MODULE 2

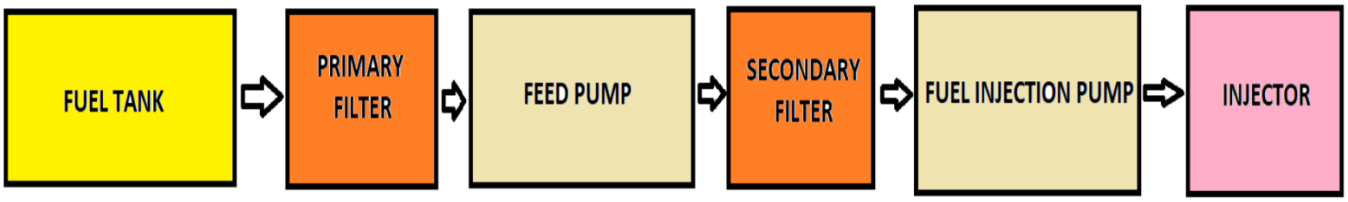
SYLLABUS:

CO2: Illustrate the working of fuel system employed in diesel vehicles.

Layout of a conventional diesel fuel system. Fuel filters - primary filter - secondary filters – purpose - construction - working of each type. Solid fuel injection system - Jerk and distributor type pumps. Working of Inline and distributor type FIP, fuel feed pump. Types of diesel fuel filter. Working of fuel injector, types of fuel injector, Governors – purpose and types (Pneumatic and centrifugal governors)

Electronic diesel fuel system - working, various sensors and their working, fuel injection pump, common rail diesel fuel system, fuel tank, fuel delivery pump, high pressure fuel injection pump, fuel rail, fuel rail pressure sensor, electronic diesel fuel injector - working, injection control, pressure relief valve, fuel temperature control, glow plugs, emission control devices.

DIESEL FUEL SUPPLY SYSTEM:



- Fuel supply system in a diesel engine has to perform certain functions. These functions along with the names of the components which perform the same are given below:

1. **Storing of fuel:** Fuel tank is usually positioned along the side of the vehicle
2. **Filtering:** Water and dirt must be removed from the diesel for which two filters are employed. Primary filter prevents large solid particles and water from going to the fuel feed pump. Secondary filter is used after the fuel feed pump and is meant to remove fine particles of dust, dirt etc. from the diesel which is to go to the injection pump.
3. **Delivery of fuel to injection pump:** From the fuel tank the fuel is delivered to the fuel injection pump by means of fuel feed pump.
4. **Injecting the fuel into engine cylinders:** Exact amount of fuel is metered, atomized and injected under high pressure to each cylinder in correct sequence according to the engine requirements. This is done by means of a fuel injection pump in conjunction with injectors for each cylinder.

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5. **Controlling the engine speed:** Diesel engine speeds tend to overshoot to dangerous values on reduction of load. This is controlled by means of a governor, which besides limiting maximum speed also regulates the fuel supply under all conditions.

FUEL FILTERS:

- Fuel filters are used to remove water and dirt from the fuel.
- There are mainly two types:
  1. Primary filter
  2. Secondary filter

1. SEDIMENTATION TYPE PRIMARY FILTER:

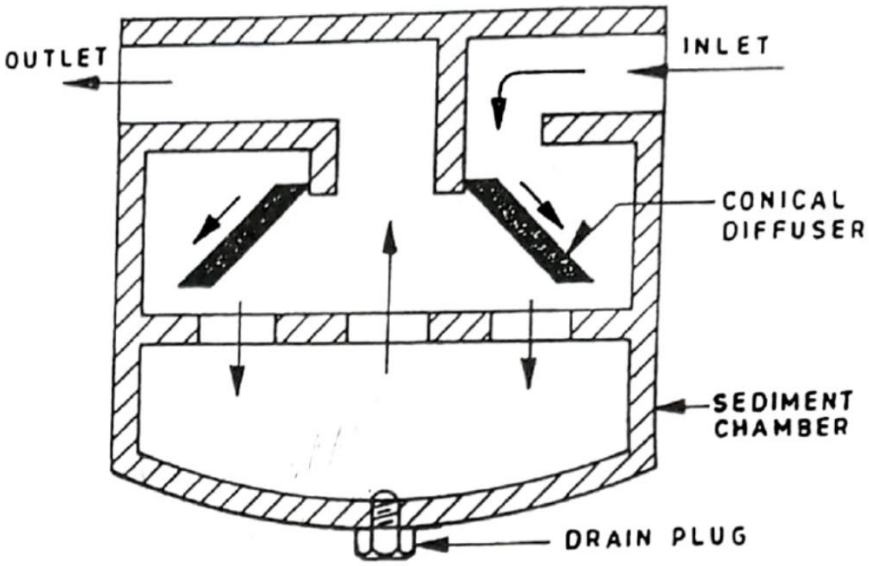


Fig. 10.5. Sedimentation type primary filter.

