BMEE303L- THERMAL ENGINEERING SYSTEMS

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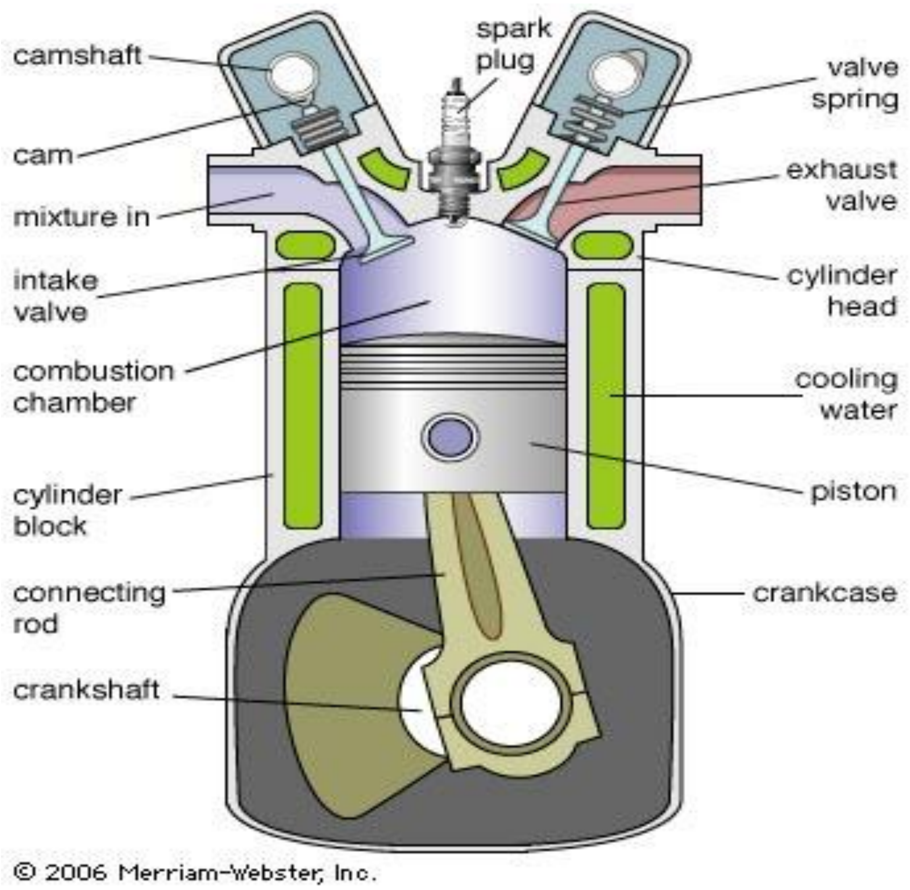
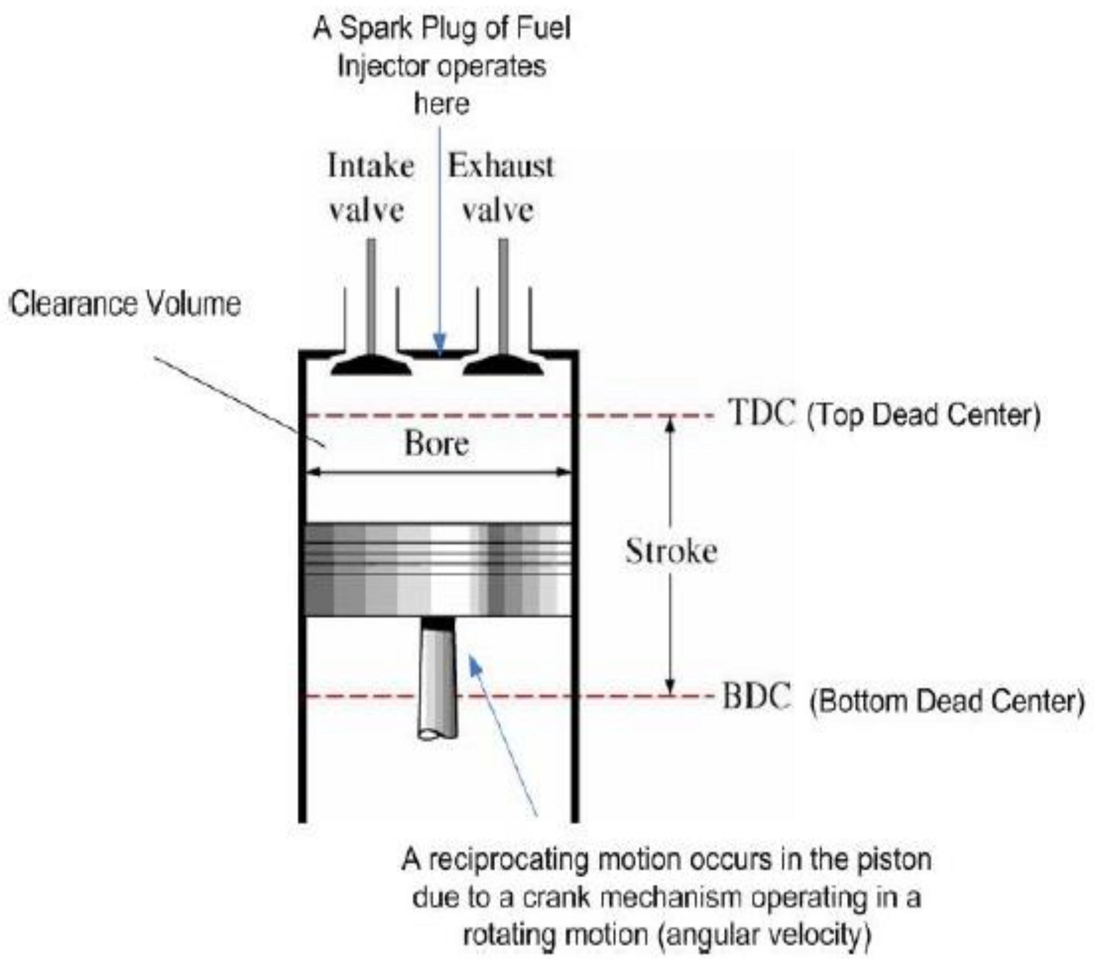
MODULE -1 IC ENGINES

- Working principle of 2-stroke and 4-stroke SI and CI engines
- Valve and port timing diagrams,
- Simple carburetor,
- Ignition system,
- Combustion stages in SI and CI engine - Knocking and detonation,
- Fuel injection system - MPFI, CRDI, GDI
- Rating of fuels
- Cooling system
- Lubrication system
- Super charging and Turbo charging





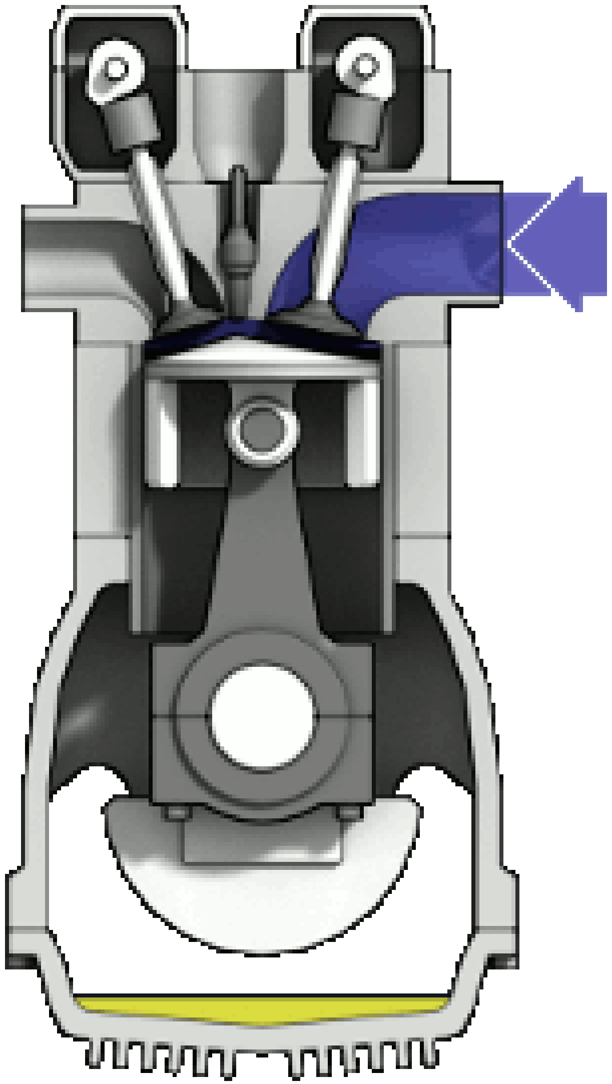
Compression ratio (CR) = Max cylinder volume / Min cylinder volume

For SI engines – 8 to 12

For CI engines – 12 to 24

4- Stroke Petrol Engine

1



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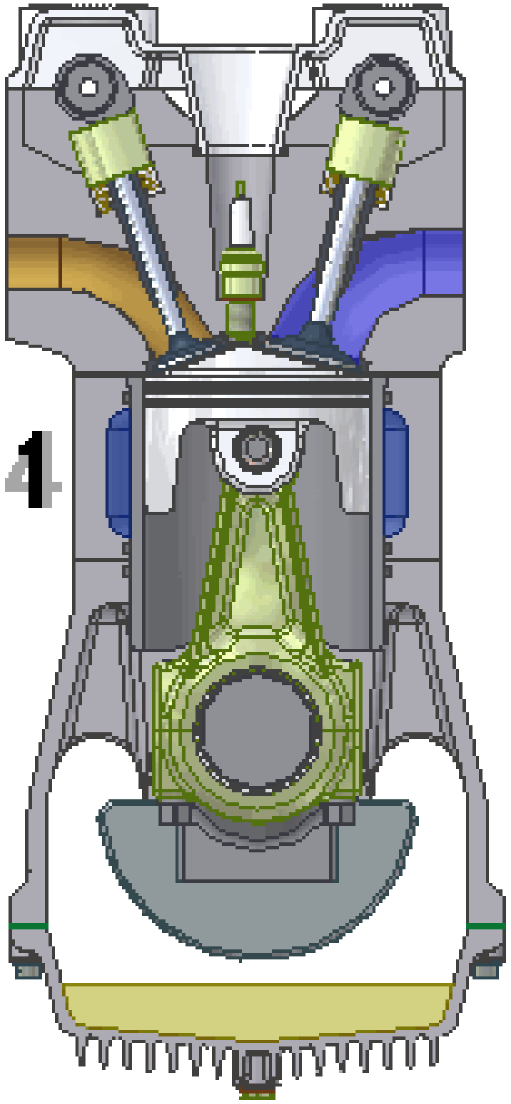
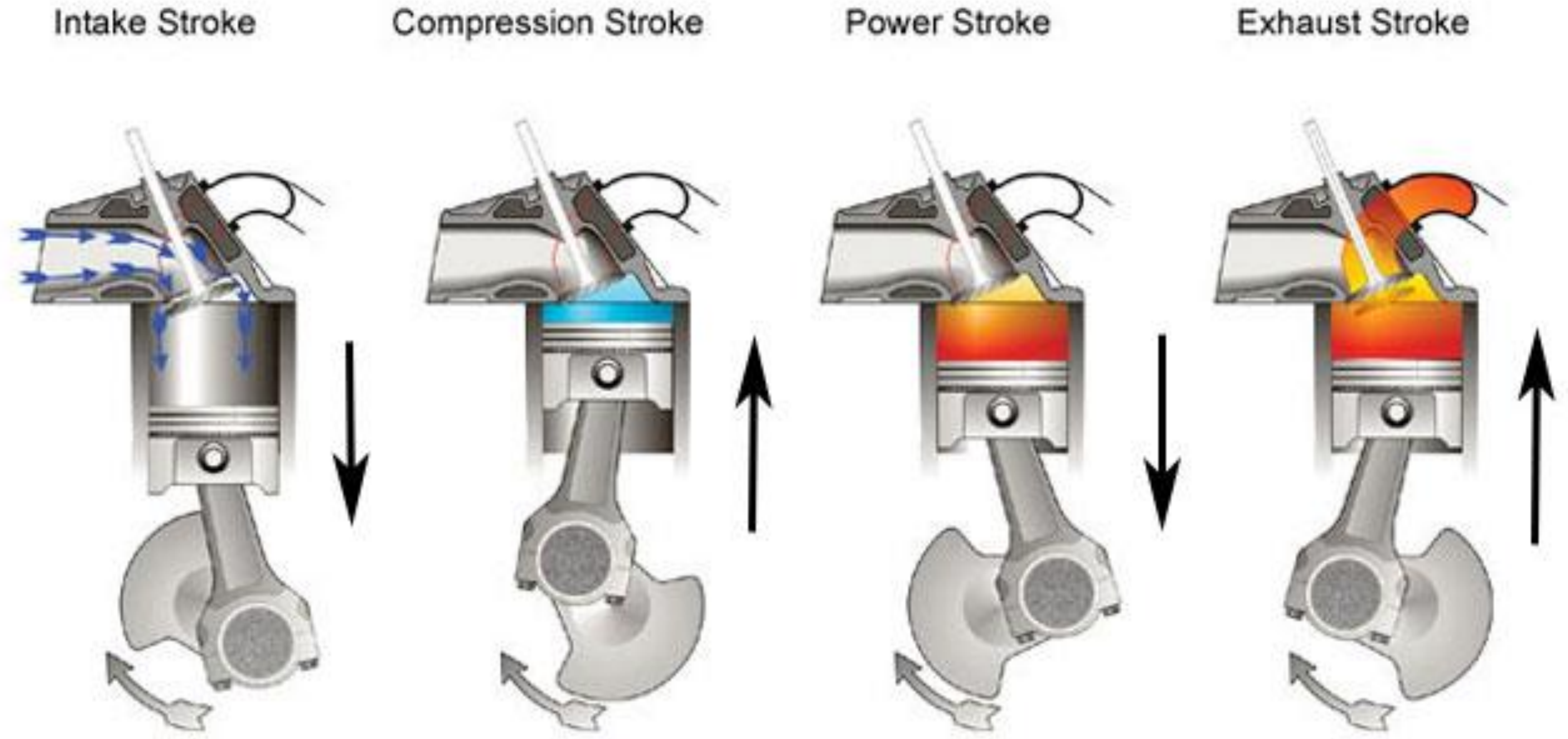
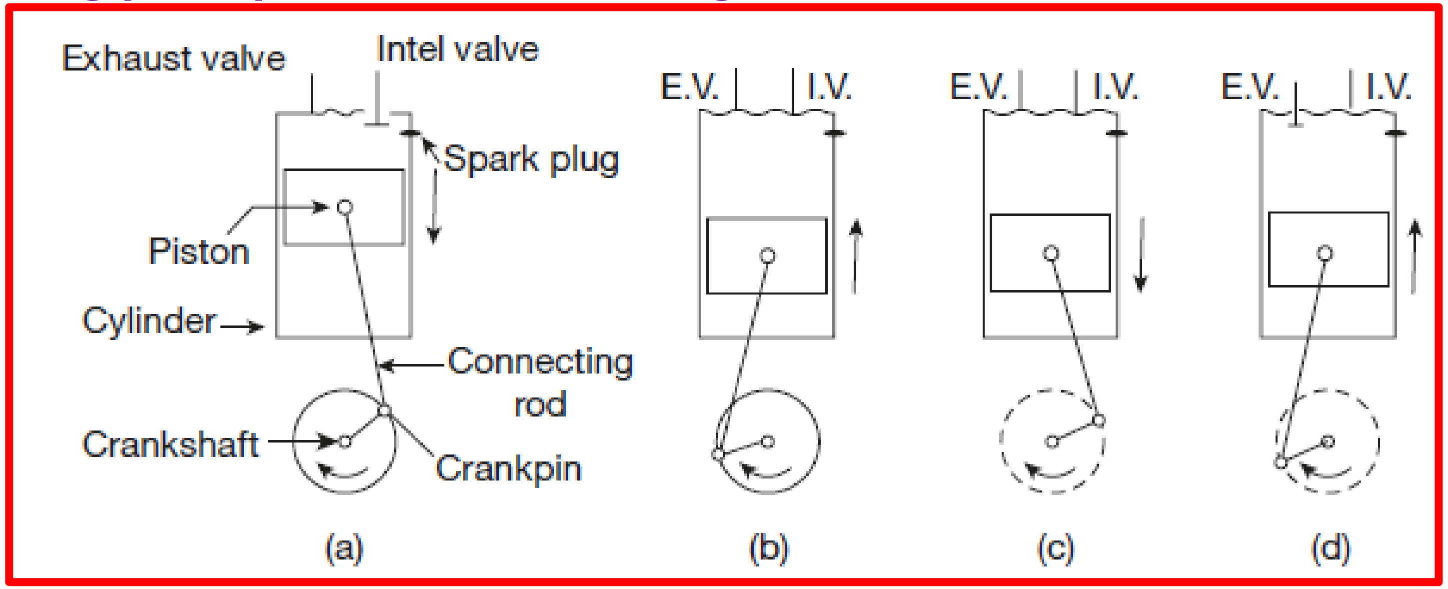



