	After evaporator - 1	After compressor - 2	After condenser - 3	After Expansion - 4	5			P1	P2	Vr

Calculations:

1. To calculate actual C.O.P. of the system:

A. Method:1

Actual refrigeration effect	=	Heater load
	=	Energy meter reading
		Time for 20 pulses
		Energy meter constant = 3200 pulses per kWhr.
		$N = \dfrac{\text{Number of pulses} \times 3600}{t_{\text{Heater}} \times \text{Energy meter constant(Heater)}}$
Actual refrigeration effect	=	

Actual Compressor work w	=	Time for 20 pulses
		Energy meter constant= 3200 pulses per kWhr.
		$W = \dfrac{\text{Number of pulses} \times 3600}{t_{\text{compressor}} \times \text{Energy meter constant(compressor)}}$
Actual Compressor work w	=	

Actual coefficient of performance	=	Actual refrigeration effect/ Actual compressor work
	=	N/W
	=	

B. Method:2

Actual refrigeration effect (N)	=	Mass of Water in tank*Specific heat of water* (Final temperature of water- intimal temperature of water)/ Duration of trail
	=	
Actual refrigeration effect (N)		

Actual coefficient of performance	=	Actual refrigeration effect/ Actual compressor work
	=	N/W
	=	

2. To calculate theoretical C.O.P. of the system:

We have

Average suction pressure ($P_{scution\ gauge}$) = bar

Average discharge pressure ($P_{discharge\ gauge}$) = bar

Absolute suction pressure

Suction gauge pressure+ barometric pressure = bar

Absolute discharge pressure

discharge gauge pressure+ barometric pressure = bar

Accordingly,

Enthalpies of refrigerant at salient points are

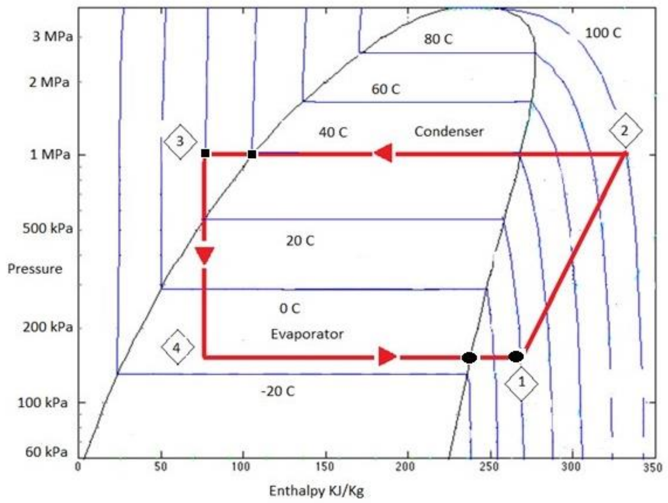


Figure3 P-h chart

Accordingly,

Enthalpy of refrigerant at inlet of compressor h_1 =______________ kJ/ kg

Enthalpy of refrigerant at outlet of compressor h_2 =______________ kJ/ kg

Enthalpy of refrigerant after condensation h_3 =______________ kJ/ kg

Enthalpy of refrigerant after expansion h_4 =______________ kJ/ kg

Theoretical refrigeration effect = N = h_1-h_4= _____________ kJ/kg

Theoretical compressor work = W = h_2-h_1 = ____________kJ/kg

Coefficient of performance = C.O.P. = N/W =___________________

(Note: These valves of enthalpies can be calculated with the help of P-h chart of R-134a)

3. **To calculate Carnot C.O.P. of the system:**

$$\text{Carnot C.O.P.} = \frac{T_L}{T_H - T_L}$$

= ---------------------

=

T_L= Saturation temperature to corresponding evaporator pressure (bar)

T_H=Saturation temperature to corresponding condenser pressure (bar).

4. **To calculate Relative C.O.P. of the system:**

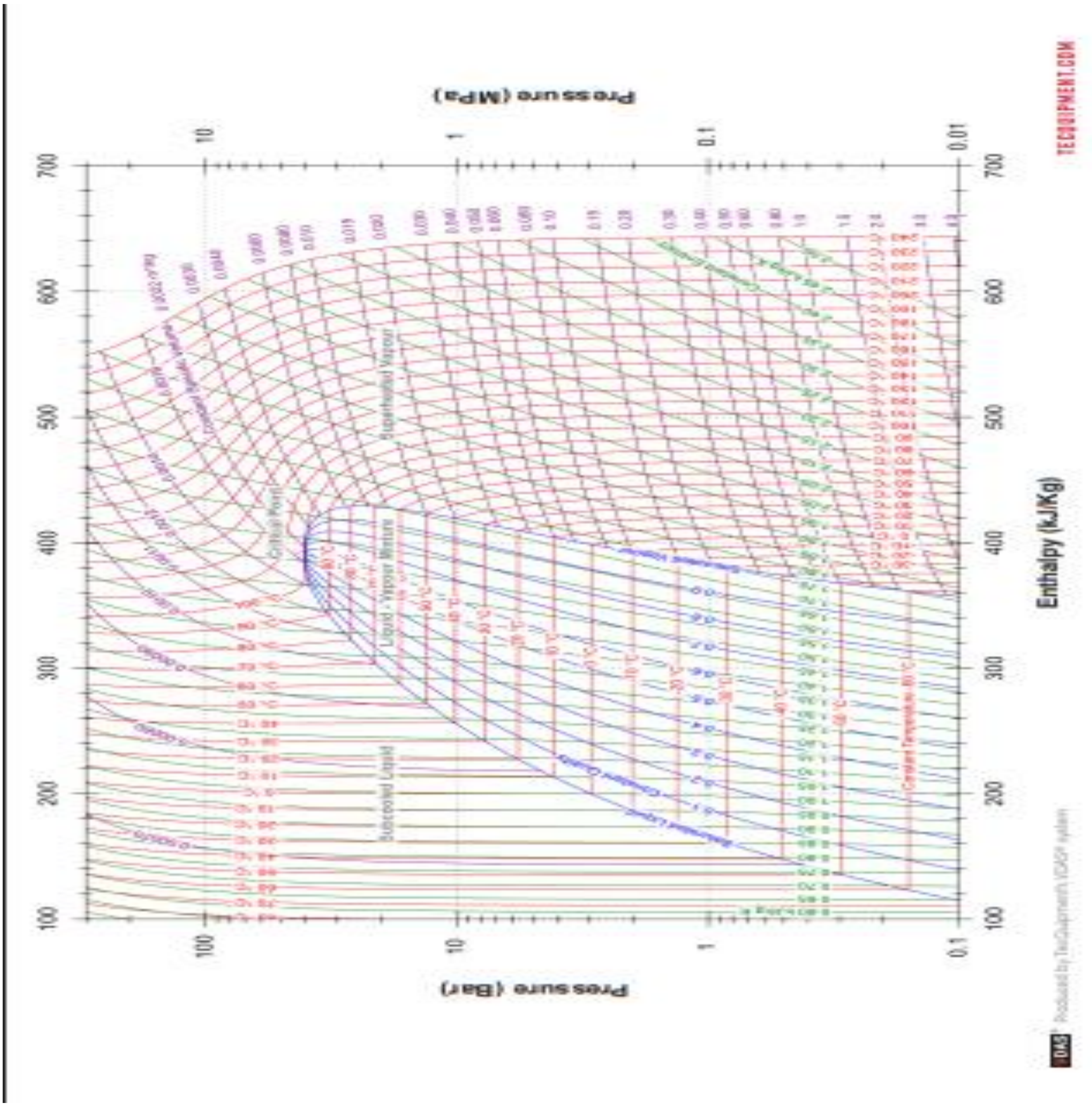
$$\text{Relative C.O.P.} = \frac{\text{Actual C.O.P.}}{\text{Therotical C.O.P.}} = \frac{..........}{..........} = ---$$

