Rashtreeya Sikshana Samithi Trust

RV Institute of Technology and Management®

(Affiliated to VTU, Belagavi)

JP Nagar, Bengaluru - 560076

Department of Mechanical Engineering

Course Name: Elements of Mechanical Engineering

Course Code: 21ME15/25

I/II Semester

2021 Scheme

MODULE-III

Fundamentals of IC Engines:

Review of Internal Combustion Engines, 2-Strokes and 4-Strokes engines, Components and working principles, Application of IC Engines in Power Generation, Agriculture, Marine and

Aircraft Propulsion, Automobile.

Insight into future mobility technology; Electric and Hybrid Vehicles, Components of

Electric and Hybrid Vehicles, Drives and Transmission. Advantages and disadvantages of EVs and Hybrid vehicles.

Refrigeration and Air-Conditioning:

Principle of refrigeration, Refrigeration effect, Ton of Refrigeration, COP, Refrigerants and their desirable properties. Principles and Operation of Vapor Compression and Vapor absorption refrigeration. Domestic and Industrial Applications of Refrigerator

Working Principles of Air Conditioning, Classification, and Applications of Air Conditioners.

Concept and operation of Centralized air conditioning system,

Contents

3.1 INTERNAL COMBUSTION ENGINE

The internal combustion engine is a heat engine in which the burning of a fuel occurs in a confined space called a combustion chamber. This exothermic reaction of a fuel with an oxidizer creates gases of high temperature and pressure, which are permitted to expand. The defining feature of an internal combustion engine is that useful work is performed by the expanding hot gases acting directly to cause movement, for example by acting on pistons, rotors, or even by pressing on and moving the entire engine itself.

This contrasts with external combustion engines such as steam engines which use the combustion process to heat a separate working fluid, typically water or steam, which then, in turn, does work, for example by pressing on a steam actuated piston.

The term Internal Combustion Engine (ICE) is almost always used to refer specifically to reciprocating engines, Wankel engines and similar designs in which combustion is intermittent. However, continuous combustion engines, such as Jet engines, most rockets, and many gas turbines are also very definitely internal combustion engines.

3.2 Four-stroke cycle (or Otto cycle)

Applications:

Internal combustion engines are most commonly used for mobile propulsion systems. In mobile scenarios, internal combustion is advantageous since it can provide high power to weight ratios together with excellent fuel energy-density. These engines have appeared in almost all automobiles, motorbikes, many boats, and in a wide variety of aircraft and locomotives. Where very high power is required, such as jet aircraft, helicopters, and large ships, they appear mostly in the form of gas turbines. They are also used for electric generators and by industry.

Internal combustion mechanics

Almost all cars currently use what is called a four-stroke combustion cycle to convert gasoline into motion. The four-stroke approach is also known as the Otto cycle, in honor of Nikolaus Otto, who invented it in 1867. Fig. 3.1 shows the graphical representation of IC engine.

The four strokes are:

1. Intake stroke
2. Compression stroke
3. Combustion stroke
4. Exhaust stroke

Parts:

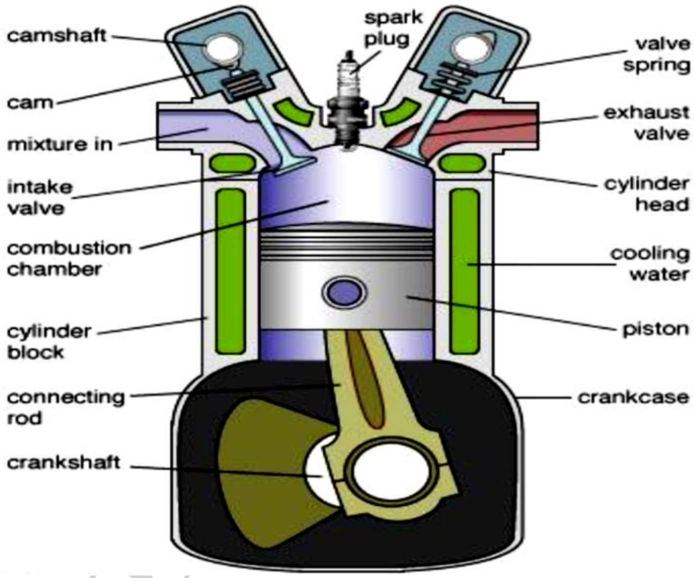

Fig. 3.1 Graphical representation of IC engine

1. Cylinder

› Part of the engine where fuel is burnt and power is developed.

› Inside diameter is called a bore. Fig. 3.2 Parts of IC engine.

› Sleeve is fitted tightly in the cylinder to prevent wearing of the block.

2. **Piston**

› Close-fitting hollow – cylinder plunger moving to and fro in the cylinder.

› *Function* – power developed by the combustion of fuel is transmitted by the piston to the crank-shaft through the connecting rod.

3. Piston rings

› Metallic rings inserted into groves provided at the top end of the piston.

› *Function* – it maintains a gas-tight joint between the piston and the cylinder.

4. Connecting rod

› Link that connects the piston and crankshaft by means of pin joint.

› *Function* – it converts the rectilinear motion of the piston into rotary motion of the crankshaft.

5. Crank and crankshaft

› Crank is a lever that is connected crankshaft and piston rod.

6. Valves

› These are devices which control the flow of intake and exhaust gases.

7. Flywheel

› Mounted on the crankshaft to maintain uniform rotation of the crankshaft.

8. Crankcase

› Enclosure for crankshaft and sump for lubricating oil.

An illustration of several key components in a typical four-stroke engine:

The parts of an engine vary depending on the engine's type. For a four-stroke engine, key parts of the engine include the crankshaft (purple), one or more camshafts (red and blue) and valves. For a two-stroke engine, there may simply be an exhaust outlet and fuel inlet instead of a valve system. In both types of engines, there are one or more cylinders (grey and green) and for each cylinder, there is a spark plug (darker-grey), a piston (yellow) and a crank (purple). A single sweep of the cylinder by the piston in an upward or downward motion is known as a stroke and the downward stroke that occurs directly after the air-fuel mix in the cylinder is ignited is known as a power stroke.

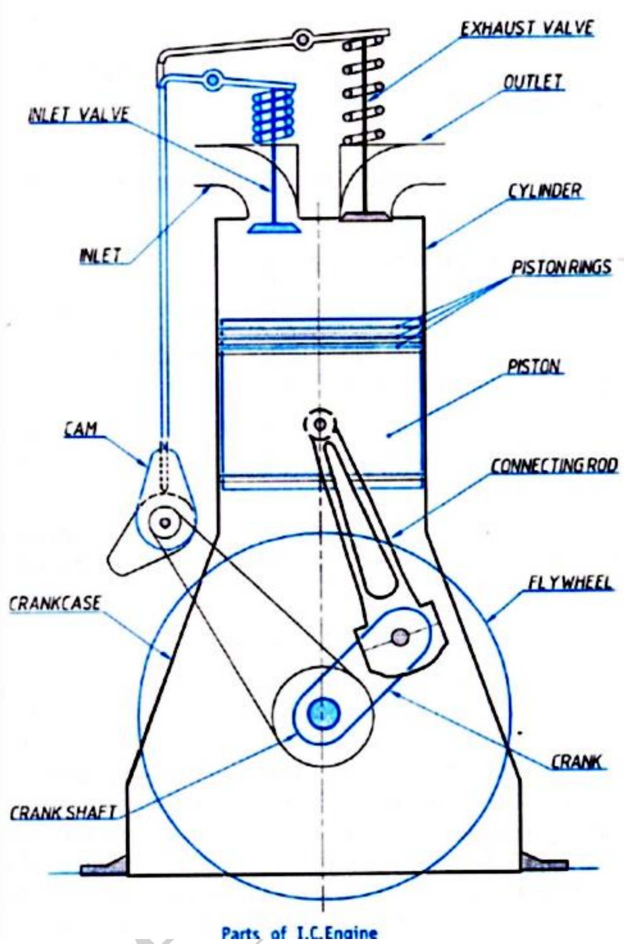

Fig. 3.2 Parts of IC engine

Classification:

I.C. Engines are classified according to:

1. Nature of thermodynamic cycle as:

1. Otto cycle engine.

2. Diesel engine.

3. Dual combustion cycle engine.

2. Type of the Fuel used as

1. Petrol engine.

2. Diesel engine.

3. Gas engine.

4. Bio-fuel engine.

3. A number of strokes as:

1. Four-stroke engine.
2. Two-stroke engine.

4. Number of Ignition as:

1. Spark ignition engine, known as S.I. Engine.
2. Compression ignition engine, known as C.I engine.

5. Number of Cylinder as:

1. Single-cylinder engine.
2. Multi-cylinder engine.

6. Position of the Cylinder as:

1. Horizontal engine.
2. Vertical engine.

7. Method of Cooling as:

1. Air-cooled engine.
2. Water-cooled engine.

3.3 Two-stroke:

Engines based on the two-stroke cycle use two strokes (one up, one down) for every power stroke. Since there are no dedicated intake or exhaust strokes, alternative methods must be used to scavenge the cylinders. The most common method in spark-ignition two-strokes is to use the downward motion of the piston to pressurize fresh charge in the crankcase, which is then blown through the cylinder through ports in the cylinder walls. Spark-ignition two-strokes are small and light (for their power output), and mechanically very simple. Common applications include snowmobiles, lawnmowers, chain saws, jet skis, mopeds, outboard motors, and some motorcycles. Unfortunately, they are also generally louder, less efficient, and far more polluting than their four-stroke counterparts, and they do not scale well to larger sizes. Interestingly, the largest compression-ignition engines are two-strokes and are used in some locomotives and large ships. These engines use forced induction to scavenge the cylinders.

