Unit 3. Carburettor

University Questions:

1. Describe with suitable sketches : Main metering system and Idling system
2. Draw the neat sketch of a simple carburettor and explain its working. What are the drawbacks of a simple carburettor?
3. Define the term idling. Explain why a rich mixture is required for idling system of a modern carburettor.
4. What are the mixture requirements for idling and normal power range? Describe with suitable sketches idling system and main metering system.
5. Describe acceleration pump system and choke of a modern carburettor.
6. What are the major difficulties to be faced if a simple carburettor is used in an automobile engine?
7. Discuss the air fuel mixture requirements for various states of engine operations.
8. Describe with suitable sketches the following systems of carburettor:
    a) Main metering system
    b) Idling system
    c) Power enrichment or economiser system
9. Derive an expression for air fuel ratio taking compressibility into account.
10. Elaborate with point the mixture requirements at different loads and speeds.
11. Explain with diagram the operation of modern carburettor at i) metering system ii) idling system
12. What is petrol injection? What are its advantages and disadvantages with conventional carburettor system?

Definition of Carburettor: "The process of formation of combustible fuel-air mixture by mixing the proper amount of fuel with air before admission to engine cylinder is called Carburetion and the device which does this job is called Carburettor."

Factors affecting Carburetion:

1) Engine speed (i.e. time for carburetion)
2) The vaporisation characteristics of the fuel
3) The temperature of the incoming air (more vaporisation but lesser 'η_V').
4) The design of the carburettor (intake manifold length, Combustion chamber shape: for uniform distribution of mixture)

Properties of air-Fuel (Petrol) mixture:

Fuel and air are mixed to form three different types of mixtures:

1) Chemically correct (stoichiometric) mixture: It is the mixture in which there is just enough air for complete combustion of the fuel. Ex. To burn one kg of Octane completely 15.12 kg of air is required. Hence, chemically correct A/F ratio for Octane is 15:1 (approximately).

2) Rich mixture: A mixture which contains less air than the stoichiometric requirement is called a rich mixture (ex. A/F ratio: 12:1, 10:1 etc.)

3) Lean mixture:A mixture which contains more air than the stoichiometric requirement is called a lean mixture (ex. A/F ratio of 17:1, 20:1 etc.)

Beyond the combustible range, the ratio is either too rich or too lean to sustain **flame propagation**. This range of useful A/F ratio runs from approximately **19:1 (lean) to 9:1 (rich).**

MIXTURE REQUIREMENTS

The primary requirement is that, the carburettor should provide an A/F ratio in accordance with engine operating requirements and this ratio must be within the combustible range.

1. Mixture requirements for Maximum power:

Figure I shows the maximum power is obtained at about 12.5:1 air fuel ratio. Maximum energy is released with slightly excess fuel is introduced so that all the oxygen present in the cylinder is utilised. More fuel than this is of no use. The combustion of excess fuel with the same amount of oxygen results in smaller energy release due to partial and incomplete combustion. More carbon monoxide is formed. Mechanical Efficiency is maximum at maximum power position.

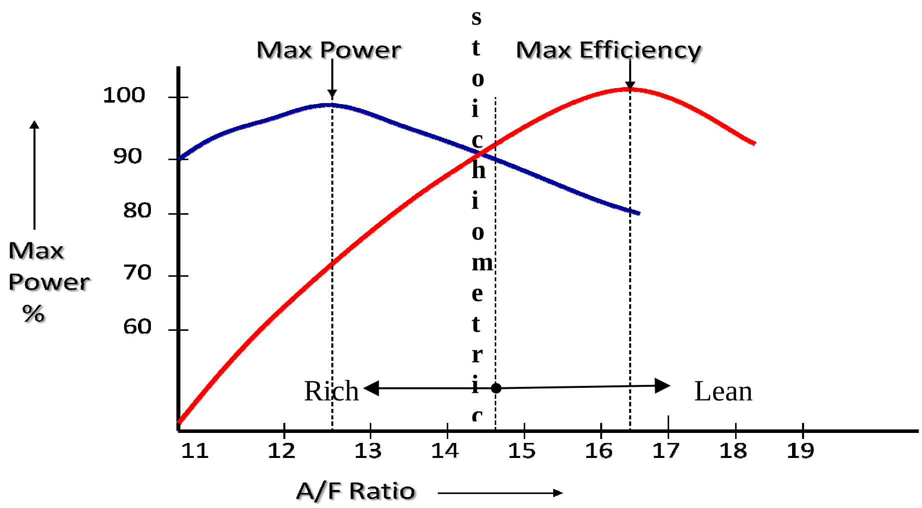


Fig. I Effect of air fuel ratio on power output and efficiency of SI engine

2. Mixture requirement for minimum specific fuel consumption:

At full throttle, the maximum efficiency occurs at an A/F ratio of about 17:1. The maximum efficiency occurs at a point slightly leaner than the chemically correct A/F ratio because excess air requires for complete combustion of fuel when mixing is not perfect; and the power, maximum temperatures associated with the inlet mixture favourably affect the chemical equilibrium and specific inlet of the gases. However, if the mixture is made too lean, the flame speed is reduced so much that the large time losses overcome the above-mentioned beneficial effects, and the efficiency falls off.