Conclusions:

1. Understand the working of vapour compression cycle and function of each component.
2. It is observed that Carnot C.O.P. > theoretical C.O.P. > actual C.O.P. due to the losses at varies points.

Questions:

1. Explain working of vapour compression cycle with the help of block diagram
2. What is role of compressor in vapour compression cycle? What type of compressor is preferred in applications of vapour compression cycle? (List out with specifications at least any two)
3. What is refrigeration effect and how it is calculated in present experiment?
4. What are the practical applications of vapour compression cycle? List out at least five of them with specifications.
5. What is function of expansion device in vapour compression cycle? What is the difference of capillary tube and thermostatic expansion valve?
6. What are different steps carried for trouble shooting of vapour compression cycle applications. (mention few of them any one application)



(Reference: Tecquipment)

Experiment No.10

Name of Experiment: To conduct trial on cascade refrigeration system

Objectives:

1. To understand the working of cascade refrigeration system.

A cascade system is a multistage application in which two separate refrigerant systems are interconnected in such a manner that one provides the means of heat rejection (condenser) for the other.The lower system may, therefore may operate at a much lower temperature.

Cascade system has the additional feature, over compound systems of permitting the use of different refrigerants in each cycle of the cascade.

Working:

Initially, when the compressor is started, the refrigerant is compressed at high pressure, and then it enters into the shell and coil type condenser, where the flowing water absorbs all the heat. Then it enters into the drier/filter, flow meter and it goes into the expansion device where its expansion takes place and pressure drops. Then it enters into the cascade condenser where it takes heat from the low side refrigerant (R-23) as shown in figure1.

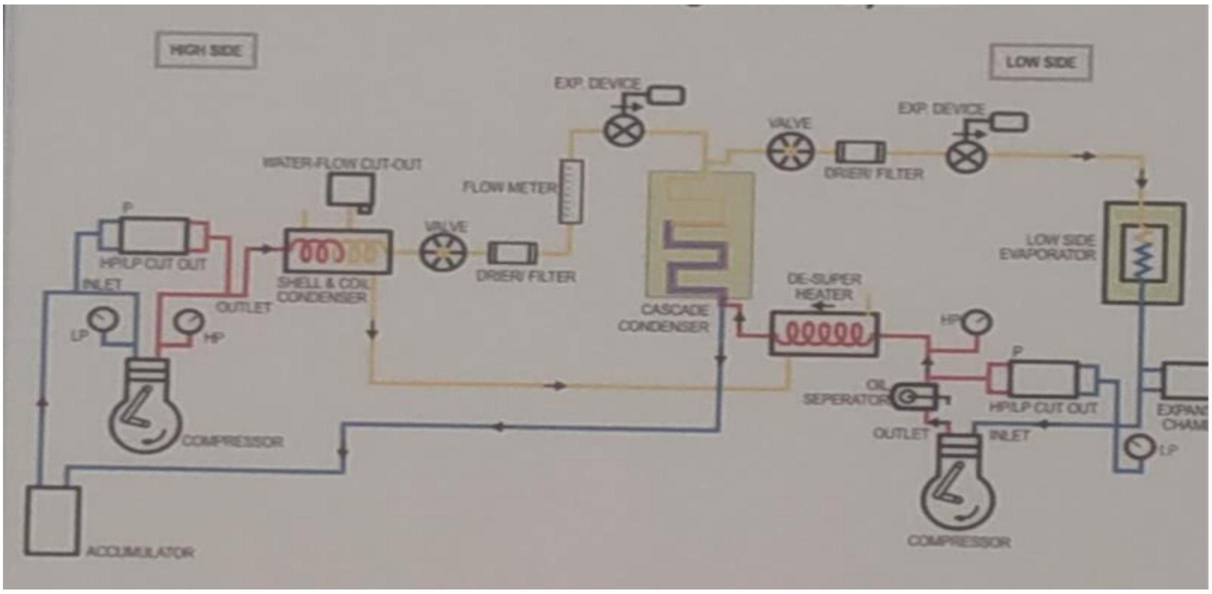


Figure1. Schematic diagram of cascade refrigeration system

In the low side system compressor discharges refrigerant at high pressure, then it enters into the oil separator where compressor oil gets separated from the refrigerant. Then refrigerant goes into de-super heater where its heat gets absorbed by flowing water, then it goes into cascade condenser (i.e., high side evaporator) where its heat is rejected and it becomes in liquid form. After passing through drier /filter, expansion device it goes into low side evaporator where it absorbs heat from chamber. It converts into low-pressure vapour state. Then it goes into the compressor as shown in figure 2.

Figure2. Photographic view of cascade refrigeration system

R-23 is having high standing pressure so it becomes trouble for compressor starting. So to avoid it refrigerant is stored in the expansion chamber where the pressure takes place. It is connected in series with the compressor inlet line.

