Third module

IGNITION SYSTEM

What is ignition system/ Purpose of Ignition system?

- Ignition system, in a gasoline/petrol engine, means a system **employed for producing electric spark to ignite the fuel–air mixture**; that is the burning of this mixture in the cylinders produces the motive force.

Function of Ignition System

- To create high voltage electric spark in the combustion chamber at correct timing in order to burn the air fuel mixture.
- This creates a potential difference of 25kV across the spark plugs.
- It provides high spark voltage to each spark plug in the correct order.
- It adjusts the spark timing with speed and load of the vehicle.
- The spark is adjusted so it can be generated when piston is near the top dead Centre.

Types of Ignition system

Conventional ignition system

a) Battery Ignition system
b) Magneto Ignition system

Electronic Ignition system

a) Distributor type Electronic Ignition system
b) Distributor less type Electronic Ignition system

Capacitor Discharge ignition system

Battery Ignition system

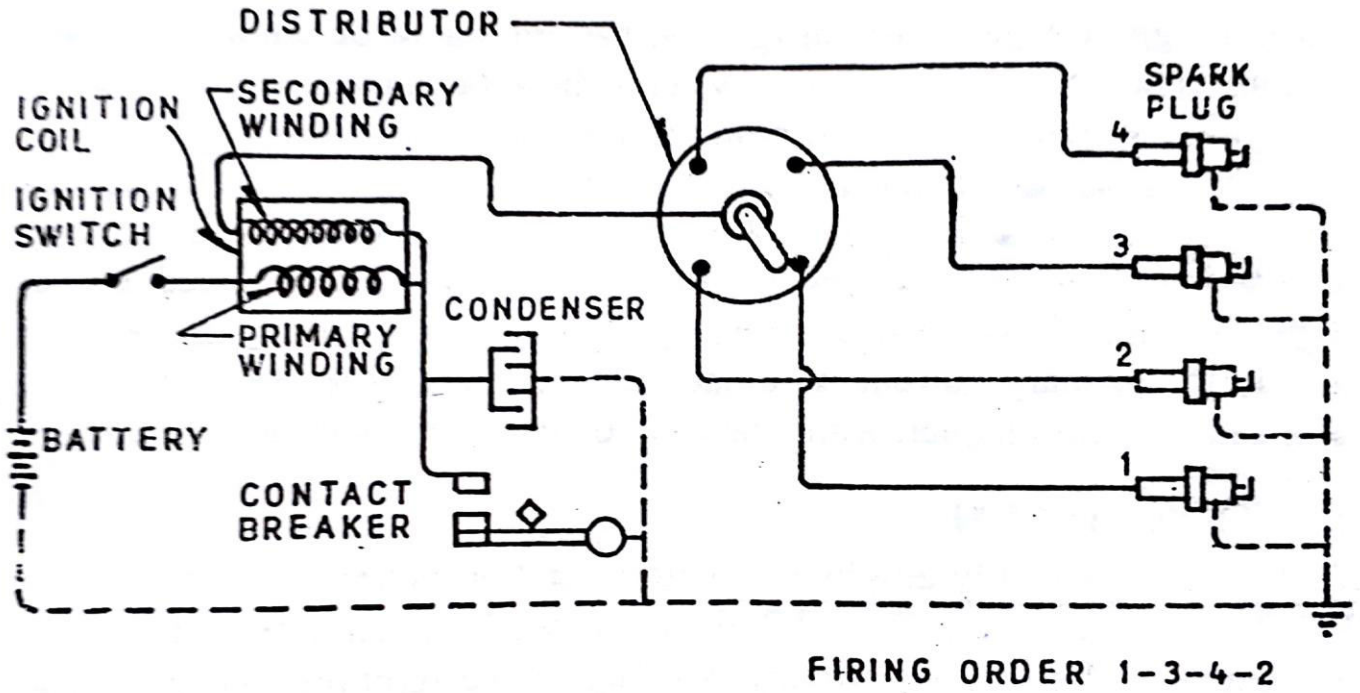


Fig. 13.2. Battery ignition system for 4-cylinder engine.

If induction effect is combined

- It mainly consists of a 12 volt battery, ammeter, ignition switch, ignition coil (step up transformer), contact breaker, capacitor, distributor rotor, distributor contact points, spark plugs, etc.
- The ignition system is divided into 2-circuits:
- (i) Primary Circuit: It consists of 12 V battery, ammeter and ignition switch, primary winding of ignition coil (it has 200-300 thick wire), condenser and contact breaker
- (ii) Secondary Circuit: It consists of secondary winding of ignition coil, distributor and spark plug.
- The secondary coil consists of about 21000 turns of thin wire. Bottom end of which is connected to bottom end of primary and top end of it is connected to centre of distributor rotor.
- Distributor rotors rotate and make contacts with contact points and are connected to spark plugs which are fitted in cylinder heads (engine earth).

Working:

- When the ignition switch is on and engine in cranked, as soon as the contact breaker closes, a low voltage current will flow through the primary winding. It is also to be noted that the contact beaker cam opens and closes the circuit 4-times (for 4 cylinders) in one revolution.
- When the contact breaker opens the contact, the magnetic field begins to collapse. Because of this collapsing magnetic field, current will be induced in the secondary winding. And because of more turns (about 21000 turns) of secondary, voltage goes into 28000-30000 volts.
- This high voltage current is brought to centre of the distributor rotor. Distributor rotor rotates and supplies this high voltage current to proper stark plug depending upon the engine firing order.
- Firing of four cylinder engine is 1-3-4-2
- Firing of six cylinder engine is 1-5-3-6-2-4

Components of Battery Ignition System

1. Battery
2. Ignition coil
3. Contact breaker
4. Condenser
5. Distributor
6. Spark plug

1. Battery:

- The battery is provided for supply the initial current to the ignition system more specifically ignition coil. Generally, the voltage of the battery is 6V or 12V or 24 V.

2. Ignition Switch:

- It is used for ON or OFF the engine. One end of the switch is connected with the Primary Winding of Ignition Coil via Ballast Resistor, and another end is connected with the Battery

3. **Ignition coil:**

- It is the main part of Battery Ignition System
- The purpose of it is to step up battery voltage so that it is sufficient for generates the spark.
- It is working as a step-up transformer, and have two winds, one is primary which have a lesser turn, and the other one is secondary which have a higher number of turns
- When the high voltage current jumps the spark plug gap, it produces the spark and the charge is ignited.

a) **Core Type Ignition Coil**

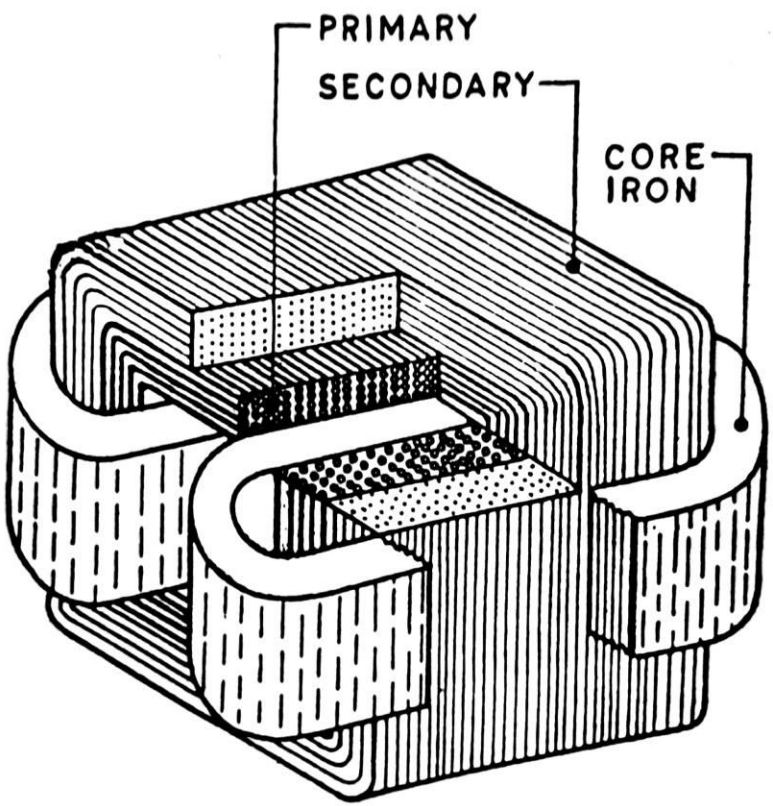


Fig. 13.5. Core type ignition coil.

- In this type, primary is wound first on the core and then outside it the secondary is wound, the proper insulation, of course, being provided between the two.

2. **Metal clad or Can type**

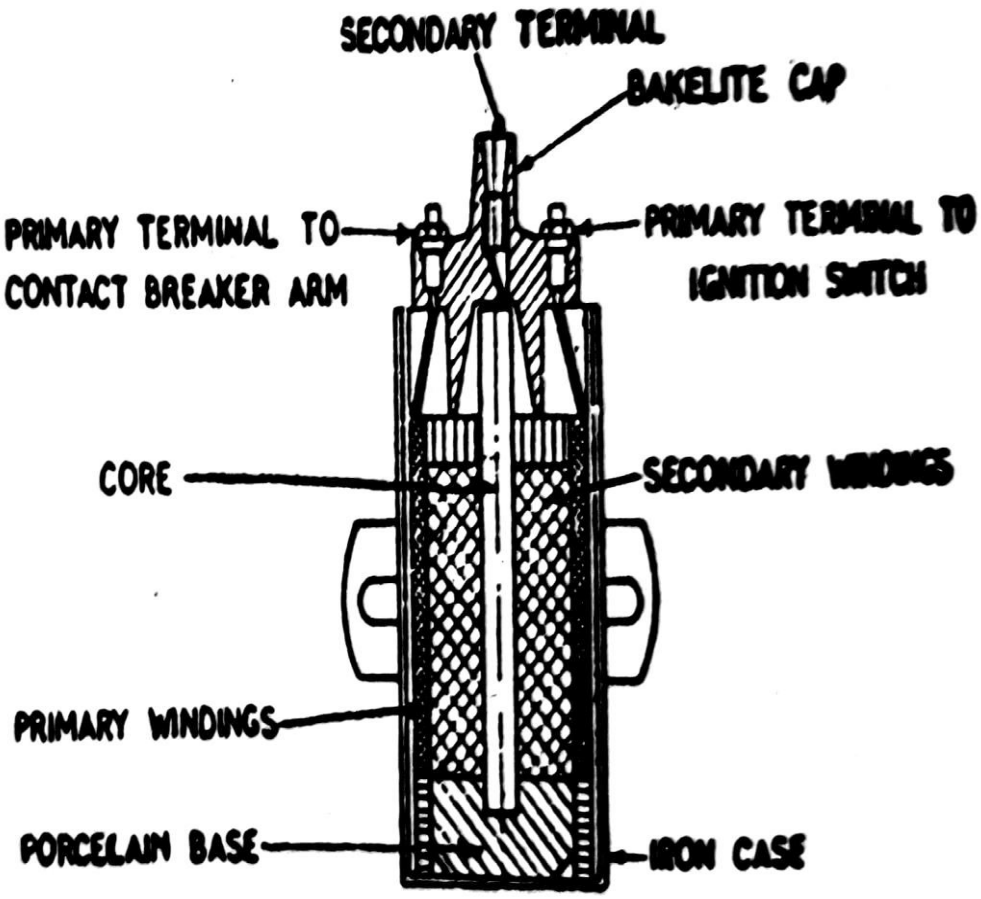


Fig. 13.6. Can type ignition coil.

- It is the most commonly used ignition coil, In this, the secondary is first wound over the core and then the primary over this.
- The inner end of the secondary winding is connected to the core, which further leads to high tension terminal of the coil, while the other end of the secondary is connected to the primary winding.
- The ends of the primary winding are connected to the Low Tension terminals of the coil, one of which is connected further to the contact breaker and the other to the ignition switch.

Ballast resister

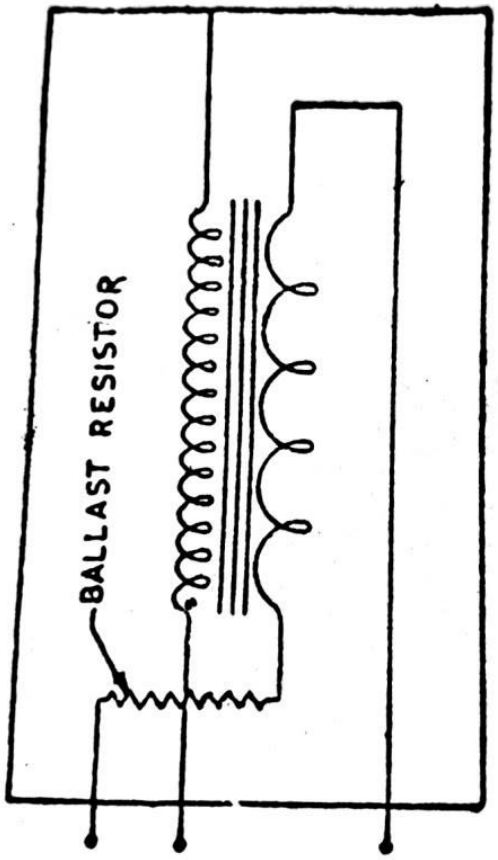


Fig. 13.7. Ignition coil with ballast resistor.

