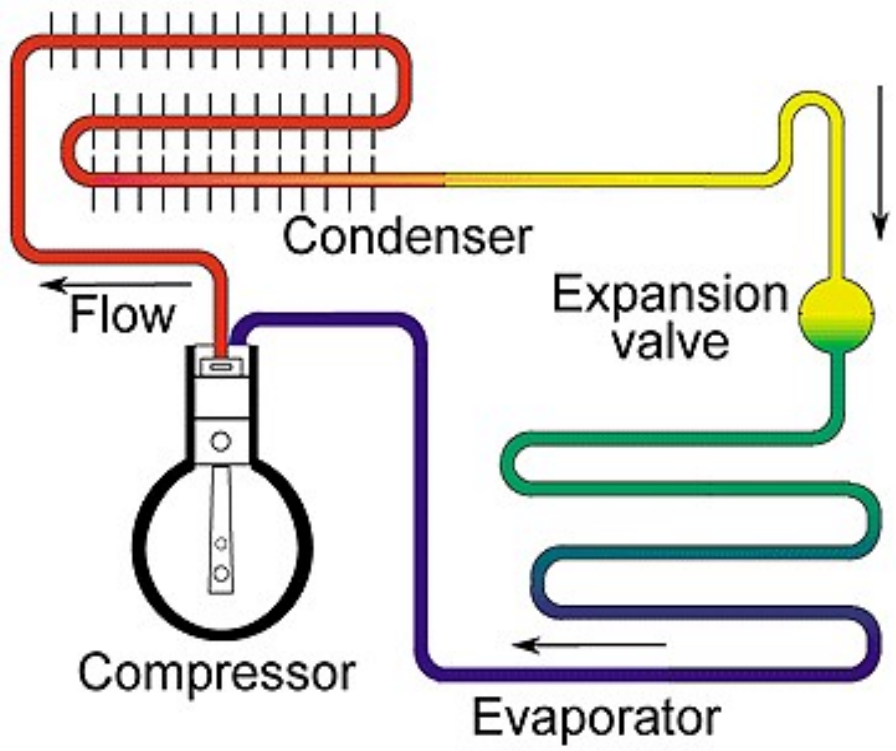
REFRIGERATION

Refrigeration



Refrigeration:

Refrigeration is defined as a process of reducing the temperature of a system below that of the surroundings and maintaining the same at that lower temperature by continuously abstracting the heat from it. This operation can only be performed by the aid of the external work. Therefore in a refrigerator power is to be supplied to remove the heat continuously from the refrigerator cabinet to keep it cool at a temperature less than the atmospheric temperature. A medium called refrigerant continuously extracts the heat from the space within the refrigerator and rejects it to the surroundings.

Principle of refrigeration

The principle of refrigeration is based on the following basic concepts.

1. Heat flows from a system at higher temperature to another at lower temperature.

2. Fluids by absorbing the heat, change from liquid phase to vapour phase and subsequently condense by giving off the heat.

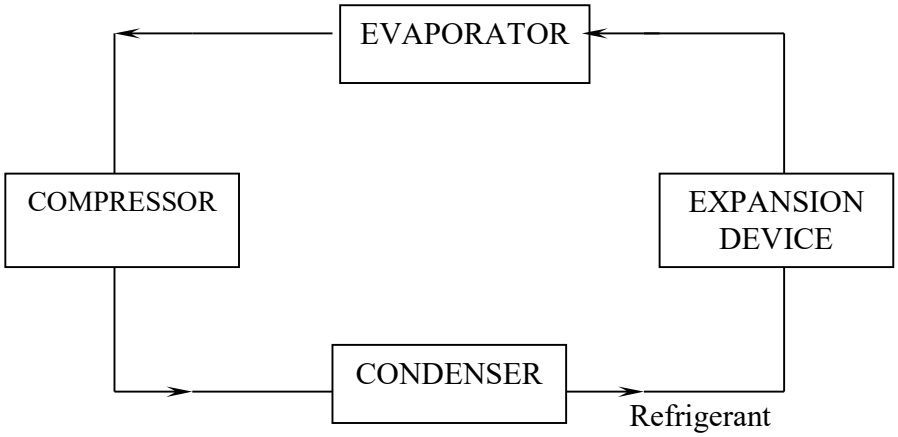
3. The boiling and freezing temperatures of a fluid depend on its pressure.

