volumetric efficiency than air-cooled engines).

22.7. FUEL SUPPLY IN S.I. ENGINES

The fuels such as petrol, benzol and alcohol used in S.I. engines vaporise easily at atmospheric conditions, therefore, the engine suction is sufficient to vaporise these fuels and no preheating is required. The oil fuels such as light oils and paraffin oils used in diesel engines do not vaporise easily and therefore the engine suction is not sufficient to vaporise therefore fuel injection arrangement is used in oil engines.

22.7.1. Carburettor

The parts of a simple carburettor are shown in Fig. 22.19 and their functions are described below

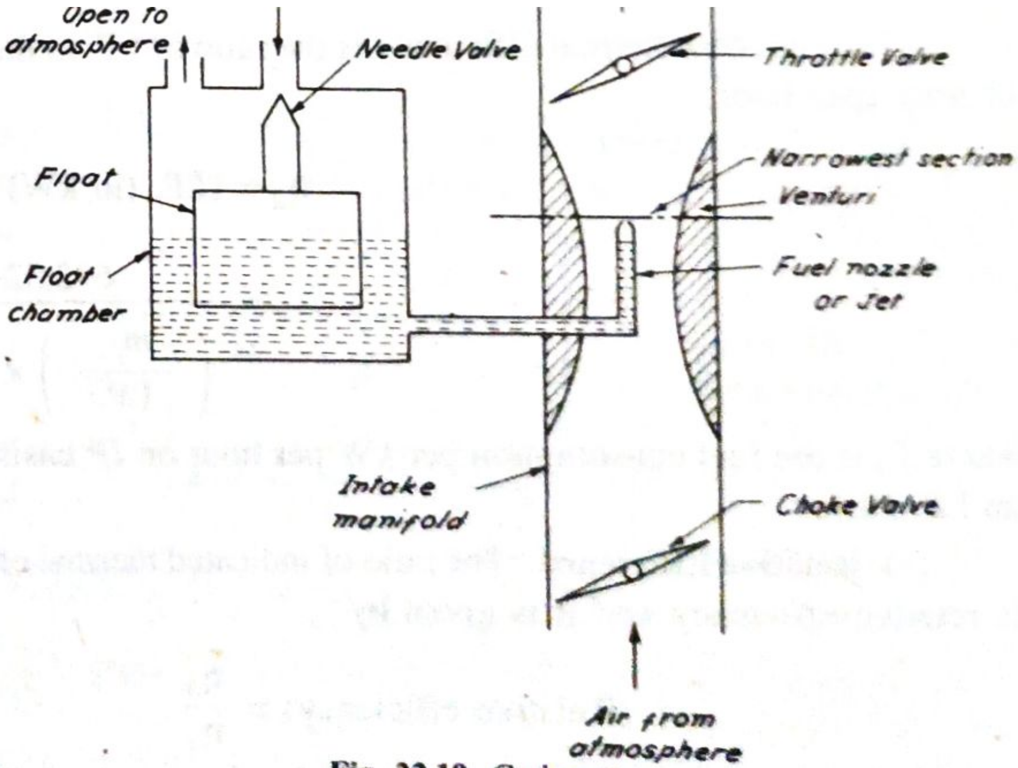

Fig. 22.19. Carburettor.

1. **Float and Float Chamber.** The level of the petrol in the chamber should be maintained constant and slightly below the top of the spray nozzle as shown in Fig. 22.19. The petrol would run from the nozzle and drip from the carburettor if the level in the float chamber is higher even when the engine is not running. On the other hand, if the level of the fuel is far below the top of the spray nozzle, the part of the pressure head (Δp) causing the flow of fuel would be unwantedly utilised to lift the fuel.

The level of the fuel in the float chamber is maintained constant with the help of float and needle valve. As the level of the fuel in the float chamber rises (this is possible if the supply from the main fuel tank to the float chamber is more than the fuel supplied by the fuel nozzle. This happens when the load on the engine decreases), the float also rises and needle valve closes the fuel inlet and decreases the fuel supply and a constant level is maintained. As the level of the fuel in the float chamber decreases (this is possible if the supply from the main fuel tank to the float-chamber is less than the fuel supplied by the fuel nozzle. This happens when the load on the engine increases), the float comes down and needle valve opens and increases the fuel supply from main fuel tank to the float chamber and the level is maintained constant.