3. Mixture requirements at different loads and speeds:

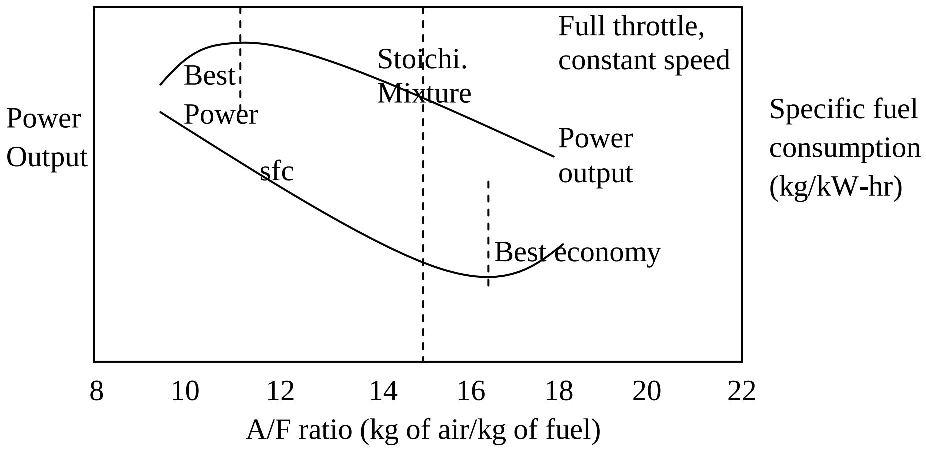


Fig.1 Variation of power output and specific fuel consumption with A/F ratio for an SI engine

Consider an engine operating at **full throttle** and **constant speed** with varying A/F ratio.

The mixture corresponding to the maximum output on the curve is called the **best power mixture** with an A/F ratio of approximately 12:1.

The mixture corresponding to the minimum point on the 'brake specific fuel consumption' is called the **best economy mixture**. The A/F ratio is approximately 16:1.

It is seen that the **best power mixture** is much **richer** than the chemically correct mixture and the **best economy mixture** is slightly **leaner** than the chemically correct.

Under normal conditions, it is desirable to run the engine on the maximum economy mixture, e.g., around 16:1 A/F ratio.

For quick acceleration and for maximum power, rich mixture 12:1 A/F ratio is required.

There are three general ranges of throttle (valve) operation:

i) **Idling** (no load condition of engine with nearly closed throttle; mixture must be rich)
ii) **Cruising** (smooth operation of engine; mixture must be leaned)
iii) **High power** [sudden speed rise (pick-up) or maximum loaded condition of engine; mixture must be rich]

Following Fig. 2 represents typical engine requirements:

