COYNE Electrical School

CHICAGO ~ ~ ILLINOIS

ESTABLISHED 1899

AUTOMOTIVE ELECTRICITY

Principles of Internal Combustion Engines

Carburetion, Ignition, Combustion, Spark Advance

Multiple Cylinder Engines, Firing Orders

Battery Ignition Systems

Parts, Connections, Operation

Ignition Timing, Dual Ignition, Special Distributors

Ignition Locks, Ignition Troubles and Repairs

High Tension Magnetos

Operation, Care and Repair

Starting Motors

Operation, Troubles and Remedies

Automobile Generators

Voltage Regulation, Charging Rate Adjustment

Cutouts, Field Protection, Troubles and Remedies

Automotive Lighting Equipment

General Trouble Shooting on Complete Wiring Systems

AUTOMOTIVE ELECTRICITY

With the tremendous number of automobiles used today for pleasure and for commercial purposes, there is a splendid field of opportunity for trained men in ignition and battery service and general automotive electrical work.

In the year 1929 alone American manufacturers produced approximately 5,000,000 motor vehicles. These and many more millions of automobiles, trucks, tractors, etc., use electricity for ignition and other very essential features of their operation.

One of the reasons for the growth of the automobile industry, which is one of the very largest of all industries in this country, lies in the improved efficiency and convenience obtained through the use of electricity for numerous things in connection with the operation of automobiles, as well as in the great improvements made in their mechanical design.

Electric ignition makes possible the high engine speeds and resulting high efficiencies of the engines used in modern motor cars. In addition to using electricity for ignition, or the igniting and exploding of the fuel at the correct time in the engine cylinders, electricity is also used: to start the engine by means of an electric motor; to provide illumination for night driving; and to operate the horn, windshield wiper, stop light, tail light, dash light and electrical instruments, cigar lighter, heater, and numerous other safety and convenience devices.

In fact, the modern motor car—with its generator, starting motor, storage battery, ignition devices and wiring, lights, horn, and other equipment—can be said to have a complete small electric power plant of its own and it has quite a variety of electrical devices and circuits which must be maintained in the best of condition for efficient operation of the car.

There are throughout the country thousands of garages which require trained electrical service men to take care of the electrical equipment on their customers' cars. This ignition and battery work is in general much cleaner, lighter, and more interesting than making mechanical repairs on automobiles. The salaries paid to experts in this line are generally a great deal higher than those of ordinary mechanics.

There are also thousands of places where a good ignition and battery man can establish a shop or business of his own and just specialize in this branch of automotive repair work.

In addition to the millions of pleasure cars there are in use a vast number of huge trucks and busses for hauling produce and carrying passengers all over the country; and there are also many thousands of tractors, which are becoming more and more extensively used in farming areas.

With the recent developments in automobile radio there is another vast field of opportunity opened up for the man with general training in electricity, radio, and ignition. Millions of automobiles already in use will soon be equipped with radio receiving sets; and, as new cars are made and sold, a great many not equipped with radio sets by the manufacturers will need to have them installed by the trained radio and ignition service man.

The aviation industry also affords tremendous opportunities in good paying and fascinating work for practically-trained ignition men. The safe operation of an aeroplane depends, of course, upon continuous operation of its engines, and the majority of these engines use electrical ignition for igniting their fuel. Therefore, it is extremely important that the magnetos, spark plugs, wiring, and all other electrical equipment on these engines be kept in perfect condition at all times. This work requires men who have a very thorough knowledge of electricity and ignition equipment and affords splendid opportunities to get into the aviation field.

Whether you ever specialize in ignition work or not you will find it very convenient and valuable to have a good general knowledge of this subject in connection with the operation of your own car, as a great deal of time and money can often be saved just by being able to quickly locate and repair some minor electrical trouble in the ignition system or wiring of your automobile.

In order to be thoroughly capable in ignition or automotive electrical service work a thorough general knowledge of practical electricity in its several branches is essential, as well as a knowledge of the operating principles of the common types of internal combustion engines. It is the purpose of this section to show you how the knowledge which you have already obtained of electricity and circuits can be applied to automotive equipment. The operation of common types of automobile engines is also briefly explained.

1. OPERATION OF INTERNAL COMBUSTION ENGINES

It is not our purpose to cover in this material all of the details of theory or design of internal combustion engines, but merely those practical points regarding their operation which will be essential to the automotive electrical service man.

In addition to being able to locate and repair troubles in the electrical wiring and electrical devices on automobiles, trucks, and tractors, the "tuning" of the ignition system is very important.