3.4 Four-stroke:

Engines based on the four-stroke cycle or Otto cycle have one power stroke for every four strokes (up-down-up-down) and are used in cars, larger boats and many light aircraft. They are generally quieter, more efficient and larger than their two-stroke counterparts. There are a number of variations of these cycles, most notably the Atkinson and Miller cycles. Most truck automotive diesel engines use a four-stroke cycle, but with a compression heating ignition system. This variation is called the diesel cycle. Fig. 3.3 four stroke cycle or otto cycle.

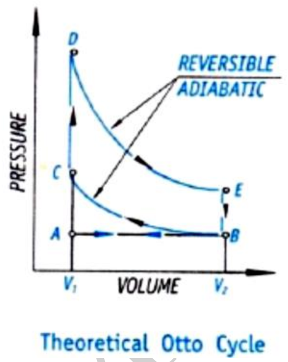

Fig. 3.3 Four stroke cycle or otto cycle

4-Stroke Internal Combustion Engine

Four-stroke petrol engine

Four-stroke petrol engine consists of Cylinder, Cover, Mechanical operated valves, Spark plug, connecting rod and crank

Suction stroke

- Inlet is open exhaust is closed. Fig. 3.4 Four stroke cycle suction stroke
- The piston moves from TDC to BDC.
- Crankshaft revolves half the rotation.
- Cranking
- Petrol air mixture is drawn into cylinder due to pressure difference.

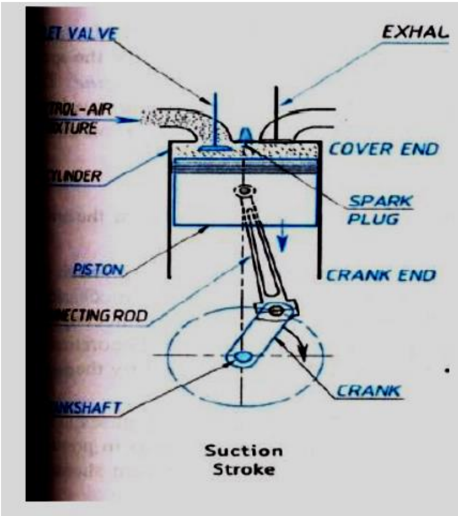

Fig. 3.4 Four stroke cycle suction stroke

- **Suction stroke**
- **Compression stroke**
- **Working stroke**
- **Exhaust stroke**

Stroke is represented by the line *horizontal line AB*

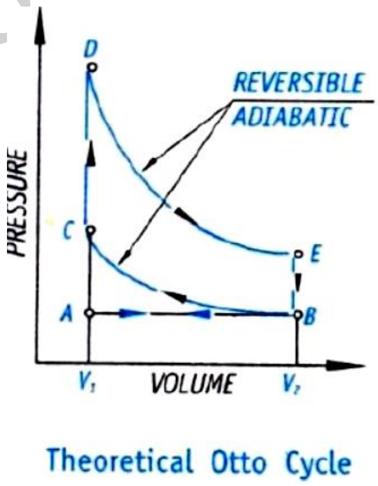

Fig. 3.5 Four stroke cycle compression stroke

Compression stroke

• Both inlet and exhaust are closed. Fig. 3.5 Four stroke cycle compression stroke

• The piston moves from BDC to TDC.

• Crankshaft revolves half the rotation.

• Cranking

• Petrol air mixture is compressed to a ratio of 1:11.

• This mixture is ignited by a spark plug.

• Reversible adiabatic.

• Represented by *curve BC.*

• Constant volume combustion process represented by vertical line CD.

Power stroke

• The piston moves from TDC to BDC. Fig. 3.6 Four stroke cycle power stroke

• Crankshaft revolves half the rotation. Burnt gases generate energy and force the piston to move down.

• The process is represented by the line DE. (Reversible adiabatic process)

• *Exhaust opens* and drops in pressure is represented by EB.

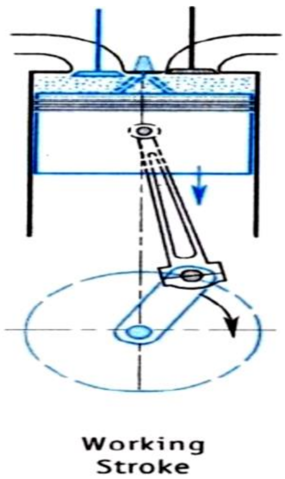

Fig. 3.6 Four stroke cycle power stroke

Exhaust stroke

- The exhaust is open and the inlet is closed. Fig. 3.7 shows four stroke cycle exhaust stroke.
- The piston moves from BDC to TDC.
- Crankshaft revolves half the rotation.
- Energy for this stroke is supplied by the flywheel.
- Burnt gases are expelled out through outlet port.
- The process is represented by a horizontal line BA. Fig. 3.8 Four stroke cycle all strokes.

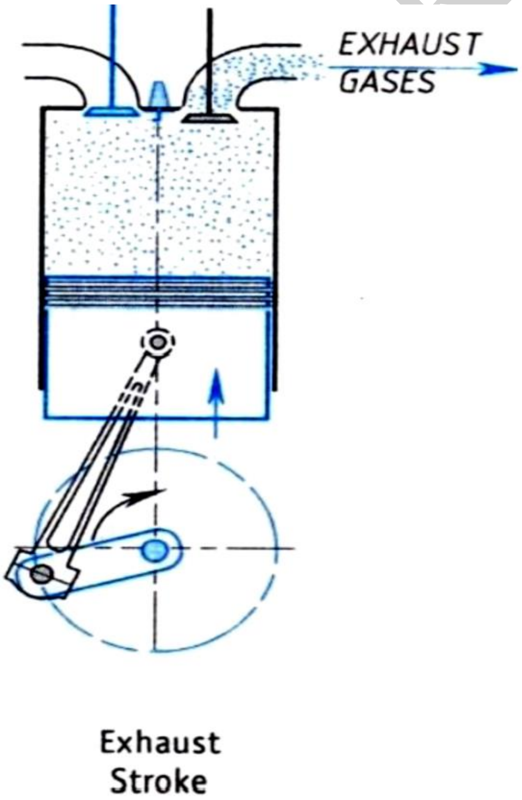

Fig. 3.7 Four stroke cycle exhaust stroke

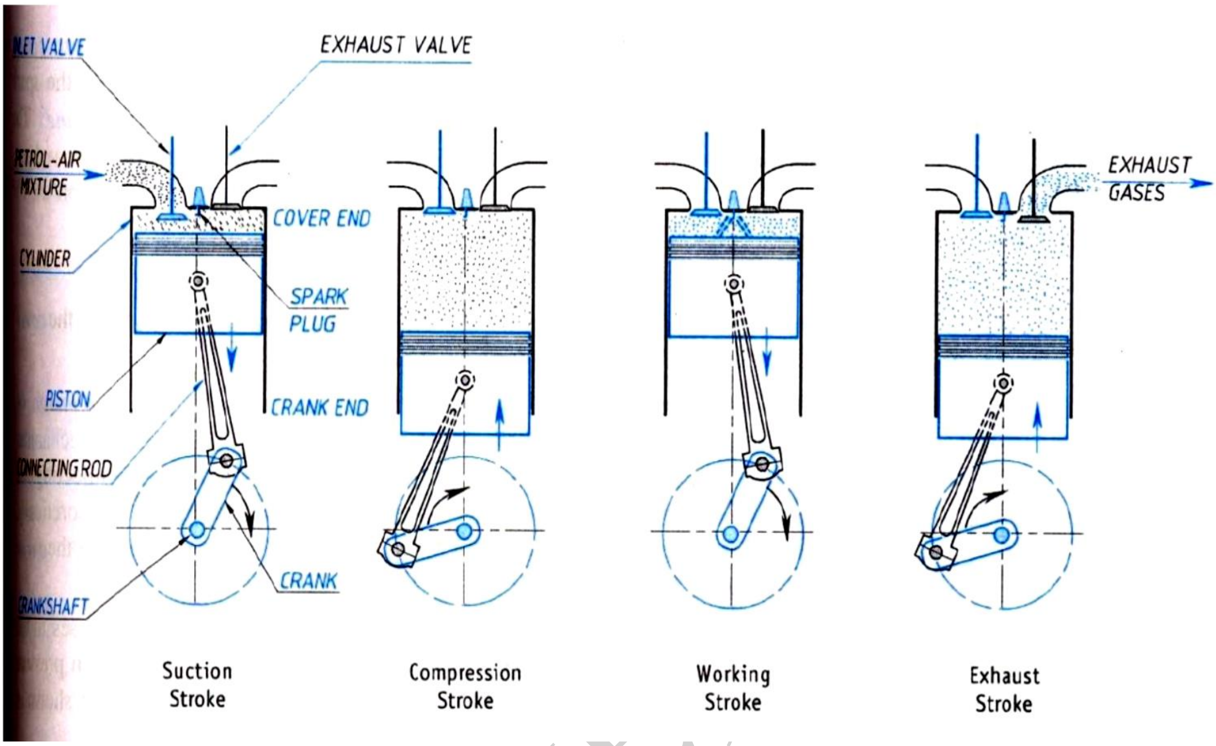

Fig. 3.8 Four stroke cycle all strokes

Four-stroke diesel engine

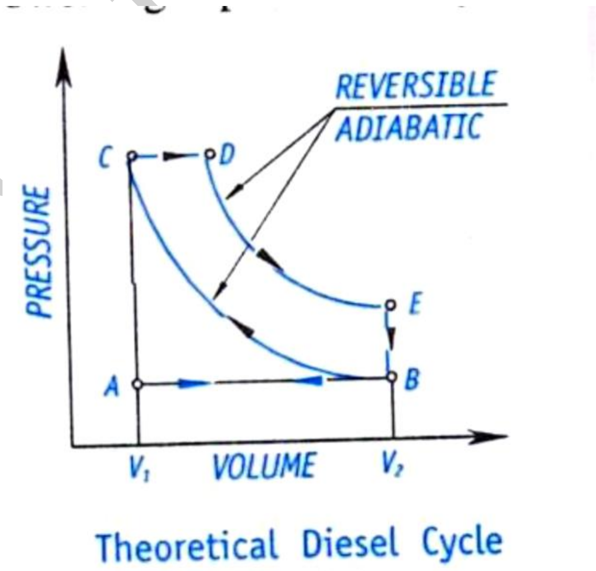

Fig. 3.9 Four stroke diesel cycle

Suction stroke

- Inlet is open exhaust is closed. Fig. 3.10 shows four stroke diesel cycle suction stroke.
- Piston moves from TDC to BDC and crankshaft revolves half the revolution.
- Cranking during the first cycle.
- Due to the pressure difference *air enters the cylinder* through the air filter.
- This process is represented by the horizontal line AB.

