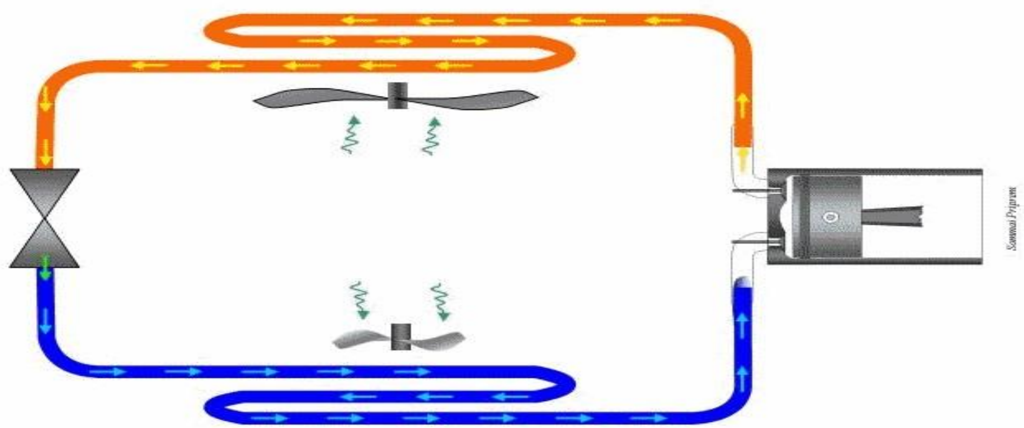
Unit-4

REFRIGERATION AND AIR CONDITIONING



Refrigeration

- It is defined as the process of providing and maintaining a temperature well below that of surrounding atmosphere.
- In other words refrigeration is the process of cooling substance.

Applications of Refrigeration

- In chemical industries, for separating and liquefying the gases.
- In manufacturing and storing ice.
- For the preservation of perishable food items in cold storages.
- For cooling water.
- For controlling humidity of air manufacture and heat treatment of steels.
- For chilling the oil to remove wax in oil refineries.
- For the preservation of tablets and medicines in pharmaceutical industries.
- For the preservation of blood tissues etc.,
- For comfort air conditioning the hospitals, theatres, etc.,

Refrigerators and heat pumps

- If the main purpose of the machine is to cool some object, the machine is named as refrigerator.
- If the main purpose of machine is to heat a medium warmer than the surroundings, the machine is termed as heat pump.

Terminologies of Refrigeration

Refrigerating Effect (N): It is defined as the quantity of heat extracted from a cold body or space to be cooled in a given time.

$$N = \frac{\text{Heat extracted from the cold space}}{\text{Time taken}}$$

Specific Heat of water and ice : It is the quantity of heat required to raise or lower the temperature of one kg of water (or ice), through one kelvin or (1^0 c) in one second.

Specific heat of water, C_{pw} = 4.19 kJ/kg K Specific heat of ice, C_{pice} = 2.1 kJ/kg K.

Terminologies of Refrigeration

• **Capacity of a Refrigeration Unit :**

- Capacity of a refrigerating machines are expressed by their cooling capacity.
- The standard unit used for expressing the capacity of •refrigerating machine is ton of refrigeration.
- One ton of refrigeration is defined as, "the quantity of heat abstracted (refrigerating effect) to freeze one ton of water into one ton of ice in a duration of 24 hours at 0^o c".

Heat extracted from at 0^o c = latent heat of ice

Latent heat of ice = 336 kJ/kg

- i.e., 336 kJ of heat should be extracted from one kg of water at 0^o C to convert it into ice.

Terminologies of Refrigeration

One ton of refrigeration $= 336 \times 1000 \text{ kJ}/24 \text{ hrs.}$

$$= \frac{336 \times 1000 \text{ kJ/min}}{24 \times 60}$$

One ton of refrigeration $= 233.333 \text{ kJ/min}$

$= 3.8889 \text{ kJ/sec}$

Terminologies of Refrigeration

Co efficient of Performance: It is defined as the ratio of heat extracted in a given time (refrigerating effect) to the work input.

Co efficient of performance = Heat extracted in evaporator

Work Input Refrigerating Effect

Co efficient of performance =

Work Input

Co efficient of performance = $\frac{N}{W}$

The COP is always greater than 1 and known as theoretical coefficient of performance.

Refrigerants

- Any substance that absorbs heat through expansion and vaporization process and loses heat due to condensation is a refrigeration process is called refrigerant.

Some examples of refrigerants are,

- Air
- Ammonia (NH_3)
- Carbon dioxide (CO_2)
- Sulphur dioxide (SO_2)
- Freon – 12
- Methyl Chloride
- Methylene chloride.

Classification of Refrigerants

Refrigerants are classified as,

(a) Primary Refrigerants: It is a working medium which is used for cooling the substance by absorption of latent heat.

E.G Ammonia (NH_3), Carbon dioxide (CO_2), Sulphur dioxide (SO_2), Freon 12, etc.,

(b) Secondary Refrigerants: Secondary refrigerant is a substance already cooled by primary refrigerant and then employed for cooling purposes.

E.g Ice, solid carbon dioxide.

These refrigerants cool the substance by absorption of their sensible heat.

Properties of Refrigeration

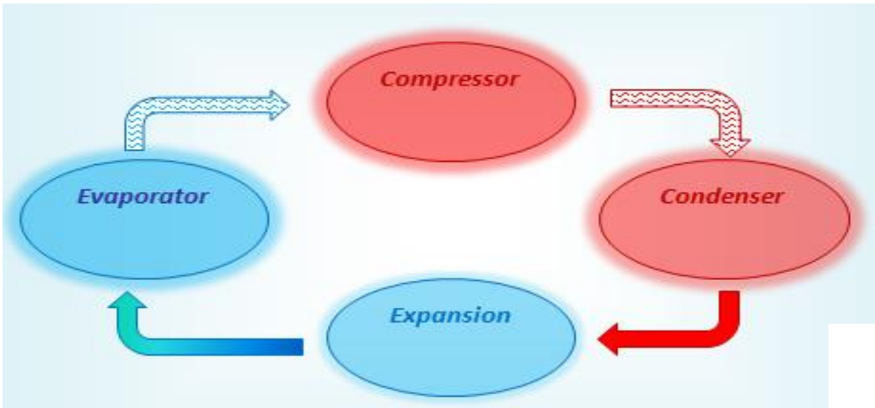
- A good refrigerant should have high latent heat of vapourisation.
- It should have low boiling and low freezing point.
- It should be non toxic and should non corrosiveness
- It should be non flammable and non explosive.
- It should have high thermal conductivity
- It should be easy to handle
- It should have low specific volume of vapour.
- It should have high co efficient of performance

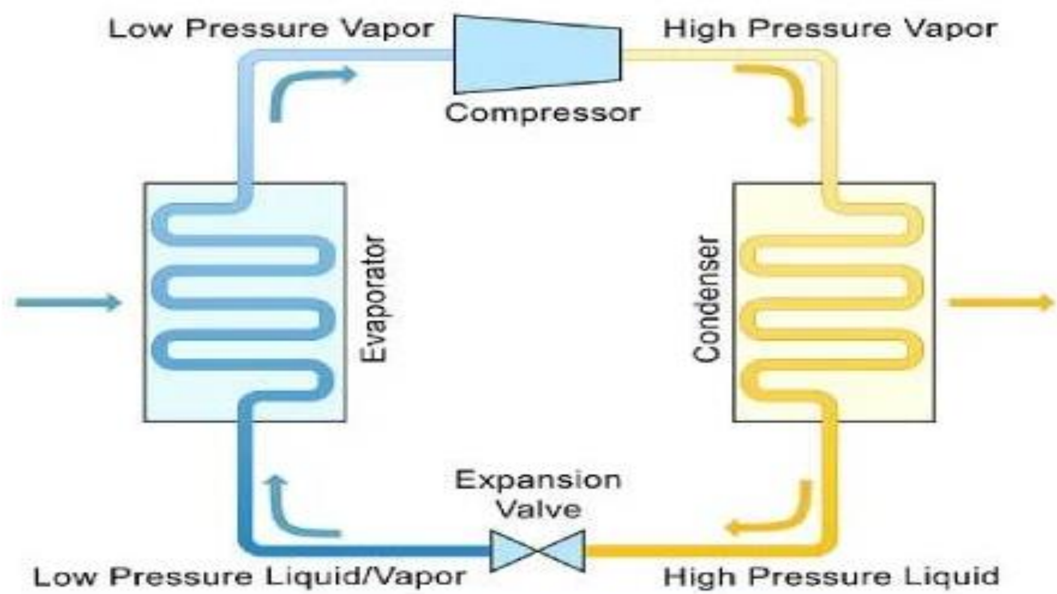
PROPERTIES OF AN IDEAL REFRIGERANT

1. The refrigerant should have low boiling point and low freezing point.
2. 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.
3. 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.
4. It must have high critical pressure and temperature to avoid large power requirements.
5. It should have low specific volume to reduce the size of the compressor.
6. It must have high thermal conductivity to reduce the area of heat transfer in evaporator and condenser.
7. It should be non-flammable, non-explosive, non-toxic and non-corrosive.
8. It should not have any bad effects on the stored material or food, when any leak develops in the system.

9. It must have high miscibility with lubricating oil and it should not have reacting property with lubricating oil in the temperature range of the system.
10. It should give high COP in the working temperature range. This is necessary to reduce the running cost of the system.
11. It must be readily available and it must be cheap also.

Refrigeration Cycle and its components:
(Air Refrigeration System)





Compressor

- Its work is to control the flow of the refrigerant by acting as a motor and a pump.
- This allows it to pressurize the *refrigerant* and reduce its volume.
- There are five types of compressors used in both commercial and domestic refrigerators.
- i.e. Reciprocating, rotary, screw, centrifugal and scroll.
- Of the five, the **reciprocating compressor** is the most commonly used in home and commercial kitchen refrigerators.


Reciprocating Compressor
Scroll compressor
Centrifugal Compressor
Types of Compressor
Reciprocating Compressor
Rotary Vane Compressor
Screw Compressor


AQAW77X
RoHS

Condenser

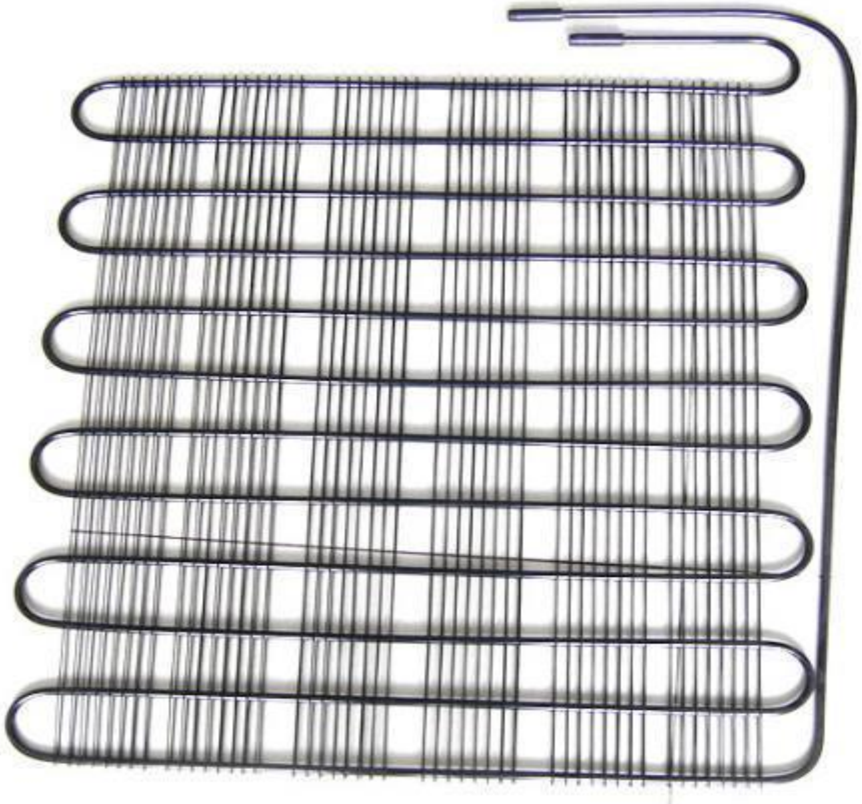
- The condenser works by condensing the refrigerant.
- The refrigerant **entering** the condenser is *hot and pressurized*.
- The condenser then cools the refrigerant by converting it into a **liquid state**.

Air-cooled condenser:

- You will find this in small refrigerators such as the ones used at home.
- They are ideal when the refrigerant quantity is small.
- The air-cooled condenser is also called coil condenser because it comes with aluminum or copper coils at the back of the fridge.
- The coils increase the surface area for cooling the refrigerant.

(i) The **natural convection** condenser which uses the natural flow of air to cool the refrigerant and

(ii) the **forced convection** condenser which uses a fan to draw in cold air.



Expansion Valve

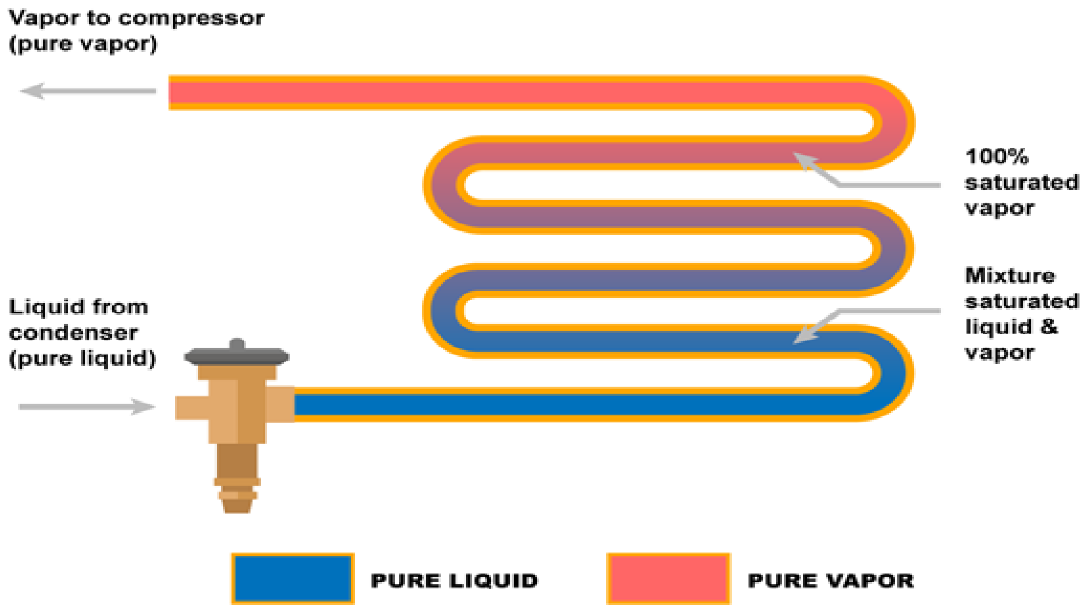
- The expansion valve helps **reduce the pressure and temperature** of the refrigerant.
- The sudden drop in pressure and temperature produces a *cooling effect*.
- The expansion valve also **regulates** the amount of refrigerant used in meeting the load requirements.
- The load, in this case, are the products that need cooling in the refrigerator.
- There are *various types* of expansion valves.