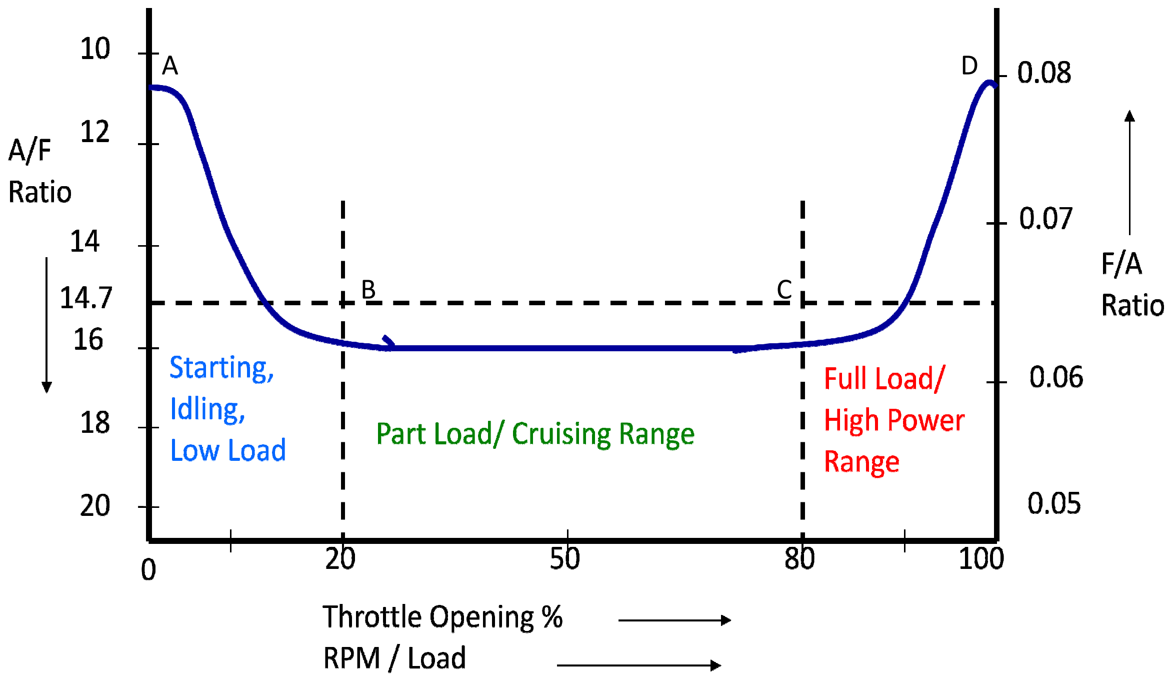


Fig.2 Performance of Carburettor necessary to fulfil engine requirements

1. Idling Range (A-B):

Under idling conditions, the engine requires a rich mixture, because of exhaust gas dilution of the fresh charge during suction stroke. Since, the clearance volume is constant, the mass of exhaust gas retained in the cylinder at the end of exhaust stroke tends to remain fairly constant throughout the throttle operation. The amount of fresh charge sucked in during idling is much less than that during the full throttle operation, due to the restricted opening of the throttle. This results in much larger proportion of exhaust gas being mixed with the fresh charge under idling conditions. The presence of this exhaust gas tends to obstruct the contact of fuel and air particles- a requirement necessary for combustion. This results in poor combustion and loss of power. It is therefore, necessary to provide more fuel particles by richening the air fuel mixture.

2. **Cruising Range (B-C):**
   As the throttle gradually opened from A to B, the exhaust gas dilution of the fresh charge reduces. Mixture requirements then proceed along line AB to a leaner A/F ratio required for the cruising operation. In the cruising range (B-C), the exhaust gas dilution problem is relatively insignificant. The primary interest lies in obtaining the maximum fuel economy. In this range carburettor provides engine with the best economy mixture.

3. **Power Range (C-D):**
   During maximum power operation, the engine requires a richer mixture due to the following reason:
   To provide best power: Since high power is desired, the carburettor setting (i.e., fully opened throttle) draws more quantity fuel and sufficient air (i.e., best power mixture) in the combustion chamber which will produce the maximum power.

Simple Carburettor

Working principle:
Both air and petrol are drawn through the carburettor and into the engine cylinders by the suction created by the downward movement of the piston. In the carburettor, air passing through into the combustion chamber picks up fuel discharged from a carburettor jet (having fine orifice). The rate at which fuel is discharged into the air depends on the pressure difference between the float chamber and the throat of the venturi. At this throat due to increase of velocity of flow, a suction effect is created. The spray of gasoline from the jet and the air entering through the venturi tube are mixed together and a combustible mixture is formed which passes through the intake manifold into the cylinders.

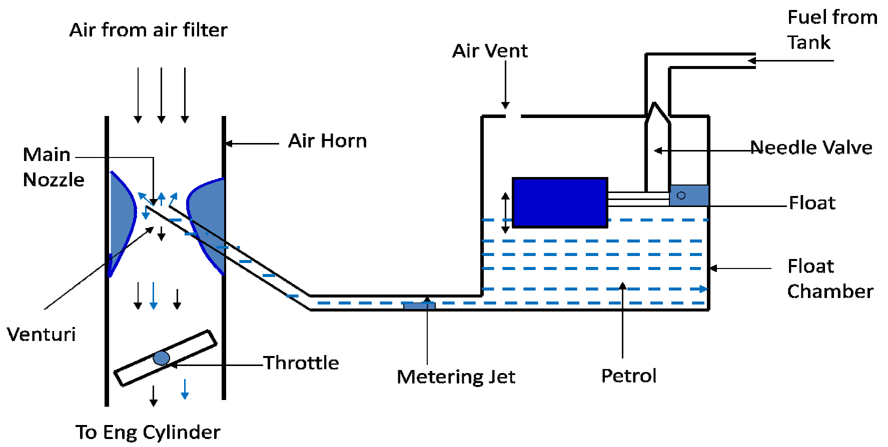


Fig. 3 Simple Carburettor principle

Description and working of Simple Carburettor: It consists of a float chamber, nozzle, metering orifice, a venturi and a throttle valve. During suction created by the piston movement in the cylinder the differential pressure between the float chamber and the throat of the venture, known as carburettor depression, fuel is discharged into the air stream. **The fuel discharge is affected by the size of the discharge jet and it is chosen to give the required air fuel ratio.** To **avoid overflow** of fuel through the jet, the level of the liquid in the float chamber is maintained at a level slightly below the tip of the carburettor discharge jet. The amount of charge (A+F) delivered to the engine is achieved by the throttle (butterfly) valve, which is situated after the venturi in the flow path.

