# Module – II

# Fuels, Fuel Supply Systems for SI and CI Engines

## Introduction

In an engine, the combustion of fuel with oxygen in the combustion chamber provides the energy necessary to drive the piston. In a SI engine, the liquid fuel and the air are generally mixed prior to their arrival in the combustion chamber i.e., outside the engine cylinder. The process of preparing this mixture is called carburetion. The basic fuel supply system in a petrol engine consists of a fuel tank, furl lines, fuel pump, fuel filters, air cleaner, carburetor and inlet manifold.

The system responsible for preparing the correct mixture of air and fuel, and directing this mixture to each of the cylinders is known as "Induction System". The Intake manifold is the ducting or piping through which the fuel and air mixture travels from the carburetor to the cylinder. The throttle in the carburetor regulates the quantity of mixture entering the cylinder. The carburetor is a device which atomizes the fuel and mixes it with air.

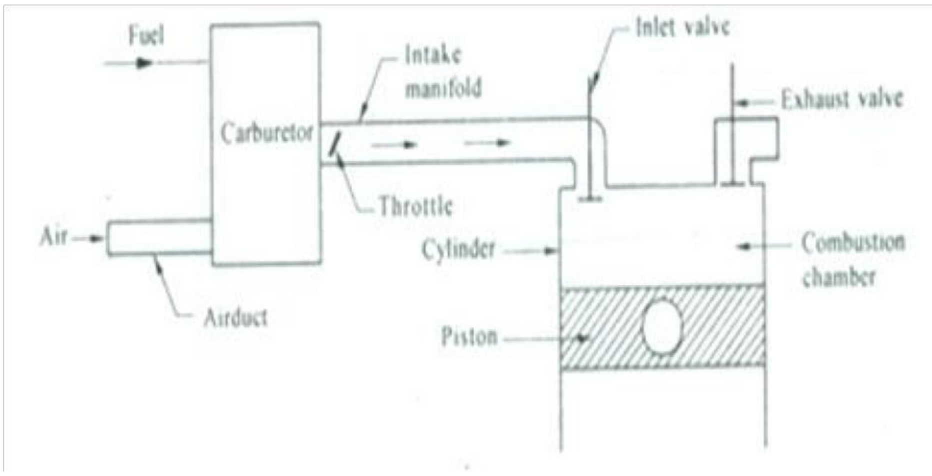


**Fig.2.1 Diagram of induction system**

## 2.1 Conventional fuels

Traditional energy sources or fossil fuels (petroleum, oil, coal, propane, and natural gas). In some cases nuclear materials such as uranium are also included. Some conventional sources typically used are fossil fuels, nuclear power, hydropower, and geothermal energy.

**Fossil Fuels:**

Clean coal technologies imply much greater processing to reduce final emissions. The resources deplete with use, so the prices will increase when demand chases supply.

**Hydropower:**

The larger hydropower dams are in place. Some want them removed, claiming that the electricity can be offset by improved efficiency and conservation. Smaller dams are being removed, yet they may be installed in other locations.

**Nuclear:**

Nuclear energy has a social problem, and only now are new plants being considered. Without reprocessing "spent fuel", the time to peak ore extraction is about 80 years.

**Geothermal:**

Geothermal energy is possible in non geyser areas where air conditioning and heating can make use of the ground heat flux.

## 2.2 Alternative fuels

Alternative fuels, known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Conventional fuels include: fossil fuels (petroleum (oil), coal, and natural gas), as well as nuclear materials such as uranium and thorium, as well as artificial radioisotope fuels that are made in nuclear reactors. Some well known alternative fuels include biodiesel, bio alcohol (methanol, ethanol, butane) chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non fossil natural gas, vegetable oil, propane, and other biomass sources.

**Bio-fuel:**

Bio-fuels are also considered a renewable source. Although renewable energy is used mostly to generate electricity, it is often assumed that some form of renewable energy or a percentage is used to create alternative fuels.

**Biomass:**

Biomass in the energy production industry is living and recently dead biological material which can be used as fuel or for industrial production.

**Algae-based fuels:**

Algae-based bio-fuels have been promoted in the media as a potential panacea to crude oil-based transportation problems. Algae could yield more than 2000 gallons of fuel per acre per year of production. Algae based fuels are being successfully tested by the U.S. Navy Algae-based plastics show potential to reduce waste and the cost per pound of algae plastic is expected to be cheaper than traditional plastic prices

**Biodiesel:**

Biodiesel is made from animal fats or vegetable oils, renewable resources that come from plants such as, jatropha, soybean, sunflowers, corn, olive, peanut, palm, coconut, safflower, canola, sesame, cottonseed, etc. Once these fats or oils are filtered from their hydrocarbons and then combined with alcohol like methanol, biodiesel is brought to life from this chemical reaction. These raw materials can either be mixed with pure diesel to make various proportions, or used alone. Despite one's mixture preference, biodiesel will release smaller number of pollutants (carbon monoxide particulates and hydrocarbons) than conventional diesel, because biodiesel burns both cleanly and more efficiently. Even with regular diesel's reduced quantity of sulfur from the ULSD (ultra-low sulfur diesel) invention, biodiesel exceeds those levels because it is sulfur-free

**Alcohol fuels:**

Methanol and ethanol fuel are primary sources of energy; they are convenient fuels for storing and transporting energy. These alcohols can be used in internal combustion engines as alternative fuels. Butane has another advantage: it is the only alcohol-based motor fuel that can be transported readily by existing petroleum-product pipeline networks, instead of only by tanker trucks and railroad cars

**Ammonia:**

Ammonia (NH3) can be used as fuel. Benefits of ammonia include no need for oil, zero emissions, low cost, and distributed production reducing transport and related pollution

**Carbon neutral fuel:**

Carbon neutral fuel is synthetic fuel—such as methane, gasoline, diesel fuel or jet fuel produced from renewable or nuclear energy used to hydrogenate waste carbon dioxide recycled from power plant flue exhaust gas or derived from carbonic acid in seawater.

**Hydrogen:**

Hydrogen is an emission less fuel. The byproduct of hydrogen burning is water, although some mono-nitrogen oxides NOx are produced when hydrogen is burned with air Liquid nitrogen is another type of emission less fuel.

**Compressed air:**

The air engine is an emission-free piston engine using compressed air as fuel. Unlike hydrogen, compressed air is about one-tenth as expensive as fossil oil, making it an economically attractive alternative fuel.

**CNG fuel:**

CNG vehicles can use both renewable CNG and non-renewable CNG. Conventional CNG is produced from the many underground natural gas reserves are in widespread production worldwide today. New technologies such as horizontal drilling and hydraulic fracturing to economically access unconventional gas resources, appear to have increased the supply of natural gas in a fundamental way.

Renewable natural gas or biogas is a methane based gas with similar properties to natural gas that can be used as transportation fuel. Present sources of biogas are mainly landfills, sewage, and animal/agri waste. Based on the process type, biogas can be divided into the following: Biogas produced by anaerobic digestion, Landfill gas collected from landfills, treated to remove trace contaminants, and Synthetic Natural Gas (SNG)

## 2.3 Normal and abnormal combustion

Under ideal conditions the common internal combustion engine burns the fuel/air mixture in the cylinder in an orderly and controlled fashion. The combustion is started by the spark plug some 10 to 40 crankshaft degrees prior to top dead center (TDC), depending on many factors including engine speed and load. This ignition advance allows time for the combustion process to develop peak pressure at the ideal time for maximum recovery of work from the expanding gases.

The spark across the spark plugs electrodes forms a small kernel of flame approximately the size of the spark plug gap. As it grows in size, its heat output increases, which allows it to grow at an accelerating rate, expanding rapidly through the combustion chamber. This growth is due to the travel of the flame front through the combustible fuel air mix itself, and due to turbulence which rapidly stretches the burning zone into a complex of fingers of burning gas that have a much greater surface area than a simple spherical ball of flame would have. In normal combustion, this flame front moves throughout the fuel/air mixture at a rate characteristic for the particular mixture. Pressure rises smoothly to a peak, as nearly all the available fuel is consumed, then pressure falls as the piston descends. Maximum cylinder pressure is achieved a few crankshaft degrees after the piston passes TDC, so that the force applied on the piston (from the increasing pressure applied to the top surface of the piston) can give its hardest push precisely when the piston's speed and mechanical advantage on the crank shaft gives the best recovery of force from the expanding gases, thus maximizing torque transferred to the crank shaft.