The term "internal combustion engine" is used on account of the fact that the energy which operates these engines is generated by the combustion or burning of a fuel mixture inside the engine itself.

One of the first commercially practical internal combustion engines was developed in France by J. J. Lenoir in 1860, and was known as a "two-stroke-cycle engine". Later in 1876 this engine was greatly improved by a German named Nicholas Otto who produced an engine of the "four-stroke-cycle type". The basic principles of these latter engines are the same as those on which all automotive engines operate.

As has been previously stated, power is developed within an internal combustion engine by the explosion or burning and expansion of a fuel mixture in a manner to apply pressure to the pistons, which in turn drive the crank shaft and flywheel of the engine.

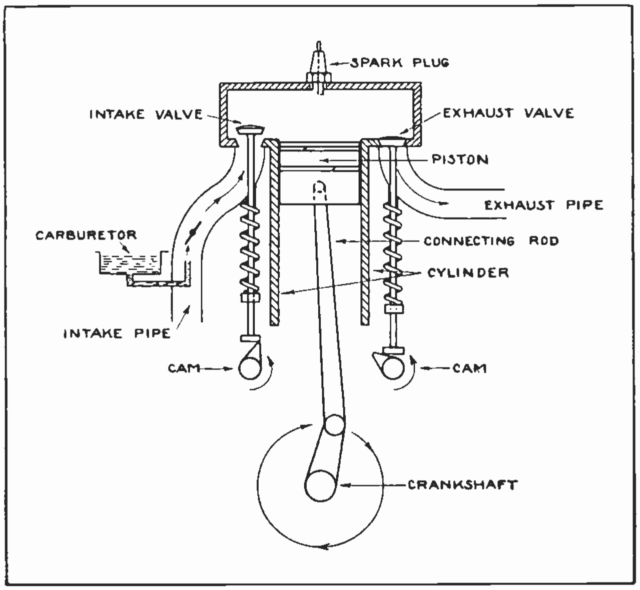


Fig. 1. This diagram illustrates the operating principle of a simple one-cylinder internal combustion engine. Study the diagram carefully while reading the explanation.

For continuous operation of these engines it is necessary to maintain a certain series of events known as a **cycle.** These cycles are then continuously and rapidly repeated as long as the engine operates.

In the four-stroke-cycle engine these steps of each cycle are as follows: 1. Intake of fuel charge. 2. Compression of fuel charge. 3. Ignition and combustion of fuel charge. 4. Exhaust of burned or waste gases.

To complete all of these steps for one cycle in any one cylinder of an ordinary automobile engine requires four strokes of the piston and two revolutions of the crank shaft. This is the reason they are called "four-stroke-cycle engines", or sometimes just "four cycle engines".

Fig. 1 is a simple diagram showing a sectional view of one cylinder of an automobile engine, and shows the following important parts: Cylinder, piston, connecting rod, crank shaft, valves and valve operating cams, and carburetor.

In this diagram the piston is shown at the commencement of the intake stroke; the intake valve on the left is open and the exhaust valve is closed. If the crank shaft is rotated to the right, or clockwise, the piston will be drawn downward on the **intake stroke** and, as it fits tightly in the cylinder, a suction or vacuum will be formed in the combustion chamber and will draw in a mixture of gasoline and air from the carburetor and through the intake pipe.

When the crank shaft revolves far enough so that the piston is about 30 degrees beyond **lower dead center** the intake valve is allowed to close by the cam moving out from under its lower end. Then, with both valves closed, the piston moves up on the **compression stroke.** This compresses the fuel charge into the relatively small space in the cylinder head called the **combustion chamber.**

When the piston arrives at the upper end of its stroke, or **upper dead center,** a spark is forced across the points of the spark plug, igniting the gas charge. Once this mixture of gasoline vapor or gasoline and air is ignited it burns at a very rapid rate. In fact so rapidly that this combustion action is often called an "explosion".

This burning of the fuel creates a very high temperature of about 3000° F. maximum, and an expansion pressure of about 300 to 400 lbs. per square inch which is exerted on the top of the piston.

The pressure is, of course, due to the tendency of the gas to expand when heated. This pressure generated by the rapidly expanding gases, forces the piston to move downward on the **power stroke,** both valves remaining closed until the piston reaches a point about 40° before the lower dead center position. At this point the exhaust valve opens through the action and timing of its cam. This stroke is known as the **power stroke.**

With the exhaust valve remaining open, the piston again moves up to the upper dead center, forcing the burned gases out through the exhaust pipe. The exhaust valve then closes and one cycle is completed. This brings the engine back again to the position first mentioned, with the piston again ready for a downward intake stroke.