As the throttle is closed less air flows through the venturi tube and less is the quantity of air fuel mixture delivered to the cylinder and hence power output is reduced (quantity governed engine). As the throttle is opened, more air flows through the venturi tube resulting in increased quantity of mixture being delivered to the engine. This increases the engine power output.

Limitation/drawback/disadvantage of simple carburettor: The simple carburettor provides the required A/F ratio only at one throttle position. At the other throttle positions the mixture is either leaner or richer depending upon whether the throttle is opened less or more. e.g. during starting or idling conditions simple carburettor is unable to supply rich mixture. Similar is the case during sudden accelerating condition.

MODERN CARBURETTOR

The modern carburettor is designed in such a way that the fuel air mixture supplied to the engine is in proportion and it is in order to meet the requirement. The essential parts of modern carburettor, as per Fig. 4, are listed below:

1) Float chamber

The function of float chamber is to supply the fuel to the nozzle at a constant pressure head. This is possible by maintaining a constant level of the fuel in the float bowl, by means of needle valve mechanism. This fuel level must be maintained slightly below the main nozzle-outlet-holes in order to provide the correct amount of fuel flow and to prevent Surging (leakage of fuel from the nozzle during tilting of vehicle) when the engine is not operating.

2) Fuel Strainer

The gasoline has to pass through a narrow nozzle exit. To prevent possible blockage of the nozzle by dust particles the gasoline is filtered by installing fuel strainer at the inlet to the float chamber of the carburettor. The strainer is usually removable so that it can be taken out and thoroughly cleaned.

3) Throttle valve

The main purpose of throttle valve is to vary the quantity of air fuel mixture during suction stroke of SI engine. The throttle valve is located downstream side of the venturi (i.e. between the carburettor venturi and the inlet manifold of the engine). The more the throttle is closed, the greater is the obstruction to the flow of (A+F) mixture and lesser is the quantity of mixture supplied to the cylinders (SI engines are quantity governed). The decreased quantity of mixture gives less powerful impulse to the pistons and the power output of the engine is reduced. Opening the throttle increases the power output and the speed of the engine. In short, it doesn’t make mixture rich or lean, the throttle is only a means to regulate the output of the engine by varying the quantity of charge (Air fuel mixture) going to the cylinder.

4) Choke or cold starting system

A rich mixture is required to start the engine when it is cold. At lesser atmospheric temperature, vaporisation tendency of fuel reduces. It is therefore necessary to provide rich mixture during cold starting of the engine. During starting, this valve is operated to **shut off partially the supply of air** to the carburettor. Partial-shutting off air-supply enrich the fuel-air mixture supplied to the cylinder, which create a combustible air fuel mixture in the combustion chamber.

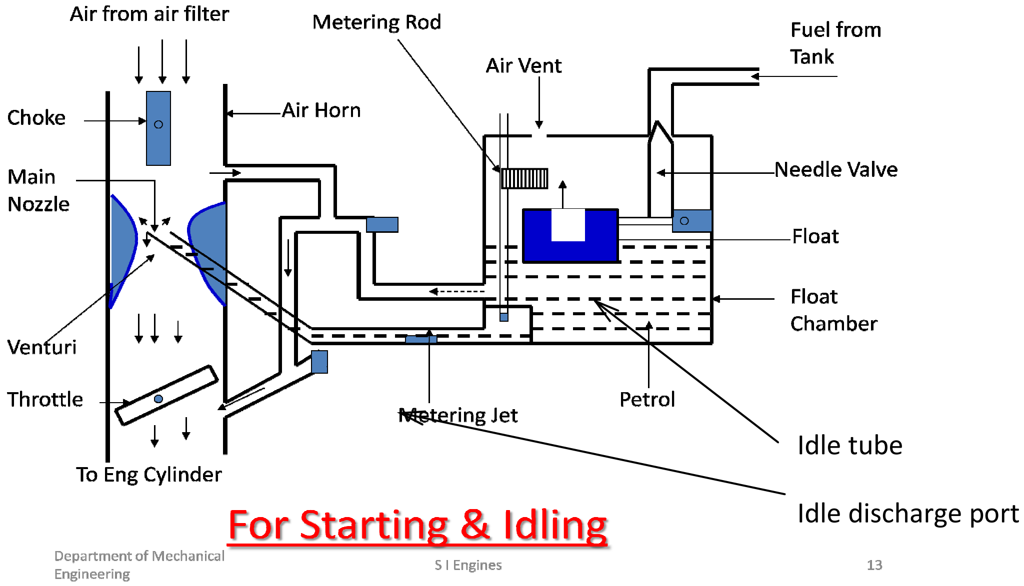


Fig. 4 Modified Simple Carburettor (Modern Carburettor)