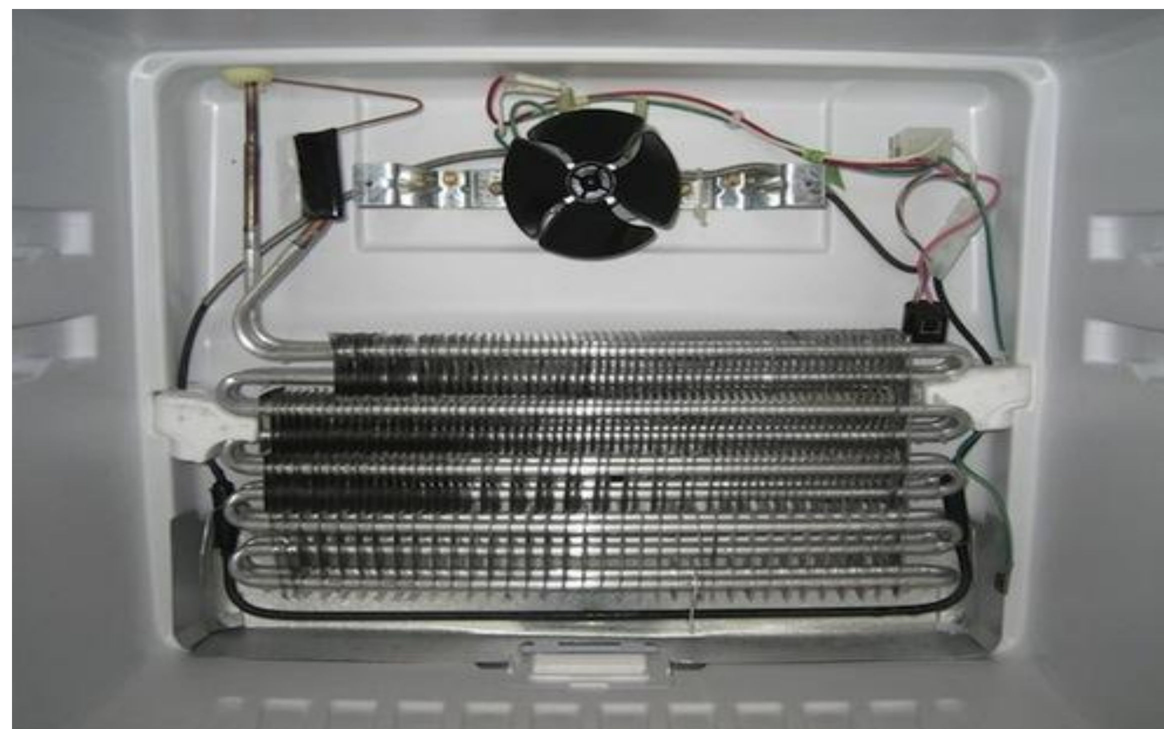
1. Capillary Tube
2. Constant Pressure or Automatic Throttling Valve
3. Thermostatic Expansion Valve
4. Float Valve


SPORLAN
SPORLAN
SPORLAN

Evaporator

- The evaporator **absorbs heat** inside the refrigerator.
- It acts as a *medium of exchange* for heat from the stored products (load) **to the refrigerant**.
- In most cases, the evaporator is the **coldest** part of the fridge or the freezer.
- Here, the refrigerant is cold and moves at a slower pace in order to absorb as much heat as possible from the load.
- As it absorbs the heat, it gets hotter and **turns into a gas**.
- By **vaporising** the refrigerant more heat is absorbed from the load.
- The refrigerant, **now** hot and in gaseous form, is then pushed back into the compressor.

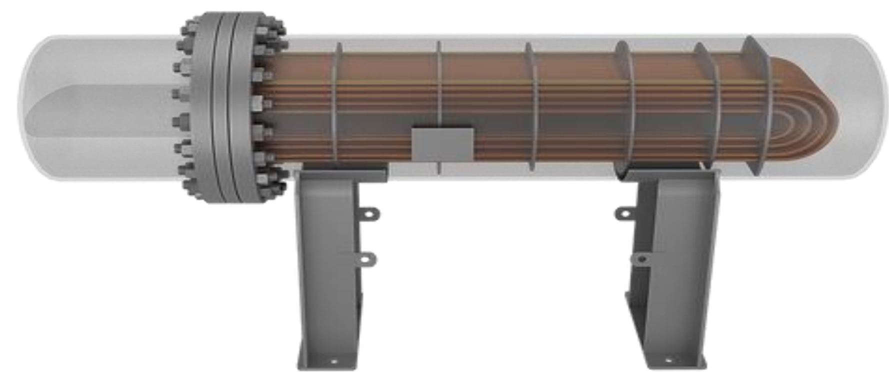

Vapor to compressor
(pure vapor)
100%
saturated
vapor
Mixture
saturated
liquid &
vapor
Liquid from
condenser
(pure liquid)
PURE LIQUID
PURE VAPOR



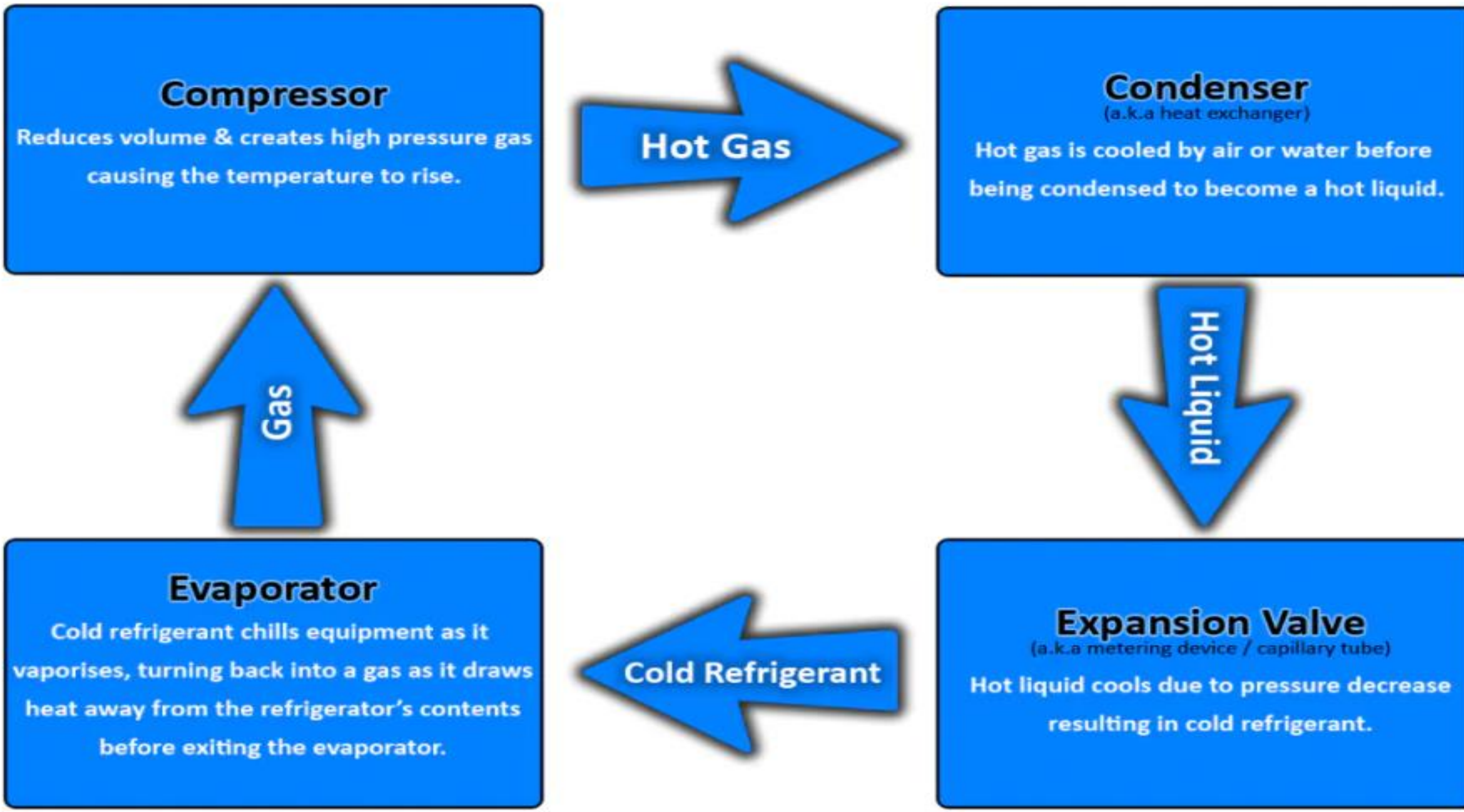
Bare tube evaporator

Plate surface evaporator

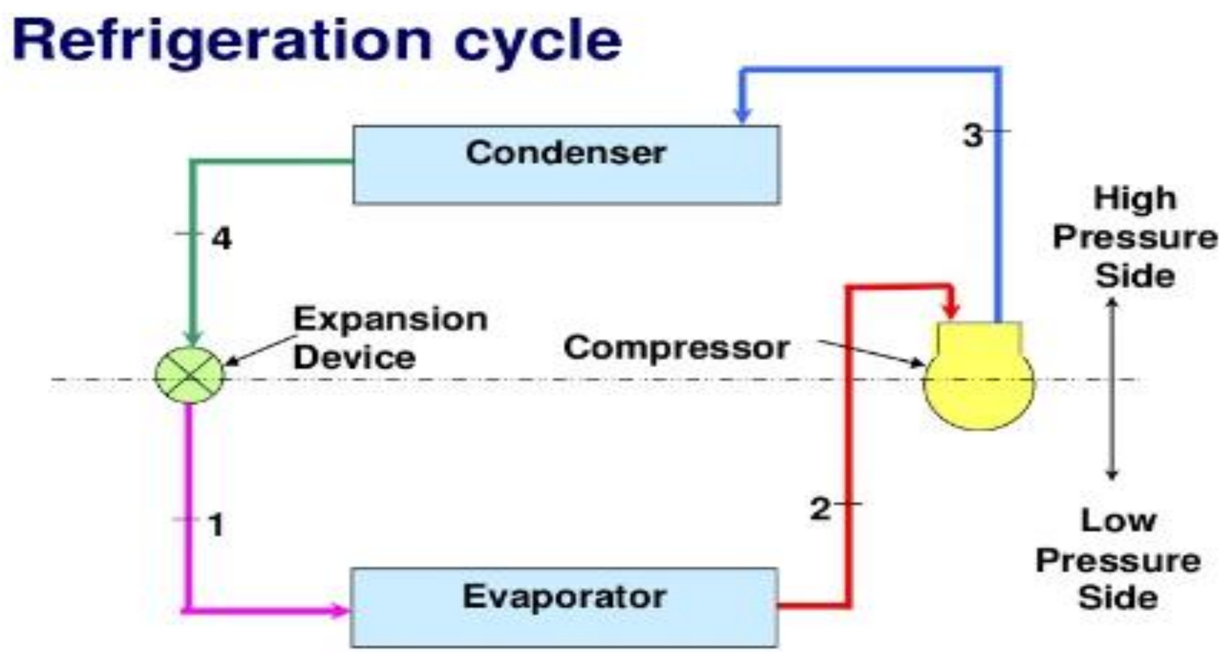
Finned tube evaporator



Shell and tube evaporator


Compressor
Reduces volume & creates high pressure gas causing the temperature to rise.
Hot Gas
Condenser
(a.k.a heat exchanger)
Hot gas is cooled by air or water before being condensed to become a hot liquid.
Hot Liquid
Expansion Valve
(a.k.a metering device / capillary tube)
Hot liquid cools due to pressure decrease resulting in cold refrigerant.
Cold Refrigerant
Evaporator
Cold refrigerant chills equipment as it vaporises, turning back into a gas as it draws heat away from the refrigerator's contents before exiting the evaporator.
Gas

Vapour Compression Refrigeration System



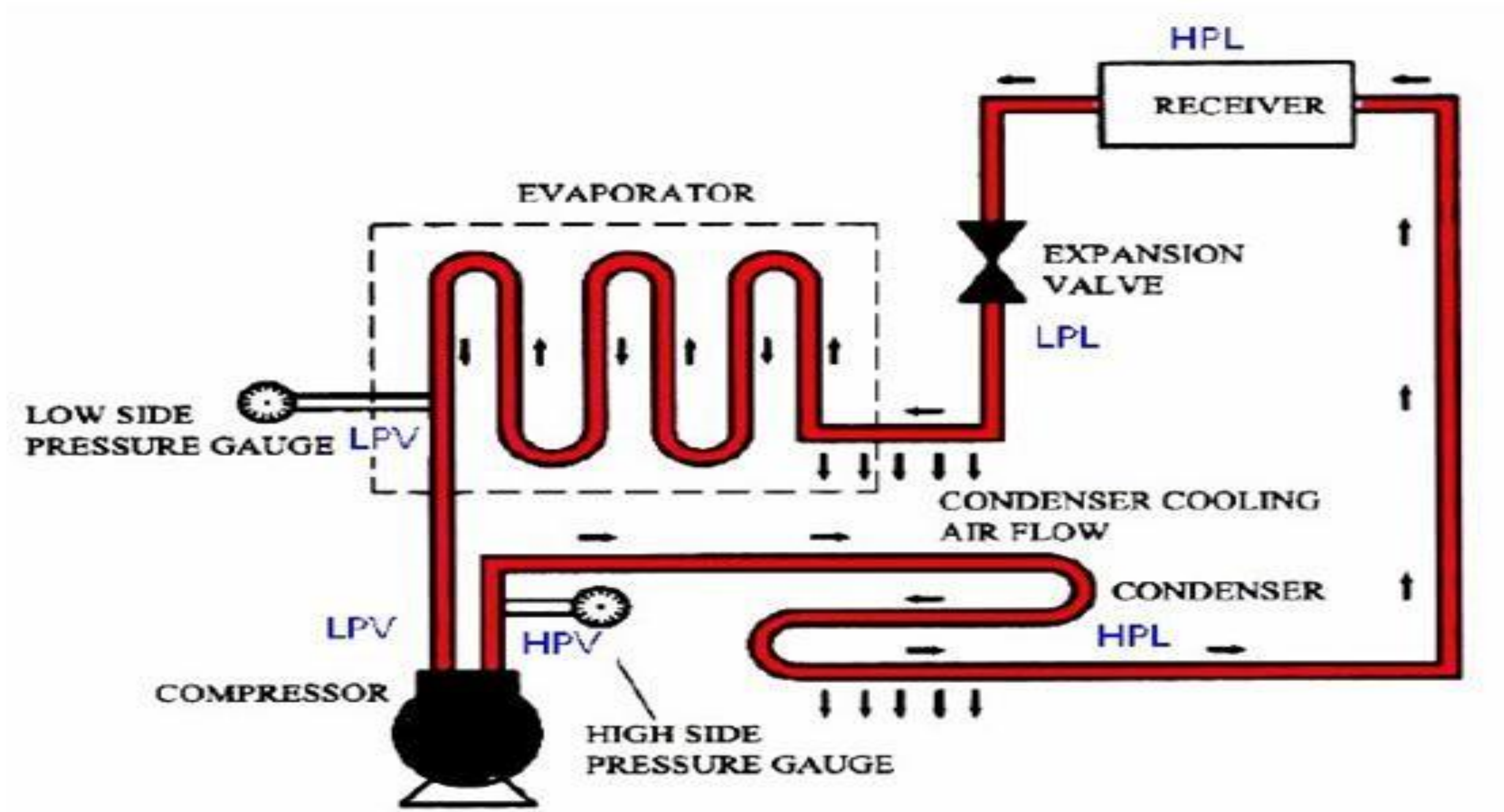
• Most common refrigeration cycle in use today.
• There are four principal control volumes involving these **components**:
• Evaporator ►Compressor ►Condenser ►Expansion valve liquid-vapor mixture
• All energy transfers by work and heat are taken as positive in the directions of the arrows on the schematic and energy balances are written accordingly.