- A ballast resistor is used in a circuit to limit the current and hence prevent it from over current faults.
- When the engine is running at slow speed, the contact breaker points are closed for a comparatively longer period of time. This causes overheating of the induction coil.
- To avoid this, a ballast resistance is sometimes inserted in the primary circuit of the coil
- This increased resistance decreases the amount of current in the primary circuit and thus avoids overheating of the coil at low engine speeds.

Contact breaker points:

- The function of s contact breaker is to make and break the primary ignition circuit.
- This is probably the weakest member of as ignition system.
- A four-cylinder engine opening a must make and break the circuit 8000 times a minute.
- Various types of contact breakers are shown below.
- A hardened steel cam attached to the end of the driving spindle actuates the lever through the heel.

Contact breaker points

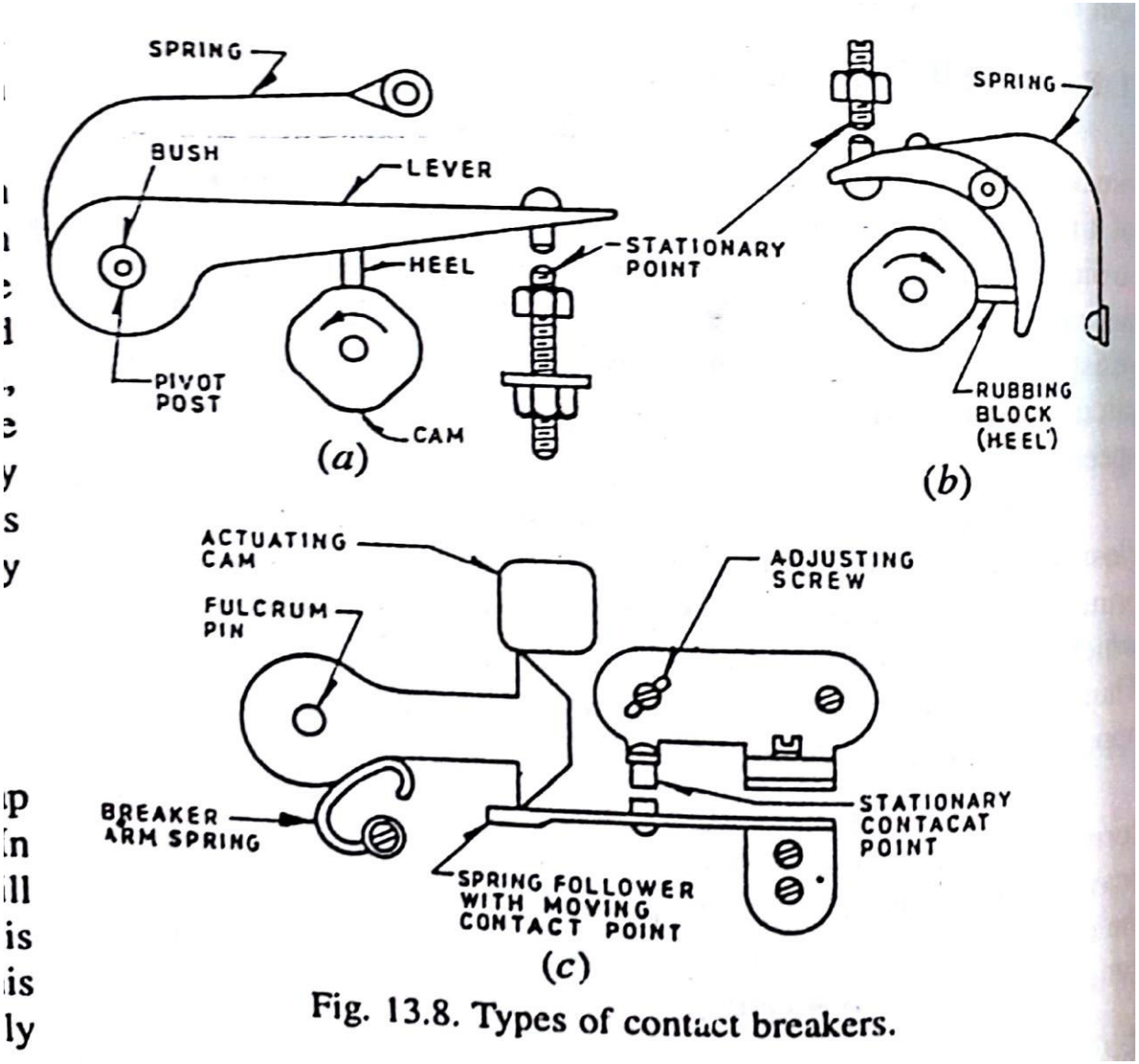


Fig. 13.8. Types of contact breakers.

- The speed of cam is always half of the engine speed. However, the number of cam faces is always equal to the number of cylinders except in case of the double lever type contact breaker.
- The main components of CB point are lever, heel, bush and the contacts
- Contact breaker cam and distributor rotor are mounted on the same shaft.

Dwell angle or Cam angle

- It is the time expressed in terms of the degree of distributor cam rotation for which contact points remains closed
- Dwell angle for 4 cylinder engine is 48 to 52 degree
- For 6 cylinder36 to 42 degree

Condenser

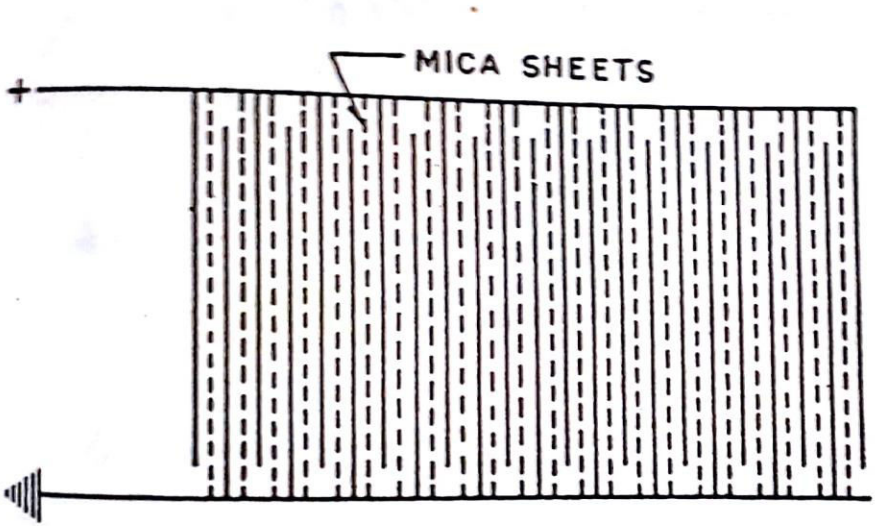


Fig. 13.10. Condenser

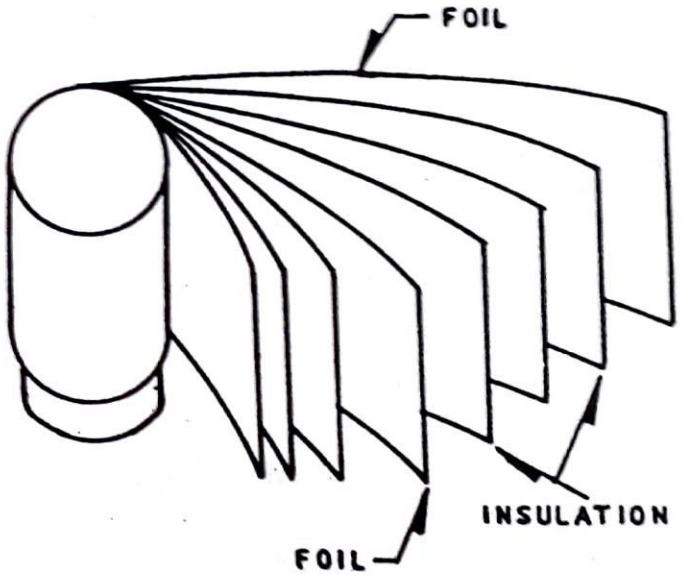


Fig. 13.11. Cylindrical condenser

It is connected across the contact breaker

The functions of a condenser are:

1) To minimize arcing and pitting of contact breaker points.

2) To intensify the spark.

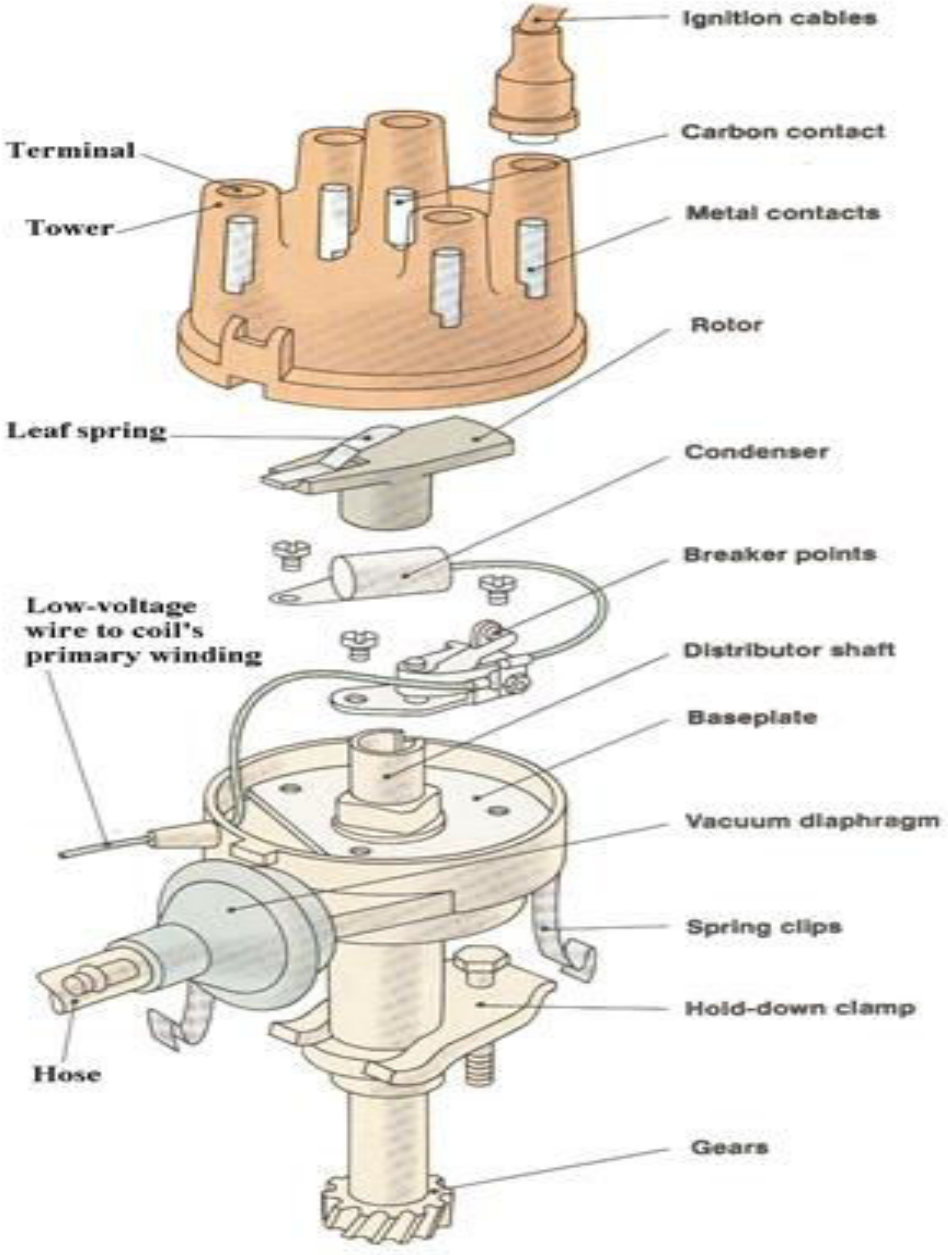
3) It absorbs the excess energy

- The condenser consists of metallic plates usually of tin foil or aluminium foil separated by thin sheets of insulating paper or mica
- These insulating sheets are kept larger than the metal plates, to prevent leakage.

Distributor

- Distributor housing contains the contact breaker, condenser, ignition advance mechanism and the distributor proper.
- The function of the distributor is to distribute the high voltage impulses to each of the sparking plugs at regularly timed intervals in the sequence of the engine's firing order.
- The common firing orders are : 4-cylinder in-line engine 1-3-4-2 or 1-2-4-3
- 6-cylinder in line engine 1-5-3-6-2-4

Distributor



- The distributor proper consists of a rotor and a cap; both of these are made of bakelite.
- The rotor point is made of nickel and is inserted in the bakelite casting.
- Rotor is fitted on the top of the shaft carrying the breaker cam.
- The distributor cap contains the same number of contacts as the number of cylinders. These contacts are made either from brass or nickel.
- Cap terminal is connected to a spark plug on the engine each by means of high tension cables and according to the firing order of the engine.