When unburned fuel/air mixture beyond the boundary of the flame front is subjected to a combination of heat and pressure for a certain duration (beyond the delay period of the fuel used), detonation may occur. Detonation is characterized by an instantaneous, explosive ignition of at least one pocket of fuel/air mixture outside of the flame front. A local shockwave is created around each pocket and the cylinder pressure may rise sharply beyond its design limits.

If detonation is allowed to persist under extreme conditions or over many engine cycles, engine parts can be damaged or destroyed. The simplest deleterious effects are typically particle wear caused by moderate knocking, which may further ensue through the engine's oil system and cause wear on other parts before being trapped by the oil filter. Severe knocking can lead to catastrophic failure in the form of physical holes punched through the piston or cylinder head (i.e., rupture of the combustion chamber), either of which depressurizes the affected cylinder and introduces large metal fragments, fuel, and combustion products into the oil system. Hypereutectic pistons are known to break easily from such shock waves

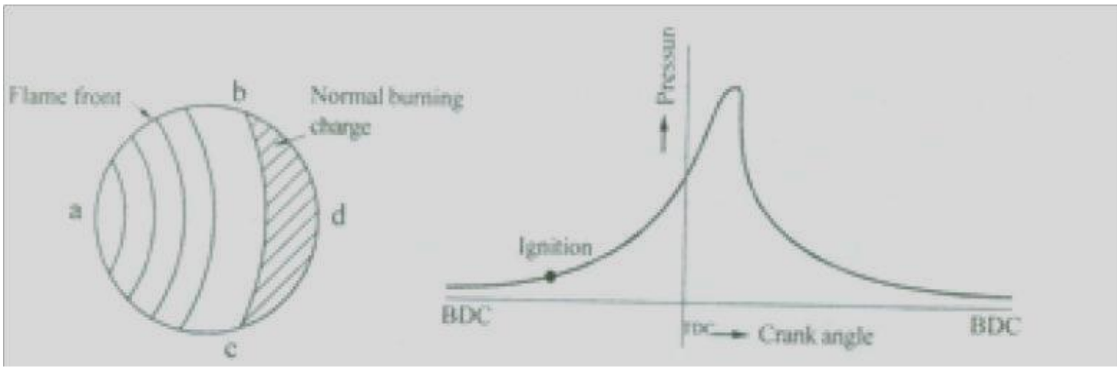


**Fig.2.2 Normal combustion**

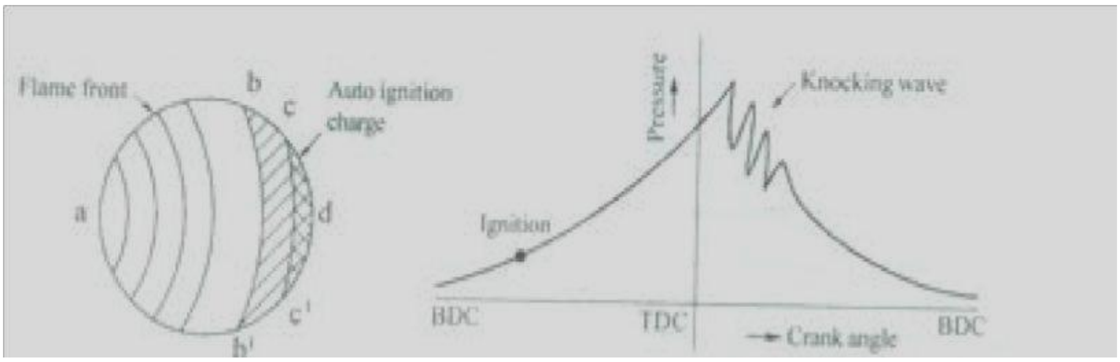


**Fig.2.3 Combustion with Detonation**

**Detonation** can be prevented by any or all of the following **technique**s:

1. The use of a fuel with high octane rating, which increases the combustion temperature of the fuel and reduces the proclivity to detonate.

2. Enriching the air–fuel ratio which alters the chemical reactions during combustion, reduces the combustion temperature and increases the margin above detonation;
3. Reducing peak cylinder pressure.
4. Decreasing the manifold pressure by reducing the throttle opening, boost pressure or reducing the load on the engine.

## 2.4 Cetane and octane numbers

**Cetane numbers:**

In diesel engines cetane number is a measure of ignition lag. Cetane is straight chain paraffin assigned with a rating of 100 cetane numbers (CN) and it has good ignition quality. It is mixed with al ha-methylnaphthalene a hydrocarbon with poor ignition quality i.e., with zero cetane number. A CFR engine running under prescribed conditions test the fuel with this mixture. Thus the cetane number of the fuel is defined as the percent by volume of cetane in a mixture of cetane a I ha-methyl that produces same ignition lag as the fuel being tested, in the same engine and under the same operating conditions.

For a diesel fuel, cetane rating is a measure of its ability to auto ignite readily when it is injected in to the compressed air in the engine. The ignition delay is influenced by several engine design parameters such as compression ratio, injection rate, injection time inlet air temperature etc. The hydrocarbon composition of the fuel and its volatility characteristics also affects the ignition delay. The cetane rating of diesel fuels ranges from 40 to 60. The octane fuels (gasoline) have cetane numbers ranging from 10 to 20 showing their poor suitability as a diesel fuel. High cetane number results in pre-ignition in diesel engine.

**Octane numbers:**

The composition of fuel affects detonation. In SI engines, for a particular fuel, the rating is done by comparing its performance with that of a standard reference fuel which is a combination of ISO octane and n-heptane. ISO octane offers great resistance to detonations and is assigned a rating of 100 octane number. On the other hand, n-heptane is a straight chain paraffin and is as sign e with a rating of '0' octane number.

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 prescribed operating conditions is termed as "octane number" of the el. f octane number of a fuel is 80, it means that it has a same knocking tendency of a mixture with 80% ISO octane and 20% n-heptane by volume. The engine used to conduct test is CFR 0- operative fuel research) variable compression ratio engine.

The fuel is to be tested in the CFR engine until the condition of detonation is reached in the engine. Then a mixture of ISO-octane and n-heptane is prepared to produce detonation under the same conditions as the fuel under test. The percentage by volume of ISO-octane in the mixture is nothing but the octane number of the fuel.

## 2.5 Fuel mixture requirements for SI engines

In stationary engines the desired air fuel ratio means that gives the maximum economy. Actual air fuel mixture requirements in an operating engine vary under variable speed and load conditions. The A/F ratios must change based on maximum over is required. Also required A/F ratio must be provided for transient conditions like, starting a warm-u and acceleration. In all these conditions, exhaust emission should be minimum.

In steady state operation (It means continuous operation at a given speed and over out with normal engine temperature) of automotive engines, there are three main areas which require' different air-fuel ratios. In each of these, the engine requirements differ. As a result the carburetor has to modify A/F. rati9 to satisfy these demands. These ranges are

1. Idling (mixture must be enriched)
2. Cruising (mixture must be leaned)
3. High Power (mixture must be enriched)

## 2.6 Types of carburetors

A carburetor is a device that blends air and fuel for an internal combustion engine. The carburetor works on Bernoulli's principle: the faster air moves, the lower its static pressure, and the higher its dynamic pressure. The throttle (accelerator) linkage does not directly control the flow of liquid fuel. Instead, it actuates carburetor mechanisms which meter the flow of air being pulled into the engine. The speed of this flow, and therefore its pressure, determines the amount of fuel drawn into the airstream.

When carburetors are used in aircraft with piston engines, special designs and features are needed to prevent fuel starvation during inverted flight. Later engines used an early form of fuel injection known as a pressure carburetor.