As long as the engine continues to operate this cycle is rapidly repeated, with the piston moving up and down and transmitting the force of each power stroke to the crank shaft through the connecting rod. The crank shaft converts this force into rotary movement of the flywheel attached to its end.

2. VALVES, PISTON, CAMSHAFT, CRANKSHAFT, and OTHER ENGINE PARTS

From the foregoing facts it is easy to see the importance and necessity of having the valves operate at exactly the right instant with respect to the position and direction of movement of the piston. This is accomplished by the rotation of the cam shaft, which is connected to and driven by the crank shaft. The valves are normally held closed by the action of springs shown in the diagram in Fig. 1, and are forced open at the proper instant by the rotation of the cams or projections on the cam shaft, which press against the lower ends of the valve stems or push rods which are sometimes placed underneath the stems.

You can also see the importance of having the spark occur at exactly the right instant to ignite the fuel mixture, that is, when the piston is at the top of its compression stroke and just ready for the downward power stroke. The method by which this is accomplished will be explained in later paragraphs.

Fig. 2 shows at the upper right a pair of valves for an automobile engine, and at the bottom is shown the cam shaft which operates the valves by means of the short push rods shown directly beneath the valves on the right. These push rods are located between the cams and the lower ends of the valve stems.

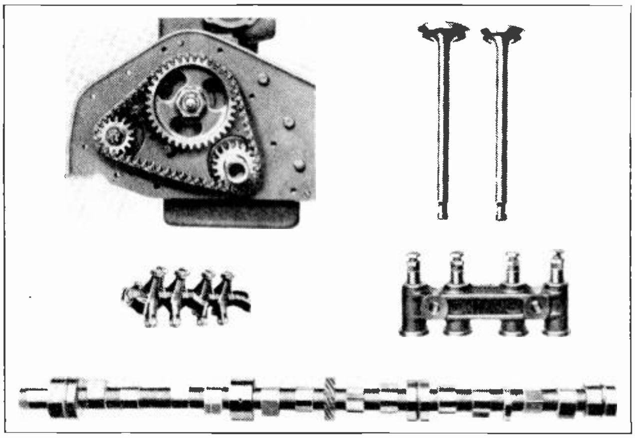


Fig. 2. This figure shows valves, push rods, rocker arms, cam shaft and cam shaft drive gears of an automobile engine. Courtesy Oldsmobile Mfg. Co.

At the upper left in this figure are shown the gears and chain by means of which the cam shaft is driven from the end of the crank shaft of the engine. On engines having overhead valves the valves are often operated by means of long push rods and overhead rocker arms. A set of these rocker arms are shown above the cam shaft on the left in Fig. 2.

Fig. 3 shows at the top a crank shaft and flywheel for a modern 6-cylinder engine. At the lower left in this figure is shown a piston attached to the connecting rod by means of which the piston imparts its energy to the crank shaft.

Note the piston rings which are located in grooves around the top of the piston to secure a tight fit to the cylinder walls and prevent leakage of any of the force from the expanding gases. These rings also help to maintain the proper suction and vacuum to draw in the fuel during the intake stroke.

At the lower right in Fig. 3 is shown the cylinder

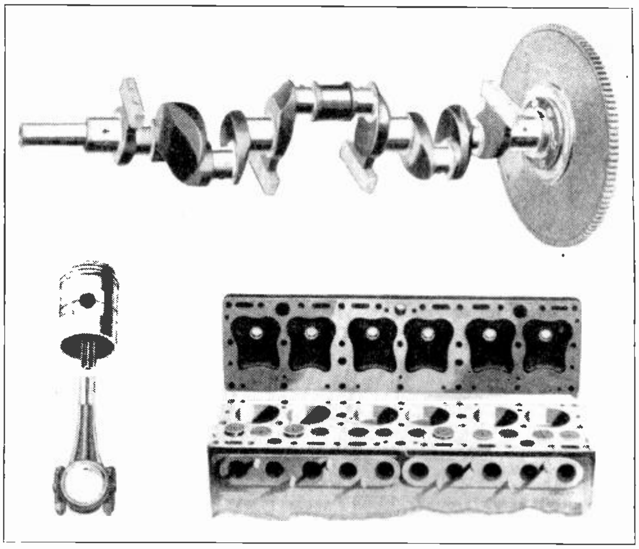


Fig. 3. At the top of this figure is shown a crank shaft and flywheel for a modern six-cylinder engine, and below are shown a piston and connecting rod and the cylinder block with the head lifted to show the cylinders, valves, etc. Courtesy Oldsmobile Mfg. Co.

