

**24AG301- APPLIED THERMODYNAMICS AND THERMAL
SYSTEMS IN AGRICULTURAL ENGINEERING**

**UNIT 2 INTERNAL COMBUSTION ENGINES FOR
AGRICULTURE**

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A **heat engine** is a device that converts **heat energy** into **mechanical work** by operating between a **high-temperature source** and a **low-temperature sink**.

Heat engines may be classified into two main classes as follows:

1. External Combustion Engines.
2. Internal Combustion Engines.

External Combustion Engines: In this case, combustion of fuel takes place outside the cylinder as in case of steam engines where the heat of combustion is employed to generate steam which is used to move a piston in a cylinder.

Internal combustion engines (I.C. engines): In this case, combustion of the fuel with oxygen of the air occurs within the cylinder of the engine. The internal combustion engines group includes engines employing mixtures of combustible gases and air, known as gas engines, those using lighter liquid fuel or spirit known as petrol engines and those using heavier liquid fuels, known as oil compression ignition or diesel engines.

Internal combustion engines may be classified as given below:

1. According to cycle of operation:

- (i) Two-stroke cycle engines
- (ii) Four-stroke cycle engines.

2. According to cycle of combustion:

- (i) Otto cycle engine (combustion at constant volume)
- (ii) Diesel cycle engine (combustion at constant pressure)

Im spee

(iff) High speed

(iii) Dual-combustion or Semi-Diesel cycle engine (combustion partly at constant volume and partly at constant pressure).

3. According to arrangement of cylinder:

- (i) Horizontal engine
- (iii) V-type engine
- (ii) Vertical engine
- (iv) Radial engine etc.

4. According to their uses:

- (i) Stationary engine
- (ii) Portable engine
- (iii) Marine engine
- (v) Aero engine etc.

(iv) Automobile engine

5. According to the fuel employed and the method of fuel supply to the engine cylinder :

- (i) Oil engine
- (ii) Petrol engine
- (iii) Gas engine
- (iv) Kerosene engine
- (v) Carburettor, hot bulb, solid injection and air injection engine.

6. According to speed of engine

- (i) Medium speed engine
- (iii) High speed engine.

7. According to method of ignition:

- (i) Spark ignition (S.I.) engine
- (ii) Compression ignition (C.I.) engine.

8. According to method of cooling the cylinder:

- (i) Air-cooled engine
- (ii) Water-cooled engine.

9. According to method of Governing:

- (i) Hit and miss governed engine
- (ii) Quality governed engine
- (iii) Quantity governed engine.

10. According to valve arrangement:

- (i) Overhead valve engine
- (ii) L-head type engine
- (iii) T-head type engine
- (iv) F-head type engine.

11. According to number of cylinders:

- (i) Single cylinder engine
- (ii) Multi-cylinder engine.

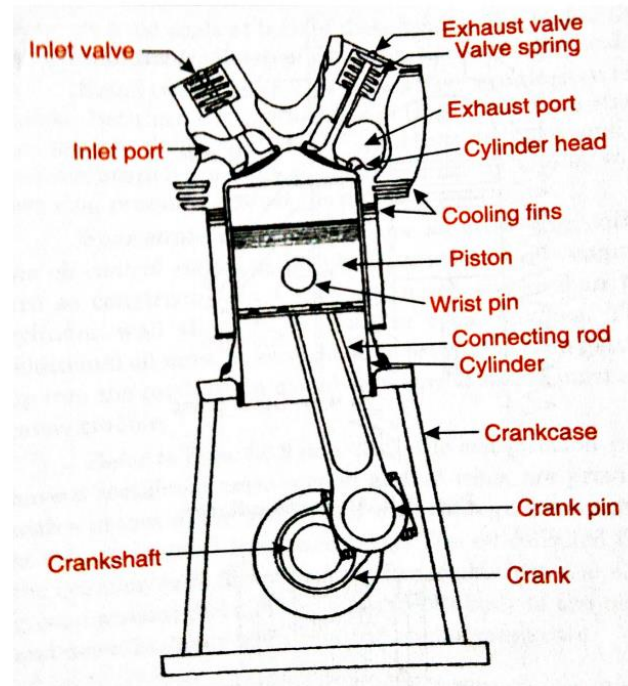
23.4. APPLICATIONS OF I.C. ENGINES

The I.C. engines are generally used for:

- (i) Road vehicles (e.g., scooter, motorcycle, buses etc.)
- (ii) Air craft
- (iii) Locomotives

BASIC IDEA OF I.C. ENGINES

The cylinder which is closed at one end is filled with a mixture of fuel and air. As the crankshaft turns it heats the cylinder. The piston is forced up and compresses the mixture in the top of the cylinder. The mixture is set alight and, as it burns, it creates a gas pressure on the cone, forcing it down the cylinder. This motion is shown by arrow '1'. The piston pushes on the rod which pushes on the crank. The crank is given rotary motion. The flywheel is used for storing energy.



