Refrigeration

Refrigeration and its meaning:

The term refrigeration is defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a continued extraction of heat from a body whose temperature is already below the temperature of its surroundings.

Applications of refrigeration:

Following are the general applications of refrigeration:

i) Domestic preservation of food items by keeping them at low temperature.
ii) Preservation and transportation of frozen/packaged food items.
iii) Preservation of blood, plasma, vaccines etc.
iv) Processing of dairy products.
v) Liquefaction of gasses in chemical industries.
vi) Removal of heat in chemical reactions in chemical process industries.
vii) Providing comfort conditioning to human beings through air conditioning.
viii) For dehumidification of air in pharmaceutical industries.

Units of Refrigeration:

Refrigeration is measured in terms of rate of heat removal from the place to be cooled and the rate of removal of heat is known as cooling load or refrigeration effect of the refrigerator. Following are some important units used to measure the cooling load/refrigeration effect.

a) Kilowatt (kJ/s):

It is the amount of heat in kJ which is being removed from the cold place per second.

b) Tons of Refrigeration (TR):

One ton of refrigeration is defined as the amount of heat flow rate required to convert one ton of water at 0 ^{0}C to one ton of ice at 0^{0}C in 24 hours.

$$1TR=3.5\ kW$$

c) British Thermal Unit per hour (BTU/h):

It is the amount of heat in British Thermal Unit (BTU) which is being removed from cold place per hour.

$$1\ BTU/h = 2.93 \times 10^{-5}\ kW$$

Coefficient of performance (COP):

Coefficient of performance of a refrigerator indicates its performance. It is defined as the ratio of cooling load or refrigeration effect to the power input to the refrigerator.

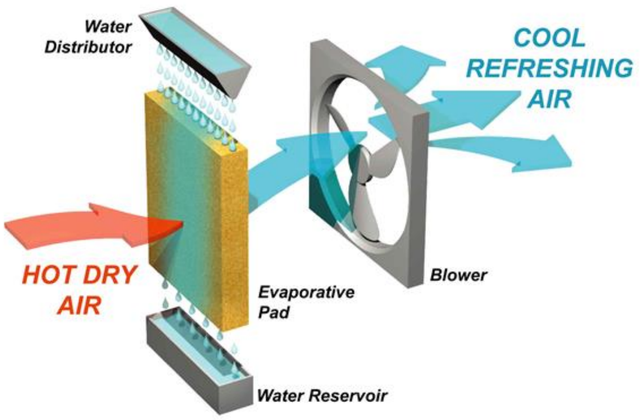
$$COP = \frac{Cooling\ Load}{Power\ input}$$

Methods of refrigeration:

Refrigeration is the act of achieving and maintaining a substance at low temperature with respect to its surrounding. This can be done through different methods which as follows:

Evaporative cooling:

Swamp coolers are used to provide evaporative cooling. They cool warmer outdoor air by blowing it over water-soaked pads as it enters the home. The water absorbs the heat from the air and evaporates.

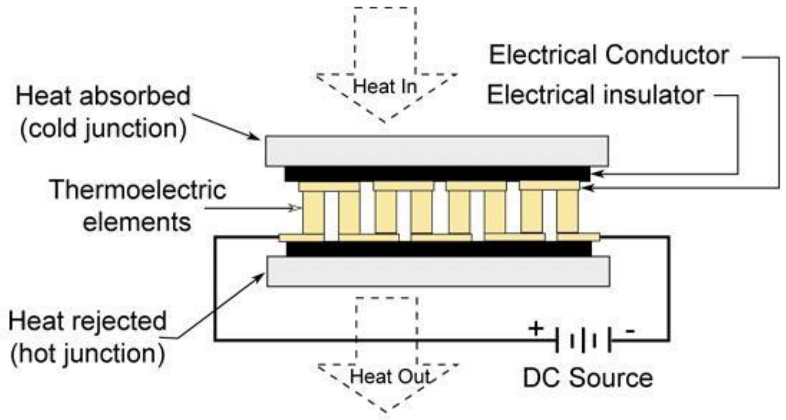


Evaporative Cooling

The cooler air is channelled into the home and the warm air out of it. Evaporative coolers are best suited for dry climates. They are also less costly to install and use about a quarter of the energy of central air conditioners.