Specifications:

A. High-side

Components	High side
Compressor	Hermetically sealed ,Emerson make
Accumulator	Dry all
Condenser	Forced convection air cooled
Drier/filter	Provided
Expansion device	Provided
Flow-meter	Provided
Evaporator	Coil in coil type
De-super heater	Not required
Expansion chamber	Not required
Oil-seperator	Not required
Hp/lp cut-out	Provided
Pressure gauges	Provided
Energy meter	Provided
Temp.scanner	Provided
Temp. Controller	Sub zero
Insulation	Puf
Temperature attained at the evaporator	**- 15 deg celsius**
Refrigerant	**R-22**
Supply	230 volts, 50 hz, 1 phase

B. Low-side

Components	Low side
Compressor	Hermetically sealed, Emerson make
Accumulator	Dry all
Condenser	Coil in coil type
Drier/filter	Provided
Expansion device	Provided
Evaporator	Natural convection type
De-super heater	Shell and coil type
Expansion chamber	Provided
Oil-seperator	Danfoss make
Hp/lp cut-out	Provided
Pressure gauges	Provided
Energy meter	Provided
Temp.scanner	Es point
Temp. Controller	Selectron
Heater	Provided
Dimmer for heater	Provided
Insulation	Puf

Observation Table:

Part1: High Side System **Refrigerant: R-22**

Sr.	Time	Suction pressure psig	Discharge pressure Psig	Refrigerant temperatures				Evaporator temperature	Energy meter compressor	Energy meter heater
				After evaporation	After compression	After condensation	After expansion			

Part2: Low side system **Refrigerant: R13**

Sr.			Time	Suction pressure psig	Discharge pressure Psig	Refigerant temperatures				Evaporator temperature	Energy meter compressor	Energy meter heater
						After evaporation	After compression	After condensation	After expansion			

Calculations & Results

Refrigeration effect at low side n2	=	Heater load	
	=	Time for 10 pulses	
	=	11.25/t	
Compressor work at low side w2	=	Time for 10 pulses	
	=	11.25/t	
C.O.P. On low side	=	N2 / w2	
	=		
Now refrigeration effect on high side n1	=	Condenser heat rejection on low side	
	=	Compressor work on low side + refrigeration effect on low side	
	=		
Compressor work on high side w1	=		
	=		
C.O.P.	=		
Results:	**=**	**Actual**	**Theoretical**
C.o.p. On low side	**=**		
C.o.p. On high side	**=**		
Overall c.o.p.	**=**		

Experiment No.11

Name of Experiment: To conduct trial on Heat Pump test rig.

Objectives;

1. To understand principle of operation and working of heat pump system.
2. To calculate theoretical, actual and relative C.O.P. of the system

Working:

The apparatus consists of refrigeration system with water-cooled shell coil type evaporator and condenser. A hermetically sealed compressor using R-134a refrigerant,

Compresses the refrigerant and sends to the condenser. Liquid refrigerant from the condenser passes through flow meter and drier/filter to capillary tube, where it is throttled to low pressure and temperature. The low temperature refrigerant passes to evaporator, boils in evaporator while absorbing heat from the water surrounding the coil and this low pressure superheated refrigerant returns to compressor.

The condenser and evaporator are shell and coil type with continuous water flow. Flow rates of condenser and evaporator can be changed to obtain different working temperatures for condenser and evaporator. Heat collected in evaporator, heat rejected to condenser and input to the system can be measured and performance of the system can be evaluated as refrigeration cycle or as a heat pump. The schematic diagram of mechanical heat pump is shown in figure 1.

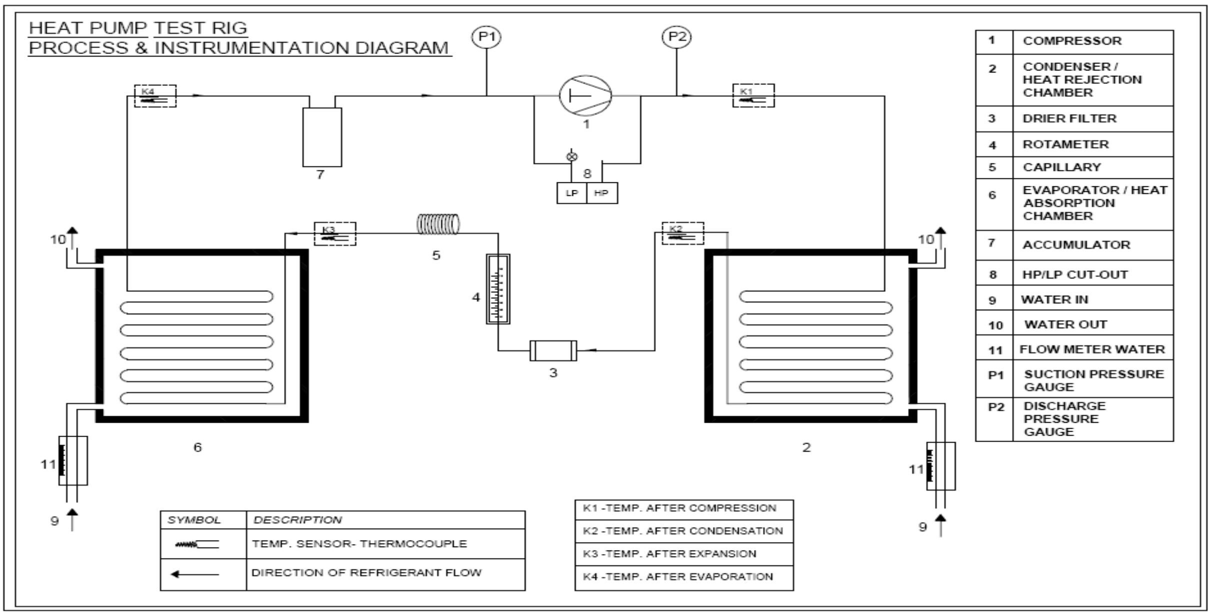


Figure 1. Schematic diagram of mechanical heat pump system.

Specifications:

1. Compressor - Hermetically sealed Emerson Climate Tech compressor,
2. Refrigerant -R-134a
3. Condenser - Shell and coil type condenser.
4. Evaporator - Shell and coil type evaporator.
5. Expansion device – capillary tube.
6. Measurements -
   A. Pressure gauges for condensing and evaporating pressure - 2-nos.
   B. Wattmeter for compressor input measurement.
7. Controls - Overload protector for compressor.
8. Necessary switches and fuse.

Experimental Procedure:

1. Connect the water supply to the unit.
2. Fill both the tanks to 10 liters of clean potable quality of water.
3. Record initial temperature of water in both the tanks

4. Water inlet temperature should be taken before switching on the compressor
5. Switch 'ON" the main supply. Switch 'ON' the compressor.
6. The temperature on the hot side will start steadily increasing and that from the cold side shall be reducing.
7. When the hot side (condenser side) reaches about 50^o C, stop the machine.
8. Record the time between initial and final readings.
9. Note down all the readings and complete the observation table.
10. May you need conduct another set of readings, drain the water completely with the help of drain valves provided at the bottom and refill the tanks with fresh water and repeat the procedure.

