UNIT-I

AUTOMOTIVE ENGINE AUXILIARY SYSTEMS

IGNITION SYSTEM

The fuel feed system for the Spark ignition engines and Compression ignition engines are clearly discussed below.

2.1. Fuel Injection system for SI engines;

2.1.1. Carburetion

Spark-ignition engines normally use volatile liquid fuels. Preparation of fuel-air mixture is done outside the engine cylinder and formation of a homogeneous mixture is normally not completed in the inlet manifold. Fuel droplets, which remain in suspension, continue to evaporate and mix with air even during suction and compression processes. The process of mixture preparation is extremely important for spark-ignition engines. The purpose of carburetion is to provide a combustible mixture of fuel and air in the required quantity and quality for efficient operation of the engine under all conditions.

Definition of Carburetion;

The process of formation of a 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 a carburetor.

Definition of Carburetor;

The carburetor is a device used for atomizing and vaporizing the fuel and mixing it with the air in varying proportions to suit the changing operating conditions of vehicle engines.

Factors Affecting Carburetion

Of the various factors, the process of carburetion is influenced
by i. The engine speed
ii. The vaporization characteristics of the fuel
iii. The temperature of the incoming air and
iv. The design of the carburetor

Principle of Carburetion

Both air and gasoline are drawn through the carburetor and into the engine cylinders by the suction created by the downward movement of the piston. This suction is due to an increase in the volume of the cylinder and a consequent decrease in the gas pressure in this chamber.

It is the difference in pressure between the atmosphere and cylinder that causes the air to flow into the chamber. In the carburetor, air passing into the combustion chamber picks up discharged from a tube. This tube has a fine orifice called carburetor jet that is exposed to the air path.

The rate at which fuel is discharged into the air depends on the pressure difference or pressure head between the float chamber and the throat of the venturi and on the area of the outlet of the tube. In order that the fuel drawn from the nozzle may be thoroughly atomized, the suction effect must be strong and the nozzle outlet comparatively small. In order to produce a strong suction, the pipe in the carburetor carrying air to the engine is made to have a restriction. At this restriction called throat due to increase in velocity of flow, a suction effect is created. The restriction is made in the form of a venturi to minimize throttling losses.

The end of the fuel jet is located at the venturi or throat of the carburetor. The geometry of venturi tube is as shown in Fig.16.6. It has a narrower path at the center so that the flow area through which the air must pass is considerably reduced. As the same amount of air must pass through every point in the tube, its velocity will be greatest at the narrowest point. The smaller the area, the greater will be the velocity of the air, and thereby the suction is proportionately increased

As mentioned earlier, the opening of the fuel discharge jet is usually loped where the suction is maximum. Normally, this is just below the narrowest section of the venturi tube. The spray of gasoline from the nozzle and the air entering through the venturi tube are mixed together in this region and a combustible mixture is formed which passes through the intake manifold into the cylinders. Most of the fuel gets atomized and simultaneously a small part will be vaporized. Increased air velocity at the throat of the venturi helps he rate of evaporation of fuel. The difficulty of obtaining a mixture of sufficiently high fuel vapour-air ratio for efficient starting of the engine and for uniform fuel-air ratio indifferent cylinders (in case of multi cylinder engine) cannot be fully met by the increased air velocity alone at the venturi throat.

2.1.2. The Simple Carburetor

Carburetors are highly complex. Let us first understand the working principle bf a simple or elementary carburetor that provides an air fuel mixture for cruising or normal range at a single speed. Later, other mechanisms to provide for the various special requirements like starting, idling, variable load and speed operation and acceleration will be included. Figure 3. shows the details of a simple carburetor.

The simple carburetor mainly consists of a float chamber, fuel discharge nozzle and a metering orifice, a venturi, a throttle valve and a choke. The float and a needle valve system maintain a constant level of gasoline in the float chamber. If the amount of fuel in the float chamber falls below the designed level, the float goes down, thereby opening the fuel supply valve and admitting fuel. When the designed level has been reached, the float closes the fuel supply valve thus stopping additional fuel flow from the supply system. Float chamber is vented either to the atmosphere or to the" upstream side of the venturi.During suction stroke air is drawn through the venturi.

As already described, venturi is a tube of decreasing cross-section with a minimum area at the throat, Venturi tube is also known as the choke tube and is so shaped that it offers minimum resistance to the air flow. As the air passes through the venturi the velocity increases reaching a maximum at the venturi throat. Correspondingly, the pressure decreases reaching a minimum. From the float chamber, the fuel is fed to a discharge jet, the tip of which is located in the throat of the venturi. Because of the differential pressure between the float chamber and the throat of the venturi, known as carburetor depression, fuel is discharged into the air stream.

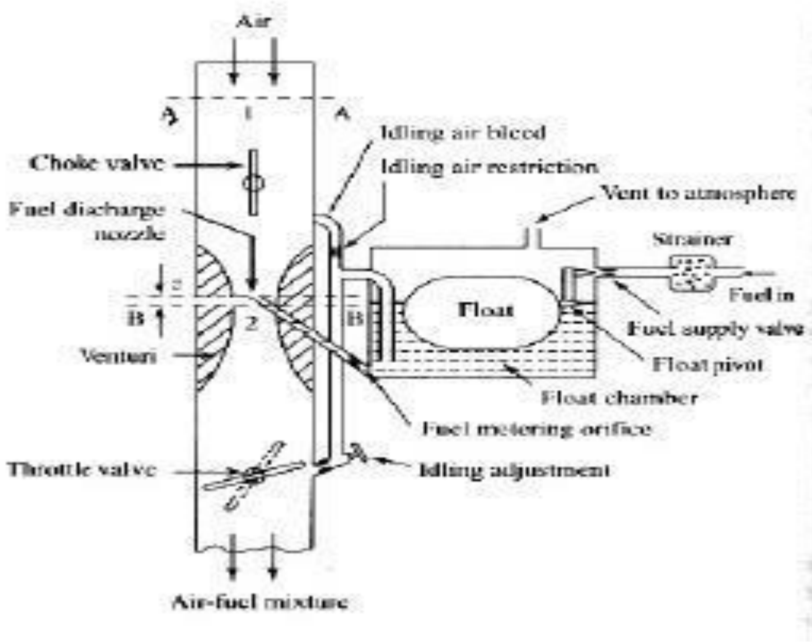


Figure: 3 The Simple Carburetor

The fuel discharge is affected by the size of the discharge jet and it is chosen to give the required air-fuel ratio. The pressure at the throat at the fully open throttle condition lies between 4 to 5 cm of Hg, below atmospheric and seldom exceeds8 cm Hg below atmospheric. 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 discharge jet. This is called the tip of the nozzle. The difference in the height between the top of the nozzle and the float chamber level is marked h in Fig.3.

The gasoline engine is quantity governed, which means that when power output is to be varied at a particular speed, the amount of charge delivered to the cylinder is varied. This is achieved by means of a throttle valve usually of the butterfly type that is situated after the venturi tube.

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. As the" throttle is opened, more air flows through the choke tube resulting in increased quantity of mixture being delivered to the engine. This increases the engine power output. A simple carburetor of the type described above suffers from a fundamental drawback in that it provides the required A/F ratio only at one throttle position.

At the other throttle positions the mixture is either leaner or richer depending on whether the throttle is opened less or more. As the throttle opening is varied, the air flow varies and creates a certain pressure differential between the float chamber and the venturi throat. The same pressure differential regulates the flow of fuel through the nozzle. Therefore, the velocity of flow of air II and fuel vary in a similar manner.

