rich mixture required for acceleration. If the throttle is suddenly opened when the engine is running at low speed, a rich mixture is provided and momentarily acceleration is possible.

Choking. A choke valve is also provided which is manually operated for starting the engine during cold weather conditions.

All the above described devices are shown in the Fig. 22.30.

22.8. FUEL SUPPLY TO DIESEL ENGINES

22.8.1. Fuel Injection Systems and its Requirements

The fuel injection system is considered one of the most important parts of the diesel engine. The performance of the engine depends very much upon the proper functioning of the injection system. It is considered as the 'heart' of the engine as it plays an important role.

The fuel injection system must satisfy the following fundamental requirements :

1. Inject the quantity of the fuel demanded by the load on the engine and maintain this metered quantity :

(*a*) constant supply of fuel from cycle to cycle operation.

(*b*) constant supply of fuel from cylinder to cylinder.

2. Inject the fuel at correct time in the cycle throughout the speed range of the engine.
3. Inject the fuel at desired rate to control the combustion and resulting rate of pressure-rise.
4. Automize the fuel to the required degree.
5. Distribute the fuel throughout the combustion chamber for better mixing.
6. Injection should begin and end sharply.

Injection systems are manufactured with great accuracy, especially the parts that actually meter and inject the fuel. Such closely fitting parts require special attention during their manufacture and, as a result, injection systems are costly items.

Injection system may be divided into two general types, as follows :

(1) Air injection

(2) Air-less or solid or mechanical injection.

22.8.2. Air Injection System

Dr. Rudlop Diesel developed this system as the means for automizing the fuel. In operation, fuel was metered and pumped to the nozzle, which was also connected to a source of high pressure air. The nozzle was simply a mechanically actuated valve. When the nozzle was opened, the air would sweep the fuel into the engine and deliver a well automized spray even though heavy and viscous fuels were used. However, the size and cost of air compressor, along with power required for operation, has made air-injection obsolete.

22.8.3. Air-less or Solid Injection

In this system, the fuel is supplied at a very high pressure (150 bar) from the fuel pump to the fuel injector and then it is injected to the combustion chamber with the help of an injector. The main parts of this system are fuel pump and fuel injector. The fuel pump is operated by a cam which is mounted on cam shaft. The power required to operate the cam is taken from the engine crankshaft. Depending upon the location of the fuel pumps and injectors, and upon the method used to meter the fuel, solid injection may further be classified as follows :

(*a*) *Common Rail System.* (A single pump for compressing the fuel, plus a metering element for each cylinder).

(*b*) *Distributor system.* (A single pump for metering and compressing the fuel, plus a driving mechanism for distributing the fuel to the various cylinders).

(*c*) *Individual pump and nozzle system.* (A separate metering and compressing pump and nozzle for each cylinder of the engine).

The arrangement and working of each system are given below.

(*a*) **Common Rail System.** In this system, there is single high pressure pump, which supplies high pressure fuel to a common header (rail). The accumulator is connected to different cylinders by separate fuel line through the fuel nozzle as shown in Fig. 22.31. The pressure in the accumulator is maintained

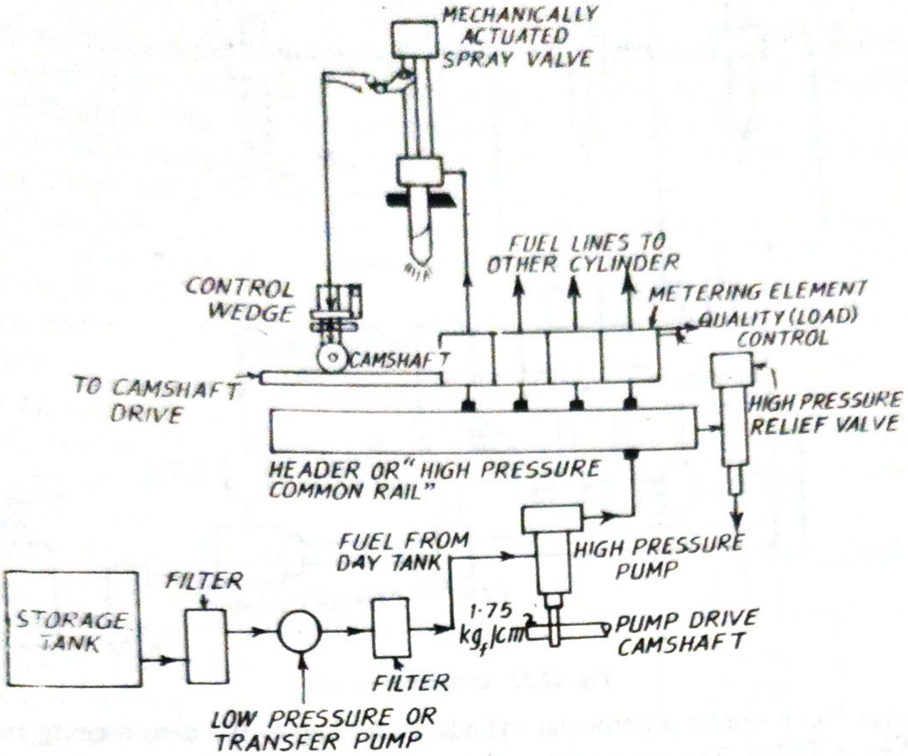


Fig. 22.31. Common Rail System.

constant with the help of pressure relief valve. The fuel is supplied to each cylinder by operating the respective fuel valve with the help of cam mechanism driven by the engine crankshaft.

The quantity of fuel injected and the timing of injection are controlled by fuel valve and not by the injection pump. The arrangement of fuel valve (metering meter) and fuel nozzle is shown in figure. This system uses spring loaded injection valves which open and close by mechanical means.

The pressure used in this system ranges between 110 to 300 bar according to the compression ratio used for the engine design.

The advantages and disadvantages of the system are listed below.

Advantages :

1. It fulfils the requirements of either, (*a*) the constant load with variable speed or (*b*) constant speed with variable load.
2. Only one pump is sufficient for multi-cylinder engines.
3. Variation in pump supply pressure will affect all the cylinders uniformly.
4. The arrangement of the system is very simple and maintenance cost is less.

Disadvantages :

1. Very accurate design and workmanship are required.
2. There is tendency to develop leaks in the injection valve.

(*b*) **Distributor System.** This system, like common rail system, employs a single high pressure pump as shown in Fig. 22.32. The high pressure pump in this system is used for metering and compressing the fuel and then the fuel is delivered to the common rotating distributor. The fuel is supplied to each cylinder by the distributor. In every cycle, the injection strokes of the pump are equal to the number of cylinders. The quantity of fuel supplied and timing of fuel supply is done by single plunger (main pump) therefore equal amount of fuel is supplied to each cylinder and at the same point in the cycle. The function of the distributor is merely to select the cylinder to receive the fuel.

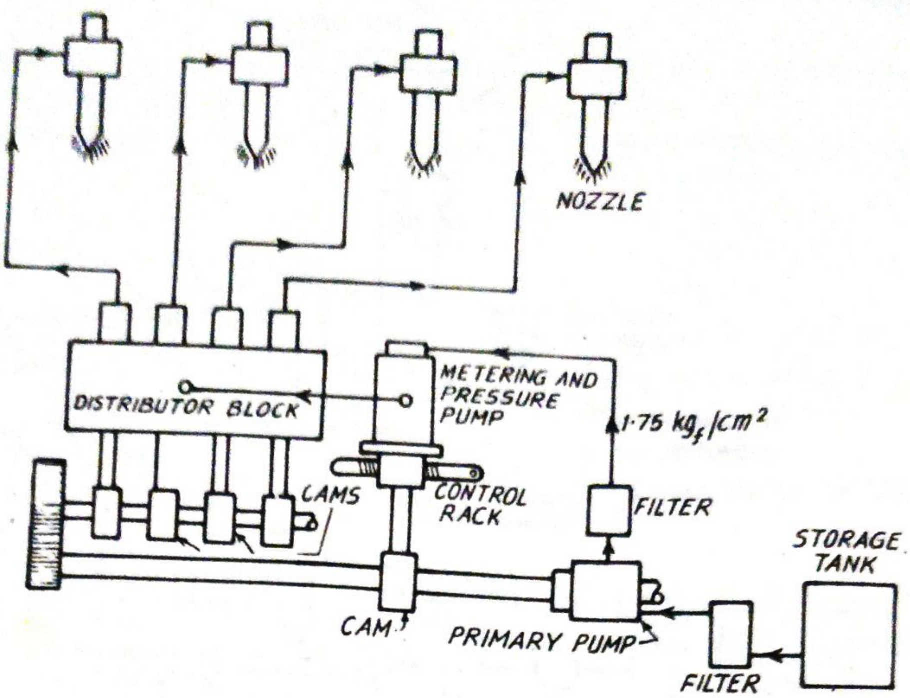


Fig. 22.32. Distributor system.