Under all engine operating conditions, the carburetor must,

1. Measure the airflow of the engine.
2. Deliver the correct amount of fuel to keep the fuel/air mixture in the proper range (adjusting for factors such as temperature)

3. Mix the two finely and evenly

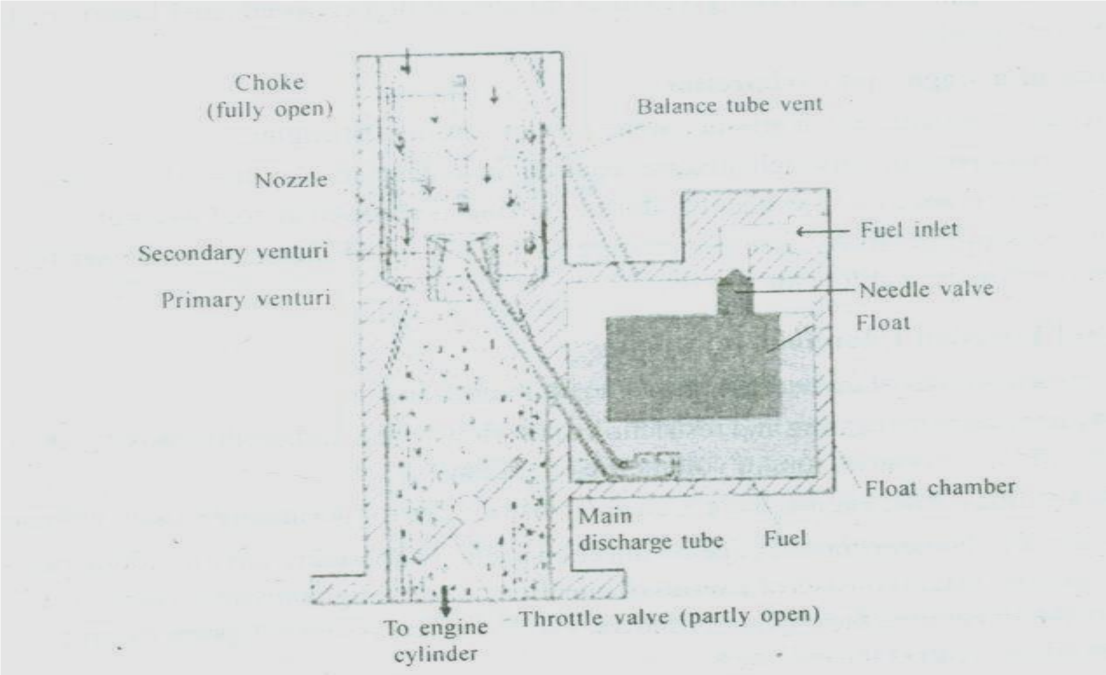


**Fig.2.4 Simple Carburetor**

A carburetor basically consists of an open pipe through which the air passes into the inlet manifold of the engine. The pipe is in the form of a Venturi it narrows in section and then widens again, causing the airflow to increase in speed in the narrowest part. Below the Venturi is a butterfly valve called the throttle valve a rotating disc that can be turned end-on to completely blocks the flow of air. This valve controls the flow of air through the carburetor throat and thus the quantity of air/fuel mixture the system will deliver, thereby regulating engine power and speed. The throttle is connected, usually through a cable or a mechanical linkage of rods and joints or rarely by pneumatic link, to the accelerator pedal on a car or the equivalent control on other vehicles or equipment.

Fuel is introduced into the air stream through small holes at the narrowest part of the Venturi and at other places where pressure will be lowered when not running on full throttle. Fuel flow is adjusted by means of precisely calibrated orifices, referred to as jets, in the fuel path.

## 2.7 C.D. & C.C. carburetors

### Carter Carburetor:

This carburetor is an American make and used in jeep. It is a down draft type and has three venturi (triple venturi diffusing type of choke). The small venturi is kept above the float chamber level, other two below the petrol level, one below other.

The carburetor consists of following circuits.

1. Float Chamber Circuit.
2. Starting Circuit.
3. Idle and Low Speed Circuit.
4. Part and Full Throttle Circuit
5. Acceleration Circuit.

**1. Float Chamber Circuit:**

It consists of a conventional float and a float chamber. Fuel enters the float chamber from main supply. A needle valve maintains fuel level in the float chamber. When the fuel level falls, the needle valve opens the inlet to admit more fuel. Air enters the carburettor from the top. The choke valve in the passage remains open during normal running.

**2. Starting Circuit:**

For starting a choke valve is provided in the air circuit. It is mounted eccentrically. When the engine is fully choked (choke valve is closed), whole of engine suction is applied at the main nozzle, which then delivers fuel. As the air flow is quite small, the mixture supplied is very rich. Once the engine starts, the spring controlled choke valve opens to provide correct amount of air during warming up period. '

**3. Idle and Low Speed Circuits:**

In this carburetor separate idling passage is provided with low speed port and idle port. For Idling rich mixture is required in small quantity and throttle valve is almost closed. The full engine suction is now applied at the idle port through which the air and fuel are drawn thus provides rich mixture. In low speed operation the throttle valve is opened further. The main nozzle also starts supplying the fuel. In this stage fuel is delivered both by main venturi and low speed port through idle passage.

**4. Part and Full Throttle Circuit:**

In part throttling, fuel is delivered by the main nozzle only. During full throttling, maximum air is passing through the venturi. To compensate this a higher rate of fuel flow is desired. This is obtained by mechanical metering method which uses a metering rod having a number of steps of diameter sizes at its bottom. It is connected with the accelerator pedal through Linkage. The area of opening between the metering rod jet and metering rod governs the amount of fuel drawn into the engine. When the accelerator pedal is pressed, the throttle is held wide open and simultaneously the metering rod is lifted up. In this condition, the smallest diameter of the rod is inside the fuel hole (jet), providing larger flow area, thus delivering more fuel.

**5. Acceleration Circuit:**

The accelerating pump will not provide continuous fuel supply for acceleration but only provides extra spurt of fuel to avoid flat spot [popping of engine]. When accelerator pedal is pressed, pump actuates giving an extra spurt of fuel for acceleration.

When the pedal is released the pump piston moves up there by sucking fuel from float chamber for next operation.

