Chapter four

SIE Metering and Manifold Phenomena

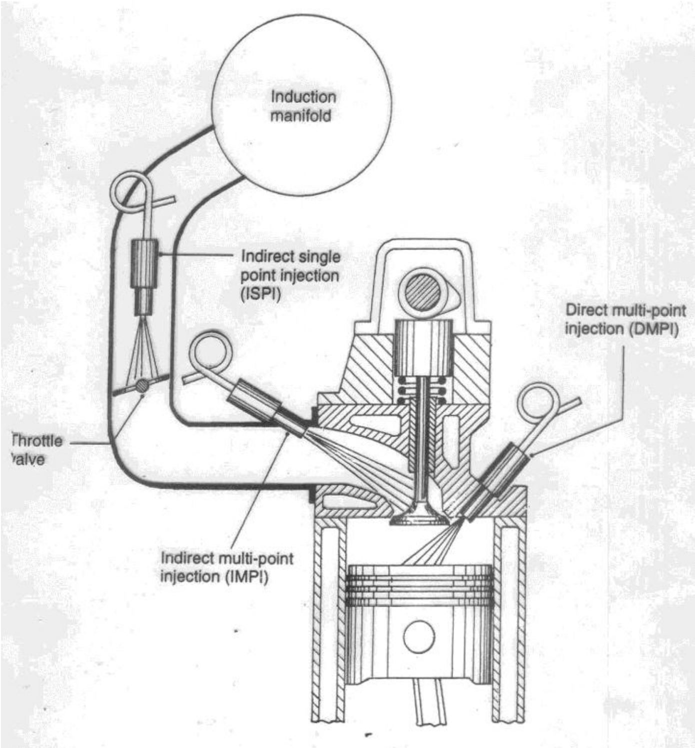
A typical value of the stoichiometric air to fuel ratio of gasoline is 14.6 thus

$$\varphi = \frac{14.6}{(A/_{F})_{Actual}}$$

4.1 Fuel injection system

The fuel injection system for conventional spark ignition engine injects the fuel into the engine intake system. The intake manifold delivers air to the engine through pipes to each cylinder, called runner.

The fuel is injected into the intake port of each engine cylinder. Thus these systems require one injector per cylinder (plus, in some system, one or more injector to supplement the fuel flow during starting and warming up).



There are both mechanically injection system and electronically controlled systems. The advantages of port fuel injection system are increased power and torque through improved volumetric efficiency and more uniform fuel distribution, more rapid engine response to change throttle position and more precise control of the equivalence ratio during cold start and engine warm up.

Fuel injection allows the amount of fuel injected per cycle, for each cylinder, to be varied in response to input derived from sensors which define the actual engine operation conditions. Two basic approaches have been developed. The major difference between them is the method used to determine the air flow rate.

1. Speed density system:

Figure 4.1 shows a schematic of a speed density system. Where engine speed and manifold pressure and air temperature are used to calculate the engine air flow. The electrically fuel pump delivers the fuel. A pressure regulator maintains the fuel pressure at fixed value (ex 270 kN/m^2) an electromagnetically actuated fuel injection valve is located either in the intake manifold tube or in the intake port of each cylinder.

The mass of fuel injected per injection is controlled by varying the duration of the current pulse that excites the solenoid coil. Typical injection times for automobile applications range from about 1.5 to 10 ms.