The distributor block selects a particular cylinder according to the cam coming in contact with the distributor as shown in figure. The appropriate valve opens just before the beginning of injection and oil is supplied to the required cylinder.

(*c*) **Individual Pump and Nozzle System.** This differs from constant pressure injection both in design and operation of the pump and fuel injector. Each injector has a separate pump and the injector contains a spring-loaded hydraulically operated automatic plunger valve. No separate mechanism is required to operate it.

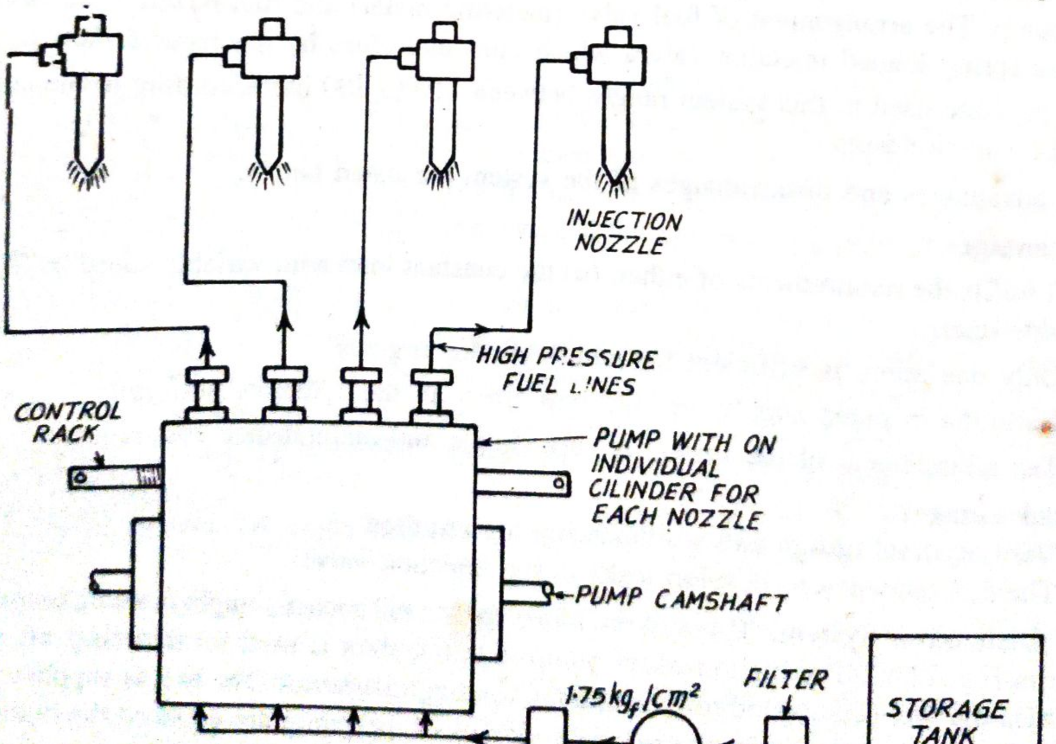


Fig. 22.33. Individual pump system.

In this system, separate pumps, each (depending upon no. of cylinders) driven individually or a single pump having four plungers in a common block may be used. In this case, the single pump is driven by the crankshaft through single cam shaft having individual cam for each cylinder.

The arrangement of the individual pump system is shown in Fig. 22.33 with all pumps in one block, four plungers in one barrel and a common cam shaft.

The design of this type of pump must be very accurate and precise as the volume of fuel injected per cycle is .05 × 10^{-3} of the engine displacement at full load and 0.001 × 10^{-3} of the engine displacement during idling. The time allowed for injecting such a small quantity of fuel is very limited (about 0.002 second at 1500 r.p.m. of the engine providing injection through 20° crank angle). The pressure requirements vary from 100 to 300 bar.

22.8.4. Fuel Injection Pump

This is widely used to supply fuel under high pressure in diesel engines. In this pump, the plunger stroke remains constant but the effective stroke is reduced by changing the position of helix on the plunger with respect to fuel inlet port.

The fuel pump is shown in the Fig. 22.34. It has a cylindrical plunger which is closely fitted into the barrel by lapping. The plunger has a constant stroke and reciprocating motion of the plunger is given by the cam. The vertical hole extends from the top of the plunger to another helical groove. When the inlet and spill port or the by pass ports are closed by the upper edge of the plunger during its ascending motion, the oil above the plunger gets compressed and the delivery valve gets lifted of its seat due to the high pressure developed. Then the fuel is forced through the pipe to injector. The supply of fuel to the injector is continued until the helical groove reaches the inlet port. The pump space in this position of the plunger communicates with the spill port through the spiral slot and the vertical groove is thus connected to the atmosphere. The pressure on the spring side is released. The delivery valve falls back to its seat and the supply of fuel to the atomiser is stopped. At this time, the fuel in the barrel escapes from the spill port or the by pass port.

During the downward stroke of the plunger, the section is seated and fuel is drawn into the barrel through the supply port.

The quantity of fuel being supplied to the injector depends upon the position of helical groove. The plunger can be rotated by means of the tooth rack. By turning the plunger to the right, the effective pumping stroke can be increased *i.e.* the instant, at which the space communication with the spill port can be delayed and so, more fuel can be supplied to the engine at higher loads. The rack is operated by the governor.

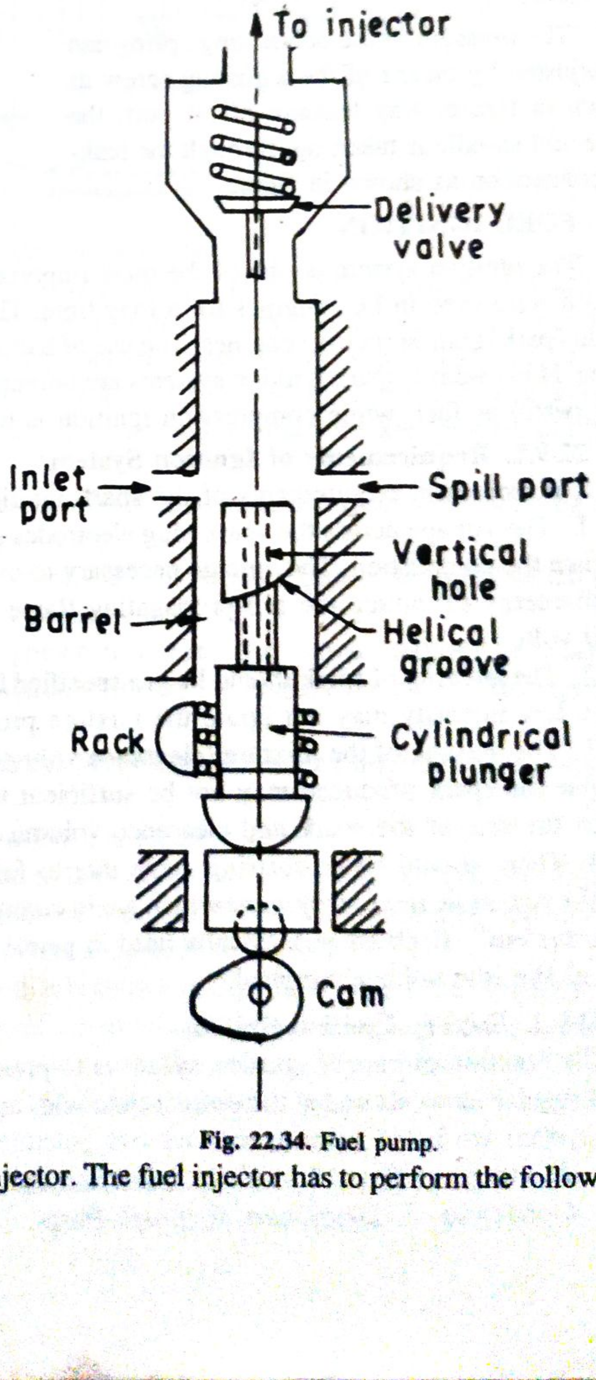


Fig. 22.34. Fuel pump.

22.8.5. Fuel Injector

The fuel from the fuel pump is supplied to the fuel injector. The fuel injector has to perform the following functions :

(*a*) To atomize the fuel to the required degree.