- It should be noted that diesel fuel is lighter than the impurities (water and solid particles), due to which they tend to gravitate quickly to the lowest position, if the fuel is allowed to become static. One such filter is shown in figure.
- The fuel from the tank enters the filter and flows around the conical diffuser funnel to accelerate downwards to the sediment chamber.
- The impurities being heavier, tend to move further down towards the bottom and settle there on account of the slow movement of the fuel through the chamber, its size being relatively large.
- The impurities thus settled down can be drained off periodically. The clean oil passes to the outlet of the filter.

2. **SECONDARY FILTER:**

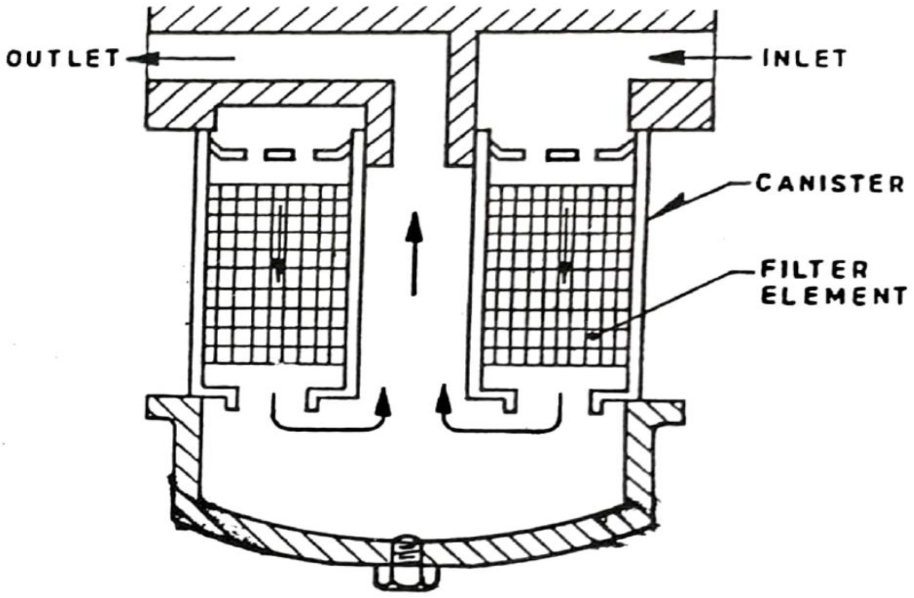


Fig. 10.6. Secondary filter

- The secondary filter is installed after the feed pump and it separates out abrasive particles and any water in the fuel. One such secondary filter is shown in Fig.
- The fine pores of the filter element retain the abrasive particles and other solid impurities, except water droplets which are forced through the element.
- However, as they have passed the element, electronic attraction produced by the resin element causes these droplets to be pulled toward each other and continue to form larger droplets which being heavier tend to settle down in the relatively larger sediment chamber.
- The lighter fuel then passes onto the filter outlet.

FUEL INJECTION PUMP:

- The amount of fuel delivered into the air stream going to the engine is controlled by a injection pump which forces the fuel under pressure.
- The fuel injection pressures generally range from 70 to 300 bar. In some systems, injection pressures can be as high as 2000 bar.
- The injection pump is driven from the engine's timing gears and its output is controlled by the driver through accelerator pedal.
- As the volume of fuel to be metered for each injection is very small and frequency of injection quite high, the pump has to be manufactured to very high precision.

Functions:

1. ***Accurate metering of the fuel injected per cycle:*** The quantity of the fuel metered should vary to meet changing speed and load requirements of the engine.

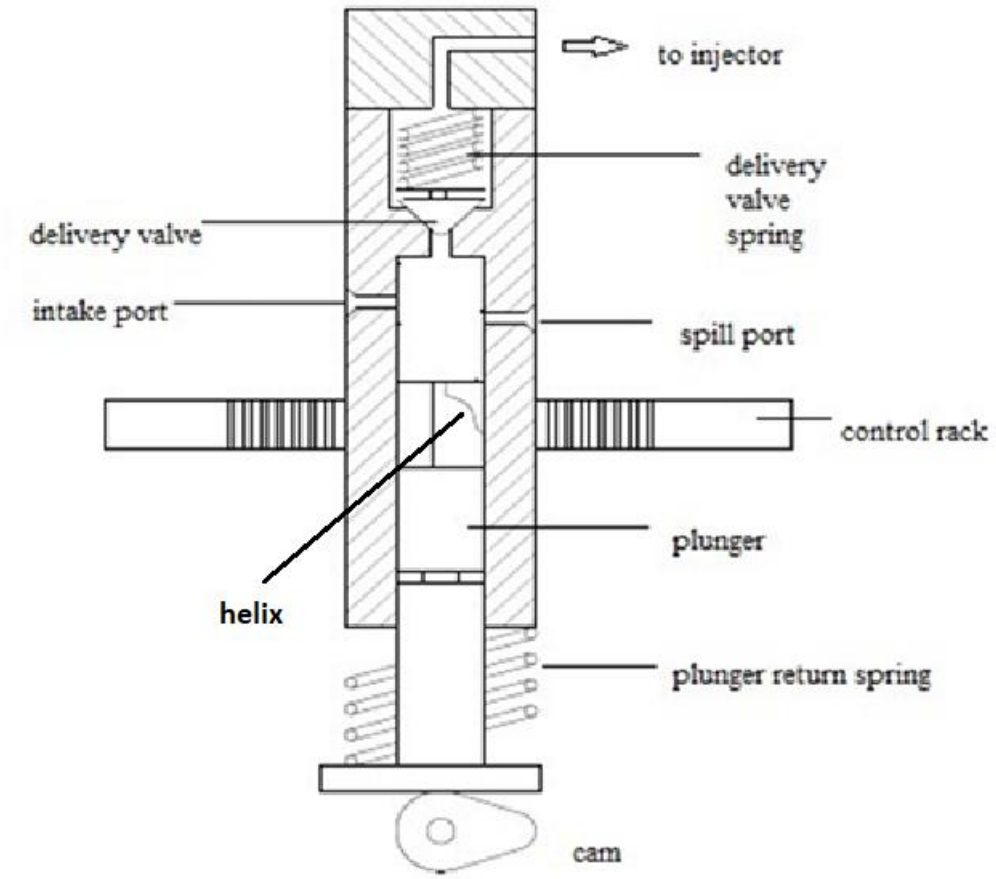
2. ***Timing the injection*** of the fuel correctly in the cycle so that maximum power is obtained ensuring fuel economy and clean burning.
3. ***Proper control of rate of injection*** so that the desired heat-release pattern is achieved during combustion
4. ***Proper atomization*** of fuel into very fine droplets.
5. ***Proper spray pattern*** to ensure rapid mixing of fuel and air.
6. ***Uniform distribution of fuel*** droplets in the combustion chamber.