Parts Common to Both Petrol and Diesel Engines

1. Cylinder

The cylinder contains gas under pressure and guides the piston. It is in direct contact with the products of combustion and it must be cooled. The ideal form consists of a plain cylindrical barrel in which the piston slides. The movement of the piston or stroke being in most cases, longer than the bore. This is known as the "stroke bore ratio". The upper end consists of a combustion or clearance space in which the ignition and combustion of the charge takes place.

2. Cylinder head

One end of the cylinder is closed by means of a removable cylinder head which usually contains the inlet or admission valve for admitting the mixture of air and fuel and exhaust valve for discharging the product of combustion. Two valves are kept closed, by means of cams geared to the engine shaft. The passage in the cylinder head leading to and from the valves are called ports. The pipes which connect the inlet ports of the various cylinders to a common intake pipe for the engine is called the inlet manifold. If the exhaust ports are similarly connected to a common exhaust system, this system of piping is called exhaust manifold.

3. Piston

A piston is fitted to each cylinder as a face to receive gas pressure and transmit the thrust to the connecting rod. The piston must (i) give gas tight seal to the cylinder through bore, (ii) slide freely, (iii) be light and (iv) be strong. The thrust on the piston on the power stroke tries to tilt the piston as the connecting rod swings, sideways. The piston wall, called the skirt must be strong enough to stand up to this side thrust. Pistons are made of cast iron or aluminium alloy for lightness. Light alloy pistons expand more than cast iron one therefore they need large clearances to the bore, when cold, or special provision for expansion.

4. Piston rings

The piston must be a fairly loose fit in the cylinder. If it were a tight fit, it would expand as it got hot and might stick tight in the cylinder. If a piston sticks it could ruin the engine. On the other hand, if there is too much clearance between the piston and cylinder walls, much of the pressure from the burning gasoline vapour will leak past the piston.

To provide a good sealing fit between the piston and cylinder, pistons are equipped with piston rings.

Small two-stroke cycle engines have two rings on the piston. Both are compression rings. Two rings are used to divide up the job of holding the compression and combustion pressure. This produces better sealing with less ring pressure against the cylinder wall.

Four-stroke cycle engines have an extra ring, called the oil control ring. Four stroke cycle engines are so constructed that they get much more oil in the cylinder wall than do two stroke cycle engines. This additional oil must be scraped off to prevent it from getting up into the combustion chamber, where it would burn and cause trouble.

5. Gudgeon pin (or wrist pin or piston pin)

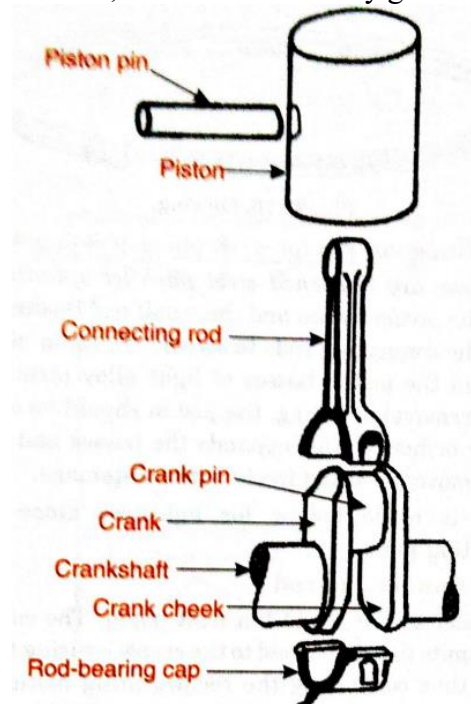
These are hardened steel parallel spindles fitted through the piston bosses and the small end bushes or eyes to allow the connecting rods to swivel. Gudgeon pins are a press fit in the piston bosses of light alloy pistons when cold.

6. Connecting rod

The connecting rod transmits the piston load to the crank, causing the latter to turn, thus converting the reciprocating motion of the piston into a rotary motion of the crankshaft. The lower or "big end" of the connecting rod turns on "crank pins".