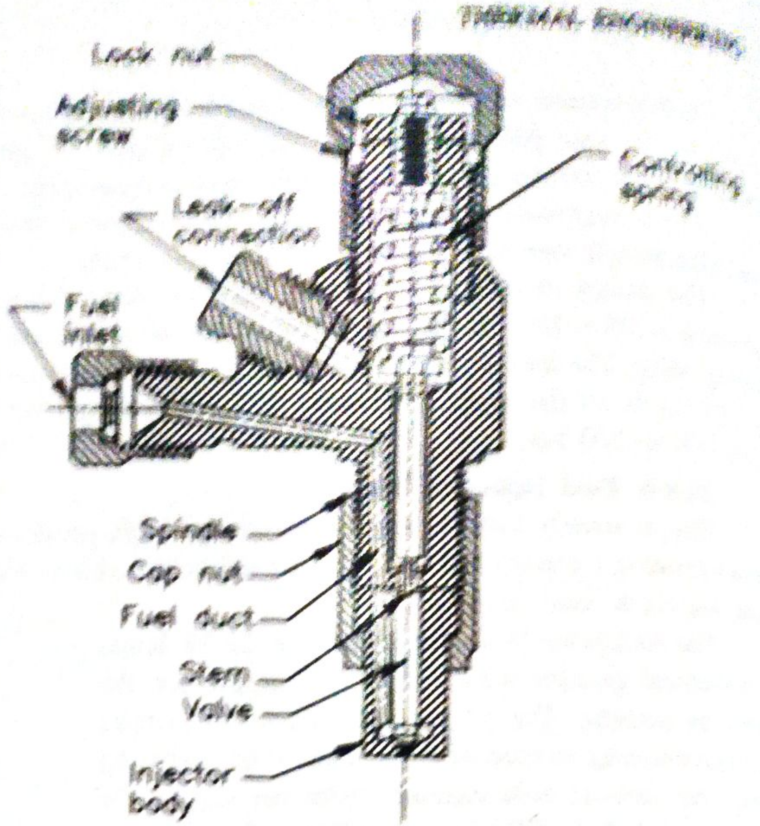


Fig. 22.35. Fuel injector

(*b*) To distribute the fuel in such a way that there is complete mixing of fuel and air.

(*c*) It must prevent the injection on the walls of the cylinder and piston top surface.

(*d*) It must start and stop the fuel injection instantaneously.

A typical spring loaded Bosch fuel injector is shown in Fig. 22.35. The spring loaded valve is lifted by the high pressure oil supplied by the pump and the fuel is injected into the combustion chamber of the engine cylinder. As the pressure of oil falls, the valve is automatically closed by the spring force. The amount of fuel injected is regulated by the duration of the open period of the valve.

The pressure of the controlling spring can be adjusted by means of the adjusting screw as shown in figure. Any leakage of oil port, the valve and spindle is taken out through the leak-off connection as shown in figure.

22.9. FUEL IGNITION

The ignition system is one of the most important systems of the I.C. engine. Hot tube and hot bulb ignition were used in I.C. engines for a long time. The ignition remained as a source of trouble for a long time in spark ignition (petrol) engines. The use of battery ignition has solved these problems in spark ignition engine. Now-a-days, spark ignition systems are universally and successfully used in all cars and automobiles using petrol as fuel, while compression ignition is used in diesel engines.

22.9.1. Requirements of Ignition System

The important requirements of the spark ignition systems are listed below :

1. The voltage across the spark plug electrodes should be sufficiently large to produce an arc required to initiate the combustion. The voltage necessary to overcome the resistance of the spark gap and to release enough energy to initiate the self-propagating flame front in the combustible mixture is about 10,000 to 20,000 volts.

2. The intensity of spark should lie in a specified limit because too high intensity may burn the electrodes and too low intensity may not ignite the mixture properly.

3. The volume of the mixture (clearance volume) at the end of compression should not be too large, otherwise the spark produced may not be sufficient to ignite the whole charge. There is definite relation between the size of the spark and clearance volume.

4. There should be no missing cycle due to failure of spark.

The two basic ignition systems which are in common use are "Battery ignition system" and "Magneto ignition system". Both are successfully used in petrol engines. The basic difference between the two is the source of the low voltage supplied.

22.9.2. Battery Ignition System

The function of battery ignition sysem 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 required components of this system are listed below :

1. A battery of 6 to 12 volts. 2. Induction coil. 3. Contact breaker.
4. Condenser. 5. Distributor. 6. Spark-Plugs.

The arrangement of all the components of battery ignition system for 4-cylinder engine is shown in Fig. 22.36.

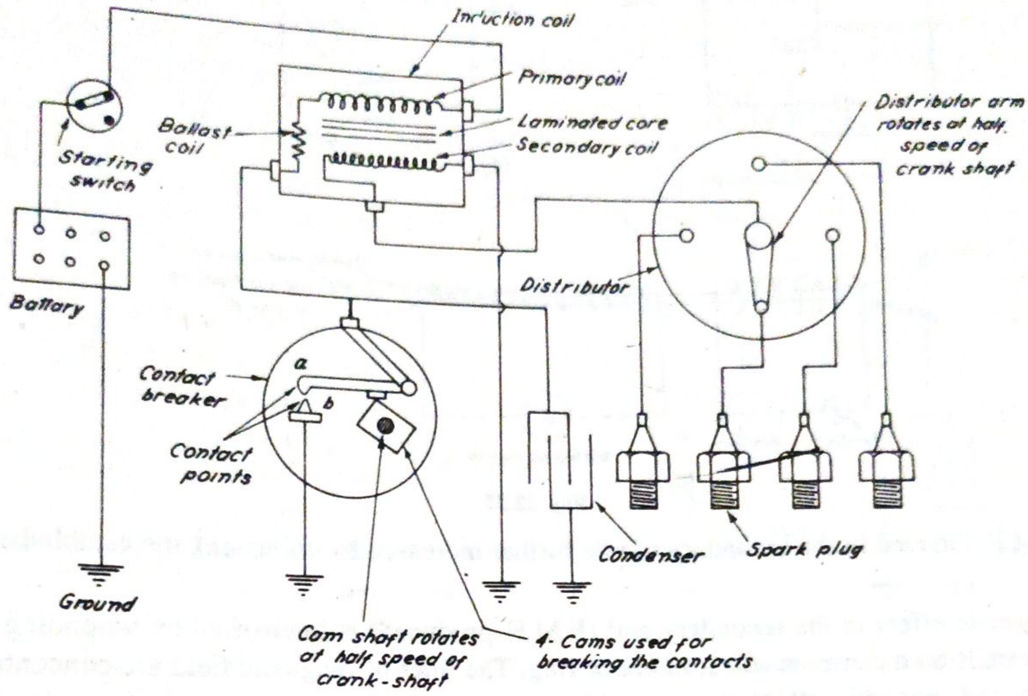


Fig. 22.36. Battery ignition system for multi-cylinder engines.

The source of current is the storage battery and it is connected to the primary of the induction coil through starting switch as shown in the figure. The other end of the primary coil is connected to the breaker and through it to the ground, when the breaker contact points are closed. (In the figure, the breaker contact points are shown in open position). As one terminal of the battery is grounded, the circuit is closed by passing the current from the battery through the starting switch, primary coil, contact breaker, ground and back to the battery when contact points are closed.

The induction coil consists of primary winding usually 100 to 200 turns and a secondary winding usually 10,000 turns. Both windings are mounted on soft iron core.

The contact breaker consists of contact points, cam shaft on which a cam is mounted which is used to break and make the contacts between the contact points.

The distributor consists of distributor arm, as shown in figure. The arm is mounted on a cam shaft and is rotated at half the speed of crankshaft. The function of the arm is to make the contact with each spark plug as shown in figure.

The distributor unit generally includes the contact breaker also to make the unit more compact, as both are drived by the same cam shaft.

A condenser is included in the circuit as shown in the figure.

Principle of Induction. An E.M.F. is produced in the coil due to the relative movement of magnetic lines and coil because the magnetic field lines are cut by the coil. The E.M.F. produced depends on the relative movement between the two, higher the movement, greater the E.M.F.

The principle of induction from one coil into another is shown in Fig. 22.37. When the current is allowed to flow through the primary coil, a magnetic field is set up and this field passes through the secondary coil and induces E.M.F. sending a current through a closed circuit. The current in the primary quickly attains a steady value and magnetic field is stabilized. The E.M.F. is not induced in the secondary as there is no relative movement between field (established by primary) and secondary.

If the primary is switched off, the established magnetic field collapses and E.M.F. once again is induced in the secondary in the opposite direction. The greater E.M.F. is induced when the circuit is broken because the collapse is more rapid.