Thermoelectric Refrigeration:

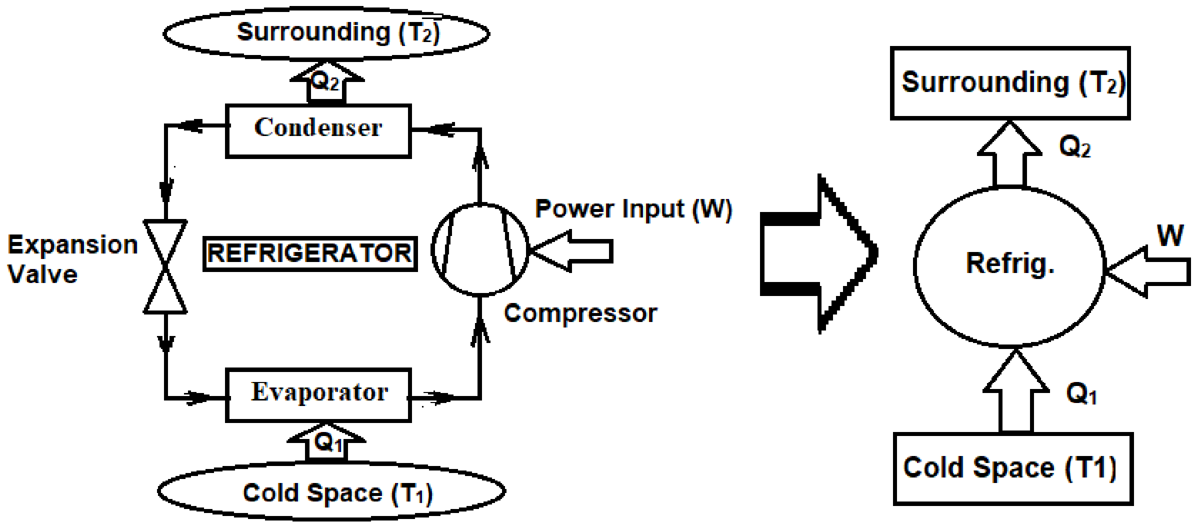
Thermoelectric refrigeration systems operate through thermocouples. A thermocouple is made up of two different metal wires that are united at both ends. Insulation separates the rest of the wires from each other. When the current is directed on the thermocouple, one end will become hot and the other cool. The hot end will typically be placed outside of the area to be cooled to keep it the same temperature as the surrounding air. The cold side, which is below room temperature, is placed in the area to be cooled, attracting heat out of the air. This type of refrigeration is generally used for small cooling loads that can be difficult to access, such as electronic systems.`



Thermoelectric refrigeration

Vapour Compression Refrigeration System:

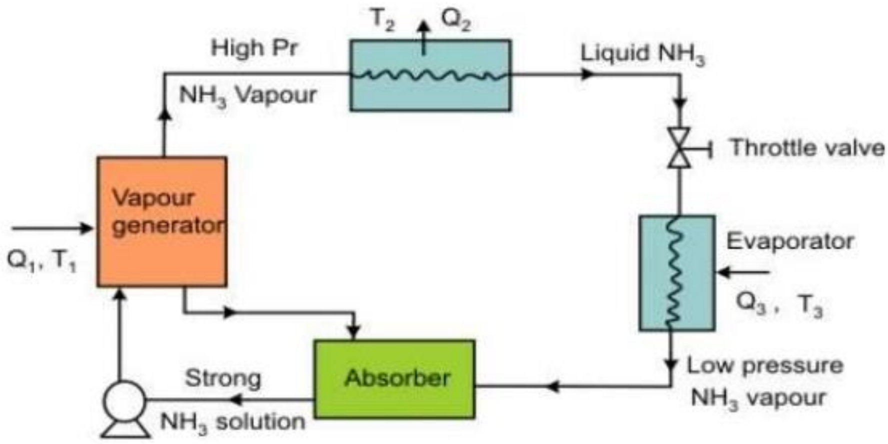
These systems use a substances which absorbs heat from the cold space by changing its phase from liquid to vapor at low pressure and rejects the heat to the atmosphere by being changing its phase from vapour to liquid at high pressure. The substance which becomes a medium to transport heat from cold space to the atmosphere is called refrigerant. The vapour compression refrigeration system consists of four components called evaporator, compressor, condenser and expansion valve. The refrigerant enters the evaporator in liquid state at low pressure where it absorbs heat from cold space and gets converted into vapour state thereafter the vapour refrigerant



Simple Vapour Compression Refrigeration Cycle enters the compressor where it gets compressed to a high pressure and then it enters the condenser where it gets condensed to liquid state by rejecting heat to the atmosphere. The high pressure liquid refrigerant then passes through an expansion valve where it gets expanded and pressure is again reduced. The low pressure liquid refrigerant again enters the evaporator for further heat absorption and the cycle is again repeated.

Vapour Absorption Refrigeration Cycle:

In vapour absorption refrigeration cycle, generally ammonia is used as refrigerant. The low pressure ammonia vapour coming out of the evaporator enters the absorber where water is stored. Due to high solubility of ammonia with water at low pressure it is solved in water and a strong ammonia-water solution is obtained. This solution is further pumped to the a generator through a pump where the solution is boiled through small amount of heat. Due to boiling, ammonia gets separated from the solution and water