4. Heat can flow from a system at low temperature to a system at higher temperature by the aid of external work as per the Second law of Thermodynamics.

Main components of a refrigerator

To accomplish the task of producing the cooling effect, a refrigerator must consist of four main parts namely 1) Evaporator 2) Compressor or Circulating System 3) Condenser 4) Expansion Device or Throttle Valve, the sequence of which is depicted in the figure below.

a) Evaporator: As the name itself implies, the evaporator is the heart of the refrigerator where the liquid refrigerant is evaporated by the absorption of heat from the refrigerator cabinet in which the substances which have to be cooled are kept. The evaporator consists of simply a metal tubing which surrounds the freezing and cooling compartments to produce the cooling effect required for freezing the ice or for lowering the temperature of perishables placed in the cooling compartment. Since it produces the cooling effect it is also sometimes called as cooling coil or freezer coil.



Parts of a Refrigerator

b) Compressor: It is a device which circulates the refrigerant to undergo the refrigeration cycle. It increases the pressure and therefore the temperature of the refrigerant. It is driven by a motor. The electrical energy input to the motor is the energy input to the refrigerators.

c) Condenser: It is an appliance in which the heat from the refrigerant which is at higher temperature is rejected to another medium, usually the atmospheric air or cooling water. In a condenser the refrigerant vapour gives off its heat to the cooling medium and condenses into liquid so that it can be expanded in the expansion device. The heat given off by the condenser includes the latent heat absorbed in the evaporator as well as the heat developed due to compression.

d) Expansion Device: An expansion device serves as a device to reduce the pressure suddenly and hence the temperature of the liquid refrigerant before it passes to the evaporator. The liquid refrigerant from the condenser is passed through an expansion valve (throttle valve) where the pressure & temperature reduces.

Unit of refrigeration

The capacity of a refrigeration system is expressed in **Tons of refrigeration** which is the unit of refrigeration. A ton of refrigeration is defined as the quantity of heat absorbed to convert one ton of water at 0^0C to one ton of ice at the same temperature in 24 hours. Here it should be noted that one American ton (2000 pounds) is taken as the standard in the refrigeration practice. In S.I. System,

1 Ton of Refrigeration = 210 kJ/min = 3.5 kW

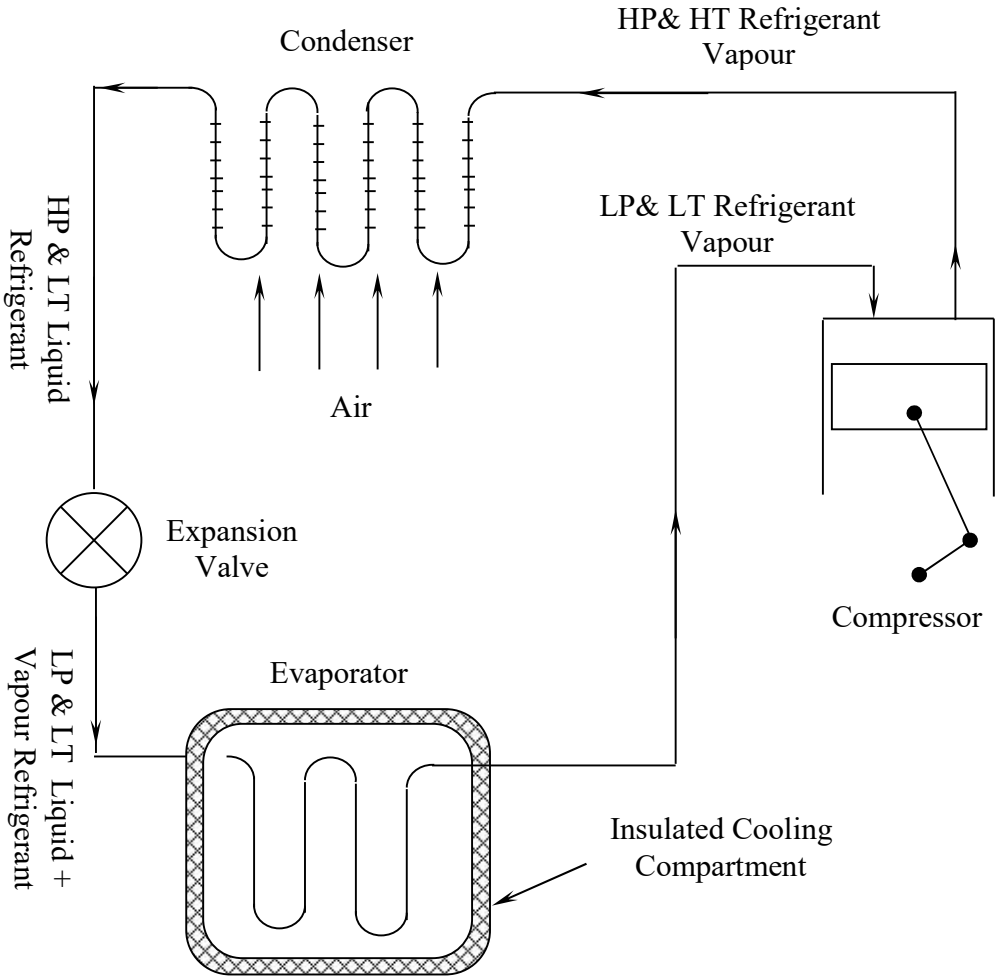
Coefficient of Performance (COP)