The Choke and the Throttle

When the vehicle is kept stationary for a long period during cool winter seasons, may be overnight, starting becomes more difficult. *As* already explained, at low cranking speeds and intake temperatures a very rich mixture is required to initiate combustion. Some times air-fuel ratio as rich as 9:1 is required. The main reason is that very large fraction of the fuel may remain as liquid suspended in air even in the cylinder. For initiating combustion, fuel-vapour and air in the form of mixture at a ratio that can sustain combustion is required.

It may be noted that at very low temperature vapour fraction of the fuel is also very small and this forms combustible mixture to initiate combustion. Hence, a very rich mixture must be supplied. The most popular method of providing such mixture is by the use of choke valve. This is simple butterfly valve located between the entrance to the carburetor and the venturi throat as shown in Fig.3.

When the choke is partly closed, large pressure drop occurs at the venturi throat that would normally result from the quantity of air passing through the venturi throat. The very large depression at the throat inducts large amount of fuel from the main nozzle and provides a very rich mixture so that the ratio of the evaporated fuel to air in the cylinder is within the combustible limits. Sometimes, the choke valves are spring loaded to ensure that large carburetor depression and excessive choking does not persist after the engine has started, and reached a desired speed.

This choke can be made to operate automatically by means of a thermostat so that the choke is closed when engine is cold and goes out of operation when engine warms up after starting. The speed and the output of an engine is controlled by the use of the throttle valve, which is located on the downstream side of the venturi.

The more the throttle is closed the greater is the obstruction to the flow *of* the mixture placed in the passage and the less is the quantity *of* mixture delivered to .the cylinders. The decreased quantity *of* mixture gives a less powerful impulse to the pistons and the output *of* the engine is reduced accordingly. As the throttle is opened, the output *of* the engine increases. Opening the throttle usually increases the speed *of* the engine. But this is not always the case as the load on the engine is also a factor. For example, opening the throttle when the motor vehicle is starting to climb a hill may or may not increase the vehicle speed, depending upon the steepness *of* the hill and the extent *of* throttle opening. In short, the throttle is simply a means to regulate the output *of* the engine by varying the quantity *of* charge going into the cylinder.

Compensating Devices

An automobile on road has to run on different loads and speeds. The road conditions play a vital role. Especially on city roads, one may be able to operate the vehicle between 25 to 60% of the throttle only. During such conditions the carburetor must be able to supply nearly constant air-fuel ratio mixture that is economical (16:1).However, the tendency of a simple carburetor is to progressively richen the mixture as the throttle starts opening.

The main metering system alone will not be sufficient to take care of the needs of the engine. Therefore, certain compensating devices are usually added in the carburetor along with the main metering system so as to supply a mixture with the required air-fuel ratio. A number of compensating devices are in use. The important ones are

i. Air-bleed jet
ii. Compensating jet
iii. Emulsion tube
iv. Back suction control mechanism
v. Auxiliary air valve
vi. Auxiliary air port

As already mentioned, in modern carburetors automatic compensating devices are provided to maintain the desired mixture proportions at the higher speeds. The type of compensation mechanism used determines the metering system of the carburetor. The principle of operation of various compensating devices are discussed briefly in the following sections.

Air-bleed jet

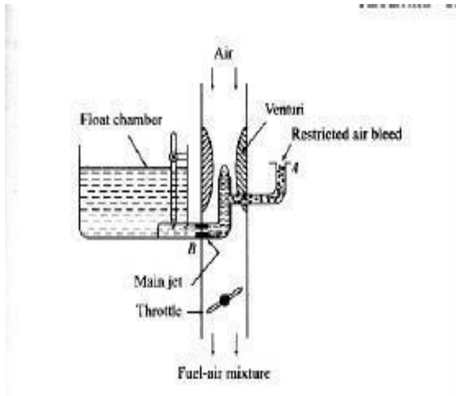


Figure: 4 Air bleed principle in a typical carburetor

Figure 4. illustrates a principle of an air-bleed system in atypical modern downdraught carburetor. As could be seen it contains an air-bleed into the main nozzle. An orifice restricts the flow of air through this bleed and therefore it is called restricted air-bleed jet that is very popular. When the engine is not operating the main jet and the air bleed jet will be filled with fuel. When the engine starts, initially the fuel starts coming through the main as well as the air bleed jet (A). As the engine picks up, only air starts coming through the air bleed and mixes with fuel at B making a air fuel emulsion.

Thus the fluid stream that has become an emulsion of air and liquid has negligible viscosity and surface tension. Thus the flow rate of fuel is augmented and more fuel is sucked at low suctions. ‘By proper design of hole size at B compatible with the entry hole at A, it is possible to maintain a fairly uniform mixture ratio for the entire power range of the operation of an engine. If the fuel flow nozzle of the air-bleed system is placed in the centre of the venturi, both the air-bleed nozzle and the venturi are subjected to same engine suction resulting approximately same fuel-air mixture for the entire power range of operation.

Compensating Jet

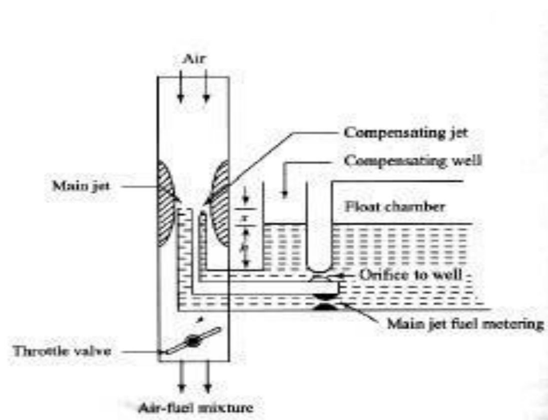


Figure: 5 Compensating Jet device

The principle of compensating jet device is to make the mixture leaner as the throttle opens progressively. In this method, as can be seen from Fig.5 in addition to the main jet, a compensating jet is incorporated. The compensating jet is connected to the compensation well. The compensating well is also vented to atmosphere like the main float chamber.

The compensating well is supplied with fuel from the main float chamber through a restricting orifice. With the increase in airflow rate, there is decrease of fuel level in the compensating well, with the result that fuel supply through the compensating jet decreases. The compensating jet thus progressively makes the mixture leaner as the main jet progressively makes the mixture richer. The main jet curve and the compensating jet curve are more or less reciprocals of each other.

Emulsion Tube

The mixture correction is attempted by air bleeding in modern carburetor. In one such arrangement as shown in Fig.6, the main metering jet is kept at a level of about 25 mm below the fuel level in the float chamber. Therefore, it is also called submerged jet. The jet is located at the bottom of a well. The sides of the well have holes. As can be seen from the figure these holes are in communication with the atmosphere. In the beginning the level of petrol in the float chamber and the well is the same.

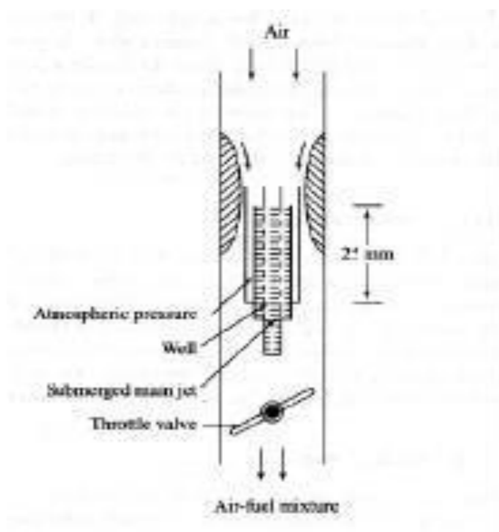


Figure: 6 Emulsion Tube

When the throttle is opened the pressure at the venturi throat decreases and petrol is drawn into the air stream. This results in progressively uncovering the holes in the central tube leading to increasing air-fuel ratios or decreasing richness of mixture when all holes have been uncovered. Normal flow takes place from the main jet. The air is drawn through these holes in the well, and the fuel is emulsified and the pressure differential across the column of fuel is not as high as that in simple carburetor.

