UNIT-II

COOLING SYSTEM

Introduction

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300 -2500 C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150 -200 C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature.

It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling.

It is also to be noted that :

(a) About 20-25% of total heat generated is used for producing brake power (useful work).

(b) Cooling system is designed to remove 30-35% of total heat.

(c) Remaining heat is lost in friction and carried away by exhaust gases.

Objectives

After studying this unit, you should be able to

- understand the methods of cooling of IC engine,
- explain the air cooling system, and
- know the water cooling system of IC engine.

There are mainly two types of cooling systems :

(a) Air cooled system, and

(b) Water cooled system.

Air Cooled System

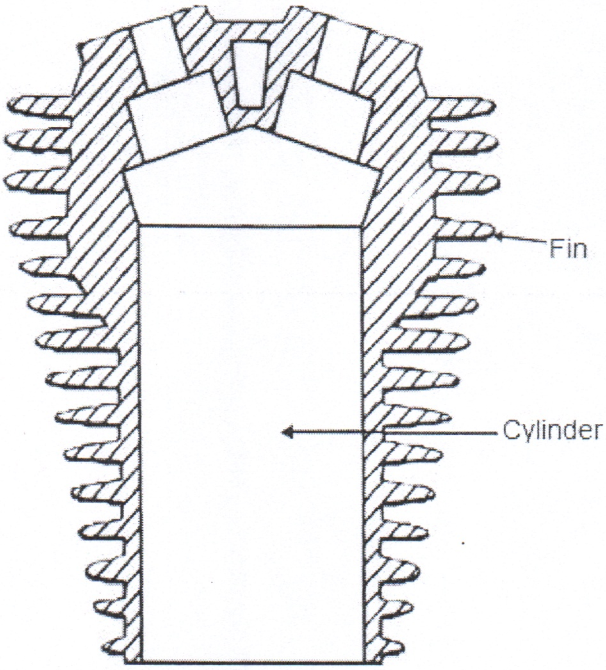
Air cooled system is generally used in small engines say up to 15-20 kW and in aero plane engines.In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air.

The amount of heat dissipated to air depends upon :

(a) Amount of air flowing through the fins.

(b) Fin surface area.

(c) Thermal conductivity of metal used for fins.



Cylinder with Fins

Advantages of Air Cooled System

Following are the advantages of air cooled system :

(a) Radiator/pump is absent hence the system is light.

(b) In case of water cooling system there are leakages, but in this case there are no leakages.

(c) Coolant and antifreeze solutions are not required.

(d) This system can be used in cold climates, where if water is used it may freeze.

Disadvantages of Air Cooled System

(a) Comparatively it is less efficient.

(b) It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

WATER COOLING SYSTEM

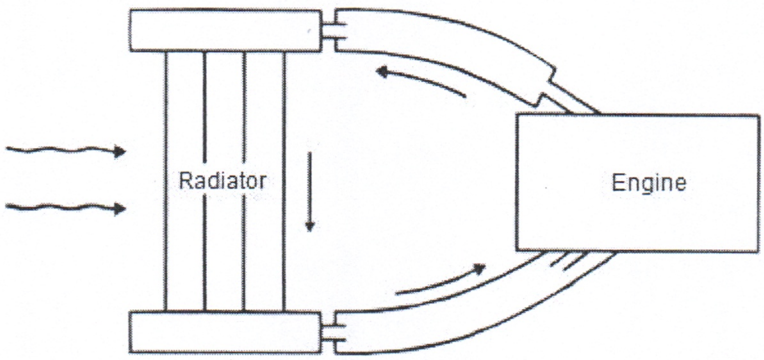
In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc. The water when circulated through the jackets, it absorbs heat of combustion. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. The cooled water is again recirculated through the water jackets.