Vapour Compression Refrigeration System

The processes of this cycle are:

- Process 1 -2: liquid-vapor mixture of refrigerant is evaporated through heat transfer from the refrigerated space.
- Process 2 -3: vapor refrigerant is compressed to a relatively high temperature and pressure requiring work input.
- Process 3 -4: vapor refrigerant liquid-vapor mixture condenses to liquid through heat transfer to the cooler surroundings.
- Process 4 -1: liquid refrigerant expands to the evaporator pressure

Vapour Compression Refrigeration System

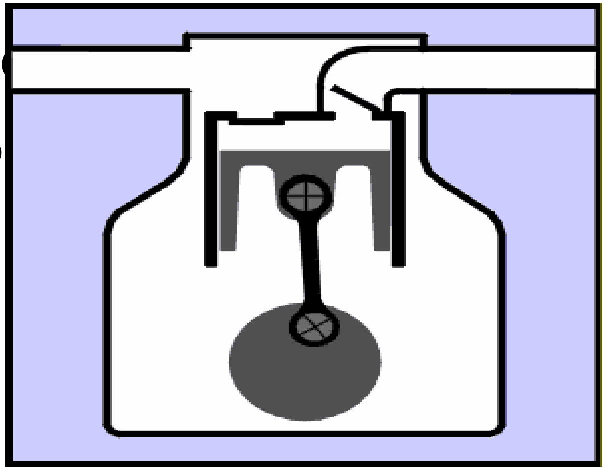


Vapour Compression Refrigeration System - Construction

- This system consists of a compressor, condenser, a receiver tank, an expansion valve and an evaporator.

Compressor :

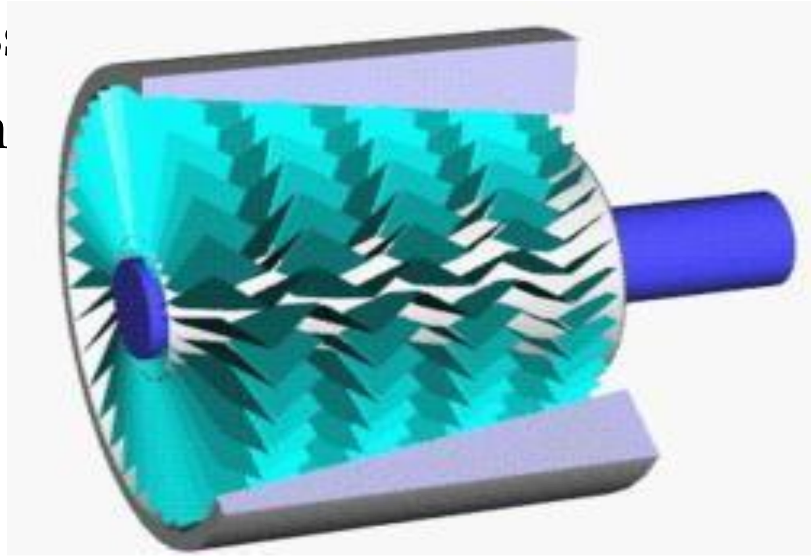
Reciprocating compressors generally used. For v
big plants centrifugal compressors directly coup
with high speed rotating engines (gas turbine)
used.



Vapour Compression Refrigeration System - Construction

Compressor:

For very big plants Centrifugal compres
directly coupled with high speed rotatin
engines (gas turbine) are used



Vapour Compression Refrigeration System - Construction

- **Condenser :** It is a coil of tubes made of copper.
- **Receiver tank:** It is the reservoir of liquid refrigerant.
- **Expansion Valve:** This is a throttle valve. High pressure refrigerant is made to flow at a controlled rate through this valve.
- **Evaporator :** It is the actual cooler and kept in the space to be cooled. The evaporator is a coil of tubes made of copper

Vapour Compression Refrigeration System - **Working**

1. The low pressure refrigerant vapour coming out of the evaporator flows into the compressor.
2. The compressor is driven by a prime mover.
3. In the compressor the refrigerant vapour is compressed.
4. The high pressure refrigerant vapour from the compressor is then passed through the condenser.
5. The refrigerant gives out the heat it had taken in the evaporator (N)
6. The heat equivalent of work done on it (w) on the compressor.
7. This heat is carried by condenser medium which may be air or water.

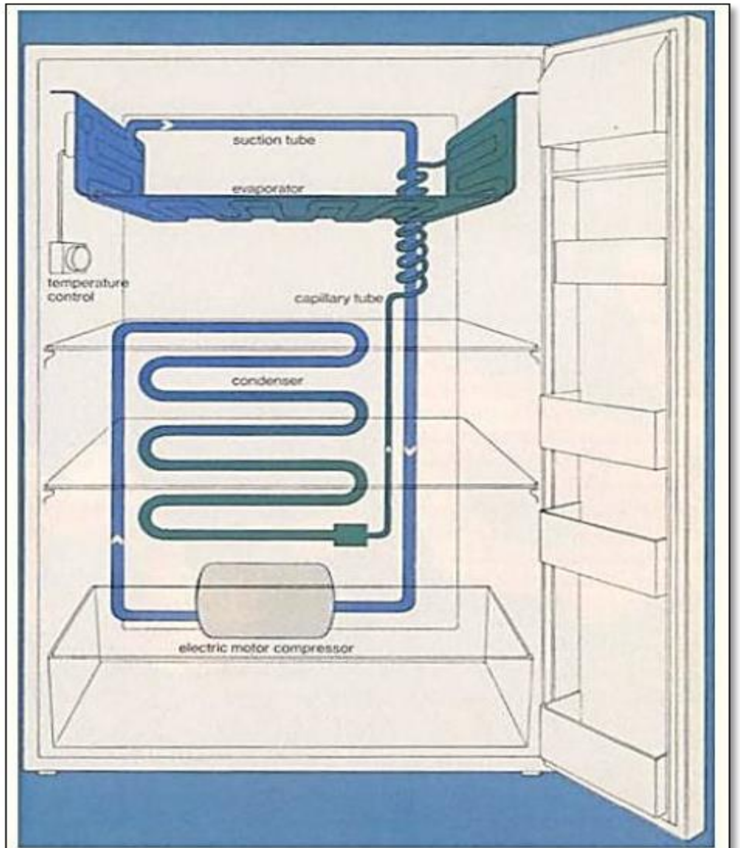
8. The high pressure liquid refrigerant then enters the expansion valve.
9. This valve allows the high pressure liquid refrigerant to flow at a controlled rate into the evaporator.
10. While passing though this valve the liquid partially evaporates.
11. Most of the refrigerant is vapourised only in the evaporator, at a low pressure.
12. In the evaporator the liquid refrigerant absorbs its latent heat of vaporization from the material which is to be cooled.
13. Thus the refrigerating effect (N) is obtained.
14. Then the low pressure refrigerant enters the compressor and the cycle is repeated.

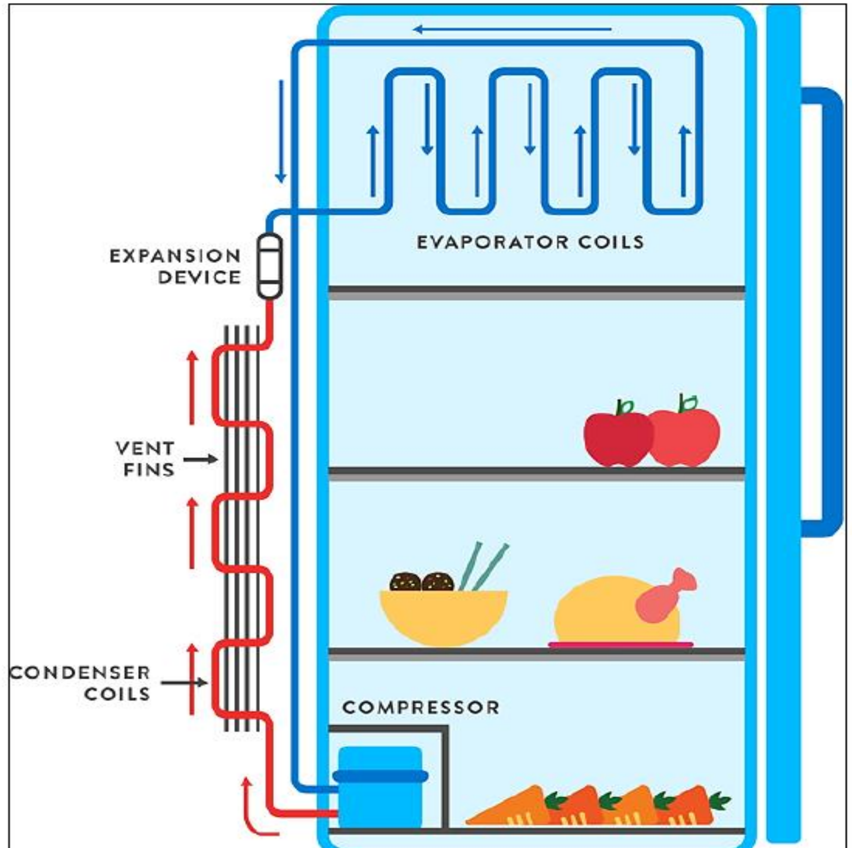
Advantages and Disadvantages over Air Refrigeration System

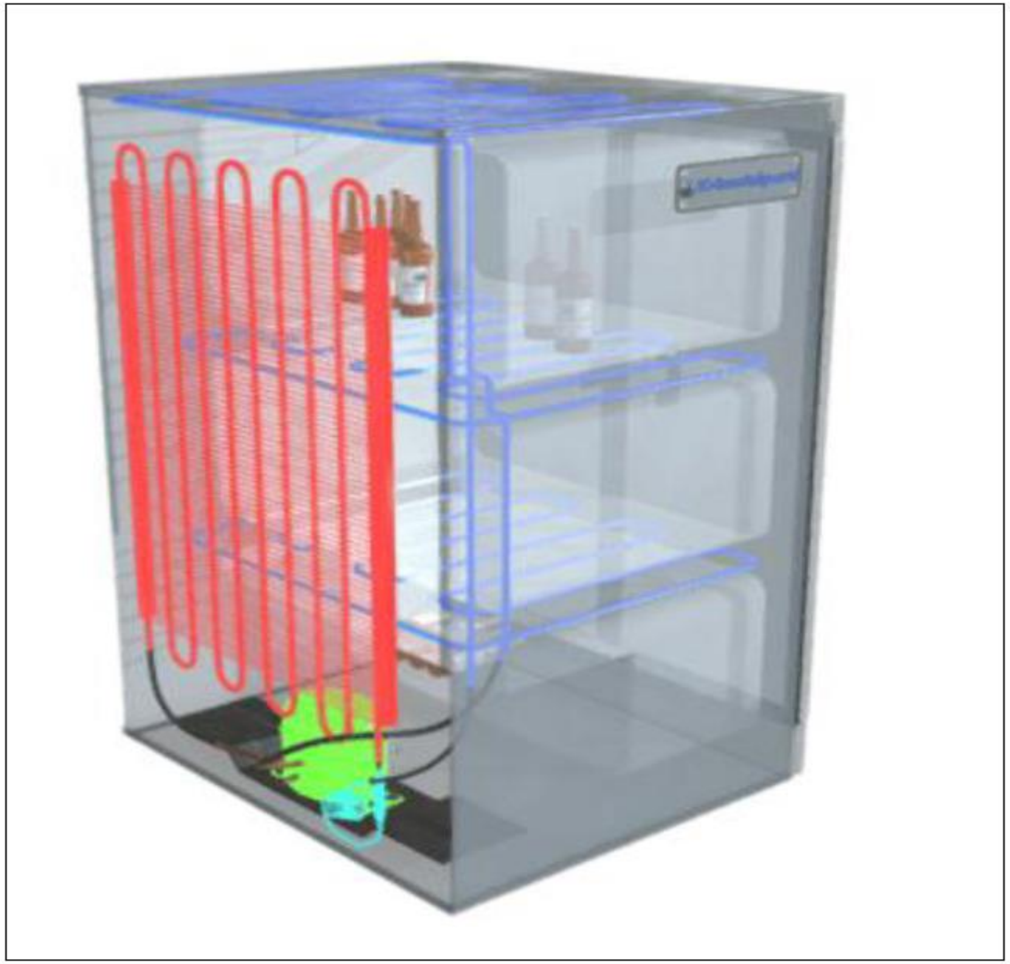
1. COP is quite high. (Working cycle is very near to reverse Carnot cycle.)
2. Cost – 1/5th of Air Ref System
3. Size of evaporator is smaller. (For same RE)
4. Required temperature of evaporator can be achieved easily just by adjusting throttle valve of same unit.

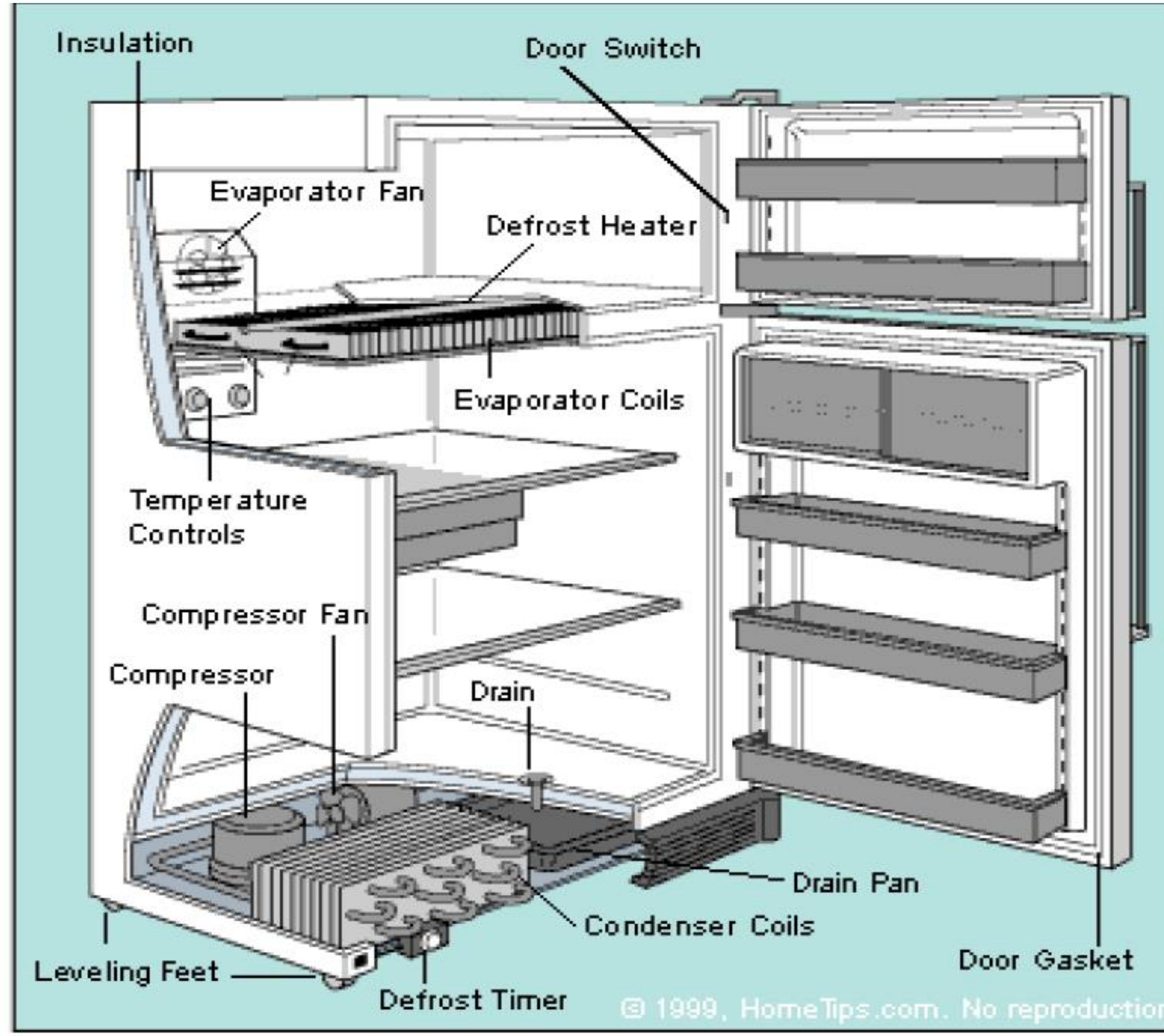
1. Initial cost is high.
2. Inflammability, leakage of vapour and toxicity. (Design improvement)