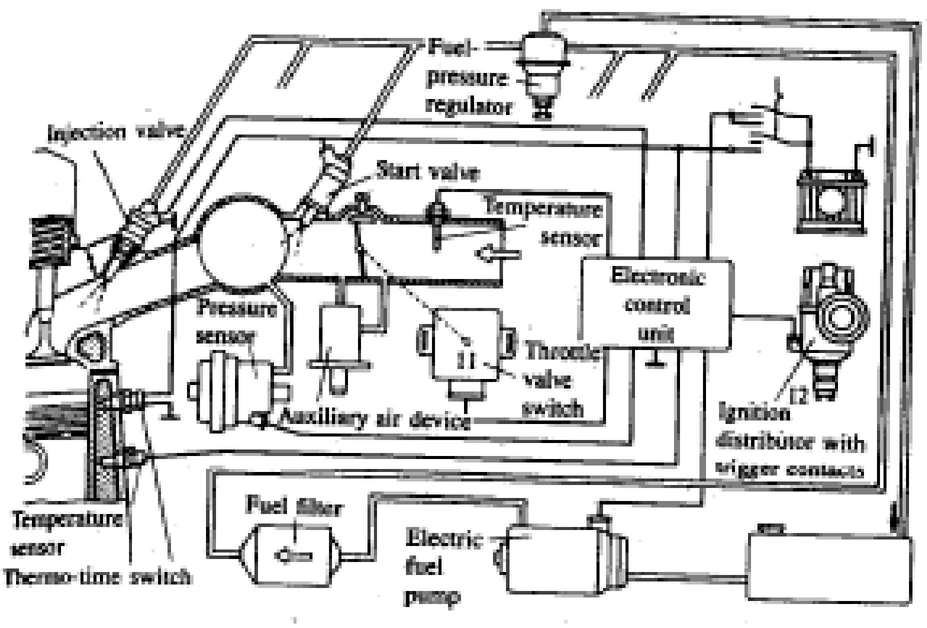


Figure 4.1 speed density electronic multi point fuel injection system Bosch D jetronic system

2. Bosch L jetronic system

Figure 4.2 shows an alternative electronic fuel injection (EFI) system which uses an air flow meter to measure the air flow directly. The air flow meter is placed upstream the throttle. The meter measure the force exerted on a plate as it is place by the following air stream. It provides a voltage proportional to the air flow rate. An alternative air flow measuring approach is use a hot wire air mass flow rate.

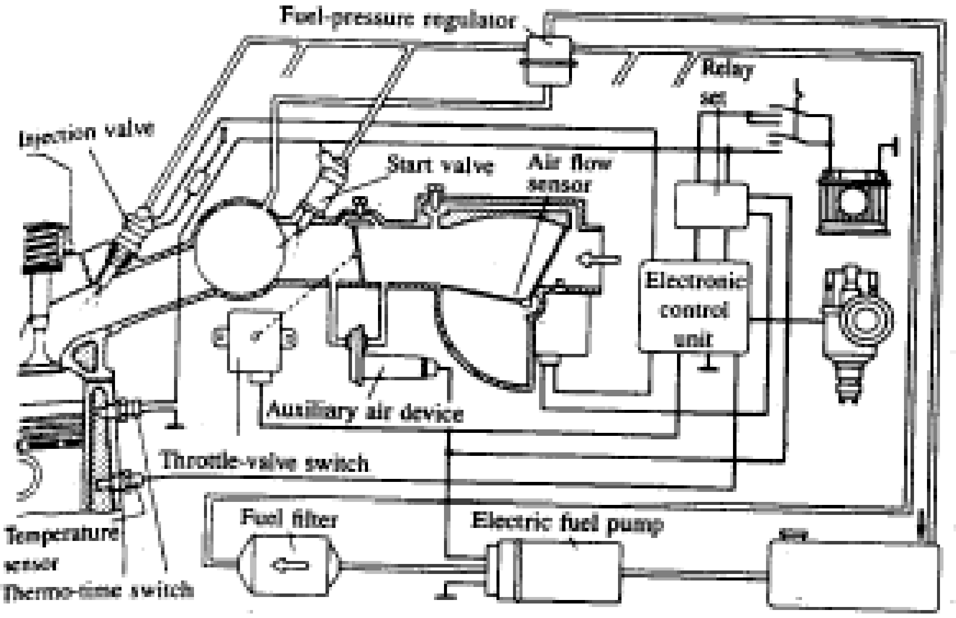


Figure 4.2 electronic multi-port fuel injection system with air flow meter Bosch L Jetronic system

The advantages of direct air flow measurement are

1. Automatic compensation tolerance, combustion chamber deposit buildup, wear, and change of valve adjustments.
2. The dependence of volumetric efficiency on speed and exhaust back pressure is automatically accounted for.

3. Less acceleration enrichment is required because the air flow signal precedes the filling of the cylinder.
4. Improve idling stability.
5. Lack of sensitivity of the system for EGR since only the fresh air flow is measured.

The mass of air inducted per cycle to each cylinder varies as

$$m_a \propto \frac{\dot{m}_a}{N}$$

Thus the primary signals for the electronic control unit are air flow and engine speed. The pulse width is inversely proportional to speed and directly proportional to air flow.

4.2 Carburetion

In engine using volatile liquid fuel, the mixture of fuel and air is formed outside the engine cylinder.