TYPES OF INJECTION PUMPS:

The fuel injection pumps are generally of two types:

1. **Jerk type**
2. **Distributor type**

1. JERK TYPE FUEL INJECTION PUMP:



- The main parts of the pump are the delivery valve, the plunger, the control sleeve and the control rack.
- The plunger contains a helix at its upper end, which serves to control the quantity of fuel to be injected. The plunger is operated by means of cam and tappet.

- Figure shows the position of the plunger at the bottom of stroke. In this position, both the intake and the spill ports are uncovered.
- As the plunger moves up, it covers the two ports after which the upward plunger movement exerts pressure on the fuel at the top and then to the delivery valve which opens against the spring force, thereby delivering the fuel under pressure.
- As soon as the helix uncovers the spill port, the fuel escapes through the vertical slot in the plunger and the spill port and pressure is released, shutting the valve down on its seat.
- Fuel delivery starts when the plunger just covers the intake and the spill ports and ends when the helix just uncovers the spill port.
- Out of these events, start of delivery cannot be varied, but end of delivery can be timed to occur earlier or later, thus varying the quantity of fuel injected according to requirements.
- This is done by rotating the plunger using the control rack. Control rack is connected to the accelerator pedal.
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2. DISTRIBUTOR TYPE FUEL INJECTION PUMP:

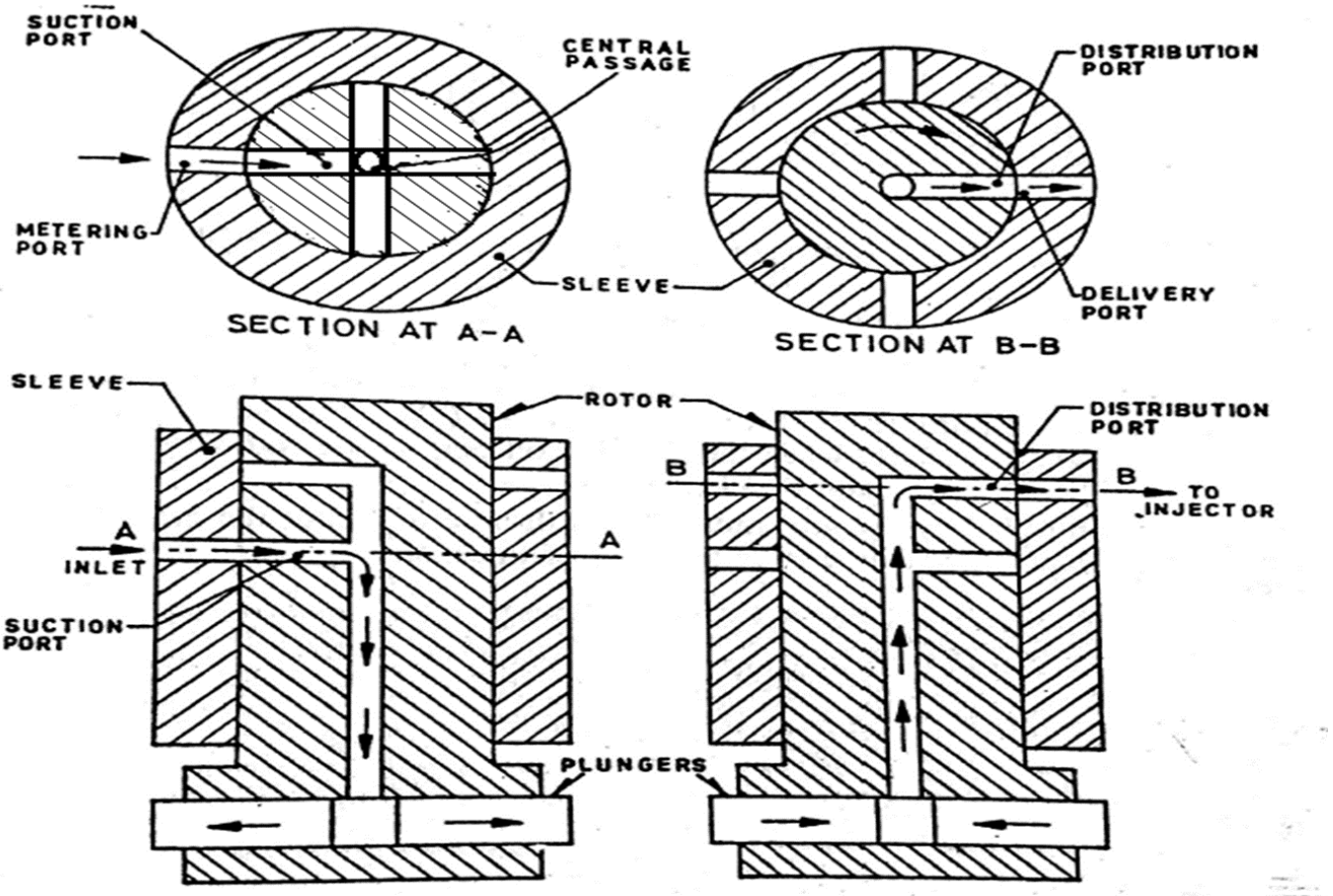

Fig. 10.18. Principle of working of distributor type fuel injection pump.
(*a*) Suction, (*b*) Delivery.

- Unlike the jerk, there is a single pumping element in this type of pump and the fuel is distributed to each cylinder by means of a rotor.

- The rotor has a central longitudinal passage and a set of radial holes (suction ports) equal to the number of engine cylinders, four in the figure shown.
- Similarly, the outer sleeve also has a set of equal number of holes (delivery ports) at a different level BB. Besides there is a metering port in the sleeve for the fuel intake at level AA and a distribution port in the rotor at level BB.
- This distribution port is connected to the central passage in the rotor. Each of the delivery ports is connected to injectors on the engine cylinders.
- As the rotor revolves, the suction ports align with the intake metering port one by one, while the distribution port aligns with the delivery ports.
- The lower end of the central passage in the rotor opens into a chamber in which two opposed pumping plungers are housed.
- As the rotor rotates, a stationary ring with internal cams operates the plungers through rollers and shoes which are placed in slots into the rotor base.
- The number of lobes on the cam ring is equal to the number of engine cylinders and these are evenly spaced around the ring.
- As the pump plungers move away from each other, the fuel is drawn into the central rotor passage from the inlet port through suction ports.
- The fuel thus charged is delivered to each cylinder in turn at high pressure, when the distribution port in the rotor coincides with the delivery port for any cylinder.

DIESEL FUEL INJECTOR:

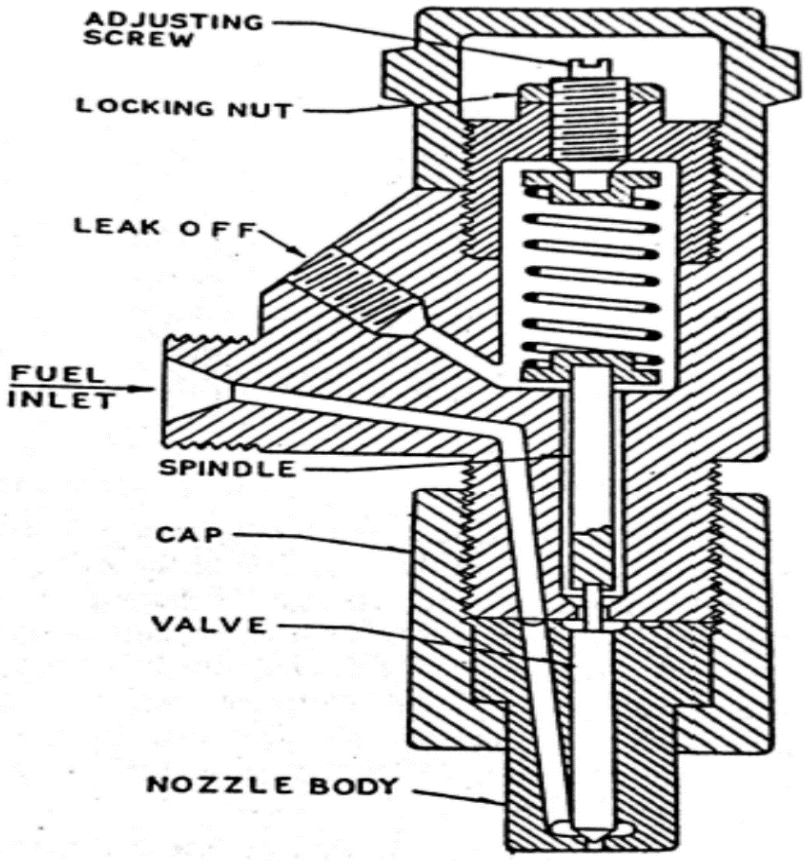

Fig. 10.21. Fuel injector (Bosch type).