Standard Values and Formulas:

Standard Barometric Pressure	=	1.013 bar = 1.013 x 10^5 N /m^2
Density of Water	=	1000 kg / m^3 = 1 kg / liter
Specific heat of water	=	4.18 kJ/kg K
Gas Constant for Air	=	287 J / kg K
Specific Gravity of R-134a at 40^0 C	=	1.2
1 Ton of Refrigeration effect	=	3500 Watts = 3.5 kJ / s
Density of air at 25^0 C	=	1.1 kg/m^3
1 kWHr (kilowatt-hour)	=	3600 kJ
1 bar	=	14.5 psig

Observation Table:

Sr.No.	Observations	Readings	Unit
1	Start time		Sec
2	End time		Sec
3	Cond. water quantity		Liters
4	Evaporator water quantity		_liters
5	Condensing pressure P_c		(psig)
6	Evaporating pressure P_e		(psig)
7	Compressor input time for 10 pulses		sec
8	Temperature after compression		^oC
9	Temperature after condensation		oC
10	Temperature after expansion		oC
11	Temperature after evaporation		oC
12	Condenser/ evaporator initial temp ^{o} C		oC
13	Condenser water final temperature ^{o} C (5)		oC
14	Evaporator water final temperature ^{o} C (6)		oC

CAUTION:

- Do not exceed the condenser side temperature beyond 50^o C
- Always use fresh water for new set of trials.
- Keep the tanks clean and dry when not in use.
- Do not tamper with any of the settings.
- Keep the unit at least 300 mm away from walls.

Figure 2: Photographic view of mechanical heat pump

Calculations:

1. **To calculate Theoretical C.O.P.**

Accordingly,

1. Enthalpy of refrigerant at inlet of compressor h_1 =______________ kJ/ kg
2. Enthalpy of refrigerant at outlet of compressor h_2 =______________ kJ/ kg
3. Enthalpy of refrigerant after condensation h_3 =______________ kJ/ kg
4. Enthalpy of refrigerant after expansion h_4 =______________ kJ/ kg

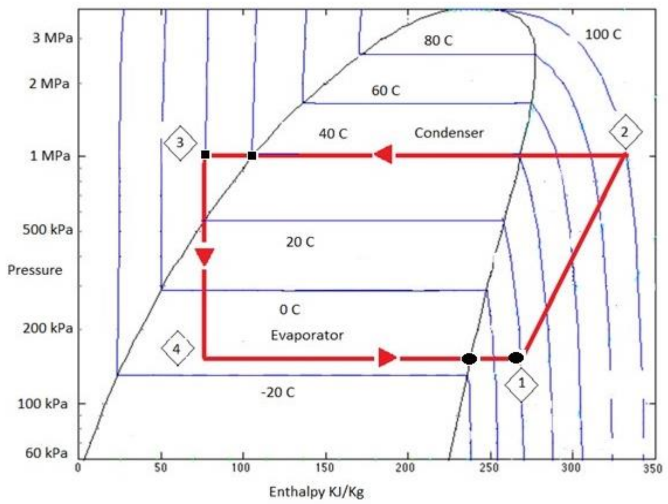


Figure3.P-h chart

5. Theoretical refrigeration effect = N = h_1-h_4= ___________kJ/kg
6. Theoretical compressor work = W = h_2-h_1 = __________kJ/kg
7. Coefficient of performance = C.O.P. = N/W = ______________

(Note: These valves of enthalpies can be calculated with the help of P-h chart of R-134a)

A. c

2. To calculate Actual C.O.P. of the system

$$\text{Actual C.O.P.} = \frac{\text{Heat aborbed in evporator}}{\text{Work supplied to compressor}}$$

1. Heat absorbed in the evaporator from water: $m_w \times C_{pw} \times (T_{W1} - T_{w2})$

   Where,

   m_w = mass of water in evaporator tank (m^3)

   C_{pw} = specific heat of water (kJ/kg K)

   T_{w1} = Initial temperature of water (°C)

   T_{w2} = Final temperature of water (°C)

2. Work supplied to the compressor $W = \dfrac{\text{Number of pulses} \times 3600}{T_{compressor} \times \text{Energy meter constant(compressor)}}$

B. **<u>condenser side</u>**

C. Heat rejected by the condenser to water: $m_w \times C_{pw} \times (T_{W2} - T_{w1})$

Where,

m_w = mass of water in condenser tank (m^3)

C_{pw} = specific heat of water (kJ/kg K)

T_{w1} = Initial temperature of water (°C)

T_{w2} = Final temperature of water (°C)

Work supplied to the compressor $W = \dfrac{\text{Number of pulses} \times 3600}{t_{compressor} \times \text{Energy meter constant(compressor)}}$

3. **To calculate Carnot C.O.P. of the system:**

$$\text{Carnot C.O.P.} = \frac{T_L}{T_H - T_L}$$

= ---------------------

=

T_L= Saturation temperature to corresponding evaporator pressure (bar)

T_H=Saturation temperature to corresponding condenser pressure (bar).

4. **To calculate Relative C.O.P. of the system:**

$$\text{Relative C.O.P.} = \frac{\text{Actual C.O.P.}}{\text{Therotical C.O.P.}} = \frac{..........}{..........} = ---$$

Conclusions:

1. Understand the working of vapour compression cycle and function of each component.
2. It is observed that Carnot C.O.P. > theoretical C.O.P. > actual C.O.P. due to the losses at varies points.

Applications:

Hot water generation for commercial and industrial uses, concentration of juices, milk and sugar syrups, concentration of dyes and chemicals, for recovery of valuable solvents from different manufacturing processes

Questions:

1. How Do Heat Pumps Work?
2. Is a heat pump better than an air conditioner?
3. Is a heat pump environmentally friendly?
4. Differentiate between 'Heat engine', 'Refrigerator' and 'Heat pump'.

Experiment No.12

Name of Experiment: To conduct trial on water cooler test rig.

Objectives;

1. To understand principle of operation and working of a Water Cooling System.
2. To determine Coefficient of Performance of the system.

Working:

The Water Cooler test set up enables students to study and understand vapour compression cycle, its components, principle and working. All the components are mounted on rigid steel frame. The trainer consists of a hermetically sealed compressor, forced convection air-cooled condenser, filter / drier, expansion device and coil wound type evaporator. Separate pressure gauges are provided to record suction and discharge pressures and digital temperature indicators for various temperatures.

The refrigerant used is R-134a which is environment friendly.

The water cooler consists of an insulated stainless steel tank around which evaporator tubes are wound and soldered. The tubes are made of refrigerated grade annealed copper tubes. This is a direct expansion type evaporator. The heat absorbed by the refrigerant is passed through water which is stored in the tank as shown in figure1.