The carburetor is a device which atomizes the fuel and mixes it with the air. The pipe that carries the prepared mixture to the engine is called the **intake manifold**.

The process of carburetion is influenced by engine speed, evaporation characteristic of the fuel, the temperature of the incoming air and the design of carburetor.

The time available for mixture formation in high speed engine is very small (few hundredths of second).

Figure (4.1) shows that the basic carburetor is a venturi tube (A) mounted with a throttle plate (B) (butterfly valve) and a capillary tube to input fuel (C). It is usually mounted on the upstream end of the intake manifold, with all air entering the engine passing first through this venturi tube. Most of the time, there will be an air filter mounted directly on the upstream side of the carburetor. Other main parts of the carburetor are the fuel reservoir (D), main metering needle valve (E), idle speed adjustment (F), idle valve (G), and choke (H).

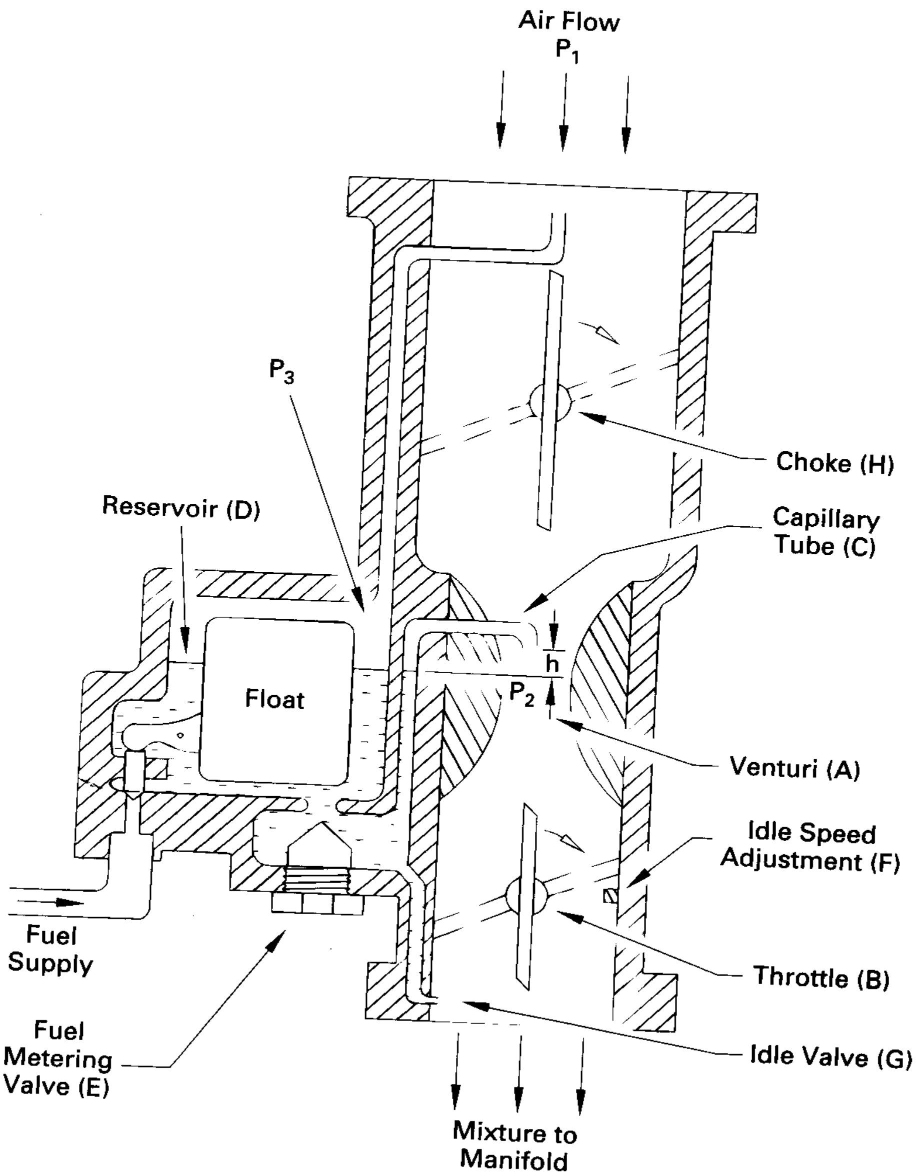


Figure (4.3) basic carburetor

As air enters the engine due to the pressure differential between the surrounding atmospheric air and the partial vacuum in the cylinders during intake strokes, it is accelerated to high velocity in the throat of the venturi. By Bernoulli's principle, this causes the pressure in the throat *P2* to be reduced to a value less than the surrounding pressure *Pi*, which is about one atmosphere. The pressure above the fuel in the fuel reservoir is equal to atmospheric pressure as the reservoir is vented to the surroundings*(P3* = *Pi* > P2).There is, therefore, a pressure differential through the fuel supply capillary tube, and this forces fuel flow into the venturi throat. As the fuel flows out of the end of the capillary tube, it breaks into very small droplets which are carried away by the high-velocity air. These droplets then evaporate and mix with the air in the following intake manifold. As engine speed is increased, the higher flow rate of air will create an even lower pressure in the venturi throat. This creates a greater pressure differential through the fuel capillary tube, which increases the fuel flow rate to keep up with the greater air flow rate and engine demand. A properly designed carburetor can supply the correct AF at all engine speeds, from idle to WOT. There is a main metering valve (E) in the fuel capillary tube for flow rate adjustment.