Acceleration Pump System

Acceleration is a transient phenomenon. In order to accelerate the vehicle and consequently its engine, the mixture required is very rich and the richness of the mixture has to be obtained quickly and very rapidly. In automobile engines situations arise when it is necessary to accelerate the vehicle. This requires an increased output from the engine in a very short time.

If the throttle is suddenly opened there is a corresponding increase in the air flow. However, because of the inertia of the liquid fuel, the fuel flow does not increase in proportion to the increase in air flow. This results in a temporary lean mixture ca11singtheengine to misfire and a temporary reduction in power output.

To prevent this condition, all modern carburetors are equipped with an accelerating system. Figure 7. illustrates simplified sketch of one such device. The pump comprises of a spring loaded plunger that takes care of the situation with the rapid opening of the throttle valve. The plunger moves into the cylinder and forces an additional jet of fuel at the venturi throat.

When the throttle is partly open, the spring sets the plunger back. There is also an arrangement which ensures that fuel in the pump cylinder is not forced through the jet when valve is slowly opened or leaks past the plunger or some holes into the float chamber.

Mechanical linkage system, in some carburetor, is substituted by an arrangement where by the pump plunger is held up by manifold vacuum. When this vacuum is decreased by rapid opening of the throttle, a spring forces the plunger down pumping the fuel through the jet.

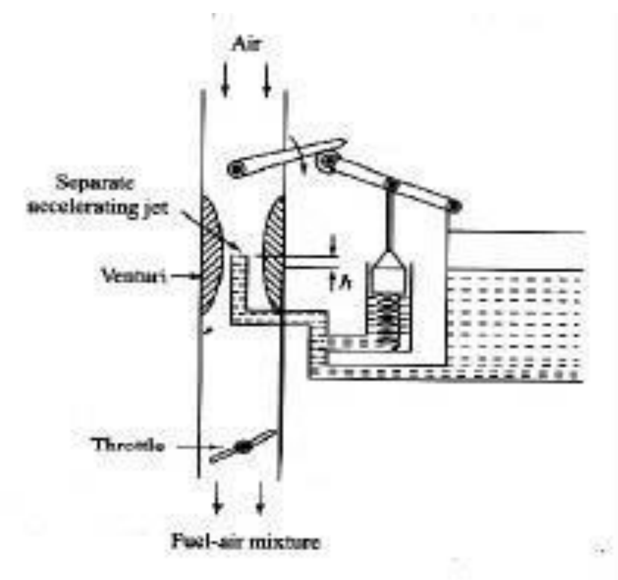


Figure: 7 Acceleration pump system

2.1.3. Types of Carburetors

There are three general types of carburetors depending on the direction of flow of air. The first is the up draught type shown in Fig.8(a) in which the air enters at the bottom and leaves at the top so that the direction of its flow is upwards. The disadvantage of the up draught carburetor is that it must lift the sprayed fuel droplet by air friction. Hence, it must be designed for relatively small mixing tube and throat so that even at low engine speeds the air velocity is sufficient to lift and carry the fuel particles along. Otherwise, the fuel droplets tend to separate out providing only a lean mixture to the engine. On the other hand, the mixing tube is finite and small then it cannot supply mixture to the engine at a sufficiently rapid rate at high speeds.

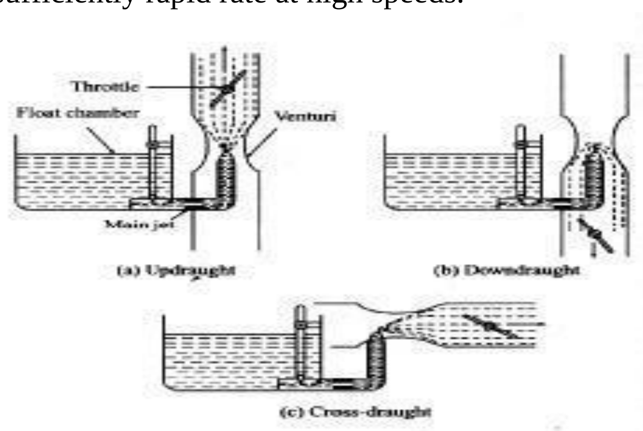


Figure: 8 Types of Carburetors

In order to overcome this drawback the downdraught carburetor [Fig.8 (b)] is adopted. It is placed at a level higher than the inlet manifold and in which the air and mixture generally follow a downward course. Here the fuel does not have to be lifted by air friction as in the up draught carburetors but move into the cylinders by gravity even if the air velocity is low. Hence, the mixing tube and throat can be made large which makes high engine speeds and high specific outputs possible.

Constant Choke Carburetor:

In the constant choke carburetor, the air and fuel flow areas are always maintained to be constant. But the pressure difference or depression, which causes the flow of fuel and air, is being varied as per the demand on the engine. Solex and Zenith carburetors belong to this class.

Constant Vacuum Carburetor:

In the constant vacuum carburetor, (sometimes called variable choke carburetor) air and fuel flow areas are being varied as per the demand on the engine, while the vacuum is maintained to be always same. The S.U. and Carter carburetors belong to tills class.

Multiple Venturi Carburetor:

Multiple venturi system uses double or triple venturi. The boost venturi is located concentrically within the main venturi.The discharge edge of the boost venturi is located at the throat of the main venturi. The boost venturi is positioned upstream of the throat of the larger main venturi. Only a fraction of the total air flows though the boost venturi. Now the pressure at the boost venturi exit equals the pressure at the main venturi throat. The fuel nozzle is located at the throat of the boost venturi.

2.2. Fuel Injection system for C I engines;

Fuel system components FUEL INJECTION PUMP - Fuel injection pump sucks fuel from the tank , pressurizes the fuel to approx. 600 - 1000 bar and sends it to the injectors. Inline FIP - Has separate pumping chambers for each cylinder Rotary FIP (Distributor pump) - Has one pumping chamber and the pump distributes to each cylinder as per sequence- firing order INJECTORS - Inject the high pressure fuel in to each cylinder. FUEL FILTER - Filters the fuel from dirt & sediments, since the Fuel injection pump requires clean fuel.

Injection system In the C.I. engine the fuel is injected into the combustion chamber, it the has to mix thoroughly with the air, ignite and burn all at the same time. To insure this happens, two types of combustion chamber have been developed. Direct Injection Indirect Injection

2.2.1. Electronic Diesel Control

Electronic Diesel Control is a diesel engine fuel injection control system for the precise of metering and delivery in fuel into the combustion chamber of modern diesel engines used trucks and cars.

EDC injection inline pump

The mechanical fly-weight governors of inline and distributor diesel fuel Injection pumps used to control fuel delivery under a variety of engine loads and conditions could no longer deal with the ever increasing demands for efficiency, emission control, and power and fuel consumption.

These demands are now primarily fulfilled by the Electronic Control, the system which provides greater ability for precise measuring, data processing, operating environment flexibility and analysis to ensure efficient diesel engine operation. The EDC replaces the mechanical control governor with an electro-magnetic control device.

2.2.2. Components in Electronically controlled Diesel Supply;

The EDC is divided into these main groups of components.