5) Idling system:

Motor vehicle engines require a rich mixture for idling and low speed operation (about 12 parts by weight air to one part by weight of fuel, 12:1). This system comes into action during starting, idling and low speed operation and goes out of action when the throttle is opened beyond about 20%.

With the throttle partially closed, the limited air flow causes very little depression (pressure drop) at the nozzle exit which will not be sufficient to draw any fuel through the main nozzle.

At the same time, the very low pressure on the downstream side of the throttle causes the fuel to rise in the idle tube and to be discharged through the idling discharge port (opening) directly into the engine intake manifold.
This suction also draws air through the idling air bleed which combines with the gasoline to help vaporise and atomize it as it passes through the idle passage. The fuel and air leaving the idle discharge port combine with the air stream that is going past the throttle in the manifold to produce the correct mixture.

As the throttle is opened and the main air flow is increased which draws fuel from the main fuel jet. It makes the pressure depression at the idling port lesser and lesser that puts idling system out of action.

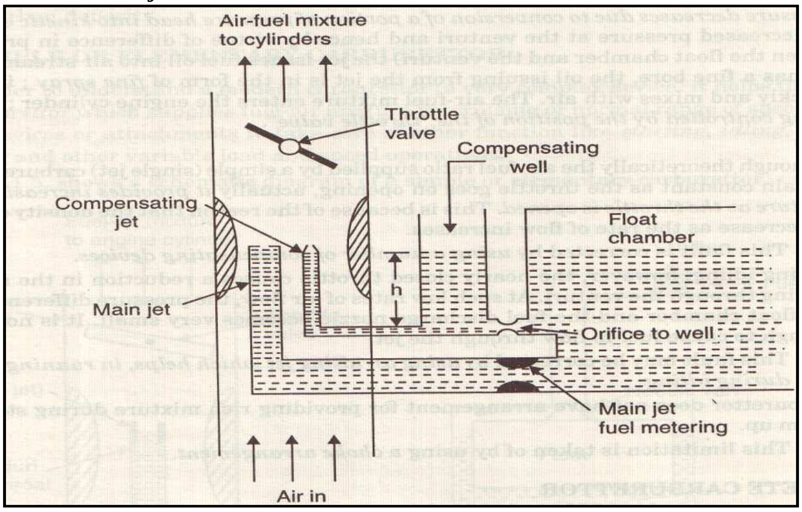
6) Metering system

The main metering system of a carburettor is designed to supply a **nearly constant basis fuel air ratio**, over a wide range of speeds and loads. This mixture corresponds approximately to best economy at full throttle (A/F ratio ~ 15.6). Since a simple carburettor tends to enrich the mixture at higher speeds the automatic compensating devices are incorporated in the main metering system to economize the mixture i.e, 15.6:1. These devices are:

i) Use of a **compensating jet** that allows an increasing flow of air through a fuel passage as the mixture flow increases.
ii) Use of Emulsion tube for air bleeding.
iii) Back suction control or pressure reduction and
iv) Use of an auxiliary air valve or port that automatically admits additional air as mixture flow increases.

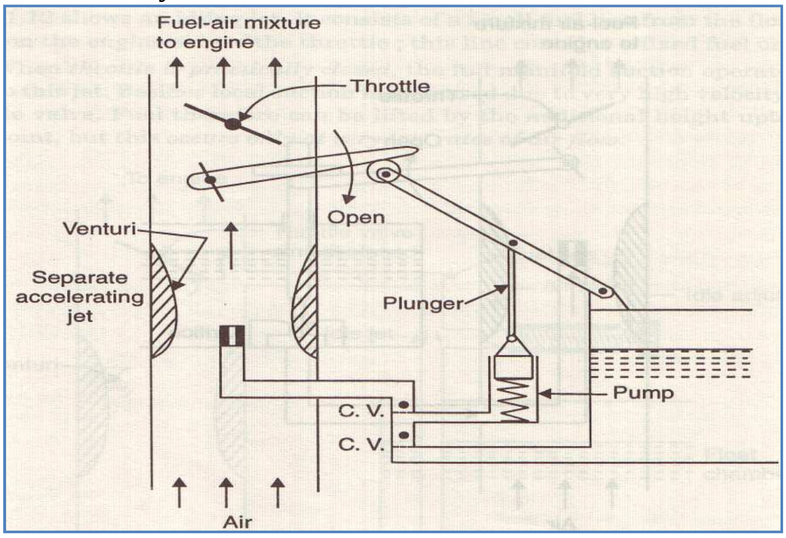
1) Compensating jet device:

In this device, in addition to the main jet, a compensating jet is provided which is in communication with a compensating well. The compensating well is open to atmosphere and gets its fuel supply from the float chamber through a restricting orifice. As the air flow increases, the level of fuel in the well decreases, thus reducing the fuel supply through compensating jet. The compensating jet thus tends towards leanness as the main jet tends towards richness, the sum of the two remains constant.



7) Accelerating system

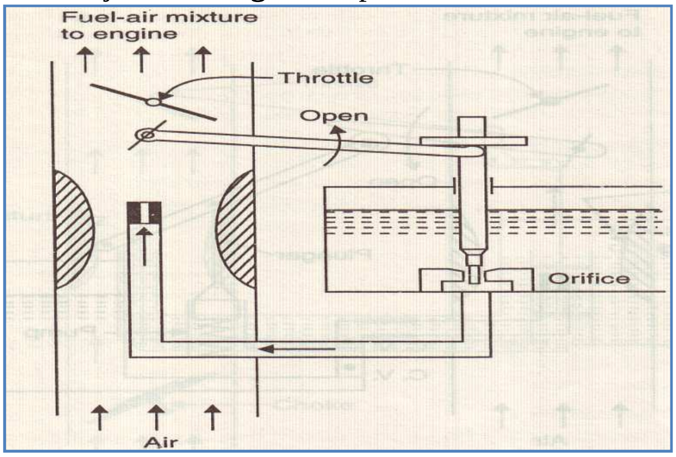
When it is required to accelerate the engine rapidly, a simple carburettor will not provide the required rich mixture. Rapid opening of throttle will be immediately followed by an increased airflow, but the inertia of the liquid fuel will cause at least a momentarily lean mixture just when richness is necessary for power (pickup). To overcome this deficiency an acceleration pump is provided, as shown in figure. The pump consists of a spring loaded plunger. A linkage mechanism is provided so that when the throttle is rapidly opened the plunger moves into the cylinder and forces an additional fuel into the venturi of carburettor.



8) Power enrichment or Economizer system

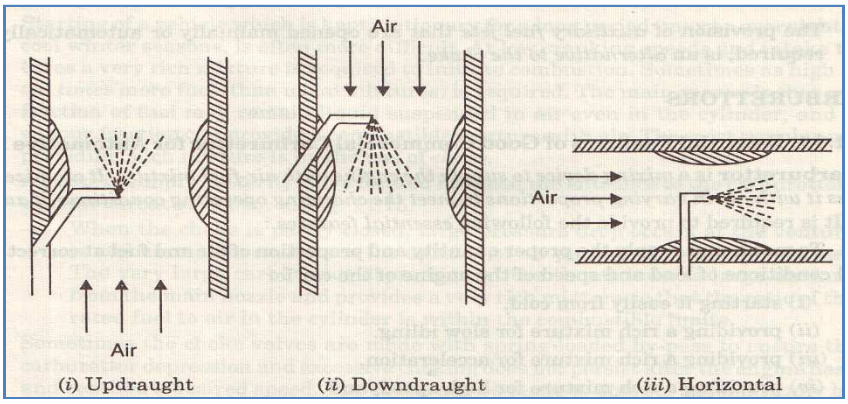
As the maximum power range of operation (75% to 100% load) is approached, some device must allow richer mixture (A/F ratio 13.1:1) to be supplied despite the compensating leanness. Such a device is the ‘meter rod economiser’, shown in fig.

This device provides a rich uneconomical mixture at high load demand without interfering with economical operation in the normal power range. It simply provides a large orifice opening to the main jet as the throttle is opened beyond a certain point.



Power enrichment or meter rod economiser

Basic types of Carburettors:



Qu. What is petrol injection? What are its advantages and disadvantages with conventional carburettor system?

