UNIT: 3 Refrigeration

Question Bank

1. Define Refrigeration cycle.
2. Explain main requirement of good refrigerant. Explain primary and secondary refrigerants. Name the refrigerant generally used.
3. What are different types of refrigeration.
4. Explain in detail the function of the refrigerator. Also draw and explain its electrical circuit.
5. Describe with neat sketch the working of drinking water cooler.
6. Describe with neat sketch **vapour absorption refrigeration** system. Compare it with **vapour compression system**.

Refrigeration

The word refrigeration refers to the process of cooling space, material, or system to lower and maintain its temperature under room temperature. Refrigeration is a type of artificial cooling. Heat is extracted from a low-temperature reservoir and transmitted to a high-temperature reservoir. Energy transfer work is classically powered by mechanical means, but it can also be powered by high temperatures, magnetism, power generation, laser, or other means. Domestic refrigerators, factory freezers, cold fusion, and air conditioning are all examples of refrigeration applications.

Refrigeration has had a significant effect on the industry, way of life, agricultural production, and population structure. Food preservation dates back to the ancient Egyptian and Chinese empires. Mechanical refrigeration technology, on the other hand, has advanced rapidly over the last couple of centuries, from ice harvesting to air-temp rail cars.

Refrigeration Cycle/Vapour Compression Type Refrigeration:

The purpose of a refrigeration cycle is to absorb and reject heat. The four basic components of a basic cycle are the compressor, condenser, expansion device, and evaporator. Let us explore them individually.

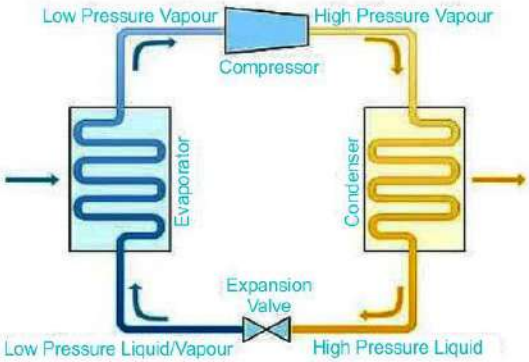

Fig. 1. Refrigeration Cycle

Compressor

- The first stage in the refrigeration cycle is compression.
- A compressor is the component of the system that boosts the pressure of the refrigerant fluid.
- The refrigeration fluid enters the compressor as a low-pressure, low-temperature gas and exits as a high-pressure, high-temperature gas.
- Compression can be accomplished through a variety of mechanical processes, and as a result, several compressed air designs are used in HVAC and cooling systems today.
- Here are a few popular ones: Reciprocate compressors, Scroll compressors, Rotary compressors, and so on.

Condenser

- In a basic refrigeration loop, the condenser is also known as the condenser coil.
- It consists of a series of tubes of external fins situated at the back of the refrigerator.
- This component aids in the conversion of the gaseous refrigerant to liquid form.
- This component receives high-temperature, high-pressure vaporised refrigerant from the compressor.

- The condenser extracts heat from hot refrigerant vapour gas vapour until it cools into a concentrated liquid state, also known as condensation.
- The coolant is a high-pressure, low-temperature fluid after condensing, and it is routed to the loop's expansion device.

Expansion device

- The expansion valve regulates the flow of coolant into the evaporator, also known as the cooling coil.
- Flow control valves are another name for expansion valves.
- It is a delicate simple tool that aids in sensing refrigerant temperature changes. However, regardless of setup, the purpose of a system's expansion device is the same: to create a pressure drop after the refrigerant exits the condenser.
- Because of the pressure drop, some of the refrigerants will quickly boil, resulting in a two-phase mixture.
- This rapid phase change is known as flashing, and it assists the evaporator, the next part of hardware in the circuit, in performing its intended function.
- These components are available in a variety of styles including fixed orifices, thermostatic valves or thermal expansion valves, and more modern automation expansion valves are all popular configurations.

Evaporator

- The evaporator is another heat exchanger in a typical refrigeration circuit, and it, like the condenser, is named after its primary function.
- Because it accomplishes what we predict air conditioning to do is absorb heat.
- It serves as the end of a refrigeration cycle.
- It is the main component of the cooler that assists in keeping the device and its contents cool at all times.
- It has high thermal conductivity tubes that aid in the absorption of heat rejected by the system's fan or coil.
- This occurs when coolant enters the exchanger as a low-temperature fluid at low pressure, and a blower forces air across the evaporator's fins, cooling the atmosphere by absorbing heat from the space in question.