The main function of the float chamber assembly is to maintain the fuel level constant in the float chamber under variable loads on engine.

2. **Venturi.** The shape of the venturi is shown in Fig. 22.20. The area for the flow of air near the fuel nozzle is decreased.

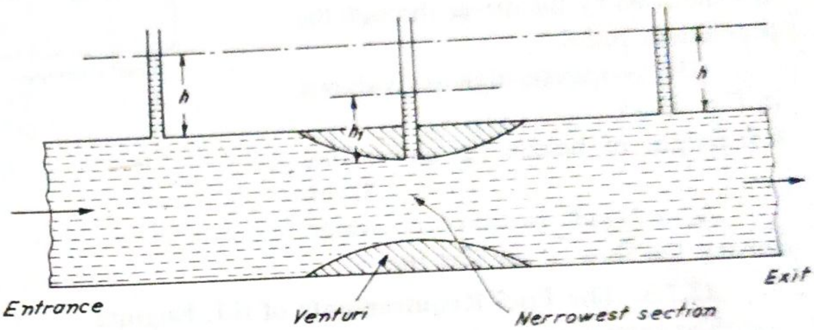

Fig. 22.20.

The principle of the venturi is illustrated as shown in Fig. 22.20. When the fluid passes through the venturi, the velocity increases and the static pressure is reduced ($h_1 < h$) and then again increases as the fluid moves to the divergent portion of the venturi. The pressure decreases from the entrance to the narrowest section and then increases again. According to Bernouli's principle, higher velocity of the air at venturi than elsewhere is accompanied by a lower pressure than that in the float chamber (float chamber pressure is atmospheric pressure as it is open to atmosphere), therefore, the fuel flows through the fuel nozzle and mixes with the air as the air flows through the venturi. The suction is created inside the engine as the engine starts and the air sucked into the engine through the venturi. The fuel is injected into the air-steam through the fuel nozzle due to static pressure difference at the nozzle and the mixture of the air and fuel is sucked into the cylinder.

Throttle Valve. The basic control element is the throttle valve. It controls the air velocity or the mixture supplied to the engine through the intake manifold and therefore the head under which the fuel flows.

Choke Valve. It is necessary to provide an extra rich mixture to the engine during starting or warm up in cold weather. The extra rich mixture ensures enough fuel availability in vaporised form for combustion. This is done by introducing the choke valve in the air passage before the venturi as shown in Fig. 22.19.

The choke valve is nearly closed during cold starting or warming and it controls the flow of air and creates high vacuum near the fuel jet. The fuel flow increases as the vacuum near the jet increases. This enriches the mixture as desired.

22.7.2. Working of Single Jet Carburettor

The main function of the carburettor is to vapourise the petrol by means of engine suction and to supply the required quantity of mixture (air and petrol) in proper proportions.

As the engine is started, the suction is created inside the cylinder and air flows from atmosphere into the cylinder. As the air passes through the venturi, the pressure of the air falls below the atmosphere and that is equivalent to h_w cm. of water as shown in Fig. 22.21. The pressure at the nozzle tip is also h_w cm. of water below atmosphere because the pressure on the fuel surface in the fuel tank is also atmospheric. This pressure difference causes the flow of the fuel through the fuel jet into the air-stream. As the fuel and air pass ahead of the venturi, the fuel gets vaporised and uniform mixture is supplied to the engine. The quantity of mixture supplied to the engine depends upon the opening of the throttle valve. In case of stationary engine, the opening of the throttle valve is controlled by the governor according to the load on the engine. In case of automobile engines on road, the opening of the throttle valve is controlled by the driver through the accelerator pedal.

The systematic diagram is shown in Fig. 22.21.

h = Height of nozzle tip above fuel level.

h_w = Head in cm of water causing the flow of air and fuel.