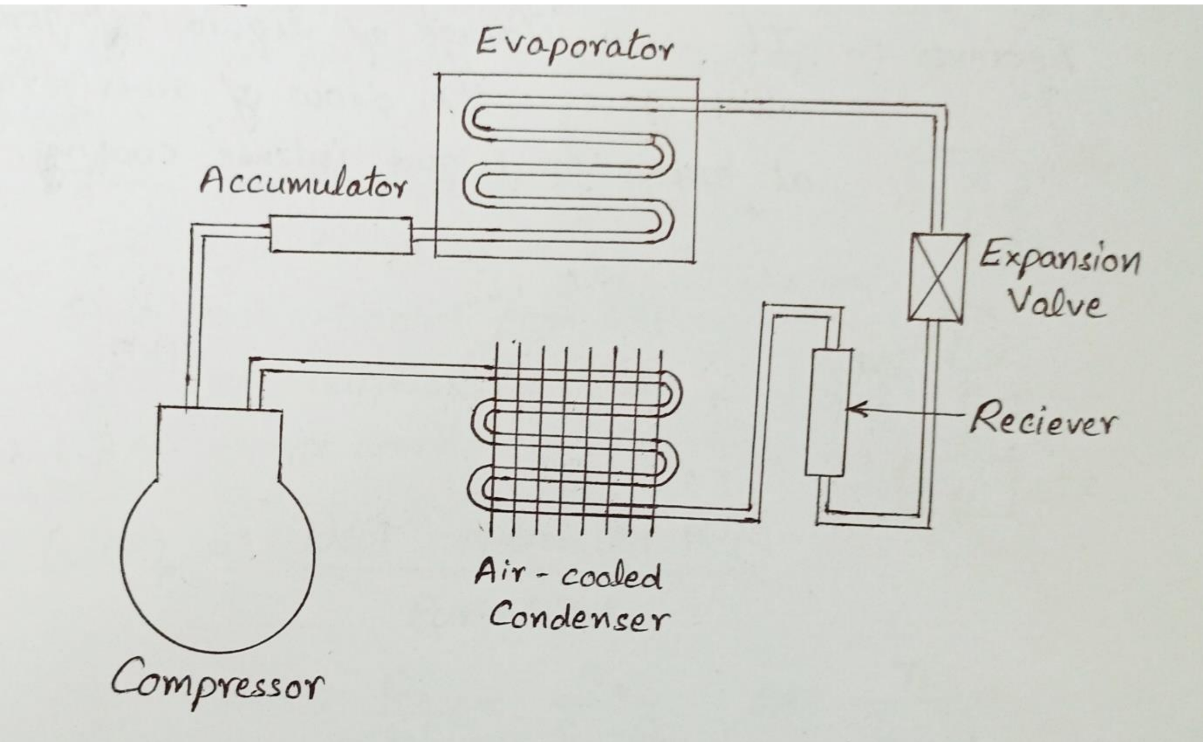
Vapour Absorption refrigeration Cycle

returns back to the absorber. The separated ammonia gas goes to the condenser where it rejects heat to the atmosphere by being condensed and returns back to the evaporator after pressure reduction in the expansion valves.

Domestic Refrigerator:

Domestic refrigerators are employed to provide a cold space for storage of food and vegetables for their preservation.

Construction and Working



Construction of Domestic refrigerator

Compressor: It is located in back side of the refrigerator at lower base of the refrigerator.

Condenser: It is located behind the refrigerator in the form of zigzag tubes on a vertical mesh. High pressure vapor refrigerant exiting the compressor enters these tubes and after heat rejection to the atmosphere, it gets condensed to a liquid state.

Evaporator: It is located in the form of tube coil wounded around the freezer box. The liquid refrigerant in evaporator coils is evaporated by absorbing the heat from the items kept inside the freezer. The cold air inside the freezer flows downwards in order to cool the stuffs kept in lower compartments.

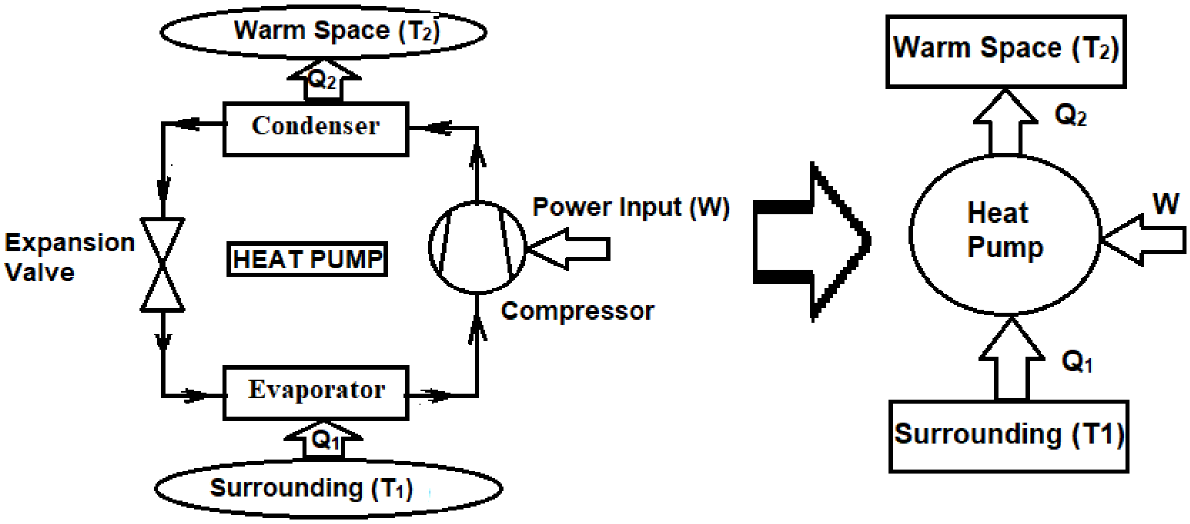
Expansion Valve: It is used to reduce the pressure of refrigerant coming out of the condenser.