- Electronic sensors for registering operating conditions and changes. A wide array of physical inputs is converted into electrical signal outputs.
- Actuators or solenoids which convert the control unit's electrical output signal into mechanical control movement.
- ECM (Electronic Control Module) or Engine ECU (Electronic Control Unit) with microprocessors which process information from various sensors in accordance with programmed software and outputs required electrical signals into actuators and solenoids.

EDC accelerator pedal assembly

1. Electronic sensors;

- Injection pump speed sensor - monitors pump rotational speed
- Fuel rack position sensor - monitors pump fuel rack position
- Charge air pressure sensor - measures pressure side of the turbocharger
- Fuel pressure sensor
- Air cleaner vacuum pressure sensor
- Engine position sensor
- Temperature sensors - measure various operating temperatures

- Intake temperature
- Charge air temperature
- Coolant temperature
- Fuel temperature
- Exhaust temperature (Pyrometer)
- Ambient temperature

- Vehicle speed sensor - monitors vehicle speed
- Brake pedal sensor - operates with cruise control, exhaust brake, idle control
- Clutch pedal sensor - operates with cruise control, exhaust brake, idle control
- Accelerator pedal sensor.

2. Electronic Control Unit;

EDC control unit

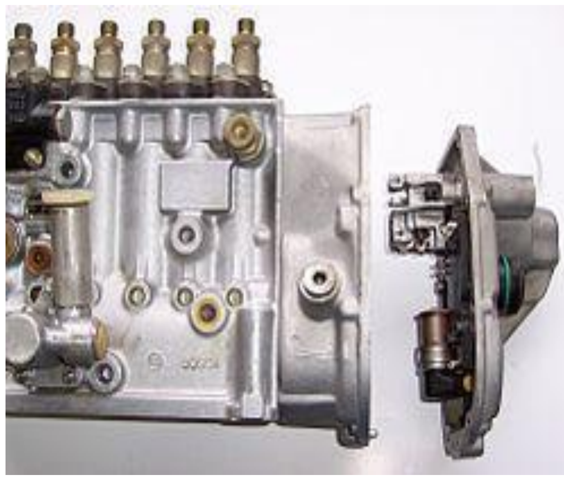
The ECU collects and processes signals from various on-board sensors. AnECU electronic module contains microprocessors, memory units, analog to digital converters and output interface units. Depending upon the parameters, a number of different maps can be stored in the onboard memory.

This allows the ECU to be tailored to the specific engine and vehicle requirements, depending on the application. The operating software of the ECU can be adapted for a wide variety of engines and vehicles without the necessity of hardware modification.

The ECU is usually located in the cab or in certain cases, in a suitable position in the engine bay where additional environmental conditions might require cooling of the ECU as well as a requirement for better dust, heatand vibrations insulation .

3. Actuators and Solenoids

Electro-magnetic actuators are usually located on the fuel pump to transfer electrical signals into mechanical action in this case fuel rack actuator and or fuel stop solenoid which means that depending on requests from control unit full fuel or no fuel quantity.



EDC pump actuator

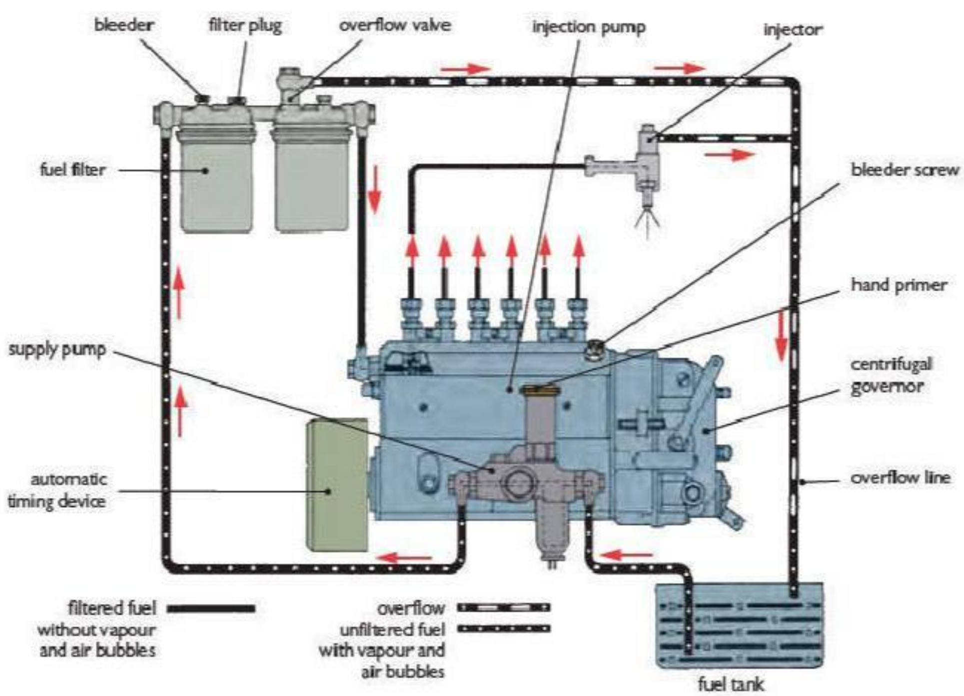
- Injectors
- Boost-pressure actuator
- Intake-duct switchoff
- Throttle-valve actuator
- Exhaust-gas recirculation actuator
- Auxiliary heating
- A/C compressor
- Radiator fan
- Electronic shutoff valve
- Rail-pressure control valve
- Diagnosis lamp

Working Principle;

The injection of fuel or the quantity of injected fuel has a decisive influence on engine starting, idling, power and emissions. The engine ECU is programmed ("mapped") with relevant data to where the fuel rack position has an equivalent signal for the amount of fuel being injected.

The driver requests the torque or engine speed requirements via accelerator pedal potentiometer thereby sending a signal to the engine ECU which then, depending on its *mapping* and data collected from various sensors, calculates in real time the quantity of injected fuel required, thus altering the fuel rack to the required position. The driver can also input additional commands such as idle speed increase to compensate e.g. for PTO operation which can be either variably set or has a preset speed which can be recalled.

The road speed function can be used to evaluate vehicle speed and possibly activate a speed limiter (Heavy Vehicles), or maintain or restore a set speed (cruise control). Further functions can include exhaust brake operation which, when activated, will result in the fuel pump rack position being set to zero delivery or idle. The engine ECU can also interface with various other vehicle systems e.g. traction control and carries out self monitoring duties and self diagnostic functions to keep the system working at an optimal level. To ensure the safe operation in case of failure, the limp home mode functions are also integrated into the system, for e.g. should the pump speed sensor fail the ECU can use an alternator speed signal function for engine RPMs counter as a backup signal.

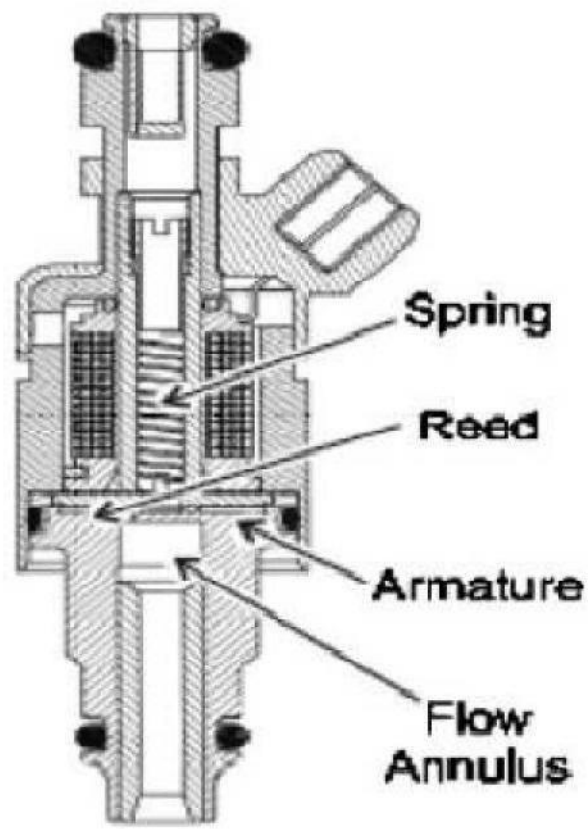


2.2.3. Fuel Injector:

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.