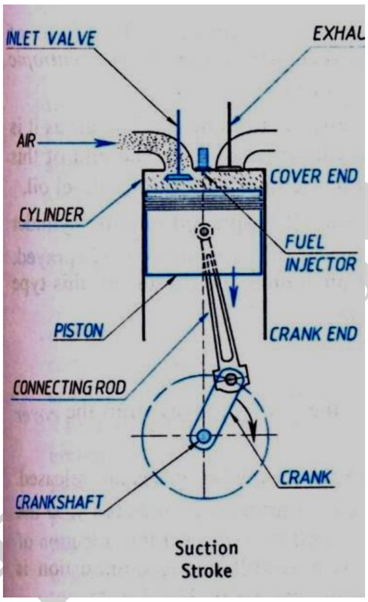

Fig. 3.10 Four stroke diesel cycle suction stroke

Compression stroke

- Inlet and exhaust are closed.
- The piston moves from BDC to TDC.
- Cranking required in the first cycle.
- Air will be compressed to a ratio of 1:20.
- Diesel oil is *sprayed* into the cylinder by *injector* and *auto-ignition* takes place.
- The adiabatic process represented by the line BC.

Power stroke

- The piston moves from TDC to BDC.
- Inlet and exhaust valves are closed.

• Burnt gases generate energy and force the piston to move down to the injection of fuel is complete.

• Constant pressure expansion due to the combustion of fuel is represented by CD.

• Expansion of burnt gases represented by the curve DE.

Exhaust Stroke

- The exhaust is open and the inlet is closed. Fig. 3.11 shows four stroke diesel cycle exhaust stroke.
- The piston moves from BDC to TDC.
- crankshaft revolves half the rotation.
- energy for this stroke is supplied by the flywheel.
- Burnt gases are expelled out through outlet port.
- Exhaust port opens at the end of the previous stroke represented by curve EB.
- Exhaust gases expelled out represented by the curve BA. Fig. 3.12 shows the four stroke diesel cycle all strokes.

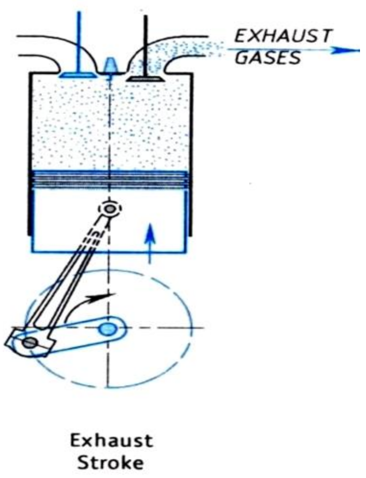

Fig. 3.11 Four stroke diesel cycle exhaust stroke

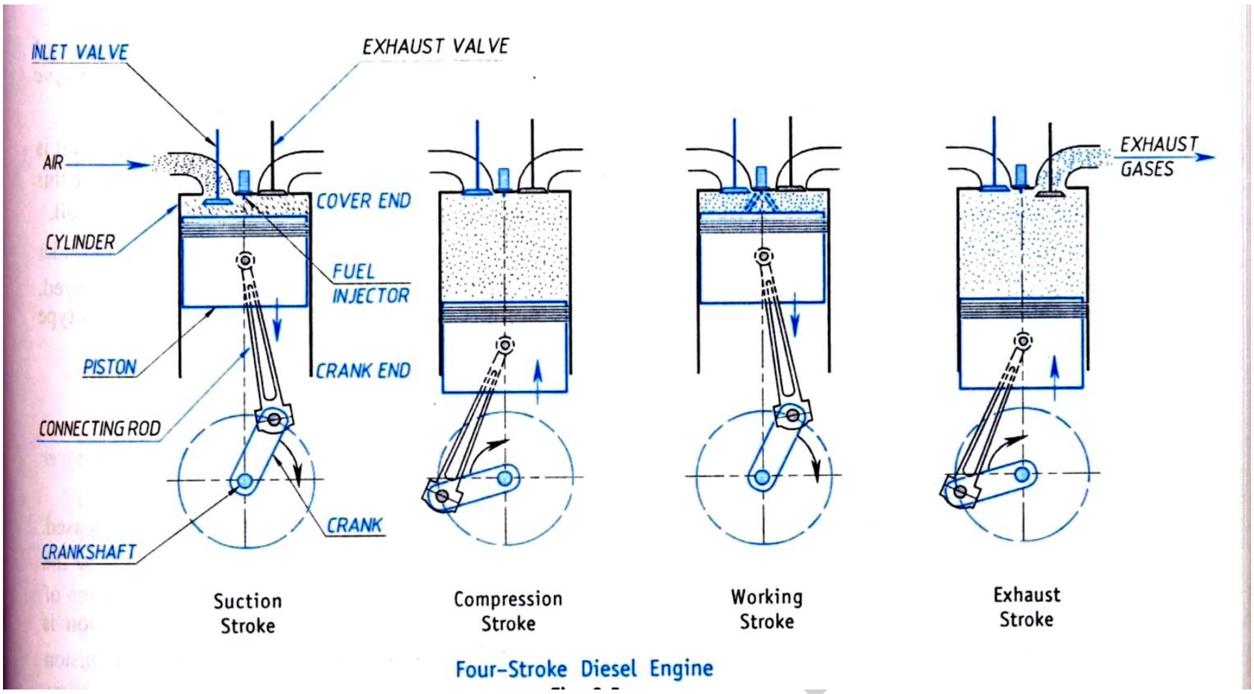

Fig. 3.12 Four stroke diesel cycle all strokes

3.5 Two-stroke petrol engine

Parts

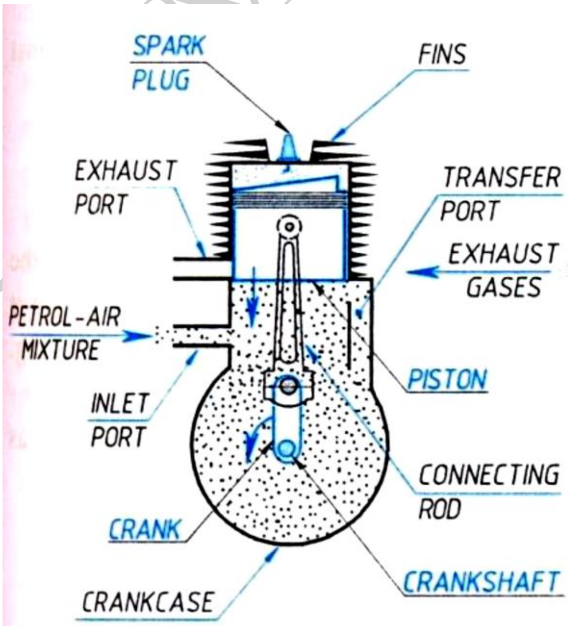

Fig. 3.13 Two stroke petrol engine parts

• Performs two strokes to complete one working cycle. Fig. 3.13 shows the two stroke petrol engine parts.

• Works on *theoretical Otto cycle*.

• Cylinder with one end fitted with a cover and another end with a sealed crankcase.

• Ports are provided one below other on circumference of the cylinder.

• The lower one is the admission port or inlet port and the upper port is the exhaust port.

• Transfer port diametrically opposite.

• Transfer port

• *Function* – transfer of petrol air mixture from the crankcase to the cylinder.

• Spark plug, connecting rod, crank.

First stroke or upward stroke

• The piston moves from BDC to TDC.

• *Function* – transfer of petrol air mixture from the crankcase to the cylinder.

• Spark plug, connecting rod, crank.

• The air-fuel mixture is drawn in through the inlet.

• Supply of petrol air mixture is cut off in upward motion of the piston.

• The piston compresses the petrol air mixture in the cylinder.

• At the end of the stroke spark plug ignites and combustion takes place.

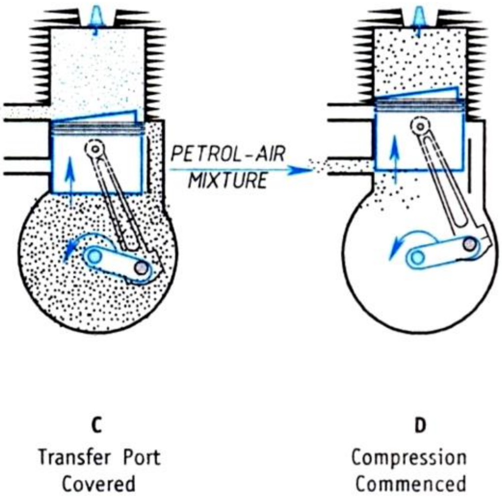

Fig. 3.14 Two stroke petrol engine strokes

Second stroke or downward stroke

• The piston moves from TDC to BDC.