- This is also known as nozzle, atomizer or fuel valve. Its function is to inject the fuel in the cylinder in properly atomised form and in proper quantity.
- It consists of mainly two parts, i.e., the nozzle and the nozzle holder.
- A spring-loaded spindle in the nozzle holder keeps the nozzle valve pressed against its seat in the nozzle body, till the fuel supplied by fuel injection pump through inlet passage exerts sufficient pressure so as to lift the nozzle valve against the spring force, when a spray of atomised fuel is fed into the combustion chamber.
- The fuel spray continues till the delivery from injection pump is exhausted when the spring
- pressure again suddenly closes the nozzle valve back on its seat.

GOVERNOR:

- The air intake decreases with speed of the engine, whereas the pump having a rising characteristic, results in over injection at higher speeds.
- On the other hand, at idling when the engine speed is less, the fuel delivered is also less when actually more fuel is required; as a result, the engine will stop.
- Similarly with increased load on the engine, the fuel delivered by the pump also increases, causing excessive carbon deposits and high exhaust temperature.
- On the other hand, a reduction of engine load will cause the speed to overshoot to dangerous values. A governor is, therefore, a necessity in case of diesel engines to control the fuel injected to ensure optimum conditions at all speeds and loads within the range specified.
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TYPES OF GOVERNORS:

1. Mechanical governor

2. Pneumatic governor

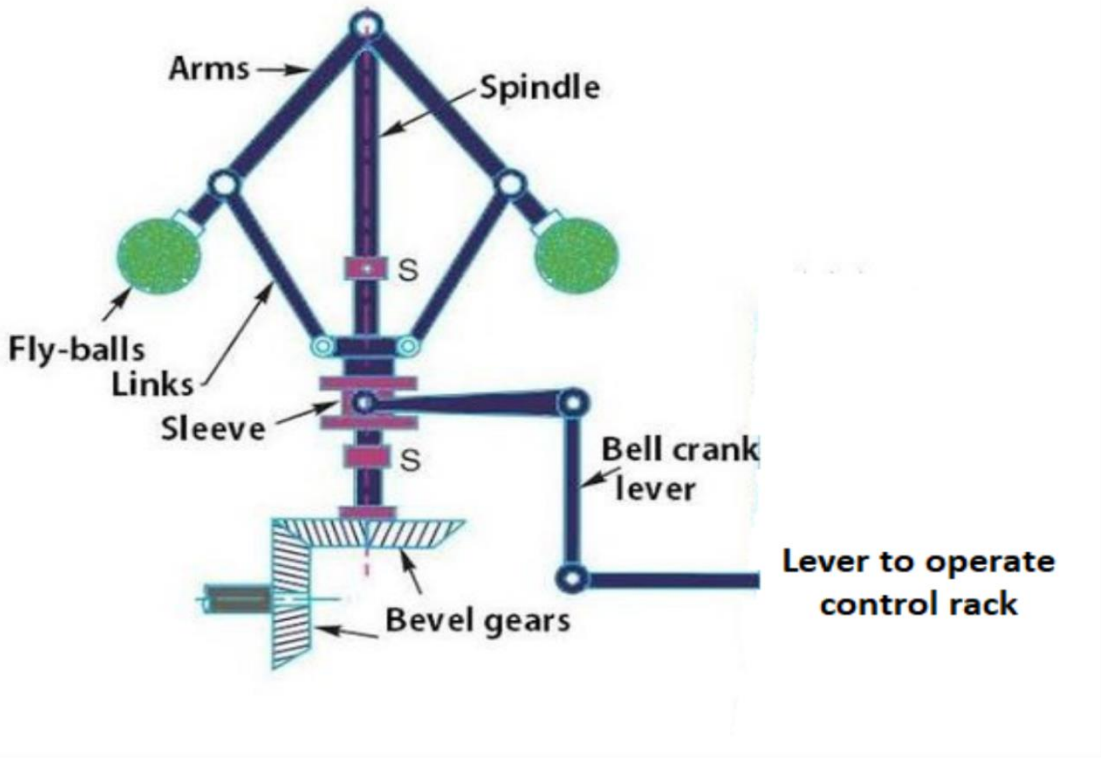
3. Hydraulic governor

1. MECHANICAL GOVERNOR:

- The principle of working of a mechanical governor may be explained with the help of Fig.
- Two spring-loaded weights are mounted on the governor shaft which gets drive from the engine.
- At one end, the bell crank levers carry balls whereas their other ends touch the lower surface of the flange of a sleeve on the governor shaft.
- As the engine speed increases, the centrifugal force due to the weights acts against the spring tension. Once the former exceeds the later, the weights fly apart, causing the other ends of the bell crank levers to raise the sleeve and hence operating the control lever in

the downward direction which further actuates the control rack on the fuel injection pump in a direction which reduces the amount of fuel delivered and hence decreases the engine speed.

- In the same way, the amount of fuel delivery is increased when the engine speed tends to decrease.