Types of Water Cooling System

There are two types of water cooling system :

Thermo Siphon System

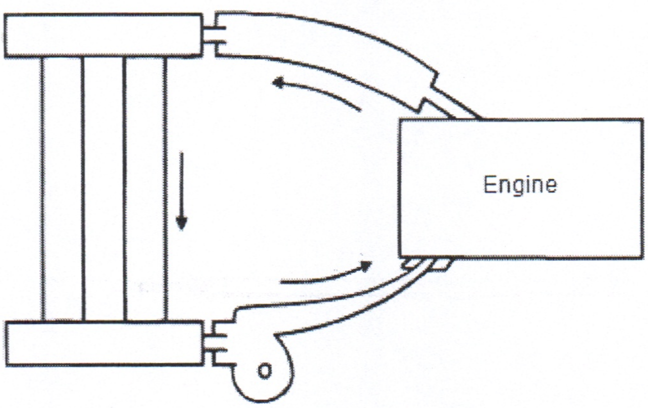
In this system the circulation of water is due to difference in temperature (i.e. difference in densities) of water. So in this system pump is not required but water is circulated because of density difference only.



Thermo Siphon System of Cooling

Pump Circulation System

In this system circulation of water is obtained by a pump. This pump is driven by means of engine output shaft through V-belts.



Pump Circulation System

Components of Water Cooling System

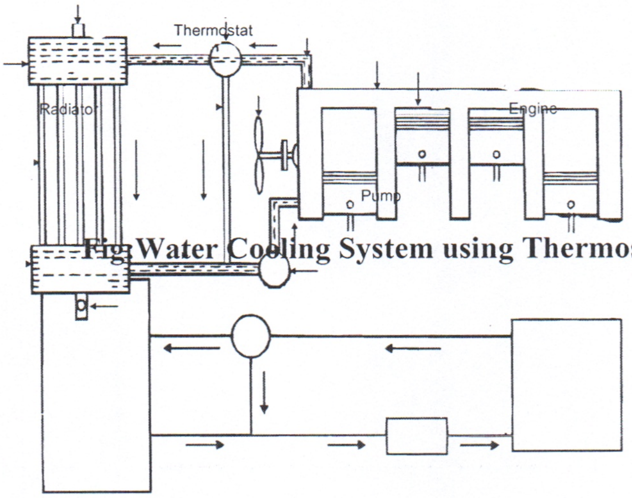


Fig:Water Cooling System using Thermostat Valve

fig:Water Cooling System of a 4-cylinder Engine

Water cooling system mainly consists of:

(a) Radiator,

(b) Thermostat valve,

(c) Water pump,

(d) Fan,

(e) Water Jackets, and

(f) Antifreeze mixtures.

Radiator

It mainly consists of an upper tank and lower tank and between them is a core. The upper tank is connected to the water outlets from the engines jackets by a hose pipe and the lover tank is connect to the jacket inlet through water pump by means of hose pipes.

There are 2-types of cores :

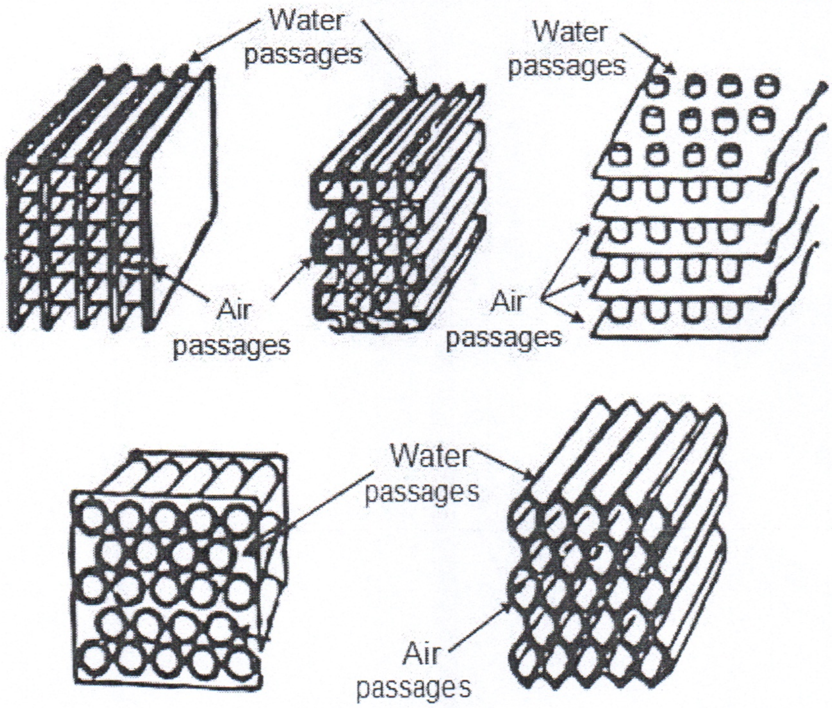
(a) Tubular

(b) Cellular as shown.