Intake Stroke
Compression Stroke
Power Stroke
Exhaust Stroke

Working principle of 4-stroke SI engines:-

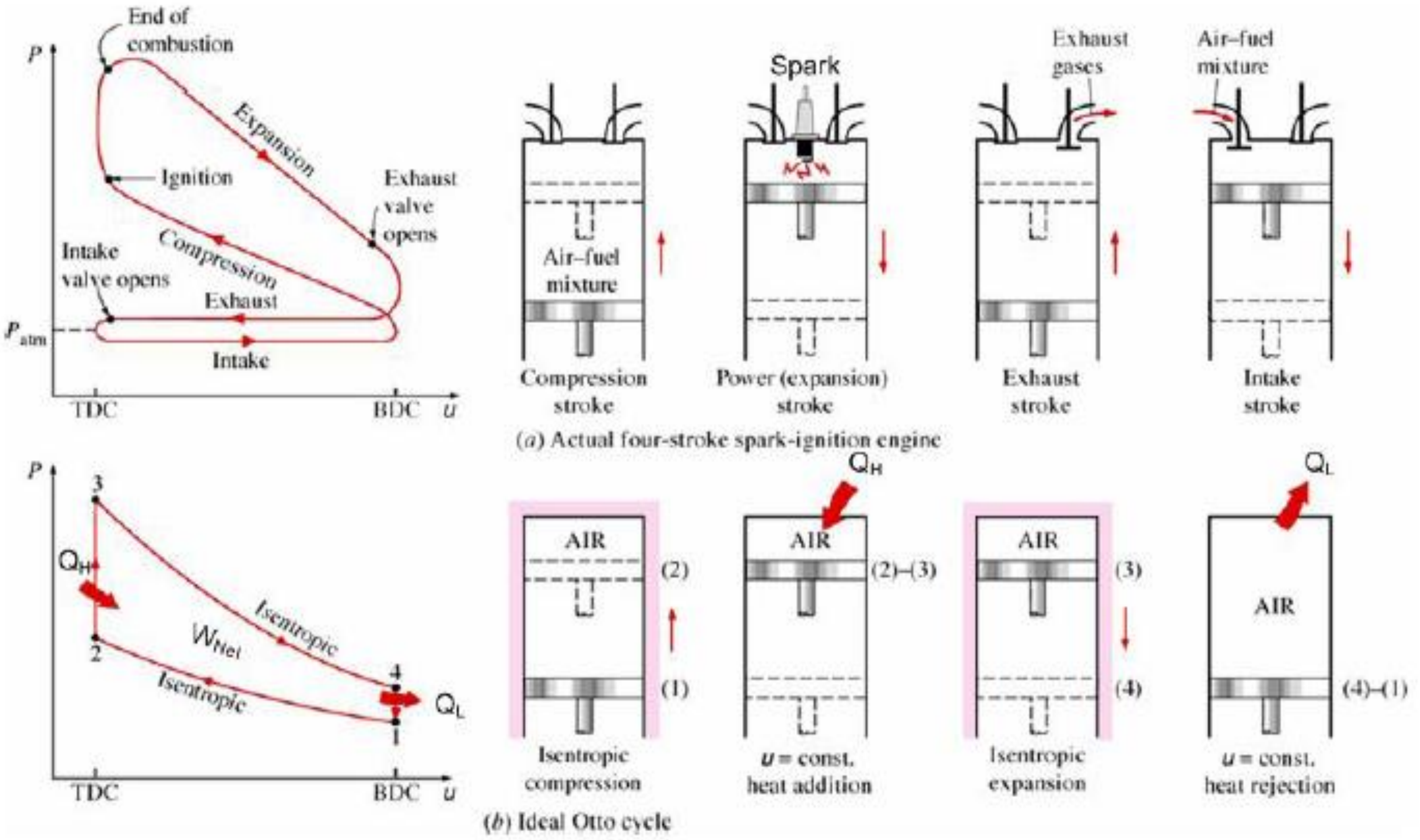


(a) Suction stroke,
(b) Compression stroke,
(c) Expansion or power stroke,
(d) Exhaust stroke

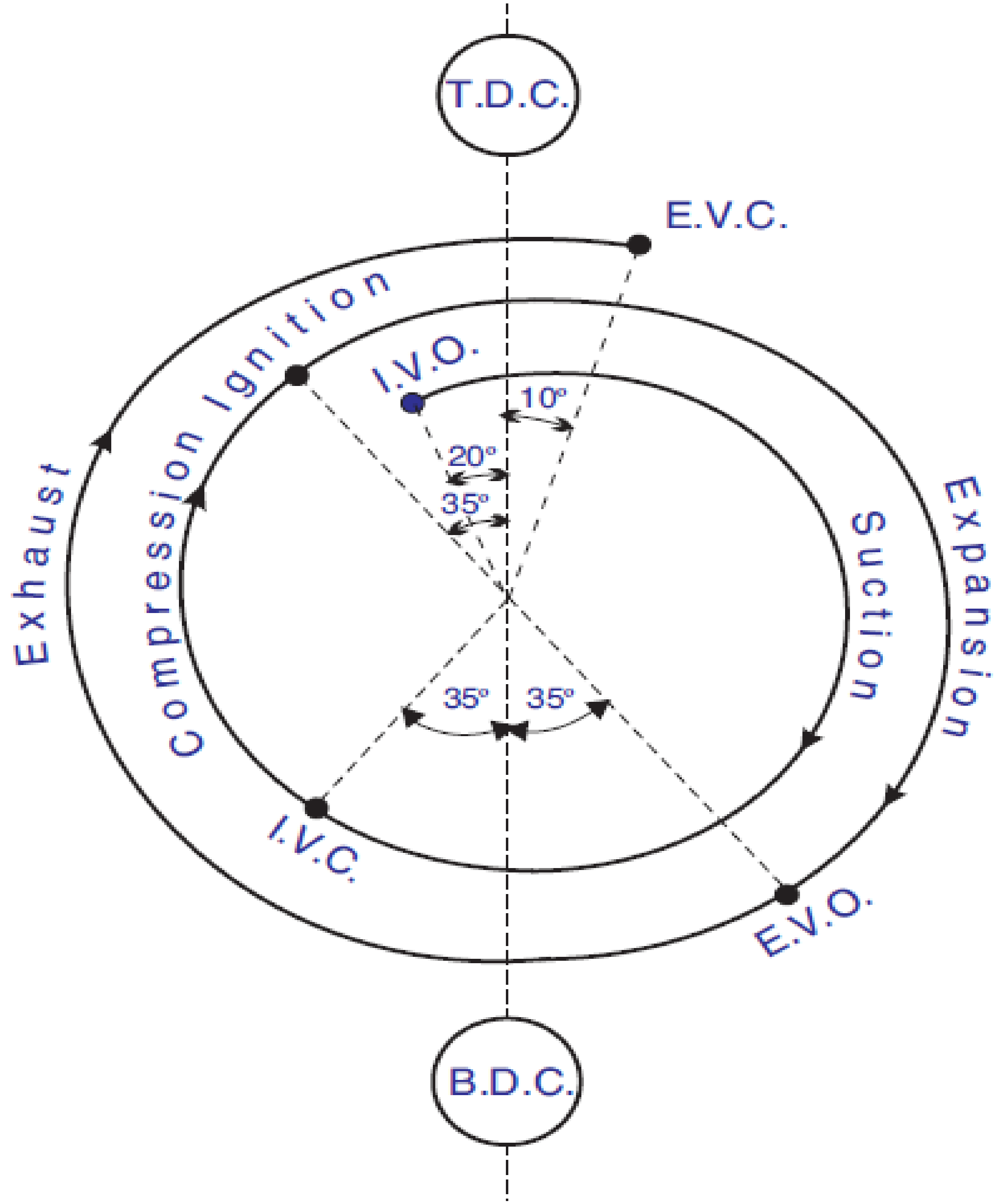
Cycle is completed in two revolution (720^o) of the crankshaft.

1. **Suction stroke:** It starts when the piston is at the top dead centre (TDC) and is about to move downwards. The inlet valve is open and the exhaust valve is closed at this time. The charge consisting of the fuel-air-mixture is drawn into the cylinder. When the piston reaches the bottom dead centre (BDC), the suction stroke ends and the inlet valve closes.
2. **Compression stroke:** The charge is compressed to the clearance volume by the return stroke of the piston with both inlet and exhaust valves are closed. At the end of the compression stroke, the mixture is ignited with the help of spark plug to convert chemical energy of fuel to heat energy.
3. **Expansion stroke:** The high pressure of burnt gases forces the piston towards BDC with both the valves in closed position to produce power.
4. **Exhaust stroke:** At the end of the expansion stroke, the exhaust valve opens with the inlet valve closed. The piston starts moving towards the TDC and sweeps the burnt gases out from the cylinder. The exhaust valve closes when piston has reached TDC.

Actual and Ideal Cycles in Spark-Ignition Engines
P-V Diagram



Valve timing diagram for 4 stroke SI engine:-



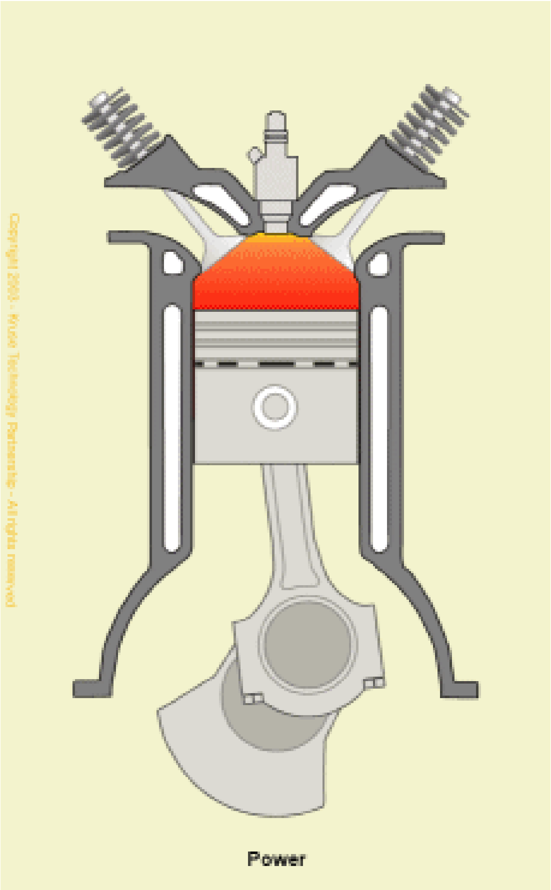
A typical valve timing diagram for a four-stroke SI engine is shown in Fig. The typical timing valves are also displayed.

IVO up to 20° before TDC; IVC up to 35° after BDC.

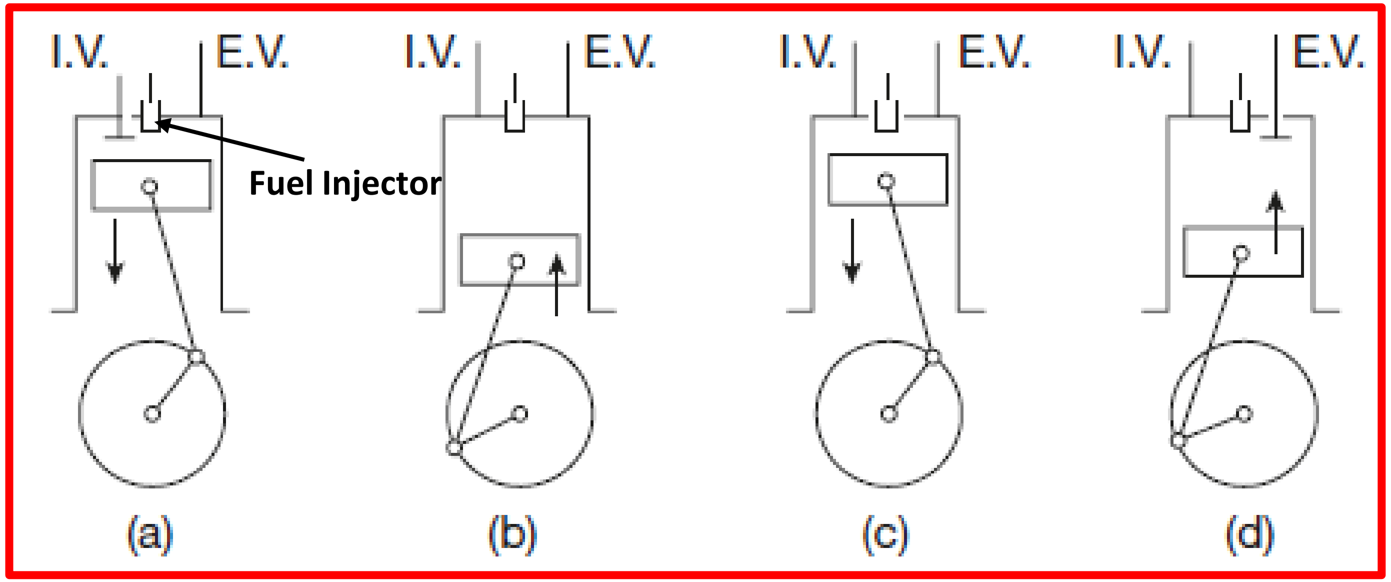
EVO about 35° before BDC; EVC about 35° after TDC.

Spark or (Ignition) starts about 35° before TDC;

4-Stroke Diesel Engine



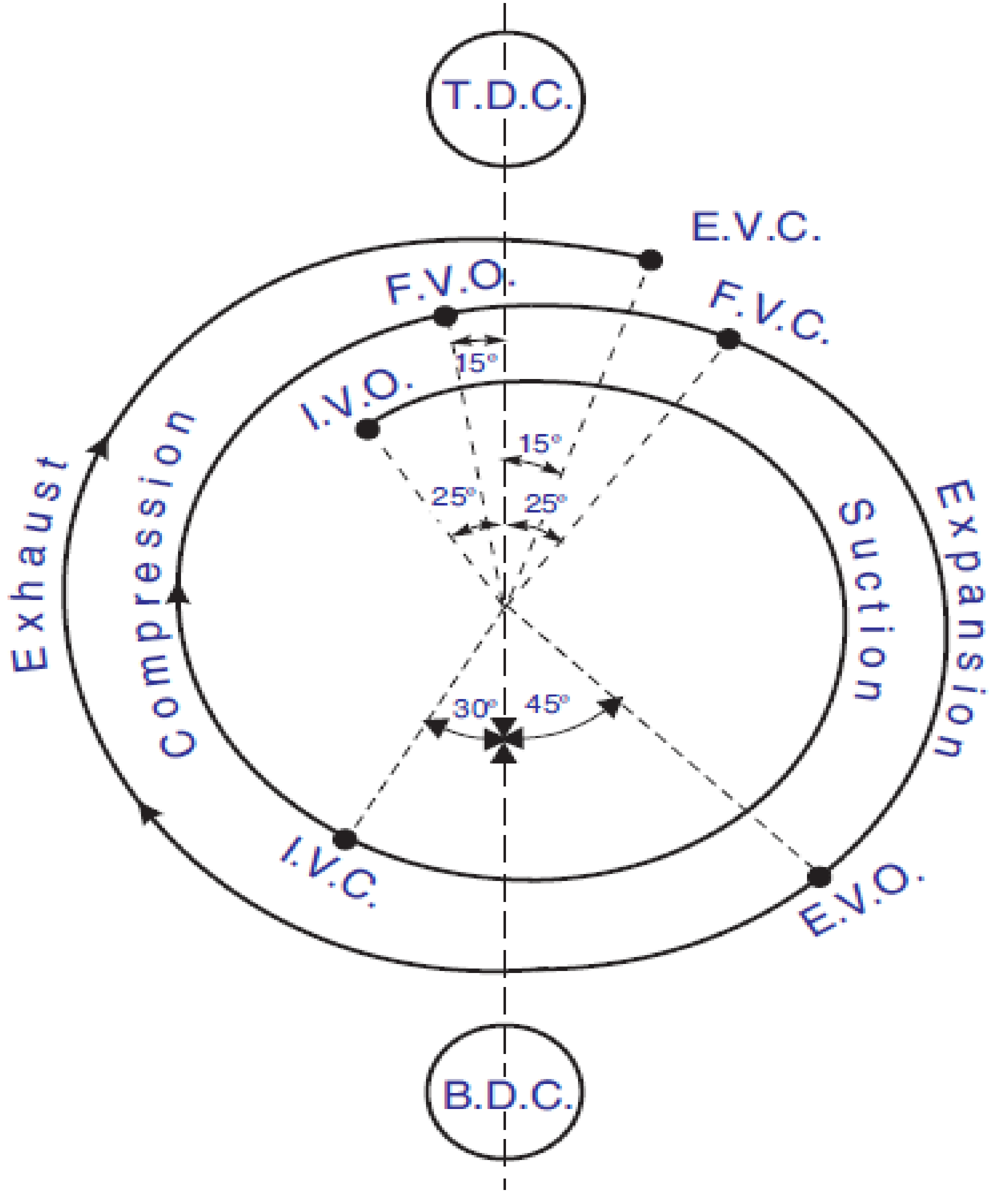
Working principle of 4-stroke CI engines:-



(a) Suction stroke,
(b) Compression stroke,
(c) Expansion or power stroke,
(d) Exhaust stroke

1. **Suction stroke:** Only air is induced during the suction stroke with the inlet valve open and the exhaust valve closed.
2. **Compression stroke:** The sucked air is compressed into the clearance volume with both valves closed.
3. **Expansion stroke:** Fuel injection starts nearly at the end of the compression stroke, resulting in combustion. The products of combustion expand and both the valves remain closed.
4. **Exhaust stroke:** The piston moves from BDC to TDC and pushes out the products of combustion with the exhaust valve open and intake valve closed.

Valve timing diagram for 4 stroke CI engine:-



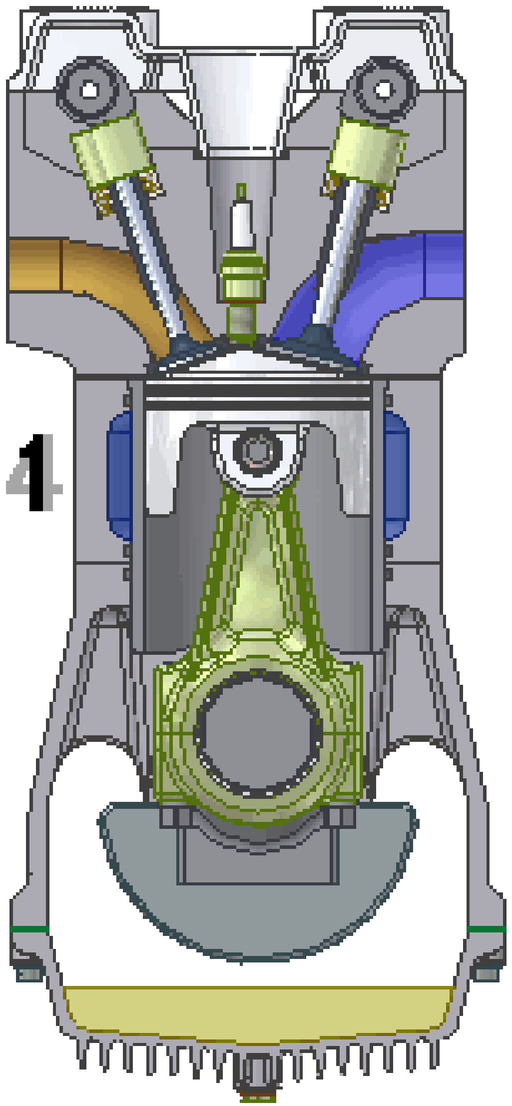
A typical valve timing diagram for a four-stroke CI engine is shown in Fig. The typical timing valves are also displayed.