• The piston performs the power stroke.

• Transfer port opens letting the fresh charge into the cylinder.

• Due to this, the burnt gases are expelled out of the cylinder. This process is called *scavenging*.

• The crankshaft rotates by half the revolution.

Compression stroke

• Both inlet and exhaust are closed.

• The piston moves from BDC to TDC.

• Crankshaft revolves half the rotation.

• Cranking

• Petrol air mixture is compressed to a ratio of 1:11.

• This mixture is ignited by a spark plug.

Power stroke

• The piston moves from TDC to BDC. Fig. 3.15 shows the two stroke petrol engine working stroke.

• Crankshaft revolves half the rotation.

• Burnt gases generate energy and force the piston to move down.

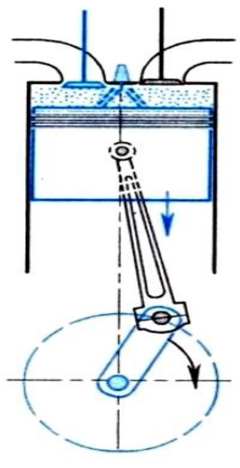

Fig. 3.15 Two stroke petrol engine working stroke

Exhaust stroke

• The exhaust is open and the inlet is closed. Fig. 3.16 shows the two stroke petrol engine exhaust stroke.

• The piston moves from BDC to TDC.

• Crankshaft revolves half the rotation.

• Energy for this stroke is supplied by the flywheel.

• Burnt gases are expelled out through outlet port.

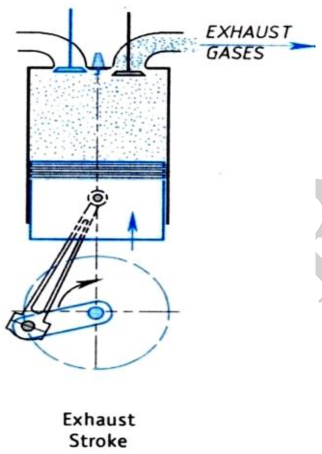

Fig. 3.16 Two stroke petrol engine exhaust stroke

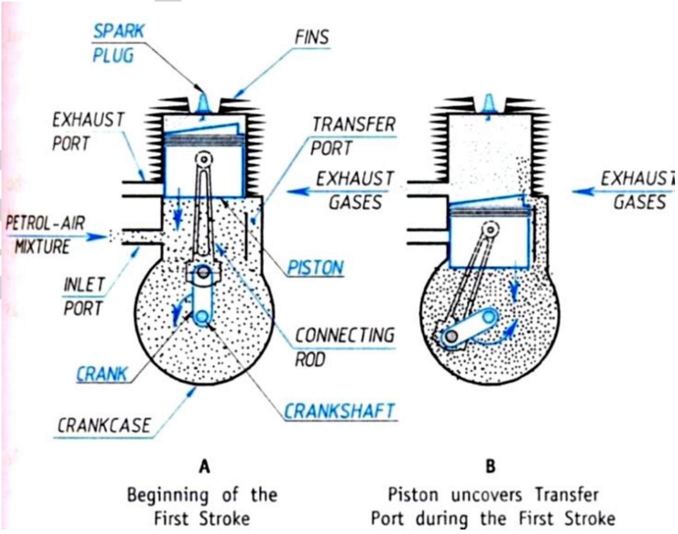

Fig. 3.17 Two stroke petrol engine stroke

Indicated Power

It is the horse power produced inside the cylinder and calculated by finding the actual mean effective pressure.

I.P for four stroke engine:

$$I.P = \frac{100\ Pm\ L\ A\ N}{60 \times 2}\ KW$$

Where: N – N is the rpm of the crank shaft.

A – Area of cross-section of the cylinder in m^2.

L – Length of the stroke in m.

Pm – Mean effective pressure in N/m^2

I.P for Two Stroke Engine:

In a two stroke engine, for each revolution of the crank there will be a power stroke

$$I.P = \frac{100\ Pm\ L\ A\ N}{60}\ kW$$

BRAKE POWER (B.P):

The net horse power available at the crank shaft is called brake horse power.

B..P = I..P – F.P.

F.P. is the horse power lost in friction.

$$B..P = \frac{2\ JINT}{60}\ KW$$

T = W.R. (9.81/1000) kN-m

Where: W – Net load acting on the brake drum in kg.

R - Radius of the brake drum in meters.

Mechanical efficiency:

It is the ratio of BP to IP.

$$\text{Mechanical efficiency} = \frac{B.P \times 100}{I..P}$$

$$= \frac{I..P - F.P \quad X \quad 100}{I..P}$$

Thermal Effeciency

Indicated Thermal Effeciency

$\eta_{indicated\text{-}thermal} = IP \ X \ 100 \ /(m \ X \ CV)$

m : Mass of fuel

CV : Calorific Value

Brake thermal efficiency

$\eta_{brake\text{-}thermal} = BP \ X \ 100 \ /(m \ X \ CV)$

APPLICATION OF IC ENGINES

Internal Combustion (IC) Engine	
Type	Application
Gasoline Engines	Automotive, Marine, Aircraft
Gas Engines	Industrial Power
Diesel Engines	Automotive, Railways, Power, Marine
Gas Turbines	Power, Aircraft, Industrial, Marine

Fig. 3.18 shows the application of internal combustion engines in different domains.

Gasoline Engine:

Gasoline engine is a kind of internal-combustion engine that generate power by burning a volatile liquid fuel (gasoline or a gasoline mixture such as ethanol) with ignition initiated by an electric spark.

Gas Turbine: A gas turbine is a internal combustion engine that can convert natural gas or other liquid fuels to mechanical energy. This energy then drives a generator that produces electrical energy. It is electrical energy that moves along power lines to homes and businesses.

Gas Engine: A gas engine is an internal combustion engine which runs on a gas fuel, such as coal gas, producer gas, bio-gas, landfill gas or natural gas.

Diesel Engine: A Diesel engine is a type of internal combustion engine which ignites fuel by injecting it into hot, high-pressure air in a combustion chamber.

3.5 REFRIGERATION & AIR-CONDITIONING

Refrigeration:

It is defined as the process of removing heat from a substance under controlled conditions and reducing and maintaining the temperature of a body below the temperature of its surroundings by the aid of external work.

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.

Refrigerant:

The medium or working substance that continuously extracts heat from the space within the refrigerator which is to be kept cool at a temperature less than atmospheric by rejecting heat to atmosphere is called refrigerant.

Principle of Refrigeration:

Heat can flow from a system at a lower temperature to a system at a higher temperature only with the aid of external work.

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 in order to form one ton of ice in 24 hours when the initial temperature of the water is 0°C.

In S.I. System,

1 Ton of Refrigeration = 210 kJ/min

= 3.5kW

Coefficient of Performance (COP):

The COP of a refrigeration system is defined as the ratio of heat absorbed in a system to the work supplied.

COP=$\frac{Q}{W}$ Where

Q = Heat Absorbed or Removed (kW)

W = Work supplied (kW)

Refrigerating effect:

The rate at which the heat is absorbed in a cycle from the interior space to be cooled.

Ice making capacity:

The capacity of a refrigerating system to make ice beginning from water (at water temperature) to solid ice. It is usually specified by kg/hr.

Relative COP

It is defined as the ratio of Actual COP to the Theoretical COP of a refrigerator

Relative COP= $\frac{\text{Actual COP}}{\text{Theoretical COP}}$

Latent Heat of Evaporation

Amount of heat required to change a substance from a solid (ICE) to a liquid (WATER) or vice versa.

REFRIGERANT:

A Refrigerant is medium it continuously extracts the heat from the space within the refrigerator which is to be kept cool at temperatures less than the atmosphere and finally rejects to it to the surroundings.

The most commonly used refrigerants are given below:

1) **Ammonia:-**

- Ammonia as a refrigerant is employed in refrigerators operating on the absorption principles.

Because of its high latent heat (1300 kJ/kg at -15°C) and low specific volume (0.509mVkg at -15°C), it produces high refrigeration effects even in small refrigerators.

- Since ammonia will not harm the ozone, it is environmentally friendly. It is widely used in cold storage, ice-making plants, etc.
- It is toxic, flammable, irritating and food destroying properties makes it unsuitable for domestic refrigerators.

2) Sulphur dioxide: -

- Earlier Sulphur dioxide was one of the most commonly used refrigerants in domestic refrigerators. Although it has better thermodynamic properties.
- It has a low refrigerating effect and high specific volume, therefore large-capacity high-speed compressors are required.
- It combines with water and forms sulfurous and sulphuric acids which are corrosive to metals.

3) Carbon dioxide: -

- The efficiency of the refrigerators using carbon dioxide refrigerant is low. Therefore it is rarely used in domestic refrigerators but is used in dry ice-making plants.
- It is colorless, odorless, non-toxic, non-inflammable and non-corrosive.

4) Methyl Chloride:-

- Methyl chloride was used earlier in domestic and small scale industrial refrigerators. Since it will burn under some conditions and slightly toxic, is not generally used.

5) Freon:-

- Freon group of refrigerants is used almost universally in domestic refrigerators. These refrigerants are colorless, almost odorless, non-toxic, non-inflammable, non- explosive and non-corrosive.
- Freon-12 and Freon-22 are the two Freon refrigerants commonly used in domestic refrigerators and air conditioners.
- Destruction of the ozone layer.