When the water is flowing down through the radiator core, it is cooled partially by the fan which blows air and partially by the air flow developed by the forward motion of the vehicle.

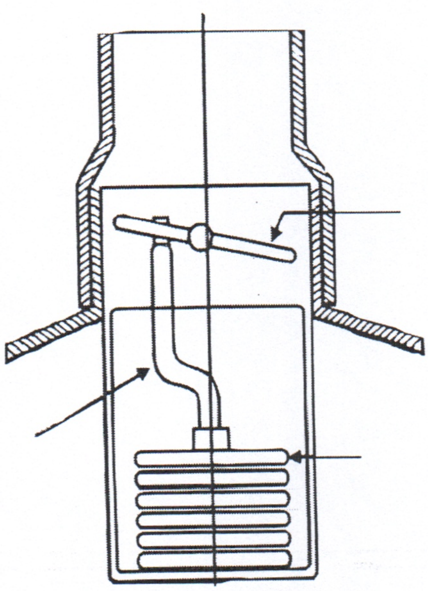
As shown through water passages and air passages, wafer and air will be flowing for cooling purpose.

It is to be noted that radiators are generally made out of copper and brass and their joints are made by soldering.



Types of Cores (a) Tabullar Radiator Sections and (b) Circullar Radiator Sections Thermostat Valve

It is a valve which prevents flow of water from the engine to radiator, so that engine readily reaches to its maximum efficient operating temperature. After attaining maximum efficient operating temperature, it automatically begins functioning. Generally, it prevents the water below 70□C.



Thermostat Valve

Figure shows the Bellow type thermostat valve which is generally used. It contains a bronze bellow containing liquid alcohol. Bellow is connected to the butterfly valve disc through the link.

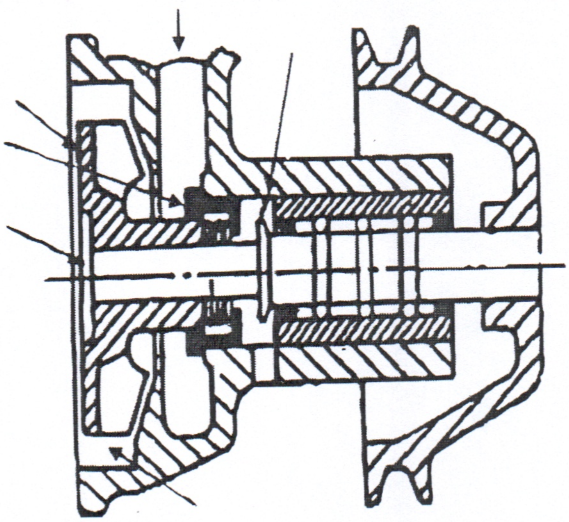
When the temperature of water increases, the liquid alcohol evaporates and the bellow expands and in turn opens the butterfly valve, and allows hot water to the radiator, where it is cooled.

Water Pump

It is used to pump the circulating water. Impeller type pump will be mounted at the front end.

Pump consists of an impeller mounted on a shaft and enclosed in the pump casing. The pump casing has inlet and outlet openings.

The pump is driven by means of engine output shaft only through belts. When it is driven water will be pumped.