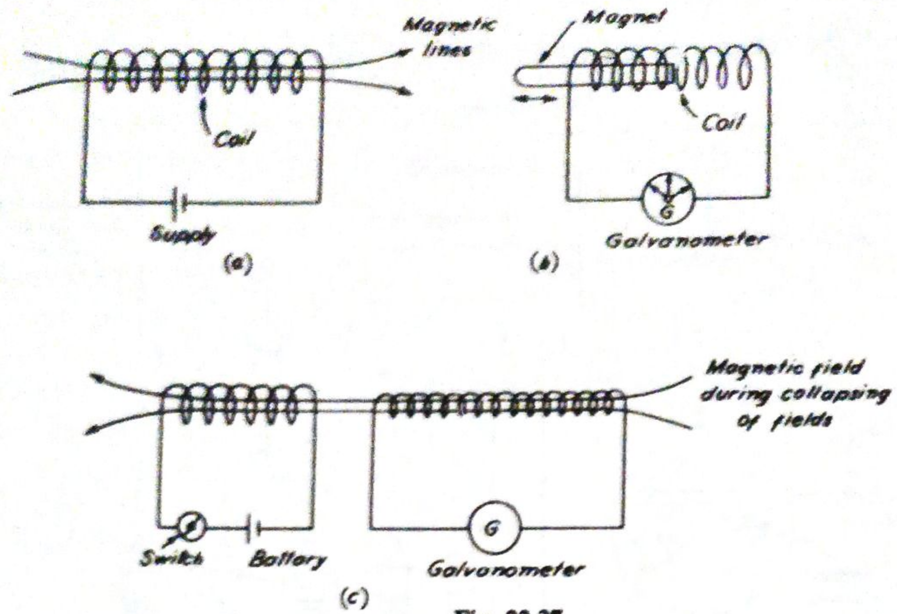


Fig. 22.37.

The E.M.F. induced in the secondary can be further increased by collapsing the established field more rapidly.

The magnetic effect in the secondary coil (E.M.F. produced) is intensified by wounding the primary and secondary coils on a common soft iron bar or ring. The lines of magnetic field are concentrated around the bar or ring and magnetic effects are intensified.

A higher E.M.F. at the secondary terminal can be obtained by suitable proportioning of primary and secondary coil around a common iron coil (1 : 100).

Principle of Ignition. A high voltage can be introduced at the terminals of the secondary coil by collapsing the field established by primary and proper proportioning of the turns of primary and secondary as mentioned earlier. If this high voltage is connected to the two points providing an air gap between them as shown in Fig. 22.38, a spark is produced. Ignition can take place in the compressed charge of petrol engine if the spark is produced in the charge at the end of compression.

Fig. 22.38.

Working of Battery Ignition System. When the primary circuit is closed by the contact breaker (it is shown in open position in the Fig. 19.37), a current begins to flow through the primary coil and magnetise core of the coil. The E.M.F. is induced in the secondary as the current in the primary increases. The E.M.F. induced in the secondary coil is proportional to the rate at which the magnetic flux increases. The E.M.F. produced in the secondary due to the growth of current in the primary is not sufficient to produce a spark at the spark plug because the primary circuit has to establish the magnetic flux.

When the primary circuit is opened by the contact breaker, the magnetic field collapses. Electromotive force is induced in the secondary which is directly proportional to the rate at which the magnetic field of the core collapses which in turn depends on the rate of decrease of the primary current. A condenser is connected across the contact breaker in the primary circuit as shown in Fig. 19.36. This helps to collapse the field very rapidly by absorbing part of the energy of the magnetic field which is thrown back into the primary winding and produces a very high voltage in the secondary. This E.M.F. in the secondary is sufficient to ignite the charge by producing the spark.

One end of the secondary coil is connected to the ground and other end is connected to the central terminal of the distributor. The distributor connects the secondary coil in turn to the different spark plugs of the engine in their firing order. The spark plug of a particular cylinder is placed in circuit of the secondary coil with the help of the distributor when the time comes for the charge in that cylinder to be ignited and at the same time the primary circuit is opened by contact breaker. A spark is produced between the points of the spark plug.

The distributor and contact breaker are generally mounted on the same cam shaft which rotates at half speed of the crankshaft. The function of the distributor is to connect the secondary to each cylinder of a multicylinder engine at the time of ignition. The contact breaker also works simultaneously with distributor and its function is to disconnect the primary circuit exactly at the same time when the spark in the particular cylinder is required. The distributor arm connects 4-spark plugs in one rotation of the cam shaft and therefore four contact points are required in 4-cylinder engines. The contact breaker has to break the contacts 4-times in four cylinder engines so it requires 4 cams as shown in Fig. 22.38. If there are n cylinders, then the contact points and cams required are also n in number.

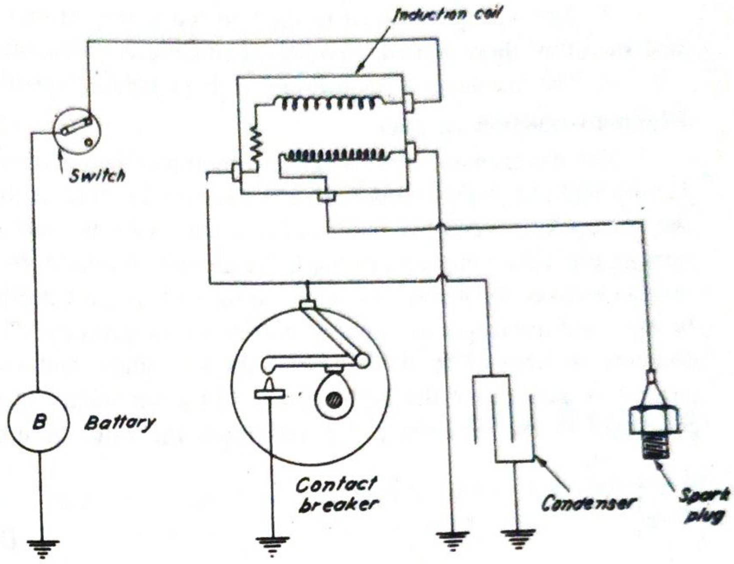


Fig. 22.39. Battery Ignition system for single cylinder engine.

In a single cylinder engine, the distributor is not required as in Scooter engine, and single cam is sufficient for giving the spark. A magneto ignition system used in single cylinder petrol engine is shown in Fig. 22.39.

Number of sparks. Number of sparks produced must be equal to number of working strokes in a single cylinder engine. If there are N_c cylinders then the number of sparks produced for that engine are :

$$N_s \text{ (Number of spark)} = n \cdot N_c \quad \dots (22.41)$$

where n = number of working strokes and N_c = number of cylinders

Further, $n = \dfrac{N}{2}$ for 4-stroke cycle engine

$= N$ for 2-stroke cycle engine where N is r.p.m. of the engine.

Thus, for 4-stroke engine $N_s = \dfrac{NN_c}{2}$ and for 2-stroke engine, $N_s = NN_c$.

22.9.3. Advantages and Disadvantages of Battery Ignition System

Advantages :

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 sparks 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.

4. The spark efficiency (intensity) remains unaffected by advance and retard positions of the timing control mechanism.

5. The simplicity of the distributor drive is another factor in favour of coil ignition.

Disadvantages :

1. The engine cannot be started if the battery runs down.

2. The weight of the battery ignition system is greater than magneto which is major consideration in adopting the system in aero-engines.

3. The wiring involved in the coil ignition is more complicated than that used in magneto ignition and therefore there is more likelihood of defects occurring in the system.

4. The sparking voltage drops with increasing speed of the engine.

Magneto-Ignition System

The arrangement of the magneto-Ignition system is shown in the Fig. 22.40. The only difference between battery and magneto system is that the battery is replaced by the rotating magnet. As the magneto rotates, the voltage and current is generated in the primary and circuit is completed passing the current through the contact breaking point and through the ground. As the current passes through the primary coil through the contact breaker, the circuit is completed through ground. As the cam shaft 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, and a high voltage is generated in the secondary. The process of generating the high voltage in the secondary is known as induction phenomenon. The voltage generated in the secondary depends upon the ratio of number of turns in the secondary and primary