WORKING OF DOMESTIC REFRIGERATOR/ REFRIGERATOR COMPONENTS









Insulation
Door Switch
Evaporator Fan
Defrost Heater
Evaporator Coils
Temperature Controls
Compressor Fan
Compressor
Drain
Drain Pan
Condenser Coils
Door Gasket
Leveling Feet
Defrost Timer
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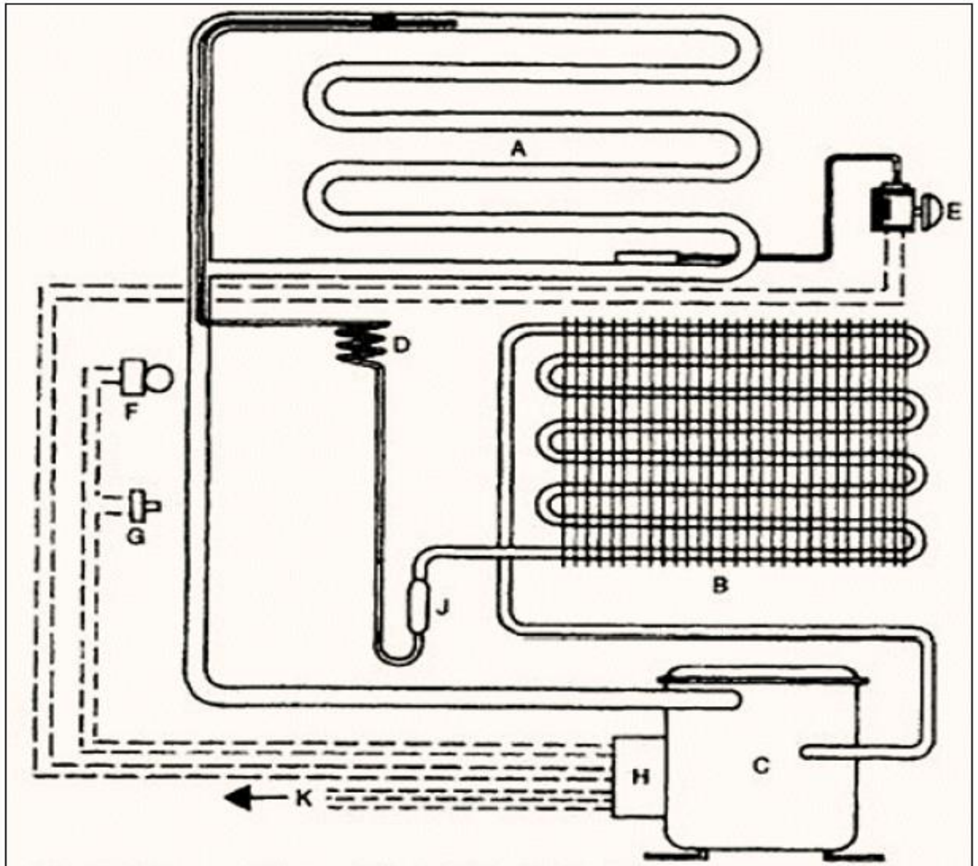
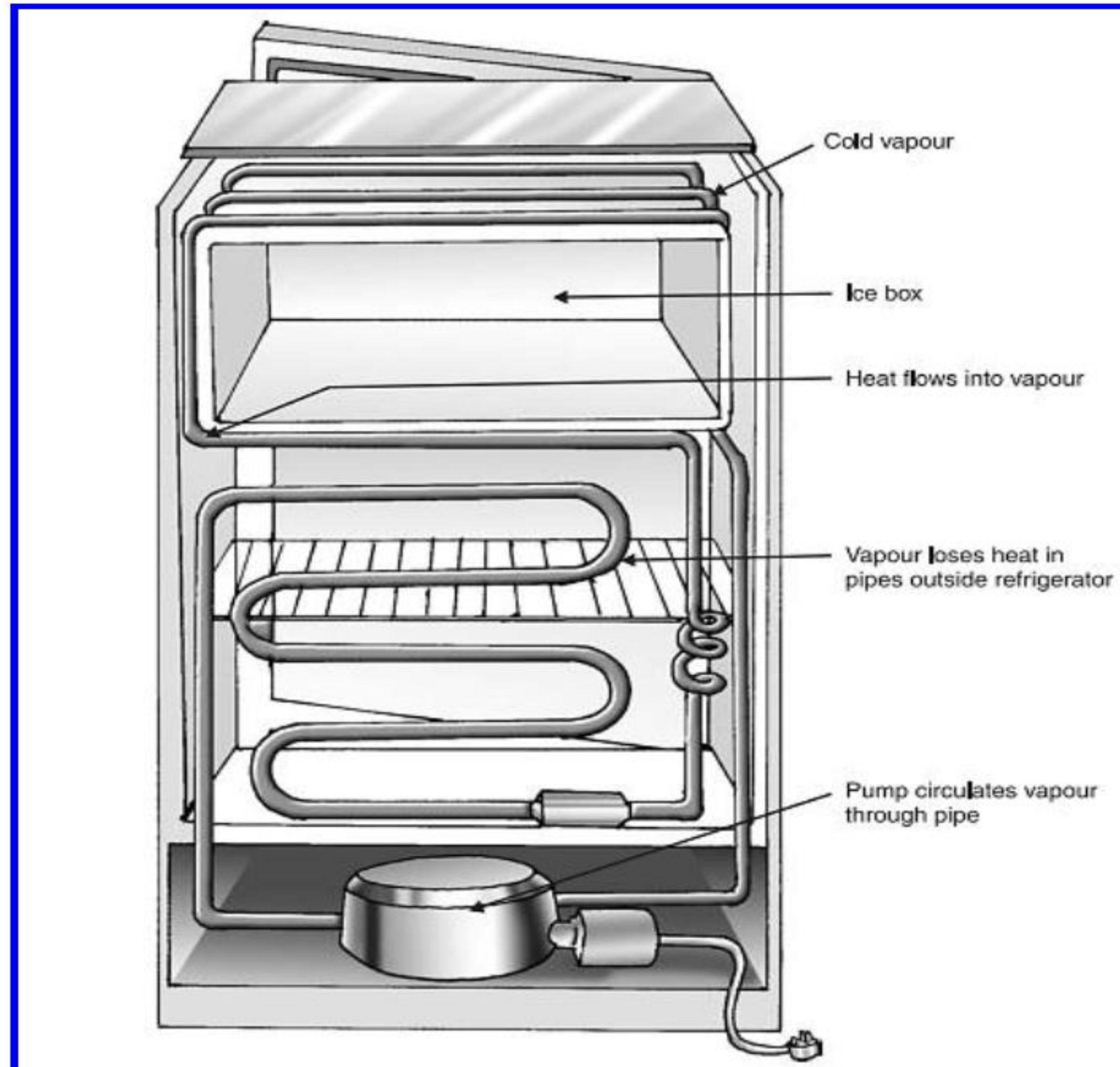
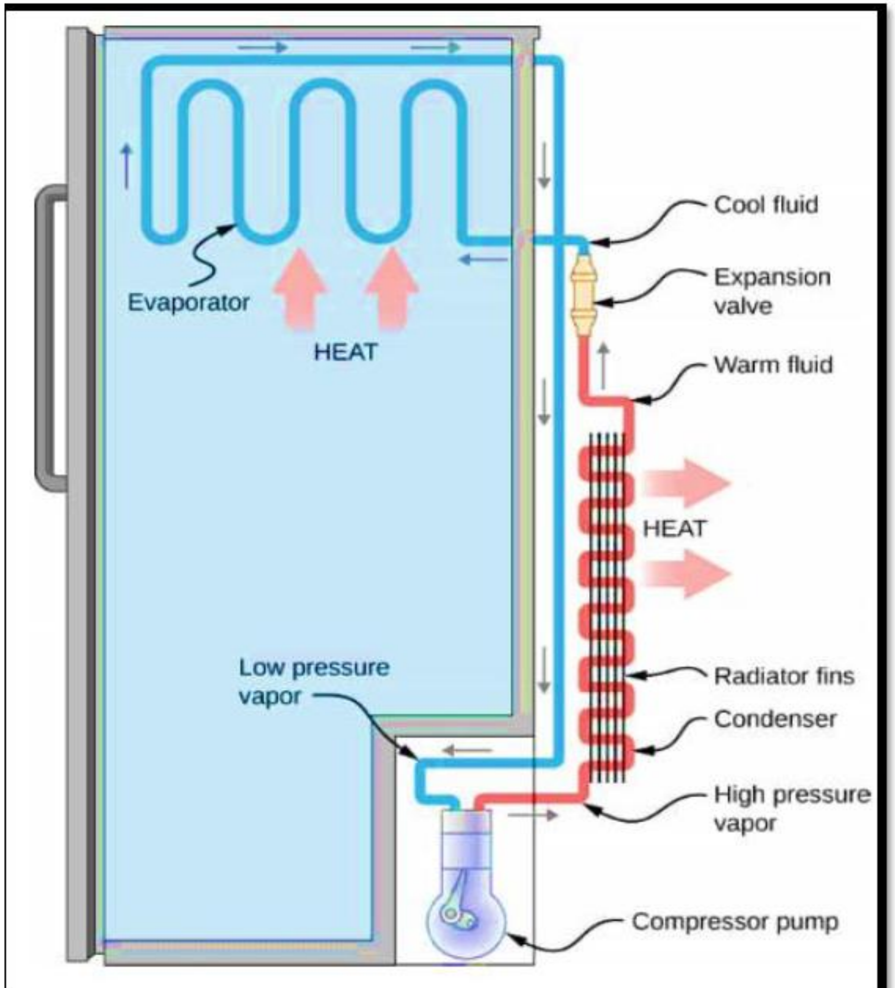


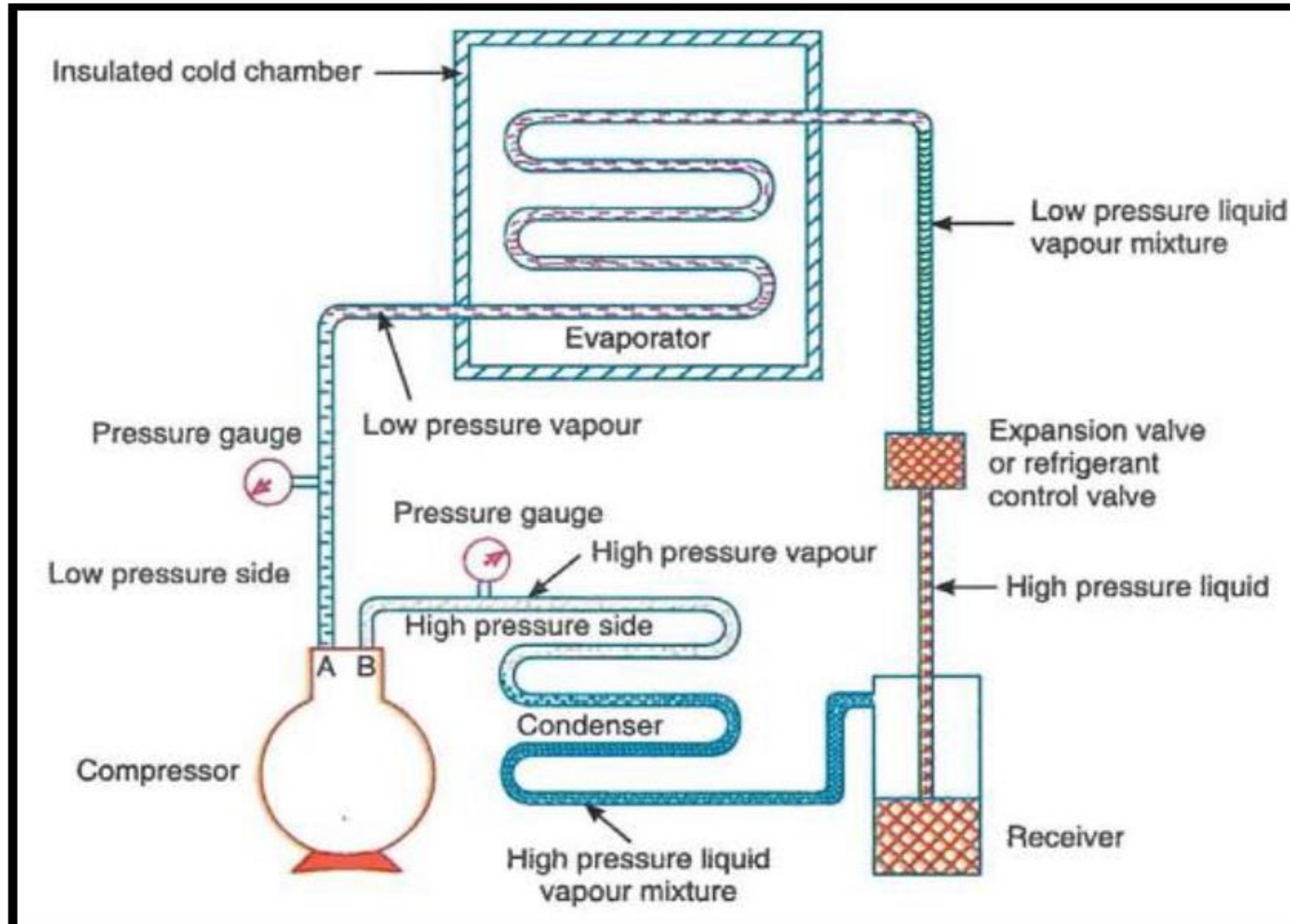
A evaporator
B condenser
C compressor
D capillary
E thermostat and cold control
F interior light
G door switch
H compressor control box
J filter drier
K mains electrical supply