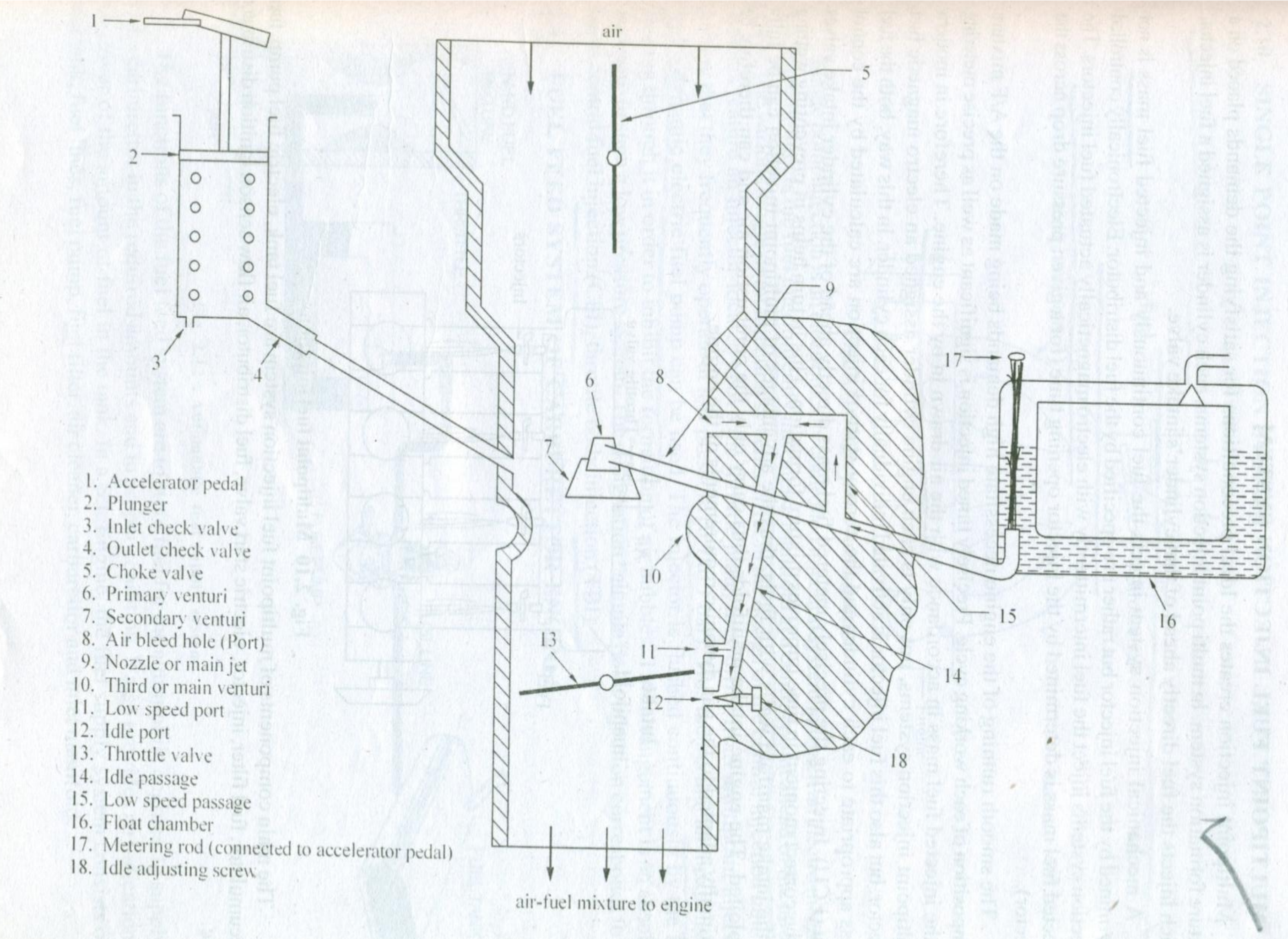


**Fig. 2.5 Carter Carburetor**

## 2.8 Multi point and single point fuel injection systems

Fuel injection is a system for admitting fuel into an internal combustion engine. It has become the primary fuel delivery system used in automotive engines, having replaced carburetors during the 1980s and 1990s. A variety of injection systems have existed since the earliest usage of the internal combustion engine.The primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburetor relies on suction created by intake air accelerated through a Venturi-tube to draw the fuel into the airstream.

Modern fuel injection systems are designed specifically for the type of fuel being used. Some systems are designed for multiple grades of fuel (using sensors to adapt the tuning for the fuel currently used). Most fuel injection systems are for gasoline or diesel applications.

Different methods of fuel injection in a 4 stroke and 2 stroke engine are as shown in fig. 2.6 (a), (b) & (c). In the manifold injection and port injection arrangements, the injector is moved farther from the combustion chamber. This provides a longer period for mixing and warming the charge.

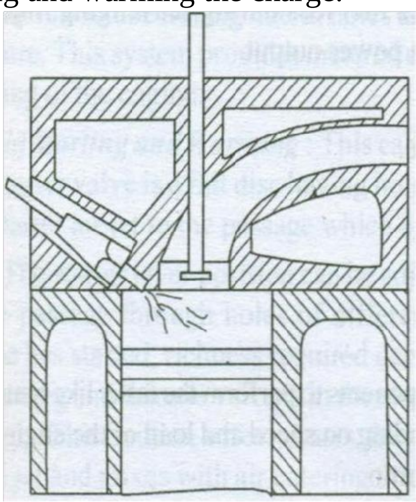

**Fig. (a) Direct injection system**

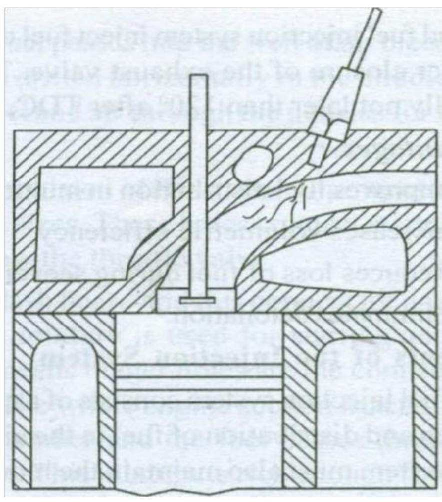

**Fig. (b) Port injection system**

The manifold injection system may be of two types. Single point and multipoint injection. In the first type one or two injectors are mounted inside the throttle body assembly. Fuel is sprayed at one point or location at the center inlet of the engine intake manifold. Hence this method is also called throttle body injection. The later type has one injector for each engine cylinder and fuel is sprayed in more than one location. Port injection employs individual injectors delivering locally to each port.

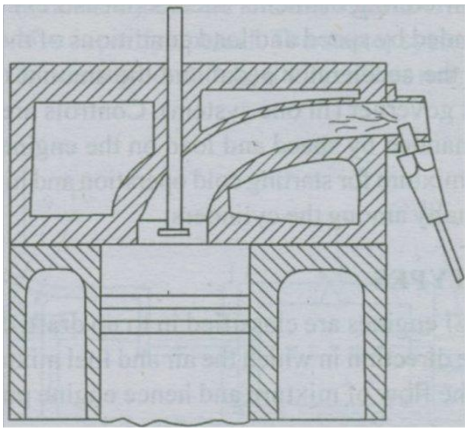

**Fig. (c) Throttle body injection**

In SI engine continuous injection, or timed injection system is used. The later type consists of a fuel supply pump to supply fuel at low pressure (2 bar). A fuel metering or injection pump and nozzle are present. The nozzle injects the fuel in the manifold or cylinder head port. In some design, the fuel is injected directly into the combustion chamber.

Timed fuel injection system injects fuel usually during the first half of the suction stroke. Injection begins after closure of the exhaust valve. This eliminates fuel loss during scavenging. Injection ends usually not later than $120^0$ after TDC, for maximum power output.

**Advantages:**

1. Improves fuel distribution in multi cylinder engine.
2. Increases volumetric efficiency.
3. Reduces loss of fuel during scavenging.
4. Eliminates detonation.

**Components of the Injection System:**

The fuel injection system consists of a number of components to perform the tasks like metering, atomization and distribution of fuel in the air mass. Depending on speed and load of the engine, the injection system must also maintain the required air fuel ratio.

Pumping elements includes necessary piping, filter etc., and are used to move the fuel from fuel tank to the cylinders. Metering elements checks (measures) the correct quantity of fuel and delivers it at the rate demanded by speed and load conditions of the engine. The metering units are controlled by a linkage to the accelerator pedal and the amount of fuel supplied by the pump is controlled by a centrifugal governor (in one system). Controls are provided to adjust the mixture strength (A/F ratio) as demanded by speed and load on the engine. Different controls are used to increase the richness of the mixture for starting cold operation and high speeds. Distributing elements divide the metered fuel equally among the cylinders.

**Single-point or throttle body injection (TBI)**

The earliest and simplest type of fuel injection, single-point simply replaces the carburetor with one or two fuel-injector nozzles in the throttle body, which is the throat of the engine's air intake manifold. For some automakers, single-point injection was a stepping stone to the more complex multi-point system. Though not as precise as the systems that have followed, TBI meters fuel better than a carburetor and is less expensive and easier to service.

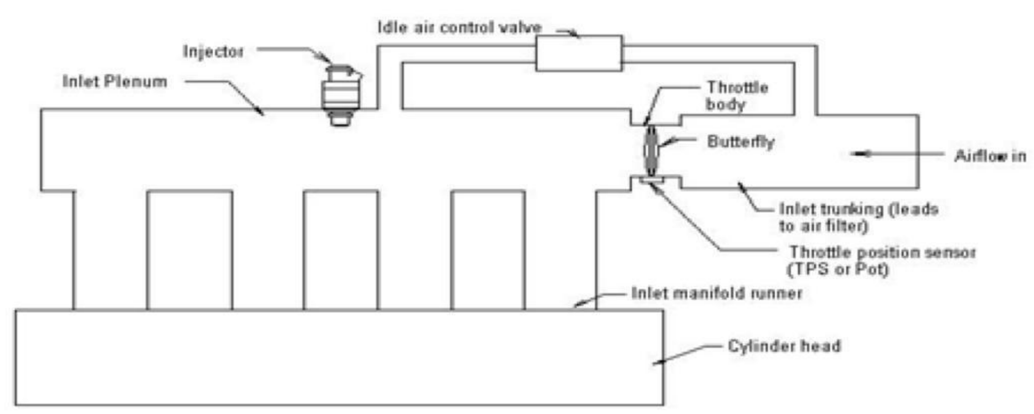


**Fig.2.7 Single point injection**

**Port or multi-point fuel injection (MPFI):**

Multi-point fuel injection devotes a separate injector nozzle to each cylinder, right outside its intake port, which is why the system is sometimes called port injection. Shooting the fuel vapor this close to the intake port almost ensures that it will be drawn completely into the cylinder. The main advantage is that MPFI meters fuel more precisely than do TBI designs, better achieving the desired air/fuel ratio and improving all related aspects.