7. Crank

The piston moves up and down in the cylinder. This up and down motion is called reciprocating motion. The piston moves in a straight line. The straight line motion must be changed to rotary, or turning motion, in most machines, before it can do any good.



8. Crankshaft

The crank is part of the crankshaft. The crankshaft of an internal combustion engine receives via its cranks the efforts supplied by the pistons to the connecting rods.

9. Bearings

Purpose of Bearings is to reduce friction and support moving parts.

10. Crank case

The main body of the engines to which cylinders are attached and which contains crank shaft is called crank case.

11. Flywheel

A flywheel (steel or cast iron disc) secured on the crankshaft performs the following functions:

- (a) Brings the mechanism out of dead centres.
- (b) Stores energy required to rotate the shaft during preparatory strokes.
- (c) Makes crankshaft rotation more uniform.
- (d) Facilitates the starting of the engine and overcoming of short time over loads as, for example, when the machine is started from rest.

12. Governor

A governor may be defined as a device for regulating automatically output of a machine by regulating the supply of working fluid. When the speed decreases due to increase in load the supply valve is opened by mechanism operated by the governor and the engine therefore speeds up again to its original speed. If the speed increases due to a decreases of load the governor mechanism closes the supply valve sufficiently to slow the engine to its original speed. Thus the function of a governor is to control the fluctuations of engine speed due to changes of load.

Pars common to petrol engine

Spark plug

The main function of spark plug is to conduct high potential from the ignition system in to combustion chamber. It provides proper gap across which spark is produced. A spark plug entails the following requirements:

It must withstand peak pressures up to at least 55 bar

(6) It must provide suitable insulation between two electrodes to prevent short circuiting

It must be capable of withstanding high temperatures to the tune of 2000°C to 2500°C over long periods of operation.

Ur) It must offer maximum resistance to erosion burning away of the spark points irrespective of the nature of fuel used.

(c) It must possess a high heat resistance so that the electrodes do not become sufficiently hot to cause the preignition of the charge within the engine cylinder.

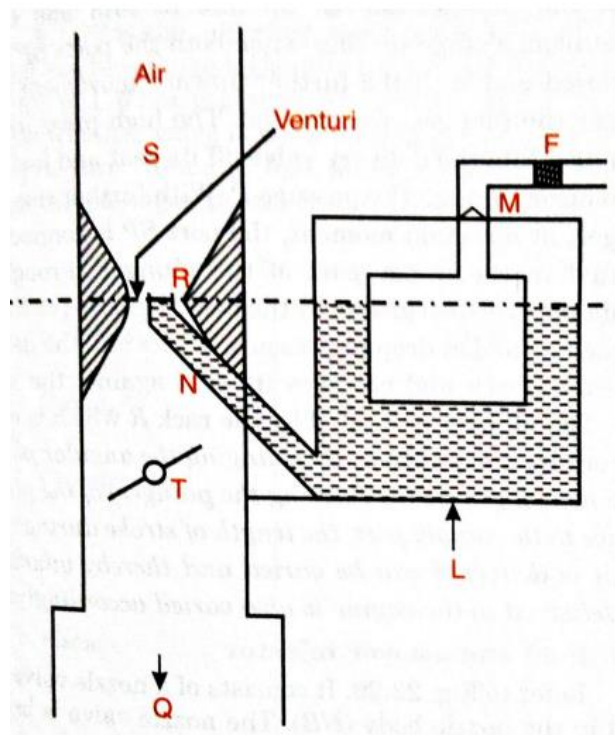
(er) The insulating material must withstand satisfactorily the chemical reaction effects of the fuel and hot products of combustion.

(vii) Gas tight joints between the insulator and metal parts are essential under all operating conditions.

The spark plug consists of a metal shell having two electrodes which are insulated from each other with an air gap. High tension current jumping from the supply electrode produces the necessary spark. Plugs are sometimes identified by the heat range or the relative temperature obtained during operation. The correct type of plug with correct width of gap between the electrodes are important factors.

Simple carburetor

The function of a carburettor is to atomize and meter the liquid fuel and mix it with air as it enters the induction system of the engine.



L is the float chamber for the storage of fuel. The fuel supplied under gravity action or by fuel pump enters the float chamber through the filter F. The arrangement is such that when the oil reaches a particular level the float valve M blocks the inlet passage and thus cuts off the fuel oil supply. On the fall of oil level, the float descends down, consequently intake passage opens and again the chamber is filled with oil. Then the float and the float valve maintains a constant fuel oil level in the float chamber. N is the jet from which the fuel is sprayed into the air stream as it enters the carburettor at the inlet S and passes through the throat or venturi R. The fuel level is slightly below the outlet of the jet when the carburettor is inoperative.