Properties of a Good Refrigerant

3.6 Thermodynamic properties:

1) **Boiling Point: -** The Temperature at which a liquid boils and turns to vapor.
   An ideal refrigerant must have a **low boiling temperature** at atmospheric pressure.
2) **Freezing Point:** An ideal refrigerant must have a very **low freezing point** because the refrigerant should not freeze at low evaporator temperatures.
3) **Evaporator and Condenser Pressure:** Both the evaporator and condenser pressures should be slightly above the atmospheric pressure.
4) **Latent Heat of Evaporation: -** latent heat of fusion is heat required to change a substance from a solid (ICE) to a liquid (WATER) or vice versa.

The latent heat of evaporation must be very high so that a minimum amount of refrigerant will accomplish the desired result, (increases the refrigeration effect). Fig. 3.19 shows properties of good refrigerant.

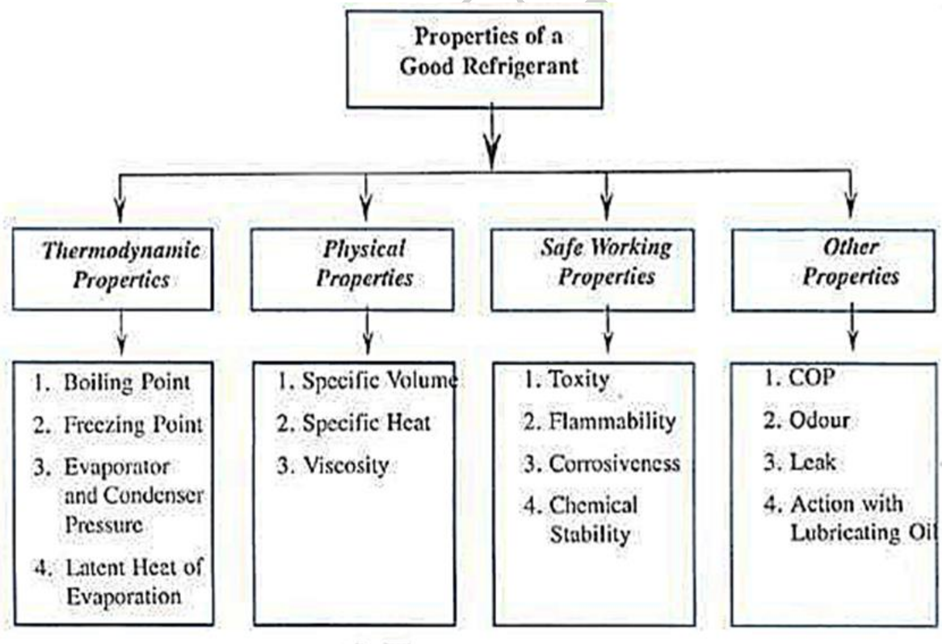

Fig. 3.19 properties of good refrigerant

Physical properties:

1) **Specific Volume:-**The specific volume of the refrigerant **must be very low.** The lower specific volume of the refrigerant at the suction of the compressor reduces the size of the

compressor.

2) **Specific heat of liquid and vapor: -**A good refrigerant must have low **specific heat when it is in liquid state: The** low specific heat of the refrigerant helps in sub-cooling of the liquid **high specific heat when it is vaporized**. High specific heat of the vapor helps in decreasing the superheating of the vapor.

3) **Viscosity:-**The viscosity of a refrigerant at both the liquid and vapor states must be **very low** as improves the heat transfer and reduces the pumping pressure.

Chemical properties:

1) **Non-toxicity refrigerant: -**A good refrigerant should be **non-toxic** because any leakage of the toxic refrigerant increases suffocation and poisons the atmosphere.

2) **Corrosiveness: -**A good refrigerant should be **non-corrosive** to prevent the corrosion of the metallic parts of the refrigerators.

3) **Chemical Stability: -** An ideal refrigerant **must not decompose** under operating conditions.

Other properties:

1) **Coefficient of Performance:-**The coefficient of performance of a refrigerant **must be high** so that the energy spent in refrigeration will be less.

2) **Odor: -**A good refrigerant must be **odorless;** otherwise some foodstuff such as meat, butter, etc. loses their taste.

3) **Leakage Tests:-**The refrigerant must be such that **any leakage can be detected** by simple tests.

4) **Action with Lubricating Oil: -**A good refrigerant **must not react with the lubricating oil** used in lubricating the parts of the compressor.

Parts of a Refrigerator

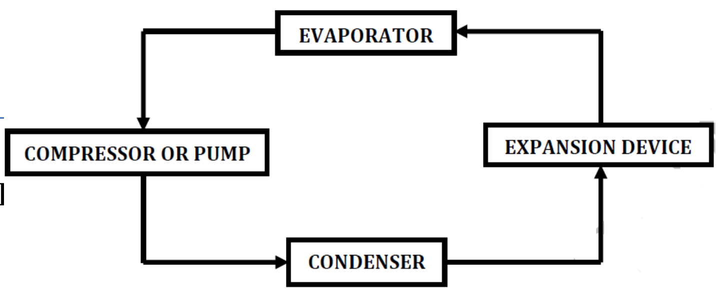

Fig. 3.20 Parts of a refrigerator

1) Evaporator:-

- In the evaporator, liquid refrigerant is evaporated by the absorption of heat from the refrigerator cabinet in which the substances which have to be cooled are kept. Fig. 3.20 shows the parts of a refrigerator.
- The evaporator consists of simply metal tubing which surrounds around the freezing and cooling compartments to produce the cooling effect required for freezing ice.
- Maintain lowering the temperature of perishables placed in the cooling compartment.

2) Circulating System: -

- The circulating system comprises of the mechanical devices such as compressors or pumps necessary to circulate the refrigerant to undergo the refrigeration cycle.
- They increase the pressure and also the temperature of the refrigerant. Generally, these devices are driven by electric motors.

3) Condenser: -

- In a condenser, the refrigerant vapor gives off its latent heat to the cooling medium (usually air/water) and consequently condenses into liquid so that it can be recirculated in the refrigeration cycle.

4) Expansion Device: -

- An expansion valve serves as a device to reduce the pressure and temperature of the liquid refrigerant before it passes to the evaporator.

Types of Refrigeration Systems

The refrigeration systems are mainly divided into two types, they are

1) Vapour Compression Refrigerator (VCR)

2) Vapour Absorption Refrigerator(VAR)

1) Vapour Compression Refrigerator (VCR):

Construction

Most commonly used refrigerants in the vapor compression refrigerator is dichlorodifluoromethane, popularly known as Freon 12. Vapour compression refrigerator 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 a throttle valve. The delivery side of the compressor is connected to a condenser which in turn is connected to a throttle valve. Fig. 3.21 shows the vapour compression refrigerator (VCR).

Working:

- The liquid refrigerant at low pressure and low temperature passing in the evaporator coiled tubes and it absorbs the heat from the contents in the freezing compartment and evaporates.
- It undergoes a change of phase from liquid to vapor state.
- The vapor refrigerant at low pressure and low temperature from the evaporator is drawn by a compressor which compresses it to higher pressures.
- The high-pressure high-temperature vapor refrigerant from the compressor flows to the condenser where it gives off its latent heat to the cooling medium (usually air/water). As a result of the loss of latent heat in the condenser.
- It undergoes a change of phase from vapor to a liquid state.
- The high pressure condensed liquid refrigerant approximately at room temperature now flows to the throttle valve in which it expands from high pressure to low pressure.
- Then passes to the evaporator coils for recirculation once again.
- The throttling expansion of the refrigerant lowers its pressure and temperature and at the same time causes it to partly evaporate.
- Hence the refrigerant coming out of the expansion valve will be a very wet vapor and at a very low temperature which will be around -10°C.
- This wet vapor now passes to the evaporator coils where it absorbs its latent heat and then recirculates to repeat the cycle continuously.

- Heat is continuously extracted by the contents of the refrigerator in the evaporator and rejected in the condenser to the atmospheric air/water. This will keep the contents of the refrigerator at the required lower temperature.