Domestic refrigerator details

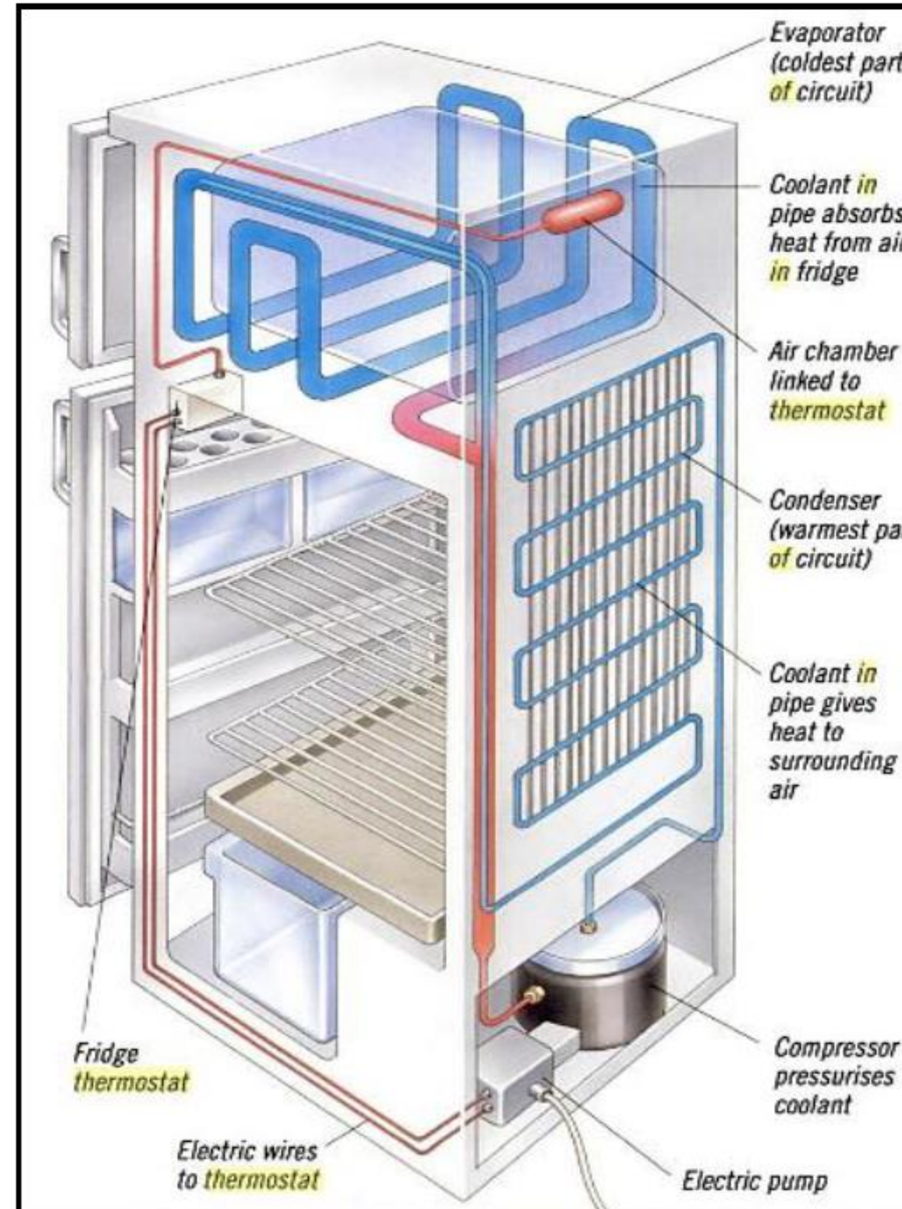


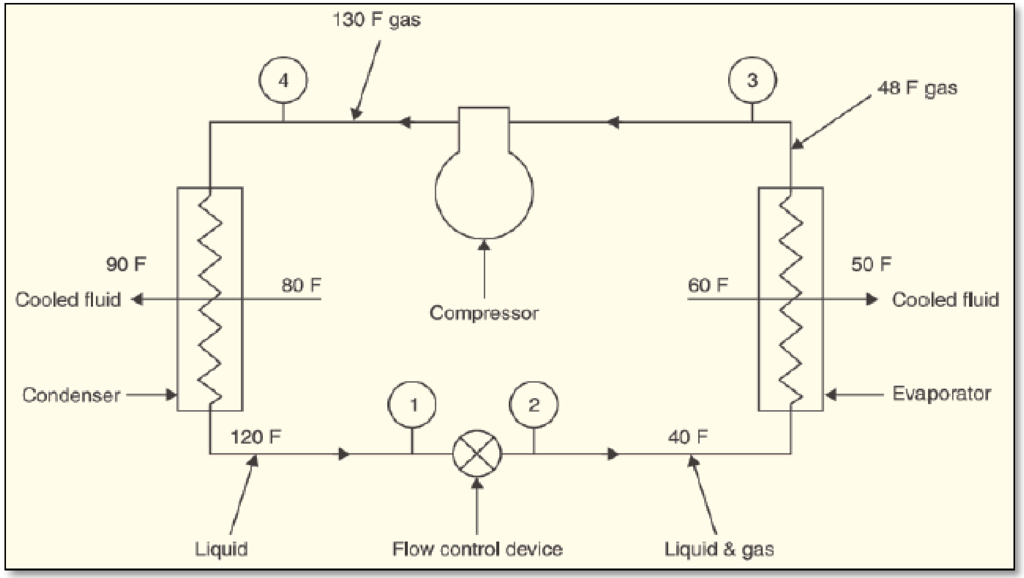
- The basic function of all the refrigerators is same. A refrigerator works by passing a refrigerant around the food items that are kept inside the refrigerator. The refrigerant absorbs heat from the articles kept inside the refrigerator and then loses that heat to the surroundings on the outside.





- ***Compressor:*** The **low pressure and temperature vapour refrigerant** from evaporator is drawn into the compressor through the **inlet or suction valve A**, where it is compressed to a **high pressure and temperature**. This high pressure and temperature vapour refrigerant is discharged into the condenser through the **delivery or discharge valve B.**
- ***Condenser:*** The condenser or cooler consists of coils of pipe in which the **high pressure and temperature vapour refrigerant** is cooled and condensed. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.
- ***Receiver:*** The **condensed liquid refrigerant** from the condenser is stored in a vessel known as receiver from where it is supplied to the evaporator through the expansion valve or refrigerant control valve.
- ***Expansion Valve:*** Also called as refrigerant control valve. The function of the expansion valve is to allow the **liquid refrigerant under high pressure and temperature** to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporised in the evaporator at the low pressure and temperature.
- ***Evaporator:*** An evaporator consists of coils of pipe in which the **liquid – vapour refrigerant at low pressure and temperature** is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporisation from the medium (air or water) which is to be cooled





- Refrigerant fluid *circulates through the piping and equipment in the direction shown. There are four* processes (*changes in the condition of the fluid) that occur as it flows through the system.*

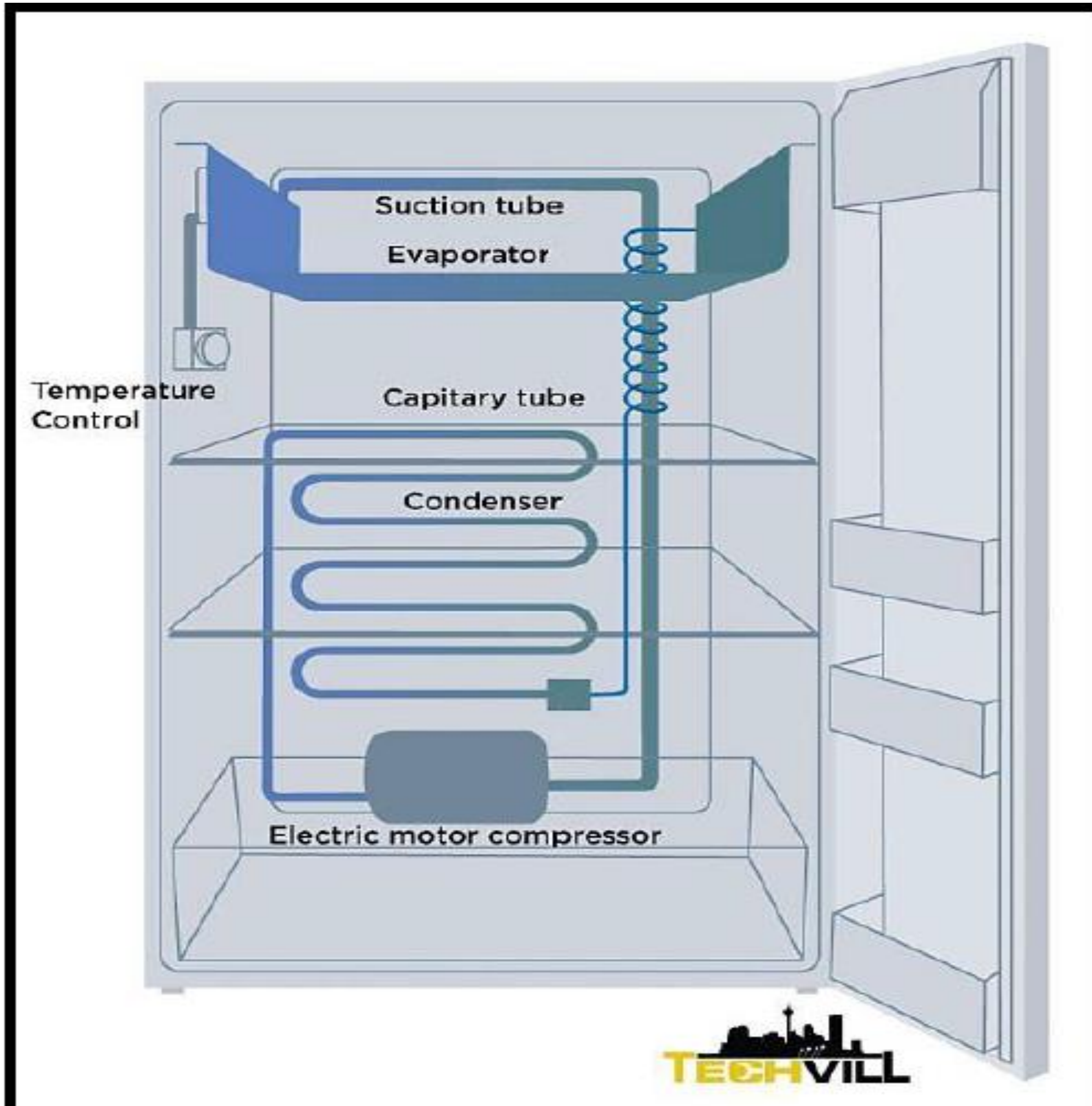
- ***Process 1–2 :*** *At point (1), the refrigerant is in the liquid state at a relatively high pressure and high* temperature. It flows to (2) through a restriction, called the *flow control device or expansion device. The* refrigerant loses pressure going through the restriction. The pressure at (2) is so low that a small portion of the refrigerant *flashes (vapourises) into a gas. But in order to vapourise, it must gain heat* which it takes from the portion of the refrigerant that did not vapourise, thus cooling the mixture and resulting in low temperature at (2).

- ***Process 2–3 :*** *The refrigerant flows through a heat exchanger called the evaporator. This heat exchanger* has two circuits. The refrigerant circulates in one, and in the other, the fluid to be cooled (usually air or water) flows. The fluid to be cooled is at a slightly higher temperature than the refrigerant, therefore heat is transferred from it to the refrigerant, producing the *cooling effect desired. The refrigerant boils because of* the heat it receives in the evaporator. By the time it leaves the evaporator, it is completely vapourised.

- ***Process 3–4 :*** *Leaving the evaporator, the refrigerant is a gas at a low temperature and low pressure. In* order to be able to use it again to achieve the refrigerating effect continuously, it must be brought back to the conditions at (1)–a liquid at a high pressure. The first step in this process is to increase the pressure of the refrigerant gas by using a compressor. Compressing the gas also results in increasing its temperature.

- ***Process 4–1 :*** *The refrigerant leaves the compressor as a gas at high temperature and high pressure. In* order to change it to a liquid, heat must be removed from it. This is accomplished in a heat exchanger called the *condenser. The refrigerant flows through one circuit in the condenser. In the other circuit, a cooling fluid* flows (air or water) at a temperature lower than that of the refrigerant. Heat therefore transfers from the refrigerant to the cooling fluid, and as a result, the refrigerant condenses to a liquid (1).

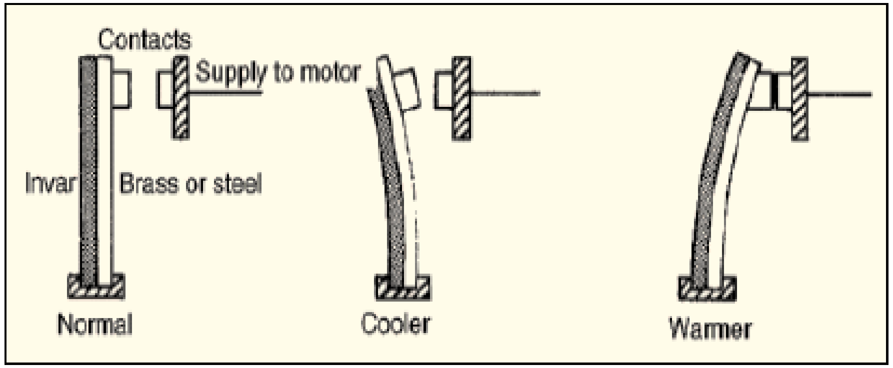
The refrigerant has returned to its initial state and is now ready to repeat the *refrigeration cycle. Of* course the processes are actually continuous as the refrigerant circulates through the system.

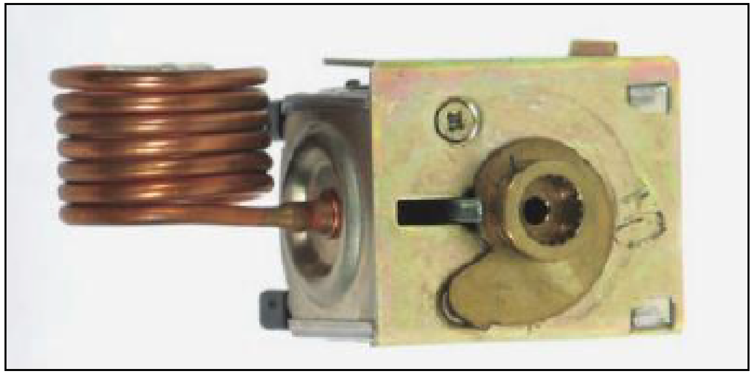


Suction tube
Evaporator
Temperature
Control
Capitary tube
Condenser
Electric motor compressor
TECHVILL

REFRIGERATOR COMPONENTS CONTROL

- The automatic control of a system is intended to maintain stable or constant conditions and also protect people and equipment. The system must regulate itself within its design boundaries. If the equipment is allowed to operate outside of its design boundaries, the system components may be damaged.
- **Temperature control** is used to maintain space or product temperature and to protect equipment from damaging itself. When used to control temperature, the control is called a **thermostat**; when used to protect equipment, it is known as a **safety device**.
- Without automatic temperature controls, the owner of the refrigerator would have to anticipate the temperature in the food compartment and get up in the middle of the night and turn it on or off to maintain the temperature. **The thermostat stops and starts the refrigeration cycle thousands of times over the course of 20 years to maintain the proper conditions.**
- **Thermostat:** The thermostat controls the cooling process by monitoring the temperature and then switching the compressor on and off. When the sensor senses that it's cold enough inside a refrigerator, it turns off the compressor. If it senses too much heat, it switches the compressor on and begins the cooling process again.





- When the inside of the refrigerator starts getting warm, a thermostat makes the pump switch on – **hear the pump as humming or whirring sound. The pump compresses the refrigerant so it condenses to a liquid.**
- A motor winding thermal protector (thermostat) is provided in compressor. The thermostat is embedded in the motor windings which senses the winding temperature. It stops the compressor when the winding temperature exceeds the safety point. **The winding insulation will progressively deteriorate if run at high winding temperatures, and the compressor motor will ultimately burnout. The winding temperature can also increase, if the compressor is run on overloaded conditions for long periods.**
- The refrigerator compressor has a protective device that keeps it from overloading and damaging itself. **This automatic overload control is designed** to function on the rare occasion that an overload or power problem might damage the compressor. One such example would be when the power goes off and comes right back on while the refrigerator is running. The overload control will open its contacts and stop the compressor for a cool-down period until it is ready to go back to work again.

Table Refrigerants and their fields of applications

1.	R717 Ammonia (NH_3) Boiling point –33.35°C	Used with open type reciprocating, rotary and screw compressors, in cold storages, ice plants, for food preservation, etc.
2.	R718 Water (H_2O) Boiling point 100°C	Used in the steam-ejector system only for air conditioning. Used as a secondary refrigerant.
3.	R11 (CCl_3F) Trichlorofluoromethane. Boiling point +23.8°C [R123 in place of R11]	Used with centrifugal compressors in large capacity central air conditioning plants. Used as a brine at temperatures as low as –100°C.
4.	R12 (CCl_2F_2) Dichlorodifluoromethane Boiling point –29.8°C (R134a in place of R12)	Widely used in domestic appliances. It is also used in commercial and industrial cooling installations, for example, frozen food display cabinets, cooling fountains, refrigerated trucks, railway wagons or containers. Used with all types of compressors, hermetic and open, piston, rotary, centrifugal and screw.
5.	R13 ($CClF_3$) Chlorotrifluoromethane, Boiling point –81.4°C	For temperatures down to –80°C in cascade freezing installations using R22 or R502 in the high temperature stage.
6.	R22 Chlorodifluoromethane ($CHClF_2$). Boiling point –40.8°C	Used as refrigerant in domestic, commercial and industrial air conditioning; commercial and industrial refrigeration including cold storages and food processing with reciprocating and often with screw compressors.
7.	R113 (CCl_2FCClF_2) Trichlorotrifluoroethane Boiling point +47.6°C	Used with centrifugal compressor for cooling water or brine for commercial or industrial applications.
8.	R114 ($CClF_2CClF_2$) Dichlorotetrafluoroethane Boiling point +3.6°C	Used with multistage centrifugal compressors for air conditioning at high temperatures and in aircraft.
9.	R502 Azeotropic mixture of 48.8% by mass of R22 and 51.2% by mass of R115 Boiling point –45.6°C	It is alternative to ammonia. It is most widely used for frozen food display cabinets, also in freezing chambers and cold stores at temperatures of the order of –35°C.