$$e' \propto \left(\frac{Ns}{Np} \right).$$

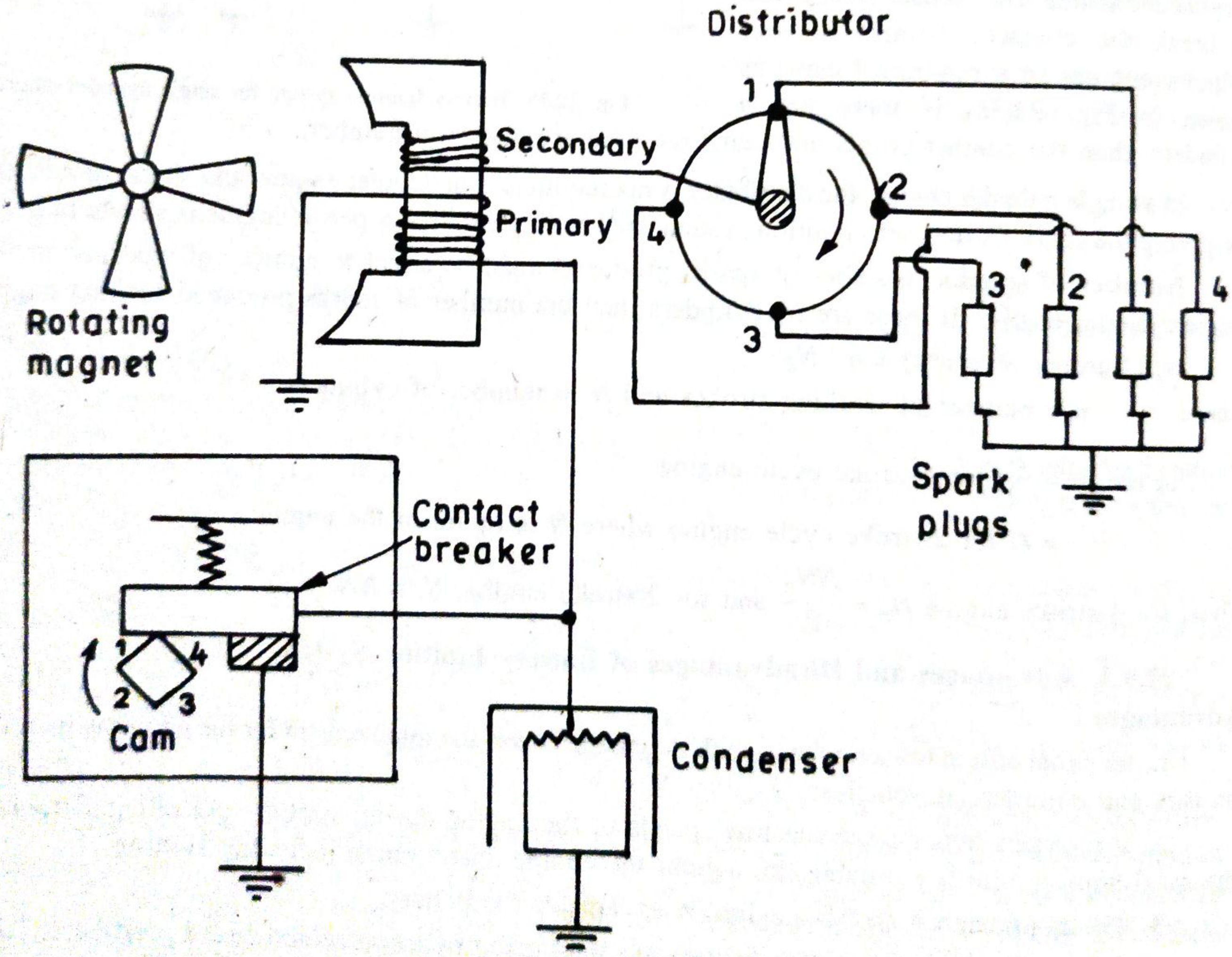


Fig. 22.40.

The purpose of the condenser is to suck the current from the primary when the primary circuit is broken which helps to decay the magnetic field rapidly and enhance the process of increasing the voltage in the secondary. The high voltage generated in the secondary is carried through the distributor through poin 1 to spark plug 1. the spark is generated due to high voltage across the spark plug gap.

In the meantime, cam-1. goes out of action and contact points touch each other and completes the primary circuit. Again the cam-2. breaks the contact points and the process described above is repeated and the spark is carried to the distributor and then to the spark plug.

In this way during one rotation of the camshaft, each spark plug in each cylinder ignites the mixture and power is generated.

In a 4-stroke engine, after every two rotations, power is developed, therefore only once the spark must occur therefore the camshaft rotates at half rpm of the crankshaft. The camshaft is rotated by transimitting the power from the crankshaft through bevel gear as shown in the Fig. 22.41.

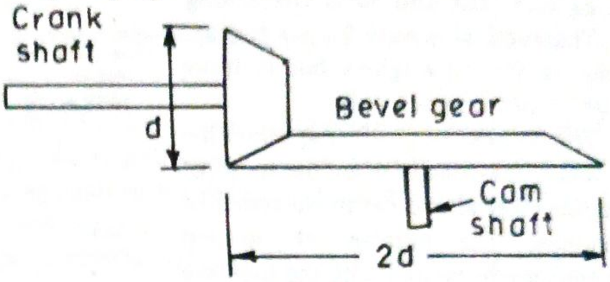


Fig. 22.41.

Advantages and Disadvantages of Magneto System over Battery ignition System

(A) Advantages

1. It is more realiable as compared to coil ignition system, because ther is no maintenance problem in magneto ignition system.
2. As the speed increases, the voltage in the primary winding also increases rapidly and intensity of spark is also higher and provides better combustion, as compared to battery ignition system. Therefore magneto ignition is very popularly used in racing cars.
3. Medium to high speeds.
4. Space required is less as compared to coil ignition systems.
5. By providing suitable shunts on magneto, the danger of burning of spark plug is minimised.
6. Very light in weight and compact in size, unit can be made.
7. Automatic time adjusting of ignition can be affected.

Disadvantages

1. Initial cost is very high as compared to coil ignition system.
2. To start with, 75 RPM is necessary.
3. For high power engines, some other devices are necessary to start ignition.

22.10. GOVERNING OF I.C. ENGINES

22.10.1. The Purpose of Governing

The purpose of governing is to maintain the speed of the engine constant regardless of the changes in the load on the engine. The mechanism used for this purpose is known as governor and method used is known as governing.

If the load on the engine decreases, the speed of the engine will begin to increase if the fuel supply is not decreased. On the other hand, if the load on the engine increases, the speed of the engine will begin to decrease if the fuel supply is not increased. The purpose of the governing is to supply the fuel to the engine according to the load on the engine and to maintain the speed of the engine constant.

22.10.2. The Methods of Governing

The governing of speed of the engine according to the load is done by one of the following methods :

1. The fuel supplied to the engine is completely cut off during few cycles of the engine. This is known as Hit and Miss Governing. This is generally used for gas engine.
2. The fuel supplied per cycle of the engine is varied according to the load on the engine. This is known as "Quality Governing". The A : F ratio is changed according to the load on the engine. Rich mixture is supplied at high loads and lean mixture is supplied at low loads. This is used for Diesel engines.
3. The quantity of air-fuel mixture supplied is varied according to the load on the engine. The A : F ratio of the mixture supplied to the engine at all loads remains nearly constant, therefore it is known as "Quantity Governing". This is used for petrol engine.

The details of each governing method are given below :

22.10.3. Hit and Miss Governing

This method is used for gas engines as well as for oil engines but is more popular in gas engines only.

This system of governing omits the explosions occasionally when the speed of the engine rises above the mean speed of the engine. The number of omitted explosions are increased with the increase in speed.

The usual method adopted for missing an explosion is to omit the opening of the gas valve in case of gas engine and putting the plunger of the oil pump out of action in the case of oil engines. During the missing cycle, the engine performs an idle cycle.

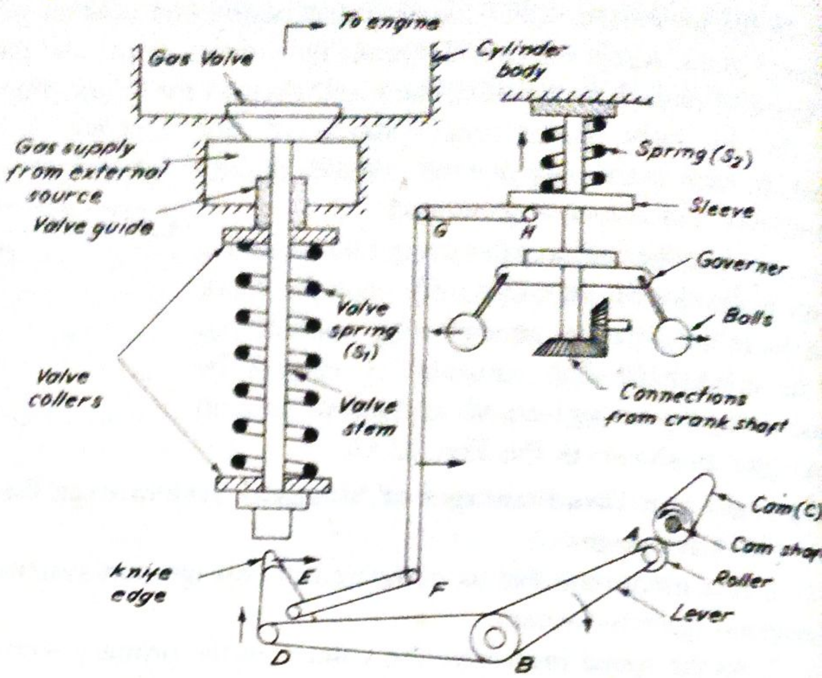


Fig. 22.42. Hit and Miss Governing.

The outline of the method used in gas engine is shown in Fig. 22.42.

The position of all the components of the system are shown in the figure when the engine is running at full load. The cam '*C*' rotates at half speed of the crankshaft. As the cam *C* pushes the point *A*, the point *D* is lifted upwards because the lever *BD* turns about the fulcrum *B* and hits the valve steam through the knife-edged point *E* and opens the valve to allow the gas to the engine cylinder. At full load condition, there is working stroke for every cycle of the engine.