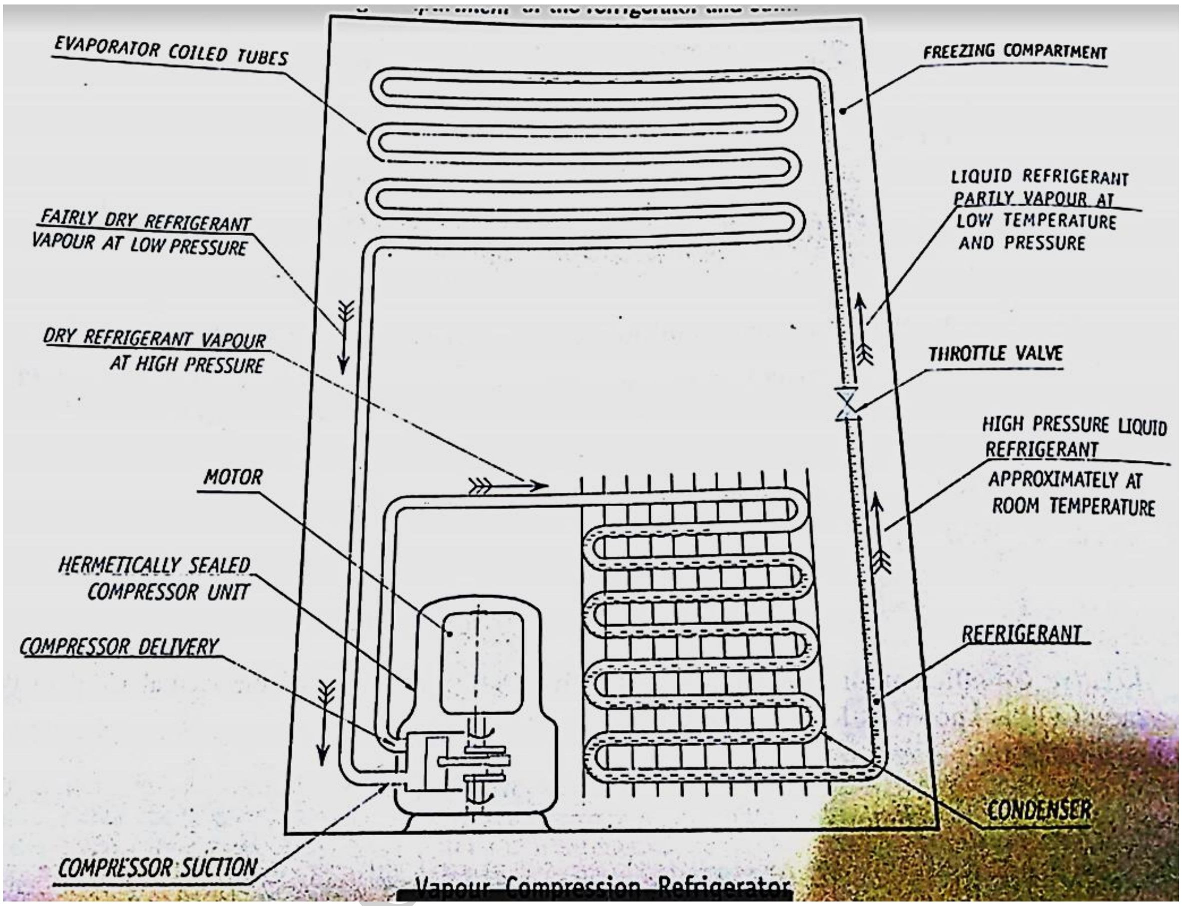

Fig. 3.21 Vapour Compression Refrigerator (VCR)

2) Vapor Absorption Refrigerator (VAR):

CONSTRUCTION

Most commonly used refrigerant in the vapor absorption refrigerator is ammonia. Vapor absorption refrigerator consists of an absorber, a circulation pump, and heat exchanger, heater cum separator, condenser, expansion valve, and evaporating coiled tubes.

Vapour absorption refrigerator consists of an evaporator made of coiled tubes installed in the freezing compartment of the refrigerator. Fig. 3.22 shows the vapor absorption refrigerator (VAR).

WORKING:

- The ammonia liquid is vaporized in the evaporator coils by absorbing the latent heat from the freezing compartment; it undergoes a change of phase from liquid to vapor state of low pressure and low-temperature properties.
- In Vapour absorption refrigerator consists of an absorber, a circulation pump, and heat exchanger, heater cum separator, condenser, expansion valve, and evaporating coiled tubes.
- Dry ammonia vapor refrigerant is dissolved in the weak ammonia solution of ammonia-water contained in the absorber, which will produce a strong ammonia solution. Since cold water (absorbent) has the capacity to absorb ammonia vapor from the evaporator.
- A circulation pump draws the strong ammonia solution from the absorber and pumps it to the heat exchanger, where it is warmed by the warm weak ammonia solution which is flowing back from the heater-separator.
- From the heat exchanger, the warm high pressure and high-temperature strong ammonia solution are passed to the heater-cum-separator provided with the heating coils.
- Heating of the high-pressure strong ammonia solution will drive out the ammonia vapor from it.
- Consequently, the solution in the heater-separator becomes weak which in turn flows back to the heat exchanger where it warms up the strong ammonia solution passing through it.
- The high-pressure ammonia vapor from the heater-separator now passes to a condenser, where it is condensed and it undergoes a change of phase from vapor to a liquid state.
- The high-pressure ammonia liquid is now expanded to low pressure and low temperature in the throttle valve.
- The low pressure condensed ammonia liquid at low temperature is passed onto the evaporator coils provided in the freezing compartment and repeat the cycle continuously.

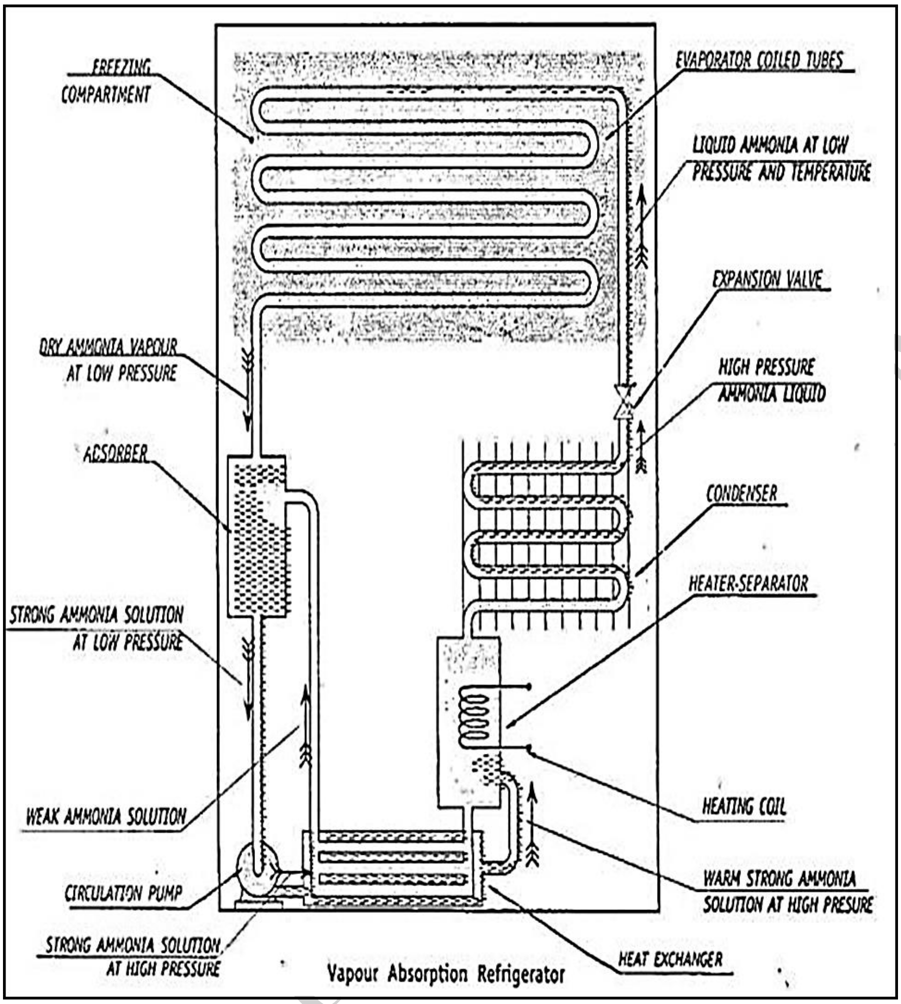

Fig. 3.22 Vapor Absorption Refrigerator (VAR)

Differences B/w Vapour Compression and Vapour Absorption Refrigerator:

Sl. No.	Principle	Vapour Compression System	Vapour Absorption System
1.	Working Method	Refrigerant vapour is compressed.	Refrigerant vapour is absorbed and heated.
2.	Type of the Energy Supplied	Works solely on Mechanical Energy.	Works solely on Heat Energy.
3.	Work or Mechanical Energy Supplied	Mechanical energy required is more because refrigerant vapours are compressed to higher pressures.	Mechanical energy required to run the pump is less since the pump is required only to circulate the refrigerant.
4.	COP	Although the coefficient performance is relatively higher, it reduces at part loads.	Although the coefficient of performance is relatively lower, it will be more or less same at part and full loads.
5.	Capacity	The design capacity is limited since a single compressor unit can produce upto 1000 tons of refrigeration.	The absorption systems can be designed to capacities well above 1000 tons.
6.	Noise	Noise is more due to the presence of the compressor.	Almost quiet in operation as there is no compressor.
7.	Refrigerant	Freon –12.	Ammonia.
8.	Leakage of Refrigerant	Due to high pressures, the chances of leakage of the refrigerant is more and is a major problem.	Almost there is no leakage of the refrigerant.
9.	Maintenance	The maintenance is high because of the compressor.	The maintenance is less.
10.	Operating Cost	The operating cost is high since the electrical energy is expensive.	The operating cost is less because the thermal energy can be supplied from sources other than the electrical energy and also the electrical energy required to run the pump is relatively less.

3.7 AIR CONDITIONING

Air conditioning is defined as the process of simultaneous control of temperature, humidity, cleanliness and air motion of the confined space

APPLICATION OF AIR CONDITIONING

Comfort application

In residential building- Single house and apartment. Institutional building- Offices, hospital, etc. Commercial building-Shopping centers, malls, etc. Transportation -Aircraft, Automobiles, ships, etc.

Process application

Hospitals-in operation theatres (To reduce infection risk, to limit patient dehydration)

Textile factories

Nuclear facilities

Data processing centers

Food cooking and processing areas

ROOM AIR-CONDITIONER

Room air-conditioner mainly consists of an evaporator, condenser, compressor, two fans one each for the evaporator and condenser units usually driven by the single motor, capillary, etc. It is generally mounted on a window sill such that the evaporator unit is inside the room and the condenser part projecting outside the building. Fig. 3.23 shows the room air-conditioner.

WORKING: The high-pressure, low-temperature liquid refrigerant from the condenser is passed to the evaporator coils through the capillary tube where it undergoes expansion.