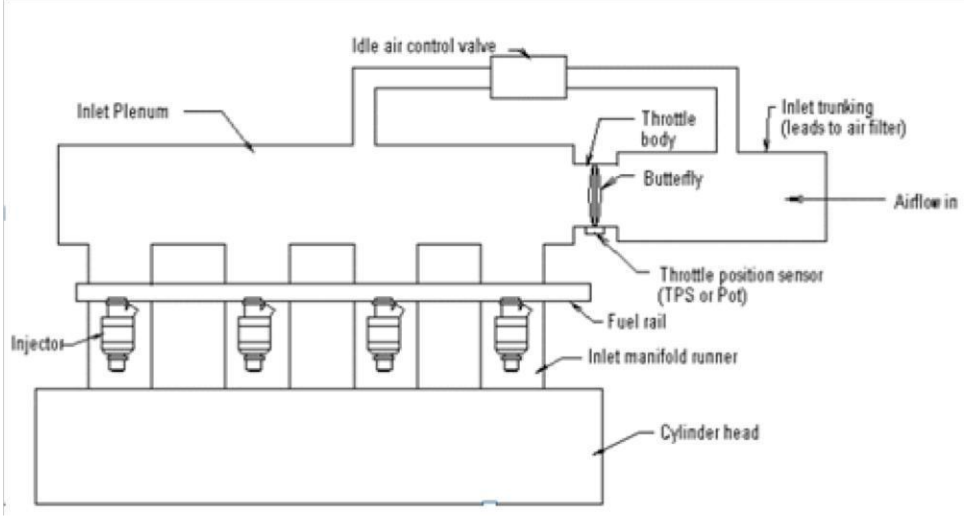


**Fig .2.8 Multipoint injection**

Also, it virtually eliminates the possibility that fuel will condense or collect in the intake manifold. With TBI and carburetors, the intake manifold must be designed to conduct the engine's heat, a measure to vaporize liquid fuel. This is unnecessary on engines equipped with MPFI, so the intake manifold can be formed from lighter-weight material, even plastic. Incremental fuel economy improvements result. Also, where conventional metal intake manifolds must be located atop the engine to conduct heat, those used in MPFI can be placed more creatively, granting engineers design flexibility.

**Types of Fuel Injection Systems:**

**Throttle body injectors or Single Point Injectors (TBI):**

Single-point injection was a first step before the more complex multi-point systems came about. Not as precise as the systems that have evolved, TBI metered fuel better than a carburetor and was less expensive and easier to service.

**Port or multi-point fuel injection (MPFI):**

Multi-point fuel injection has a separate injector nozzle for each cylinder, just outside its intake port, which is why the system is sometimes called port injection. Delivering the fuel vapor this close to the intake port ensures that it will be drawn completely into the cylinder.

The primary advantage is that MPFI meters fuel more precisely than TBI, achieving the desired air/fuel ratio. MPFI lessens the possibility that fuel will condense in the intake manifold.

**Sequential fuel injection (SFI):**

Sometimes called sequential port fuel injection (SPFI) or timed injection, SFI is a type of multi-port injection. Though basic MPFI uses multiple injectors that spray their fuel at the same time or in groups. Sequential fuel injection triggers each injector nozzle independently and is timed like spark plugs. SFI sprays the fuel immediately before or as the intake valve opens.

**Fuel Feed System of Carburettor Engines:**

The functions of the fuel feed system are to store fuel for the automobile engines, to supply it to the carburetor in the required amounts and in proper condition. It also provides an indication to the driver of the amount of fuel in the tank. In a S.I. Engine, the fuel supply system consists of a fuel tank, fuel lines, fuel pump, fuel filter, air cleaner, carburetor and inlet manifold.

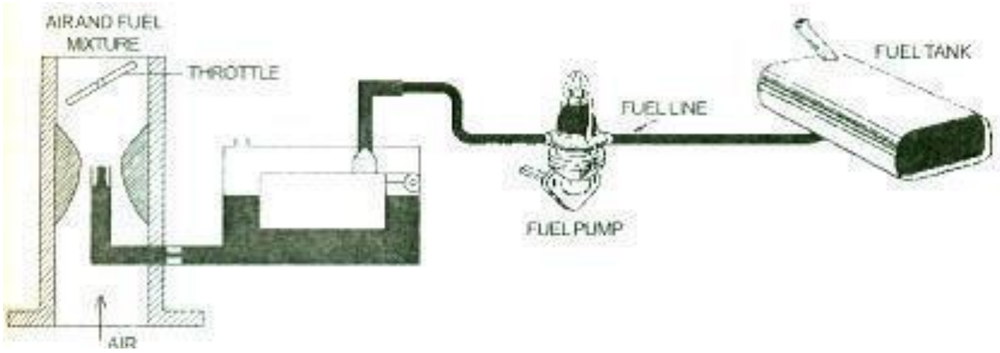


**Fig. 2.9 Automobile fuel supply system**

## 2.9 Fuel transfer pumps

Many types of fuel pumps are used in the modern car fuel feed systems, all of which operate on the same principle. A fuel pump transfers petrol from the tank to carburetor [fuel injection system] through a fine grain filter. It must deliver petrol in sufficient volume at desired pressure to keep the carburetor (float chamber) full of petrol, irrespective of engine speed.

There are two types of pumps which are most commonly used

1. Mechanical type fuel transfer pump [A.C. Mechanical pump].
2. Electrical fuel pump [S U. Electrical pump]

**(a) Mechanical Fuel Pump:** A mechanically operated diaphragm type fuel pump is shown in figure. It is mounted on the engine and is operated by an eccentric mounted on the cam shaft of the engine. The pump consists of a spring loaded flexible diaphragm actuated by a rocker arm which in turn operated by an eccentric.

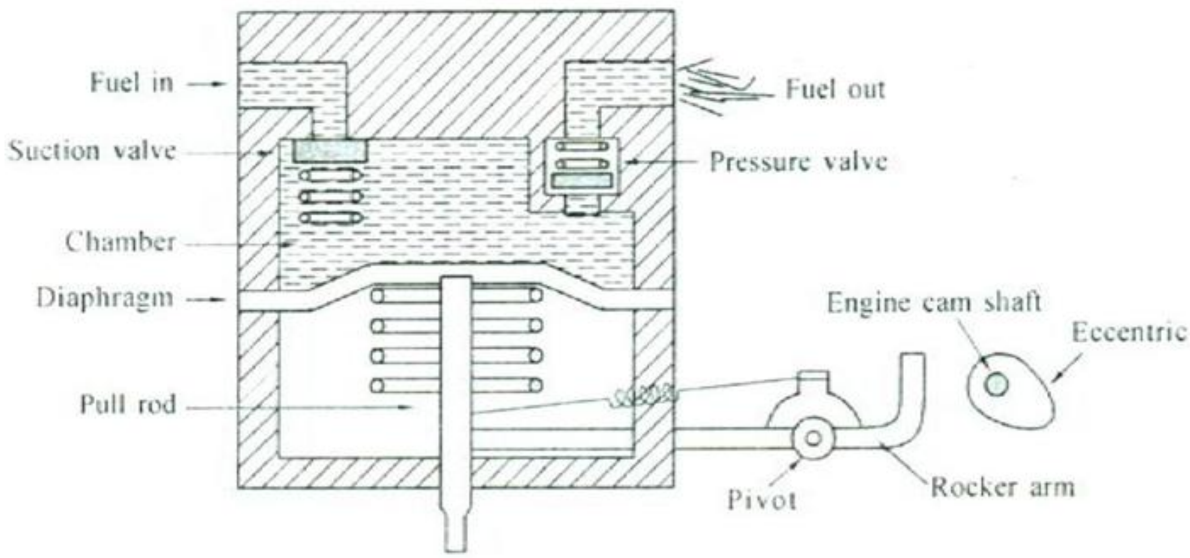


**Fig. 2.10 Mechanical Fuel pump**

Inlet and outlet (spring loaded) valves are provided to ensure fuel flow in the proper direction. As rocker arm is moved by the eccentric, the diaphragm is pulled down, causes a partial vacuum in the chamber. This causes the inlet valve to open and admits fuel into the pump chamber through strainer. Further rotation of the eccentric will release the rocker arm and diaphragm moves upward, causes' inlet valve to close while the outlet valve opens and hence the pump delivers fuel to the carburetor (float chamber).