Required Properties of Ideal Refrigerant:

1. A refrigerant should have high latent heat of vaporization at the evaporator pressure. The high latent heat results in a high refrigerating effect per kg of refrigerant circulated.
2. The refrigerant should have a low boiling point and low freezing point. 3. It must have low specific heat and high latent heat. Because high specific heat decreases the refrigerating effect per kg of refrigerant and high latent heat at low temperature increases the refrigerating effect per kg of refrigerant.
4. It must have high critical pressure and temperature to avoid large power requirements.
5. It should have a low specific volume to reduce the size of the compressor.
6. The pressures required to be maintained in the evaporator and condenser should be low enough to reduce the material cost and must be positive to avoid leakage of air into the system.
7. It must have high thermal conductivity to reduce the area of heat transfer in the evaporator and condenser.
8. It should be non-flammable, non-explosive, non-toxic, and non-corrosive.
9. It should not have any bad effects on the stored material or food when any leak develops in the system.
10. It must have high miscibility with lubricating oil and it should not have to react properly with lubricating oil in the temperature range of the system.
11. It should give a high COP in the working temperature range. This is necessary to reduce the running cost of the system.
12. Both the evaporator and condenser pressure should be above atmospheric pressure and as near to the atmospheric pressure as possible

Primary and secondary refrigerants

◉ Primary refrigerants are those fluids, which are used directly as working fluids, for example in VCR and absorption-based systems.
◉ These fluids provide the necessary refrigeration by undergoing a phase-change process in the evaporator, absorbing latent heat.
◉ As the name implies, secondary refrigerants are those liquids, which are used for transporting thermal energy from one location to other.
◉ Secondary refrigerants are also known referred to as brines or antifreezes.
If the operating temperatures are above 0°C, then pure water can also be used as secondary refrigerant, for example in large air conditioning systems (like we have in IIT Kanpur).
◉ Antifreezes or brines are used when refrigeration is required at sub-zero temperatures.
◉ Unlike primary refrigerants, secondary refrigerants do not undergo phase change as they transport energy from one location to other.

Secondary refrigerants are also called as Cooling medium.
◉ Cooling Medium: is a working fluid cooled by the refrigerant to transport the cooling effect between a central plant and remote cooling units and terminals
◉ Chilled water, brine, and glycol are used as cooling media in many refrigeration systems.
◉ It reduces the extensive circulation of the primary refrigerant.
An important property of a secondary refrigerant is its freezing point. Generally, the freezing point of a brine will be lower than the freezing point of its constituents (i.e. mixture components).
◉ The temperature at which freezing of a brine takes place depends on its concentration. The concentration at which a lowest temperature can be reached without solidification is called as eutectic point.
◉ The commonly used secondary refrigerants are the solutions of water and ethylene glycol, propylene glycol or calcium chloride. These solutions are known under the general name of brines.

Working Principle of Refrigeration

The operating principle of a refrigerator is straightforward:

- It takes heat from one area and deposits it in another.
- When a low-temperature liquid is passed close to a fluid that needs to be cooled, heat from those objects is transmitted to the fluid. It evaporates and absorbs heat during this process.

When the gas is compressed, it heats up and cools when it is enlarged. The same principle applies when a bicycle pump feels warm when one uses a pump to pump air inside it, but cold when perfume is sprayed. This physics principle, along with a few other components, assists the fridge in keeping the food cool.

Working of Refrigerator

- The refrigerant circulates inside the refrigerator by changing from liquid to gas. This is known as evaporation. It achieves the desired effect by cooling the surrounding area
- To maintain the fridge running, the pressure of the refrigerant is reduced via a capillary tube. To begin evaporative cooling and modify the refrigerant from liquid to gas, the pressure must be reduced.
- The capillary tube is the outlet, and the outdoor area is the evaporator. When we release the fluid into the pressure drop open space, it changes from a liquid to a gas.
- The gas refrigerant must be converted to liquid form. The compressor does this by compressing the gas to a greater pressure and temperature.
- The gas becomes heated under high pressure. This must be cooled in the condenser. This is situated on the back of the refrigerator to allow air to cool the contents.
- The condenser cools the gas inside, converting it back to liquid.
- This changed liquid refrigerant returns to the refrigerator exchanger, and the cycle begins again. This keeps the fridge running.
- This is the refrigerator's mechanism. The process appears complicated, but it is based on scientific principles, making it possible.