Maintenance of Domestic Refrigerator:

1. Levelled properly.
2. 230 V, 50 Hz supply. Voltage fluctuations-Compressor motor burnout
3. Refrigerator unit-closed to supply-overload and lighting extension cords may reduce the line voltage to a dangerous level.
4. Should not exposed direct rays to sun –Add the load of operation
5. 25 cm gap – condenser and wall
6. Without load operation – 02 hrs before loading
7. Condenser – No dust – periodical cleaning – no material covers the portion
8. Urgent need of ice – Thermostat to 5 – tray deflection to the out position. Afterwards change it to original position
9. Defrosting – periodically – frost is barrier – hinders cooling – load operation
10. Harsh cleaners- defrosting – by striking or chipping off the ice – Leakage of gas
11. Tray should be kept out when it's desired to collect the dripping water from freezer chest – defrosting
12. Food – closed container – wrapped in polythene or aluminum foil
13. Properly earthed – operated on three point plug – improper earthing – fatal accident

TROUBLE SHOOTING OF REFRIGERATOR

S No.	Symptoms	Causes
1.	**Motor fails to start on giving supply**	• Thermostat contacts open • Blown fuses in the main switch • Overload release open • Open circuit in the main winding • Open circuit in the auxiliary winding • Burnt or shorted winding • Excessive overload • Bent rotor shaft etc.
2.	**Motor runs slower than normal speed**	• Low voltage • Overload • Shorted main winding • Defective electromagnetic relay • Worn – out bearings
3.	**Motor runs hot**	• Low voltage • Overload • Shorted or grounding winding • Worn – out bearings
4.	**Motor does not start and gives humming noise**	• Low voltage • Overload • Open circuit in the auxiliary winding
5.	**Motor runs with noise**	• Shorted winding • Improperly connected poles • Loose rotor bar • Worn – out bearings • Foreign material in the rotor.

S No.	Symptoms	Causes
6.	Motor starts very frequently	• Bad door seal • Wrong setting of thermostat
7.	Motor keeps on running even though it is very cold inside the refrigerator	• Wrong setting of thermostat • Defective thermostat
8.	Motor operates normal with normal cooling in freezer but cooling in the rest portion is unsatisfactory	• Bad door seal • Opening of door too frequent
9.	Too much frosting around the freezer	• High atmospheric humidity or steaming hot liquids stored.
10.	Noisy operation	• Bearings faulty • Loose mounting bolts

	Defect		Cause		Remedy
1.	*Motor does not start on giving supply.*	(*i*)	Power not reaching the motor due to (*a*) Blown fuse (*b*) Thermostat contacts open (*c*) Overload release open.	(*i*)	(*a*) Check for blown fuses in the main switch (*b*) Thermostat wiring may be open, thermostat may be defective or improperly adjusted (*c*) Relay may be defective
		(*ii*)	Motor defective	(*ii*)	Main winding may be open or shorted or grounded
2.	*Motor runs hot*	(*i*)	Overload	(*i*)	Reduce load
		(*ii*)	Low voltage	(*ii*)	Install automatic voltage regulator
		(*iii*)	Insulation failure of motor winding developing short-circuit between turns or with ground	(*iii*)	Replace or repair the sealed unit
		(*iv*)	Bearings worn-out	(*iv*)	Replace or repair the sealed unit
3.	*Motor does not start and gives humming noise*	(*i*)	Either relay contacts being not closed or aux. winding being open	(*i*)	Replace relay or replace or repair sealed unit
		(*ii*)	Low voltage	(*ii*)	Install automatic voltage regulator
		(*iii*)	Motor overloaded accompanied with tripping of overlaod relay	(*iii*)	Choke in the refrigerant circuit which requires purging.
4.	*Motor runs slow*	(*i*)	Low voltage	(*i*)	Correct the voltage
		(*ii*)	Overload of motor	(*ii*)	Check for choke of the refrigerant piping.

	Defect		Cause		Remedy
5.	*Motor keeps on running even though it is very cold inside the refrigerator*	(*i*)	Defective thermostat due to short in its wiring or sticking contacts	(*i*)	Check and repair
		(*ii*)	Wrong setting of thermostat	(*ii*)	Set correctly
6.	*Motor keeps on running but (i) Cooling is insufficient*	(*i*)	Less refrigerant gas in the system due to (*a*) Leakage of gas or (*b*) Partial choking of capillary (Indicated by hot capillary up to point of choke and cold beyond it)	(*i*)	(*a*) Replenish the gas lost due to leakage (*b*) Purge the system and recharge it.
	(ii) Cooling is nil	(*ii*)	(*a*) No refrigerant in the system (indicated by the unit, tubing and condenser being at ambient temperature) (*b*) Complete choke of capillary	(*ii*)	(*a*) Recharge gas (*b*) Purge the system and recharge.
7.	*Motor starts at short intervals otherwise cooling is good*	(*i*)	Improper setting of thermostat	(*i*)	Readjust the switch
		(*ii*)	Bad door seal	(*ii*)	Replace the door seal
8.	*Motor runs normal with normal cooling in freezer but cooling in the rest of compartment is not satisfactory*		Defective door seal or warped door or opening of refrigerator door too frequently		Replace or repair door seal or door and reduce the frequency of opening of the refrigerator door.
9.	*Too much frosting around the freezer*		High atmospheric humidity or steaming hot liquids stored		Avoid keeping hot liquids and defrost frequently.
10.	*Motor works normal with good cooling but defrosting starts all of a sudden. Cooling again starts after sometime*		Presence of moisture in the refrigerant cycle		Install drier on h.p. side or if already installed replace silica gel.
11.	*Noisy operation*	(*i*)	Bearings faulty	(*i*)	Repair sealed unit
		(*ii*)	Loose mounting bolts	(*ii*)	Tighten the bolts

HISTORY OF REFRIGERATION AND AIR - CONDITIONING

$$1\ \text{kW} = 3413\ \text{Btu}$$

$$20\ \text{kW} \times 3413\ \text{Btu/kW} = 68{,}260\ \text{Btu of heat energy}$$

Btu – British Thermal Unit

- The term **refrigeration** is used here to include both the cooling process for preserving food and comfort cooling (air-conditioning).
  - **Preserving food is one of the most valuable uses of refrigeration. The rate of food spoilage gets slower as molecular motion slows, which retards the growth of bacteria that causes food to spoil. Below the frozen hard point, which for most foods is considered to be 0°F, food-spoiling bacteria stop growing .**
  - **Comfort cooling systems, commonly referred to as air-conditioning systems, are used, for example, to cool our homes and commercial spaces and are classified as high-temperature refrigeration systems.**

- **Air - Conditioning:** Air conditioning is a combined process that performs many functions simultaneously.
  a. It conditions the air, transports it, and introduces it to the conditioned space.
  b. It provides heating and cooling from its central plant or rooftop units.
  c. It also controls and maintains the temperature, humidity, air movement, air cleanliness, sound level, and pressure differential in a space within predetermined limits for the comfort and health of the occupants of the conditioned space or for the purpose of product processing.
- **Air – Conditioning System:** An air conditioning, or HVAC&R, system is composed of components and equipment arranged in sequence to condition the air, to transport it to the conditioned space, and to control the indoor environmental parameters of a specific space within required limits.

HVAC&R: Heating, Ventilation, Air – Conditioning and Refrigeration

TON Rating of Refrigeration and Air - Conditioning

- Air conditioners are rated in Tons capacity instead of kW or kVA rating because Air conditioners are designed on the basis of quantity of heat removal from room, hall or specific area.
  a. One ton is equal to the amount of heat required (288,000 Btu) to melt one ton of ice in a 24-hour period.
  b. Quantity of heat is termed in Tons means if an air conditioner is able to remove 1000 kilo calories of heat or 4120 kilo joules or 12000 Btu of heat in an hour is rated as 1 Ton of AC.
  c. One ton of refrigeration is the amount of heat necessary to melt 1 ton of ice in a 24-hour period. It takes 288,000 Btu to melt 1 ton of ice in a 24-hour period, or 12,000 Btu in 1 h, or 200 Btu in 1 min.
  d. One Ton always means 12000 Btu of heat removal per hour, irrespective of the working substance used and the operating conditions. This unit of refrigeration is currently used in UK, USA and India.

1 Ton = 12,000 BTU/h

1 Watt = 3.412141633 BTU/h

1 Ton = 12,000 / 3.412141633 = 3,516.8528 Watts = 3.5168528 kW.

1 Ton = 3,516.8528 Watts = **3.516 kW.**

1 Ton = 3,516.8528W / 746 = 4.7142798928 Hp →→→ (1 Hp = 746 Watts)

1 Ton = 4.714 Hp

AIR – CONDITIONING / AIR - CONDITIONERS

Air conditioning is the process of treating air in an *internal environment to establish and maintain required* standards of temperature, humidity, cleanliness, and motion. This is how each of these conditions is controlled:

1. **Temperature :** *Air temperature is controlled by heating or cooling the air. Cooling technically* means the *removal of heat, in contrast to heating, the addition of heat.*
2. **Humidity :** *Air humidity, the water vapour content of the air, is controlled by adding (humidification)* or removing (*dehumidification) water vapour from the air.*
3. **Cleanliness :** *Air cleanliness or air quality is controlled by either filtration, the removal of undesirable* contaminants using filters or other devices or by *ventilation, the introduction of outside air into the* space which dilutes the concentration of contaminants. Often *both filtration and ventilation are* used in an installation.
4. **Motion :** *Air motion refers to air velocity and to where the air is distributed. It is controlled by* appropriate air distributing equipment.

WORKING OF ROOM WINDOW AIR - CONDITIONER

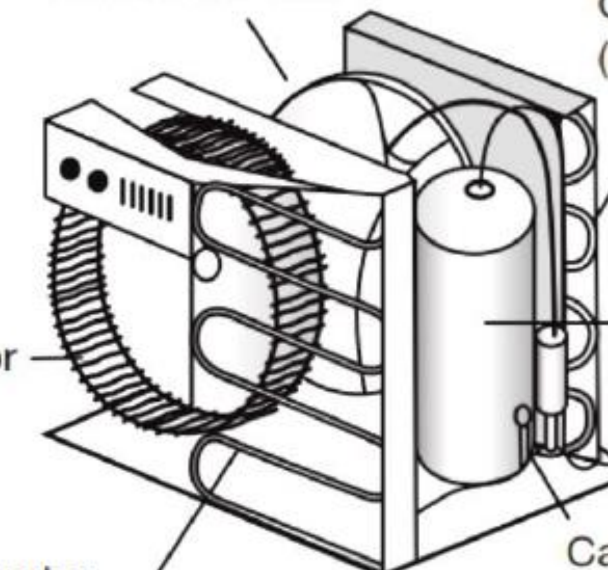
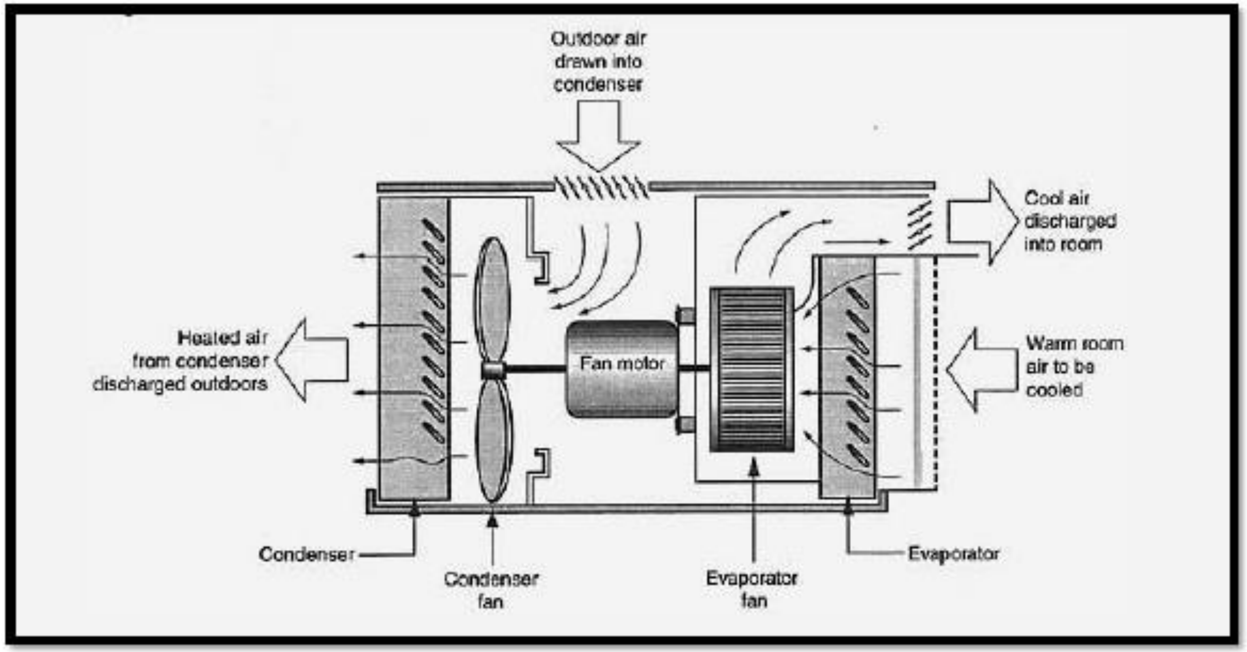
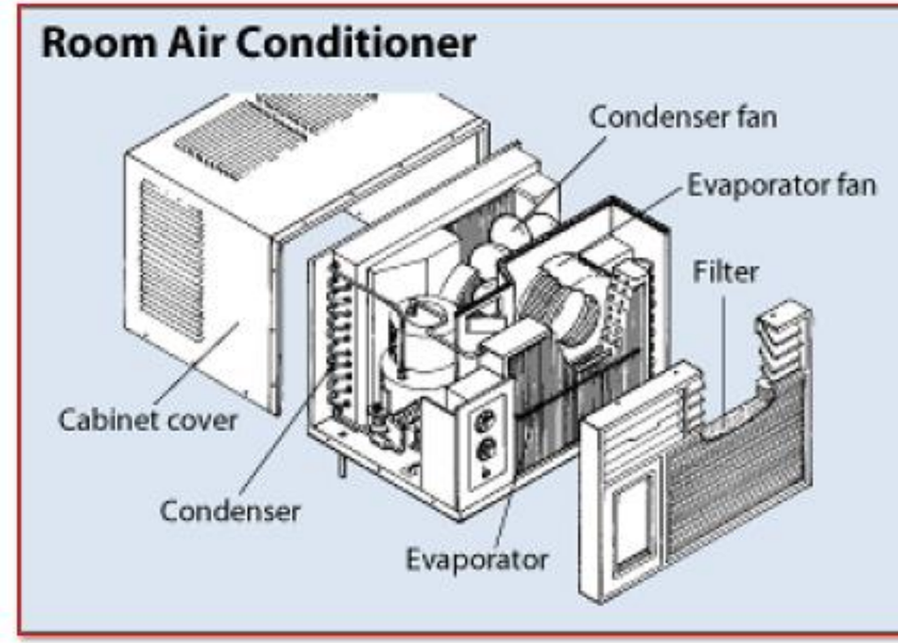
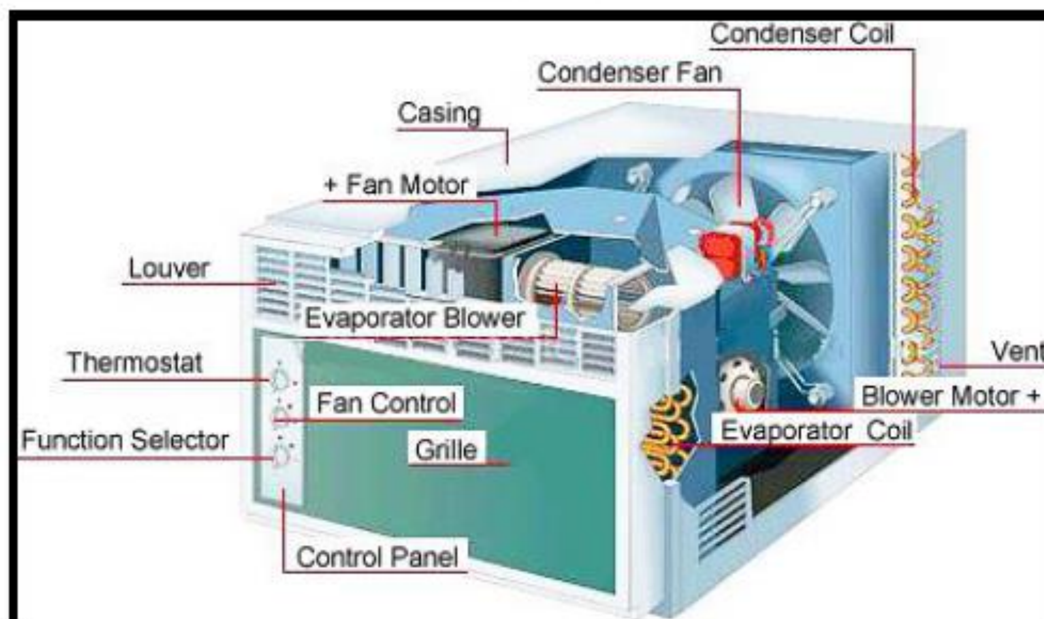