2.3. Introduction of Ignition System;

- For petrol engine - Battery ignition system , Magneto ignition system Injection system
- For diesel engine - Fuel supply system.

Battery ignition system:

Battery ignition system has the following elements

- Primary Ignition Circuit(low voltage)
- Battery
- Ignition switch
- Primary windings of coil
- Contact breaker
- capacitor
- Secondary Ignition Circuit (high voltage)
- Secondary windings of coil
- Distributor cap and rotor (if the vehicle is so equipped)
- Spark plug wires &
- Spark plugs

IGNITION SYSTEM – Magneto System Ignition Switch Distribution Contact Breaker Coil Magneto Condenser Power Generation Spark Generation Magneto Unit Rotor Arm

IGNITION SYSTEM – Dynamo/Alternator System Dynamo/ Alternator Distributor Contact Breaker Coil Ignition Switch Secondary Windings Primary Windings Condenser Battery

Ignition Switch Coil Packs IGNITION SYSTEM – Electronic Systems Control Unit Timing Sensor Timing Disc Engine Speed Sensing Unit Alternator Battery

In all spark ignition engines which work on the Gasoline either 2-Stroke or 4-Stroke cycle principle and utilize a carburetor or fuel injection system, the combustion of the air-fuel mixture is initiated by an electric spark.

The term ‘Spark Ignition’ means that a brief electric arc is produced between the electrodes of a spark plug, the energy for which is derived from an external power source. In most cases this power source is the vehicle battery, which is constantly being supplemented by the alternate while the vehicle is mobile.

A different method of ignition is employed in diesel engines. This is called ‘compression ignition’ and relies on the fact that when air compressed, its temperature rises. In diesel engines, compression ratio of between 16:1 and 25:1 are common, and at the end of a compression the temperature of the trapped air is sufficiently high to ignite the diesel fuel that is sprayed into the cylinder at the appropriate time.

The functions of ignition system

The functions of the coil ignition systems in general use on motor vehicle may be divided into three areas. These are:

- Production of the high voltage necessary to produce a spark at the plug gap.
- Distribute the spark to all the cylinders at proper time based on the firing order.
- Varying the timing of the spark depending on the various operating conditions of the engine like cranking time, varying speed and load, so that the best performance is obtained from the engine under all operating conditions.

Mechanism of Ignition

It must be remembered that vehicle battery voltages are usually 12 volt or 24 volt and this value is too low to produce a heavy spark at the plug gap in a cylinder under compression. For this reason one of the major functions of the battery ignition system is to raise the battery voltage to the required level and then apply it to spark plugs.

This process is correctly initiated in the primary circuit and completed in the secondary winding of the ignition coil. Depending on the type of engine and the conditions existing in the cylinders, a voltage of between 5,000 to 20,000 volts is required and this is called the **ionizing voltage** or **firing voltage.**

This firing voltage forces the electrons to jump between the electrodes of the spark plug in the gap to produce the required spark. The electric spark has sufficient heat energy to ignite the air-fuel mixture which later continues to burn itself.

The conventional coil ignition system

Inductive ignition systems: that uses an **ignition coil** to perform the step up transformer action and to increase the electrical voltage. The ignition coils of the inductive ignition systems operate on the principle of electromagnetic induction (EMI) irrespective of whether it is triggered by contact breakers or by electronic triggering units.

Note:

As a reminder of the principle of EMI, a voltage will be induced into a coil whenever the following factors are present:

(a) a magnetic field

(b) a set of conductors

(c) a relative movement between the magnetic field and conductors.

The factors affecting the operation of the Ignition system.

The factors that determine the value of the voltages induced into the ignition coil windings during the ignition cycle are:

The strength of the magnetic field.
The stronger the magnetic field produced in the coil primary winding, the greater the possibility of producing a high secondary voltage.

The number of conductors on the secondary winding being cut by the magnetic field. This is important when considering the voltages produced in both coil windings during the ignition cycle.

The source of the high voltage pulses of current produced in the inductive ignition system is in the ignition coil. The coil stores the energy in the magnetic field around the primary winding and at the required instant of ignition, transforms it into a pulse of high voltage current in the secondary
winding. From here it is delivered to the correct spark plug via the high tension (HT) cables. This 'Inductive storage device' may vary in design between certain manufacturers, but in general the
most common construction is as shown in figure below.

This coil contains a rod shaped, laminated soft iron core at its centre, and the soft iron cover surrounds both primary and secondary windings. Both of these soft iron components are used to intensify and maximize the effect of the primary magnetic field and thus, the energy stored. The iron core must be laminated to minimize the effects of eddy currents that are produced during operation and so keep to a minimum the heat developed. The outer soft iron cover is slotted to allow circulation of the oil filling which is used for cooling purposes.

Around the laminated core, the secondary winding is wounded. This consists of many turns of very fine insulated copper wire (generally in the vicinity of 20,000 turns). One end of this winding is connected to the HT outlet of the coil via the laminated iron core which it used as the pick-up point for this connection. The other end is connected to the positive (+) low tension primary terminal.

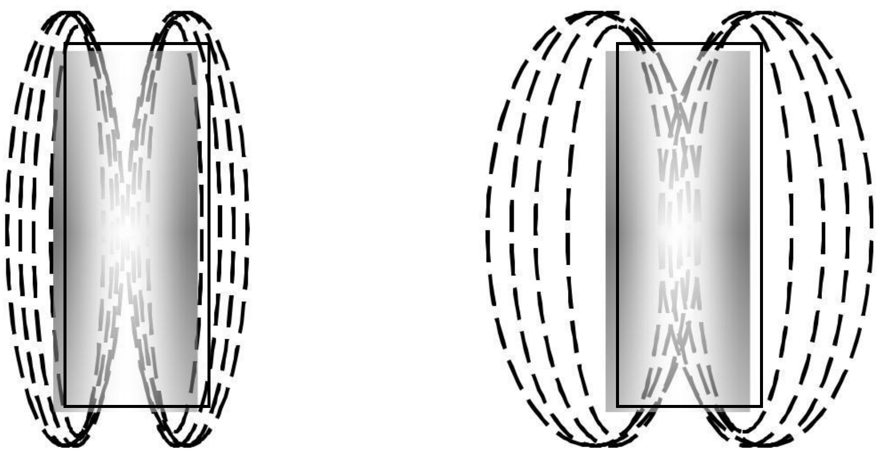
Over the top of the secondary winding the primary winding is wounded with the insulation. The primary winding consisting of a few hundred turns of relatively heavy insulated copper wire. The ends of the primary winding are connected to the two low tension, or primary terminals. A reason for placing the primary winding over the secondary is that it is in this coil, which caries the full primary circuit current (approximately 2 ampere in standard systems), the secondary winding generates the heat and by placing it thus, the cooling oil is given ready access to it.