When the load on the engine is decreased, the speed of the crank-shaft increases and the speed of the governor also. The balls fly out as the speed of the spindle, on which the governor is fixed, increases. The governor sleeve is pushed up and the point '*H*' of the lever *GH* also goes up and the point *F* on the lever *GF* moves towards the right as shown in figure. The point '*E*' on the knife edge is also moved towards the right and misses the opening of the gas valve. The loss of power due to missing cycle decreases the speed of the engine. The point *E* is lifted up by the cam during the missing cycle also but as it is pushed away (towards the right) from the original position, it is not possible to open the gas valve. The number of the missing cycles increases with the further decrease in load. The missing cycles are zero when the engine is running at full load condition. The directions of motion of all components under low load condition are shown by an arrow on the figure.

This method is known as "Hit and Miss" method because the valve is opened by giving the hit and speed control is achieved by missing the openings of the gas valve.

The principle and mechanism of the method used for oil engine are exactly same but the plunger of the fuel pump is put out of action instead of gas valve.

With this method of governing the engine, the engine either works under maximum efficiency condition or does not fire at all. This method gives better economy at light loads than any other method. The great disadvantage of this method is, the engine requires heavy flywheel as the absence of turning effort on the crankshaft during the idle cycle. This method is used for the engines of small B.P. (below 40 B.P.) and do not require close speed regulation.

22.10.4. Quality Governing

The amount of fuel supplied to the diesel engine cylinder per cycle is varied according to the load on the engine in this method of governing.

The quantity of fuel supplied according to the load on the engine is varied by one of the following methods.

(a) The stroke of the fuel pump plunger is varied by the governor and quantity of oil supplied is varied according to load.

The weight of fuel supplied by the fuel pump is given by

$m_f = \frac{\pi}{4} d^2 L \rho_f$ where d is the diameter of the fuel pump and L is the stroke of the fuel pump. As L is varied the fuel supplied to the engine cylinder also varies.

(b) A control valve is inserted to the delivery side of the fuel pump. The opening of the valve is controlled by the governor. It opens after a part of delivery stroke is performed. In this system, the oil is delivered to the engine cylinder from the fuel pump during some part of the delivery stroke and returned back to the suction side during the remaining part of the delivery stroke.

(c) The closing of suction valve of the fuel pump may be delayed. The suction valve of the fuel pump remains open during first part of the delivery stroke, therefore part of the fuel oil is returned back to the fuel pump during some part of the delivery stroke and delivered to the engine during the remaining part of the delivery stroke. The method is known as "Spill Method".

(d) The stroke of the pump plunger remains constant at all loads but the effective stroke is changed according to the load on the engine. By changing the angular position of the helical groove on the plunger of the fuel pump relative to the suction port, the amount of fuel delivered can be changed. The details of this are already given under the heading "fuel pump". This is the common method used in all modern C.I. high speed engines.

In all these systems, the air supply remains constant and the quantity of fuel supplied is changed, therefore the quality of the mixture (A : F) changes according to the load on engine.

22.10.5. Quantity Governing

This is used in many gas engines and is commonly used for all petrol engines. The mixture strength supplied to the engine is maintained constant but the quantity supplied to the engine is varied by means of a throttle valve. The movement of the throttle valve is regulated by the lift of the centrifugal governor. The arrangement is shown in Fig. 22.43.

As the engine speed increases (due to decrease in load), the governor balls fly out and the governor sleeve lifted up and partly throttle valve is closed reducing the quantity of mixture supplied to the engine cylinder. This reduces the indicated mean effective pressure and ultimately the power developed by the engine.

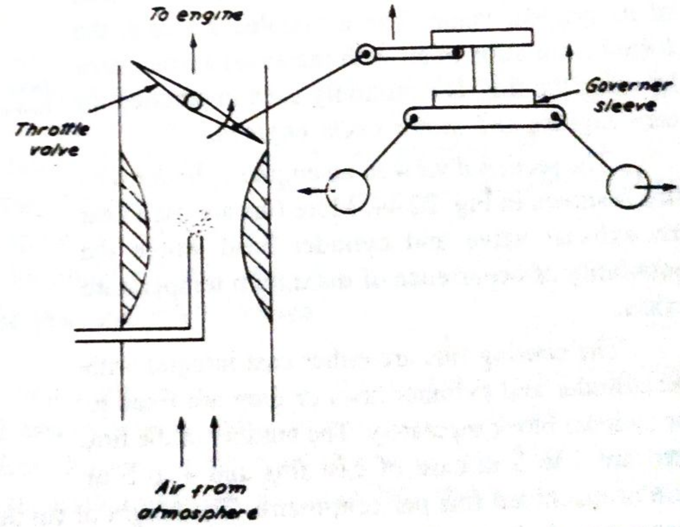


Fig. 22.43. Quantity Governing used for petrol engine.

This system of governing can be used for gas engines in various ways. The air and gas supplied, each can be throttled by separate valves in the air and gas passages and then supplied to the engine or a mixture of air and gas of constant A : F ratio coming out from the mixing valve is supplied to the engine cylinder. The quantity of mixture supplied is controlled by varying the lift of the main inlet valve.

22.11. COOLING OF I.C. ENGINES

22.11.1. The Purpose of Cooling. The peak temperature occurred in reciprocating internal combustion engines are in the range of 2000°C to 2500°C. The large amount of heat produced due to the fuel combustion is absorbed by the cylinder walls, piston, cylinder head and engine valves. The temperature of these parts increase and will reach the average temperature of the burnt gases. The overheating of these parts over 250 to 300°C causes the following effects.

1. The high temperature reduces the strength of the piston and piston rings and uneven expansion of cylinder and piston may cause the seizure of the piston.

2. The high temperature may cause the decomposition of the lubricating oil and lubrication between the cylinder wall and piston may break down resulting in a scuffing of the piston.

3. If the temperature around the valve exceeds 250°C, the over-heating of the valves may cause the scuff of the valve guides due to lubrication break down. Further increase in temperature may cause the burning of valves and valve seats.

4. The tendency of the detonation increases with an increase in temperature of the cylinder body.

5. The pre-ignition of the charge is possible in spark ignition engines if the ignition parts initially are at high temperature.

To avoid all the adverse effects mentioned above, it is necessary to cool the engine. The cooling system used for I.C. engine generally carry 30 to 35% of the total heat generated in the cylinder due to the combustion of fuel.

22.11.2. Air-Cooling of Engines

The heat transfer coefficient for air-cooling is very low as mentioned earlier. This heat transfer coefficient can be increased further by using the forced flow of air over the engine surface as done in aero-engines. The heat transfer coefficient with air-cooling with forced circulation is also considerably lower (50 W/m^2-K) compared with water cooling system. The other method of increasing the heat transfer rate from the cylinder surface is to increase the surface area by providing the fins. The use of fins increases the heat transfer surface by 5 to 10 times of its original value. The air-cooled systems, the forced circulation of air with increased surface area by using the fins, is commonly used in practice for aero-engines and motor cycle engines.

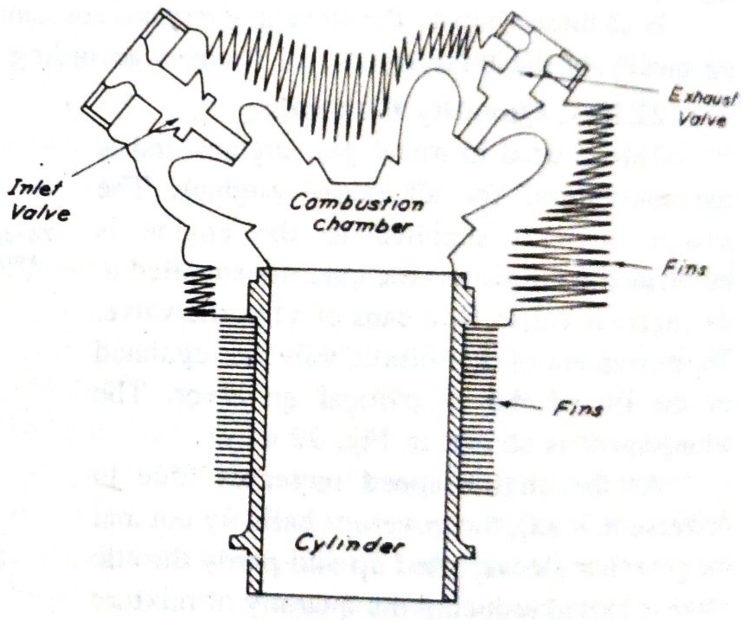


Fig. 22.44. Fins on cylinder.

The sectional view of an engine-cylinder with fins is shown in Fig. 22.44. More fins are used near the exhaust valve and cylinder head where the possibility of occurrence of maximum temperature exists.