- The low-pressure, low-temperature liquid refrigerant passes through the evaporator coils.
- The evaporator-fan continuous draws the air from the interior space within the room through an air filter by forcing it to pass over the evaporator coils.
- The air from the interior passing over the evaporator coils is cooled by the refrigerant which consequently evaporates by absorbing the heat from the air.
- It undergoes a change of phase from liquid to vapor state.
- The low-pressure vapor refrigerant from the evaporator is drawn by the suction of the compressor which compresses it and delivers it to the condenser.
- The high- pressure, high-temperature refrigerant vapor now flows through the condenser coils.
- The condenser-fan draws the atmospheric air from the exposed side-portions of the air conditioner which is projecting outside the building.
- The high-pressure, high-temperature refrigerant passing inside the condenser coils condenses by giving off the heat to the atmospheric air.
- It undergoes a change of phase from vapor to a liquid state.

- The cooled high-pressure refrigerant from the condenser passes through the capillary tube where it undergoes expansion and is again recirculate to repeat the cycle continuously.

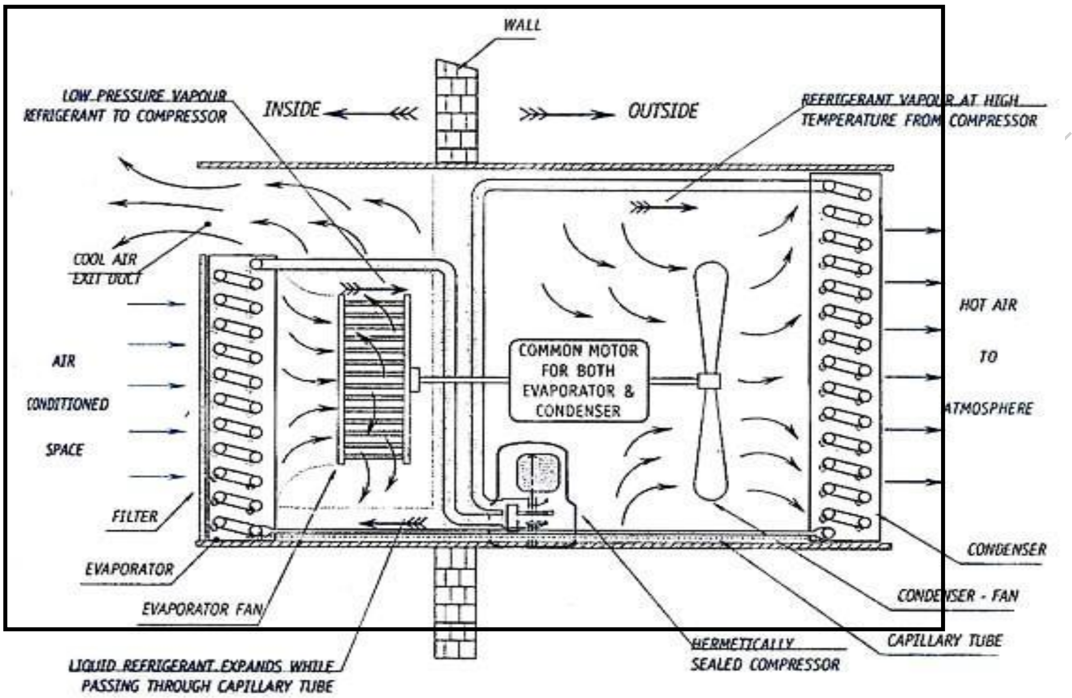

Fig. 3.23 Room Air-Conditioner

Classification of Air-conditioning:

Basis	Types
Comfort Season of the Year Equipment arrangement	Human comfort A.C. Industrial A.C. System Winter A. C. system Summer A. C. system Year around A. C. system Unitary system Central station system Combination system

Application of Air-conditioning:

- **Industrial applications:** To control chemical and bio-chemical reactions. Example textile, printing industry.
- **Commercial applications:** In theatres, hotels, departmental stores, banks etc.
- **Transport applications:** In automobiles, trains, aircrafts, ships etc
- **Special applications:** In T.V. centres, computer centres, automatic telephone exchange building, hospital etc.

Centralized Air-Conditioning system:

- Central air conditioning systems serve multiple spaces from one base location. These typically use chilled water as a cooling medium and use extensive ductwork for air distribution.
- The principal advantages of central air conditioning systems are better control of comfort conditions, higher energy efficiency and greater load-management potential. The main drawback is that these systems are more expensive to install and are usually more sophisticated to operate and maintain
- Centralized systems are defined as those in which the cooling (chilled water) is generated in a chiller at one base location and distributed to air-handling units or fan-coil units located through out the building spaces. The air is cooled with secondary media (chilled water) and is transferred through air distribution ducts. A typical chilled water central system is depicted in Figure below. The system is broken down into three major subsystems: the chilled water plant, the condenser water system (or heat rejection system) and the air-delivery system
- Chilled Water System: The chilled water system supplies chilled water for the cooling needs of all the building's air-handling units (AHUs). The system includes a chilled water pump which circulates the chilled water through the chiller's evaporator section and through the cooling coils of the AHUs. The system may have primary and secondary chilled water pumps in order to isolate the chiller(s) from the building: the primary pumps ensure constant chilled water flow through the chiller(s), while the secondary pumps deliver only as much chilled water is needed by the building AHUs

- Condenser Water System: A refrigeration system must also reject the heat that it removes. There are two options for heat rejection: 1) air cooled and 2) water cooled. Air cooled units absorb heat from the indoor space and rejects it to ambient air. Air cooled units incorporate a condensing unit comprising of condenser, compressor, propeller fans and controls assembled in one unit and located outdoors. Water cooled units absorb the heat from the indoor space and rejects that heat to water which in turn may either reject heat via fluid coolers or cooling towers, or dry air coolers with adiabatic kits. Due to the lower refrigerant condensing temperatures compared to air cooled systems, water cooled chillers have higher coefficient of performance (COP).

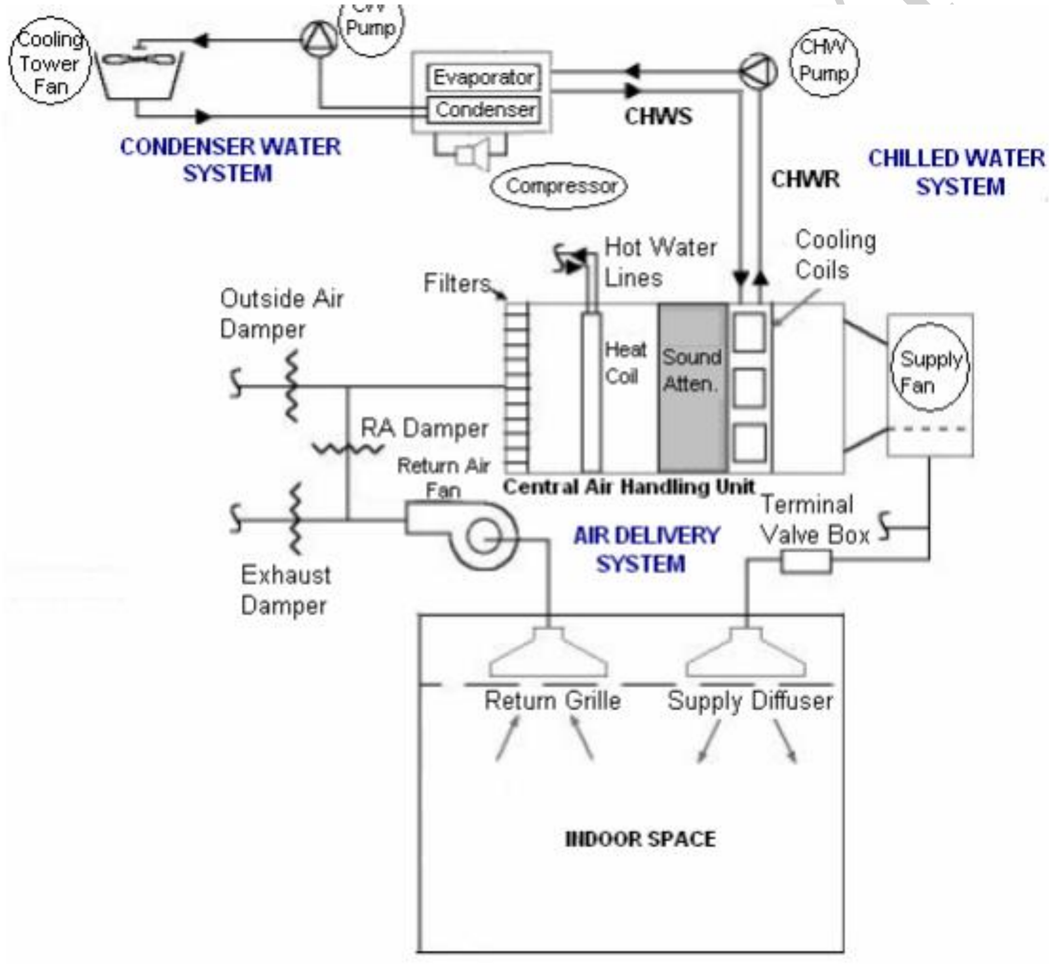

Fig. 3.24 shows chilled water central system

- Air Delivery System: Air is drawn into a building's HVAC system through the air intake by the air handling unit (AHU). Once in the system, supply air is filtered to remove particulate matter (mold, allergens, and dust), heated or cooled, and then circulated throughout the building via the air distribution system, which is typically a system of supply ducts and registers.

3.8 Insight into future mobility technology

Electric and Hybrid Vehicles:

Growing concerns over the limited supply of fossil-based fuels are motivating intense activity in the search for alternative road transportation propulsion systems. In addition, regulatory pressures to reduce urban pollution, CO_2 emissions and city noise have made plug-in electric vehicles a very attractive choice as the alternative to the internal combustion engine. However, despite the enormous benefits of such vehicles, their adoption and uptake has, to this point, been disappointing.