A ceramic insulator at the base of the coil supports the core and winding and at the top is a plastic-type insulator which provides a location point for the high-tension and primary terminals. This top insulator is sealed into the outer case to prevent the loss of coolant oil or the energy of moisture.

Operation of an Ignition coil

Electromagnetic induction is the effect of creating the voltage in a conductor by means of relative movement between the conductor and a magnetic field. In the ignition coil the conductors remain stationary and the magnetic field is moved across them. To develop these necessary conditions, the first requirement in the ignition oil is the production of a magnetic field. This is the function of the primary winding.

When the ignition switch is closed, the primary winding of the coil is connected to the positive terminal of the vehicle battery. Now, if the primary circuit is completed through the contact breaker points a current will flow in the circuit, creating a magnetic field in the coil around the soft iron core. This magnetic field grows outwards from the core until it has reached maximum value and the core is fully magnetized and ceases to grow further.



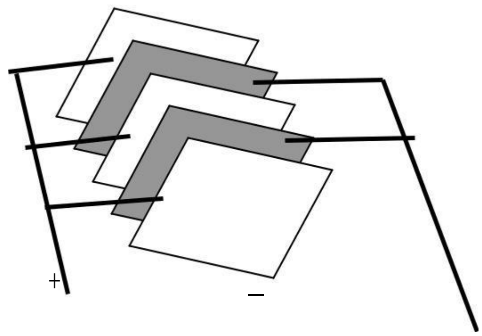
Growing Magnetic field

To provide the very high voltage necessary to create a spark across the plug gap, the secondary winding has a very large number of turns. NOTE: The ratio of the number of secondary turns to the number of primary turns is very large – approximately 100:1. The effect of this high ration is to produce a very high voltage in the secondary winding when the magnetic field is collapsed rapidly across it as the contact breaker points are opened.

To understand the operation of the ignition coil, it is necessary to have the knowledge of the effect of winding insulated wire into the form of a coil and then passing a current through it. In earlier chapters of this course, an explanation was given of how a magnetic field forms around a wire when current flows through it.

Construction

The construction of a capacitor is quite simple. It is made of two strips of metallised paper, separated by a thin dielectric (insulator), generally of waxed paper or plastic, both rolled tightly together and fitted into a metal container. An insulated flexible lead is attached to one of the metallised plates and brought out for connection to the insulated side of the contacts. The other metallised plate is attached to the metal container which has facilities for connecting it to a good earth either inside or outside the distributor, thus effectively connecting the capacitor across, or in parallel, with the points.



As a general statement it can be said that a capacitor is a device which has the ability to store an electrical charge. When a capacitor is 'charged', each plate will hold an equal but opposite charge. That is the plate connected to the negative side of the circuit will acquire a negative charge, and the plate connected to the positive side of the circuit, a positive charge. Once these opposite charges are stored on the plates, they will attract each other through the separating dielectric,

and thus tend to prevent the charge escaping or leaking away.

NOTE: The loss of electrical charge from a capacitor is termed the capacitor's leakage. Among the tests applied to a capacitor is a test for leakage, which must be below a certain rate of loss.

Removing the charge from a capacitor is called discharging it. This is accomplished by connecting a conductor across its plates. The excess electrons are attracted from the negatively charged plate to the positively electrons are attracted from the negatively charged plate to the positively charged plate. The electron flow continues until such time as both charges equalize, i.e. there is no potential difference between the plates.

The factors affecting the capacity of a capacitor:

(a) The area of the plates holding the charges and the number of plates used.
(b) The distance the plates are separated, i.e. the thinner the dielectric, the greater the attractive force between the charges, and therefore the higher the capacity.
(c) The type of dielectric, e.g. plastic, mica, paper, air, etc.

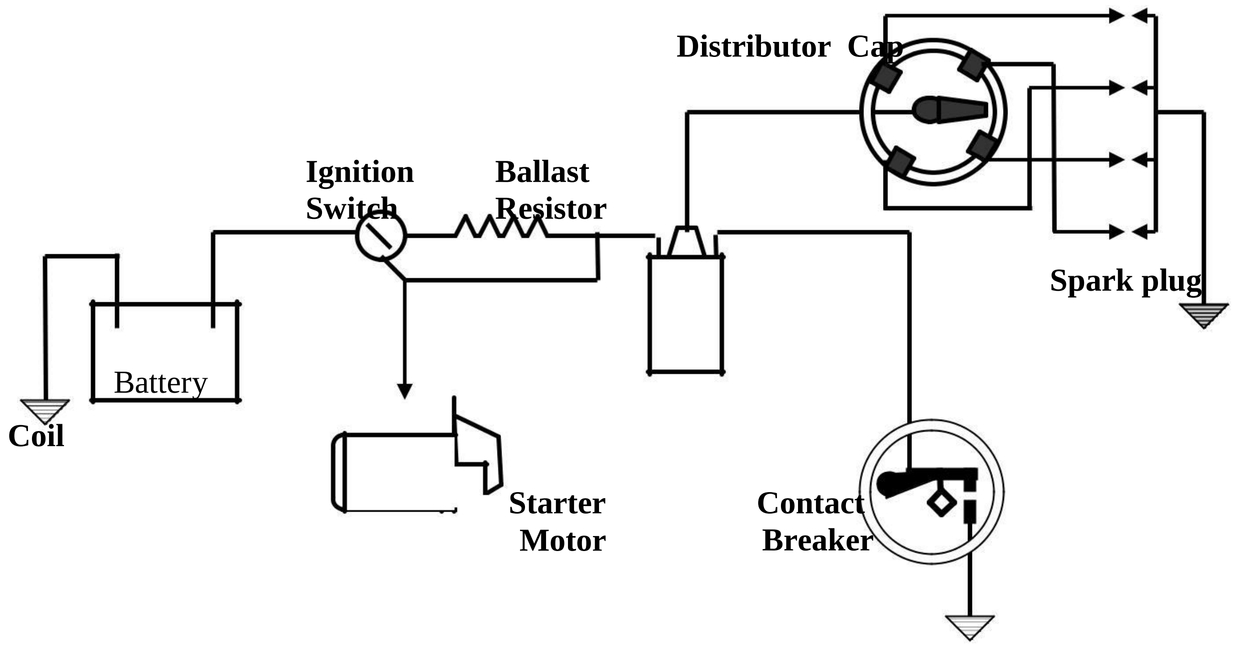
Unit of Capacitor

The amount of charge a capacitor can hold is termed its capacitance (symbol C) which is measured in a unit called the farad (symbol F). Since the farad is a large quantity and it is difficult to have such a big capacitor in real time, the capacitors are generally measured by micro farad (Symbol µF)

Automotive capacitors are in the vicinity of 0.20 to 0.30 microfarads (one microfarad = 10^{-6} farads, or 1 millionth of a farad).

The operation of a capacitor in an ignition circuit is relatively simple, but tends to appear complex because of the number of events, or changes, that occur simultaneously. The following explanation presents these changes as a logical, sequential set of events.

CIRCUIT OF THE IGNITION CIRCUIT



A simple circuit shown above can illustrate the position of the major components of an ignition system. **With the ignition switch 'on'**: when the breaker contacts initially close, a current commences to flow in the primary circuit and the magnetic field builds up relatively slowly, due to the self induced voltage that is developed at this time

During this 'closed circuit period' of the ignition cycle, the capacitor is in parallel with the breaker contacts which are closed at this time. As the distributor shaft continues its rotation the cam lobe lift the breaker gently to open the contacts.