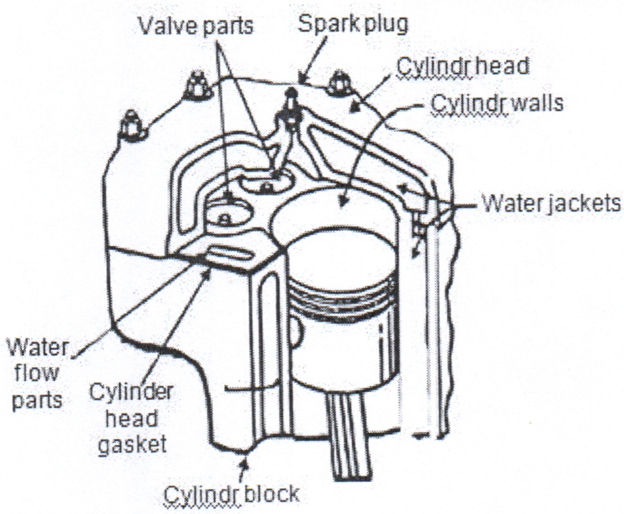
Water Pump

Fan

It is driven by the engine output shaft through same belt that drives the pump. It is provided behind the radiator and it blows air over the radiator for cooling purpose.

Water Jackets

Cooling water jackets are provided around the cylinder, cylinder head, valve seats and any hot parts which are to be cooled. Heat generated in the engine cylinder, conducted through the cylinder walls to the jackets. The water flowing through the jackets absorbs this heat and gets hot. This hot water will then be cooled in the radiator (Referred Figure).



Water Jackets

Antifreeze Mixture

In western countries if the water used in the radiator freezes because of cold climates, then ice formed has more volume and produces cracks in the cylinder blocks, pipes, and radiator. So, to prevent freezing antifreeze mixtures or solutions are added in the cooling water.

The ideal antifreeze solutions should have the following properties :

(a) It should dissolve in water easily.

(b) It should not evaporate.

(c) It should not deposit any foreign matter in cooling system.

(d) It should not have any harmful effect on any part of cooling system.

(e) It should be cheap and easily available.

(f) It should not corrode the system.

No single antifreeze satisfies all the requirements. Normally following are used as antifreeze solutions :

(a) Methyl, ethyl and isopropyl alcohols.

(b) A solution of alcohol and water.

(c) Ethylene Glycol.

(d) A solution of water and Ethylene Glycol.

(e) Glycerin along with water, etc

Advantages

Uniform cooling of cylinder, cylinder head and valves.

Specific fuel consumption of engine improves by using water cooling system
If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.

Engine is less noisy as compared with air cooled engines, as it has water for damping noise.

Disadvantages

(a) It depends upon the supply of water.

(b) The water pump which circulates water absorbs considerable power.

(c) If the water cooling system fails then it will result in severe damage of engine.

(d) The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts.

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.

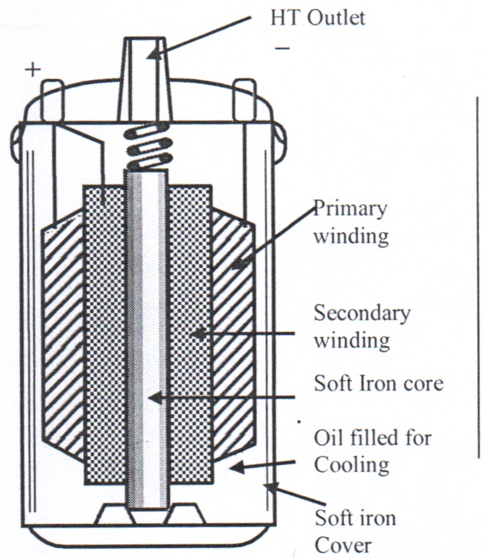
The factors affecting the operation of the Ignition system.

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

(a) 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.

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

(c) The speed of relative movement between the magnetic field and the conductors. The faster the magnetic field can be made to cut the conductors, the higher will be the value of voltage induced into the coil windings.



Ignition Coil

Construction of the Ignition coil

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.