Accumulator: It prevents the unevaporated liquid refrigerant from entering to the compressor.

Receiver: It is a storage of liquid refrigerant which governs the flow of refrigerant at excess load and intense cooling.

Heat Pump:

Heat pump is a device which is used to maintain a space warmer than the colder surrounding by pumping heat into the warm space from cold surrounding. It works on vapour compression cycle.



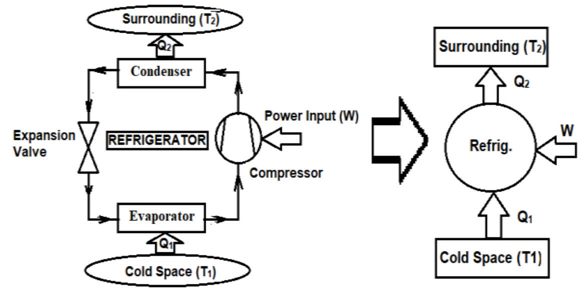
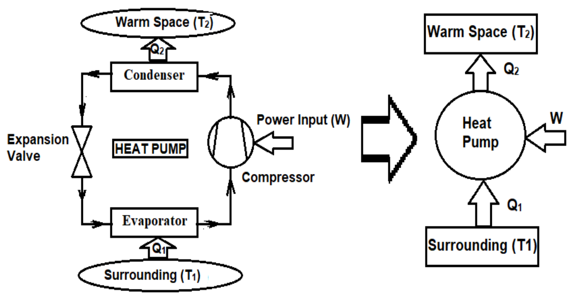
Schematic diagram of Heat Pump

COP of heat pump:

Since the purpose of heat pump is to warm a place rather than to cool a place, therefore heating load is the prime objective to be reached. The heating load is here is Q_2 rather than Q_1. Therefore COP of heat pump may be defined as:

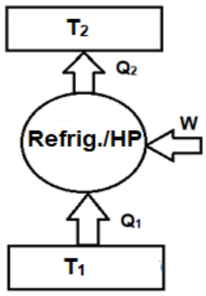
$$COP_{heat\ pump} = \frac{Heating\ load}{Power\ Input}$$

Difference between Refrigerator and Heat Pump:

Refrigerator	Heat Pump
	
Refrigerator is used to keep a place colder than its surrounding	Heat Pump is used to keep a place warmer than its surrounding.
$COP_{Refrg.} = \frac{Q_1}{W}$	$COP_{HP} = \frac{Q_2}{W}$

Relationship between COP of refrigerator and COP of heat pump:

From energy balance equation for refrigerator/heat pump:



$$Q_1 + W = Q_2$$

$$W = Q_2 - Q_1$$

$(COP)_{Refrig.} = \frac{Q_1}{W} = \frac{Q_1}{Q_2 - Q_1}$ ……….(1)

$(COP)_{Heat\ Pump} = \frac{Q_2}{W} = \frac{Q_2}{Q_2 - Q_1}$ ……..(2)

Equation (2) – Equation (1) gives

$$(COP)_{Heat\ Pump} - (COP)_{Refrig.} = \frac{Q_2 - Q_1}{Q_2 - Q_1} = 1$$

$$(COP)_{Heat\ Pump} = 1 + (COP)_{Refrig.}$$

Ideal or reversible or Carnot refrigerator and heat pump:

Ideal refrigerator and heat pump also called Carnot refrigerator and Carnot heat pump are those in which all the processes are ideal or reversible processes.

Ideal COP:

Ideal COP of refrigerator = $\frac{T_1}{T_2 - T_1}$ ……………………….**(1)**

Where T_1 is the absolute temperature of cold space and T_2 is the absolute temperature of surrounding.

Ideal COP of Heat Pump = $\frac{T_2}{T_2 - T_1}$……………………….**(2)**

Where T_2 is the absolute temperature of warm space and T_1 is the absolute temperature of cold surrounding.