Drawbacks/disadvantages of conventional carburettors:

1) In multi-cylinder engines, the mixture supplied to various cylinders changes in quality and quantity because the suction manifold passages are of unequal lengths. The mixture proportion is also affected due to fuel condensation in inlet manifolds (at lower temperatures).
2) Carburettors do not give free flow passage for the mixture, because of presence of choke tubes, jets, throttle valves, inlet pipe bends etc. Thus there is loss of volumetric efficiency.
3) The carburettor has many wearing parts. After wear of these parts, it operates less efficiently.
4) Carburettor icing may take place at low temperatures.
5) Surging (rising and falling or spilling) of fuel take place when the carburettor is tilted (during air filling in case of scooter) or during acrobatics in aircraft.
6) Backfiring may take place and there is risk of fuel igniting outside the carburettor unless flame-traps are provided.

Petrol Injection System:

In petrol injection system, petrol is injected directly into the combustion chamber of (cylinder) by fuel pump. However, there is difference between petrol injection and diesel injection method.

In diesel engine, the moment at which fuel injection starts has a very significant influence on the combustion process because the fuel ignites with the highly compressed air. In this situation it is necessary to start fuel at about 15° to 25° before top dead centre (i.e. at the end of compression stroke). The fuel injection pressure has to be higher than the maximum compression pressure. The fuel injection pressure is about 120 bar and above.

In petrol injection, fuel injection timing is not critical and the petrol can be injected during the suction stroke in the inlet manifold even at low pressures. There are two important methods of injection are continuous injection system and timed injection system.

1) In case of **'continuous injection system'**, fuel is sprayed at low pressure continuously into the air supply during suction stroke. No timing device is used. [**Advantages** of continuous injection system:
    a) It promotes efficient atomization of fuel and uniform strength of mixture, b) the evaporative effect of fuel cools the compressed charge and gives higher volumetric efficiency]
2) The '**timed injection system'** is similar to high speed diesel engines. Here, fuel supply is controlled by opening of air throttle at regular intervals

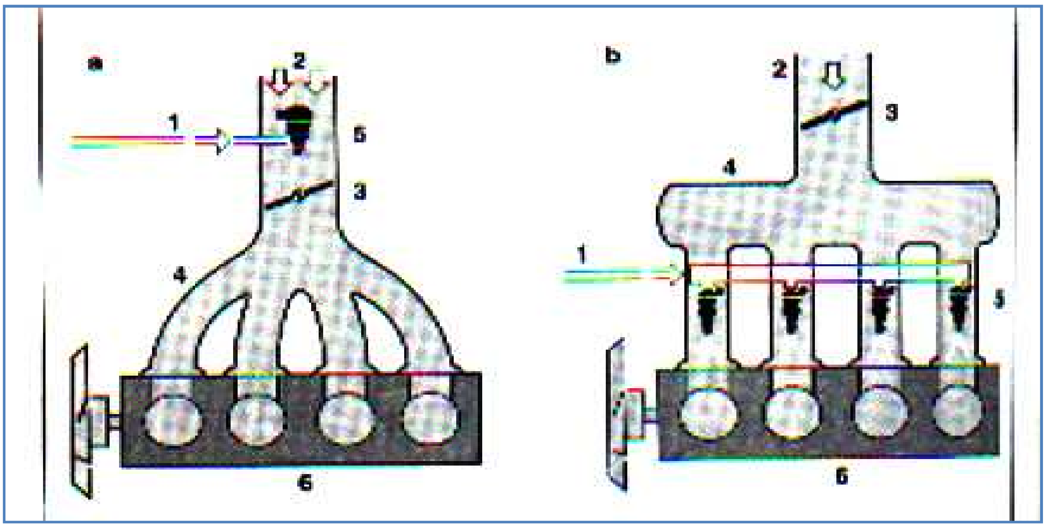
Methods of Petrol injection system:
- Injection into intake manifold by low pressure injection system
- Direct injection into cylinders by high pressure injection system
- Semi-direct injection close to inlet valve

Advantages of Petrol injection system
1. Increased volumetric efficiency and hence increases power and torque,
2. Better distribution of mixture to each cylinder and hence lower specific fuel consumption,
3. Freedom from blowbacks and icing
4. Better starting and acceleration
5. Lower mixture temperature in the engine cylinders

Disadvantage of petrol injection system
1. High initial cost
2. Increase service problem
3. More weight than carburetor system
4. Injection systems produce more noise

Two types of petrol injection depending upon number of locations of injection points:

1) Single point fuel injection (SPFI) 2) Multipoint fuel injection (MPFI)



**1-Fuel injection line, 2-Air from air filter, 3- Throttle valve, 4- inlet manifold,
5-petrol injectors, 6-cylinder bank**

ELECTRONIC FUEL INJECTION SYSTEM

Modern fuel injection systems use engine sensors, a computer, and a solenoid operated fuel injectors to meter and injects the right amount of fuel into the engine cylinders. These systems called electronic fuel injection (EFI) that use electrical and electronic devices to monitor and control engine operation.