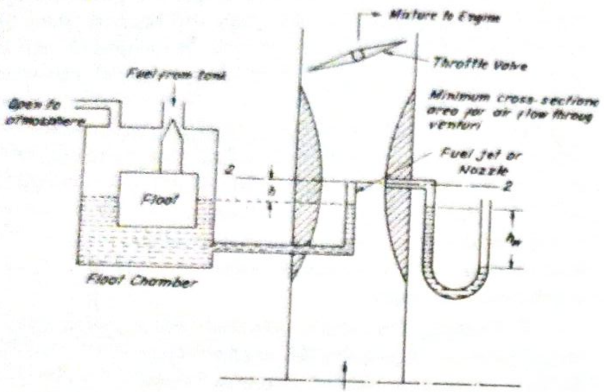

Fig. 22.21. Carburettor.

22.7.3. The Fuel Requirements of S.I. Engines

The operating conditions of spark ignition engine are grouped as

1. Steady running
2. Transient operation

Most of the time, the engine runs at steady condition as running of the automobile on the road is concerned. Steady running is defined as continuous operation at a given mean speed and power output. The transient operation includes starting, warming, idling and process of changing from one load or speed to another.

The required fuel-air ratios for the above mentioned running conditions of the engine are listed below.

Running condition	*F.A. Ratio*
1. Starting	0.2 : 1
2. Warming	0.15 : 1
3. Idling	0.085 : 1
4. Running with maximum thermal efficiency (80% throttle)	0.06 to 0.07 : 1
5. Running with developing maximum power (80% throttle)	0.0775 to 0.08 : 1
6. Full throttle	0.085 : 1
7. Acceleration	0.1 : 1

These requirements are shown in Fig. 22.22 taking percentage throttling on x-axis and A : F ratio on y-axis.

The design of the nozzle (diameter of nozzle) of the carburettor should be such that, it should fulfil all the above required conditions.

The F : A ratio increases an increase in throttle opening (increase in speed at constant load) for a particular diameter of the nozzle. This F : A ratio further increases with the increase in diameter as shown in Fig. 22.22.

It is obvious from Fig. 22.22 that if the diameter of the jet is d_1, then it fulfills more or less all the required conditions but the fuel consumption is considerably higher than that required. This is highly

uneconomical as most of the time, the fuel supplied is more than that required. If the diameter of the jet is d_2, then it fulfills the required running condition but it is not useful for starting and accelerating operations. Selection of diameter 'd' partly fulfills starting and accelerating conditions and also fulfills full running conditions supplying richer mixture than required but it is more economical than the diameter d_1.

After selecting the best suitable diameter d, extra arrangements can be introduced to fulfil the starting and accelerating conditions by supplying more fuel at these conditions. The required F : A ratio under normal running condition can be achieved either by supplying more quantity of air or reducing the quantity of fuel with introducing extra arrangements.

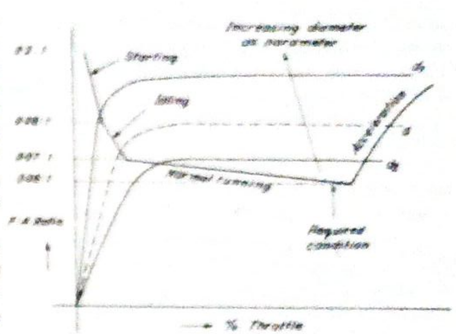

Fig. 22.22.

22.7.4. Limitations of Single Jet Carburettor

The drawbacks of single jet carburettor are listed below :

1. A single jet carburettor cannot provide a very rich mixture as required at the time of starting the engine :

This is, because, at low speed (starting or idling) the pressure difference causing the fuel flow is very small, (as the throttle is nearly closed). It is not possible to discharge fuel to make the mixture considerably rich.

2. Also, it cannot provide very rich mixture required for sudden acceleration of the engine.

3. For gradually increasing pressure difference over the jet (at higher speed of the engine), the weight of the petrol discharged from a single jet increases at a greater rate than does the air supply. Hence a single jet carburettor gives a progressively richer mixture as the air speed increases when set to give a correct mixture at low air speeds.