Ignition Advancing:

- It is of great importance that the ignition should occur at the correct moment
- Theoretically spark is given at TDC at the end of compression stroke
- But it takes certain time called ignition delay to start the combustion after the spark, so the spark must occur prior to the moment at which maximum pressure is desired.
- The difference between this moment and the occurrence of spark in terms of degrees of crankshaft rotation is termed the ignition advance.

The various factors affecting the ignition advance are

- **1. Nature of fuel**
- Different fuels have different rates of burning and therefore the nature of the fuel determines the ignition advance required for the engine.
- **2. Engine speed**
- At higher speeds, less time is available for the combustion to start, for the same degree of crankshaft rotation. So at higher speeds more advance is needed
- **3. Load**
- At smaller load, at part throttle more ignition advance is needed
- At heavy loads, the throttle is opened fully, lesser ignition advance.
- **4. Engine Temperature**
- In a cold engine more spark advance is required, whereas in the hot engine, rapid combustion needs less ignition advance.

Ignition Advance Methods

1. Centrifugal Advance:

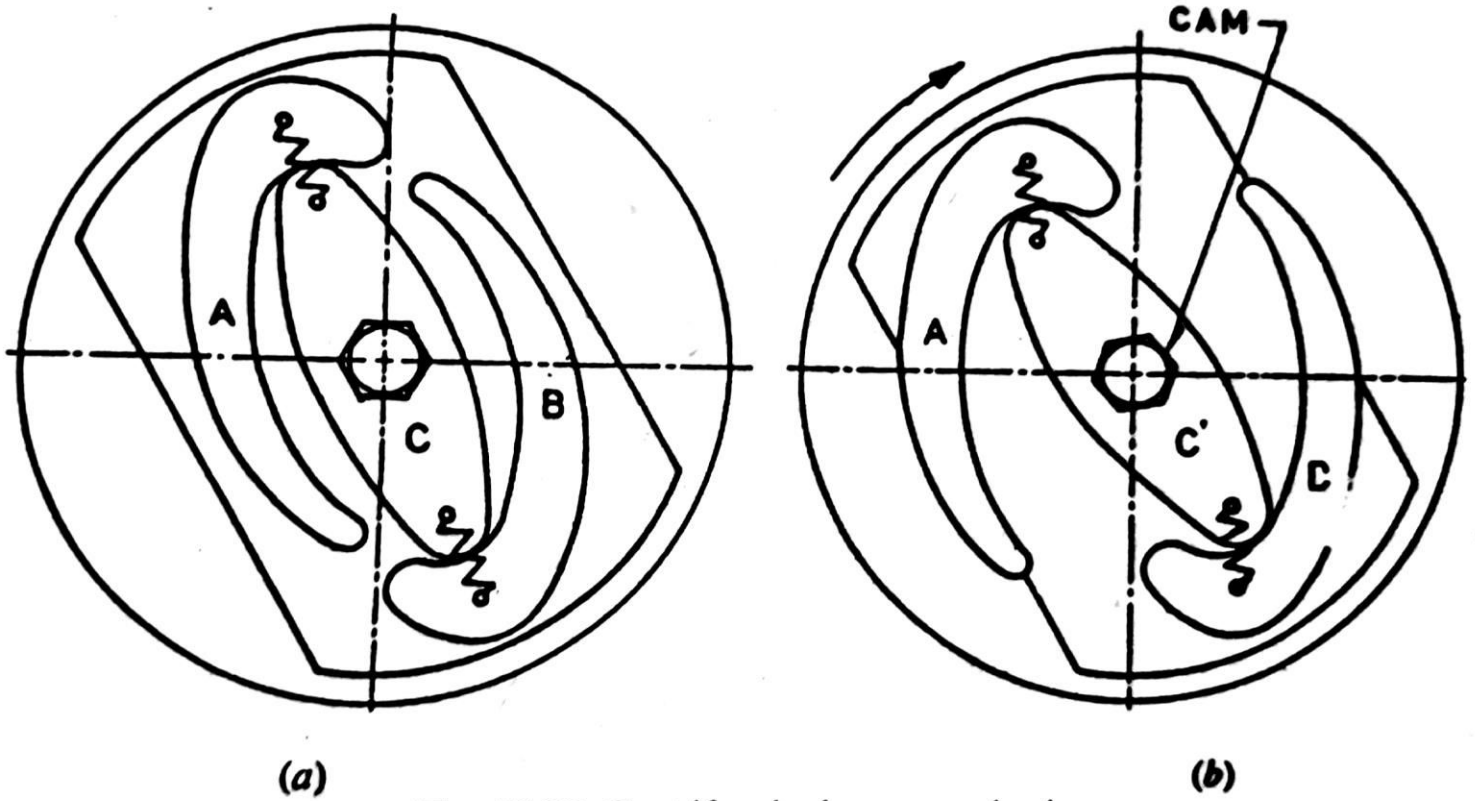


Fig. 13.20. Centrifugal advance mechanism.
(*a*) No advance, (*b*) Full advance

- This method provides the ignition timing control according to engine speed. The distributor shaft, from its gear (lower) end to the rotor-carrying (upper) end is not a single piece.
- It is actually in two pieces connected together through the centrifugal advance arrangement, which consists of two centrifugal weights A and B as shown in Fig
- These weights are pinned and connected with the breaker plate C by means of springs.
- As the engine speed increases, the weight move out due to centrifugal force and the plate C is also rotated.
- This causes the cam rotate, hence the CB point opens early
- When speed decreases the vice versa occurs

Vacuum advance mechanism

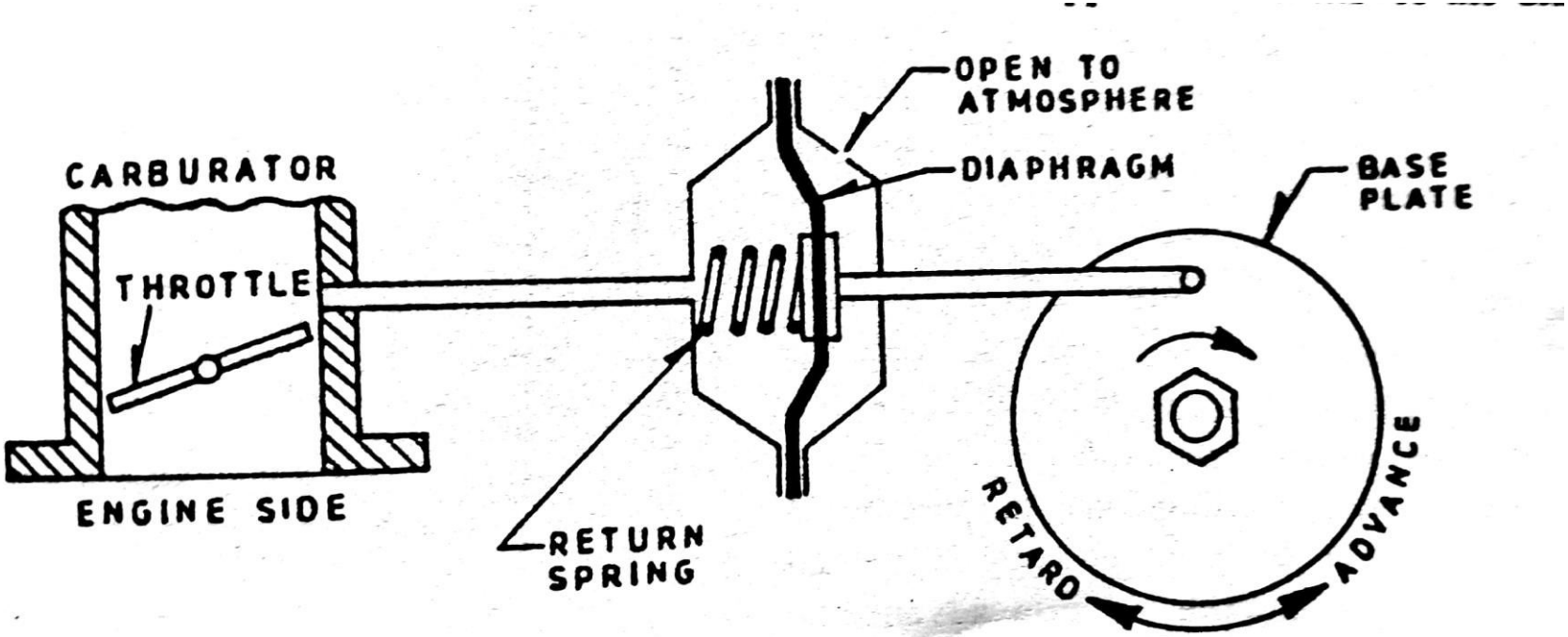
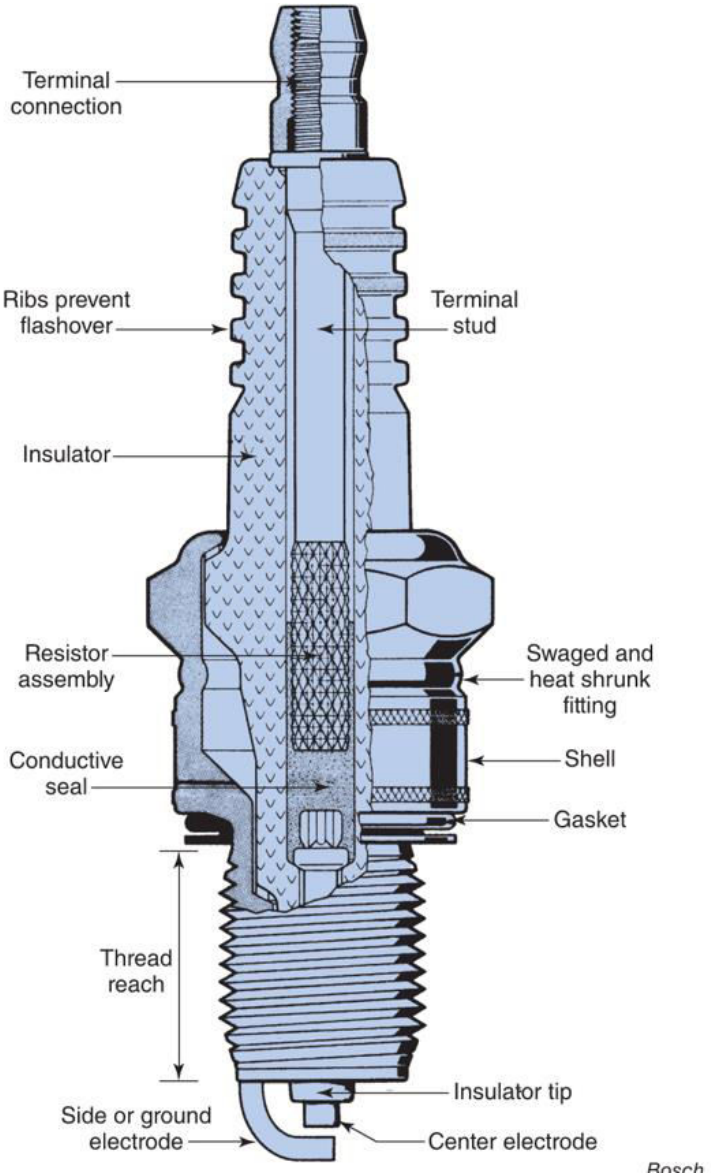


Fig. 13.23. Vacuum advance mechanism

- A vacuum advance unit senses any variation of ported or manifold vacuum, which are direct measure of engine load.
- Thus it provides ignition advance according to engine load
- It is independent of the engine speed.
- The manifold vacuum during light load conditions like idling and deceleration is highest while it is lowest under heavy engine load.
- The vacuum advance unit contains a rubber diaphragm which is connected to the base plate of the distributor. One side of the diaphragm is open to atmosphere while the other side is subjected to the vacuum from the carburetor.
- A return spring on the vacuum side of the diaphragm keeps the advance unit at zero advances.
- When throttle valve is opened, the vacuum is applied, which moves the diaphragm against the return spring to rotate the base plate in the direction opposite to the usual distributor rotation causing the ignition to advance.

SPARK PLUG

- It is mounted in the cylinder head
- The function of it is to provide the spark for ignition
- The plug has three main parts,
- The centre electrode, the ground electrode and the insulator separating them.
- Besides these, these are the body shell, the sealing ring and the gasket washer
- The upper end of the centre electrode is connected to the spark plug terminal, where H.T. cable from the ignition coil in case of single cylinder engines (or from distributor in case of multi cylinder engines) is connected.