The cooling fins are either cast integral with the cylinder and cylinder head or they are fixed to the cylinder block separately. The number of the fins used are 2 to 3 in case of cast fins and 4 to 5 in case of machined fins per centimetre. The height of fin depends on the type of material and manufacturing process used. Generally the height of fin used lies between 2 cm to 5 cm.

Advantages and Disadvantages of Air-Cooled System

1. The design of air-cooled system is simple and less costly.

2. Each cylinder of the multi-cylinder engine can be removed separately as no common cooling system is used for the engine. It is easy to renew in case of accident.

3. There is no danger of leakage of the coolant.

4. The freezing in the cooling system is not at all a danger which is very common in water-cooled systems.

5. The installation of air-cooled system is easier as it does not require radiator, headers and piping connections.

6. The weight of the cooling system per B.P. of the engine is far less than water cooling system.

22.11.3. Water Cooling System

The water cooling system is further subdivided into two groups.

1. Thermo-siphon or Natural Circulation System.
2. Forced circulation system.

1. **Thermo-siphon System.** The arrangement of the system is shown in Fig. 22.45. The force (pressure head) required to circulate the water through the system is the difference in pressure head due to hot and cold water. This force is given by

$$F = h\,(\omega_c - \omega_h) = h \cdot \Delta\omega.$$

where h = Height of the radiator tubes through which the water is circulated.

ω_c = Weight density of cold water.

ω_h = Weight density of hot water.

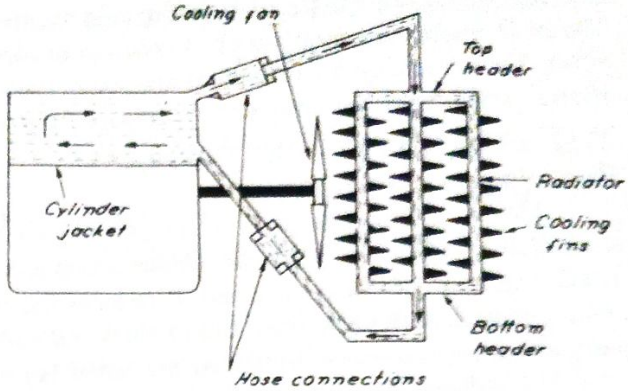


Fig. 22.45. Thermo siphon system.

The difference in density is limited as the rise in temperature of the water passing through the engine is limited. The rate of circulation is less as the force causing the flow of water is limited. This cannot be used for heavy duty engines as the heat carrying capacity of this system is limited.

The water as passed through the radiator is cooled by the flow of air passed over the radiator tubes by the cooling fan. The cooled water rises to the cylinder jacket ; take the heat from the cylinder wall and then it enters into the radiator from the top header and comes down. It is cooled as it is passed through the radiator tubes.

The limitations of this system are listed below :

1. The engine should be placed as low as possible in relation to the raaiator as the force causing the flow is limited by the temperature difference of hot and cold water.

2. The water level in the system should not fall below the level of the delivery pipe ; otherwise the circulation of water in the system will stop. This causes the boiling of water and formation of steam resulting in further loss of water which may damage the engine in a short period.

3. The use of this system is recommended for small capacity engines.

22.11.4. Advantages and Disadvantages of Water-Cooled System

Advantages :

1. The specific fuel consumption of water-cooled engine is less than that of the air-cooled engine.
2. Uniform cooling of valve, cylinder head and cylinder is possible with water cooling.
3. It is necessary to keep the engine at the front for the mobile vehicles and air craft engines for air-cooling but this is not at all necessary with water-cooled engines. The cooling system can be located conveniently at required place.
4. As far as design of cooling system is concerned, the engine size does not involve anv serious problem.
5. Compact engine design with minimum frontal area is possible.

Disadvantages :

1. It is dependent on supply of water.
2. Serious damage may be caused to the engine within a short period of time in the case of failure of the cooling system.
3. The pump requires considerable power compared with the power required for the fan.
4. Initial and maintenance costs are higher.

Antifreeze Solutions. When the temperature of atmosphere falls below 0°C, there is every possibility of freezing the water, circulated in the cooling system of the engine. The freezing of water may stop the circulation and finally it may reduce the cooling. It may also cause damage due to volume expansion during freezing. To prevent the freezing during cold weather conditions, the antifreeze solutions are generally used. The main antifreezes used are (1) a solution of alcohol and water and (2) solution of ethylene glycol and water. The percentage by volume of antifreeze used in water is dependent on the atmospheric temperatures. Higher percentages are used with decreased atmospheric temperatures.

22.12. LUBRICATION OF I.C. ENGINES

Requirements of Lubrication

Almost all machine parts of an I.C. engine have relative motion and rub against each other. The lubrication is required to reduce the rubbing action and increase the life of the engine. The purpose of lubrication in I.C. engine is generally two fold. It reduces the rubbing action between different machine parts having relative motion with each other and to carry out part of the heat generated inside the cylinder. The engine parts which are generally lubricated are listed below :

1. Cylinder and piston.
2. Main bearings
3. Big end and small-end bearings of the connecting rod.
4. Gears carrying the motion from one shaft to another shaft.

There are many other minor parts which also require lubrication as rocker arm, push arm, camshaft drive and so on.

The lubrication system is considered one of the most important systems to increase the life and for smooth working of the engine.

Desirable Properties of a Lubricant. The lubricant used must have some properties for the successful performance of the engine. The properties required for a good lubricant used in I.C. engine are listed below.

1. Viscosity. It is a measure of fluid resistance to flow and the unit used for the viscosity of the oil is poise. This property is most important property of lubricating oil because it determines how efficiently the oil film separates the moving surfaces from each other and prevents them rubbing directly on each other. The value of the viscosity of lubricant used should lie within a certain range because lower viscosity will cause seizing of the rubbing surfaces therefore viscosity of the lubricant should be selected in such a way that it should not go down below a certain minimum value at the highest temperature at which the parts are likely to operate. The higher viscosity than this will be always safe but it gives higher coefficient of friction which causes greater power loss.

Flash Point. Flash point of the lubricant is the temperature at which it forms vapours and produces combustible mixture with air. The high flash point is always desirable because low flash point will allow the lubricating oil to burn and deposit the carbon on the different moving parts. The minimum flash point of lubricating oil used in I.C. engine varies from 200 to 250°C.

Pour Point. Pour point of the lubricating oil is the temperature below which oil will cease to flow in the pipe line under controlled test conditions. Low pour points are always recommended as its flow will start even when the engine is started in cold weather.

Carbon Residue. The carbon percentage in lubricating oil should be as minimum as possible because its burning forms the carbon deposits on piston head, piston rings and combustion chamber walls and increases the running action.

Neutralisation. The lubricating oil should be neither acidic nor alkaline otherwise it will have corrosive action on the parts of the engine. The acidity of the oil is generally given by noting the neutralization number of an oil. The neutralization numbers of different lubricating oils are given in different codes.

Lubricating Systems. The lubrication system is subdivided mainly into three groups.

1. Charge Lubrication System. This is the most simplest method of lubrication and does not require oil-filter and oil pump. In this system, the lubricating oil is pre-mixed with the petrol therefore the fuel carries the lubricating oil in the cylinder which helps for lubricating the piston and cylinder. Most of the oil burns with the fuel due to high temperature and burnt oil is carried with the exhaust gases. The lubricating oil cannot be recovered in this system.

This type of lubrication is generally used for two stroke spark ignition engines of scooter and motor cycle. The quantity of lubricating oil mixed with the petrol is 3 to 6% of petrol.

The advantages of this system are listed below :

1. It does not require seperate lubricating system so it is most economical.
2. There is no risk of failure of lubrication system.
3. The lubricating oil supplied is regulated at various loads and speeds by the increased fuel flow.

The carbon deposits due to the burning of the oil on the spark plug and on other parts and non-recovery of the oil used are the main disadvantages of this system.

Wet Sump Lubrication System. This system employes a large capacity oil sump at the base of crank case and oil is passed to the different parts with the help of pressure pump. The oil returns back to the sump after serving the purpose. The oil under-pressure is circulated generally through the different parts. This system is further subdivided into splash lubrication and pressure lubrication.

Dry Sump Lubrication System. In this system, the oil from the sump is carried to a separate storage tank outside the engine cylinder block. The oil from the sump is pumped through filter into the storage tank with the help of a pump. The oil from the storage tank is further pumped by the another pump to the cylinder through oil cooler. This is generally used for high capacity engines. The pressure of the oil used in this system lies between 3 to 8 bar.

Lubrication of Different Engine Parts

Lubrication of Main Bearings. The main bearings are lubricated satisfactorily with the help of ring or chain type feeder. The arrangement of the system is shown in Fig. 22.46.