IVO up to 25° before TDC; IVC up to 30° after BDC.

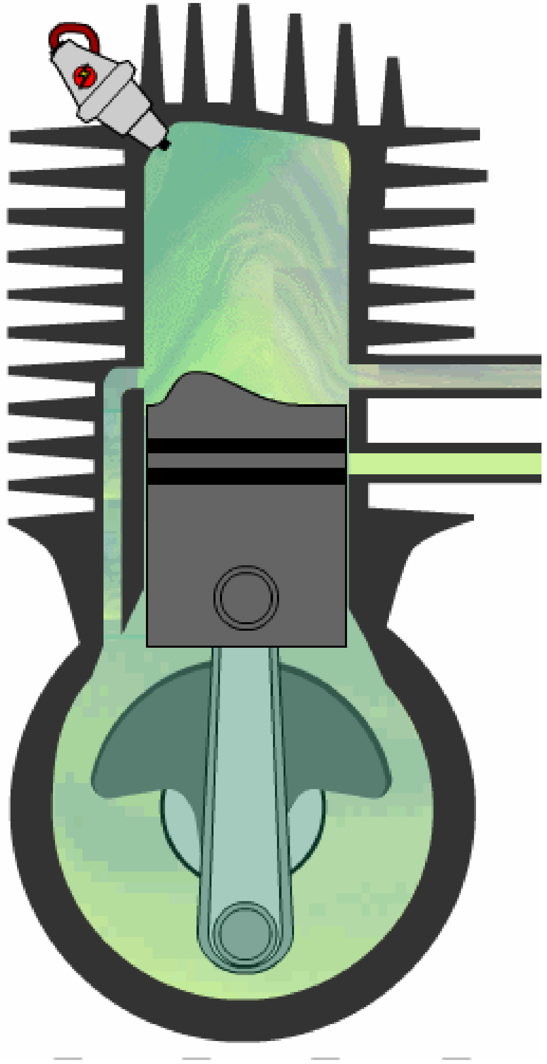
EVO about 45° before BDC; EVC about 30° after TDC.

Fuel valve opens (FVO) about 15° before TDC; Fuel valve closes (FVC) about 25° after TDC.

4- stroke Engine



2- stroke Engine



Two-stroke Spark Ignition (SI) engine

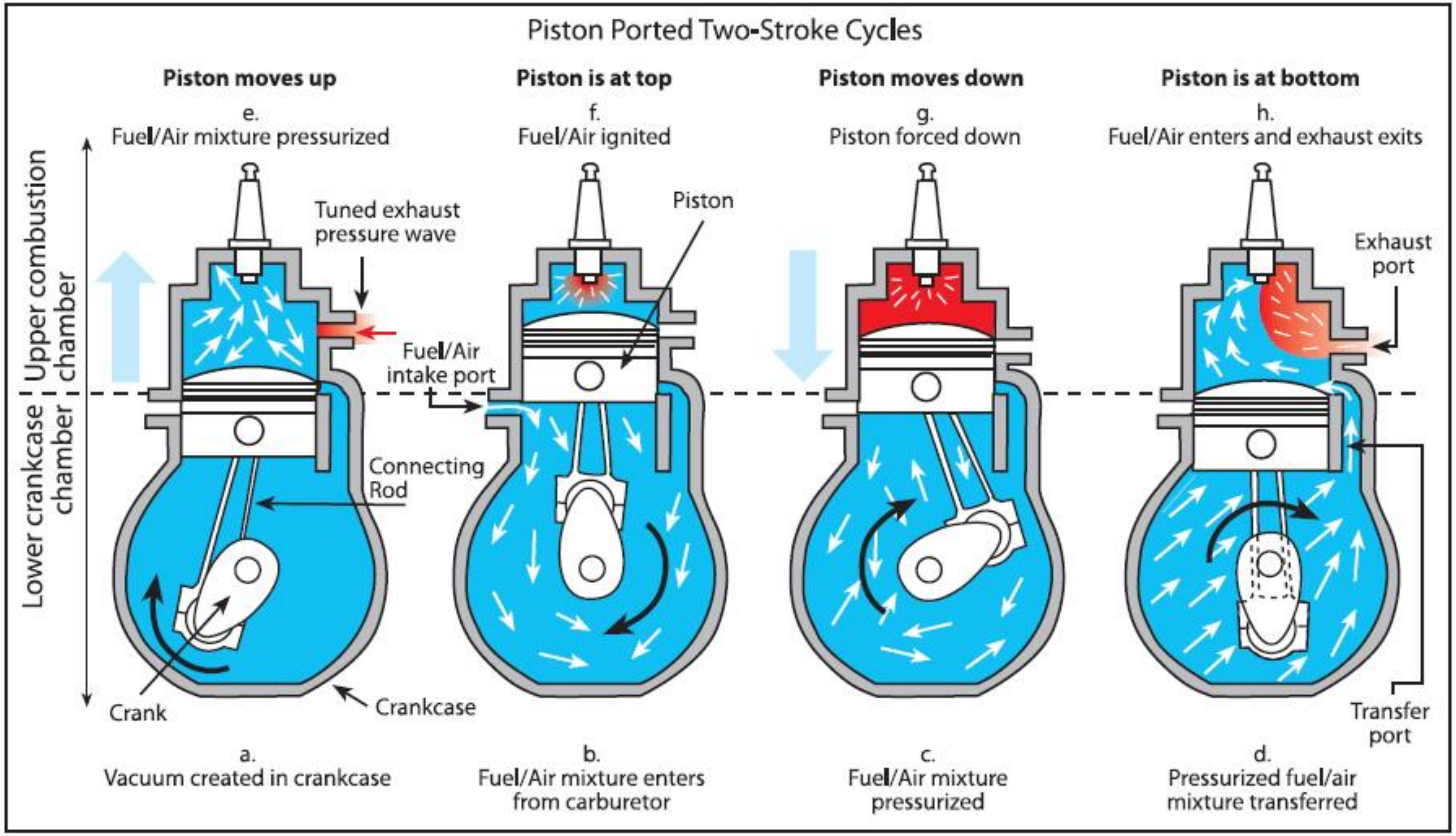
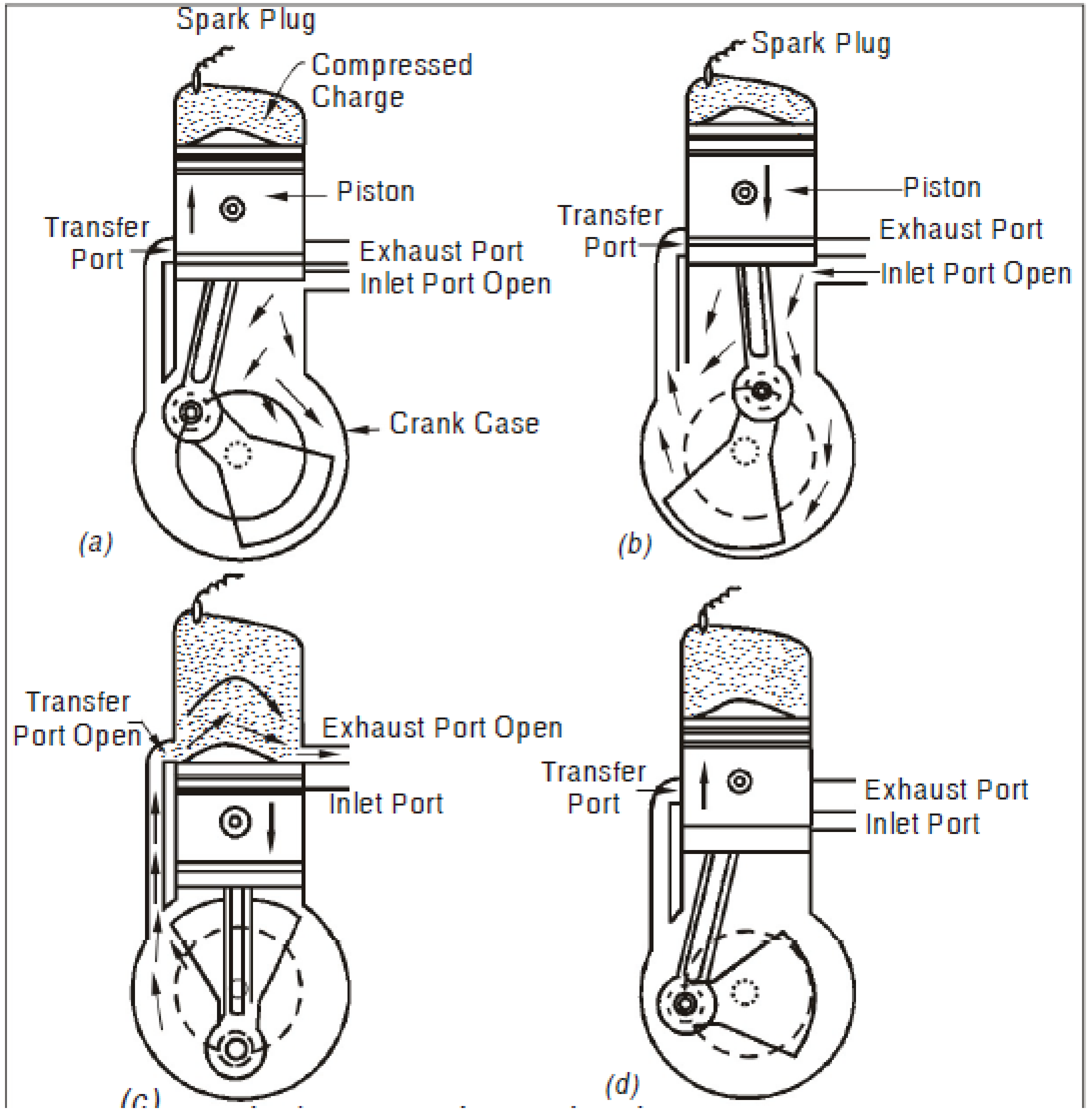


Figure 4-3. Piston ported inlet for a two cycle engine.

Working principle of 2-stroke SI engines:-



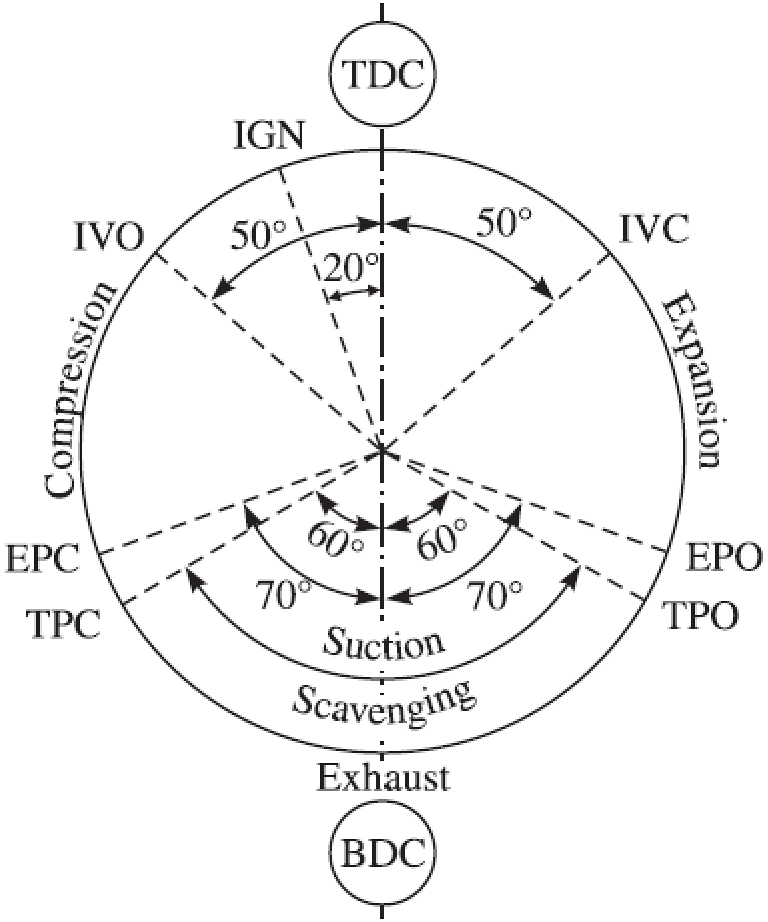
Crankcase scavenged two-stroke SI engine

Cycle is completed in one revolution (360^o) of the crankshaft.

- One working stroke for every revolution of the crankshaft.
- Two stroke engine has ports instead Of valves.
- Piston of two stroke engine is used to open and close the inlet and exhaust ports.
- Process 1 : Piston is at TOP of its stroke- Inlet Port opens- mixture of air and petrol vapour enters crankcase.
- Process 2 : Downward stroke of the piston, the inlet port is closed and the mixture is slightly compressed.
- Process 3 : Exhaust port is uncovered to allow the burnt gases to escape. Same time, the slightly compressed charge enters the cylinder through the transfer port – The incoming charge flows upwards and forces out the burnt exhaust gases - **Scavenging process.**
- Process 4 : Piston now moves upwards and the ports are closed. The charge is compressed and ignited by spark plug.

(a) Scavenging,
(b) Compression,
(c) Expansion or power stroke,
(d) Exhaust stroke

Port timing diagram for 2 stroke SI engine:-

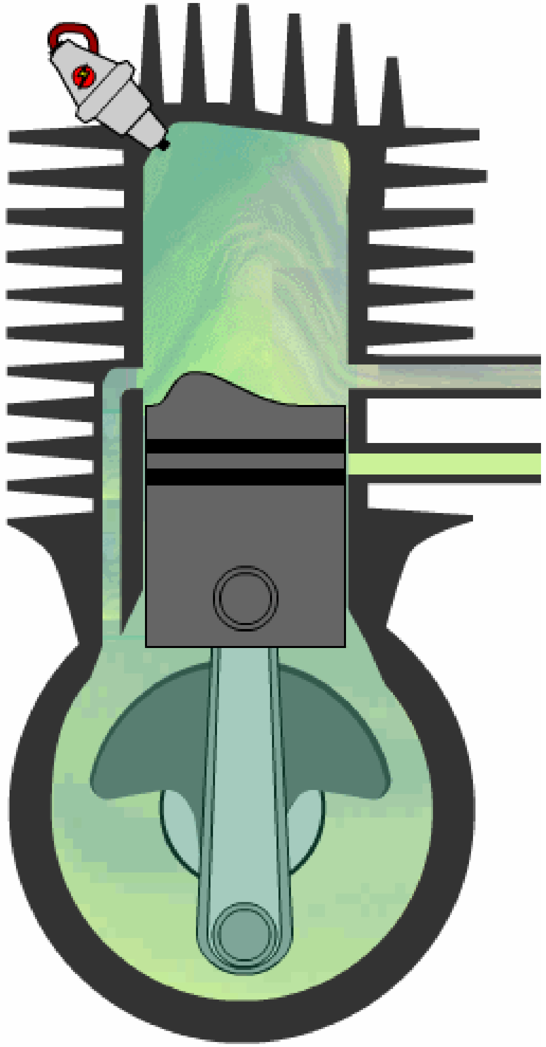


1.*Inlet port:* The inlet port opens 35° to 50° prior to the TDC position which closes in equal amount after TDC position.

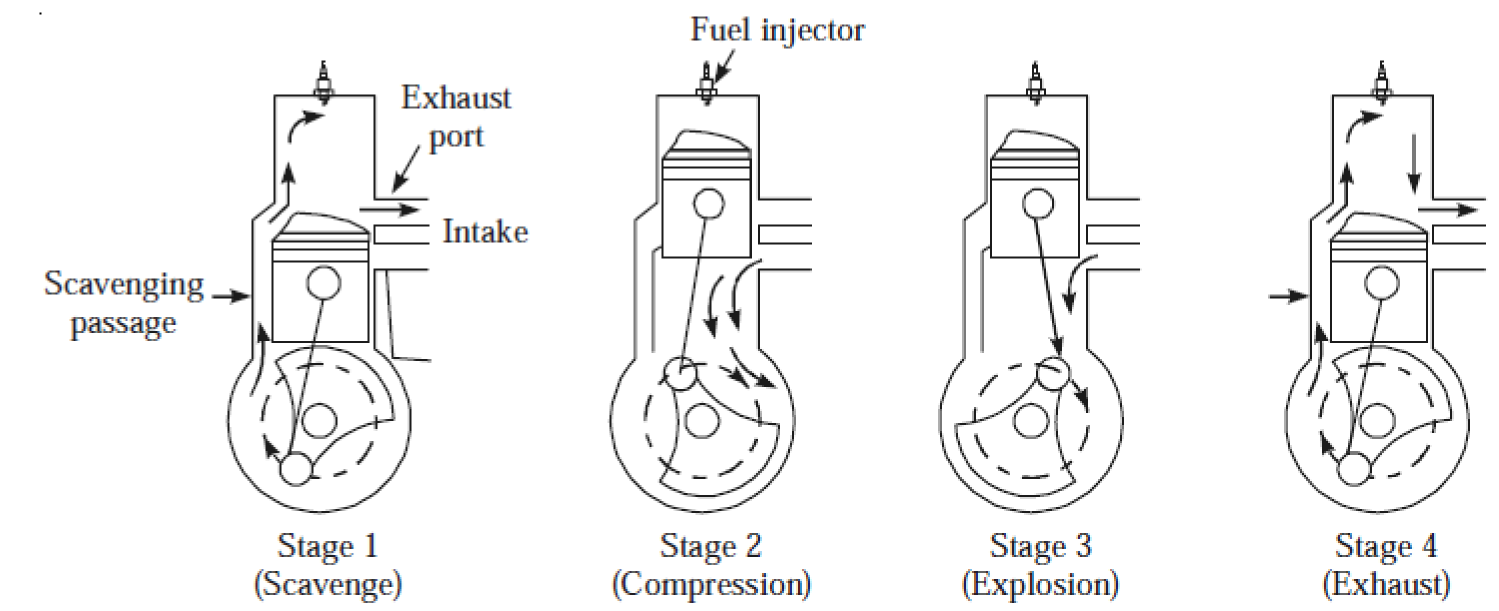
2. *Exhaust port:* The exhaust port opens and closes 35° to 70° before and after BDC position, respectively.

3. *Transfer port:* Transfer port opens 35° to 60° in advance to the BDC position and closes 35° to 60° after TDC position.