Single jet carburetor

The air passing through the air filter enters the vertical tube having a venturi section or diffuser. There is a chock valve and a throttle valve after the venturi, in the float chamber constant level of fuel is maintained with the help of the float and the needle valve.

The rate of flow rate at any section is constant

$$G_a = C_z A_z \rho_z = C_y A_y \rho_y = C_x A_x \rho_x \qquad 1$$

$G\left(\frac{kg}{s}\right)$, $\quad C_x, C_y, C_z \quad$ $velocity\ at\ x, y, z\ \ \frac{m}{s}$

$\rho_x, \rho_y, \rho_z \quad$ $density\ at\ x, y, z$

The pressure drop is very small so

$$\rho_o = \rho_x = \rho_y = \rho_z = atmospheric\ air\ density\ (\frac{kg}{m^3}) \qquad 2$$

The energy equation for flow between section xx and yy for air can written as

$$\frac{P_x}{\rho_o} + \frac{{C_x}^2}{2} = \frac{P_y}{\rho_o} + \frac{{C_y}^2}{2} \qquad 3$$

Where p is the pressure

$${C_y}^2 - {C_x}^2 = \frac{2}{\rho_o}(P_x - P_y) \qquad 4$$

From equation 1 $\quad C_x = \frac{A_y}{A_x} C_y \qquad 5$

Or $\quad {C_y}^2 - {C_x}^2 = {C_y}^2 (1 - \left(\frac{A_y}{A_x}\right)^2) \qquad 6$

$$\Delta Pxy = \frac{\rho_o}{2} {C_y}^2 (1 - \left(\frac{A_y}{A_x}\right)^2) \qquad 7$$

$$C_y = \sqrt{\frac{2\Delta Pxy}{\rho_o (1 - \left(\frac{A_y}{A_x}\right)^2)}} \qquad 8$$

$$G_a = \rho_o A_y C_y = \rho_o A_y \sqrt{\frac{2\Delta Pxy}{\rho_o (1 - \left(\frac{A_y}{A_x}\right)^2)}} \qquad 9$$

$$G_a = k_{da} A_y \sqrt{2\Delta P_{xy} \rho_o} \qquad kg/s \qquad 10$$

k_{da} is the discharge coefficient of the air

Flow of fuel

The energy equation for steady flow between section mm and nn considering the velocity of fuel in section nn is negligible

$$h_n + \frac{P_n}{\gamma_f} = h_m + \frac{P_m}{\gamma_f} + \frac{{C_m}^2}{2g} \qquad 11$$

$$C_m = \sqrt{2g \left[\left(\frac{P_n - P_m}{\gamma_f} \right) + (h_n - h_m) \right]} \qquad 12$$

$$G_f = k_{df} A_m \sqrt{2\rho_f(\Delta Pxy - g\rho_f \Delta h)} \qquad kg/s \qquad 13$$

Where k_{df} is the discharge coefficient of the fuel orifice ($k_{df} = (0.75 - 0.8)$