As the piston moves down in the engine cylinder, suction is produced in the cylinder as well as in the induction manifold Q as a result of which air flows through the carburettor. The velocity of air increases as it passes through the constriction at the venturi R and pressure decreases due to conversion of a portion of pressure head into kinetic energy. Due to decreased pressure at the venturi and hence by virtue of difference in pressure (between the float chamber and the venturi) the jet issues fuel oil into air stream. Since the jet has a very fine bore, the oil issuing from the jet is in the form of fine spray; it vapourises quickly and mixes with the air. This air-fuel mixture enters the engine cylinder; its quantity being controlled by varying the position of the throttle valve T.

Limitations:

i. Although theoretically the air-fuel ratio supplied by a simple (single jet) carburettor should remain constant as the throttle goes on opening, actually it provides increasingly richer mixture as the throttle is opened.

(ii) During idling, however, the nearly closed throttle causes a reduction in the mass of air flowing through the venturi. At such low rates of air flow, the pressure difference between the float chamber and the fuel discharge nozzle becomes very small. It is sufficient to cause fuel to flow through the jet.

(iii) Carburettor does not have arrangement for providing rich mixture during starting and warm up.

Air fuel mixture:

The theoretically correct mixture is 15:1 (approximate). Uniform supply of each mixture would result in burning without leaving excess of air or fuel. But it is difficult to get such a mixture in actual practice. When there is too little air, some of the fuel goes unburnt or simply changed to carbon. When there is too much air in mixture, it burns slowly and erratically and there is a loss of power.

There is however a range of mixtures between which combustion will take place.

The 'lower limit' is approximately 7: 1 to 10: 1. This mixture is barely explosive.

The 'upper limit' is approximately 20: 1. The mixture burns irregularly.

Mixture requirements of automotive engines:

For "average cruising speeds" the air-fuel ratio is approximately from 15: 1 to 7: 1.

In order to obtain "maximum power" to be able to accelerate the engine quickly, a richer mixture of the ratio of about 12: 1 is desirable. This is also called maximum power ratio. To start the engine from cold even a mixture richer than this but above the lower limit is obtained.

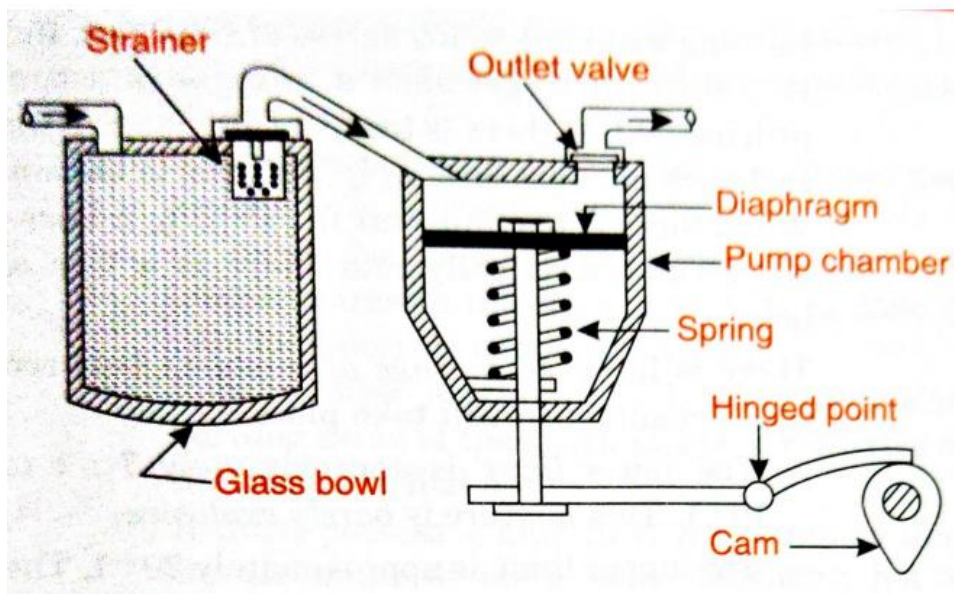
For "maximum economy", i.e., less fuel consumption for unit power, the mixture ratio may be approximately 16: 1 to 17: 1. The ratio, however, entails loss of power.