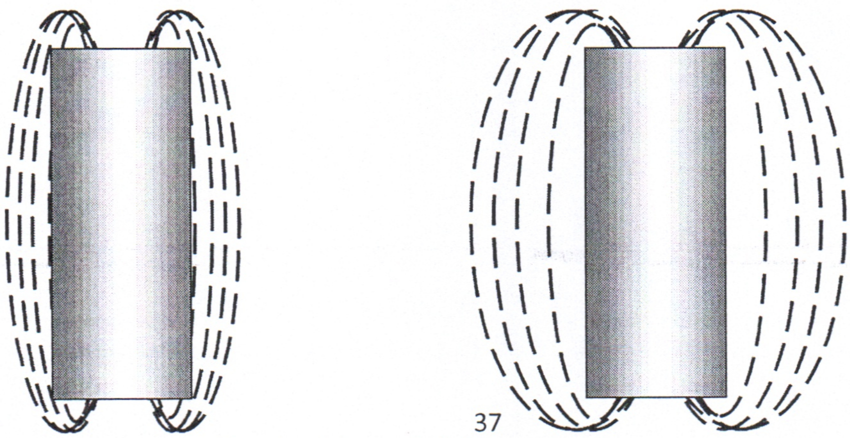
Over the top of the secondary winding the primary winding is wounded with the insulation. The primary winding consisting of a few hundred turns of relatively heavy insulated copper wire. The ends of the primary winding are connected to the two low tension, or primary terminals. A reason for placing the 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.



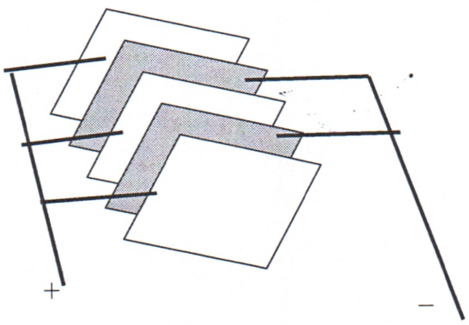
Growing_Magnetic_field

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.

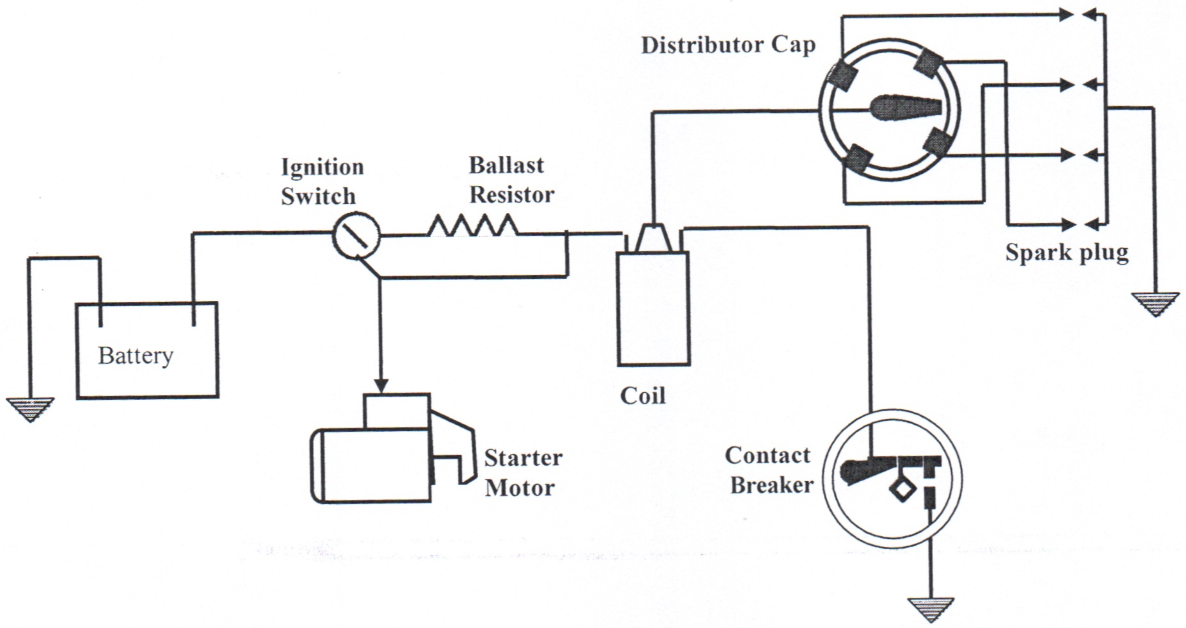
Unit of Capacitor

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.

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.