Methods of Refrigeration

There are two methods of refrigeration that are cyclic and non-cyclic. Each is explained below.

Cyclic Process

- The heat is taken from the cold reservoir and thrown into the high-temperature reservoir during the cyclic process of refrigeration.
- The natural flow of heat, according to the second law of thermodynamics, is from the high-temperature reservoir to the low-temperature reservoir.
- Because the flow of heat is reversed in the cyclic refrigeration process, external work must be performed on the system.
- The refrigeration cycle is also known as the Reverse Carnot Cycle because it is the inverse of the thermal power cycle or Carnot cycle, in which heat flows from a high-temperature reservoir to a low-temperature reservoir.

Non-Cyclic process

- Cooling is accomplished in non-cyclic refrigeration by melting ice or subliming dry ice.
- These techniques are employed for small-scale refrigeration in laboratories and workshops, as well as in portable coolers.
- Ice's effectiveness as a cooling agent is due to its continuous melting point of 0 °C. Food and other grocery items that are kept at this temperature or slightly higher have a longer storage life.
- Solid carbon dioxide rapidly converts from a solid to a vapour phase at -78.5 °C, making it useful for keeping products at cold temperatures during the melting process.
- Total loss refrigeration occurs when the cooling agent evaporates and is then released into the atmosphere into space.

Applications of Refrigeration

The main applications of refrigeration are as follows:

- Refrigeration systems are frequently used in the chemical industry to separate and liquefy gases and vapours.
- Refrigeration processes are excellent for ice production.
- The primary application of refrigeration is the cold storage of perishable foods.
- A refrigeration system serves to cool the water if it is necessary.
- In the manufacturing processes and heat treatment of steels, it is used to control the humidity of the air.
- In oil refineries, chilling the oil to remove wax.
- For the preservation of capsules and medications in the pharmaceutical sector.
- They are also used in medical fields to preserve blood, medical fields, tissues, and so on.

Difference between Refrigeration and Air Conditioning

A few differences between refrigeration and air conditioning are as follows:

Sr. No	Refrigeration	Air conditioning
1.	Heat is transferred to an area with a high temperature.	Heat is removed to keep the temperature low.
2.	The circulation system is meant to keep cool air inside the unit.	The circulation system is intended to direct cool air apart from the unit.
3.	A single unit houses the exchanger, compressor, and condenser.	The evaporator and the other components which are the compressor and condenser are in two separate units.
4.	Gas is supplied to the operation via pipes.	The unit's built-in chemicals extract air from the surrounding environment.
5.	Its main purpose is to simply adjust the temperature to cool or freeze.	Its main purpose is to reduce the temperature while maintaining purity and humidity.
6.	A fan inside the unit is not required.	A fan inside the unit is necessary.
7.	Temperatures must be between 1°C and 4°C.	Temperatures range from 18°C to 24°C.
8.	Power consumption is less.	Power consumption is more.
9.	Its purpose is only cooling.	Its purpose is both cooling and heating.
10.	An example is a refrigerator.	An example is the air conditioner.

Construction and working of Storage type water cooler:

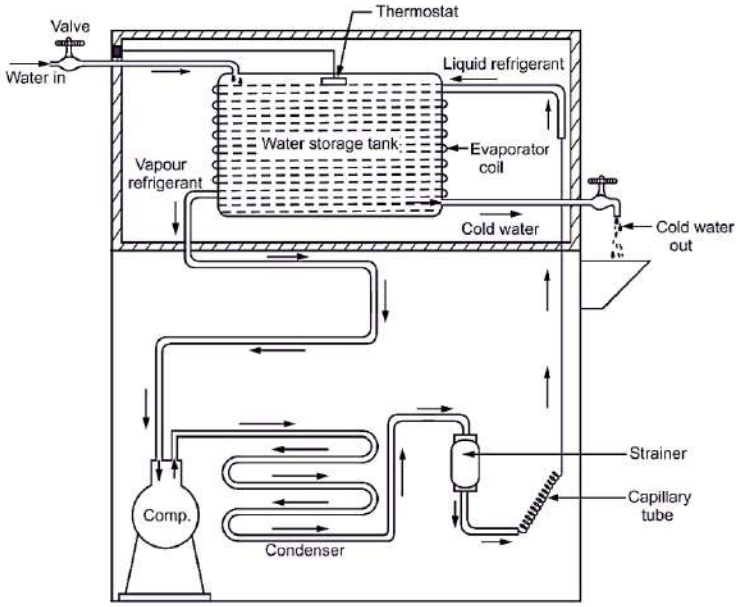

Fig: Storage type water cooler

In storage type, tap water (water to be cooled) is stored in a large storage tank, surrounded by a cooling coil (see Figure 1). It takes more time in the beginning to lower the temperature of water. It is generally used in schools, offices, hospitals etc.

Cycle used: Vapour compression cycle.

Refrigerant: R-134a.

The storage-type water cooler has an evaporator coil soldered on the out- side surface of the wall. The tank is made of stainless steel or GI sheet. The water level in the water tank is maintained and controlled by a float valve.

Construction: The water cooler has a metal sheet cabinet. It consists of a hermetically sealed compressor, condenser, capillary tube, accumulator, refrigerant coil, water cooling coil, thermostat, relay, overload protection etc. The thermostat is provided to control the temperature of the water. Separate inlet and outlet connections of water are provided to the storage tank. The water

level is maintained with the help of a float valve to minimise the wastage of refrigerated water. A push-type water tap is generally provided for drawing cold water.

Working: When the vapour compression system starts to operate, the heat of water is taken up by the refrigerant flow through the evaporator coil and gets evaporated. This vapour refrigerant is sucked by the compressor, where it is compressed to high pressure, high temperature and is sent to the condenser. In an air-cooled condenser, the heat content of refrigerant is rejected to the atmosphere. A condenser fan is placed in front of the condenser coils to produce an artificial draught of air. This increases rate of cooling and refrigerant and condensation of vapour refrigerant into liquid refrigerant occurs in short time. From condenser outlet, the liquid refrigerant passes through a capillary tube to the evaporator coil and the cycle is repeated number of times, till the desired cooling of water occurs. As soon as, the desired temperature is attained by water in the storage tank, the compressor is cut-off by thermostat.

Applications: Used in offices, schools, hospitals, factories etc.

Construction and Working of Domestic Refrigerator

Primary function of domestic refrigerator: "To provide food storage space or cabinet maintained at low temperature (0°C to 4°C) for the preservation of food."

Secondary function of domestic refrigerator: "Formation of ice cubes."

Refrigeration cycle used: Vapour Compression Cycle (V.C.C.).

Commonly used Refrigerant: R -134a.

Capacity of the domestic refrigerator: It is expressed in terms of "Litres". Standard refrigerators of capacity 90, 165, 210, 300, 420 litres etc. are available in market.

Construction of Domestic Refrigerator:

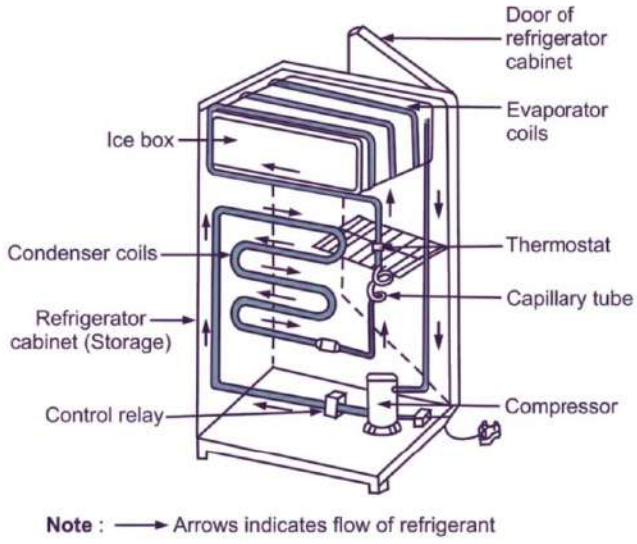

Fig. 1: Domestic refrigerator

Refrigeration system of domestic refrigerator consists of following main components:

- Hermetically sealed compressor.
- Fin and Tube type evaporator.
- Accumulator.
- Thermostat.
- Air-cooled condenser.
- Capillary tube.
- Drier and strainer.