4. It cannot reduce the quantity of air flow during starting as required in cold weather conditions.

5. The automatic control of air and fuel according to the required conditions is not possible.

The carburettor used in a variable speed engine must fulfil all the following requirements.

1. It must automize the fuel and mix it homogeneously with the air.
2. It must be able to run the engine smoothly without hunting or fuel wastage.
3. It must provide rich mixture during starting and idling.
4. It must provide a constant air-fuel ratio during normal running of the engine which is the maximum period.
5. It must provide rich mixture required for quick acceleration of the engine.
6. It must be able to start the engine even in very cold weather conditions (during snowfall).
7. All operations should be automatic.

To fulfil the above requirements, the following devices are introduced.

(*a*) A starting or a pilot jet (to start engine).
(*b*) Compensating devices (to provide constant A : F ratio during normal operation conditions).
(*c*) An automatic control of choke valve (to start the engine in cold weather).

22.7.5. Starting or pilot jet

It is already mentioned that, the engine requires considerably rich mixture at the time of starting. As the speed is low, during starting, the pressure difference causing the flow of fuel is not sufficient to supply the required quantity of fuel. The exhaust left in the clearance volume also reduces the effective fuel-air ratio. Therefore, a separate arrangement is provided to supply rich mixture to the engine during starting. The separate arrangement is used for strating known as pilot jet.

The arrangement of the starting jet is shown in Fig. 22.23.

A fuel line connection from the main line is taken as shown in Fig. 22.23 and it is connected to a point near the engine side of the throttle valve.

At the starting, the throttle valve is nearly closed and the pressure near the throttle (towards the engine side) is considerably less (500 cm of water below atmosphere). This is because, the air passing through the throttle valve has very high velocity as area provided for the flow is small. This low pressure is transferred to the float chamber through the starting fuel line. The pressure on the uspstream side of this starting jet is atmospheric (float chamber pressure). The fuel is therefore drawn through the starting jet and is discharged on the low pressure side of the throttle valve (engine side). A small amount of air is allowed through the screw arrangement as shown in Fig. 22.23. This helps in the initial adjustment of the proper amount of fuel to be supplied. The air passing through air screw is used as carrier.

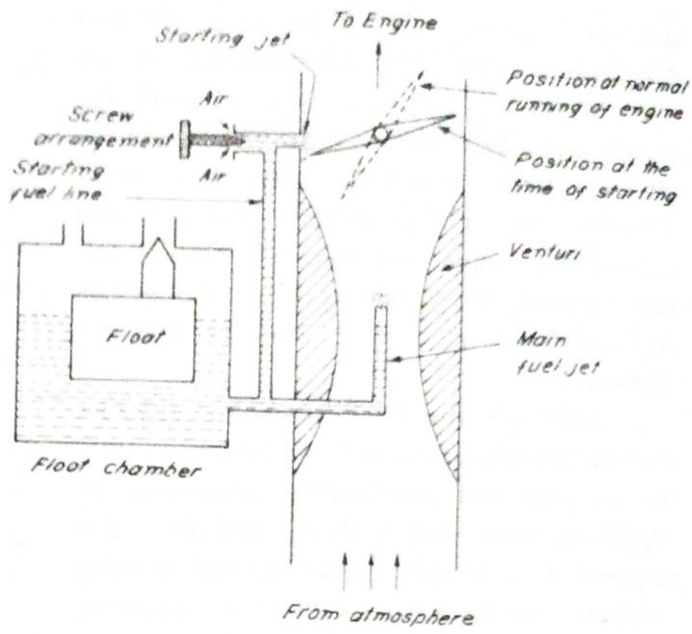

Fig. 22.23. Starting jet arrangement.

In this way, the starting jet supplies sufficiently rich mixture to the engine.

There is no flow of fuel or very small flow through the main jet during starting as the pressure difference (Δp) causing the flow of fuel is small.