4. *Ignition:* Ignition takes place by the spark at 15° to 20° before TDC position as the charge requires some time to ignite. It may be noted that the exhaust and transfer ports open and close at equal angles on either side of the BDC position.



Working principle of 2-stroke CI engines:-



Cycle is completed in one revolution (360^{o}) of the crankshaft.

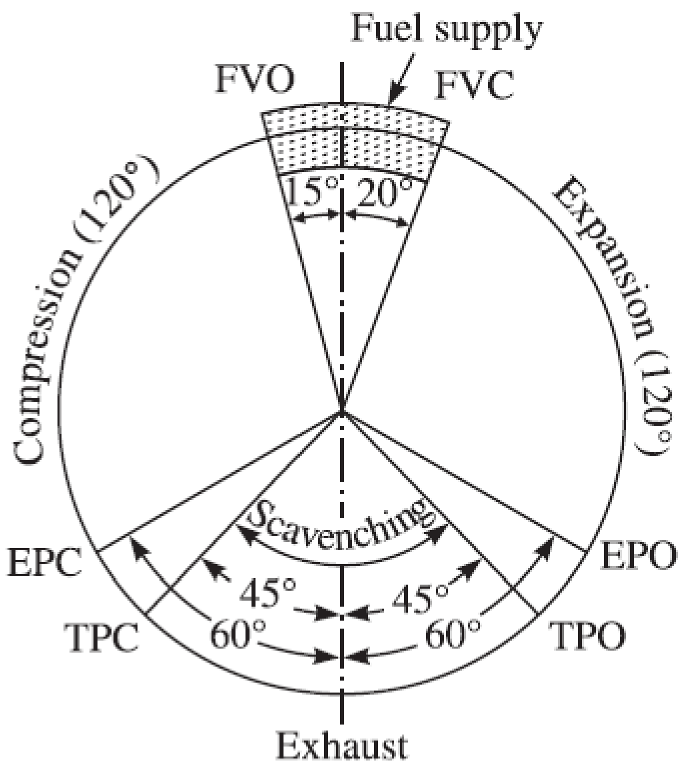
Stage 1: When the piston is just at the beginning of the upward stroke, the inlet valves in the cylinder head are open and the exhaust ports are uncovered. The fresh air is admitted through the valves and the gases are expelled out through the exhaust port. This is due to the fact that the fresh air is supplied slightly above the atmospheric pressure.

Stage 2: The piston moves upwards and covers exhaust ports. The air inlet valves are also closed. The air is compressed to a pressure of about 3.42 MPa through the valve. The compressed air has a very high temperature which is sufficient to ignite the fuel.

Stage 3: The fuel oil is injected at a pressure of about 8.336 MPa through the fuel injection valve. This is located centrally at the top of the combustion chamber. The high temperature compressed air burns the fuel and pushes the piston downwards.

Stage 4: The piston now moves upwards and uncovers the exhaust ports. The burnt gases flow out through the ports into the atmosphere. At this moment, there is some pressure in the cylinder which reduces to that of the atmosphere. After the piston has uncovered a certain portion of the exhaust ports, the air inlet valves open, and the fresh air flows into the cylinder. The fresh air forces the remaining exhaust gases through the exhaust ports till they are covered by the piston on its upward stroke. The cylinder is now full of fresh air to start with the next cycle.

Port timing diagram for 2 stroke CI engine:-



1. *Inlet port:* The inlet port opens 35° to 50° prior to the TDC position which closes in equal amount after TDC position.

2. *Exhaust port:* The exhaust port opens and closes 35° to 70° before and after BDC position, respectively.

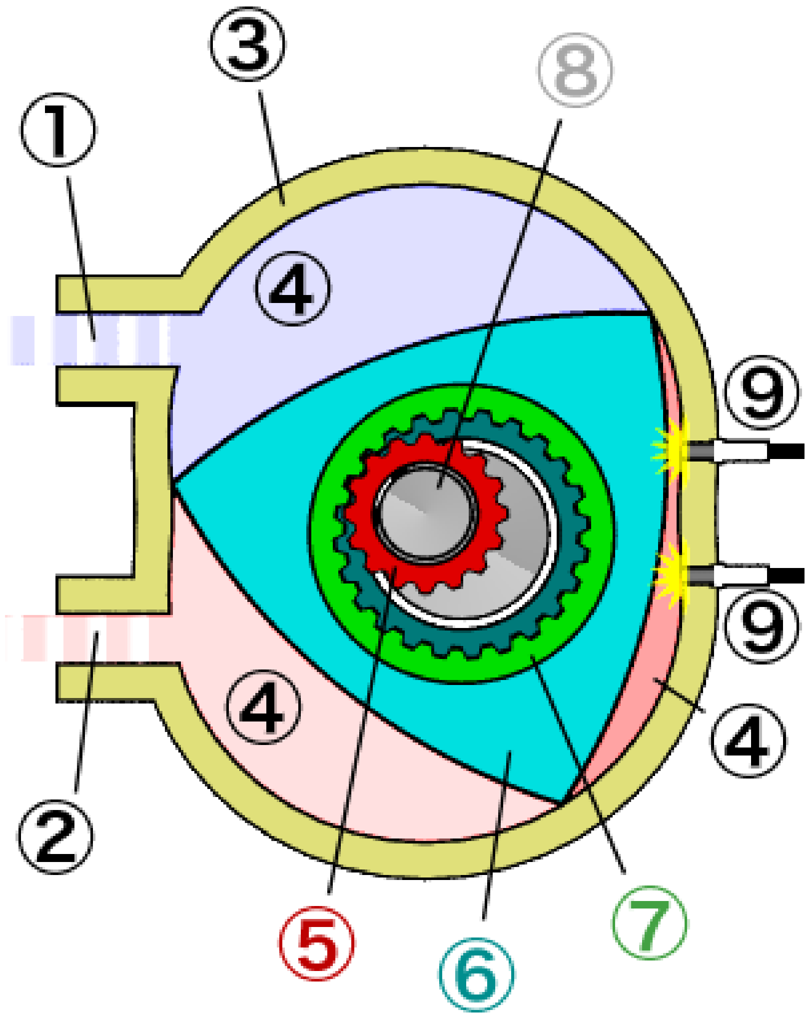
3. ***Transfer port:*** The transfer port opens 35° to 60° in advance to the BDC position and closes 35° to 60° after TDC position.

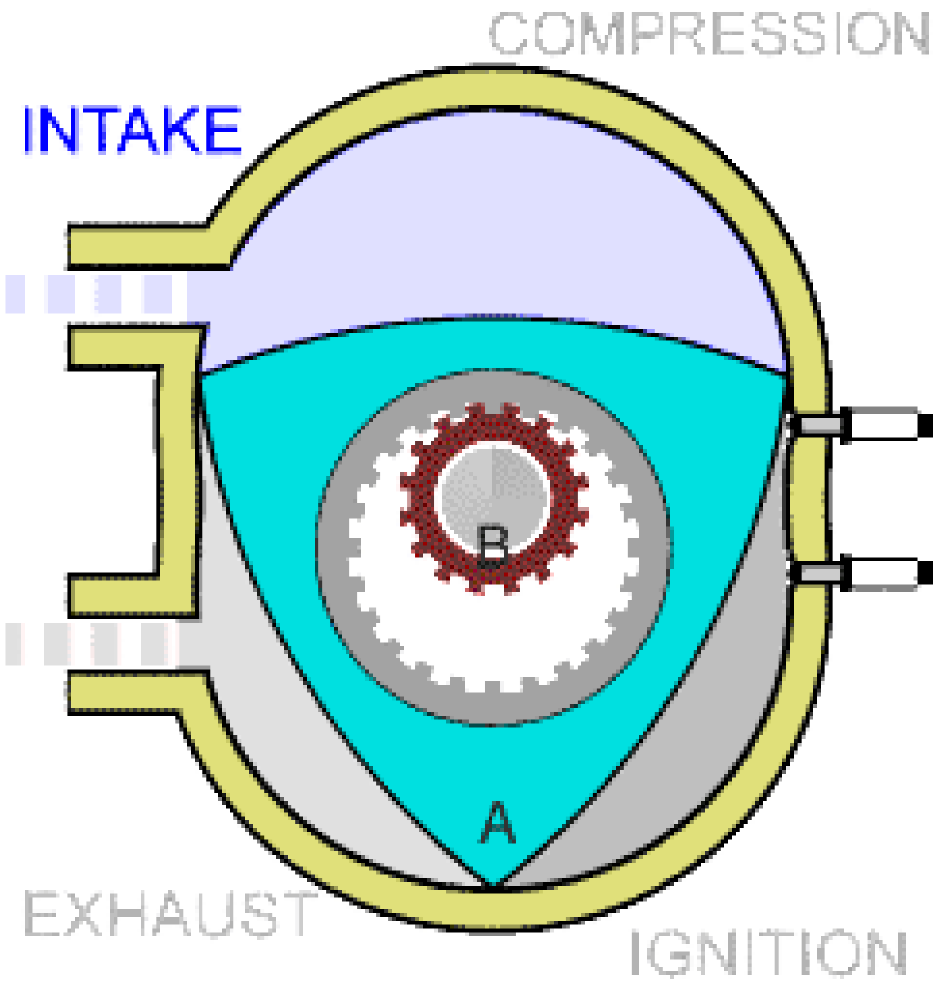
4. ***Ignition:*** Fuel injection valves opens 10° to 15° before TDC position as the air requires some time to start ignition which closes 15° to 20° after TDC position for better and efficient combustion. The scavenging period for petrol engines must not exceed above 70° where as, this period is large in case diesel engines.

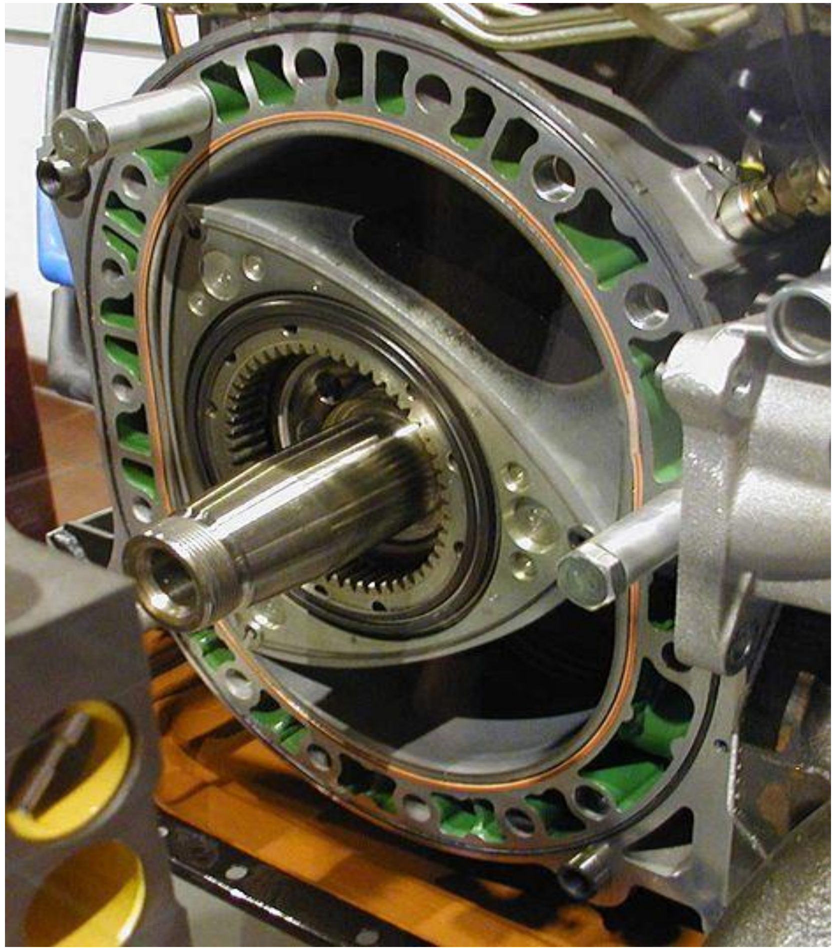
Wankal Engine

Parts of Wankal Engine

1. Engine inlet
2. Exhaust outlet
3. Housing
4. Combustion chambers
5. Stationary gear
6. Rotor
7. Internal gear
8. Eccentric shaft
9. Spark plugs




COMPRESSION
INTAKE
B
A
EXHAUST
IGNITION



Advantages

- Simpler & lighter
- High reliability
- Smooth flow of power
- High power to weight ratio
- Severely overheated engine cannot seize
- Smaller frontal area of equivalent power

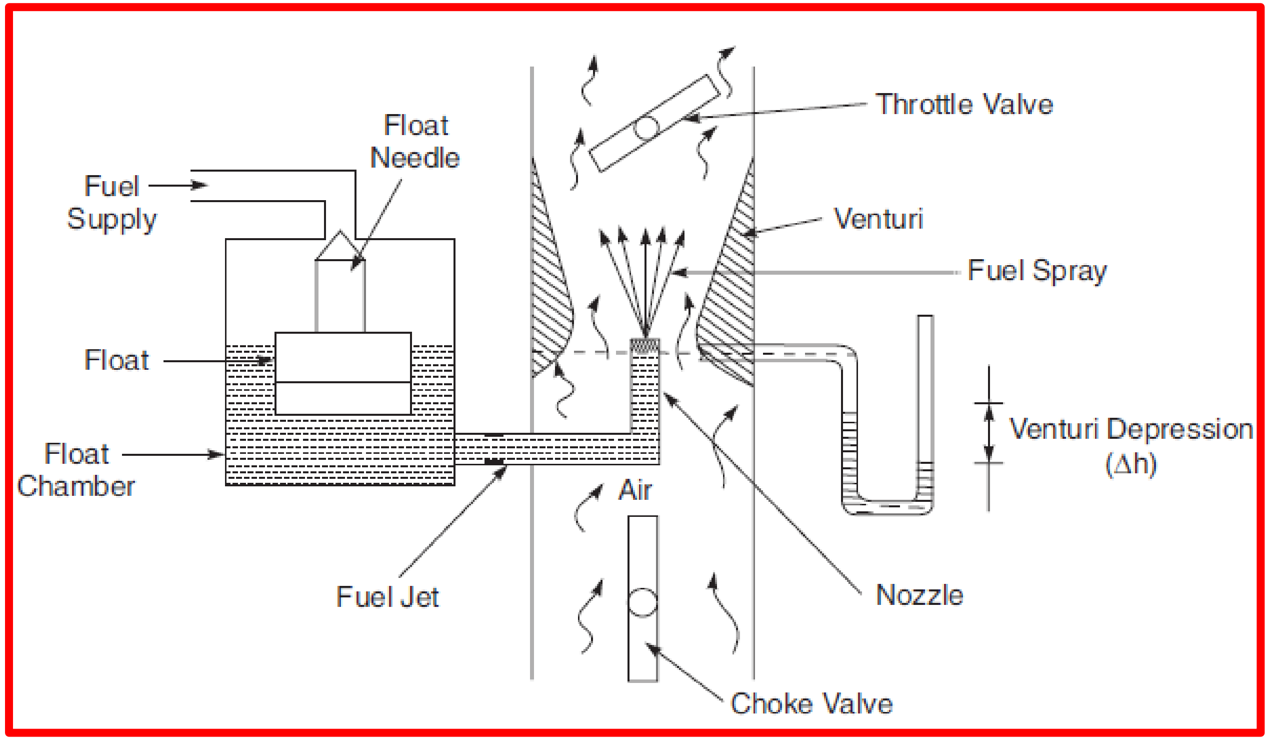
Disadvantages

- Less efficiency
- More fuel consumption
- Less effective sealing

SIMPLE CARBURETOR:-

The function of a carburettor is to atomize & meter the liquid fuel and mix it with air for all conditions of operation.

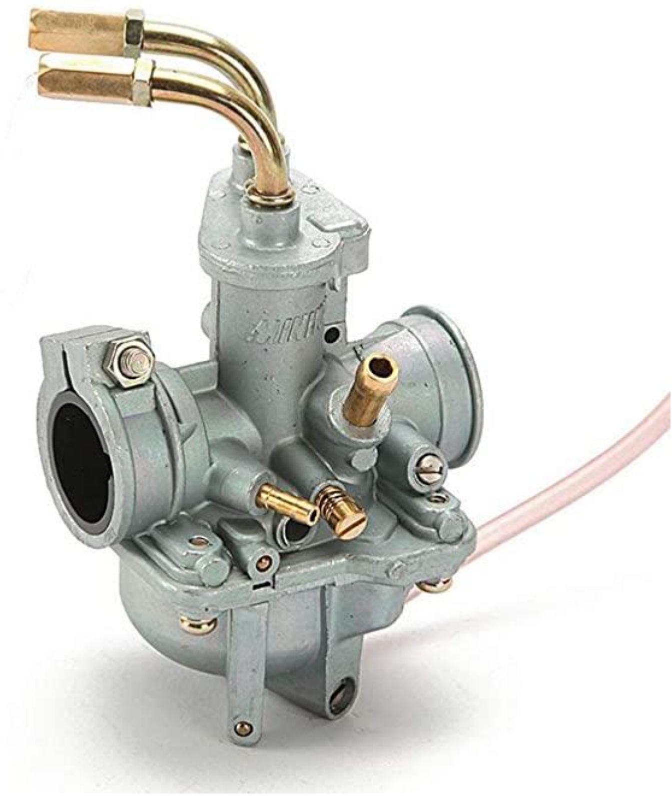
- The fuel supply to the **float chamber** is controlled by the **action of the float** and the attached fuel supply valve.
- During the intake stroke of the engine, the piston moves from TDC to BDC , and **creates a vacuum** in suction manifold.
- Due to **fall in the pressure**, the atmospheric air rushes into carburetor.
- Near the venturi, the **velocity increases**, **pressure decreases** and the fuel oozes out in the form of a jet.
- The **fuel gets mixed with air** and is then inducted into the cylinder.



- Because of the **narrow passage** at the venturi throat, the air velocity increases and its pressure falls. This is known as '**carburetor depression**' at venturi throat.
- This causes **fuel to come out as jet** in the form of a **spray**. This fuel spray vaporizes and mixes with the incoming air, and the mixture goes into the cylinder through the throttle valve.