It takes a certain number of degrees of distributor shaft rotation and therefore a measurable period of time for this to occur.

When the contacts are open and instantly a resistance is presented to the primary circuit because of this contact gap. The primary current is interrupted and the magnetic field is starting to collapse. The current produced by the self induced voltage has to enter the plates of the capacitor. Since the high resistance will be induced across the contacts due to their separation and it will naturally take the low resistance path.

Capacitor function

When the contacts gap is slowly widening and the self induced voltage is rapidly rising towards the 200-300 volt level. The capacitor is rapidly charging up. As the capacitor reaches the fully charged state, the contacts have opened to such a degree that even this high voltage cannot jump the gap and so the primary circuit currents comes to an 'instant halt'.

This sudden stopping of the primary current, produced by the action of the capacitor, gives an extremely fast collapse of the magnetic field. The mutually induced voltage, generated in the secondary winding at this instant will be very high. Since the secondary winding has about 100 times as many turns as the primary winding, the secondary voltage will be about 100 times higher than the primary voltage (200 to 300 volts).

The secondary voltage at this instant is fed out through the HT circuit to the correct spark plug where it ionizes the plug gap and forms a spark which ignites the air-fuel mixture. For the period of time of spark duration the capacitor remains fully charged. After the energy of the secondary circuit has been expended in the HT spark, the capacitor discharges back through the battery, ignition switch and coil primary to the opposite plate of the capacitor, thus recharging it in the reverse direction. The capacitor then discharges back again to recharge itself in the original direction – but at a lower value. It continues this oscillating cycle of charge and discharge until all of the stored energy is dissipated across the resistance of the primary circuit. The distributor cam continues its rotation, the points close again and the whole cycle is repeated.

2.4. CRDI - Common rail fuel injection system:

Common rail direct fuel injection is a modern variant of direct fuel injection system for petrol and diesel engines. On diesel engines, it features a high-pressure (over 1,000 baror 100 MPa or 15,000 psi) fuel rail feeding individual solenoid valves, as opposed to low-pressure fuel pump feeding unit injectors (or pump nozzles). Third-generation common rail diesels now feature piezoelectric injectors for increased precision, with fuel pressures up to 3,000 bar (300 MPa; 44,000 psi). In gasoline engines, it is used in gasoline direct injection engine technology.

Working Principle;

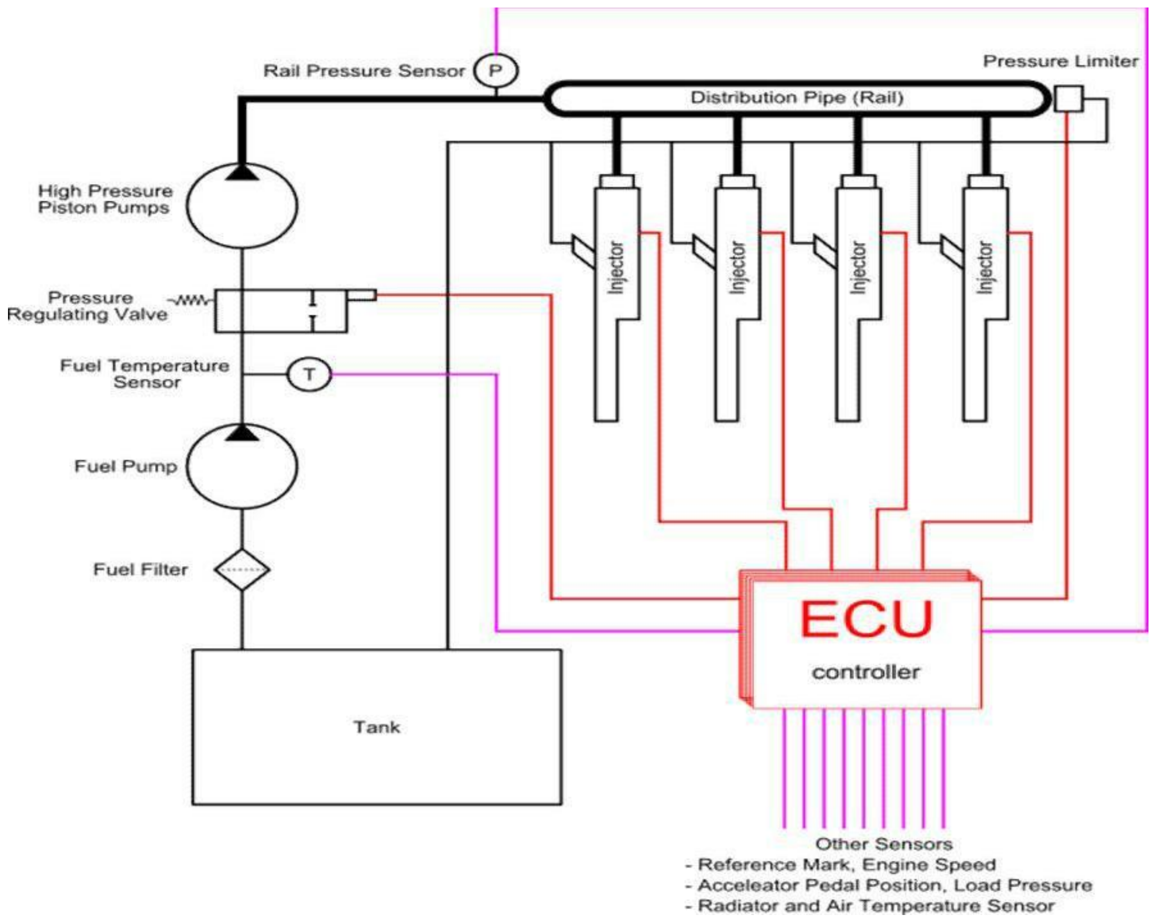
Solenoid or piezoelectric valves make possible fine electronic control over the fuel injection time and quantity, and the higher pressure that the common rail technology makes available provides better fuel atomisation. To lower engine noise, the engine's electronic control unit can inject a small amount of diesel just before the main injection event ("pilot" injection), thus reducing its explosiveness and vibration, as well as optimising injection timing and quantity for variations in fuel quality, cold starting and so on. Some advanced common rail fuel systems perform as many as five injections per stroke. Common rail engines require a very short (< 10 seconds) to no heating-up time[depending on ambient temperature, and produce lower engine noise and emissions than older systemsDiesel engines have historically used various forms of fuel injection. Two common types include the unit injection system and the distributor/inline pump systems (See diesel engine andunit injector for more information). While these older systems provided accurate fuel quantity and injection timing control, they were limited by several factors:

- They were cam driven, and injection pressure was proportional to engine speed. This typically meant that the highest injection pressure could only be achieved at the highest engine speed and the maximum achievable injection pressure decreased as engine speed decreased. This relationship is true with all pumps, even those used on common rail systems. With unit or distributor systems, the injection pressure is tied to the instantaneous pressure of a single pumping event with no accumulator, and thus the relationship is more prominent and troublesome.
- They were limited in the number and timing of injection events that could be commanded during a single combustion event. While multiple injection events are possible with these older systems, it is much more difficult and costly to achieve.
- For the typical distributor/inline system, the start of injection occurred at a pre-determined pressure (often referred to as: pop pressure) and ended at a pre-determined pressure. This characteristic resulted from "dummy" injectors in the cylinder head which opened and closed at pressures determined by the spring preload applied to the plunger in the injector. Once the pressure in the injector reached a pre-determined level, the plunger would lift and injection would start.