FIGURE Window Air Conditioner and it Components


Outdoor air
drawn into
condenser
Cool air
discharged
into room
Heated air
from condenser
discharged outdoors
Fan motor
Warm room
air to be
cooled
Condenser
Condenser
fan
Evaporator
fan
Evaporator


Room Air Conditioner
Condenser fan
Evaporator fan
Filter
Cabinet cover
Condenser
Evaporator


Condenser Coil
Condenser Fan
Casing
+ Fan Motor
Louver
Evaporator Blower
Thermostat
Fan Control
Function Selector
Grille
Control Panel
Vent
Blower Motor +
Evaporator Coil

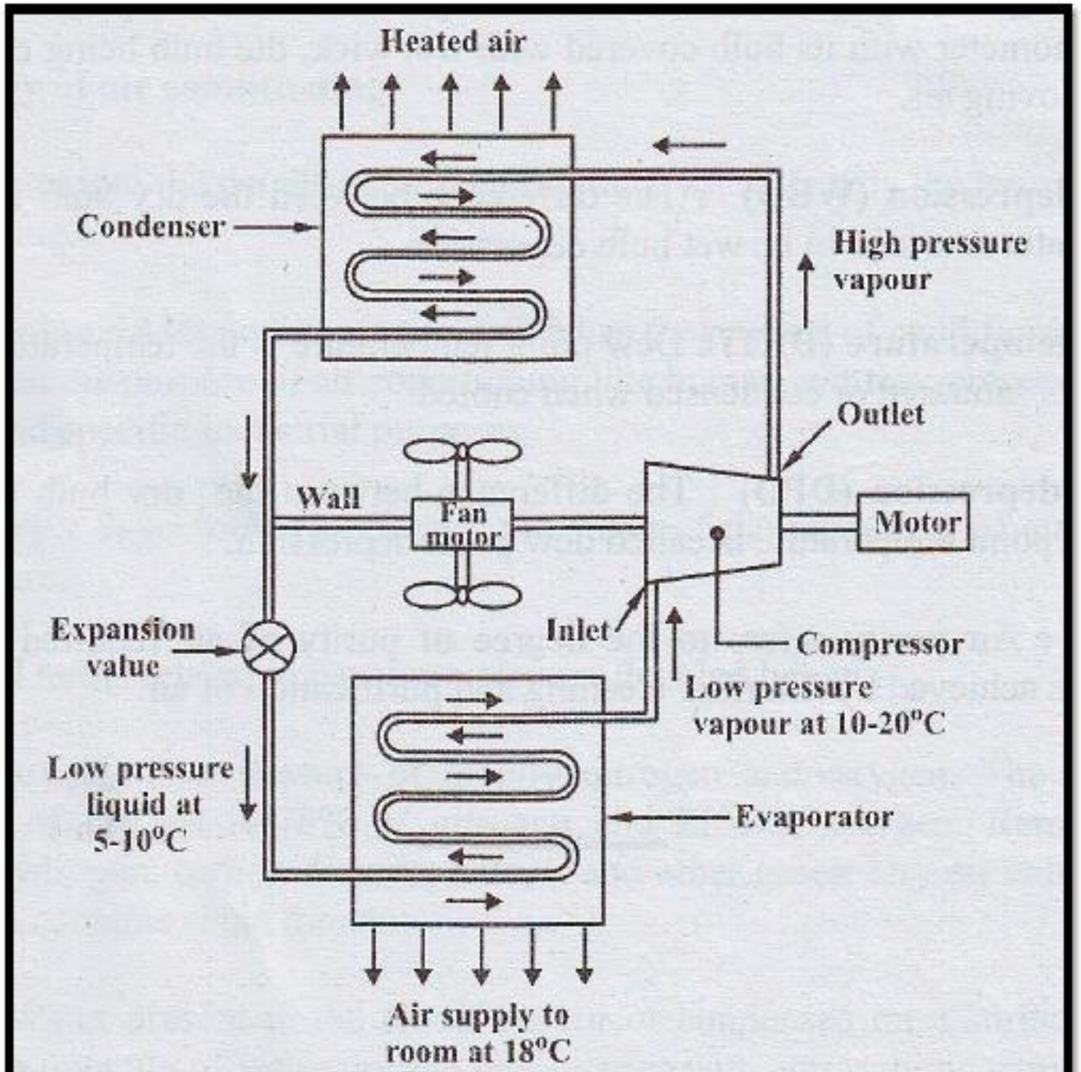
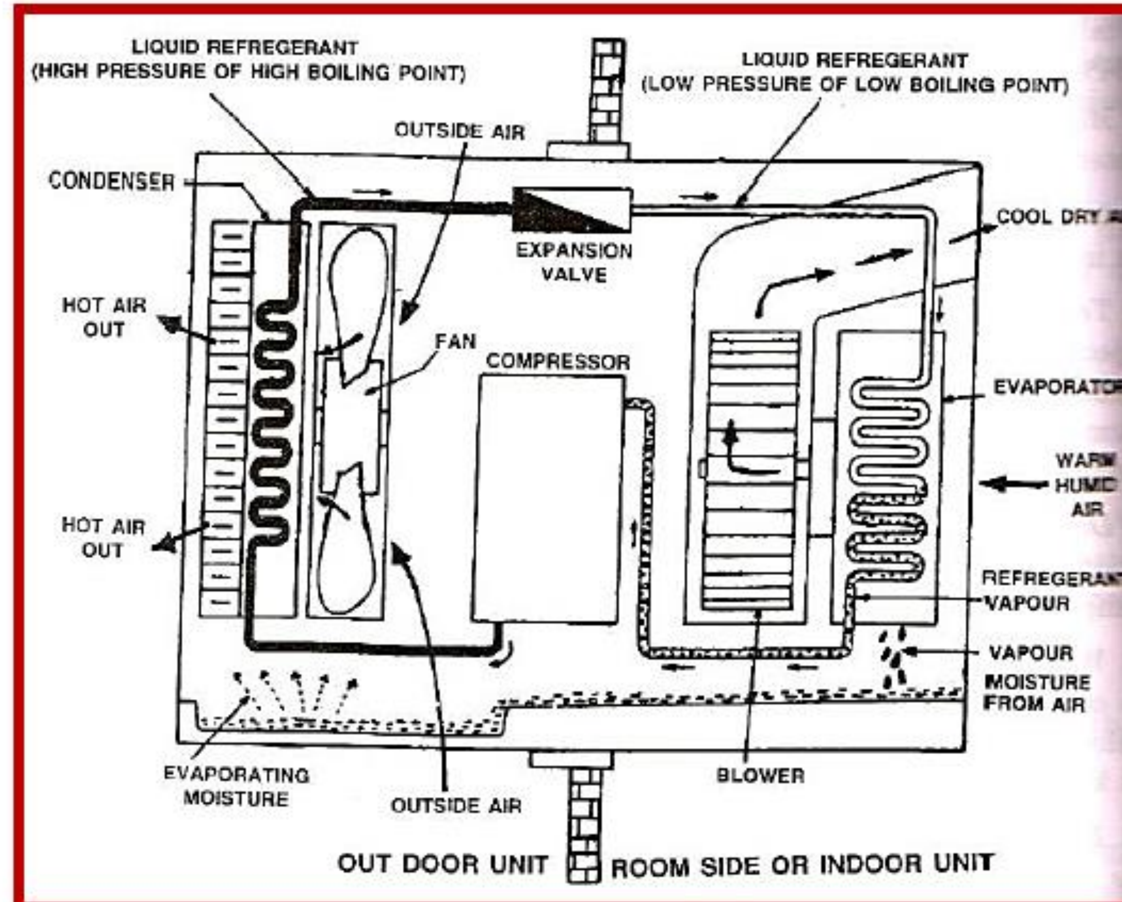
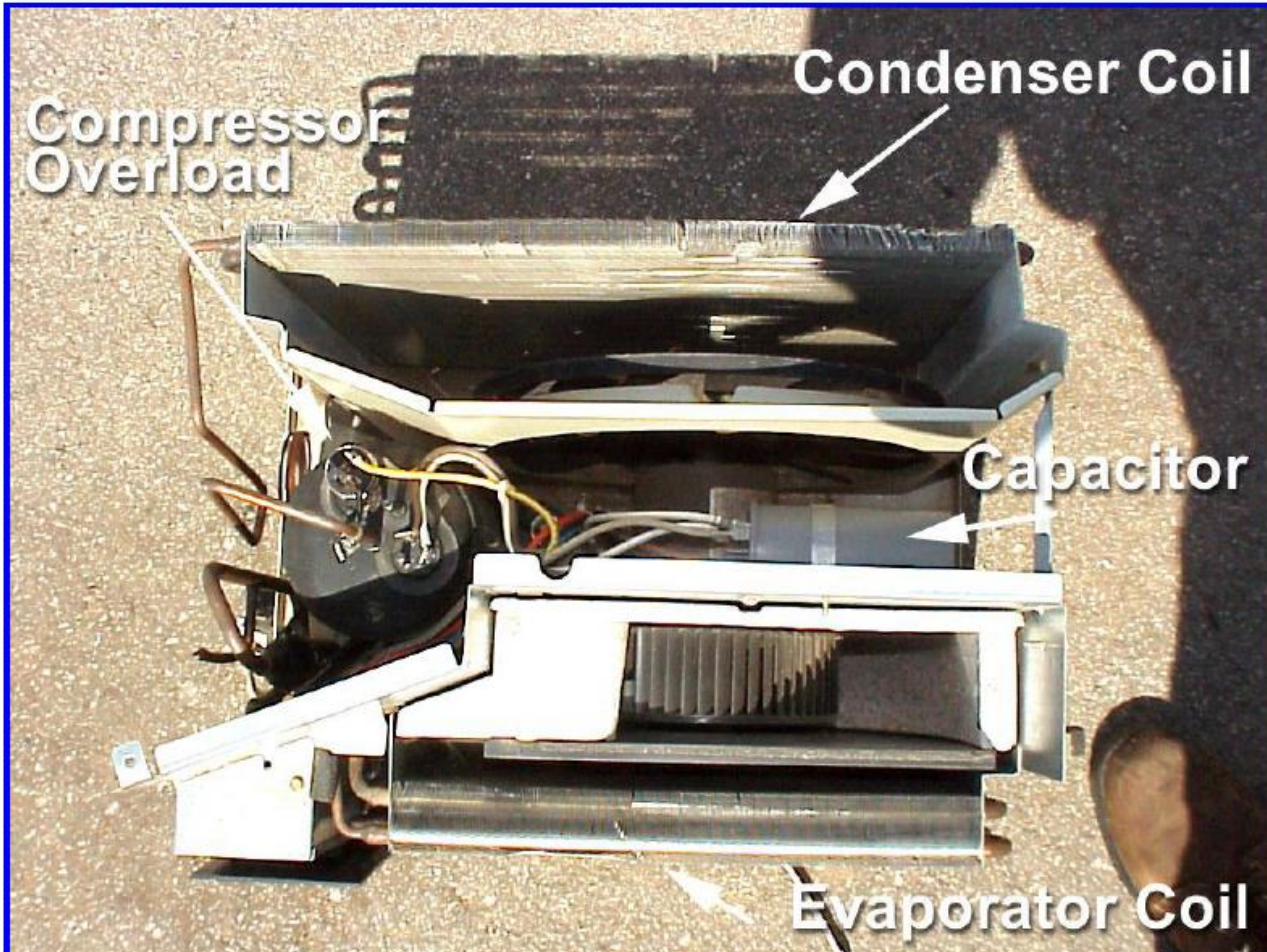


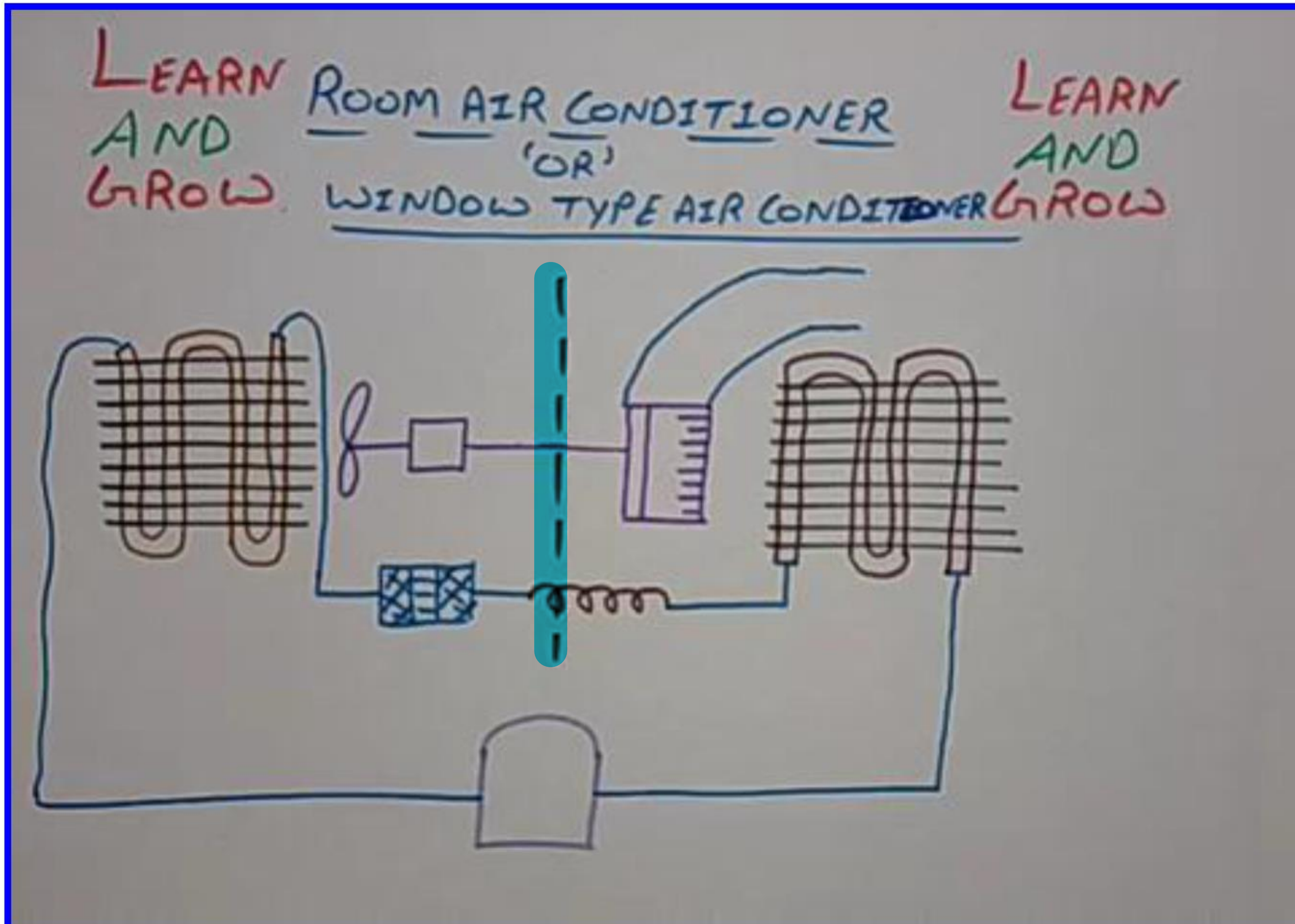
Fig.1 Window room air conditioner



- **These types of AC are designed to be fitted in window sills.**
- **A single unit of Window Air Conditioner houses all the necessary components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil enclosed in a single box.**
- **Since a window AC is a single unit, it takes less effort to install as well as for maintenance.**
- **This is the most commonly used air conditioner for single rooms.**
- **Parts of the Window Air Conditioner: The whole assembly of the window air conditioner can be divided into two compartments:**
  - **the room side, which is also the cooling side** and
  - **the outdoor side from where the heat absorbed by the room air is liberated to the atmosphere**.