The performance of a refrigeration system is expressed by a factor known as Coefficient of Performance or COP. The COP of a refrigeration system is defined as the ratio of heat absorbed in a system to the work supplied.

$$COP = \frac{Heat\ Absorbed\ (kW)}{Work\ Supplied\ (kW)}$$

Vapour Compression Refrigeration system

In a vapour compression refrigerator a vapour is used as the refrigerant. It is circulated through the system in which it alternately evaporates and condenses, thus undergoing a change of phase from liquid to vapour and again vapour to liquid. During evaporation it absorbs the latent heat from the refrigerated space and subsequently gives off that heat while condensing. A vapour compression refrigeration system makes use of the mechanical energy supplied to the compressor to run the refrigerator. Figure below shows the vapour compression refrigeration system. It consists of an evaporator made of coiled tubes installed in the freezing compartment of the refrigerator and connected to the suction side of the compressor and outlet of the throttle valve as shown. The delivery side of the compressor is connected to the condenser inlet and condenser outlet is connected to the inlet of throttle valve.



Vapour Compression Refrigeration System

The object of including a compressor in this system is to draw the vapours from the evaporator and to compress them to higher pressures so that the saturation temperature corresponding to this higher pressure is greater than the temperature of the cooling medium of the condenser, so that the high pressure vapour can reject heat in the condenser get condensed to liquid state and be ready to expand to the evaporator pressure again. In order to maintain the interior of the refrigerator within the desired temperature range, the motor driving the compressor it controlled by a thermostat switch.

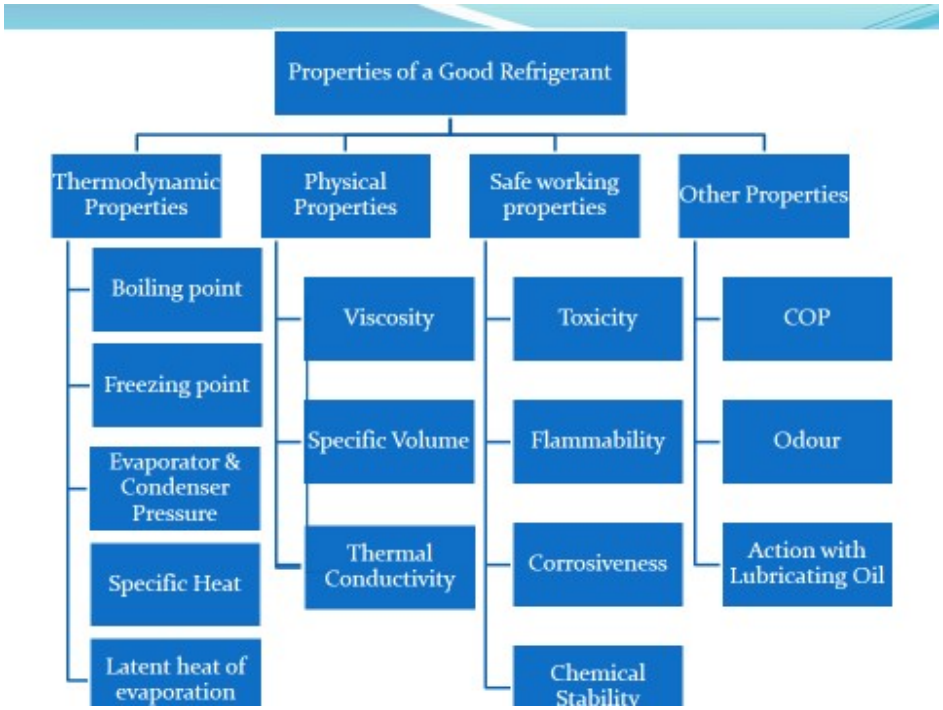
Working:

The refrigerant at low pressure and temperature coming from the expansion valve enters the evaporator coiled tubes and absorbs the heat from the contents in the freezing compartment and

evaporates. This in turn lowers temperature of the freezing compartment. The evaporated refrigerant at low pressure from the evaporator is drawn by a compressor which compresses it to higher pressures so that the saturation temperature of the refrigerant corresponding to the increased pressure is higher than the temperature of the cooling medium (atmospheric air) in the condenser, so that the high pressure-high temperature vapours can reject heat in the condenser and be ready to expand in the throttle valve to the lower evaporator pressures again.

The high pressure high temperature refrigerant vapour from the compressor flows to the condenser where it gives off its latent heat to the atmospheric air and condenses into liquid. The high pressure condensed liquid refrigerant approximately at room temperature now flows to the throttle valve where it expands to lower pressure and temperature and passes into the evaporator coils for recirculation once again thereby repeating the refrigeration cycle.

Desirable properties of a Good Refrigerant



The desirable properties of an ideal refrigerant are classified into the following four categories:

Thermodynamic Properties:

- *Boiling point:* An ideal refrigerant should have low boiling temperature to give better refrigeration effect.
- *Freezing point:* An ideal refrigerant should have low freezing point, because the refrigerant should not freeze at lower temperature
- *Evaporator and condenser pressure:* To avoid the leakage of the atmospheric air into the refrigeration system and also to enable the detection of the leakage of the refrigerant, *both the evaporator and condenser pressures should be slightly above the atmospheric pressure.*
- *Latent heat of evaporation:* This must *be very high* so that a minimum amount of refrigerant will give the desired result. In other words it increases the refrigeration effect.
- *Specific Heat:* A good refrigerant must have high specific heat when it is vapourised and low specific heat when it is in liquid state. The high specific heat of the refrigerant helps in decreasing the super-heating of the vapour. The low specific heat of the refrigerant helps in sub-cooling of the liquid and easy drop in temperature after expansion. Both these desirable properties will increase the refrigerating effect.
- ***Physical Properties:***
- *Specific Volume:* It is the volume per unit mass. It must be very low, as it will reduce the size of the compressor
- *Viscosity:* The *viscosity of a refrigerant in both the liquid and vapour states must be very low* as it improves the heat transfer and reduces the pumping effort required.
- *Thermal conductivity:* Refrigerant should have high thermal conductivity for high heat transfer

Safe Working Properties:

- *Toxicity:* A good refrigerant should be *non-toxic,* because any leakage of the toxic refrigerant increases suffocation and poisons the atmosphere or any food items stored.
- *Flammability:* A good refrigerant should be *non-flammable.*

- *Corrosiveness:* A good refrigerant should be *non-corrosive* to prevent the corrosion of the metallic parts of the refrigerators.
- *Chemical Stability:* An ideal refrigerant must not *decompose* under operating conditions.

Other Properties:

- *Coefficient of Performance:* The *coefficient of performance of a refrigerant must be high* so that the energy spent in refrigeration will be less.
- *Odour:* A *good refrigerant must be odourless;* otherwise some food stuff such as meat, butter, etc. loses their taste.
- *Action with Lubricating Oil:* A *good refrigerant must not react with the lubricating oil* used in lubricating the parts of the compressor.

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