When the float chamber is full of petrol, pumping of more fuel is not needed till some of it is consumed. If the engine runs continuously at light loads, the earn shaft will be running all the time and there is excessive pressure in the pump. This may damage the pump itself. To avoid this rocker arm and pull rod connection is made flexible and when the float chamber is full, the diaphragm is not operated though the cam shaft is running.

**(b) Electrical Fuel Pump:**

This pump contains a flexible diaphragm which is operated by electrical means [Electro magnet]. The middle of the diaphragm is fixed to an armature. A rod extends from middle of diaphragm and passes through a center hole in the electro magnet (solenoid). The other end of the rod carries electrical contact points. Return springs are used to keep the diaphragm in position.

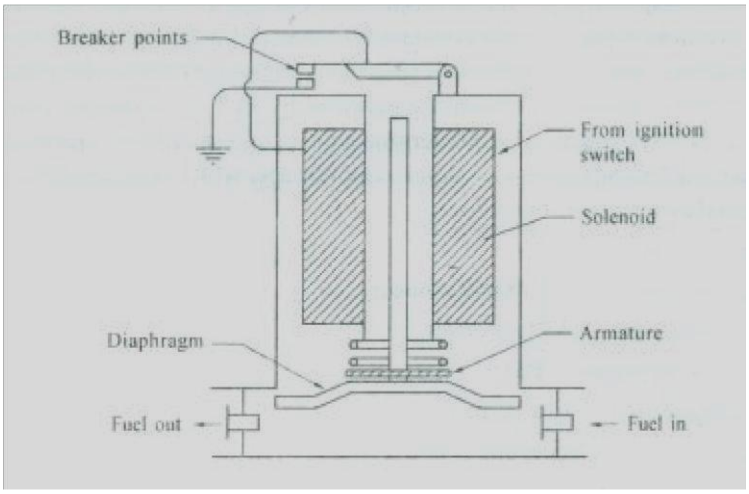


**Fig. 2.11 Electrical pump [S.U. type]**

Closing the ignition switch, energies the electromagnetic winding. Thus magnetic flux is generated which pulls the armature compressing the return spring and there by moves the diaphragm up. This causes suction in the pump chamber and fuel is drawn into the chamber through inlet valve. But as the armature moves, the rod disconnects the breaker points and thus interrupts the electric supply. The electro magnet is de-energized and the armature falls back due to spring action.

This causes the diaphragm to move down creating pressure in the chamber to open outlet valve. Thus fuel is delivered to the float chamber. The cycle repeats and fuel continues to be pumped. These pumps need not be located close to the engine. These electrical pumps are located near the fuel tank and are not subjected to engine heat. These pumps start operating immediately as the ignition is switched on.

## 2.10 Fuel filters

A fine mesh gauge is used as a filter to clean the petrol. It is more suitable where petrol contains very large dust particles, but not so effective in preventing the fine particles and the water from going inside the cylinder. Ordinary chamois leather which is first moistened with petrol can be used as an effective device which allows only petrol to pass through it and water will be intercepted. Fine grit, of course cannot pass through it.

## 2.11 Fuel injection pumps and injectors.

The fuel injection pump delivers accurately, metered quantity of fuel under high pressure, at the correct instant and in the correct sequence, to the injector fitted on each engine cylinder. In most of the engines the injection pressure ranges from 7 to 30 MPa and in some cases it may be as high as 200 MPa.

The timing gears drives the injection pumps and its output is controlled by drives through accelerator pedal. The injection system has to deliver very small volume of fuel, hence the volume of fuel to be metered is very small for each injection. The frequency of injection is quite high. For example, in a 4 stroke, 4 cylinder diesel engine, at maximum speed of6000 rpm, about 150 rnm of fuel is to be metered and injected 20 times in a second.

In a two stroke engine the number of injections per second are twice this valve. Generally the fuel injection pumps are classified in to jerk pump type and distributor type;

### 2.11 (a) Jerk Pump type fuel injection pump:

A single cylinder jerk pump type fuel injection pump is as shown in figure. It consists of a spring loaded delivery valve, plunger, control sleeve and control rack. The fuel quality to be injected is controlled by the plunger which contains a helix at its top end. The plunger in turn is operated by using a cam and tappet.

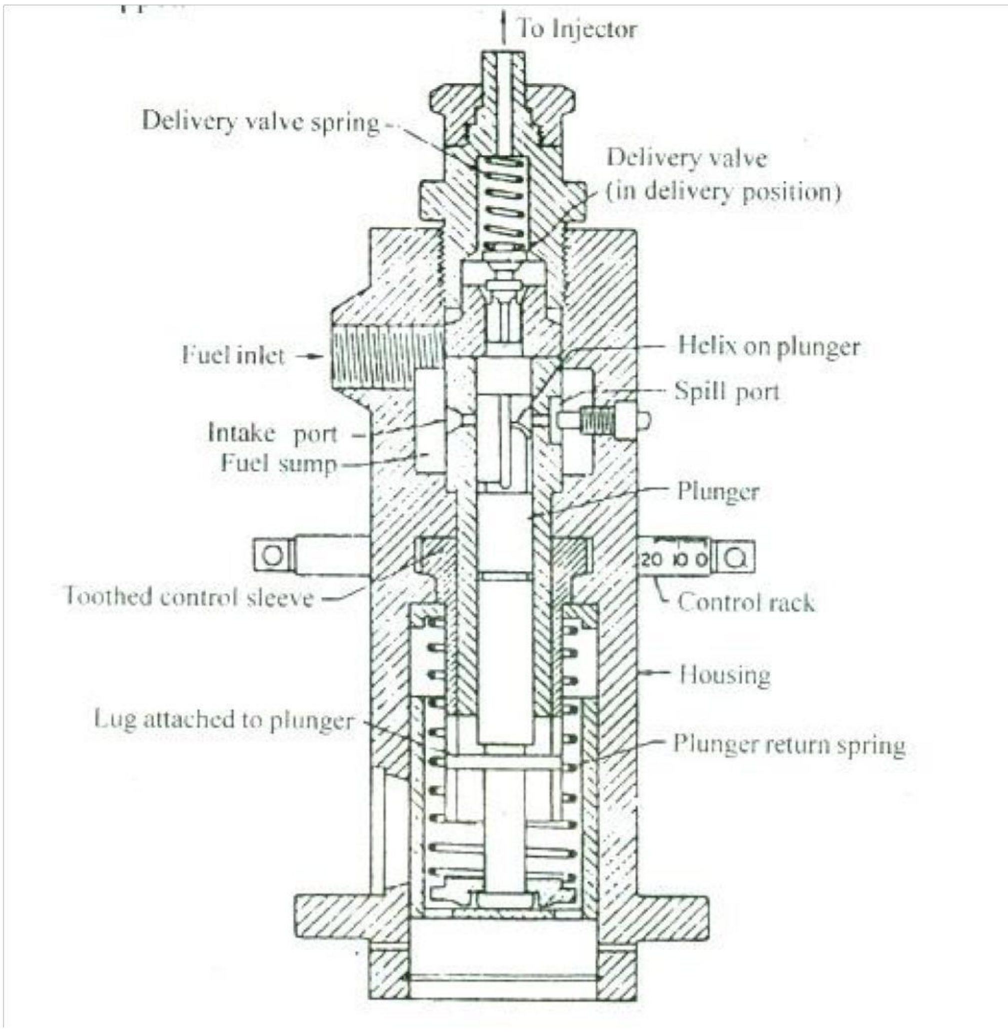


**Fig. 2.12 Single cylinder jerk type fuel injection pump**

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 cam produces forward or delivery stroke and the action of spring returns the plunger. As the plunger performs down ward stroke, it uncovers the inlet port present in the barrel at atmospheric pressure and fills the space above the plunger and also vertical groove and space below the helix.