Hence, it is essential that the carburettor should be so designed that proper proportions of air and fuel are obtained to meet these varying operating conditions.

Fuel pump (for carburettor-petrol engine).

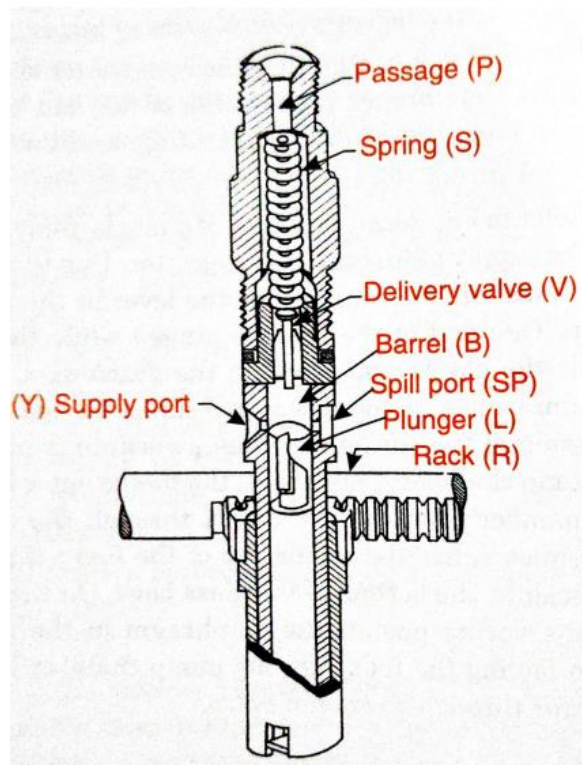
Fuel pump for petrol engine

This type of pump is used in petrol engine for supply of fuel to the carburettor. Due to rotation of the crankshaft the cam pushes the lever in the upward direction. One end of the lever is hinged while the other end pulls the diaphragm rod with the diaphragm. So the diaphragm comes in the downward direction against the compression of the spring and thus a vacuum is produced in the pump chamber. This causes the fuel to enter into the pump chamber from the glass bowl through the strainer and the inlet valve, the impurities of the fuel; if there is any, deposit at the bottom of the glass bowl. On the return stroke the spring pushes the diaphragm in the upward direction forcing the fuel from the pump chamber into the carburetor through the outlet valve.



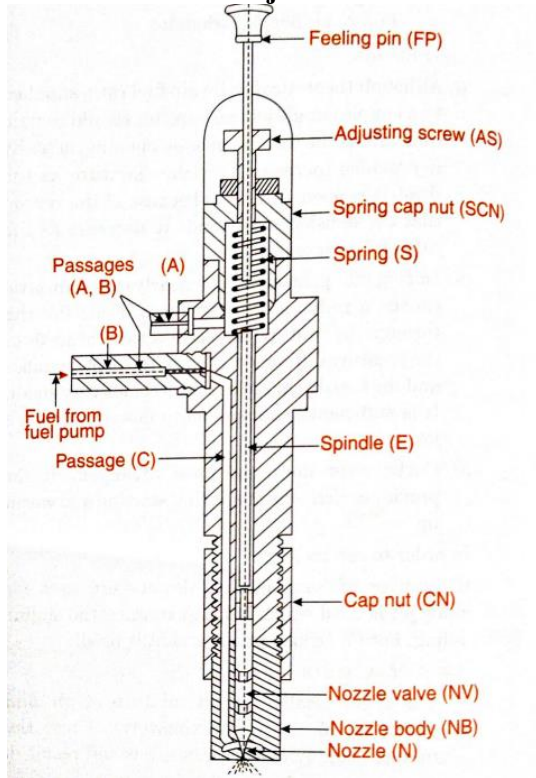
Fuel pump for diesel

L is the plunger which is driven by a cam and tappet mechanism at the bottom (not shown in the figure) B is the barrel in which the plunger reciprocates. There is the rectangular vertical groove in the plunger which extends from top to another helical groove. V is the delivery valve which lifts off its seat under the liquid fuel pressure and against the spring force (S). The fuel pump is connected to fuel atomiser through the passage P, SP and Y are the spill and supply ports respectively. When the plunger is at its bottom stroke the ports SP and Y are uncovered (as shown in Fig.) and oil from low pressure pump (not shown) after being filtered is forced into the barrel.