As the throttle is opened (engine started), the suction above the throttle valve (towards the engine side) decreases and the suction (or Δp) at the main fuel jet increases. This causes less flow of fuel through starting jet and more flow of fuel through the main jet. At the wide open throttle (normal running speed of the engine), the suction near the throttle valve (towards the engine side) is not sufficient to draw any fuel from the starting jet and the required fuel is entirely supplied by the main fuel jet. The starting jet is an elementary single jet like main jet which supplies rich mixture at nearly closed throttle position and a progressively weaker mixture as the throttle is opened and stops the fuel supply under normal running condition.

22.7.6. Compensating Devices

A mixture of constant air-fuel ratio is always required for wide range of speed of an engine for economic operation. This required condition cannot be fulfilled with a single jet carburettor as it gives richer mixture with increasing speed. A number of devices are used to fulfil the above requirement. The increased richness of the mixture with increasing speed can be reduced either by supplying more quantity of air (proportionately increased) or reducing the quantity of fuel supplied (proportionately decreased) and A : F ratio of the mixture supplied to the engine is maintained constant at all normal running speeds. These devices used to maintain the A : F ratio constant irrespective of speed of the engine are known as compensating devices. The commonly used compensating devices are listed below :

1. Auxiliary Air Valve 2. Compensating Jet

3. Pressure Reduction in the Float Chamber 4. Tapered Metering Pin.

The arrangements of different systems and their working are described below :

1. **Auxiliary Air Valve.** Fig. 22.24 shows the arrangement of auxiliary air valve. The vacuum near the venturi increases with the increasing speed of the engine and this causes the valve spring to lift the valve

supplying additional air and prevents the mixture from becoming overrich. The opening of the valve is proportional to the speed of the engine.

An auxiliary port can also be used instead of valve as shown in Fig. 22.25. Additional quantity of air is admitted by opening of the butterfly valve as shown. The opening of the butterfly valve is directly proportional to the engine speed. This method is generally used in air craft carburettor for altitude compensation.

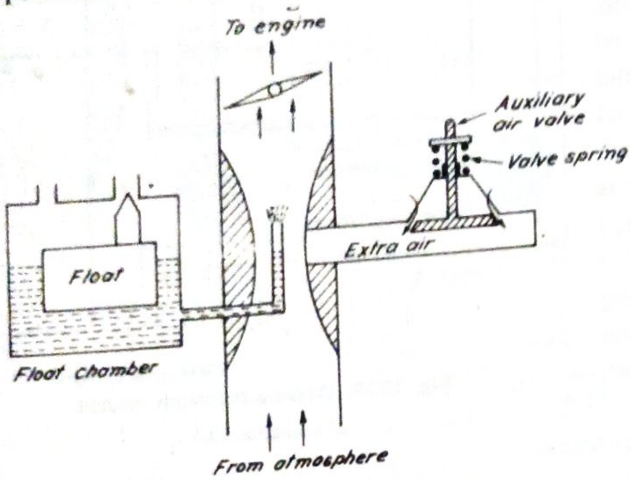

Fig. 22.24. Auxiliary Valve Carburettor.

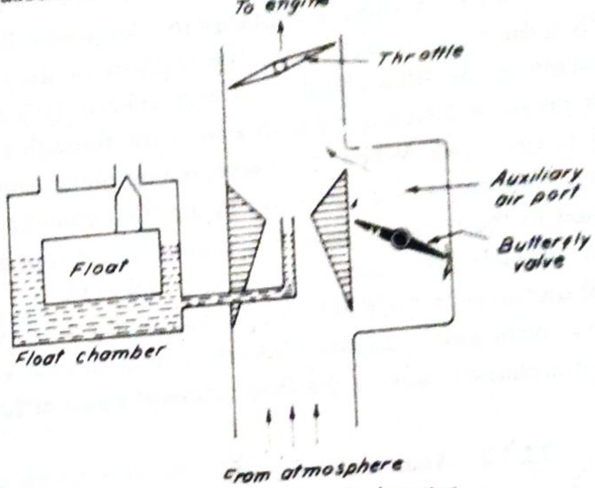

Fig. 22.25. Auxiliary Port Carburettor.