When the plunger raises up, it covers the ports and compresses the fuel. The compressed fuel lifts the delivery valve and it is supplied to the injector through the delivery valve. As the plunger moves up wards, the spill port will be uncovered by the plunger helix and the helical groove on the plunger connects the space above the plunger with the suction line. The oil at high pressure in the space above the plunger is by passed back in to the pump and there by decreases pressure near the delivery valve. This closes the delivery valve due to action of spring.

The fuel quantity delivered through the delivery valve depends upon the opening position of the spill port with respect to helical groove. Depending on the load on the engine, the position of helical groove with respect to spill port can be changed by rotating plunger with control rack. The quantity of fuel can be varied from zero to that required at full load by changing the positions of the rack.

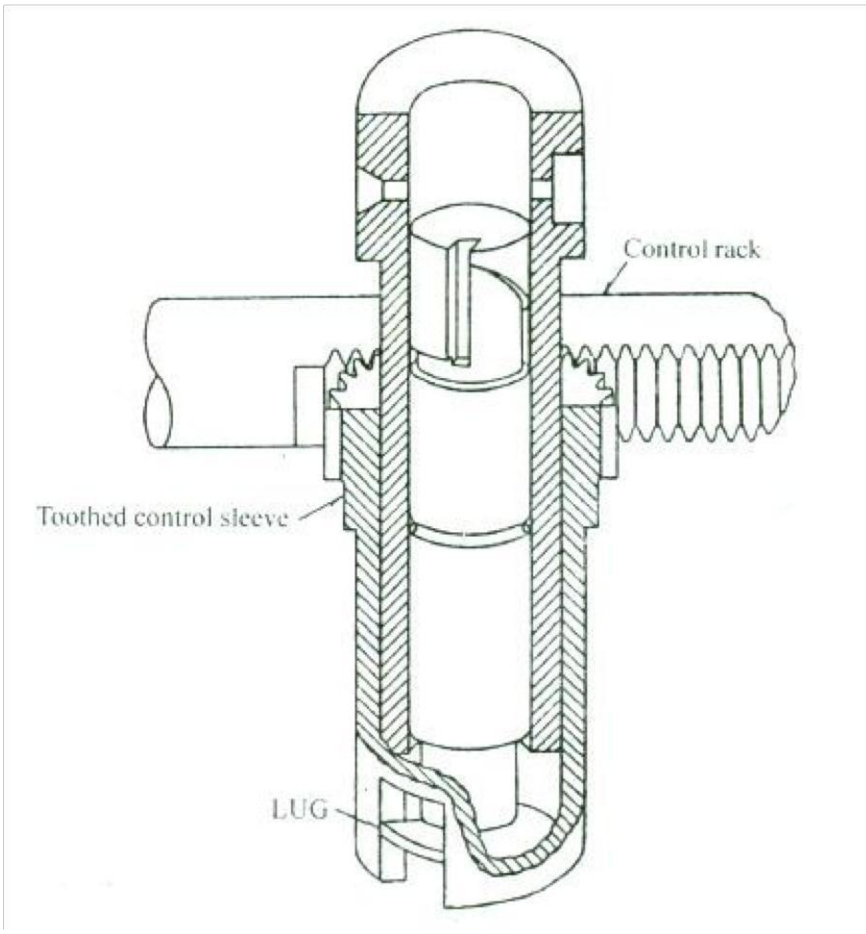


**Fig. 2.13 Arrangement showing the control of fuel delivery**

An Injection Pump is the device that pumps fuel into the cylinders of a diesel engine. Traditionally, the injection pump is driven indirectly from the crankshaft by gears, chains or a toothed belt (often the timing belt) that also drives the camshaft. It rotates at half crankshaft speed in a conventional four-stroke engine. Its timing is such that the fuel is injected only very slightly before top dead centre of that cylinder's compression stroke. It is also common for the pump belt on gasoline engines to be driven directly from the camshaft. In some systems injection pressures can be as high as 200 MPa (30,000 PSI).

Types of Fuel Injectors:

**Top-Feed** – Fuel enters from the in the top and exits the bottom.

**Side-Feed** – Fuel enters on the side on the injector fitting inside the fuel rail.

**Throttle Body Injectors** – (TBI) Located directly in the throttle body.

## Fuel Injectors:

Depending on the method of fuel control the injectors are classified into

(1) Mechanical

(2) Electronic type.

Mechanical method is obsolete now. A governor was used to control fuel supply and a fuel distributor was used to send the fuel to correct injector.

**Mechanical Fuel injection:**

In this system an electrically driven fuel pump delivers the fuel at a specified pressure (700 kpa) into a metering distributor. The relief valve returns excess fuel to the tank and thus maintains the metering distributor at constant pressure. The metering distributor supplies fuel to each injector in turn.

The quantity of fuel delivered is also controlled in the distributor by engine manifold pressure. The injector is held closed until the fuel pressure opens it to deliver atomized spray of fuel.

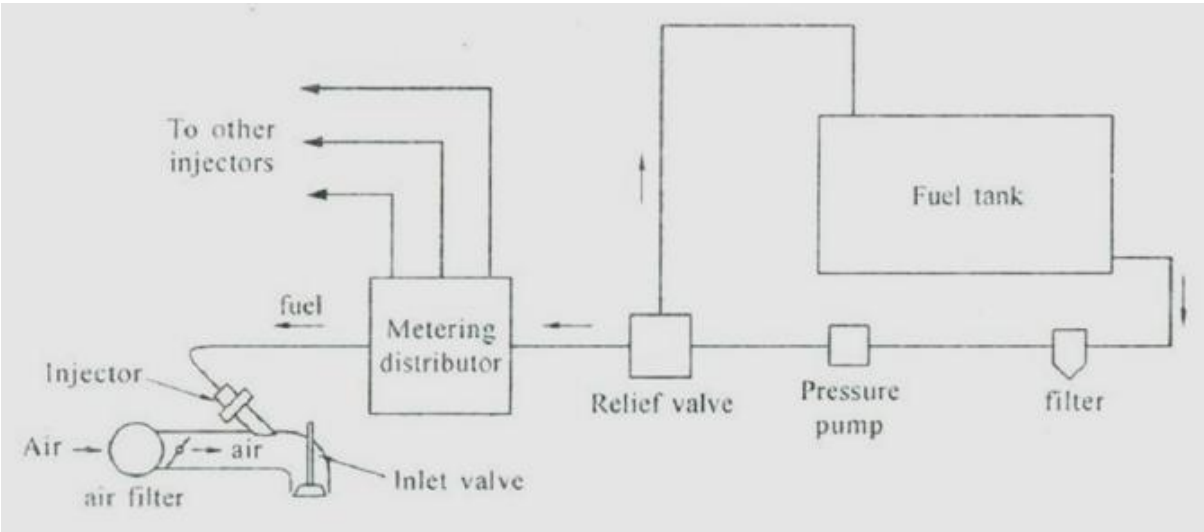


**Fig.2.12 Mechanical Petrol Injection System**

**2) Electronic Fuel Injection:**

An electric fuel pump draws the fuel from the tank through a filter and supplies the same to the injectors at a pressure which is held constant by means of a fuel pressure regulator which returns excess fuel to the tank. This prevents vapour lock in the fuel lines. The injectors are held closed by spring and are opened by solenoids energized by ECU (electronic control unit). The strength of the ECU control signal, which determines the open time of the injector to control the amount of fuel injected depends upon the engine requirements which are determined by the ECU from the sensor signals from critical locations.

The common sensors used are

1. Manifold absolute pressure (MAP) sensor.
2. Barometric pressure (BARO) sensor.
3. Throttle position sensor (TPS)
4. Coolant temperature sensor (CTS).
5. Vehicle speed sensor (VSS) etc.