2. <u>PNEUMATIC GOVERNOR:</u>

- pneumatic governor shown in figure consists of two main parts, the venturi unit and the diaphragm unit.
- The venturi unit is connected to the engine inlet manifold and the diaphragm unit is fitted on the fuel injection pump. The two units are connected by a vacuum pipe.
- Accclerator pedal controls the position of the butterfly valve in the venturi unit and hence the amount of vacuum from the inlet manifold, which is applied to the diaphragm via the vacuum pipe.
- As the diaphragm is connccted to the fuel pump control rack, the rack is operaled left or right depending upon the amount of vacuum applied.
- Thus the position of the accelerator pedal determines the position of the pump control rack and hence the amount of fuel injected.
- Thus this is an all speed type of governor.

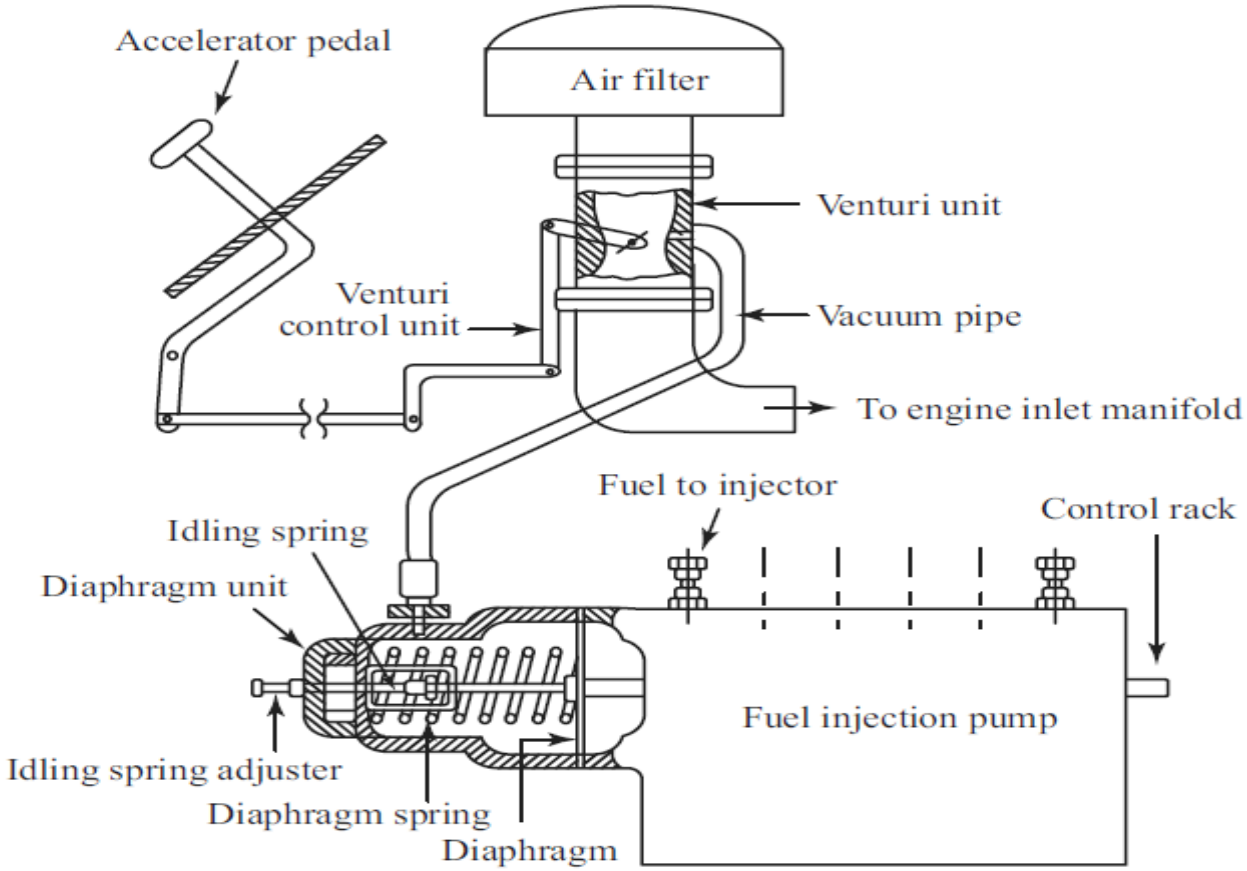
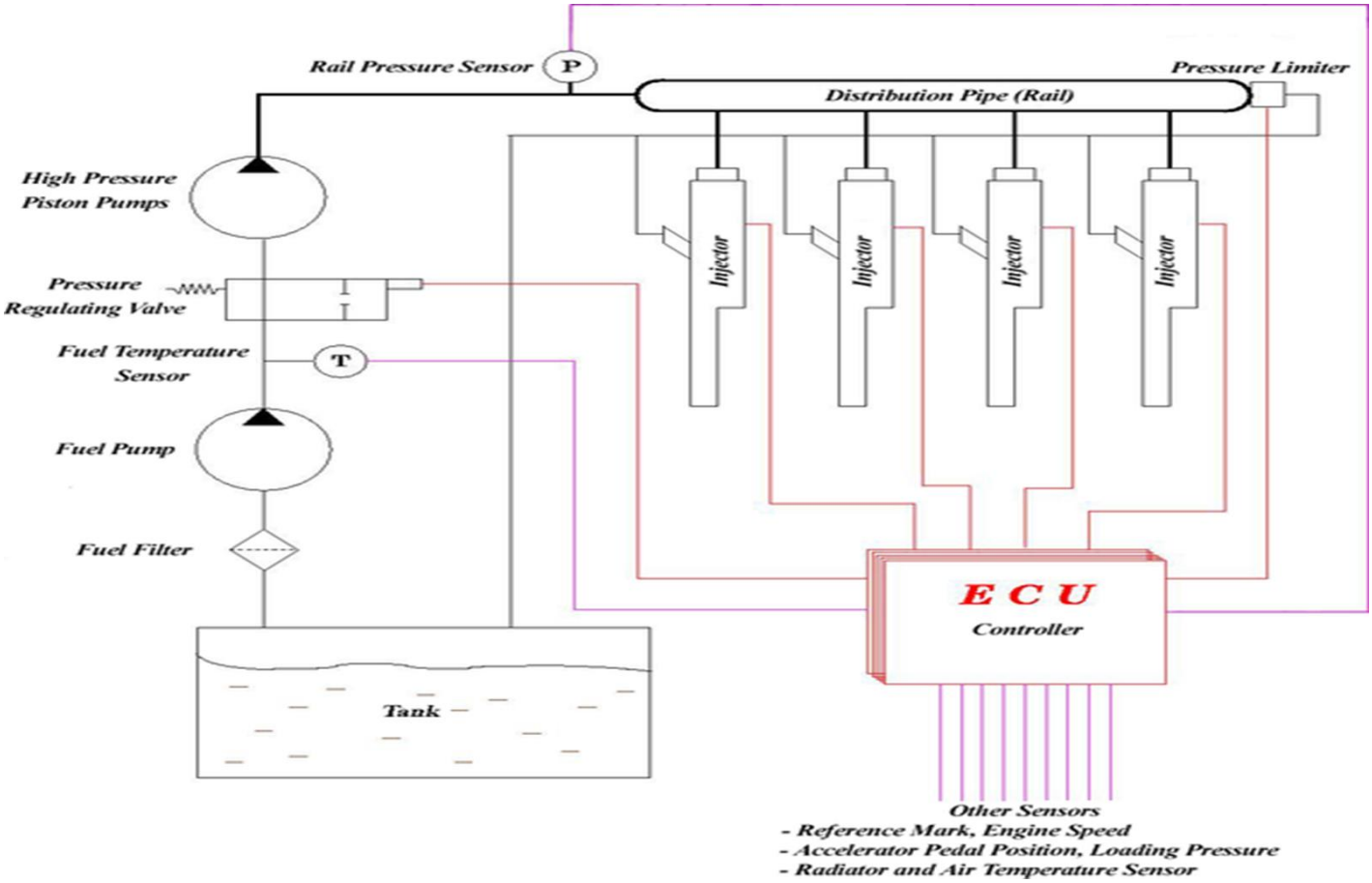