The fuel air ratio

$$\frac{F}{A} = \frac{G_f}{G_a} = \frac{k_{df} A_m}{k_{da} A_y} \frac{\sqrt{2\rho_f(\Delta Pxy - g\rho_f \Delta h)}}{\sqrt{2g\rho_o \Delta Pxy}} \qquad 14$$

$$\frac{F}{A} = \frac{k_{df} A_m}{k_{da} A_y} \sqrt{\frac{\rho_f}{\rho_o}} \sqrt{\frac{Pxy - g\rho_f \Delta h}{g\Delta Pxy}} \qquad 15$$

$$\frac{F}{A} = Z \frac{k_{df}}{k_{da}} \sqrt{1 - \frac{\rho_f \Delta h}{\Delta Pxy}} \qquad 16$$

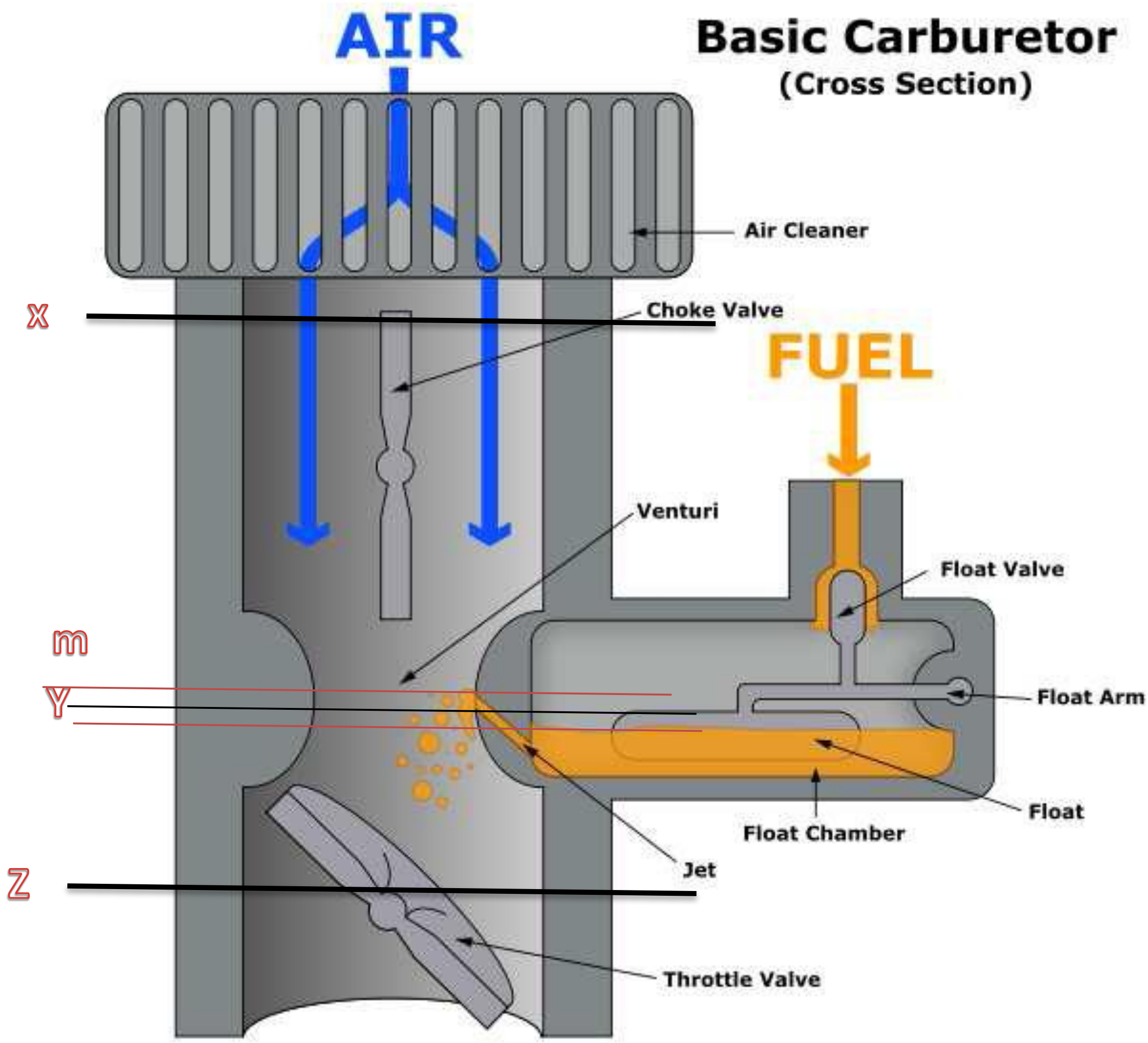


Figure 4.4 single jet carburetors

Complete carburetor

In order to satisfy the demands of an engine under all conditions of operation the following additional devices are added to the simple carburetor

1. Main metering system
2. Idling system
3. Power enrichment or economizer system
4. Acceleration pump system
5. Chock system

1. Main metering system

The main metering system is designed to supply a nearly constant basic air to fuel ratio over a wide range of speeds and loads. This mixture corresponds to air fuel ratio of 14.6 (stoichiometric). Since a simple carburetor tend to enrich the mixture at high speeds. Automatic devices are in carbureted in the main metering system to correct this tendency.