Benefits and Challenges:

Basically, an Electric Vehicle (EV) is a vehicle that no longer relies solely on an Internal Combustion Engine (ICE) as the only propulsion mechanism, but rather uses an electric drive system as a replacement, or to enhance, the ICE. Roughly speaking, three types of electrically propelled vehicles can be distinguished.

- A Hybrid Electric Vehicle (HEV) combines an ICE and an electric motor within the drive train. Mostly, the electric motor supports the ICE for fuel economy and/or performance. The vehicle is then either propelled by the combustion engine or the electric drive.
- A Plug-in Hybrid Electric Vehicle (Plug-in Hybrid Electric Vehicle (PHEV)) is a vehicle equipped, in general, with a larger battery compared to HEVs, that allows recharging of the battery via home outlets or at charging stations. While in most cases both the electric drive and the ICE are able to propel the vehicle, some vehicles use solely the electric drive. In this latter case the ICE can be used to recharge the battery or directly produce electricity for the electric drive. Also, in most cases PHEVs can be used in a full electric mode if there is enough energy stored in the battery. This allows one to select when and where to release pollutants.
- A Full Electric Vehicle (FEV) runs solely on an electric drive system. As with PHEVs their batteries are large and can be recharged in charging stations or at home. Since there are no

pollutants released while driving, these vehicles are often marketed as zero-emission vehicles. Naturally, this is not exactly a correct terminology, since the recharging of the batteries will cause emissions depending on the actual emissions of the power generation in the country. Due to the fact that many power plants are located in less populated areas, the use of FEVs still has beneficial effects on emissions in population centers. Such vehicles may be considered as filters for turning dirty into clean energy.

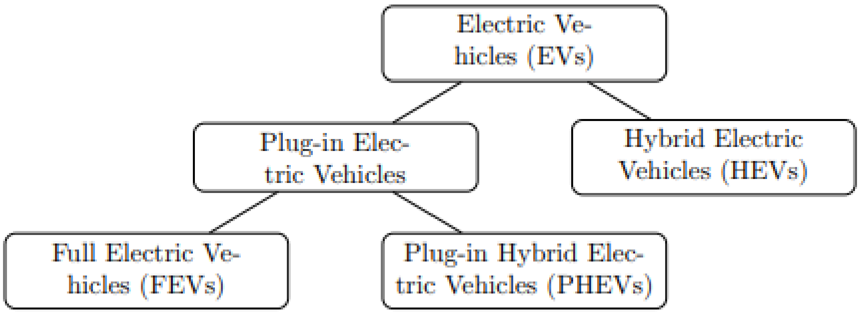

Fig. 3.25 Classification of different EV types

Electric Car Components and Functions:

Electric cars (vehicles) components and functions can be explained by means of picture (Fig. 3.26) below.

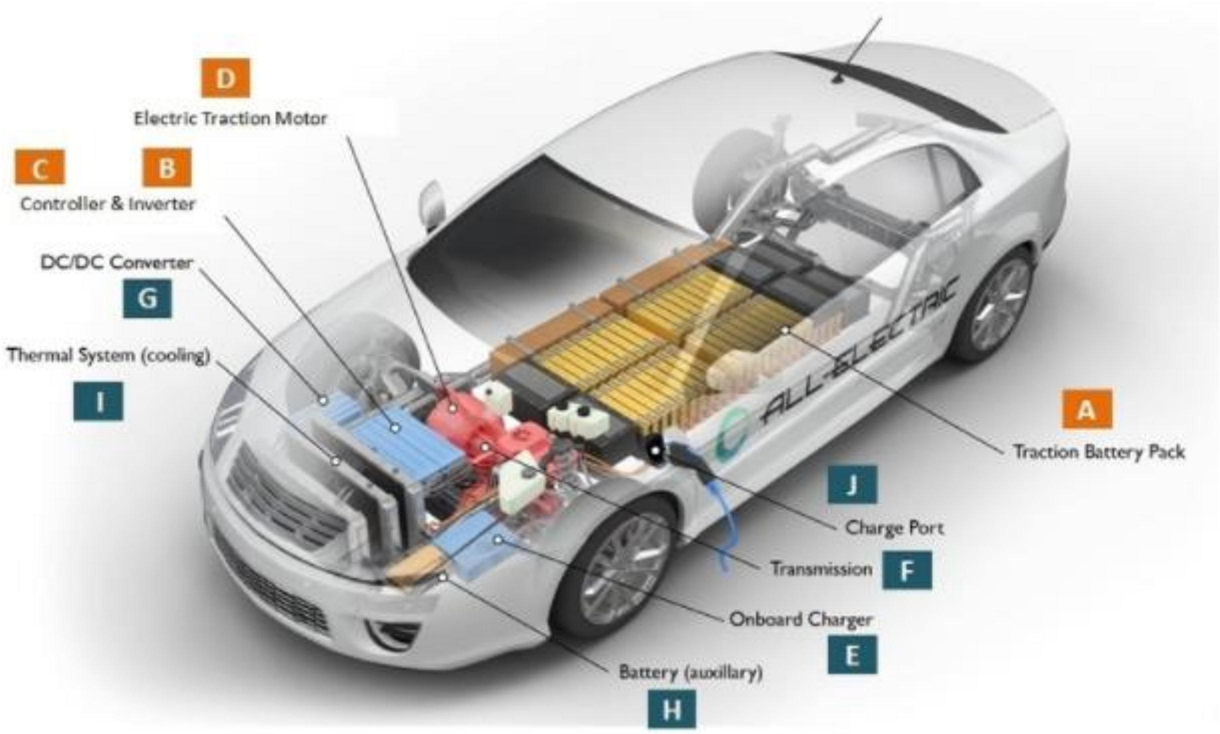

Fig. 3.26 Components of electric car

How Does An Electric Car Work?

When the car pedal is pressed, then:

- Controller [C] takes and regulates electrical energy from batteries [A] and inverters [B]
- With the controller set, the inverter then sends a certain amount of electrical energy to the motor (according to the depth of pressure on the pedal)
- Electric motor [D] converts electrical energy into mechanical energy (rotation)
- Rotation of the motor rotor rotates the transmission so the wheels turn and then the car moves.

Note: The working principle above is for battery electric vehicle (BEV) type

The basic main elements of electric cars installed in almost all types of electric cars are as follows:

- **Traction Battery Pack (A)**: The function of the battery in an electric car is as an electrical energy storage system in the form of direct-current electricity (DC). If it gets a signal from the controller, the battery will flow DC electrical energy to the inverter to then be used to drive the motor. The type of battery used is a rechargeable battery that is arranged in such a way as to form what is called a *traction battery pack*. There are various types of electric car batteries. The most widely used is the type of lithium-ion batteries.

- **Power Inverter (B)**: The inverter functions to change the direct current (DC) on the battery into an alternating current (AC) and then this alternating current is used by an electric motor. In addition, the inverter on an electric car also has a function to change the AC current when regenerative braking to DC current and then used to recharge the battery. The type of inverter used in some electric car models is the bi-directional inverter category.
- **Controller (C):**The main function of the controller is as a regulator of electrical energy from batteries and inverters that will be distributed to electric motors. While the controller itself gets the main input from the car pedal (which is set by the driver). This pedal setting will determine the frequency variation or voltage variation that will enter the motor, and at the same time determine the car's speed. In brief, this unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and the torque it produces. This component will determine how electric car work.
- **Electric Traction Motor (D)**: Because the controller provides electrical power from the traction battery, the electric traction motors will work turning the transmission and wheels. Some hybrid electric cars use a type of generator-motor that performs the functions of propulsion and regeneration. In general, the type of electric motor used is the BLDC (brushless DC) motor

What is Hybrid Car?

Hybrid cars are becoming more popular and more common. Basically, a hybrid car is one that uses two or more engines i.e., an electric motor and a conventional engine (either petrol or diesel). The electric engine powers the car at lower speeds, and the gas engine powers it at higher speeds. A hybrid car like Toyota Prius and Civic Hybrid not only conserves fuel but also produces less CO2 emissions.

How Hybrid-Electric Vehicles Work?

Hybrid-Electric Vehicles (HEVs) combine the advantage of both the internal combustion engine or gasoline engines and electric motors that use energy stored in batteries. The key areas of performance are regenerative braking, dual power sources, and less idling.

- **Regenerate braking:** A hybrid electric vehicle cannot be plugged in for the battery to charge. The battery is charged with the help of regenerative braking and by the internal combustion engine. It helps to transform kinetic energy produced by the moving car into electrical energy stored back into the batteries. The electric motor powers the vehicle as well as resists its motion. When you apply brakes to slow down, this resistance slows down the wheel and simultaneously recharges the batteries.
- **Dual power:** Depending on driving circumstances, power can come from either the engine, motor or both. The electric motor is in use at low speeds. When you pick up the speed, your combustion engine kicks in. Afterward, the electric battery recharges itself using the combustion engine. The electric motor also provides additional power to assist the engine in accelerating or climbing.
- **Automatic start/shutoff:** When the vehicle comes to a stop, it automatically shuts off the engine and restarts it when the accelerator is pressed down. This automation is much simpler with an electric motor. The additional power provided by the electric motor can potentially allow for a smaller engine. The battery not only power auxiliary loads, but it also reduces engine idling when it stops. These features altogether result in better fuel economy without hampering performance.

Advantages of a Hybrid Car:

- Environmentally Friendly
- Financial Benefits
- Less Dependence on Fossil Fuels
- Regenerative Braking System
- Built From Light Materials
- Assistance From Electric Motor
- Smaller Engines

- Automatic Start and Stop

Disadvantages of a Hybrid Car:

- Less Power
- Can be expensive
- Poorer handling
- Higher Maintenance Costs
- Accident from High Voltage in Batteries
- Battery Replacement is Pricey
- Battery Disposal and Recycling