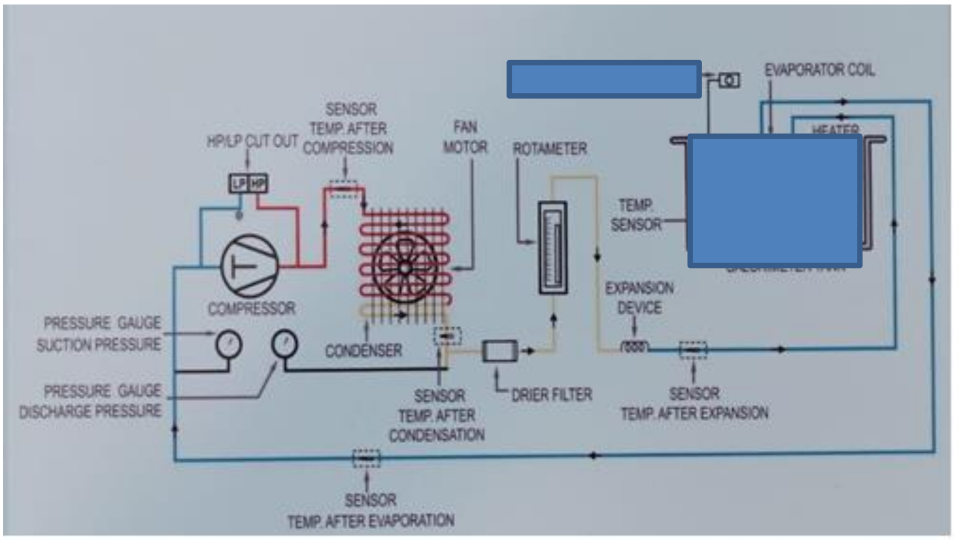


Figure1. Schematic diagram of water cooler test rig

Specifications

A. Refrigeration System

Parameter	**Description**
Capacity	20 Liters water storage
Compressor	Hermetically sealed
Condenser	Forced convection air cooled.
Condenser fan	Axial flow type
Evaporator	Direct expansion type
Expansion device	Capillary Tube
Accumulator	Copper / M.S. shell suction line accumulator provided.
Insulation	Polyurethane Foam (PUF)
Refrigerant	R-134 a.

B. Controls & Indications

Temperature	Thermostat with Indication & 6 channel digital display
Pressure	Pressure gauges 2 Nos. provided

C. Electrical System

Supply	230 Volts, 50 Hz, 1 phase.
Input power	500 Watts.
Rated current	2.8 Amps.
Energy-meters	Provided for compressor

D. Construction

Water Tank	Stainless Steel
Outer body	Stainless steel / or powder coated.
Size	1000 x 1200 x 450 (L X H X D) mm

Operating Instructions:

1. Place the machine in the proper position where its level is horizontal and it is well ventilated.
2. Give 230 volts, 50Hz, and 1 phase supply to the unit.
3. Fill water in the tank up to over flow level.
4. Switch ON the main switch.
5. Connect the water supply to the feeding.
6. Start the compressor by putting the switch ON.
7. The tank temperature will start dropping down.
8. Record all the readings as per the observation table.
9. Calculate the results as mentioned in the manual

Figure2. Photographic view of water cooler test rig.

Standard Values and Formulas:

Standard Barometric Pressure	**=**	**1.013 bar = 1.013 x 10^5 N /m^2**
Density of Water	**=**	**1000 kg / m^3 = 1 kg / liter**
Specific heat of water	**=**	**4.18 kJ/kg K**
Gas Constant for Air	**=**	**287 J / kg K**
Specific Gravity of R-134a at 40^0 C	**=**	**1.2**
1 Ton of Refrigeration effect	**=**	**3500 Watts = 3.5 kJ / s**
Density of air at 25^0 C	**=**	**1.1 kg/m^3**
1 kWHr (kilowatt-hour)	**=**	**3600 kJ**
1 bar	**=**	**14.5 psig**

Observation Table:

Sr.No.	Observations	Readings	Unit
1	Start time		Sec
2	End time		Sec
3	Water quantity in water tank		Liters
4	Condensing pressure P_c		(psig)
5	Evaporating pressure P_e		(psig)
6	Compressor input time for 10 pulses		sec
7	Temperature after compression		^oC
8	Temperature after condensation		oC

Calculations:

1. **To calculate Theoretical C.O.P.**

8. Enthalpy of refrigerant at inlet of compressor h_1 =______________ kJ/ kg
9. Enthalpy of refrigerant at outlet of compressor h_2 =______________ kJ/ kg
10. Enthalpy of refrigerant after condensation h_3 =______________ kJ/ kg
11. Enthalpy of refrigerant after expansion h_4 =______________ kJ/ kg

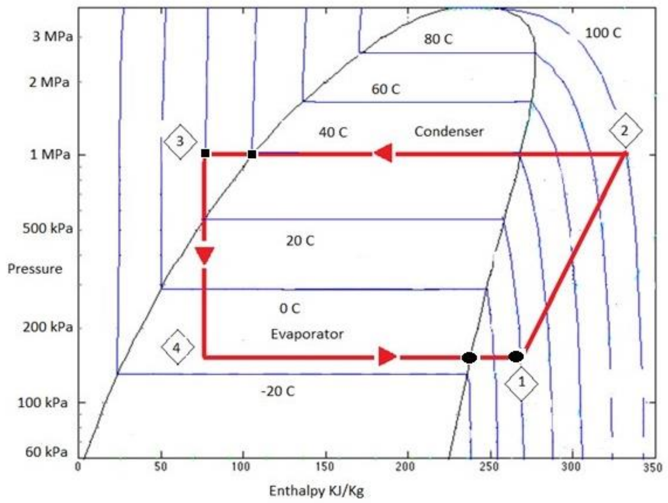


Figure3.P-h chart

12. Theoretical refrigeration effect = N = h_1-h_4= __________kJ/kg

13. Theoretical compressor work = W = h_2-h_1 = _________kJ/kg

14. Coefficient of performance = C.O.P. = N/W = _____________

(Note: These valves of enthalpies can be calculated with the help of P-h chart of R-134a)

2. To calculate Actual C.O.P. of the system

$$\text{Actual C.O.P.} = \frac{\text{Heat aborbed in evporator}}{\text{Work supplied to compressor}}$$

5. Heat absorbed in the evaporator from water: $m_w \times C_{pw} \times (T_{W1} - T_{w2})$

   Where,

   m_w = mass of water in evaporator tank (m^3)

   C_{pw} = specific heat of water (kJ/kg K)

   T_{w1} = Initial temperature of water (°C)

   T_{w2} = Final temperature of water (°C)

6. Work supplied to the compressor $W = \dfrac{\text{Number of pulses} \times 3600}{T_{compressor} \times \text{Energy meter constant(compressor)}}$

3. To calculate Carnot C.O.P. of the system:

$$\text{Carnot C.O.P.} = \frac{T_L}{T_H - T_L}$$

= ---------------------

=

T_L= Saturation temperature to corresponding evaporator pressure (bar)

T_H=Saturation temperature to corresponding condenser pressure (bar).