DRAWBACKS OF SIMPLE CARBURETOR:-

CARBURETOR:-



- It provides the required A/F ratio only at **one throttle position**.
- It gives **proper mixture at only one engine speed and load**, therefore it is suitable only for engines **running at constant speed**.
- At **very low speeds**, the mixture supplied by a simple carburetor is **so lean** that it will not ignite properly.
- The working of simple carburetor is affected by changes of **atmospheric pressure.**
- Quantity of **fuel issuing out** will change and not match with the **velocity of air flowing through the venturi** therefore **proper mixture formation** does not take place with increasing or decreasing speed.
- Volumetric efficiency will affect due to restrictions in flow passage.
- It is not suitable for **multi cylinder engine.**

IGNITION SYSTEM:-

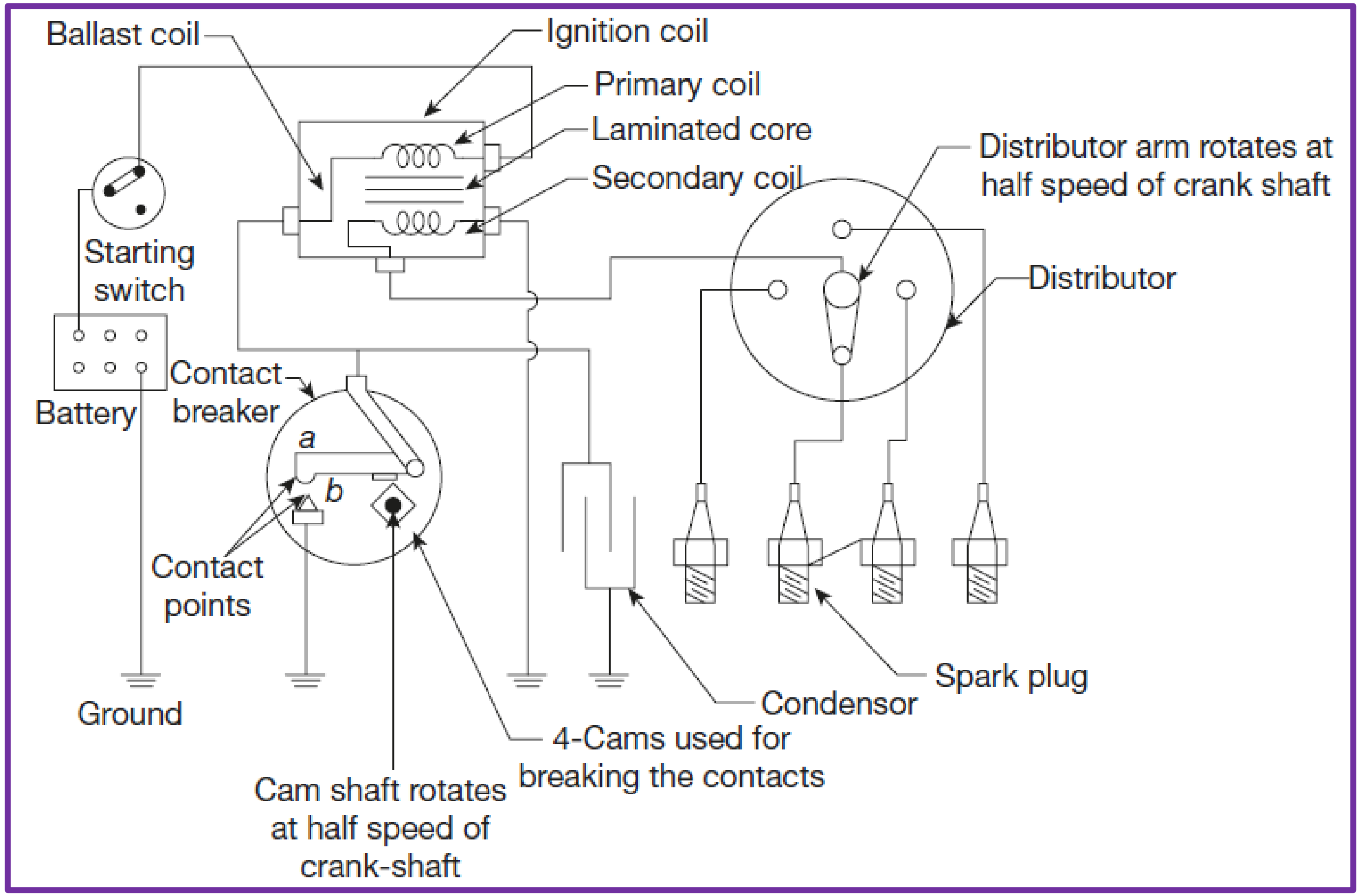
"The function of ignition system is to produce high voltage spark and to deliver it to the spark plugs at regular intervals and at the correct time with respect to the crank position".

- **The ignition system of an IC engine (petrol engine) produces a spark in the spark plug at the end of the compression process.**
- **This electric spark ignites the charge (fuel/air mixture) in the engine combustion chamber.**
- **Each cylinder requires a separate spark plug which is mounted on the cylinder head.**

There are three main ignition systems used in petrol engines. They are as follows:

1. **Conventional battery coil ignition system**
2. **Magneto ignition system**
3. **Capacitor discharged ignition system (CDI system)**

Battery or coil ignition system:-



Battery ignition system for multi cylinder engine

Most of the modern spark ignition engines use battery ignition system.
This system consists of the following components :

1. Battery (6 or 12 volts), **2. Ignition switch**
3. Ignition coil, **4. Circuit/contact breaker**
5. Condenser, **6. Distributor.**

Working of Battery Coil ignition system:-

- Ignition switch is turned **ON**- Primary circuit gets closed and the current starts flowing through it.
- This current sets up the **magnetic field** around the soft iron core of the coil.
- Current flow to condenser- When Breaker points are opened. If it closed – current flows through contact breaker.
- When the current passes through the condenser, the condenser charges, **the primary current falls**, and the magnetic field gets collapses.

- This change in the magnetic field induces a current in the **primary winding** that flows in the same direction as the primary current.

Working of Battery Coil ignition system:-

- charges the **condenser voltage to much higher than battery voltage** thus stopping the current flowing from the battery.
- Due to these processes, the condenser gets discharged into the battery.
- Now **reverse the direction of the primary current** and magnetic field induces a **high voltage** in the secondary winding.
- Now the **high voltage sends** to the distributor by the high-tension wire.
- Between distributor and spark plug an ignition harness is connected as you can see in the diagram.
- Now the **current passes** to **spark plug** one by one and it will **produce spark** for the burning of an air-fuel mixture.

Working of Battery Coil ignition system:-

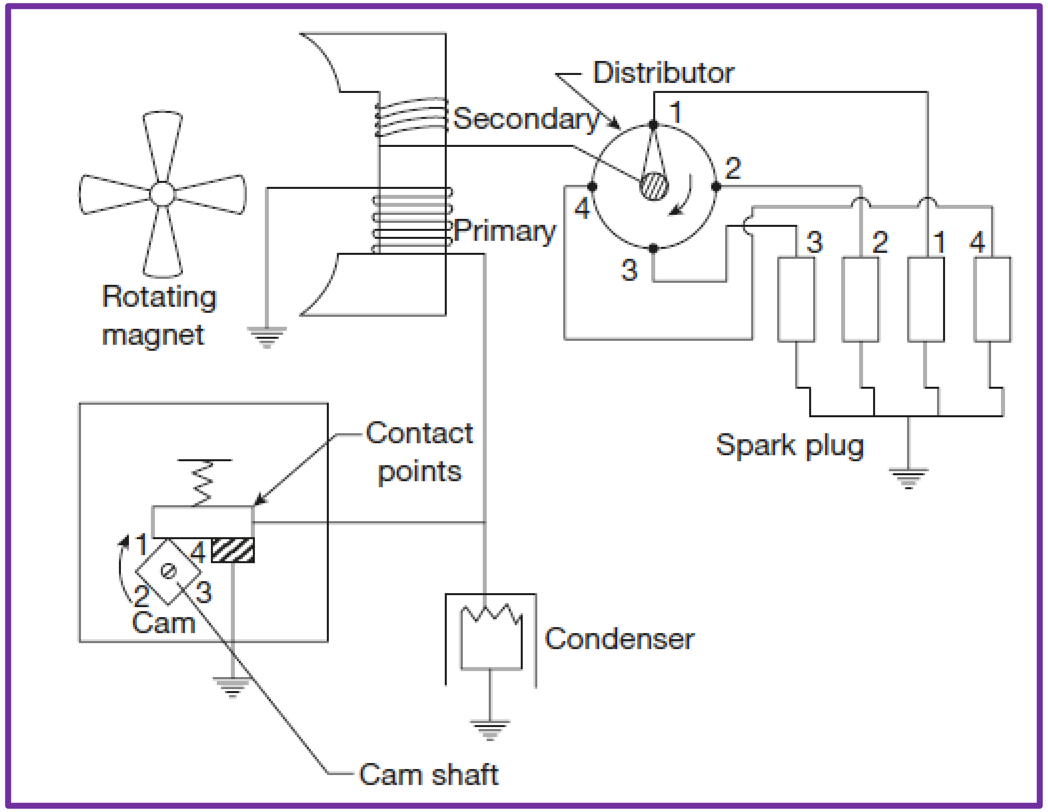
Advantages of Battery Coil ignition system:-

1. Its initial cost is low compared with magneto. This is the main reason for the adoption of coil ignition on cars and commercial vehicles.
2. It provides better spark at low speeds of the engine during starting and idling. This is because the
maximum current is available throughout the engine speed range, including starting.
3. The maintenance cost is negligible, except for the battery.

Disadvantages of Battery Coil ignition system:-

1. The engine cannot be started if the battery runs down.
2. The weight of the battery ignition system is greater than the magneto which is a major consideration in adopting the system in aero-engines.
3. The wiring involved in the coil ignition is more complicated than the one used in a magneto ignition. This results in more likelihood of defects occurring in the system.
4. The sparking voltage drops with increasing speed of the engine.

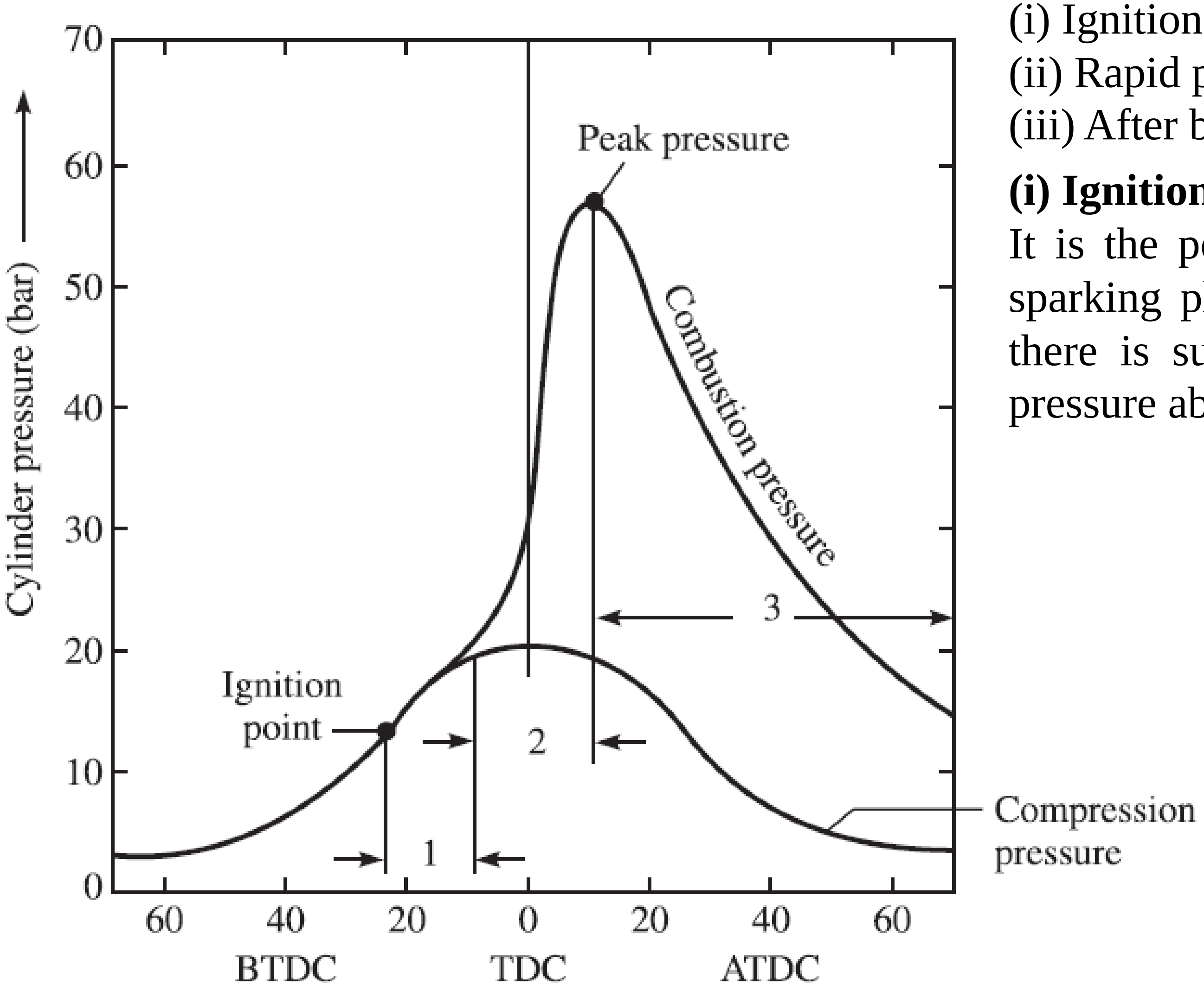
Magneto ignition system:-



The only difference between the battery and the magneto system is that the battery is replaced by the rotating magnet.

- As the magneto rotates, the voltage and current are generated in the primary coil and the circuit is completed by passing the current through the contact breaking point and the ground.
- As the current passes through the primary coil through the contact breaker, the circuit is completed through the ground.
- As the camshaft rotates, the cam 1 opens the contact breaker and interrupts the flow of current in the primary.
- This causes the decay in the magnetic field lines and cuts the lines of magnetic field in the secondary coil, and a high voltage is generated in the secondary coil.
- The process of generating the high voltage in the secondary coil is known as the induction phenomenon.
- The voltage generation in the secondary depends on the ration of number of turns in the secondary and primary coils.

Combustion stages in SI engine:-



The three phases of combustion in a spark ignition (Petrol) Engine

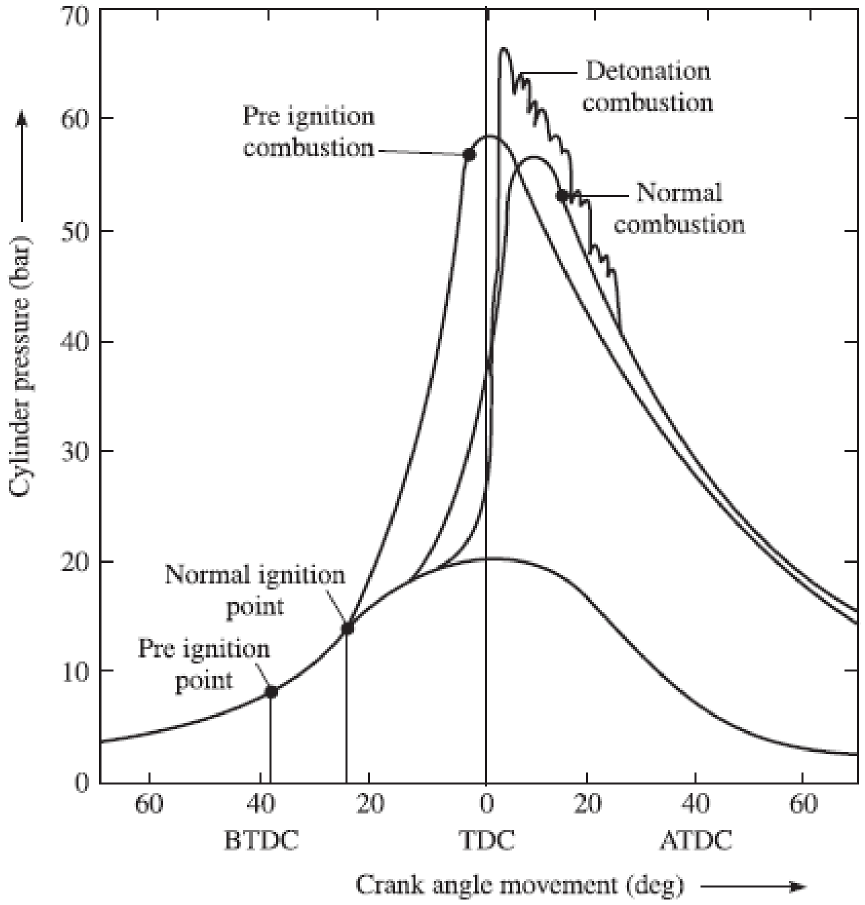
(i) Ignition delay
(ii) Rapid pressure rise or uncontrolled combustion
(iii) After burning or late burning.

(i) Ignition delay:-
It is the period between the instant timed spark passes between the sparking plug electrodes and establishes a flame, to the point where there is sufficient burning to produce a noticeable rise in cylinder pressure above that of compression pressure.

(ii) uncontrolled combustion:- This phase is approximately constant in crank angle movement and covers the period between the initial pressure rise above that of the compression pressure to the point where it peaks the cylinder. It is the period where the expanding flame front travels across the combustion chamber and releases the energy contained within the air/fuel mixture.

(iii) After burning or late burning:-
This phase covers the period from peak pressure to the point where the exhaust valve opens during the pistons power stroke.