Compensating jet or Double jet. The arrangement of the compensating jet is shown in Fig. 22.26. The area of the main jet and compensating jet provided for supplying the fuel is equivalent to a single main jet. The total area of both is designed to give required A : F ratio for a particular speed.

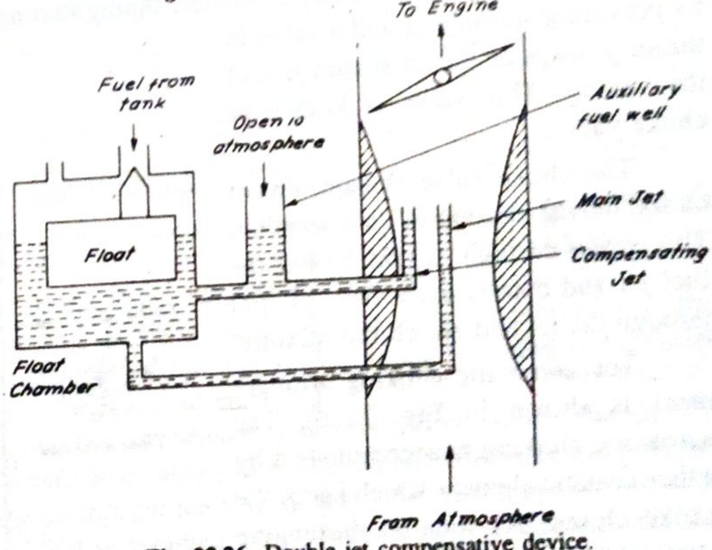

Fig. 22.26. Double jet compensative device.

With the increase in speed, the main jet as well as compensating jet deliver more fuel and mixture becomes richer. The characteristic of the compensating jet of making the mixture rich reverse within a very short period. The flow of fuel through the compensating jet increases with the increasing speed but the flow of fuel from the float chamber to the auxiliary well is restricted by an orifice '*O*' as shown in figure. The fuel level in the auxiliary well decreases with an increase in speed of the engine because the fuel supplied from the auxiliary well to the compensating jet is more than the fuel supplied from the float chamber to the auxiliary well through the restricted orifice '*O*'. This (decreasing the fuel level in the auxiliary well) is continued until the fuel level in the auxiliary well falls below the restricted orifice. When this condition is reached, the pressure on the downstream side of the auxiliary jet is atmospheric and becomes independent of the pressure in the venturi. The compensating jet delivers lean mixture and this compensates for the rich mixture supplied by the main jet under increased speed of the engine and the overall A : F ratio is maintained constant.

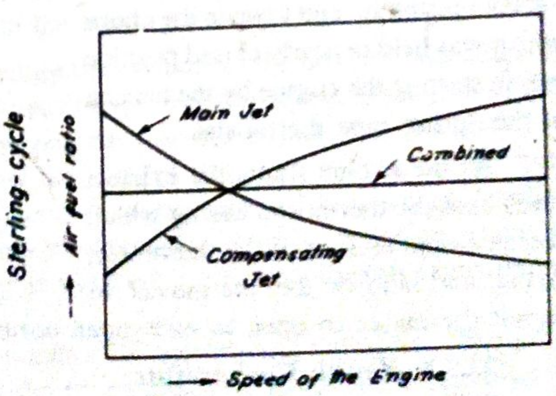

Fig. 22.27.

The air-fuel characteristics of each of these jets and a combined characteristic are shown in Fig.

Pressure Reduction Method. The arrangement of the system is shown in Fig. 22.28. A large vent line and a small vent line are connected to the top of the float chamber from the entrance of the carburettor and venturi throat. A valve V is placed in a large vent line. When the valve is wide open, the pressure on the fuel surface in the float chamber is atmospheric (p_1) and the pressure difference causing the flow through fuel jet is ($p_1 - p_2$). When the valve is completely open then pressure on the fuel level in the float chamber is equal to the pressure near the venturi throat (p_2) and the pressure difference causing the fuel flow is zero and therefore there will be no fuel flow. By adjusting the control valve, any desired pressure difference can be maintained causing the flow of desired rate of fuel.