4. To calculate Relative C.O.P. of the system:

$$\text{Relative C.O.P.} = \frac{\text{Actual C.O.P.}}{\text{Therotical C.O.P.}} = \frac{\text{..........}}{\text{..........}} = ---$$

Conclusions:

3. Understand the working of vapour compression cycle and function of each component.
4. It is observed that Carnot C.O.P. > theoretical C.O.P. > actual C.O.P. due to the losses at varies points.

Applications

As water is palatable at 12 to 15^{o} C, it used in offices, schools, colleges, restaurants, factories for drinking water storage and cooling.

Questions:

A. What are different components and controllers used in water cooler?
B. What is the temperature range of drinking water?
C. What are the benefits of drinking of cold water?
D. List out leading manufacturer of water cooler in the India (at least three)
E. Write the technical specifications of water coolers (leading manufactures in India at least three)

Experiment No.13

Name of Experiment: To conduct trial on air conditioning test rig.

Objectives:

1. To evaluate the tonnage capacity of the air conditioning system by enthalpy difference method.
2. To evaluate actual and theoretical C.O.P. of the system.
3. To plot the refrigeration cycle on P-H & T-S charts.
4. To plot the psychometric processes on psychometric charts.

Working:

The Air Conditioning system is works on Vapour compression Refrigeration cycle using R 22 as a refrigerant. It has hermetically sealed compressor, which sucks vapour refrigerant from the evaporator. The vapour is compressed to higher pressure and consequently to higher temperature in the compressor. The high pressure and high temperature refrigerant then enters the condenser, where its latent heat is removed by rejecting the heat to the air passing over the forced convection condenser.

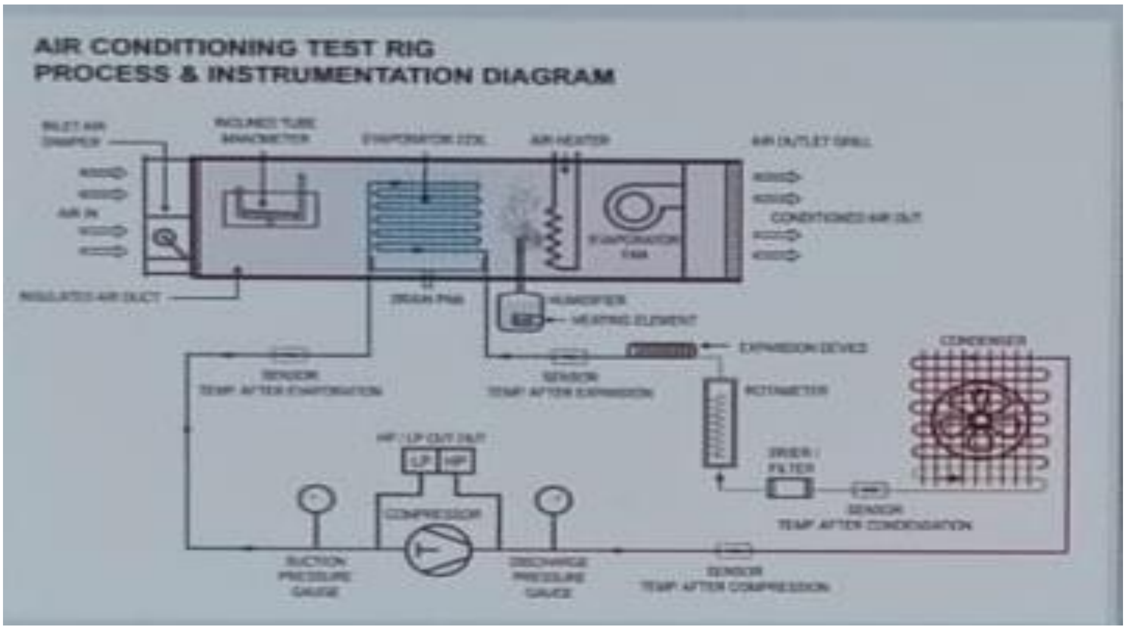


Figure1. Experimental setup of air conditioning test rig.

The liquefied refrigerant passes through drier (where any residual moisture is absorbed) and through rotameter (where flow is measured) and enters the expansion device. In the expansion device, (either a capillary tube or expansion valve) the refrigerant is throttled to a lower pressure and as a result, the temperature of the refrigerant also reduced.

This low temperature wet vapour flows through the evaporator, which is a forced convection air-cooled evaporator. Here, the refrigerant picks up heat from air passing over it and gains heat; it evaporates and enters the compressor. This cycle repeats. The schematic diagram of experimental set-up shown in figure 1.

In addition to basic system components, many controls such as overload protector, thermostat, HP/LP cut-out are provided to safeguard the system against any malfunctioning. To accomplish psychometric processes, heating elements and humidification arrangement is provided. To vary the airflow, air dampers are provided. For measurement of pressures dial type pressure gauges are fitted and to record temperatures digital temperature scanner is incorporated. The photographic view of air conditioning test rig is shown in figure2.

Specifications:

Capacity	:	0.75 tr @ rated test conditions
Compressor	:	Hermetically sealed. Make: emerson climate tech.or any equivalent make.
Condenser	:	Forced convection air cooled.
Condenser fan	:	Axial flow.
Drier/ filter	:	Provided.
Expansion device	:	Capillary tube.
Evaporator	:	Direct expansion, shell & coil type Water in shell & refrigerant in coil
Evaporator fan	:	Centrifugal / axial flow type
Dehumidifier	:	finned type air heater.
Humidifier	:	Provided
Refrigerant	:	R-22
Hp / lp cut-out	:	Alco/ or danfoss / or indfoss or any equivalent make.
Temperature	:	6 channel facility with digital display.
Pressure	:	2 nos.; dial type pressure gauges.
Refrigerant flow	:	Glass tube rotameter provided.

Air temperature	:	DBT & WBT measurement by sling psychrometer.
Air flow measurement	:	By inclined tube manometer.
Supply	:	220-240 volts, 50 hz, 1 phase.
Input power	:	1.2 kw.
Rated current	:	5 amps.
Indicating lamps	:	Provided for compressor and heater.
Energy-meter	:	Range 0-20 a; provided for compressor
Material	:	Panel: 1.2 mm thick
Outer finish	:	Powder coating

Procedure:

1) Connect the supply cable to regulated / stabilized power supply.
2) Switch ON the main switch.
3) Put ON the AHU fan.
4) Record the DBT & WBT at the inlet and at the outlet of the duct. (Ensure that the well of WBT is filled with water.) Use psychrometer.
5) Switch ON the compressor.
6) Allow the system to reach steady state.
7) Record the air temperatures at inlet and outlet (DBT & WBT) Use psychrometr.Record the Energy-meter reading.
9) Record suction and discharge pressures.
10) Record Rotameter reading, refrigerant temperatures at various locations viz: before &after compression and before & after expansion.
11) Measure velocity head with the help of manometer at inlet of the ducting.
12) Take minimum 6 to 8 numbers of readings in 15 minutes of intervals each.