Detonation or Knocking:-



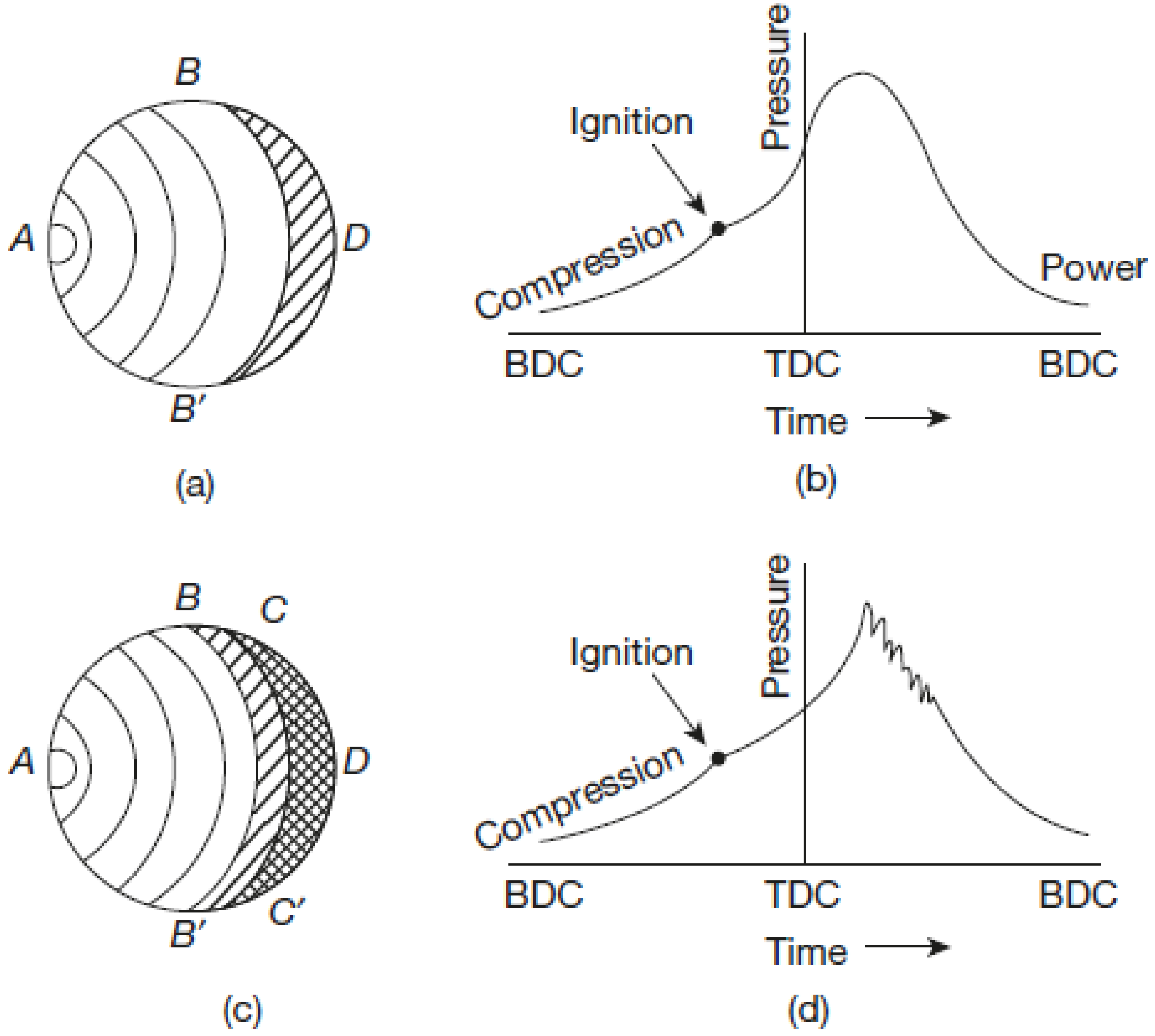
Detonation is mainly caused by the advancing flame front radiating heat, compressing and raising the temperature of the still unburned air/fuel mixture until the remaining combustible end-gas mixture ignites spontaneously.

- If the **surface ignition occurs** in advance of the spark, then it is called **pre-ignition**.
- **Pre-ignition** causes an increase in the compression work, and this causes a reduction in power.
- Pre-ignition leads to higher peak pressures and this in turn can cause self-ignition.
- Detonating combustion is identified by a ringing metallic knocking noise, sounding like a high pitched ping.

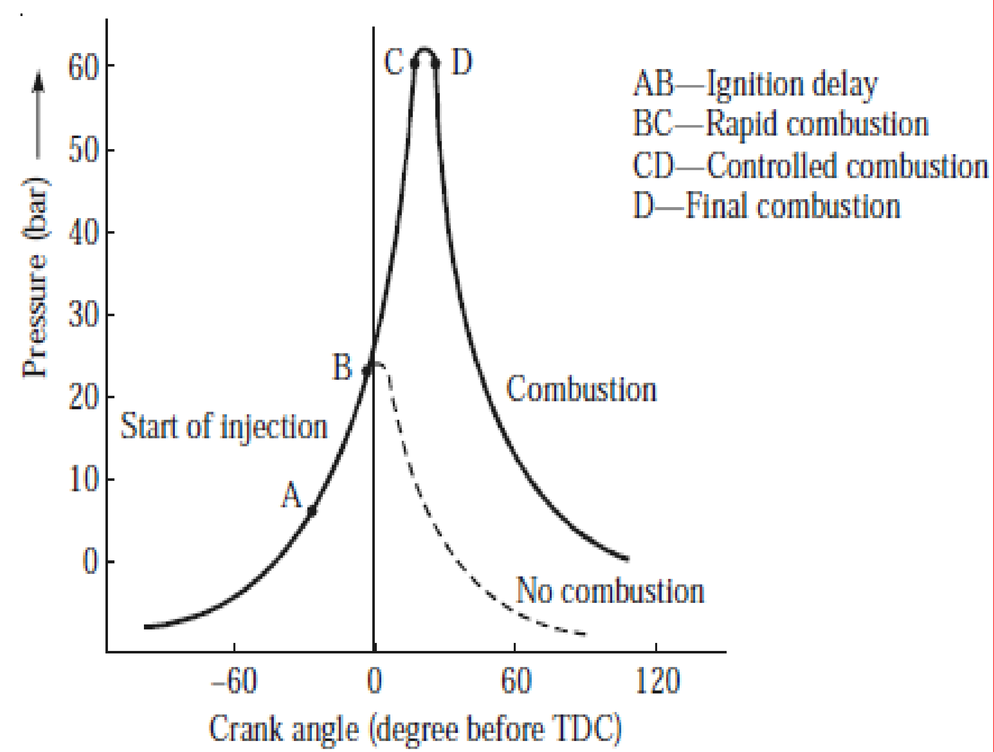
The influencing factors necessary to eliminate or minimize detonation are as follows:

i) Maximize **flame frontal area** and reduce the distance the flame path travels;
(ii) Maximize the **speed of burning** by increasing turbulence;
(iii) Maximize thorough mixing of the **air/fuel mixture** by promoting swirl;
(iv) Maximize the **octane number** of the fuel to match the engine compression ratio;
(v) Retard **ignition timing** when necessary; however, this does result in a slight loss of engine power.

Normal and Knocking combustion comparison in SI engine:-



Combustion stages in CI engine:-



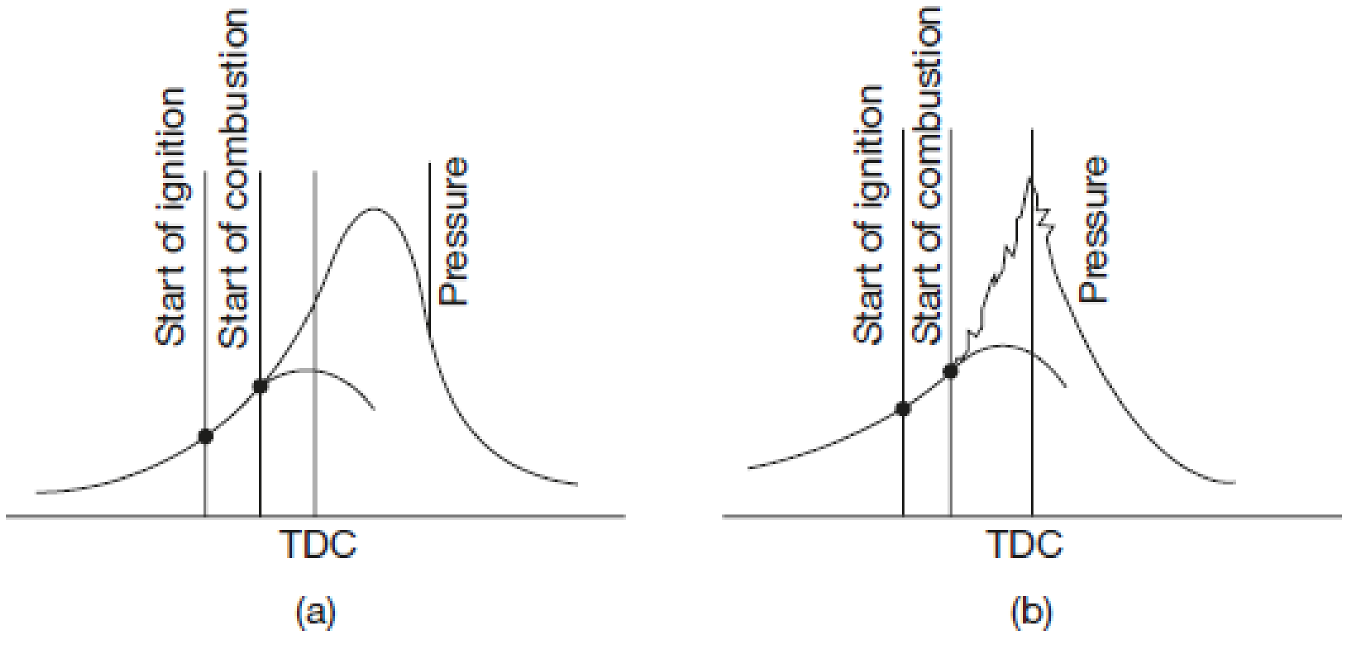
First stage—ignition delay period: During the first stage, some fuel has been admitted but has not yet been ignited. The ignition delay is counted from the start of injection to the point where the pressure-time (crankshaft rotation) curve separates from the pure air compression curve. The delay period is a sort of preparatory phase.

Second stage—rapid or uncontrolled combustion (premixed flame): In the second stage, the pressure rise is rapid because during the delay period the fuel droplets have had time to speed over a wide area and they have fresh air all around them. This period is counted from the end of the delay period to the point of maximum pressure on the indicator diagram. About one-third of the heat is evolved during this period.

Third stage—controlled combustion (diffusion flame): At the end of the second stage, the temperature and the pressure are so high that the fuel droplets injected during the last stage burn almost as they enter and any further pressure rise can be controlled by the injection rate. The period of controlled combustion is assumed to end at maximum cycle temperature. About 70%–80% of total heat of the fuel is supplied during this period.

Fourth stage—after burning: Due to poor distribution of fuel particles, combustion continues during the part of the remainder of the expansion stroke. This after-burning can be called the fourth stage of combustion. The after-burning period is about 70°–80° of crank angle from the TDC. The total heat evolved during the end of entire combustion process is 95–97% and 3–5% of heat goes to unburnt fuel.

Knocking in CI engine:-



Combustion in CI engine:
(a) Without knocking, (b) With knocking

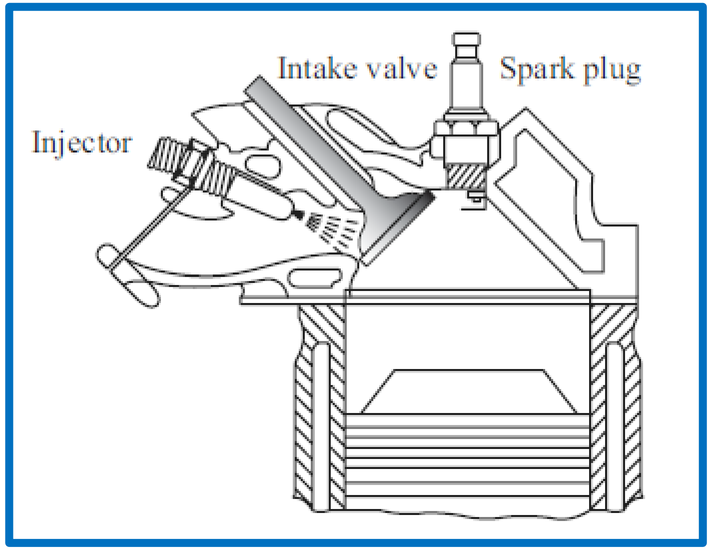
- The fuel injection takes place over a definite period.
- If the **ignition delay** of the injected fuel is small the first droplets start burning in a relatively short time after injection and relatively small amount of fuel will be accumulated in the chamber.
- Therefore, the rate of pressure rise will be smooth as shown in Fig.
- However, if the delay period is longer, the accumulation of fuel will be larger as the actual burning of the first droplets is delayed.
- When actual burning starts, the **accumulated fuel** and additional fuel injected starts burning and can **cause too rapid rate of pressure rise**.
- This rapid rate of pressure rise causes pulsating combustion and creates heavy noise.

- This pulsating variation of pressure due to sudden burning of accumulated fuel is shown in Fig.(b)
- **This type of abnormal combustion is known as *knocking*.**
- This knocking occurs during the initial period after the delay period when the burning of the **first portion of the fuel is uncontrolled**, thus giving rise to an excessive **rate of pressure rise**.

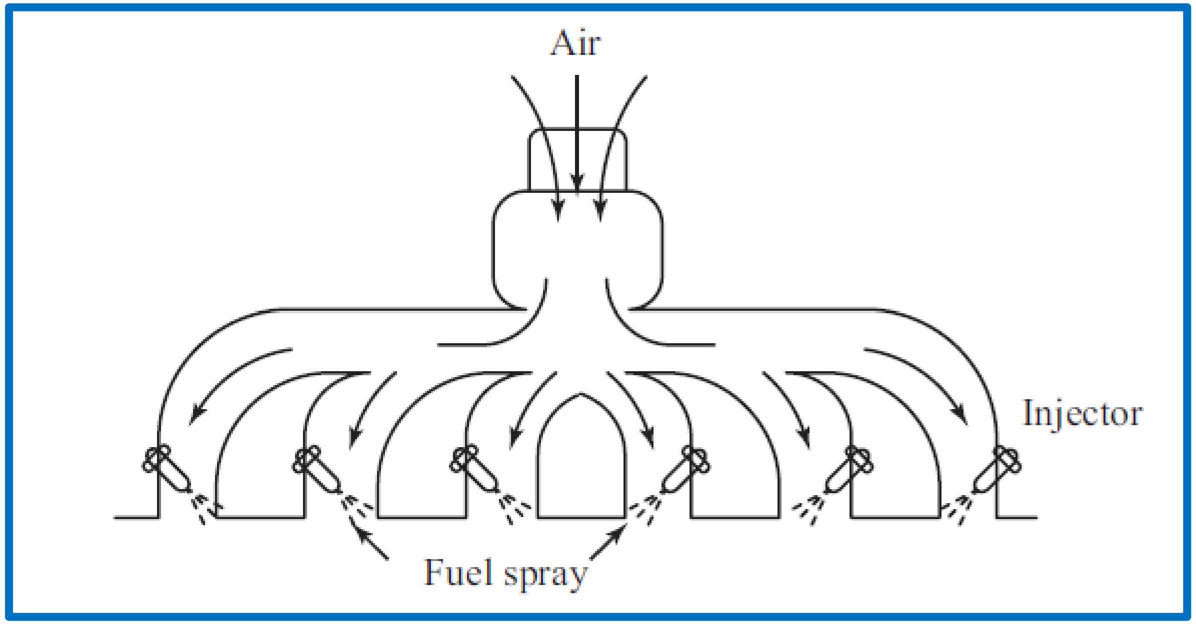
Fuel injection system:

1. MPFI [MultiPoint Fuel Injection System]
2. CRDI [Common Rail Direct Injection System]
3. GDI [Gasoline Direct Injection system]

The main purpose of the Multi-Point Fuel Injection (MPFI) system is to supply a proper ratio of gasoline and air to the cylinders.