When the plunger moves up due to cam and tappet mechanism, a stage reaches when both the ports SP and Y are closed and with the further upward movement of the plunger the fuel gets compressed. The high pressure thus developed lifts the delivery valve off its seat and fuel flows to atomiser through the passage P. With further rise of the plunger, at a certain moment, the port SP is connected to the fuel in the upper part of the plunger through the rectangular vertical groove by the helical groove; as a result of which a sudden drop in pressure occurs and the delivery valve falls back and occupies its seat against the spring force. The plunger is rotated by the rack R which is moved in or out by the governor. By changing the angular position of the helical groove (by rotating the plunger) of the plunger relative to the supply port, the length of stroke during which the oil is delivered can be varied and thereby quantity of fuel delivered to the engine is also varied accordingly.

Fuel atomizer or injector



It consists of a nozzle valve (NV) fitted in the nozzle body (NB). The nozzle valve is held on its seat by a spring 'S' which exerts pressure through the spindle E. 'AS' is the adjusting screw by which the nozzle valve lift can be adjusted. Usually the nozzle valve is set to lift at 135 to 170 bar pressure. FP is the feeling pin which indicates whether valve is working properly or not. The oil under pressure from the fuel pump enters the injector through the passages B and C and lifts the nozzle valve.

The fuel travels down the nozzle N and is injected into the engine cylinder in the form of fine sprays. When the pressure of the oil falls, the nozzle valve occupies its seat under the spring force and fuel supply is cut off. Any leakage of fuel accumulated above the valve is led to the fuel tank through the passage A. The leakage occurs when the nozzle valve is worn out.

The main functions of a fuel injection system are:

1. Filter the fuel.
2. Measure or measure the correct quantity of fuel to be injected.
3. Time the fuel injection.
4. Control the rate of fuel injection.
5. Atomise or break up the fuel to fine particles,
6. Properly distribute the fuel in the combustion chamber.

(a) Air injection

In this method of fuel injection air is compressed in the compressor to a very high pressure (much higher than developed in the engine cylinder at the end of the compression stroke) and then injected through the fuel nozzle into the engine cylinder. The rate of fuel admission can be controlled by varying the pressure of injection air. Storage air bottles which are kept charged by an air compressor (driven by the engine) supply the high pressure air. This method is obsolete these days.

(b) Solid or airless injection

It is also termed as mechanical injection. Here a fuel pump is used which supplies a measured quantity of fuel to the atomiser or injector which injects it (fuel) at a very high velocity into the

engine cylinder in the form of sprays. The injection pressure varies from 100 to 145 bar (or even more in some cases). This pressure is produced by the fuel pump.

Ignition system

Petrol engine

The two basic ignition systems in current use are:

1. Battery or coil ignition system.
2. Magneto ignition system.

Battery or coil ignition system.

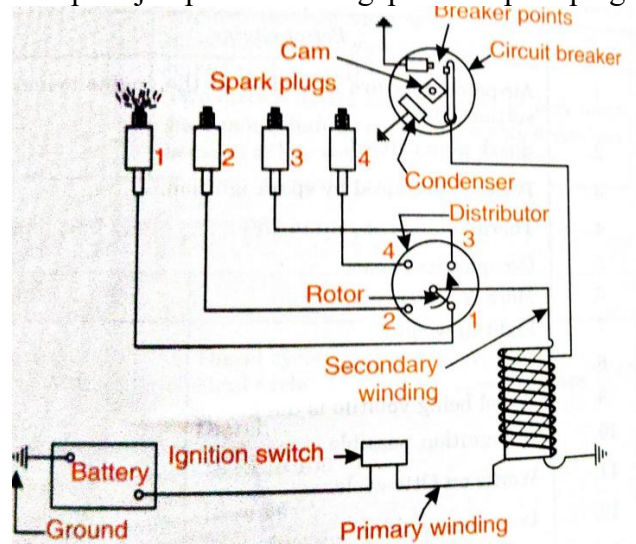
Most petrol engines follow this method.

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

One terminal of the battery is ground to the frame of the engine, and other is connected through the ignition switch to one primary terminal of the ignition coil (consisting comparatively few turns of thick wire wound round an iron core) The other primary terminal is connected to one end of the contact points of the circuit breaker and through closed points to ground. The primary circuit of the ignition coil thus gets completed when contact points of the circuit breaker are together and switch is closed. The secondary terminal of the coil is connected to the central contact of the distributor and hence to distributor rotor. The secondary circuit consists of secondary winding (consisting of a large number of turns of fine wire) of the coil, distributor and four spark plugs. The contact breaker is driven by a cam whose speed is half the engine speed (for four-stroke engines) and breaks the primary circuit one for each cylinder during one complete cycle of the engine.