The oil ring rests on the main shaft where a small portion of the main bearing shell has been cut-away as shown in the figure. The lower end of the oil ring is allowed to submerge in the oil bath as shown in the figure. The oil ring rotates with the main shaft and carries the oil from the oil bath to the bearing and it is distributed to the bearing through the oil groove. The surplus oil flows to the ends of the bearing and drops back into the oil bath. Chains or more rings are provided instead of single ring to carry more oil.

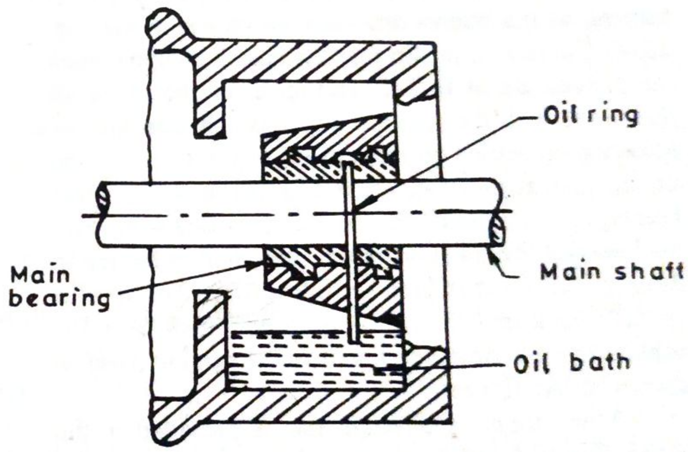


Fig. 22.46. Ring Lubrication.

This type of lubrication is more useful for medium speed engines because at high speeds, the oil will be thrown off due to centrifugal force and at low speeds, the amount of oil carried is not sufficient.

Lubrication of Cylinder and small end bearing of connecting rod. The cylinder and small end bearing (gudgeon pin) are lubricated with the help of side feed lubricator as shown in Fig. 22.47.

The oil is supplied to the surface of piston thorugh the hole provided in the cylinder wall. The oil falling on the surface of the piston is spread over the surface of the cylinder walls.

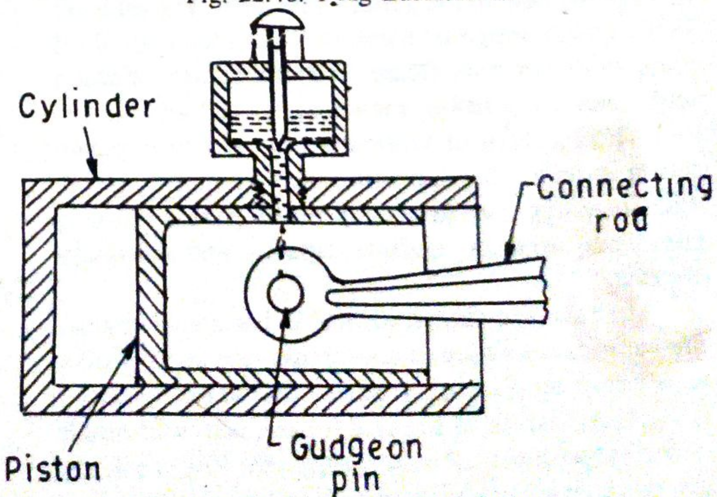


Fig. 22.47. Side feed lubricator.

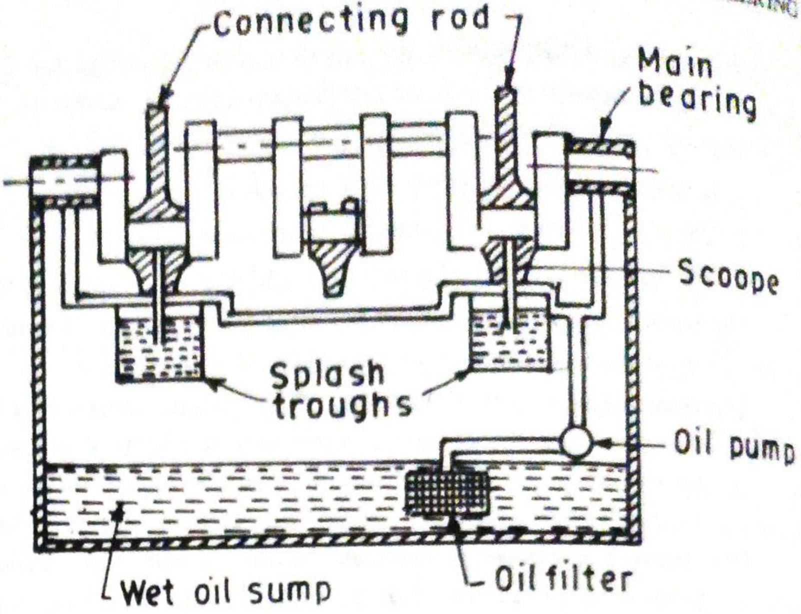


Fig. 22.48.Splash lubrication for multi-cylinder engine.

A hole is also provided in the piston wall just above the hole in the bearing of the small end of the connecting rod as shown in the figure. When these two holes come in line with the hole in the cylinder wall, the drops of oil fall directly in small end bearing and gets lubricated. The supply of oil to the small end bearing takes place twice in one revolution.

Splash Lubrication. The another method which is commonly used for lubricating the cylinder and piston is known as "Splash Lubrication". With the help of this system, the small end, and big end of connecting rod as well as main bearings and cam-shaft bearing are also lubricated.

The arrangement o the splash lubrication used for multicylinder engine is shown in Fig. 22.48.

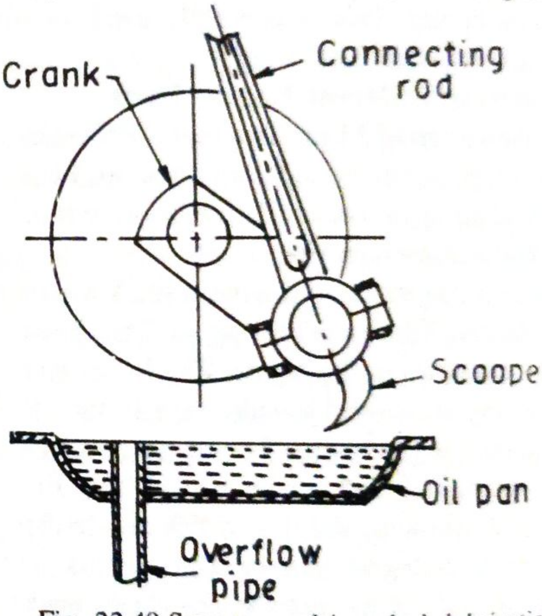
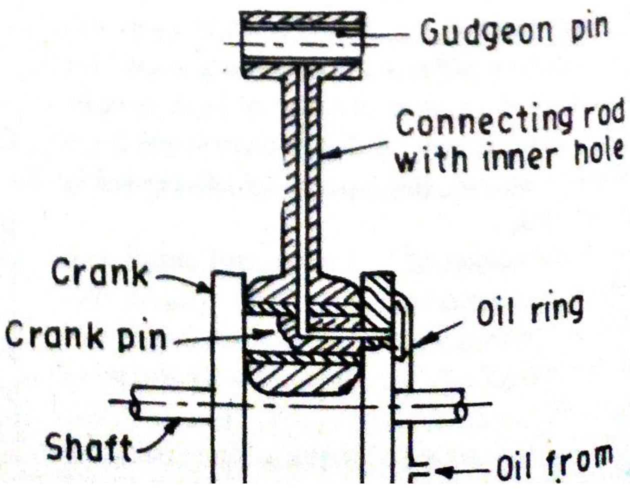


Fig. 22.49.Scoope used in splash lubrication.

The scoopes are provided to the caps of big-end-bearing of the connecting rods as shown in the Fig. 22.49. These scoops dip into the splash troughs when the pistons are at B.D.C. and splashes the oil in all directions with the rotation of cranks. A thin mist of splashed oil settles on the surface of the cylinder and on the other parts which are to be lubricated. The main bearings and cam shaft bearings are provided with small pockets and the oil splashed by scoops is collected in those pockets and is used for lubrication. The surplus oil falls back into the oil sump. Sometimes the oil is supplied to the main bearings from the pump itself as shown in the figure.

Many times, a through hole is provided in the connecting rod and it is connected with the scoope, therefore some oil is supplied to the crank pin and through the hole to the gudgeon pin also. The oil level in the splash trough is maintained with the help of oil pump as shown in the figure. The arrangement of scoop with connecting rod is shown in Fig. 22.49.



This system of lubrication is used to lubricate piston, cylinder, big and small end of connecting rod, main bearings and cam-shaft bearings also. This is commonly used for medium capacity and stationary engines.

In a single cylinder, vertical or horizontal engine, the pump is not required and crank case sump works as a splash tough and simplifies the whole system.

Lubrication of big end (crank pin) and small