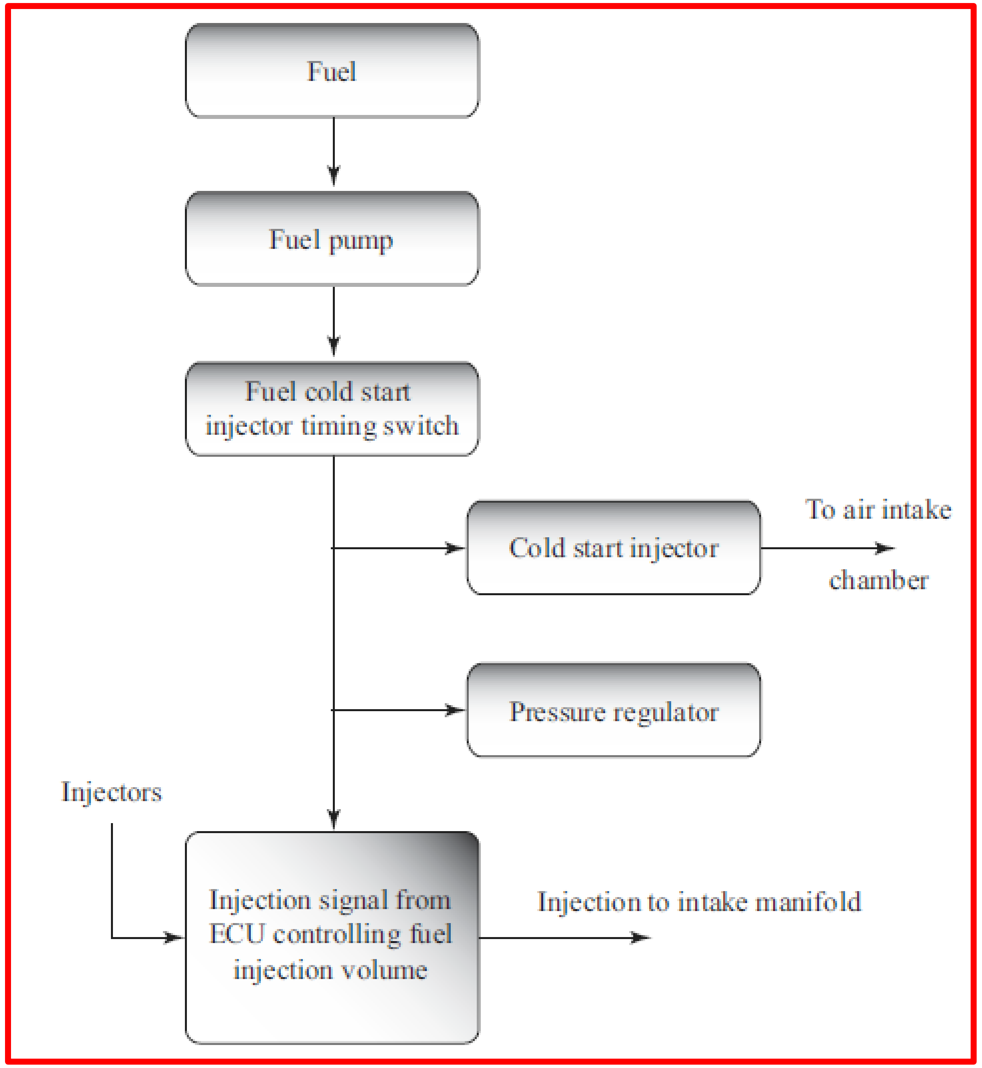


Port injection



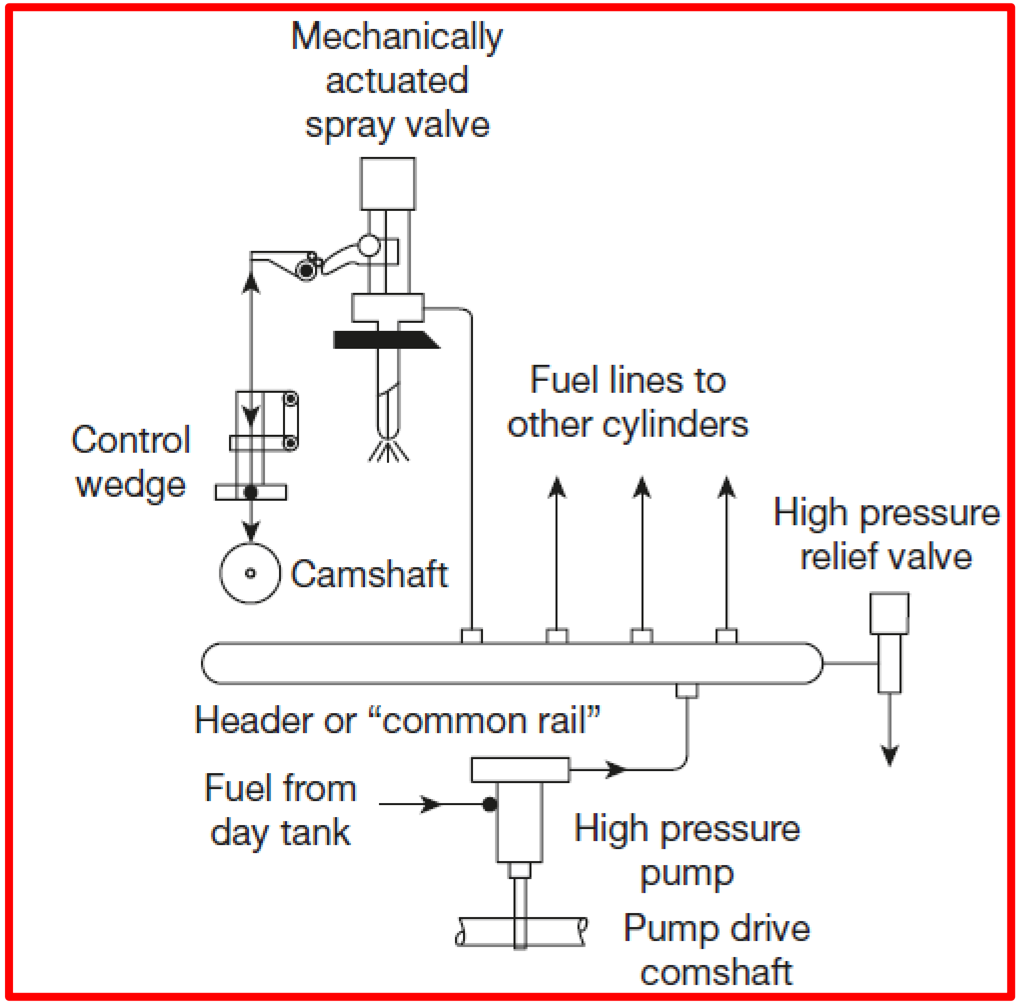
Multi-point fuel injection (MPFI) near port

MPFI [MultiPoint Fuel Injection System]:



- The MPFI-fuel system is shown in the form of block diagrams in Fig.
- In this system, fuel is supplied by the fuel pump.
- At the time of starting, the cold start injector is operated by the cold start injector time switch.
- The cold start injector injects fuel into the air intake chamber, thus enriching the air-fuel mixture.
- The pressure regulator regulates the pressure of the fuel.
- The injectors receive signals from the ECU and inject the fuel into the intake manifold.

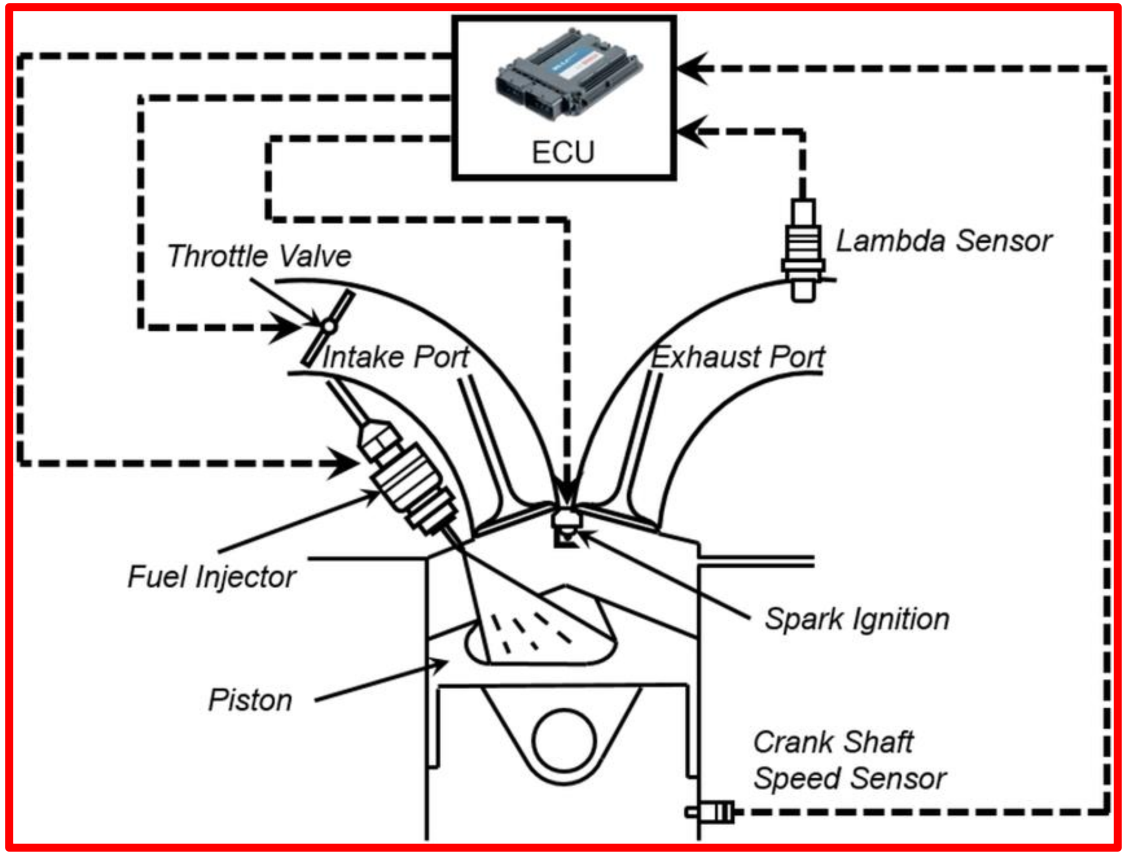
CRDI [Common Rail Direct Injection System]:



- In this system, there is a single high pressure pump, which supplies high pressure fuel to a common header (rail).
- The accumulator is connected to different cylinders by a separate fuel line through the fuel nozzle as shown in Fig.
- The pressure in the accumulator is maintained constant with the help of a pressure relief valve.
- The fuel is supplied to each cylinder by operating the respective fuel valve with the help of a cam mechanism driven by the engine crank shaft.
- The quantity of fuel injected and the timing of injection are controlled by fuel valve and not by the injection pump.
- The arrangement of the fuel valve (metering meter) and the fuel nozzle is shown in Fig.
- This system uses spring loaded injection valves which open and close by mechanical means.
- The pressure used in this system ranges between **110–300 bar,** according to the compression ratio used for the engine design.

For Electronic injection :- Pressure used is between 500–850 bar.

GDI [Gasoline Direct Injection System]:



- The major advantages of a GDI are increased fuel efficiency and higher power output.
- Emission levels can also be more accurately controlled with the GDI system.
- In addition, there are no throttling losses in most GDI engines.
- Further, pumping losses are considerably reduced because of the absence of the throttle plate.
- Engine speed is controlled by the engine control unit or engine management system (EMS).
- It regulates fuel injection function and ignition timing.

➢ The engine management system (EMS) continually chooses among three combustion modes:
1) ultra lean burn,
2) stoichiometric, and
3) full power output.

Each mode is characterized by the **air-fuel ratio**.

Rating of SI Engine Fuels-octane Number

The tendency to **knock** depends on the **composition of fuel.** Fuels differ widely in their ability to resist knock.

The **rating of a particular fuel** is done by comparing its performance with that of a standard reference fuel which is usually a combination of **iso-octane** and **n-heptane**.

The percentage of *iso*-octane by volume in a mixture of *iso*-octane and *n*-heptane, which exactly matches the knocking intensity of a given fuel, in a standard engine under given standard operating conditions, is termed as 'octane number' of the fuel.

An octane number of 80 means that the fuel has the same knocking tendency as a mixture of 80% *iso*-octane and 20% *n*-heptane by volume.

Note:
Iso-octane - Offers great resistance to knock

n-heptane - Offers poor resistance to knock rating

Rating of CI Engine Fuels-octane Number

The tendency to **knock** depends on the **composition of fuel.** Fuels differ widely in their ability to resist knock.

The **rating of a particular fuel** is done by comparing its performance with that of a standard reference fuel which is usually a combination of **iso-Cetane** and **alpha-methyl naphthalene**.

The percentage of *iso-Cetane* by volume in a mixture of *iso-Cetane* and *alpha-methyl naphthalene*, which exactly matches the knocking intensity of a given fuel, in a standard engine under given standard operating conditions, is termed as 'cetane number' of the fuel.

An cetane number of 80 means that the fuel has the same knocking tendency as a mixture of 80% *iso-cetane* and 20% *alpha-methyl naphthalene* by volume.

iso-Cetane - **Offers great resistance to knock**
Rating of 100 cetane number.
alpha-methyl naphthalene –
Offers poor resistance to knock
Rating of 0 octane number.

Cooling System

A system, which controls the engine temperature, is known as a cooling system.

NECESSITY OF COOLING SYSTEM

The cooling system is provided in the IC engine for the following reasons:

- The temperature of the burning gases in the engine cylinder reaches up to 1500 to 2000°C, which is above the melting point of the material of the cylinder body and head of the engine. (Platinum, a metal which has one of the highest melting points, melts at 1750 °C, iron at 1530°C and aluminium at 657°C.) Therefore, if the heat is not dissipated, it would result in the failure of the cylinder material.

- Due to very high temperatures, the film of the lubricating oil will get oxidized, thus producing carbon deposits on the surface. This will result in piston seizure.

- Due to overheating, large temperature differences may lead to a distortion of the engine components due to the thermal stresses set up. This makes it necessary for, the temperature variation to be kept to a minimum.

- Higher temperatures also lower the volumetric efficiency of the engine.

Cooling System

REQUIREMENTS OF EFFICIENT COOLING SYSTEM

The two main requirements of an efficient cooling system are:

1. It must be capable of removing only about 30% of the heat generated in the combustion chamber. Too much removal of heat lowers the thermal efficiency of the engine.

2. It should remove heat at a fast rate when the engine is hot. During the starting of the engine, the cooling should be very slow so that the different working parts reach their operating temperatures in a short time.

TYPES OF COOLING SYSTEM

There are two types of cooling systems:

(i) Air cooling system and

(ii) Water-cooling system.

Cooling System

AIR COOLING SYSTEM:

- ❖ In this type of cooling system, the heat, which is conducted to the outer parts of the engine, is radiated and conducted away by the stream of air, which is obtained from the atmosphere.
- ❖ In order to have efficient cooling by means of air, providing fins around the cylinder and cylinder head increases the contact area.

- ❖ The fins are metallic ridges, which are formed during the casting of the cylinder and cylinder head The amount of heat carried off by the air-cooling depends upon the following factors:

(i) The total area of the fin surfaces,
(ii) The velocity and amount of the cooling air and
(iii) The temperature of the fins and of the cooling air.

- ❖ Air-cooling is mostly tractors of less horsepower, motorcycles, scooters, small cars and small aircraft engines where the forward motion of the machine gives good velocity to cool the engine.

- ❖ Air-cooling is also provided in some small industrial engines. In this system, individual cylinders are generally employed to provide ample cooling area by providing fins. A blower is used to provide air.

Cooling System

Advantages of Air Cooled Engines:

Air cooled engines have the following advantages:

1. Its design of air-cooled engine is simple.

2. It is lighter in weight than water-cooled engines due to the absence of water jackets, radiator, circulating pump and the weight of the cooling water.

3. It is cheaper to manufacture.

4. It needs less care and maintenance.

5. This system of cooling is particularly advantageous where there are extreme climatic conditions in the arctic or where there is scarcity of water as in deserts.

6. No risk of damage from frost, such as cracking of cylinder jackets or radiator water tubes.

Cooling System

WATER COOLING SYSTEM

It serves two purposes in the working of an engine:

a) It takes away the excessive heat generated in the engine and saves it from over heating.

b) It keeps the engine at working temperature for efficient and economical working.

This cooling system has four types of systems:

(i) Direct or non-return system,

(ii) Thermo-Syphone system,

(iii) Hopper system and

(iv) Pump/forced circulation system.

Cooling System

Thermo-Syphon Water Cooling System:

This system works on the principle that hot water being lighter rises up and the cold water being heavier goes down. In this system the radiator is placed at a higher level than the engine for the easy flow of water towards the engine. Heat is conducted to the water jackets from where it is taken away due to convection by the circulating water. As the water jacket becomes hot, it rises to the top of the radiator. Cold water from the radiator takes the place of the rising hot water and in this way a circulation of water is set up m the system. This helps in keeping the engine at working temperature.

Disadvantages of Thermo-Syphon System:

1 Rate of circulation is too slow.

2. Circulation commences only when there is a marked difference in temperature.

3. Circulation stops as the level of water falls below the top of the delivery pipe of the radiator. For these reasons this system has become obsolete and is no more in use.

Cooling System

Force Circulation Water Cooling System

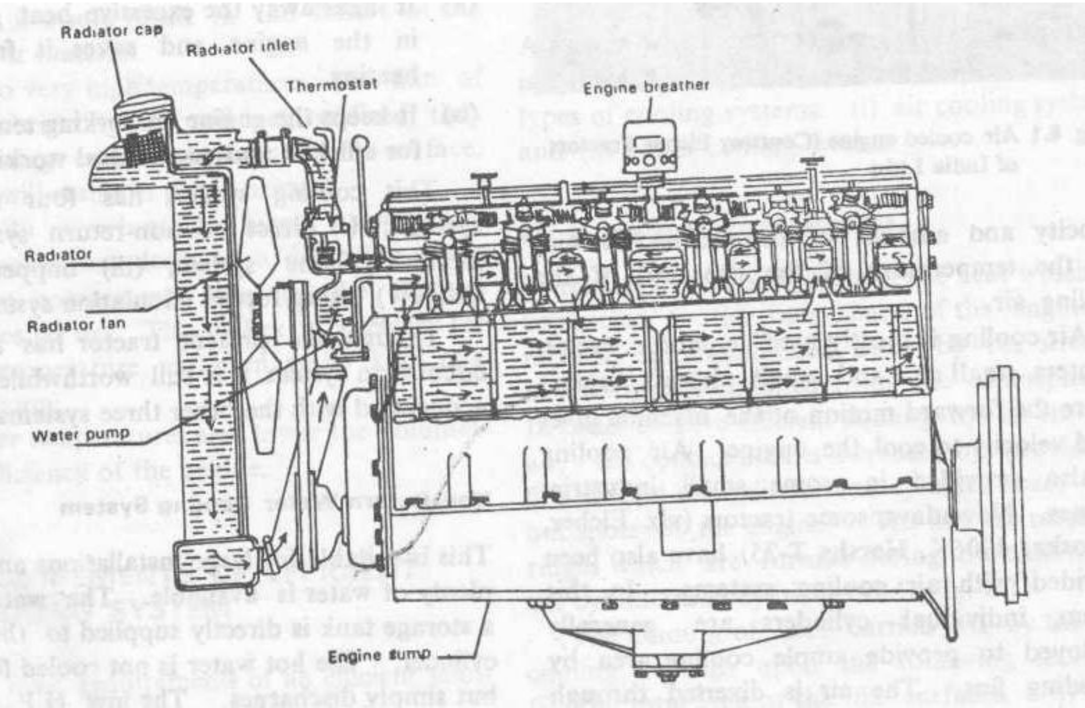
- This system is similar in construction to the thermo-syphon system except that it makes use of a centrifugal pump to circulate the water throughout the water jackets and radiator

- The water flows from the lower portion of the radiator to the water jacket of the engine through the centrifugal pump. After the circulation water comes back to the radiator, it loses its heat by the process of radiation. This system is employed in cars, trucks, tractors, etc.

Parts of Liquid Cooling System

The main parts in the water-cooling system are:

(i) water pump,
(ii) fan,
(iii) radiator and pressure cap,
(iv) fan belt
(v) water jacket,
(vi) thermostat valve,
(vii) temperature gauge and
(viii) hose pipes.



Cooling System

- **Non-Return Water Cooling System**

- This is suitable for large installations and where plenty of water is available. The water from a storage tank is directly supplied to the engine cylinder.

- The hot water is not cooled for reuse but simply discharges. The low H.P. engine, coupled with the irrigation pump is an example.

Lubrication System

I. C. engine is made of many moving parts. Due to continuous movement of two metallic surfaces over each other, there is wearing moving parts, generation of heat and loss of power in the engine lubrication of moving parts is essential to prevent all these harmful effects.