Fig. 8.10 Principle of pneumatic governor

COMMON RAIL DIRECT INJECTION (CRDI):

- CRDI is an electronic fuel injection system used in diesel engines in which, the timing of injection and the amount of fuel injected is controlled by ECU (electronic control unit).
- Some important features are:
  - Very high injection pressures of the order of 2500 bar.
  - Complete control over start, and end of injection.
  - Injection pressure is independent of engine speed.
  - Ability to have more than one injection during a single power stroke.
- A high-pressure accumulator element, called rail, is fed by a high-pressure fuel pump. This common rail feeds all the injectors on the engine.
- The injectors themselves are activated by solenoid valves. Solenoid valves and the fuel pump are electronically controlled.
- Thus, the common rail, serves as the high-pressure reservoir where the injection pressure is independent of the engine speed and load, due to which the injection parameters can be freely controlled.



- The main components of the system are the low-pressure pump, the high-pressure pump, the common rail, ECU, injection lines, the injectors, sensors and actuators.
- the fuel from the fuel tank is pumped by a low-pressure electric fuel pump through a filter, to the high-pressure pump, which builds up the high pressure in the common rail with the help of a pressure regulator valve which is controlled by an ECU (Electronic Control Unit) through pressure sensor.
- Thus, the fuel pressure in the rail is independent of engine speed and the injected fuel quantity.
- A pressure limiter valve guards the system against excess pressure.
- The fuel is injected in the engine combustion chamber by the injection nozzle of an injector controlled by a solenoid-operated valve.
- The injector receives its operation signals from the ECU.
- Pilot injection (also called pre-injection) is a short burst of fuel before the main injection during each combustion cycle. It helps reduce combustion noise. Thus, a double pre-injection would result in less noise compared to a single pre-injection.
- The common sensors employed are:
  - ***Crankshaft speed sensor:*** This registers the speed and angle of crankshaft without contact.
  - ***Camshaft speed sensor:*** It measures the speed and position of the camshaft without contact.