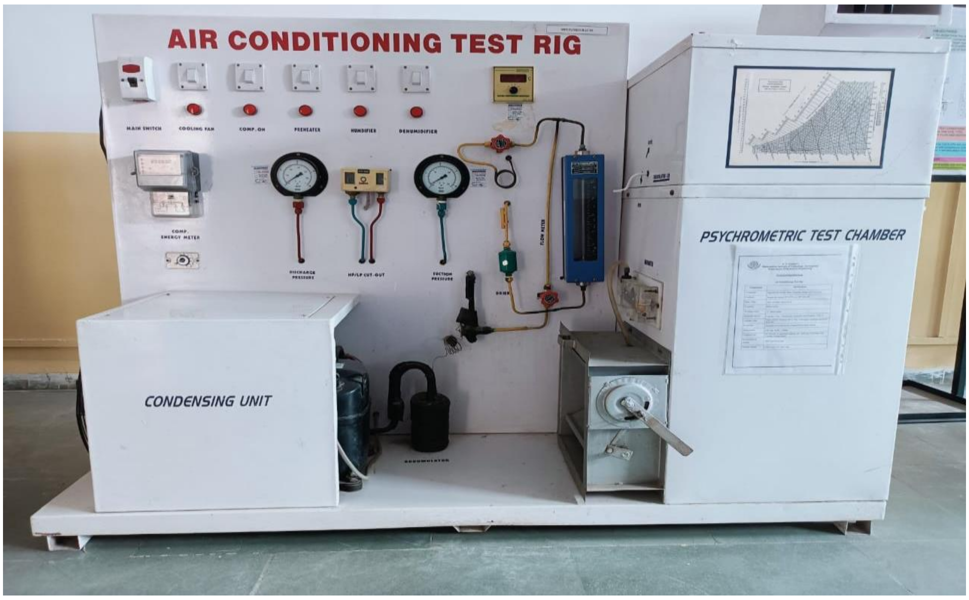


Figure 2. Photographic view of air conditioning test rig.

Standard Values and Formulae

Standard Barometric Pressure	=	1.013 bar = 1.013 x 10^5 N /m^2
Density of Water	=	1000 kg / m^3
Gas Constant for Air	=	287 kg / kJ K
Specific Gravity of R-22 at 40^0 C	=	1.2
1 Ton of Refrigeration effect	=	3500 Watts = 3.5 kJ / s
Density of Air at 25^0 C	=	1.1 kg/m^3

Observation table:

Sr.No.	Time hrs	Inlet air temp. ^{0}c		Outlet air temp. ^{0}c		Suction pressure (lp) psig	Discharge pressure (hp)psig	Refrigerant Temperatures ^{0}c				Energy meter kwhr	Refrigerant flow	Manometer reading mm of wg	Sectional area of the duct
		DBT	WBT	DBT	WBT			After evaporation	After compression	After	After expansion				

Calculations:

To determine

1. **Tonnage capacity of the A.C. system:**

Inlet conditions	:	°C DBT °C WBT
Outlet conditions	:	°C DBT °C WBT
Inlet air enthalpy h_1	=	kJ/kg
Outlet air enthalpy h_2	=	kJ/kg
Enthalpy difference	=	h_1-h_2 kJ/kg
Velocity head, h	=	mm of liquid column
Velocity of air	=	m /s
Air outlet sectional area, A	=	m^2
Volume flow rate of air, Q	=	V x a = m^3/s
Mass flow rate of air m	=	Volume flow rate x density of air
	=	Q x 1.1 kg /sec
Refrigeration effect (actual) N	=	Mass flow rate x enthalpy difference
	=	m x (h_1-h_2) kJ/ sec
Tonnage capacity TR	=	N/ 3.5 TR

2. **Actual C.O.P. of the system**

Refrigeration effect (actual) N	=	mass flow rate x enthalpy difference
		m x (h1-h2) kj / sec
compressor work, W	=	energy meter reading/ time in hrs.
	=	kw or kJ/ s
Actual C.O.P.	=	N/ W
	=	

3. **Theoretical C.O.P. of the system:**

To evaluate theoretical C.O.P. of the system, carry out following procedure.

1. For any set of readings at a particular time, note suction and discharge pressures in psig.
2. Divide these pressures by 14.5 to convert them into bar.
3. Add barometric pressure of the present location to obtain absolute pressures in bar.
4. Locate these pressures on "Y" axis of P-h chart. Draw two horizontal lines, one for low pressure and one for high pressure.
5. Locate particular temperatures on these lines and mark 1,2,3,4.
6. Find out enthalpies at salient points by referring to "X'' axis of P-H chart.

   h_1= kJ/kg

   h_2= kJ/kg

   h_3= kJ/kg

   h_4= kJ/kg

7. N= refrigeration effect= h_1-h_4= kJ/kg
8. W= compressor work = h_2-h_1= kJ/kg
9. Theoretical C.O.P. = N / W = $(h_1-h_4) / (h_2-h_1)$

Conclusions

1. Understand the working of air conditioning system and effect on varies psychometric properties and its processes.
2. Calculated theoretical and actual C.O.P. of the systems.
3. The cooling capacity of the plant = ---------------kW i.e.-----------TR
4. The Actual C.O.P. of the system is -------------------------
5. The theoretical C.O.P. of the system is ------------------

Questions:

1. Define and explain an 'air-conditioning system with neat sketch. Name its basic elements.
2. Explain with neat sketch explain the main components of central air-conditioning system.
3. Explain the difference between summer air-conditioning and winter air conditioning.
4. Define room sensible heat factor. How room sensible heat factor line is drawn on the psychometric chart?
5. List the application of air-conditioning & Define room sensible heat factor and effective room sensible heat factor.
6. State the factor which should be taken into consideration while selecting a system of air conditioning

Experiment No.14

Name of Experiment: To conduct trial on window air conditioning system.

Objectives:

1. To calculate.
   a) Actual C. O. P
   b) Theoretical C. O. P of the cycle.
2. To determine tonnage capacity of the window type air conditioner.
3. To plot operating cycle on p-h chart.

Working:

The window conditioning system works on vapour compression Refrigeration cycle using R-22 as a refrigerant.

This system is having a hermetically sealed compressor, which sucks refrigerant vapour from the evaporator. The vapour is compressed to higher pressure and consequently to higher temperature in the compressor. The high pressure and high temperature refrigerant then enters the condenser, where its latent heat is removed by rejecting the heat to the air passing over the forced convection condenser. The liquefied refrigerant passes through drier (where any residual moisture is absorbed) and through rotameter (where flow is measured) and enters the expansion device. In the expansion device, (either a capillary tube or expansion valve) the refrigerant is throttled to a lower pressure and as a result, the temperature of the refrigerant also reduced. This low temperature wet vapour flows through the evaporator, which is a forced convection air cooled evaporator. Here, the refrigerant picks up heat from air passing over it and gains heat; it evaporates and enters the compressor. This cycle repeats. For measurement of pressures dial type pressure gauges are fitted and to record temperatures digital temperature scanner is incorporated. The schematic diagram of window air-conditioning system is shown in figure1 and 2.