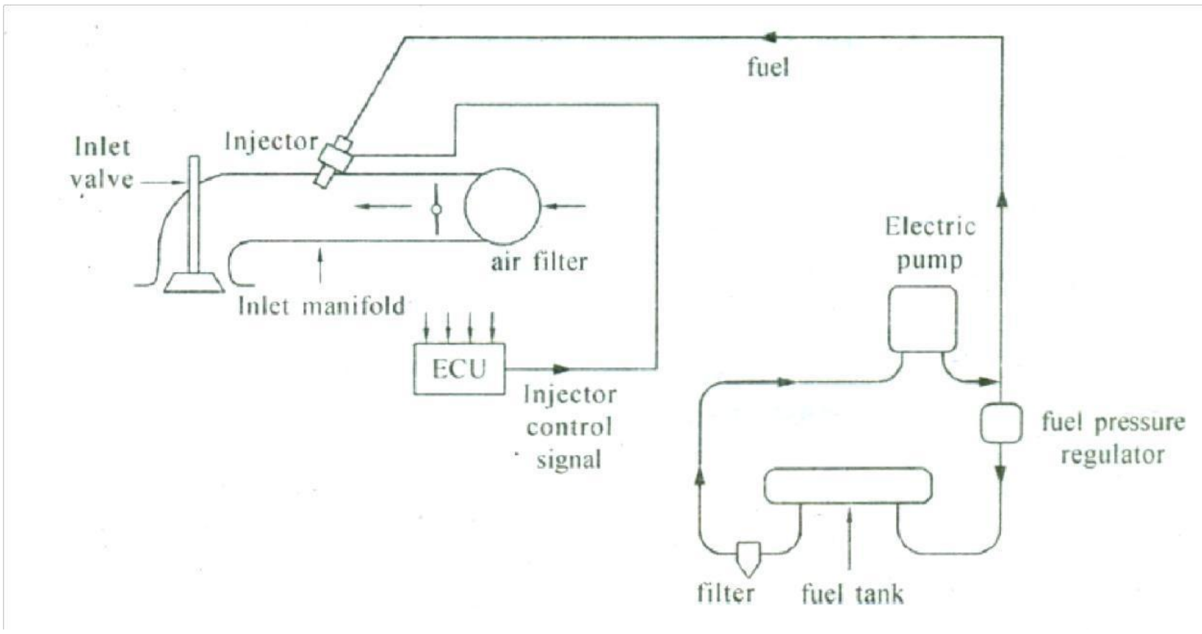


**Fig.2.13 Electronic Fuel Injection System**

**FUEL INJECTOR**:

The fuel injector is used,

i) To atomize the fuel to the required degree of fineness.

ii) To distribute the fuel for proper mixing of fuel and air.

iii) To prevent fuel injection on cylinder walls and top of the piston.

iv) The fuel injection must start stop instantaneously.

A spring loaded fuel injector is as shown in figure. The fuel pump supplies fuel to the injector and high pressure fuel lifts the spring loaded valve. The fuel is then injected into the combustion chamber of the engine cylinder. As the pressure decreases, the valve is automatically closed by the spring force. The duration of open period of the valve controls the amount of fuel injected in to the combustion chamber.

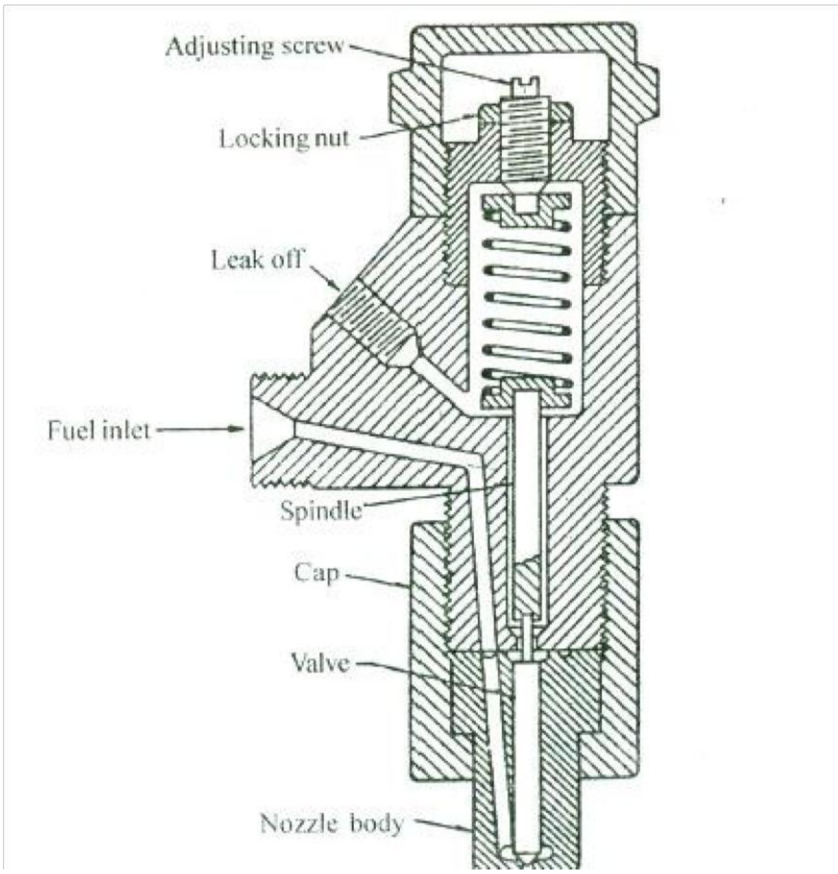


**Fig.2.14 Fuel Injector**

## GOVERNING AND FUEL CONTROL:

Governors are used on engines to keep their speeds below a set maximum. Governors maintain engine speed constant irrespective of changes in the load. The governor is usually placed between carburetor and intake manifold. Vacuum and centrifugal type governors are most commonly used. The operation of vacuum type depends on the pressure of the moving fuel and air mixture. When this pressure reaches a set value, the fuel mixture is not permitted to enter the engine at a faster rate.

The centrifugal type is attached to the cam shaft by a gear drive. The fly weight movement attached to pivot arms of governor is used to control the flow of mixture in the carburetor, thus controls the engine speed. If the engine load decreases the speed of engine will begin to increase, if the fuel supply is not decreased and if load increases, speed begins to decrease, if fuel supply is not increased.

The governor supplies fuel to the engine depending on engine load and thus maintain the speed constant. Different methods are used to control the flow of fuel and hence controls the speed according to load.

They are

**1. Hit and Miss Method:**

In this method, the fuel supply is completely cut off during few cycles of the engine. This is generally used in gas engines.

**2. Quality Governing:**

Depending on the engine load, the fuel supply per cycle of the engine is varied i.e. A:F ratio is changed depending on the engine load. At high loads rich mixture is supplied and lean mixture is supplied at low loads. This method is used for diesel engines.

**3. Quantity Governing:**

In this method, the quantity of air fuel mixture supplied is varied according to engine load. The A/F ratio of the mixture supplied to the engine at all loads remains nearly constant. This is used for Petrol engines.

# QUESTIONS

1. What are the main components of a fuel system?
2. Briefly discuss the mixture requirements for steady state operation of an SI engine.
3. Briefly discuss the transient mixture requirements in a SI engine.
4. What are the difficulties experienced by a simple carburettor.
5. What are the limitations of single jet carburettor?
6. What are the different types of carburettor?
7. With sketch explain down draught, horizontal and up draught carburettor.
8. With a neat sketch explain the working of any one constant choke carburettor.
9. Draw the neat sketch of a SU carburettor and explain its working.
10. Explain the working of an acceleration pump.
11. What is the function of fuel feed pump.
12. Draw the sketch of mechanical fuel pump and explain its working.
13. Differentiate between constant choke and constant vacuum carburettor.
14. What are the components of injection system?
15. Draw the neat sketch of a carter carburettor and explain different circuits.
16. Explain the working of an acceleration pump.
17. What are the methods of governing? Explain briefly
18. Differentiate-between constant choke and constant vacuum carburetor.
19. With neat sketch, explain fuel-mixture requirements for Sl engines
20. Sketch and explain various circuits of Solex carburetor
21. What is the necessity of a carburettor? Explain Carter carburettor with sketch
22. Explain any two fuel injectors with sketch.
23. What do you mean by octane and cetane number
24. Explain with a neat sketch, normal and abnormal combustion.
25. What are the main functions of a carburetor? Explain S.U. carburetor.
26. Draw the sketch-of electrical fuel pump and explain its working.