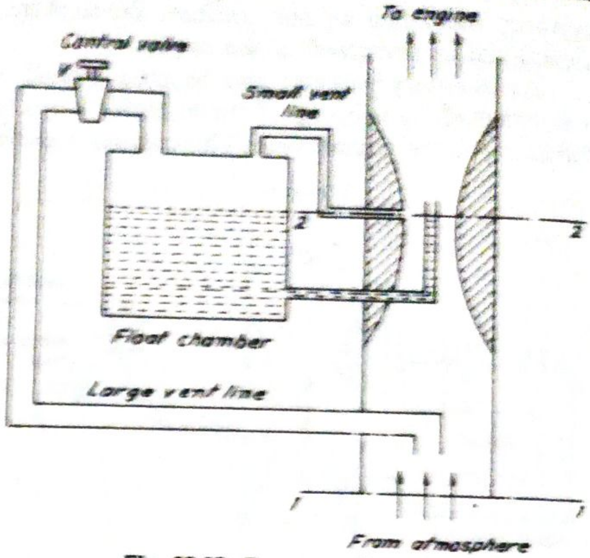

Fig. 22.28. Pressure reduction method of compensation.

22.7.7. Automatic Choke

It is necessary to provide a rich mixture during starting of the engine in cold weather. This is accomplished by providing starting jet and a valve in the air-passage on the air stream side of the venturi. This valve is known as choke valve.

The choke valve is kept almost closed during starting in cold weather. This creates the high vacuum around the fuel jet and causes extra flow of fuel through the jet and enrich the mixture.

The automatic choking arrangement is shown in Fig. 22.29. The automatic choking is accomplished by a thermostatic element which keeps the choke closed. As soon as the engine starts, the manifold vacuum causes the vacuum piston to tend to open the choke which was held in nearly closed position before starting the engine by the tension of the spring type thermostat.

As the engine starts, the exhaust gases heat the thermostat casing which decreases the tension of the thermostat spring and allows the thermostat to permit the choke to open to wide-open position.

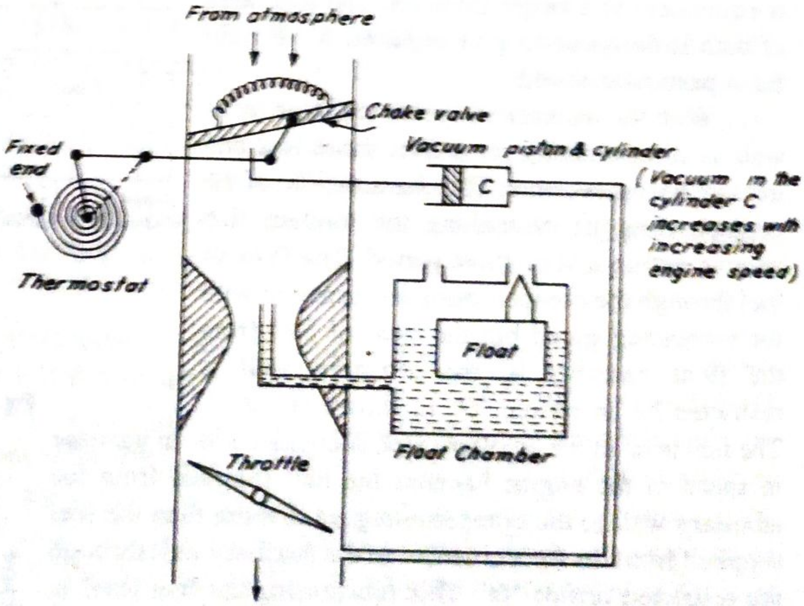

Fig. 22.29. Automatic Choking.

22.7.8. Zenith Carburettor

This is one of the carburettors commonly used in many petrol engines. It provides float control, starting jet, compensating jet and accelerating device. The arrangement of this carburettor is shown in Fig. 22.30.