Terminal connection
Ribs prevent flashover
Terminal stud
Insulator
Resistor assembly
Swaged and heat shrunk fitting
Conductive seal
Shell
Gasket
Thread reach
Insulator tip
Side or ground electrode
Center electrode
Bosch

Spark plug

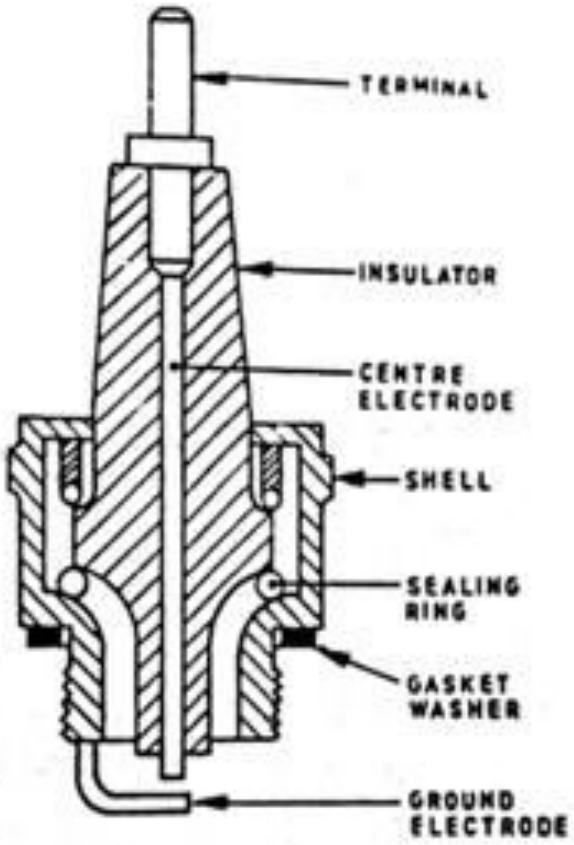


Fig. 13.33. Spark plug.

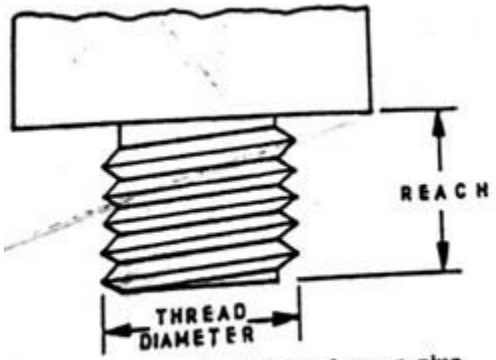


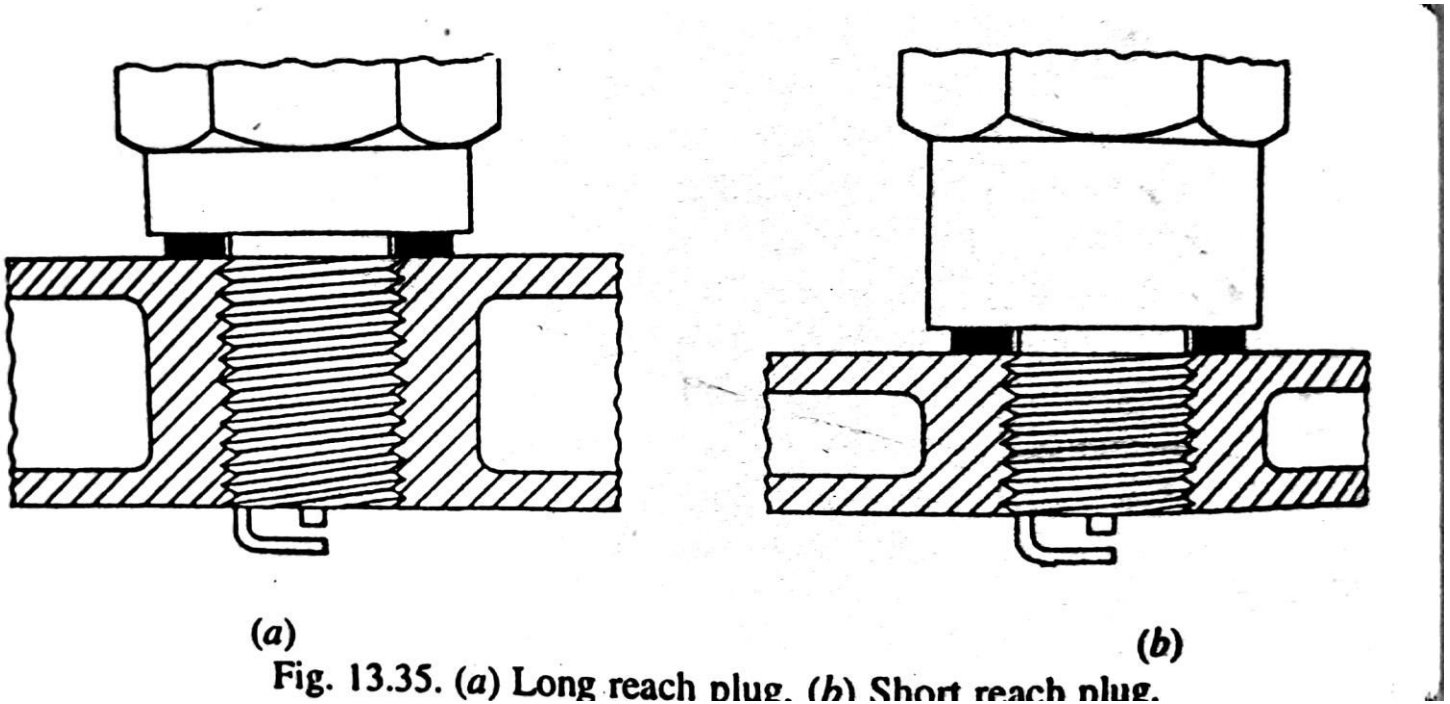
Fig. 13.34 Main dimensions of a spark plug.

Materials

- Body shell – low carbon steel
- Insulator – mica or Alumina
- Central electrode – silicone manganese nickel alloy
- Ground electrode – nickel and manganese alloy

Types of spark plug
a)based on length of threaded portion

earlier.



(a) (b)

Fig. 13.35. (a) Long reach plug. (b) Short reach plug.

b) Based on heat dissipation

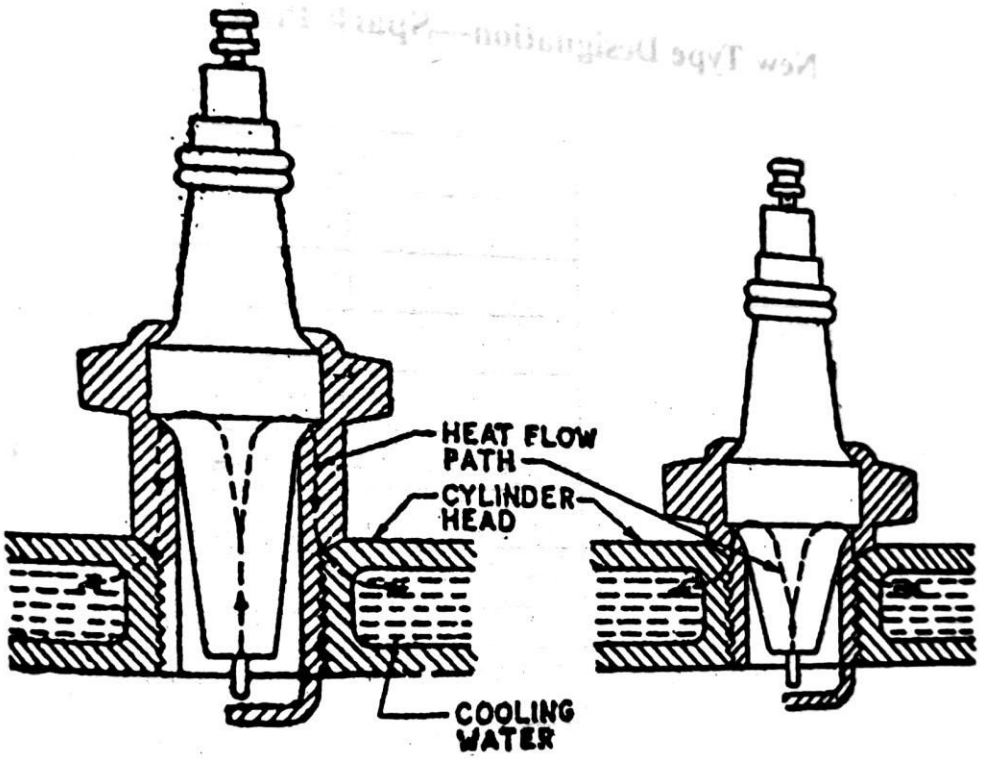


Fig. 13.36. (*a*) Hot plug, (*b*) cold plug.

a) Hot plug

- Hot plugs or soft plugs has a long heat transfer path and is recommended for cool running, low compression engines and other engines that are used at low speed. Unless this type of plug is used on these engines, carbon will build upon the insulator so misfiring occurs after a short period of time.
- Used in medium duty and low speed engines

b) Cold plug

- Cold or hard plug has a short heat transfer path and is recommended for the hot running. This plug has good thermal conductivity and is used in engines with high compression ratios and high power output.
- It have a copper core in the centre electrode to help carry heat from the tip of the electrode
- Used in heavy duty, high speed engines where high temperature is there.

Spark plug specification / designation

① → Threaded diameter and design features..

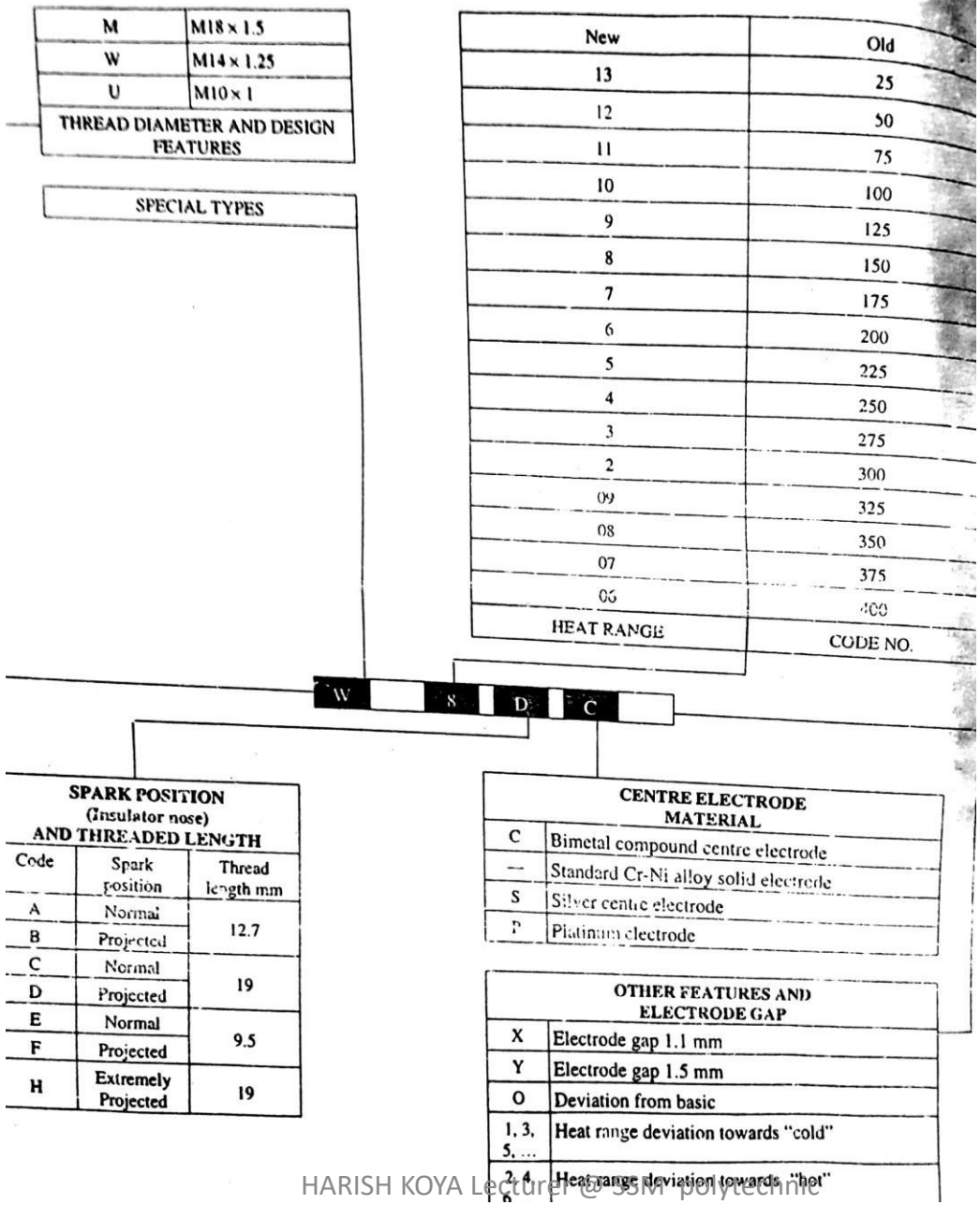
② → Heat range.

③ → Spark position.

④ → Centre electrode material.

- Specification details are attached below.

New Type Designation—Spark Plug



2) Magneto ignition system

- In battery ignition system, current in the primary winding is supplied by the battery, but in magneto using magnet we produce and supplies the current in the primary winding.