An electronic control unit (ECU) or the computer receives electrical signals in the form of current or voltage from various sensors. It then uses the stored data to operate the injectors, ignition system and other engine related devices. As a results less unburned fuel leaves the engine as emissions and the vehicle gives better milage.

It consist of four units

1. **Fuel delivery system**
   The fuel delivery system consists of an electrically driven fuel pump which draws fuel from the fuel tank and forces it through a filter, into a pressure line via pressure regulator.
2. **Air induction system**
   The incoming air flows from air filter to an air flow meter designed to generate a voltage signal, which is dependent on air flow.

   A cold start magnetic injection valve is fitted just behind the throttle valve to inject additional fuel for cold start.

   After cold start the extra air required for idling in addition to richer air-fuel mixture is supplied by an auxiliary air valve which by-passes the throttle valve. This extra air is needed to increase engine speed after cold start to the acceptable idling speed.

3. **Electronic control unit**
   The operating data are measured at different locations of the engine by sensors and then transmitted electrically to the electronic control unit which computes the amount of fuel injected during each engine cycle. The sensors used are for manifold pressure, engine speed and temperature at intake manifold. The amount of fuel injected is varied by varying the injector opening time only.

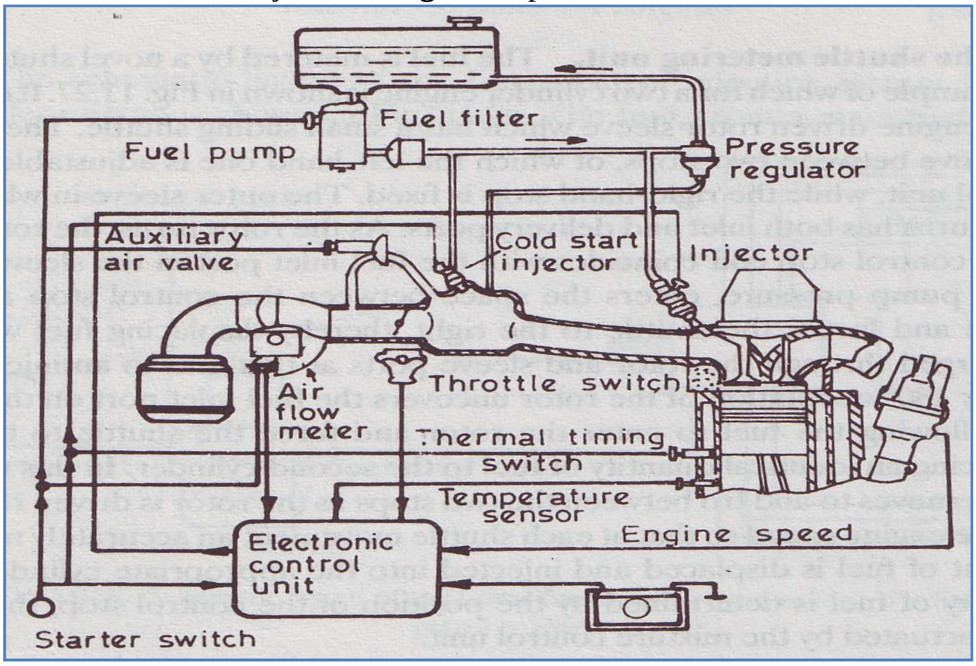
Typical sensors for an electronic fuel injection system include the following;

i) Exhaust gas or oxygen sensor: It senses the amount of oxygen in the engine exhaust and calculates air fuel ratio to supply in the combustion chamber.

ii) Engine temperature sensor: It senses the temperature of the engine coolant and from this data the computer adjusts the mixture strength to rich side for cold starting.

iii) Air flow sensor: It monitors mass or volume of air flowing into the intake manifold for adjusting the quantity of fuel.

iv) Air inlet temperature sensor, v) Throttle position sensor, vi) Manifold pressure sensor, vii) Camshaft position sensor, viii) Knock sensor



Advantages of EFI system:

i) Improvement in the volumetric efficiency due to comparatively less resistance in the intake manifolds.

ii) It eliminates the carburettor pressure losses and almost eliminates the requirement of manifold heating.

iii) Manifold wetting is eliminated since the fuel is injected into or close to the cylinder and need not flow through the manifold

iv) Better atomization leads to easier starting of the engine.

v) Carburettor icing is eliminated

vi) Less volatile fuel can be used since distribution problem is eliminated.

vii) Variation of air fuel ratio is almost negligible even when the vehicles takes different positions like turning, moving on gradients, uneven roads etc.

Disadvantages of EFI system:

1) High maintenance cost,
2) Difficulty in servicing, and
3) Possibility of malfunction of some sensors