PURPOSE OF LUBRICATION

Lubrication produces the following effects:

(a) Reducing friction (b) Cooling (c) Sealing and (d) Cleaning

(a) Reducing frictional effect: The primary purpose of the lubrication is to reduce friction and wear between two rubbing surfaces. Two rubbing surfaces always produce friction. The continuous friction produce heat which causes wearing of parts and loss of power. In order to avoid friction, the contact of two sliding surfaces must be reduced as far a possible. This can be done by proper lubrication only. Lubrication forms an oil film between two moving surfaces. Lubrication also reduces noise produced by the movement of two metal surfaces over each other.

(b) **Cooling effect:** The heat, generated by piston, cylinder, and bearings is removed by lubrication to a great extent. Lubrication creates cooling effect on the engine parts.

(c) **Sealing effect:** The lubricant enters into the gap between the cylinder liner, piston and piston rings. Thus, it **prevents leakage of gases** from the engine cylinder.

(d) **Cleaning effect:** Lubrication keeps the engine clean by removing dirt or carbon from inside of the engine along with the oil.

Lubrication System

A good lubricant should have the following qualities:

1. It should have sufficient viscosity to keep the rubbing surfaces apart

2. It should remain stable under changing temperatures.

3. It should keep lubricated pans clean.

4. It should not corrode metallic surfaces.

ENGINE LUBRICATING SYSTEM

The lubricating system of an engine is an arrangement of mechanism and devices which maintains supply of lubricating oil to the rubbing surface of an engine at correct pressure and temperature.

The parts which require lubrication are: (i) cylinder walls and piston (ii) piston pin (iii) crankshaft and connecting rod bearings (iv) camshaft bearings (v) valves and valve operating mechanism (vi) cooling fan (vii) water pump and (viii) ignition mechanism.

There are three common systems of lubrication used on stationary engines, tractor engines and automobiles:
(i) Splash system (ii) Forced feed system and (iii) Combination of splash and forced feed system.

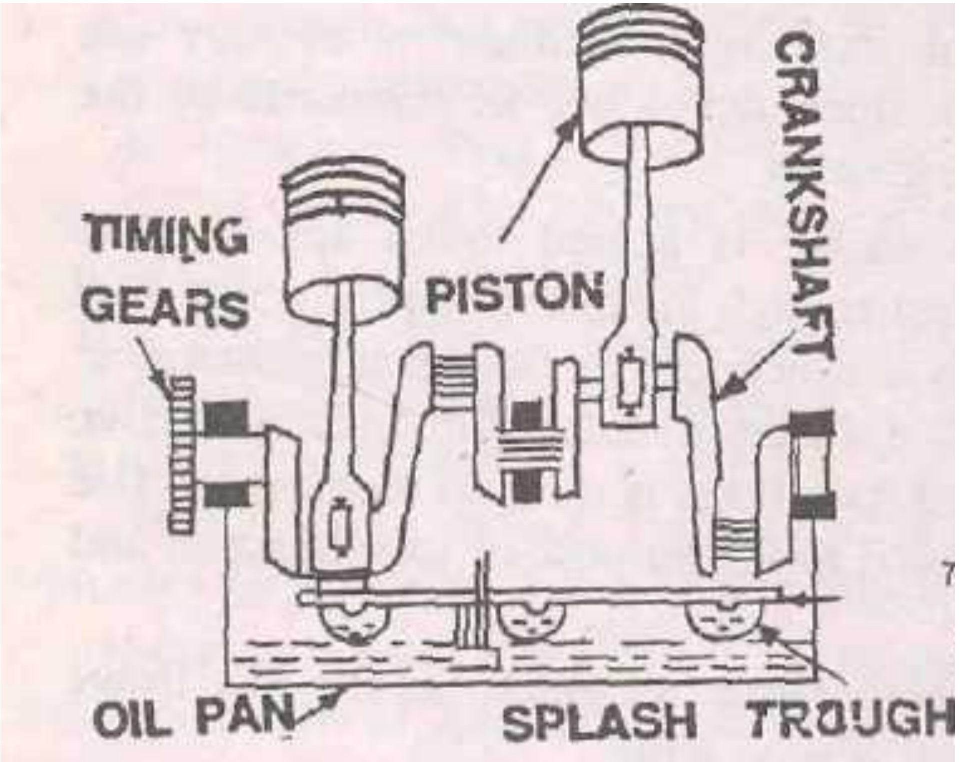
Lubrication System

SPLASH SYSTEM

- In this system, there is an oil trough, provided below the connecting rod. Oil is maintained at a uniform level in the oil trough. This is obtained by maintaining a continuous flow of oil from the oil sump or reservoir into a splash pan, which has a depression or a trough like arrangement under each connecting rod.

- This pan receives its oil supply from the oil sump either by means of a gear pump or by gravity. A dipper is provided at the lower end of the connecting rod. This dipper dips into to oil trough and splashes oil out of the pan.

- The plashing action of oil maintains a fog or mist of oil that drenches the inner parts of the engine such as bearings, cylinder walls, pistons, piston pins, timing gears etc.



Lubrication System

Disadvantages:

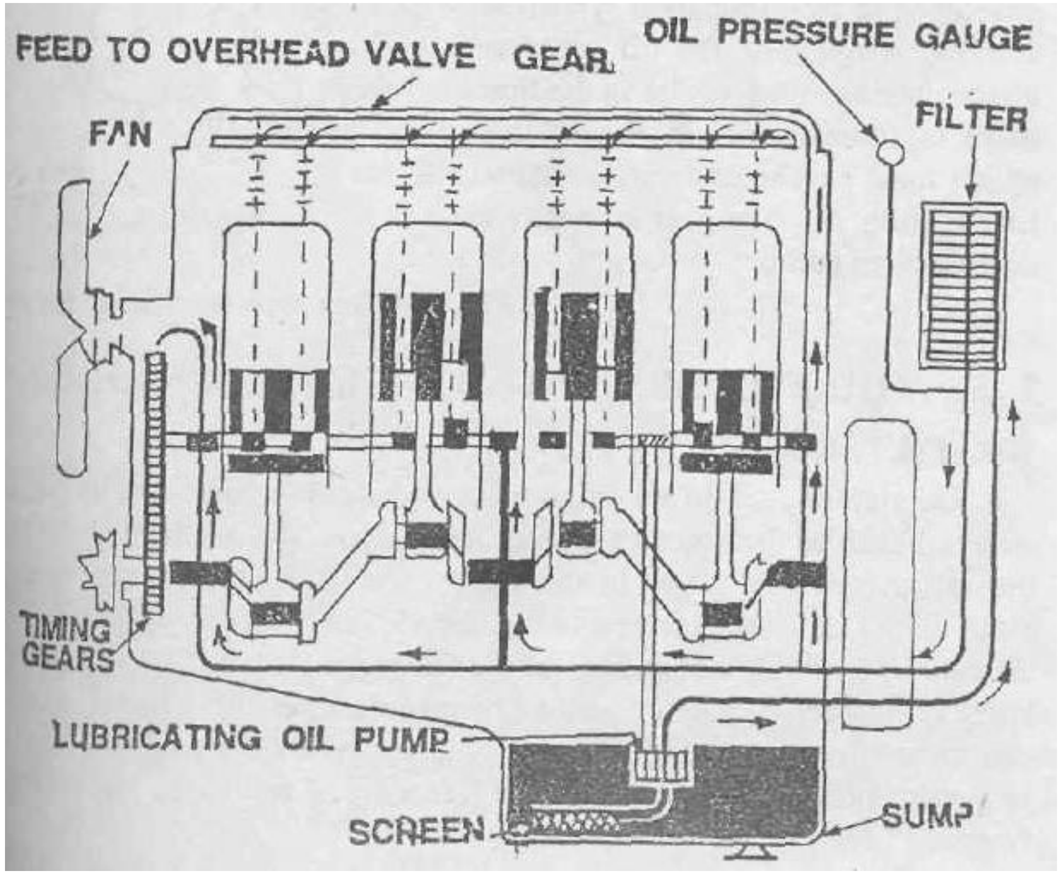
- lubrication is not very uniform and when the rings are worn, the oil passes the piston into combustion chamber, causing carbon deposition, blue smoke and spoiling the plugs. There is every possibility that oil may become very thin through crankcase dilution.

- The worn metal, dust and carbon may be collected in the oil chamber and be carried to different parts of the engine, causing wear and tear.

Lubrication System

FORCED FEED SYSTEM:

- In this system, the oil is pumped directly to the crankshaft, connecting rod, piston pin, timing gears and camshaft of the engine through suitable paths of oil.
- Usually the oil first enters the main gallery, which may be a pipe or a channel in the crankcase casting. From this pipe, it goes to each of the main bearings through holes. From main bearings, it goes to big end bearings of connecting rod through drilled holes in the crankshaft.
- From there, it goes to lubricate the walls, pistons and rings. There is separate oil gallery to lubricate timing gears. Lubricating oil pump is a positive displacement pump, usually gear type or vane‘ type. The oil also goes to valve stem and rocker arm shaft under pressure through an oil gallery.

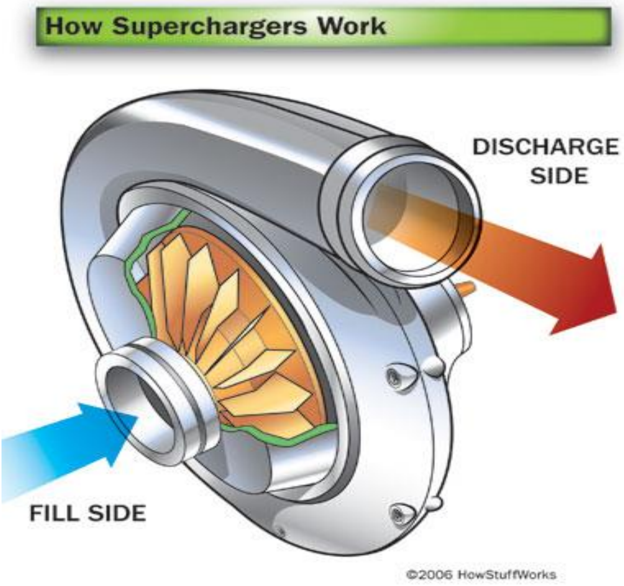


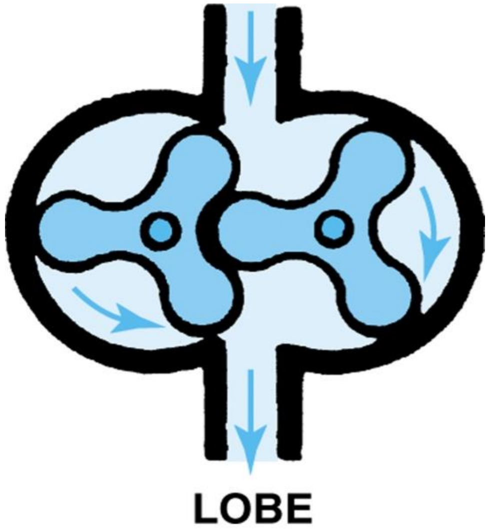
- The excess oil comes back from the cylinder head to the crankcase. The pump discharges oil into oil pipes, oil galleries or ducts, leading different parts of the engine. This system is commonly used on high speed multi-cylinder engine in tractors, trucks and automobiles.

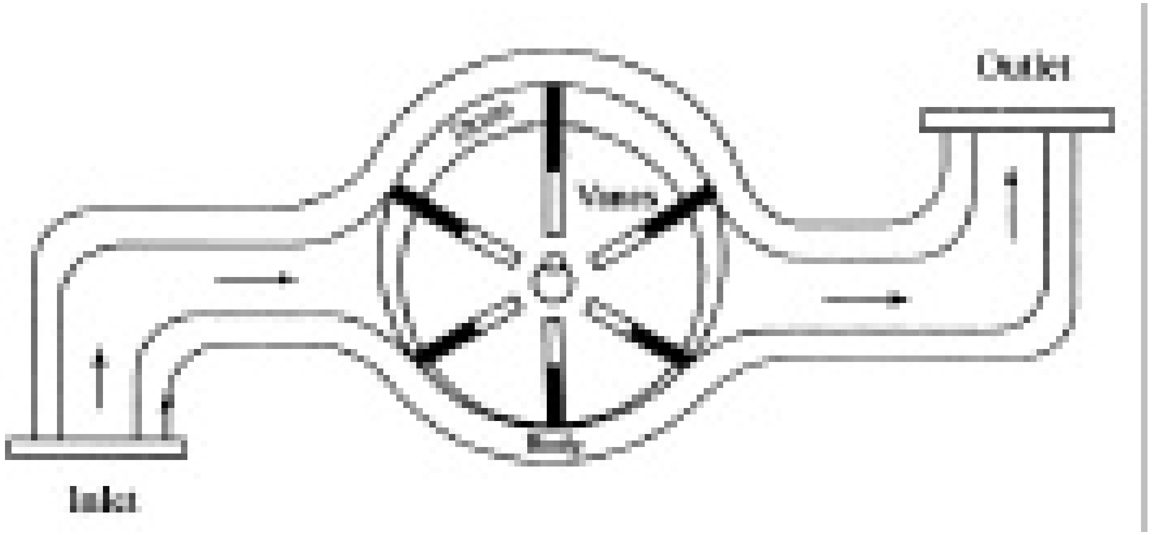
Supercharging

- The purpose of supercharging an engine is to raise the density of the air charge
- More air and fuel per cycle will be forced into the cylinder
- Supercharging increases the power output of the engine.
- Certain percentage of power is consumed in compressing the air.
- The engine should be designed to withstand the higher forces due to supercharging.
- The increased pressure and temperature as a result of supercharging, may lead to detonation.
- Fuels used must have better antiknock characteristics

Types of Superchargers







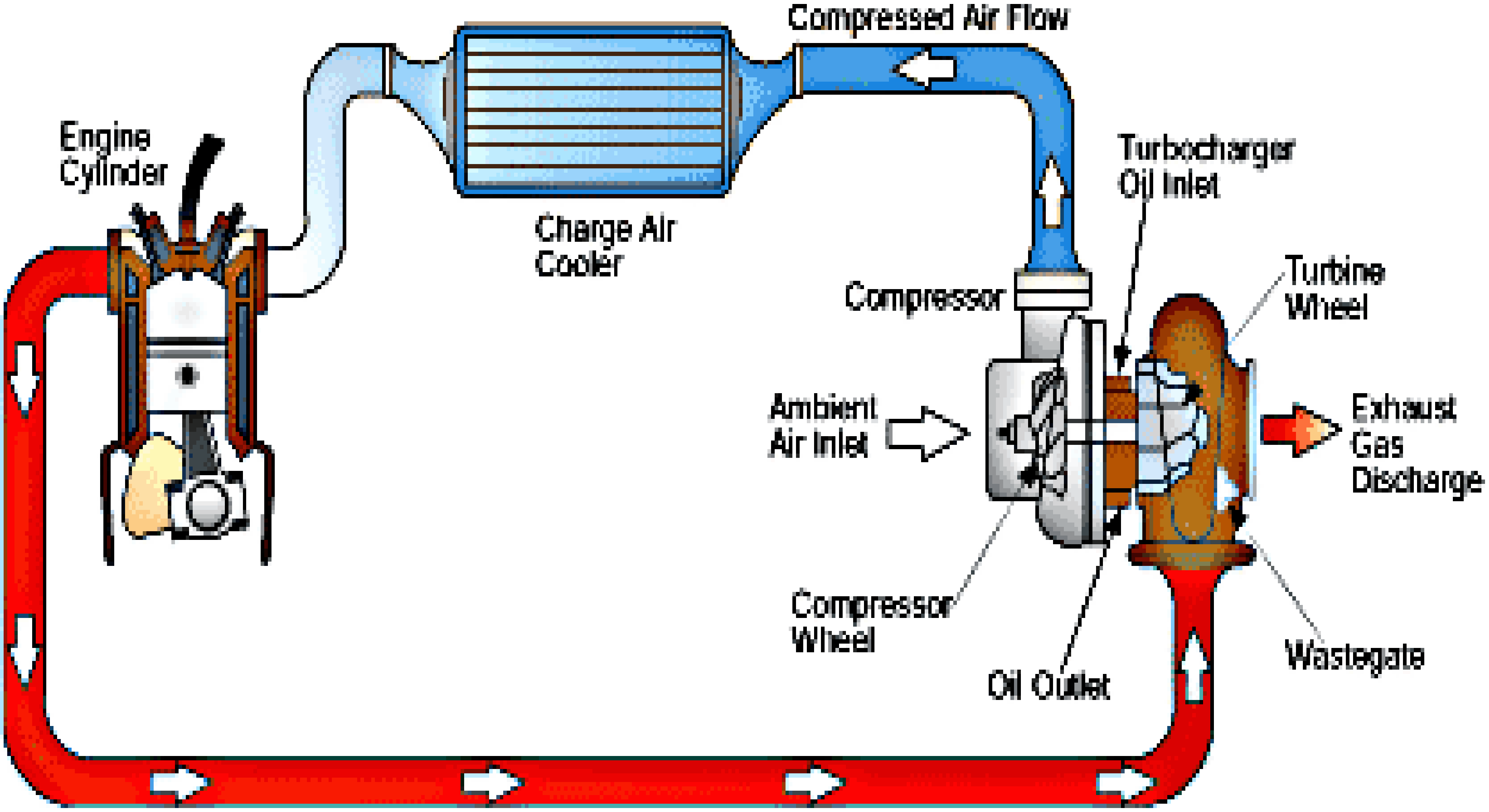
Supercharging of Engine

- Use of inter cooling of the charge before it is fed to the engine
- Poor fuel economy - Supercharging is not very popular
- It is **used when large amount of power needed to compensate altitude loss**
- Thermal Loading (High temperature of piston and combustion chamber)

Effects of Supercharging

- Better fuel and air mixing
- Better atomization of fuel
- More complete and smoother combustion of fuel
- Better torque characteristics and Higher power output
- Better scavenging of products
- Quicker acceleration of vehicle
- Improved cold starting
- Increased Mechanical efficiency
- Increased thermal stress
- Increased heat losses due to turbulence
- Increased over lap period
- Increased cooling requirements of piston and valves

Turbocharging



Turbocharging

- Turbochargers deliver compressed air to the inlet side of the carburetor or fuel control unit
- Unlike a supercharger, it is driven by the exhaust gases produced by the combustion process

- Boot up pressure is 1 – 2 bar
- Typical turbocharger will start to deliver boost from about 1800 rpm
- Turbine speed from 10,000 – 1,50,000 rpm

- It requires special exhaust manifold
- Blade erosion is common – solid particles and other combustion products