Types:

a) Rotating armature type

- It consists of a permanent magnet fitted with two pole shoes as shown. Between the poles is rotated an armature carrying the primary and the secondary windings.
- The primary winding, like the ignition coil, consists of a few hundred turns of thick wire, whereas secondary winding comprises some thousands turns of thin wire.
- The contact breaker and condenser are also inserted into the primary circuit and rotated with the armature.
- When the armature is rotated, its windings cut the magnetic flux between the magnetic poles producing electricity.
- The working of magneto ignition system is similar to battery coil ignition system

a) rotating armature type

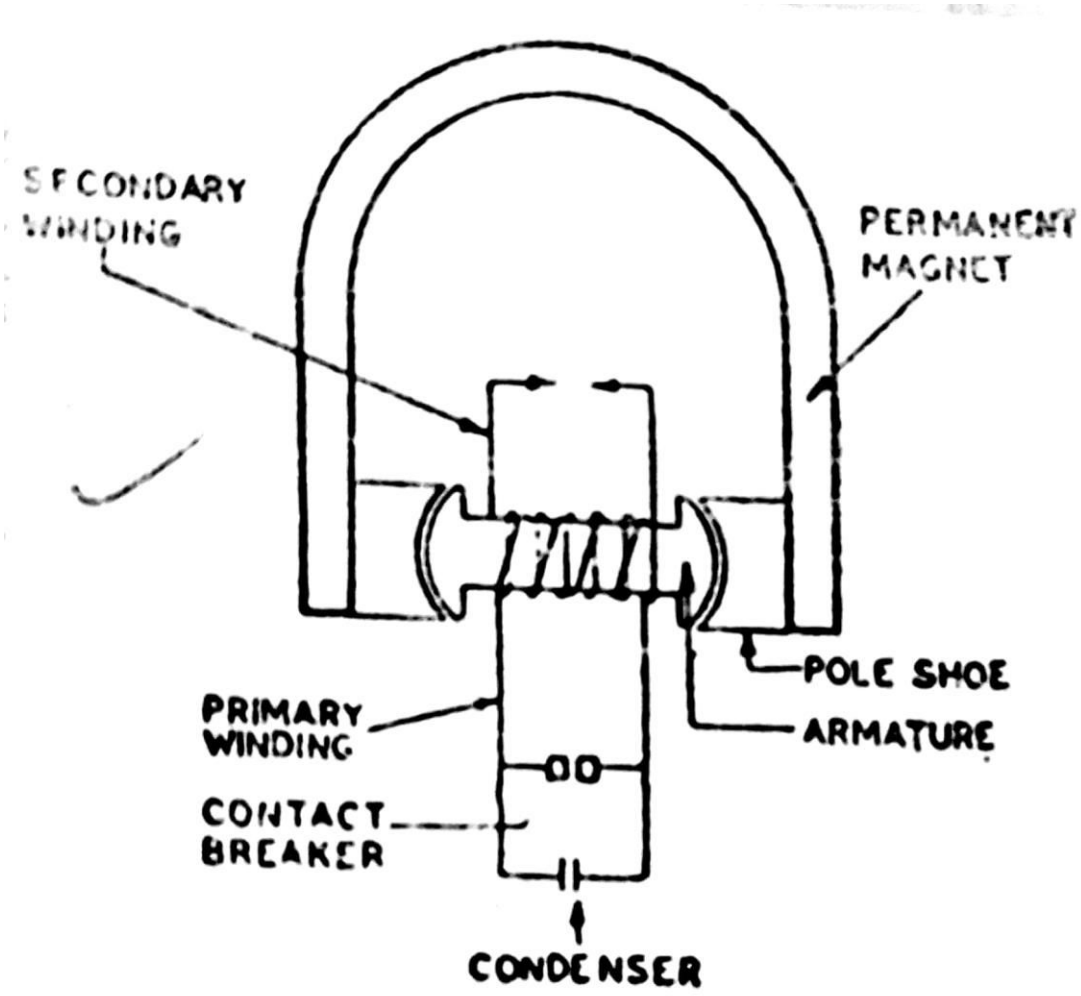
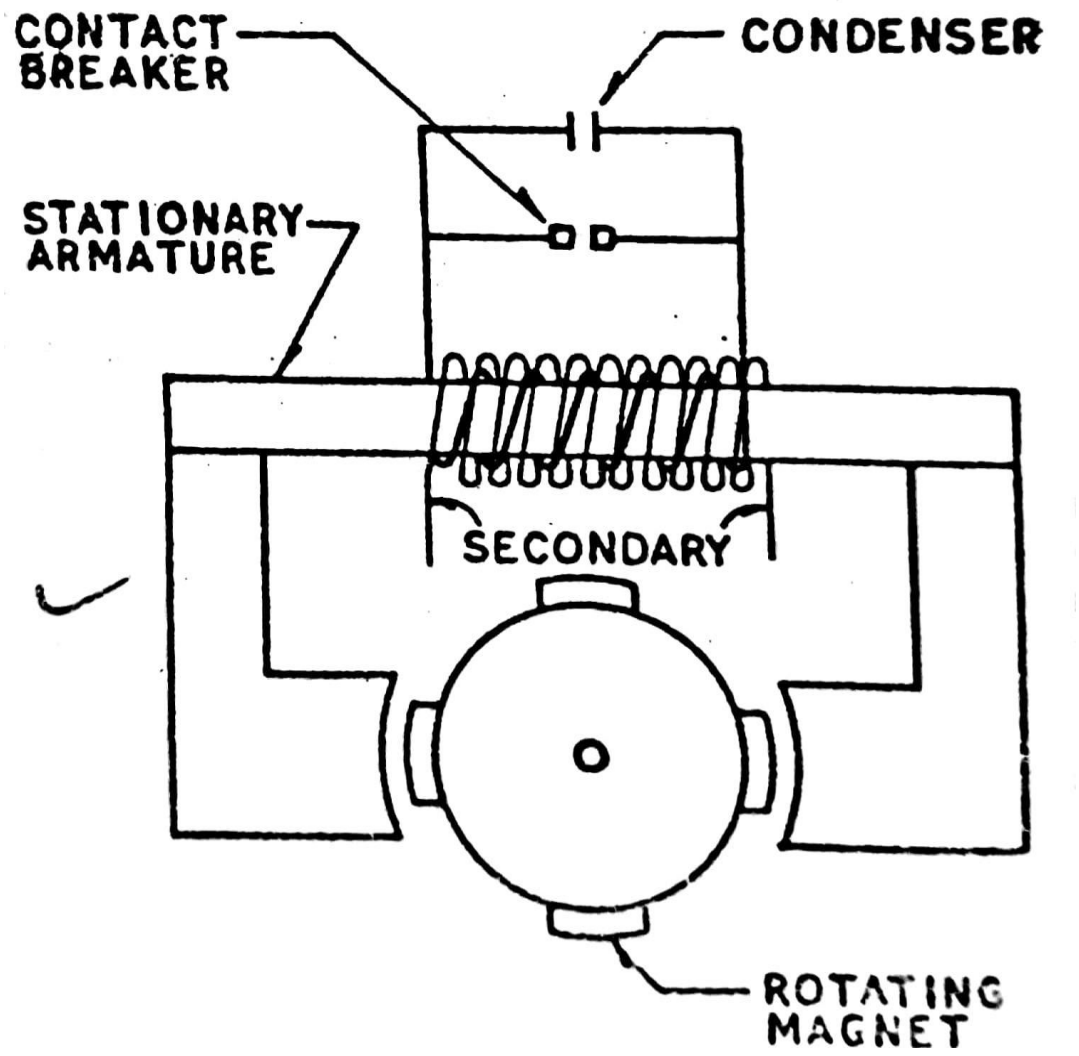


Fig. 13.45. Rotating armature type magneto.

b)Rotating magnetic type



b) Rotating magnetic type

- The principle of this is virtually the same as that of the rotating armature type explained previously.
- However, in this it is the magnet rotates where as the primary , secondary windings, condenser, CB points with armature are stationary.

The advantages of this type are:

- Larger armature may be provided, which means more space for insulation.
- No centrifugal stresses occur in the windings, because these remain stationary.
- Contact breaker and condenser are also stationary

3) Electronic Ignition System

- Conventional Battery and magneto ignition Systems have drawbacks, because Its Construction is difficult, maintenance is required etc

Types of electronic ignition system

1) Distributor type (Breaker less Ignition) system

2) Distributor less type system

a)Waste spark method

b) Coil on plug ignition

3) Capacitor discharge method. (CD ignition) system

1) Distributor Type Electronic Ignition system

- It is similar to the conventional Ignition System, except that in this system, a timer or triggering device is employed instead of contact breaker
- This timer may be a Magnetic pickup sensor or a Hall-effect switch or an optical switch which triggers the ignition module also called the electronic ignition control unit (E.C.U.).
- This control unit primarily contains transistor circuit whose base current is triggered off and on by the timer which results in the stopping and starting of the primary current.

Breaker less ignition system

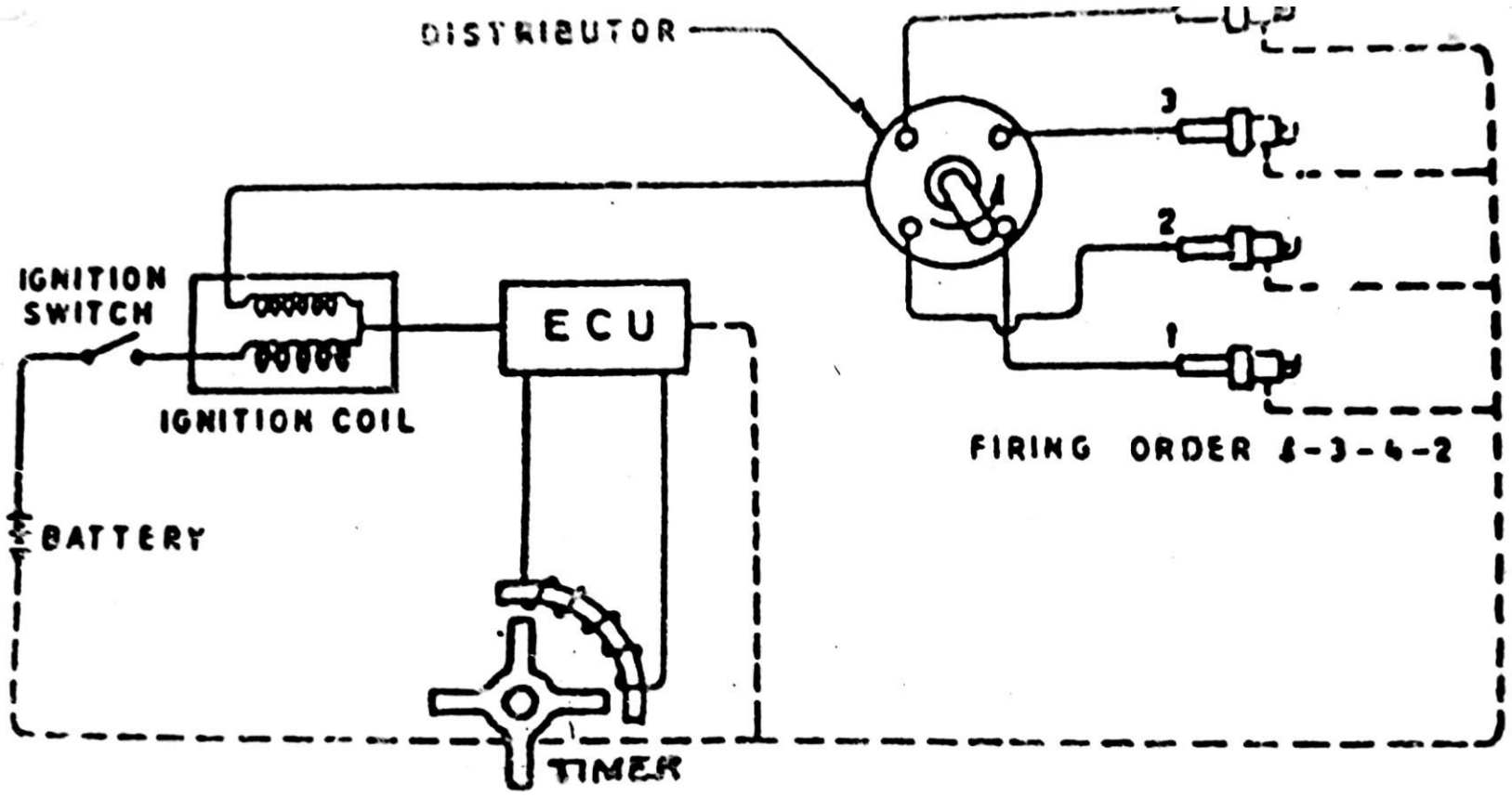


Fig. 14.10. Simplified diagram for an electronic ignition system.

Electronic triggering devices

- Electronic triggering devices send a signal current to the ignition control module, which then breaks the primary circuit.
- The parts of the triggering device do not wear, which gives it a much longer life expectancy than contact points. Since the triggering device does not wear, engine timing does not change. This improves engine performance, emissions out-put, and reliability.
- There are three types of triggering devices currently in use:
- Magnetic pickup sensors/pulse Generator
- Hall-effect switches.
- Optical sensors.