The breaker points are held on contact by a spring except when forced apart by lobes of the cam.

To start with, the ignition switch is made on and the engine is cranked ie., turned by hand when the contacts touch, the current flows from battery through the switch, primary winding of the induction coil to circuit breaker points and the circuit is completed through the ground. A condenser connected across the terminals of the contact breaker points prevent the sparking at these points. The rotating cam breaks open the contacts immediately and breaking of this primary circuit brings about a change of magnetic field; due to which a very high voltage to the tune of 8000 to 12000 V is produced across the secondary terminals. (The number of turns in the secondary winding may be 50 to 100 times than in primary winding). Due to high voltage the spark jumps across the gap in the spark plug and air-fuel mixture is ignited in the cylinder.



Terminologies

Bore. The inside diameter of the cylinder is called

Stroke. As the piston reciprocates inside the engine cylinder, it has got limiting upper and lower positions beyond which it cannot move and reversal of motion takes place at these limiting positions.

The linear distance along the cylinder axis between two limiting positions, is called stroke.

Top Dead Centre (T.D.C.). The top most position of the piston towards cover end side of the cylinder is called "top dead centre". In case of horizontal engines, this is known as inner dead centre.

Bottom Dead Centre (B.D.C.). The lowest position of the piston towards the crank end side of the cylinder is called "bottom dead centre". In case of horizontal engines it is called outer dead centre.

Clearance volume. The volume contained in the cylinder above the top of the piston, when the piston is at top dead centre, is called the clearance volume.

Swept volume. The volume swept through by the piston in moving between top dead centre and bottom dead centre, is called swept volume or piston displacement. Thus, when piston is at bottom dead centre, total volume = swept volume + clearance volume.

Compression ratio. It is ratio of total cylinder volume to clearance volume.

Refer to Fig. 23.30. Compression ratio (r) is given by

$$r = \frac{V_s + V_c}{V_c}$$

where, V_s = Swept volume, and

V_c = Clearance volume.

The compression ratio varies from 5 : 1 to 11 : 1 (average value 7 : 1 to 9 : 1) in *S.I. engines* and from 12 : 1 to 24 : 1 (average value 15 : 1 to 18 : 1) in *C.I. engines*.

Working cycles

(a) Constant volume or Otto cycle. The cycle is

so called because heat is supplied at constant volume. Petrol gas and light oil work on this cycle. In the case of a petrol engine the proper mixing of petrol and air takes place in the carburettor which is situated outside the engine cylinder. The proportionate mixture is drawn into the cylinder during the suction stroke. In a gas engine also, and gas is mixed outside the engine cylinder and mixture enters the cylinder during the suction stroke. In light oil engines the fuel is converted to vapours by a vapouriser which receives heat from the exhaust gases of the engine and their mixture flows towards engine cylinder during suction stroke.

(b) Constant pressure or Diesel cycle.

In this cycle only air is drawn in the engine cylinder during the suction stroke, this air gets compressed during the compression stroke and its pressure and temperature increase by a considerable amount. Just before the end of the stroke a metered quantity of fuel under pressure adequately more than that developed in the engine cylinder is injected in the form of fine sprays by means of a fuel injector. Due to very high pressure and temperature of the air the fuel ignites and hot gases thus produced throw the piston downwards and work is obtained.