Domestic refrigerator has a cabinet shape. Compressor is located in its basement, whereas, condenser and receiver are located at the backside. Refer Fig. 1. Compressor is a back cylindrical-shaped machine. Suction, dis-charge and charging tubes are fitted to the compressor. On the compressor body, control devices such as relay, overload protector etc. are fitted. Evaporator remains exposed inside the storage cabinet. Ice trays are kept in the ice box, which is a part of evaporator for producing small quantity of ice. Condenser is a black coloured wounded coil or tube generally kept at backside. By adjusting thermostat knob, desired temperature in the evaporator can be set. Strainer is provided to remove impurities from the refrigeration system. Drier is provided to remove moisture (i.e. water vapour associated with refrigerant) from the refrigeration system. A soft rubber gasket with magnetic wire is provided at the door of cabinet

to provide a tight seal to prevent atmospheric air from entering into the refrigerator cabinet through small openings.

Working of Domestic Refrigerator:

Low pressure, low temperature liquid refrigerant enters In to the evaporator, absorbs heat from the space to be refrigerated or cooled and gets converted into low-pressure, low-temperature vapour refrigerant. It creates cooling effect in the space to be refrigerated, Refer Fig. 2. This low pressure vapour refrigerant is sucked by the compressor, where its pressure and temperature are increased by compression. High pressure and high temperature vapour refrigerant delivered by compressor is cooled and condensed to liquid state in the condenser. Thus, heat is rejected by the refrigerant in the condenser. Then, this high pressure liquid refrigerant is passed through capillary tube, where it undergoes throttling expansion and due to expansion, its pressure is reduced to obtain low pressure liquid refrigerant. Low pressure and low temperature liquid refrigerant is supplied to evaporator, where it absorbs heat from the space to be cooled. This completes one cycle. The above cycle is repeated again and again, till the desired refrigerating effect is achieved.

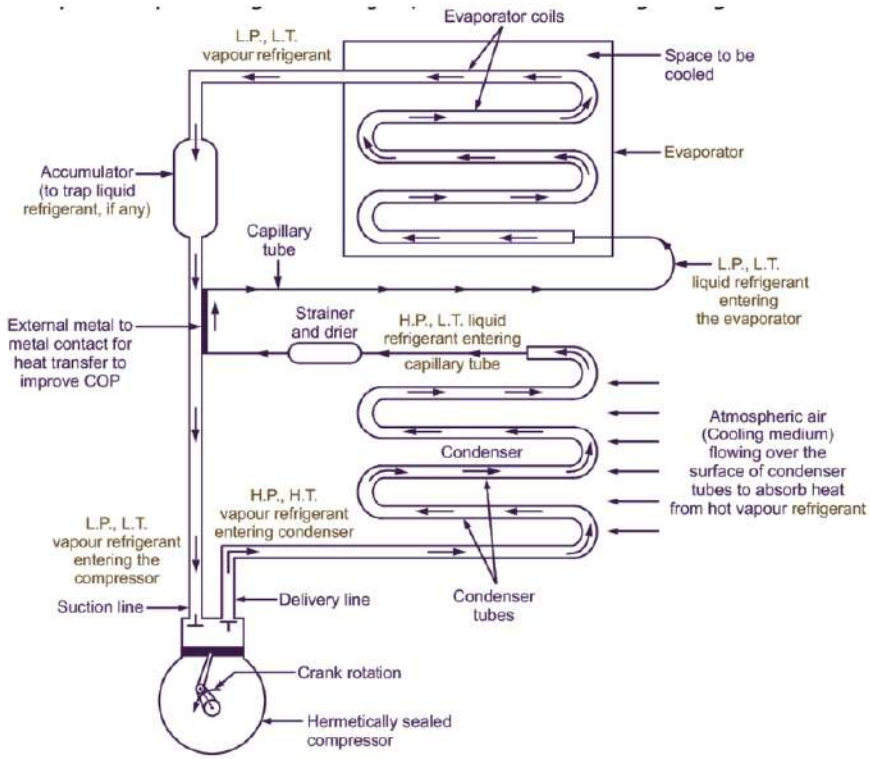

Fig. 2: Working cycle (V.C.C.) of domestic refrigerator