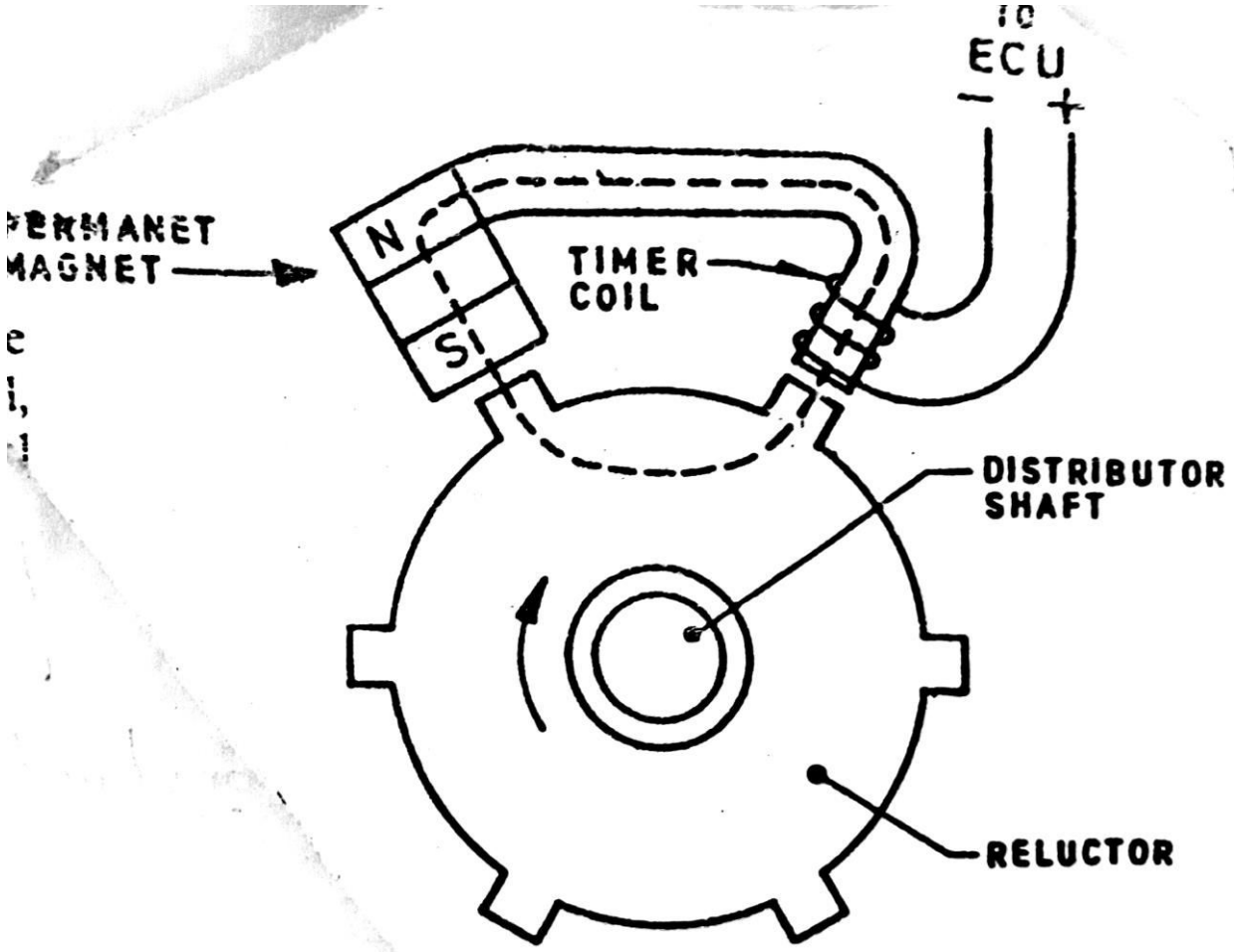
Most triggering devices are installed in or on the engine block and are operated by the rotation of the crankshaft or camshaft. Some triggering devices are operated by rotation of the distributor shaft

a)Magnetic pick up sensor/ Pulse generator

- A magnetic sensor is used to generate an alternating voltage, which is used, instead of contact breaker points, to control the make and break of the current build-up in the primary winding of the ignition coil
- A magnetic sensor consists of three main components, a permanent magnet, a timer coil and a Reluctor.
- Out of these the first two are stationary, while the Reluctor rotates

Reluctor: (also called timer core or armature) which is in the form of a toothed wheel, is mounted on the distributor shaft. It has the same number of teeth as the number of engine cylinders.

Magnetic sensor/Pulse generator



- As the reluctor wheel rotates, its teeth come very close to the pole plates of the permanent magnet, this reduces the reluctance of the air gap between the reluctor tooth and the timer coil and the other reluctor tooth and the magnet.
- This results in a strong magnetic field around the timer coil, permitting the control current to flow across the emitter-base circuit through the timer coil to the electronic control unit where the primary current in the emitter-collector circuit flows. This allows the ignition coil to build up a strong magnetic field.
- However, when the reluctor tooth passes away from the timer coil, the wide air gap offers high reluctance and results in weak magnetic field for the timer coil, which reverses the induced voltage and turns off the base current and hence the emitter-collector (primary) current of the transistor. This collapses the magnetic field in the ignition coil to produce high voltage at the spark plug.

Hall effect switch

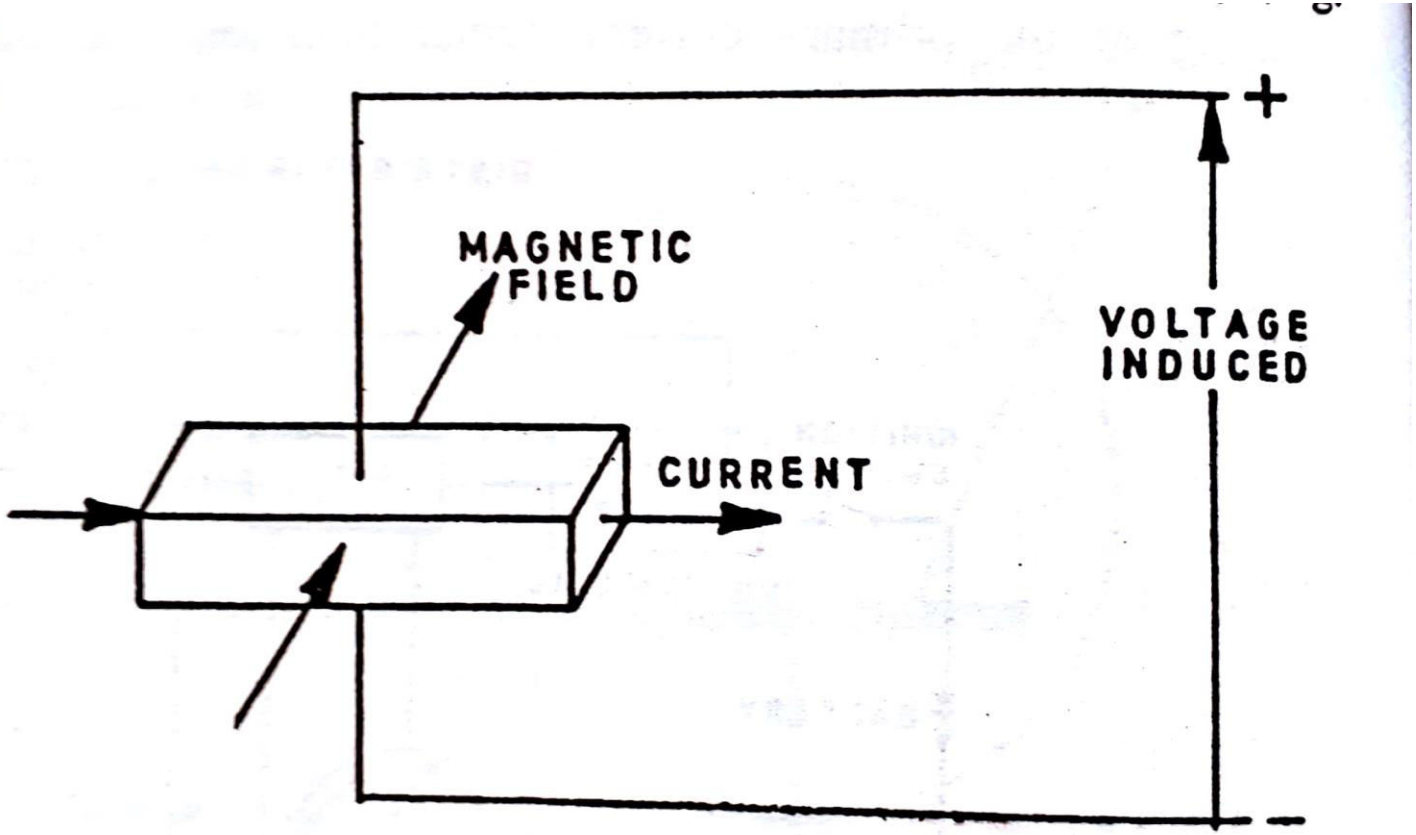
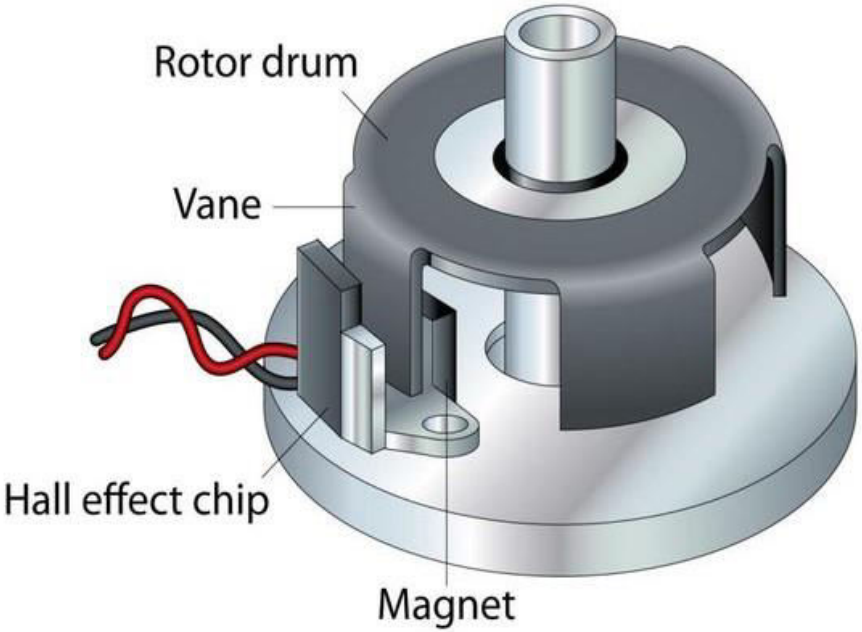
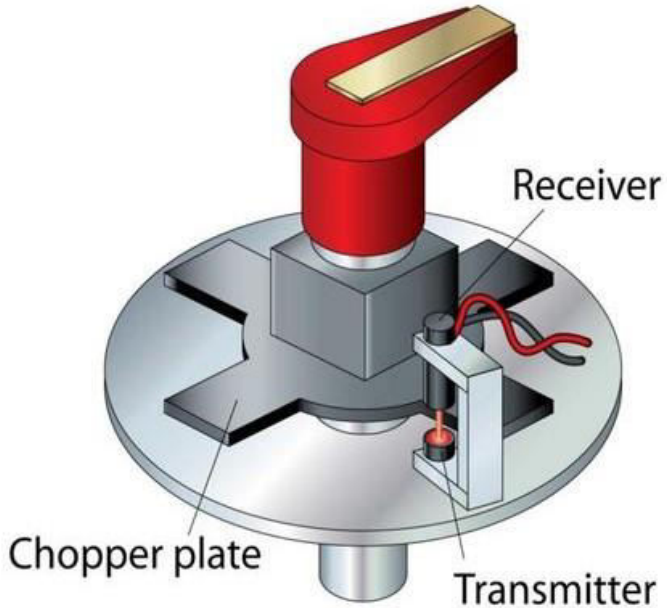


Fig. 14.12. Hall effect.