In common rail systems, a high-pressure pump stores a reservoir of fuel at high pressure — up to and above 2,000 bars (200 MPa; 29,000 psi). The term "common rail" refers to the fact that all of the fuel injectors are supplied by a common fuel rail which is nothing more than a pressure accumulator where the fuel is stored at high pressure.

This accumulator supplies multiple fuel injectors with high-pressure fuel. This simplifies the purpose of the high-pressure pump in that it only needs to maintain a commanded pressure at a target (either mechanically or electronically controlled). The fuel injectors are typically ECU-controlled. When the fuel injectors are electrically activated, a hydraulic valve (consisting of a nozzle and plunger) is mechanically or hydraulically opened and fuel is sprayed into the cylinders at the desired pressure.

Since the fuel pressure energy is stored remotely and the injectors are electrically actuated, the injection pressure at the start and end of injection is very near the pressure in the accumulator (rail), thus producing a square injection rate. If the accumulator, pump and plumbing are sized properly, the injection pressure and rate will be the same for each of the multiple injection events.



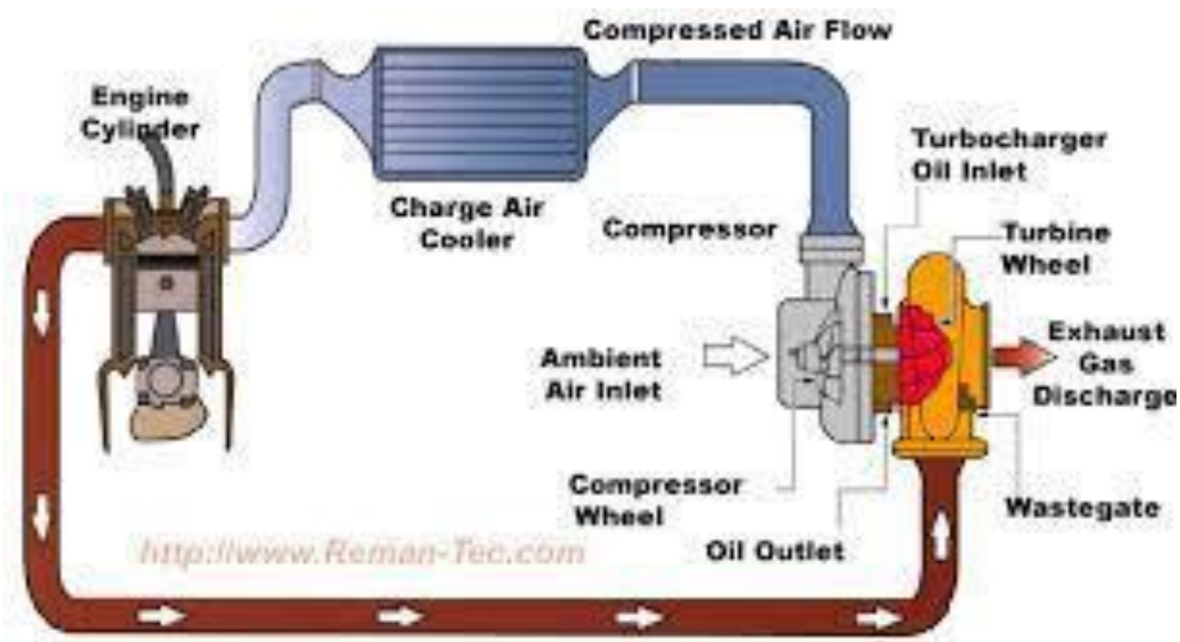
2.5. Turbocharger:

The turbo charger utilizes the wasted heat energy in the exhaust system, to run a compressor which compresses the intake air. Compressed intake air has more density and hence more fuel can be injected increasing the power of the engine. Turbo charging is an ideal way to increase the engine power without increasing the engine size.

A turbocharger, or turbo (colloquialism), from Greek "τύρβη" ("wake"), (also from Latin "turbo" ("spinning top"), is a turbine-driven forced induction device that increases an engine's efficiency and power by forcing extra air into the combustion chamber. This improvement over a naturally aspirated engine's output results because the turbine can force more air, and proportionately more fuel, into the combustion chamber than atmospheric pressure alone.

Turbochargers were originally known as turbosuperchargers when allforced induction devices were classified as superchargers. Nowadays the term "supercharger" is usually applied to only mechanically driven forced induction devices. The key difference between a turbocharger and a conventional supercharger is that the latter is mechanically driven by the engine, often through a belt connected to the crankshaft, whereas a turbocharger is powered by a turbine driven by the engine'sexhaust gas. Compared to a mechanically driven supercharger, turbochargers tend to be more efficient, but less responsive. Twincharger refers to an engine with both a supercharger and a turbocharger.

Turbochargers are commonly used on truck, car, train, aircraft, and construction equipment engines. They are most often used with Otto cycle and Diesel cycle internal combustion engines. They have also been found useful in automotive fuel cells.



2.6. Catalytic converter

Catalytic converter is a vehicle emissions control device that converts toxicpollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction(oxidation or reduction). Catalytic converters are used in internal combustion engines fueled by either petrol (gasoline) or diesel—including lean burn engines.

The first widespread introduction of catalytic converters was in the United Statesautomobile market. Manufacturers of 1975 model year equipped gasoline-powered vehicles with catalytic converters to comply with the U.S. Environmental Protection Agency's stricter regulation of exhaust emissions. These "two-way" converters combined carbon monoxide (CO) with unburned hydrocarbons (HC) to produce carbon dioxide (CO_2) and water (H_2O). In 1981, two-way catalytic converters were rendered obsolete by "three-way" converters that also reduceoxides of nitrogen (NO_x); however, two-way converters are still used for lean burn engines.

Although catalytic converters are most commonly applied to exhaust systems in automobiles, they are also used on electrical generators, forklifts, mining equipment, trucks, buses, locomotives, motorcycles, and airplanes. They are also used on some wood stoves to control emissions. This is usually in response to government regulation, either through direct environmental regulation or through health and safety regulations.

Construction of a catalytic converter;

The catalyst support or substrate. For automotive catalytic converters, the core is usually a ceramic monolith with a honeycomb structure. Metallic foil monoliths made of Kanthal (FeCrAl) are used in applications where particularly high heat resistance is required Either material is designed to provide a large surface area. The cordierite ceramic substrate used in most catalytic converters was invented by Rodney Bagley, Irwin Lachman andRonald Lewis at Corning Glass, for which they were inducted into the National Inventors Hall of Fame in 2002.

The washcoat. A washcoat is a carrier for the catalytic materials and is used to disperse the materials over a large surface area. Aluminum oxide, titanium dioxide, silicon dioxide, or a mixture of silica and alumina can be used. The catalytic materials are suspended in the washcoat prior to applying to the core. Washcoat materials are selected to form a rough, irregular surface, which greatly increases the surface area compared to the smooth surface of the bare substrate. This in turn maximizes the catalytically active surface available to react with the engine exhaust. The coat must retain its surface area and prevent sintering of the catalytic metal particles even at high temperatures

The catalyst itself is most often a mix of precious metals. Platinum is the most active catalyst and is widely used, but is not suitable for all applications because of unwanted additional reactions and high cost. Palladium and rhodium are two other precious metals used. Rhodium is used as a reduction catalyst, palladium is used as an oxidation catalyst, and platinum is used both for reduction and oxidation. Cerium, iron, manganese and nickel are also used, although each has limitations. Nickel is not legal for use in the European Union because of its reaction with carbon monoxide into toxic nickel tetracarbonyl.[citation needed] Copper can be used everywhere except North America,[clarification needed]where its use is illegal because of the formation of toxic dioxin .[citation needed]