  The room side and outdoor side are separated from each other by an insulated partition enclosed inside the window air conditioner assembly.


Compressor
Overload
Condenser Coil
Capacitor
Evaporator Coil


LEARN AND GROW
ROOM AIR CONDITIONER
'OR'
WINDOW TYPE AIR CONDITIONER
LEARN AND GROW

COMFORT AIR - CONDITIONING

- To produce comfortable and healthy conditions for occupants.
- Comfort air – conditioning is the process of treating air so as to control simultaneously the prevailing conditions of **temperature, humidity, cleanliness and distribution** in the conditioned space to meet the comfort and health requirements of the occupants.
- The important places intended for human occupancy and requiring comfort air conditioning are the **residences, departmental stores, cinema halls, malls, commercial buildings, hotels** etc.
- Human requirements must be known to understand comfort air – conditioning.
  - Human body is a **thermostat with inner temperature of 98.4^{0}F (37^{0}C) and outer temperature of about 26.5^{0}C**. Under normal conditions our body emits 2500 kcals per 24 hours (**45% dissipated by radiation; 30% by convection and remaining 25% by evaporation**)
  - Heat dissipated by radiation, convection and evaporation is governed by surrounding temperature, air temperature and humidity of air. **It is necessary for human body to dissipate the above proportion of heat in order that we may feel convenient and comfortable**.
  - For producing comfort, it is required to maintain surrounding temperature between **22^{0}C to 25^{0}C during summer and 17^{0}C to 20^{0}C during winter and humidity between 40 – 60%**

INDUSTRIAL AIR - CONDITIONING

- A large number of manufacturing, inspection, measuring processes require a close control of temperature and relative humidity.
- Industrial air conditioning is generally defined as the process of simultaneously controlling the temperature, relative humidity, ventilation, cleaning and movement of air within an enclosure intended for the manufacture, inspection and movement of a product which is sensitive to atmospheric conditions (e.g. manufacture of rayon and various plastics, photographic material manufacturing etc.)

SMART Air - Conditioners

- In a nut shell, “smart” air conditioners are part of the new class of home technologies that allow you to use the product with your home **Wi-fi through your smartphone or tablet**, so that you don’t even have to be at home to adjust the temperature.
- **Alternatively said**, **The Smart AC Controller controls your air conditioner’s power, temperature, mode, and fan speed from your phone anytime, anywhere in the world. Set weekly schedules, turn your air conditioner on and off automatically**
- **THE PROS OF SMART AIR CONDITIONERS:** Smart air conditioners have several pros to offer:
    1. **Convenience:** You can turn the air conditioner on or off using a smartphone or device, whether you're at home or out. This means you have full control over your home's atmosphere as temperatures rise and fall.
    2. **Smart home connectivity:** If you have other smart devices in your home, such as automatic window blinds or lights, you can connect these devices to control the temperature of your home better. For example, if you live in a hot climate, you can program the air conditioner to turn on, the blinds to shut, and the lights to dim to cool your home.
    3. **Multiple options:** Smart air conditioners come in various types, including in-window, portable, in-wall, and split units. Multiple options allow you to choose an air conditioner that works best for you, your home, and your temperature needs
    4. **Long-term cost savings:** Smart air conditioners come with a hefty initial price tag. Still, you'll save on energy costs by turning the air conditioner off when you're not home.

❑ THE CONS OF SMART AIR CONDITIONERS

1. **Price:** Smart air conditioners are pricey because these devices are relatively new to the market. Depending on the size of the unit you choose, a smart air conditioner can range in price from $300 to thousands.
2. **Multiple units are required:** Smart air conditioners don't work centrally, so multiple units are required to cool an entire home.
3. **Installation:** Installing a smart air conditioner can be difficult, depending on the unit you choose. These also take up valuable space in a home. For example, a window unit needs to be installed in the lower half of the window, rendering the window unavailable for use.

LG Dual Inverter Smart Wi-Fi Air Conditioner

BTUs: 9,500, 14,000, 18,000, 22,000 | **Room size:** 450, 800, 1,000, 1,300 square feet | **Energy Efficiency Ratio:** 14.7 | **Works with:** Alexa, Google Assistant

Automatic Window Blinds

- A room air conditioner's efficiency is measured by the **energy efficiency ratio** (EER). The EER is the ratio of the cooling capacity (in British thermal units [Btu] per hour) to the power input (in watts). The higher the EER rating, the more efficient the air conditioner.
- So a system with an EER rating of 10 will produce 10 Btu's of cooling for every watt of power consumed under the specified conditions.

INVERTER BASED AIR CONDITIONERS

- The inverter technology is the latest advancement concerning the electromotor of compressors. An **inverter is used to regulate the speed of the compressor motor in order to adjust the temperature**.
- The main feature of an **inverter AC is its ability to control its compressor motor speed.** The regulated speed allows the unit to maintain the temperature without having to power down its motor. **This means an inverter air conditioning unit is way more energy-efficient than non-inverter ones.**
- The inverter air conditioning offers variable compressor speed. **The sensor embedded in the inverter regulates the power in accordance with the room temperature, thus resulting in less electricity consumption and higher energy-efficiency.**
- **When compared to non-inverter ACs, inverter air conditioners have fluctuation detection capabilities and automatic adjustments made to the overall compressor speed. This advanced mechanism helps save energy, proving beneficial to the surroundings.**

Major Benefits –

- **Cost-effective**

Owing to the operational method of inverter air conditioner, its compressor does not work at full capabilities, hence saving you from paying a huge amount of money at the cost of electricity units. Thus it is much more efficient than a non-inverter AC as it helps you save a lot on electric bills.

- **Energy-efficient**

The inverter technology is regarded as the best solution when it comes to economic and energy-saving operation. In an inverter model, the heating and cooling are automated in a seamless and power-saving manner

- **Better Cooling**

A non-inverter AC cannot adjust the level of cooling, so it cannot cool the area faster when required. On the other hand, **inverter AC** can run the compressor at a higher speed to cool the entire area fast when required.

- **Silent Operation**

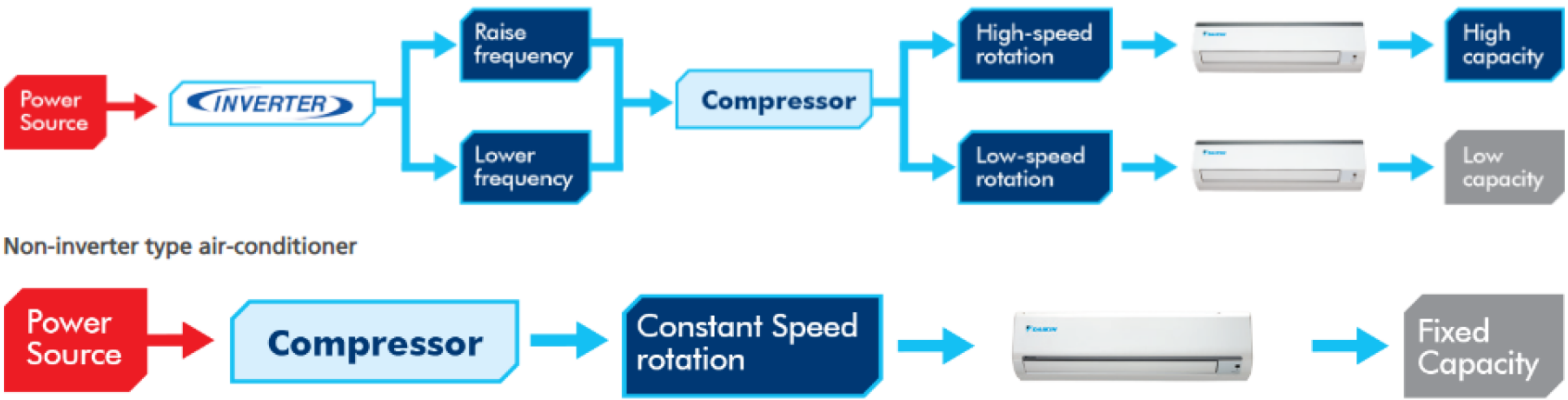
The inverter AC runs at a very slow speed, thus it is much more silent.

- **Sound Sleep**

AC enables you to have a sound sleep as it maintains the temperature of the room steady at the temperature you set on the thermostat of the AC.

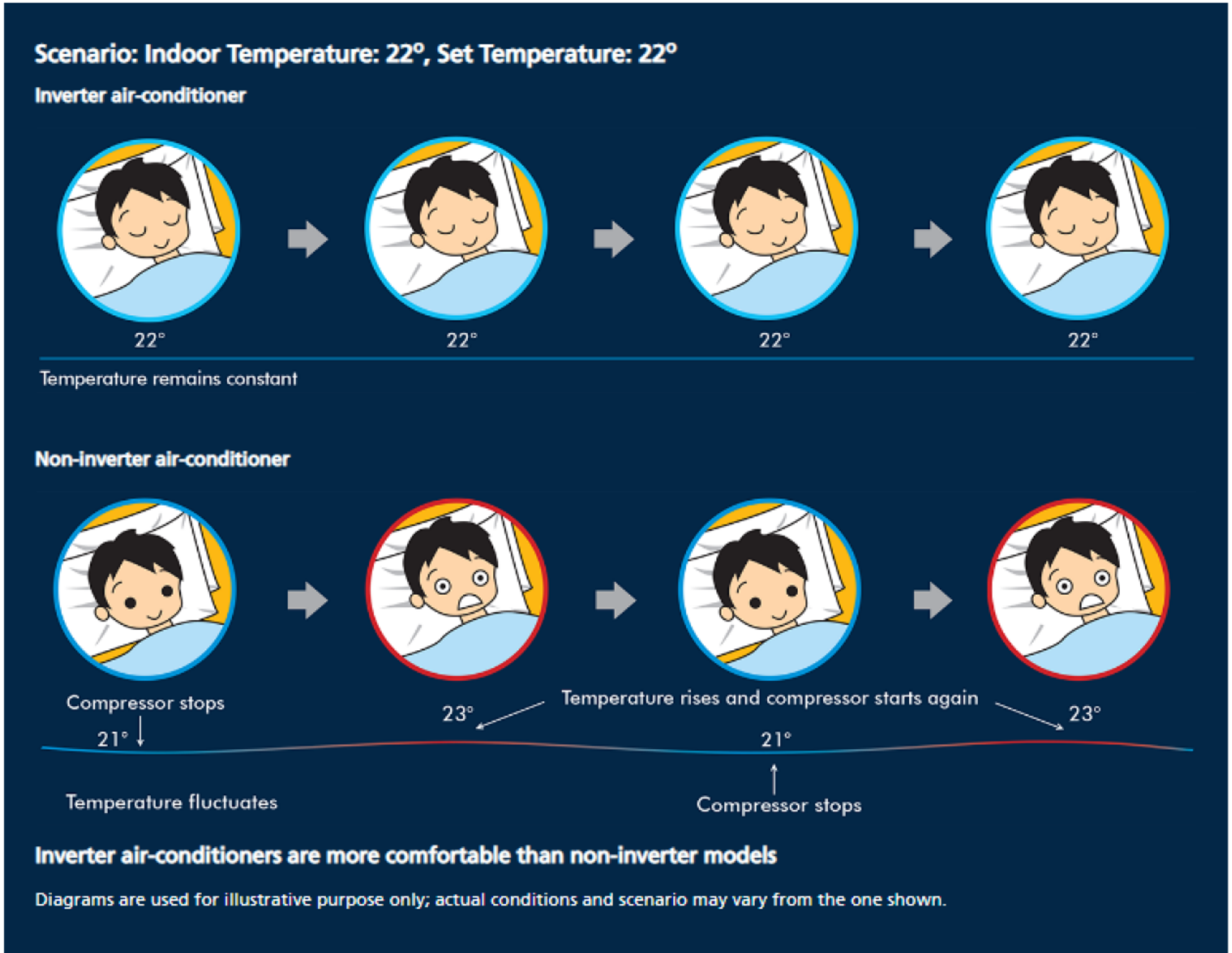
Variable capacity operation

Inverter power control



Inverter air-conditioners are able to vary their operating capacity. Non-inverter air-conditioners can only operate at a fixed capacity.

Compressor speed can be varied by using a motor with a variable frequency drive. Power consumed by a motor varies as the cube of its speed, i.e. if speed increases from **800 to 1000 rpm (an increase of 25%)**, the power requirement will go up $\left[\frac{1000}{800}\right]^3 = 1.95$ **an increase of 95% as against the speed increase of only 25%**. Hence, a compressor driven by a variable speed motor, with its speed modulated to match the load and an appropriate modulating control, offers substantial power saving.



As the power consumed by a motor varies as the cube of its speed, substantial energy saving is achieved with reduced speeds at lower loads **e.g. due to a reduction in load, a motor running at 80% of its full speed will consume only $(0.8)^3 = 0.512$, i.e. 51.2% of its full load current.**

CALCULATION OF RATING OF ELECTRICAL EQUIPMENT

- The amount of heat required for personal comfort in enclosed space such as room or office depends upon the following:
  1. **Number of changes of air per hour:**
  2. **Area of windows.**
  3. **Situation of walls, external or internal.**
  4. **The exposure of the ceiling**
  5. **Material of which walls, floor and ceilings are composed**
  6. **The temperature of outside air and**
  7. **Whether the building is to be heated continuously or intermittently.**

Ques: **It is proposed to condition 3000 m^3 of air per hour from a temperature of 5^0C to 20^0C. It is further necessary to evaporate 5 kg of moisture per 1,000 m^3 of air per hour to control humidity. Estimate the power required if heat required to raise the temperature of 1 m^3 of air through 1^0C is 1220 J and latent heat of evaporation is 2450×10^3 J/kg**

Heat required to raise the temperature of air,

H1 = **Volume of air to be conditioned** × **heat required to raise the temperature of 1 m^3 of air through 1^0C** × **difference of temperatures**

= **3000 × 1220 × (20 – 5) Joules = 54.9×10^6 J**

The moisture present in the air $= \dfrac{5 \times 3000}{1000} = 15$ kg

Latent heat required to evaporate the moisture, *H2* = 15 × 2450 × 103 = 36.75×10^6 Joule

Total Heat Required = H1 + H2

$= (54.9 + 36.75) \times 10^6 =$ **91.65×10^6 J / Hour**

Power Required $= \dfrac{91.65 \times 10^6}{3600 \times 1000}$ = **25 kW**