Hall effect



OPUS

Hall Effect:

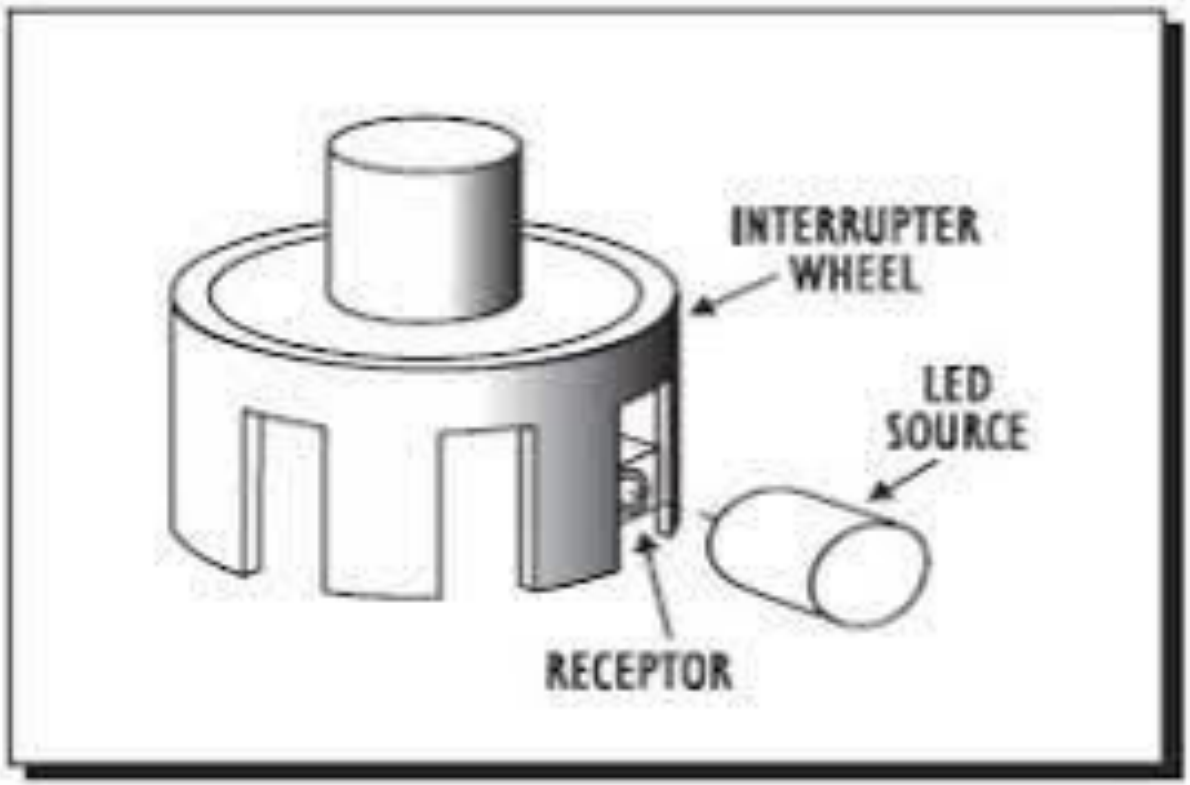
- When a thin semi-conductor chip (usually silicon) carrying current is crossed at right angles by a magnetic field, a potential difference is produced at the edges of the chip.
- Hall Effect is very small in metals, but is considerably increased when applied to semiconductors such as germanium and silicon, where that effect has been used as a very accurate electronic switch.

Working:

- A steel shutter with windows is connected to the distributor rotor, the number of windows being the same as the number of engine cylinders.
- As the distributor rotates, the shutter and the window alternately covers and uncovers the semi-conductor chip from the permanent magnet, thereby disallowing and allowing the magnetic field to strike the semi- conductor sensor.
- As the shutter covers the sensor from the magnetic field, the current stops flowing from the sensor.
- This stoppage of the sensor current stops the base current in the electronic control unit transistor thereby turning off the primary (emitter-collector) current there, thus acting as a timer to switch off the primary current.
- This type of timer switch is more accurate than the magnetic pulse generator.

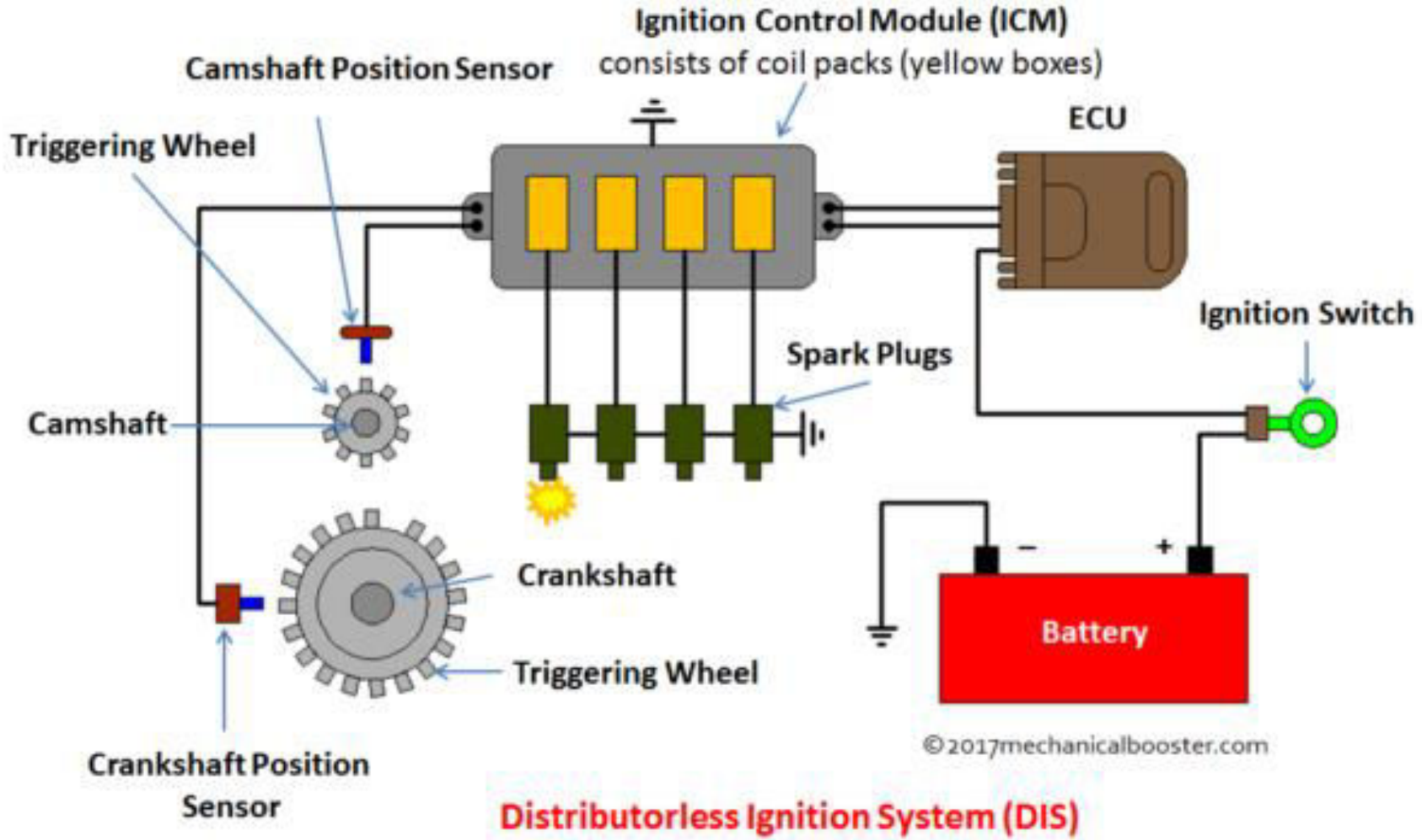
Optical Sensor

- An optical sensor is used in some ignition systems.
- This type of sensor consists of a rotor plate a light-emitting diode, and a photosensitive diode.
- The rotor plate has many slits in it through which light passes from the light-emitting diode (LED) to the photosensitive diode (light-receiving diode).
- As the rotor plate turns, it interrupts the light beam from the LED to the photosensitive diode.
- When the photosensitive diode does not detect light, it sends a voltage signal to the ignition control module, prompting it to fire the coil.



Distributor less ignition system

- As the name suggests, a distributorless ignition system has no distributor.
- It uses a crank- shaft speed and position sensor, which is a magnetic pickup sensor, a Hall-effect switch, or an optical sensor. The crankshaft sensor is mounted on or in the engine block.
- Some distributorless systems have a second sensor on the camshaft. The crankshaft sensor performs the same job that a pickup coil, Hall-effect switch, or optical sensor does in a distributor, matching the firing of the spark plug to the piston compression stroke.
- The advantage of this system is the elimination of the distributor assembly, rotor, and distributor cap.


Ignition Control Module (ICM)
consists of coil packs (yellow boxes)
Camshaft Position Sensor
Triggering Wheel
ECU
Ignition Switch
Spark Plugs
Camshaft
Crankshaft
Triggering Wheel
Crankshaft Position Sensor
Battery
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Distributorless Ignition System (DIS)

- An electrical signal is generated whenever the crankshaft is rotating. This signal is sent to the ignition control module and/or the ECM
- The ignition control module or ECM uses this signal to determine the position of each piston in the engine.
- On systems with crankshaft and camshaft sensors, both sensor readings are used to determine piston position.
- The sensor input may also be used by the ECM to determine engine rpm and the amount of ignition timing advance
- Besides, instead of a single ignition coil for all cylinders, there may be separate ignition coil for each cylinder, or two cylinders may share one coil.
- According to the ignition coil number and position,there are several types of distributorless ignition systems, including waste spark systems, coil-near-plug systems, and coil-on-plug system

Waste spark Ignition system

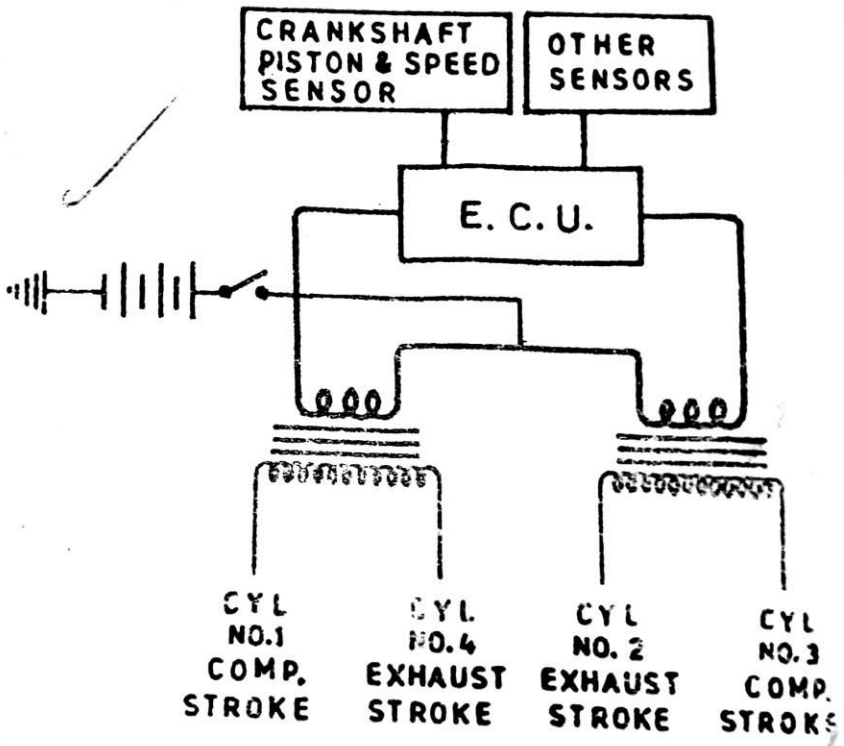


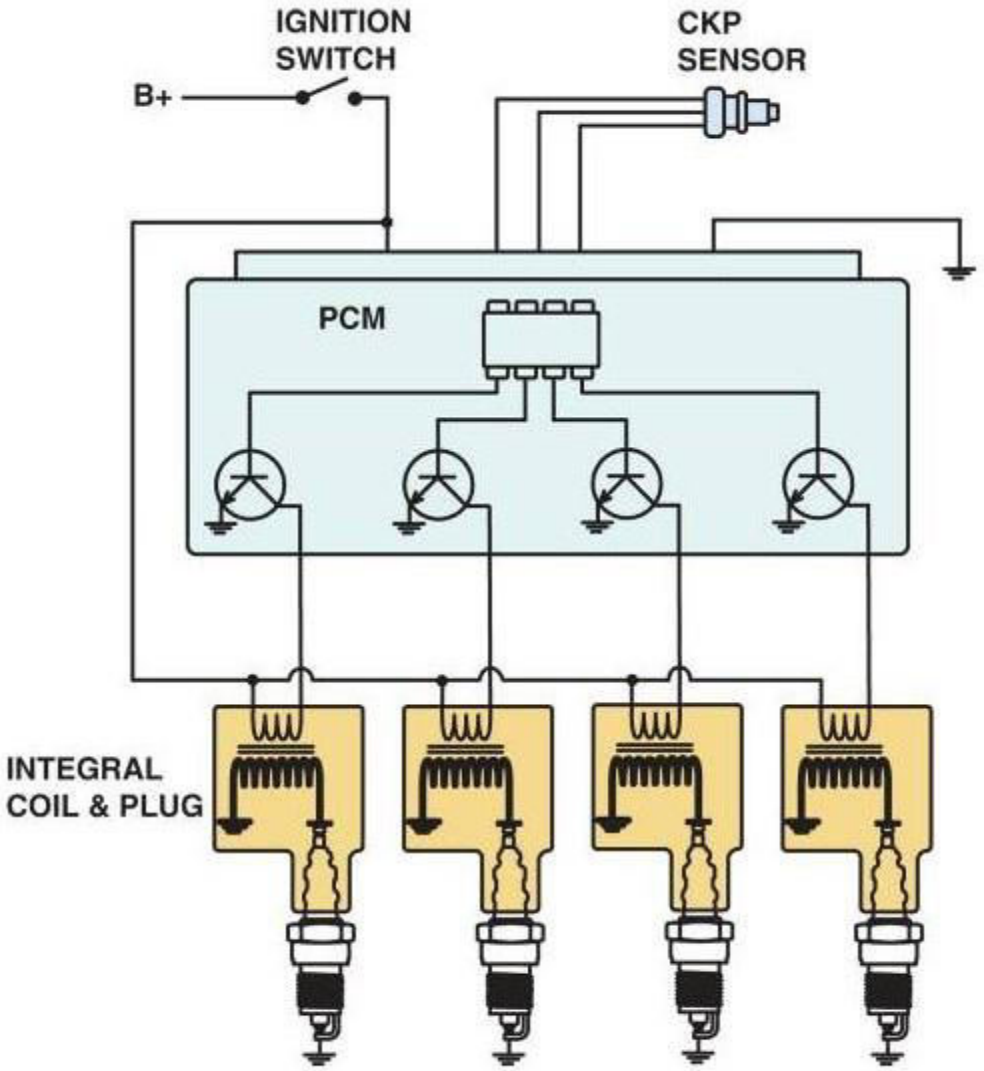
Fig. 14.14. Paired cylinders in a distributorless 4-cylinder