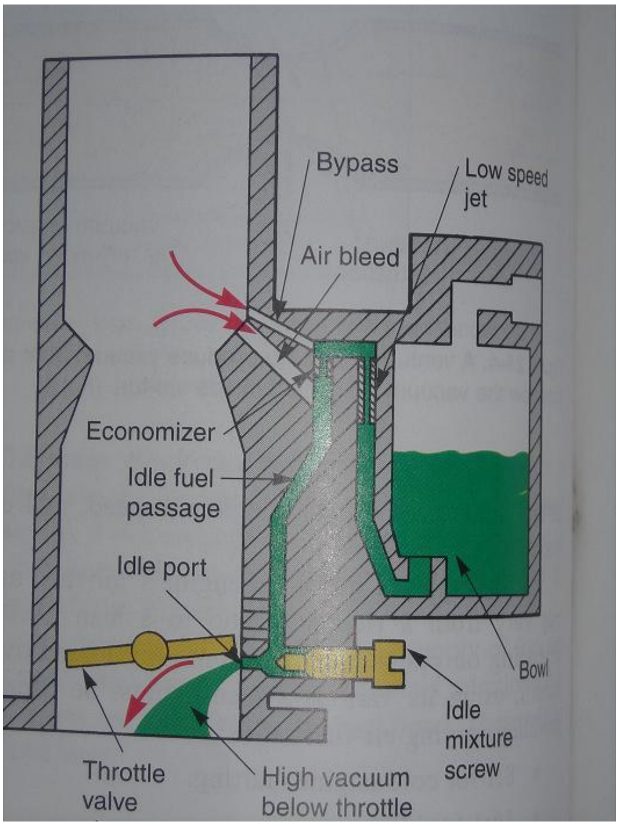
1. Compensation system ZENETH

As air flow increase the fuel level decreases in the compensation vessel hence reduces fuel supply through compensation nozzle. The compensation jet tends towards leanness, as the main jet tend toward richness. The sum of the two remains constant. At even high rates of air flow the vessel is empty, air is blend through the compensation nozzle to continue the leanness effect.

2. Air breaking system SOLEX

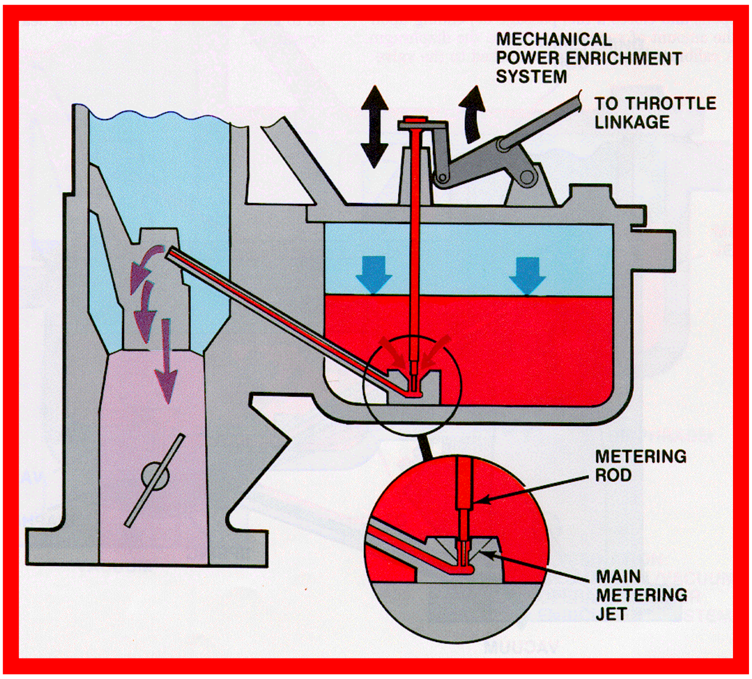
Idling system

At idling and low load the engine required rich mixture. The metering system supplies almost no fuel at idling (low air speed) so separate idling jet must be added to the basic carburetor when the throttle is partially closed the fuel manifold suction operates on the outlet of this jet.