- ***Knock sensor:*** detects ping or preignition noise so that the ignition timing can be retarded.
- ***Mass Air flow sensor:*** To measure quantity of air drawn into the engine.
- ***Manifold absolute pressure (MAP) sensor:*** monitors vacuum in the engine intake manifold so that the mixture strength can be adjusted with changes in engine. load.
- ***Throttle position sensor (TPS):*** senses the movement of the throttle plate so that the mixture flow can be adjusted for engine speed and acceleration.
- ***Coolant temperature sensor (CTS):*** senses the temperature of the engine coolant, and from this data the computer adjusts the mixture strength.
- ***Manifold air temperature (MAT) sensor:*** checks the temperature of the ambient air entering the engine for fine tuning the mixture strength.
- ***Exhaust oxygen sensor:*** senses the amount of oxygen in the engine exhaust and calculates air-fuel ratio.
- ***Vehicle speed sensor (VSS).***

DIESEL EMISSION CONTROL DEVICES:

1. EXHAUST GAS RECIRCULATION (EGR)
2. CATALYTIC CONVERTER
3. DIESEL PARTICULATE FILTER (DPF)

EXHAUST GAS RECIRCULATION: (EGR)

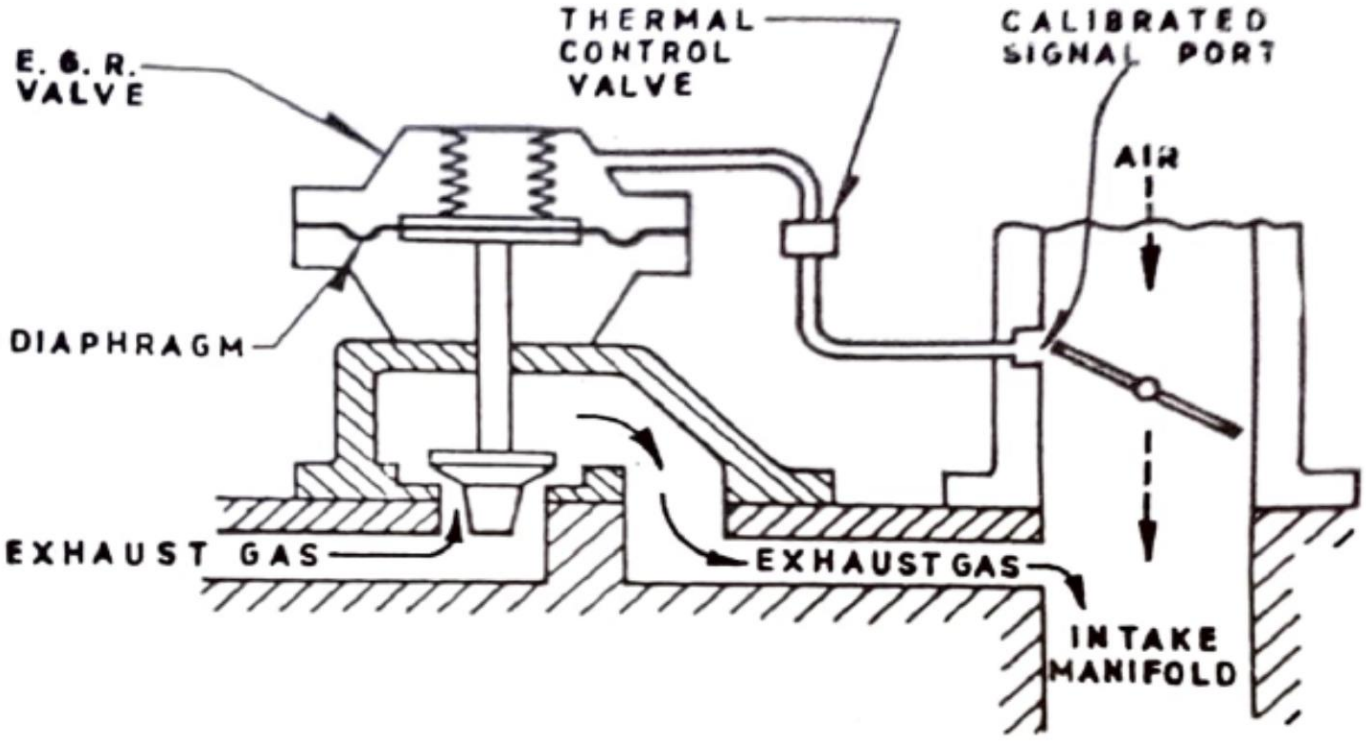


Fig. 18.14. Conventional EGR valve.

- The amount of exhaust gas admitted is regulated by a vacuum controlled valve, called the EGR valve.
- It consists of a spring-loaded vacuum diaphragm linked to a tapered valve which controls the passage for the exhaust gas.
- Ported vacuum from the throttle valve is connected to the EGR valve vacuum chamber.
- The EGR valve is closed at idle by spring pressure and less ported vacuum.
- When the throttle is opened from the idle position, ported vacuum applied will gradually open the tapered valve, causing the exhaust gas to flow into the intake manifold.
- However, when the throttle valve is fully open, there is no manifold vacuum, so the tapered valve is closed by the spring. Thus, EGR system does not affect full power operation.
- It is thus seen that in this system, exhaust gas is recirculated only when the engine operating conditions form NOx.
- The thermal control valve in the vacuum line is installed in the engine cooling system and serves to prevent EGR operation at low engine temperatures.