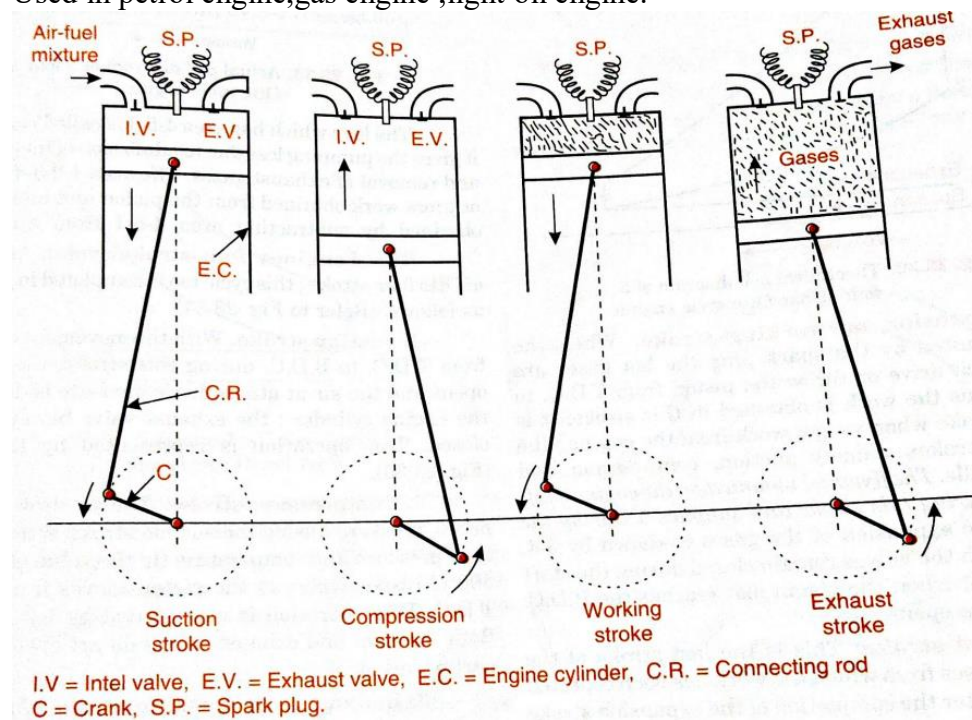
Indicator diagram

An indicator diagram is a graph between pressure and volume: former on vertical axis and later on horizontal axis.

Four stroke cycle engines

Otto cycle

Used in petrol engine, gas engine, light oil engine.



1. Suction stroke :The piston moves from top dead centre (T.D.C.) to bottom dead centre (B.D.C), the inlet valve opens and proportionate fuel-air mixture is sucked in the engine cylinder. This operation is represented by the line 1-2 in the figure below. The exhaust valve remains closed throughout the stroke.

2. Compression stroke. In this stroke, the piston (1-2) moves towards (T.D.C.) and compresses the enclosed air-fuel mixture drawn in the engine cylinder during the suction stroke. The pressure of the mixture rises in the cylinder to a value of about 8 bar. Just before the end of this stroke the spark-plug initiates a spark which ignites the mixture. Combustion takes place at constant volume (line 2-3) in the figure below. Both the inlet and exhaust valves remain closed during the stroke.

3. Expansion or working stroke. When the mixture is ignited by the spark plug the hot gases are produced which drive or throw the piston from T.D.C. to B.D.C. and thus the work is obtained in this stroke. It is during this stroke when we get work from the engine; the other three strokes namely suction, compression and exhaust being idle. The flywheel mounted on the engine shaft stores energy during this stroke and supplies it during the idle strokes. The expansion of the gases is shown by 3-4. (Fig. below). Both the valves remain closed during the start of this stroke but when the piston just reaches the B.D.C. the exhaust valve opens.

4. Exhaust stroke. This is the last stroke of the cycle. Here the gases from which the work has been collected become useless after the completion of the expansion stroke and are made to escape through the exhaust valve to the atmosphere.

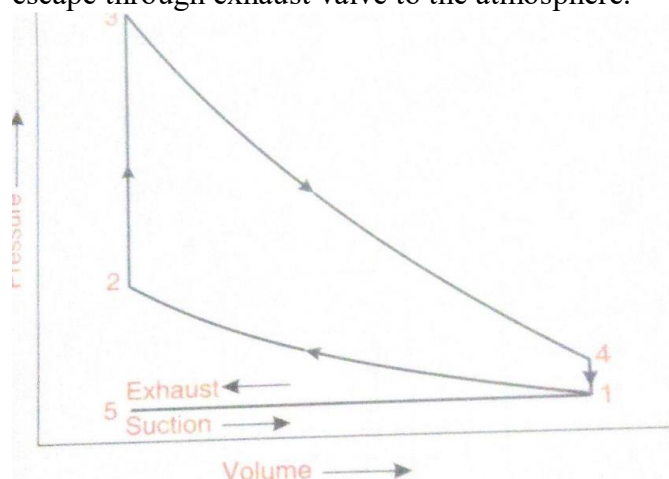


Fig. below shows the actual indicator diagram for the Otto cycle engine. It may be noted that the suction line 1-2 is below the atmospheric pressure line. This is due to the fact that owing to the restricted area of the inlet passage the air-fuel mixture cannot cope with the speed of the piston. The exhaust line 4-5 is slightly above the atmospheric pressure line. This is due to restricted exhaust passages which do not allow the exhaust gases to leave the engine-cylinder quickly.