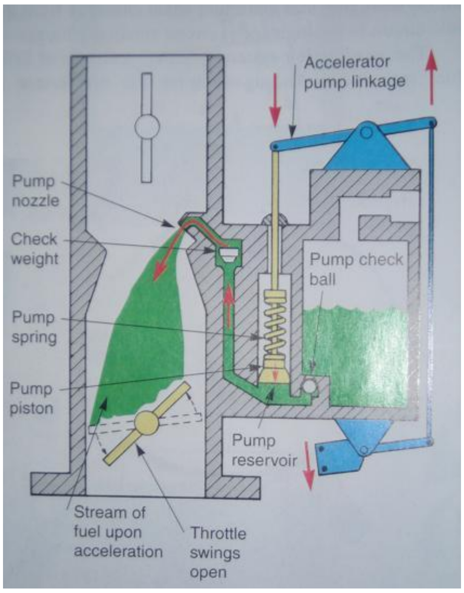
Power enrichment (economizer system)

As the max power range of operation (75-100)% load is approached a rod connected with the throttle opens a large orifice to enrich the mixture (air fuel ratio about 13/1)



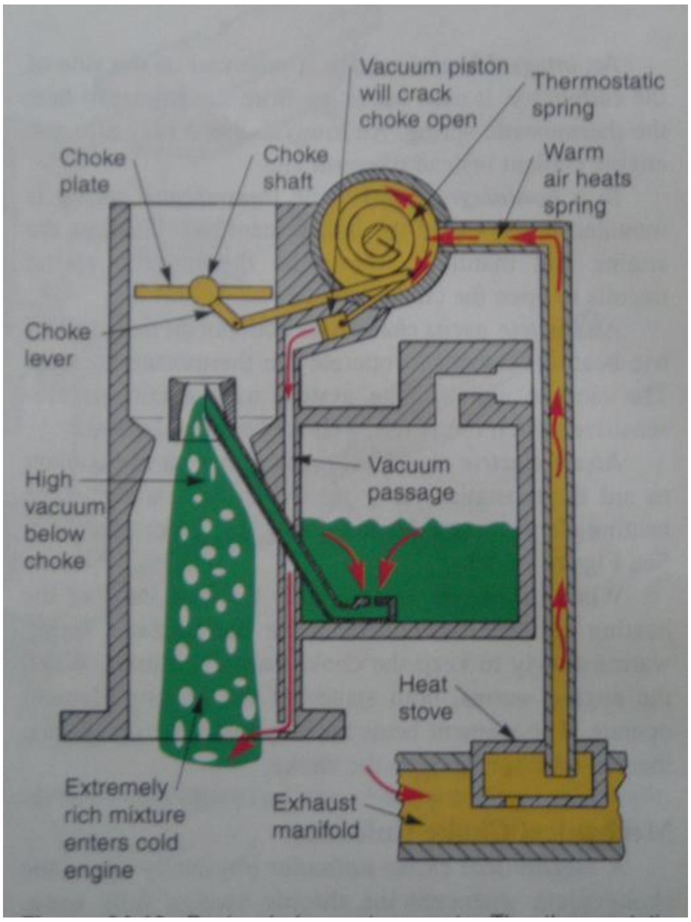
Acceleration pump

During acceleration rapid opening of the throttle will be immediately followed by an increased air flow but inertia of fuel will caused a momently lean mixture. When the throttle is rapidly opened the plunger moves down into the cylinder and forces an additional fuel in the venturi. When the throttle is opened slowly the fuel will be located passed the plunger or through some holes in the float chamber.



Chock

During cold starting period at low crank speed and before engine has warmed up, a mixture much richer than usual mixture (about 5-10 % time of fuel) must be supply, this is achieved by a chock which is a butter fly type valve placed a head of venturi throat by partially closing the valve. A large pressure drop can be produce at the venturi throat this strong section will drop large quantity of fuel from the main jet to give a richer fuel air combustible mixture.



Size of carburetor

The size of carburetor is normally given in term of chock tube in mm and jet size in hundredth of mm

Ex: jet of 50 has a diameter (0.5) mm