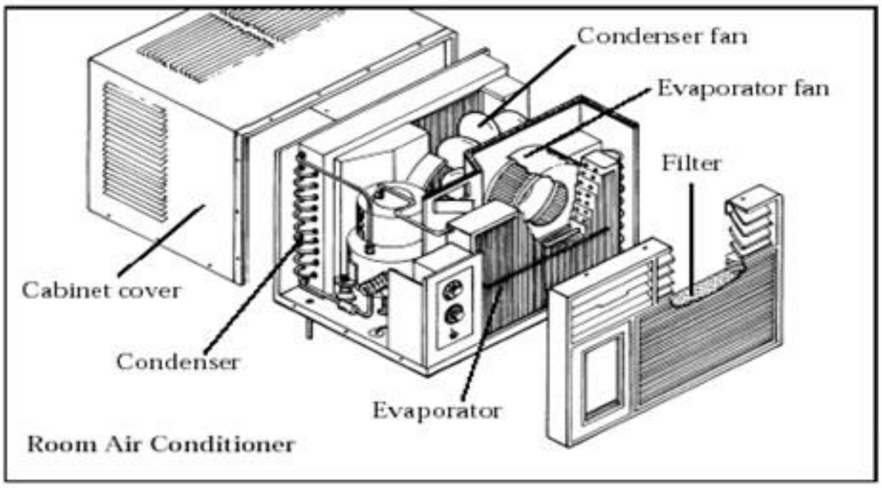


Figure1. Window air conditioning unit.

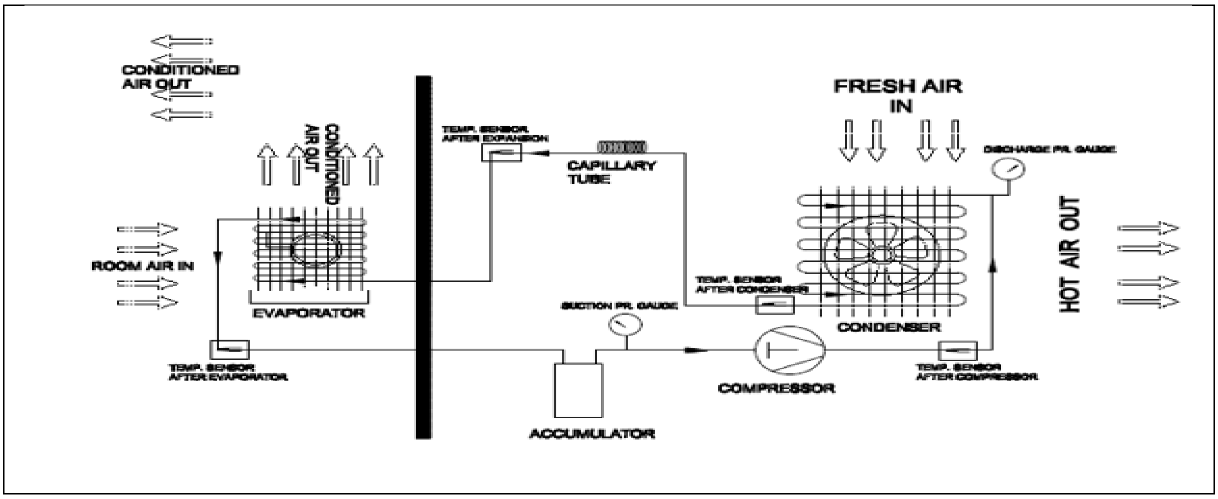


Figure 2. Schematic diagram of window air-conditioning system

Figure2. Photographic view of window air conditioning system

Specifications:

Nominal capacity	:	3350 watts at rated test conditions
Make	:	Blue star ltd.
Compressor	:	Hermetically sealed, rotary
Condenser	:	Forced convection air cooled
Evaporator	:	Forced convection air cooled
Expansion device	:	Capillary tube
Thermostat	:	On panel
Energy meter	:	For compressor provided
Pressure gauges	:	1 no for suction pressure 1 no for discharge pressure
Temperature indicator	:	Digital temperature indicator

Dry bulb temperature and wet bulb temperature measurement	:	By sling psychrometer
Air flow measurement	:	By inclined tube manometer

1. **To calculate actual C.O.P. of the system:**

C.O.P.	=	Refrigeration effect**/** work input N / w
Now, N	=	Cooling effect
	=	Enthalpy difference of air at inlet and outlet.
To calculate enthalpy at inlet we have h_1	=	Enthalpy of air at inlet condition
	=	Enthalpy of air corresponding to its wet bulb temperature
Similarly, enthalpy of air at outlet condition h_2	=	kj/kg
Enthalpy difference	=	$H_1 - h_2$ kJ/kg
	=	
	=	KJ/kg
Refrigeration effect	=	m (h_2- h_1) kJ/ s
Where m	=	Mass flow rate of air which can be computed with the help of inclined tube manometer
To find out work input to the system, we have Energy meter reading difference	=	Final reading – initial reading
	=	unit = 1 kwhr = 3600 kJ
Time elapsed	=	seconds
Work input per unit time (input power)	=	kW

2. **Theoretical C.O.P. of the system**

To evaluate theoretical C.O.P. of the system, carry out following procedure.

1. For any set of readings at a particular time, note suction and discharge pressures in psig.
2. Divide these pressures by 14.5 to convert them into bar.
3. Add barometric pressure of the present location to obtain absolute pressures in bar.
4. Locate these pressures on "Y" axis of P-H chart. Draw two horizontal lines, one for low pressure and one for high pressure.
5. Locate particular temperatures on these lines and mark 1,2,3,4.
6. Find out enthalpies at salient points by referring to "X'' axis of P-H chart.

   h_1=

   h_2=

   h_3=

   h_4=

7. N= Refrigeration Effect= h_1-h_4 = KJ/kg
8. W= Compressor Work = h_2-h_1 = KJ/Kg
9. Theoretical C.O.P. = N / W = $(h_1 - h_4) / (h_2 - h_1)$

3.Draw the psychometric processes on hand drawn and actual psychometric chart such cooling, humidification, heating etc.

Results:

The capacity of the air conditioner		kW TR
The actual C.O.P. Of the system	:	
The theoretical C.O.P. of the system	:	

Conclusions:

1. Understand working of window air conditioner and its components.