- In a waste spark ignition system, there is one ignition coil for every two cylinders. In this type of system, a four-cylinder engine has two coils, a six cylinder has three coils, and a V-8 has four coils

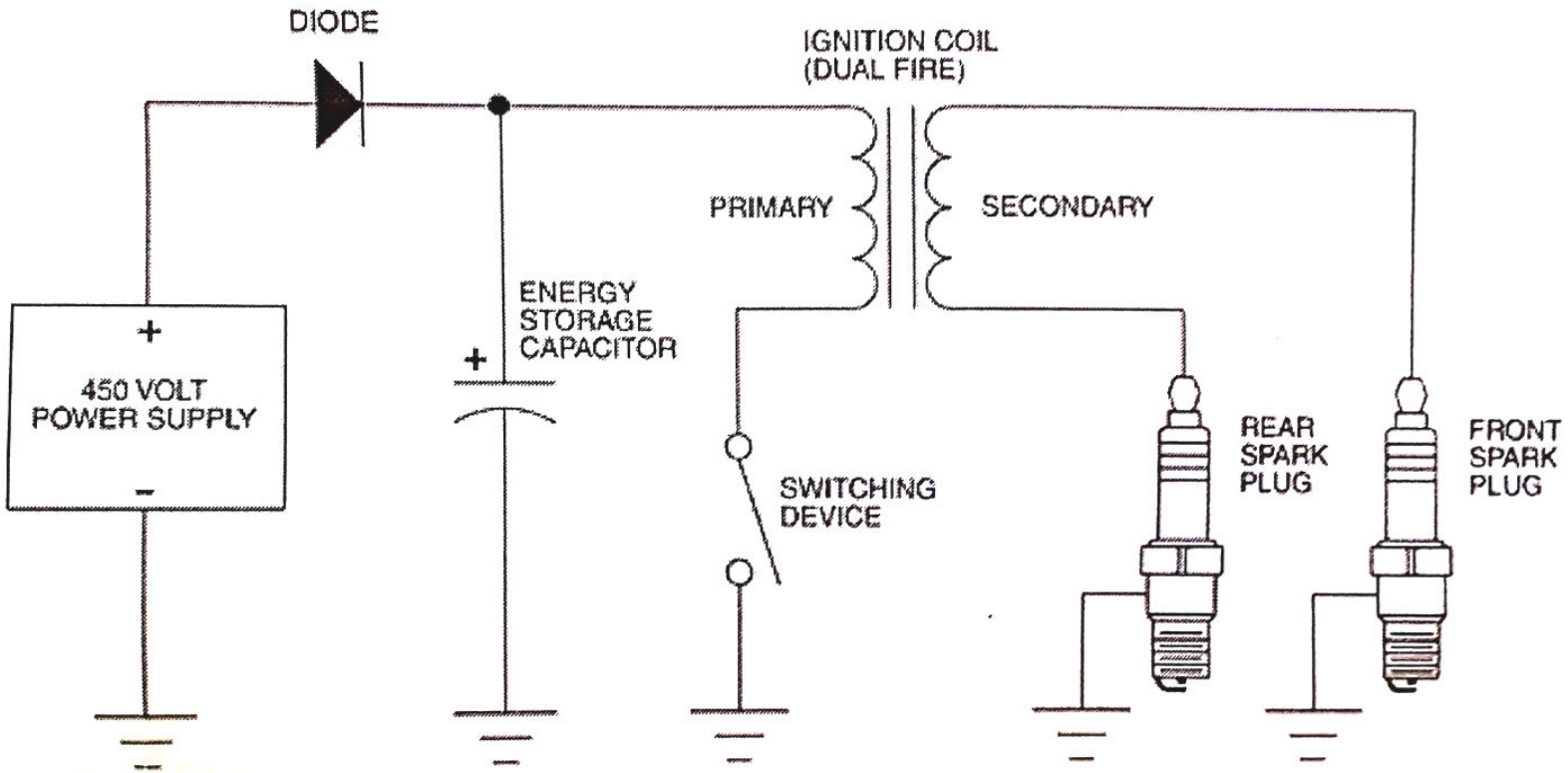
- The coils are often mounted together in a coil pack. Each coil in a waste spark system has two discharge terminals. These terminals are connected to two spark plugs through conventional resistor secondary wires.
- In effect, the coil fires both plugs at the same time. The coil wires are arranged so the coil fires one plug in a cylinder that is on the top of the compression stroke and the other plug in a cylinder that is on the top of the exhaust stroke.
- The plug firing on the top of the exhaust stroke has no effect on the operation of the engine. Therefore, the arc at this plug is referred to as a waste spark.
- Since it takes very little voltage to jump the spark plug gap on the exhaust stroke, the coil is powerful enough to fire both plugs

Coil-on-Plug System

- Many late-model engines are equipped with a coil-on-plug (COP) ignition system, or a direct ignition system.
- These systems do not use secondary (spark plug) wires or conductor strips. Instead, the coil assemblies are installed directly over the spark plugs,
- There is one coil assembly for every spark plug.
- Each coil assembly consists of a coil, a module, and a spark plug boot,
- The spark plug boot prevents arcing and keeps water from entering the coil-to-plug connection.


IGNITION
SWITCH
B+
CKP
SENSOR
PCM
INTEGRAL
COIL & PLUG

Capacitor discharge ignition system



- In this method, electrical energy is stored in a charging capacitor.
- When ignition is timed to occur, a thyristor power switch completes the capacitor-primary winding circuit of the ignition coil.
- Due to this, the capacitor will discharge through the primary winding instantaneously, causing a sudden flow of current there, which induces a very high voltage surge in the secondary winding, causing the spark to occur at the spark plug terminals.
- This voltage has a very fast rise time compared with a conventional inductive system.
- This super fast rise time and high voltage ensures that even a carbon- or oil-fouled plug will be fired. The characteristics of this system are much better than the induction type system.
- However, the duration of the spark (about 0.1 millisecond) being very small, can cause problems particularly during starting.
- This is overcome by providing multi-sparking facility.

Ignition Timing and Advance Mechanisms

- As engine speed increases, it is necessary to fire the mixture sooner. If this is not done, the piston would reach TDC and start down before the air-fuel mixture can be properly ignited. To properly fire the air-fuel charge, a device is needed to advance the engine timing (firing more degrees before TDC compared to manufacturer's timing specifications) as the engine speed increases.
- It is also necessary to retard the timing (firing the spark closer to, or slightly after, TDC compared to manufacturer's specifications) to control exhaust emissions and prevent spark knock.
- When the engine is being cranked, ignition timing must be at or near top dead center (TDC).
- When the engine is at idle, very little advance is necessary.
- At higher engine speeds, it is necessary to fire the mixture somewhat sooner. To see this concept, look at Figure 10-22. In this example, the pressure of a burning air-fuel charge will end when the piston reaches 23° after TDC.

- In Figure1 shows that the combustion cycle must start at 18° before TDC in order to be complete by 23° after TDC.
- In Figure2, engine speed has tripled. It is now necessary to ignite the charge at 40° before TDC in order to complete combustion by 23° after TDC.
- On older vehicles with distributors, vacuum and centrifugal devices were used to advance the timing.
- All engines made within the last 30 years have the timing advance controlled by the vehicle ECM based on inputs from various engine sensors.
- In late-model vehicles, the ECM monitors all engine and external variables, such as engine rpm and temperature, engine accessory operation, manifold vacuum, barometric pressure, airflow rate, air temperature, throttle opening, exhaust gas oxygen, transmission gear, vehicle speed, system voltage, and whether the engine is knocking.
- The ECM advances or retards the timing to exactly match the needs of the engine and vehicle. On some systems, the computer contains the ignition control module and controls the coil directly.
- On other systems, the ignition control module is separate, and it interacts with the engine control computer. In either case, the amount of advance is set by the computer and cannot be adjusted

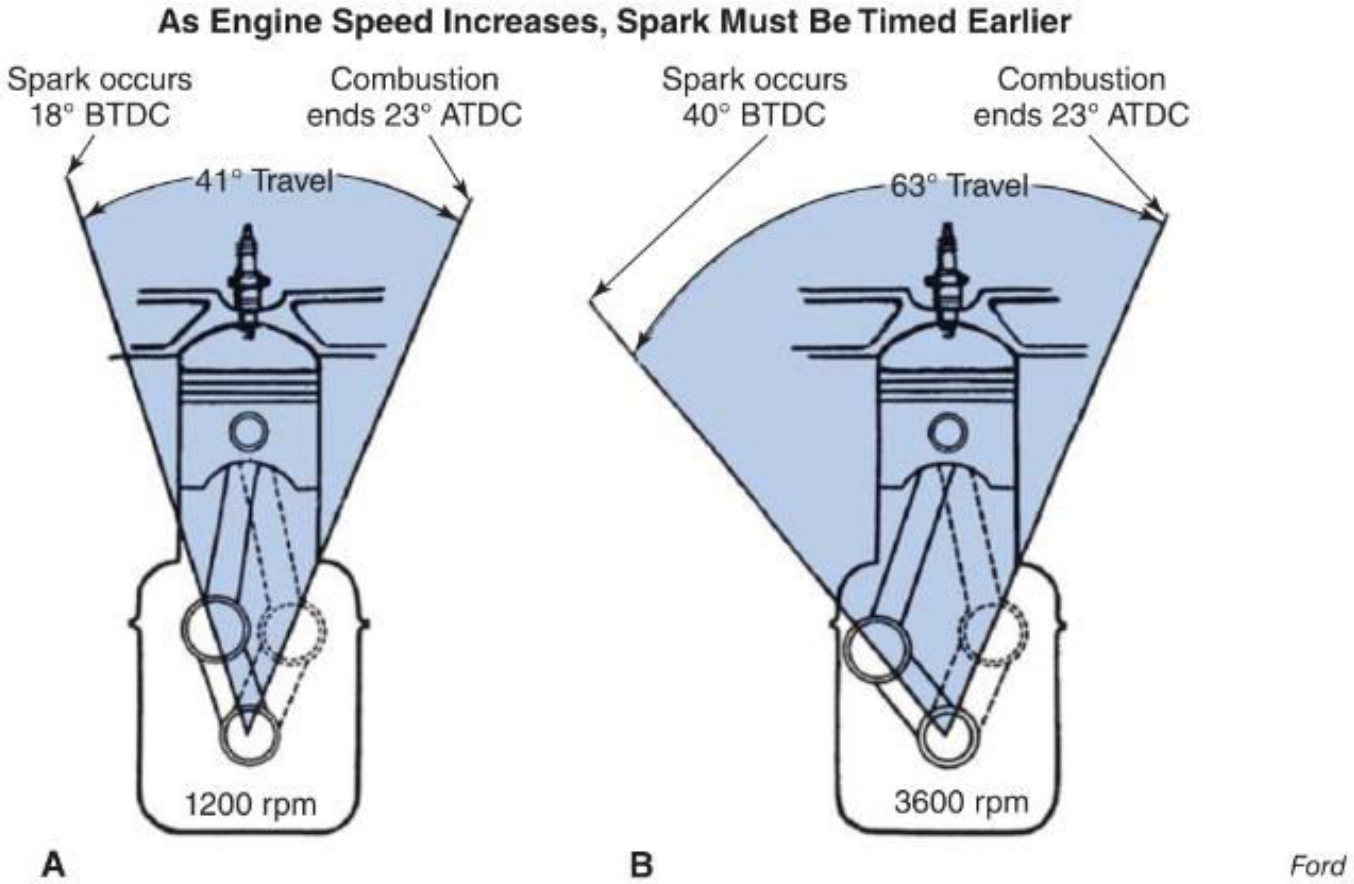


Figure 10-22. As engine speed increases, the spark must be timed sooner. A—At 1200 rpm, only 41° of crankshaft travel is required. B—At 3600 rpm, 63° of crankshaft travel is necessary.