block of a 6-cylinder engine with the cylinder head removed. In the block you can see the intake and exhaust valves for each cylinder, some of these valves open and some closed. The intake and exhaust ports or openings which admit the gases to and from the valve chambers are shown along the side of the cylinder block. In the cylinder head can be seen the combustion chambers with their spark plug openings. When the head is in place on the cylinder block these combustion chambers each fit directly above their respective cylinders and valves.

Fig. 4 shows an excellent sectional view of the end of an automobile engine of the side valve or L-head type. In this view the piston can be seen at the top of the cylinder and the connecting rod is shown leading from the piston to the crank shaft. Just above and to the left of the lower end of the connecting rod can be seen the end of the cam shaft with one cam projecting to its left. The push rod can be seen directly above and resting upon this cam, and above the push rod are the valve and valve spring. The tubular guide through which the valve stem slides up and down is called the "valve guide".

The intake and exhaust manifolds are shown projecting from the left of the cylinder block, and the passage through which the exhaust gases leave the cylinder through the valve can be clearly seen. The spark plug is located on top of the combustion chamber, and is connected by a wire to one of the terminals of the ignition distributor mounted on top of the engine.

3. VALVE TIMING

Theoretically each stroke of an automotive engine begins and ends at either the **upper dead center** or **lower dead center**, and we might think that the valves should open and close at these positions. However, in actual practice the valves are timed to open and close at points earlier and later than the exact upper and lower dead centers, because of the inertia of the gases.

For example, the closing of the intake valve is usually delayed to about 30 degrees after lower dead center (L.D.C.), in order to allow the engine to draw in the maximum gas charge and develop its maximum power. During the intake stroke the column of gas mixture moves through the intake manifold to the cylinder with a velocity of about 200 feet per second, and the gas due to its momentum continues to crowd into the cylinder even after the piston has passed L.D.C.

As long as this gas fuel is flowing into the cylinder the valve should remain open, in order to take in the maximum fuel charge; and this is the reason for delaying the closing of the intake valve until about 30 degrees after L.D.C.

On the power stroke the exhaust valve generally opens when the piston reaches a point about 40 degrees before L.D.C., thus allowing the exhaust gases to start their escape while there is still a little pressure in the cylinder (approximately 50 lbs. per square inch). This loses a little of the pressure from the fuel combustion, but it actually increases the total power of the engine by effecting a more thorough cleaning or scavenging of the exhaust gases from the cylinder, and also by eliminating all back pressure on the piston as it starts to move up on the exhaust stroke.

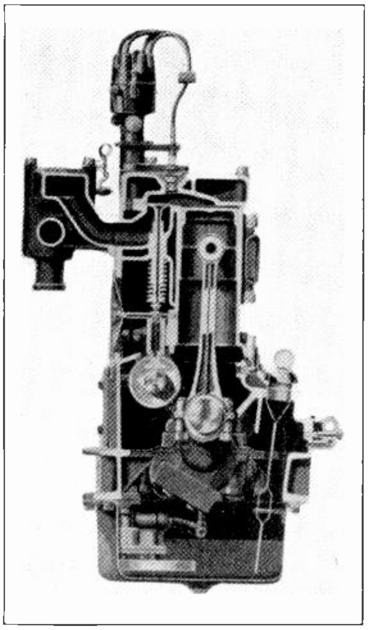


Fig. 4. This sectional end-view of a modern automobile engine clearly shows the arrangement and location of important parts such as piston, connecting rod, crank shaft, cam shaft, valves, etc. Courtesy Oldsmobile Mfg. Co.

When the U.D.C. is reached the exhaust valve closes, and about 10 degrees later the intake valve opens. The purpose of this slight delay in the opening of the intake valve is to create a slight vacuum in the cylinder before opening it, and also to eliminate the possibility of fuel loss through the exhaust valve which has just closed.

Fig. 5 is a diagram illustrating this valve timing or the points at which the valves open and close with regard to upper and lower dead center in each revolution of the crank shaft. In this figure the time is expressed in degrees of crank movement, allowing 360 degrees for one complete revolution of the crank shaft.

The diagram not only shows the positions at which the valves open and close but also shows in degrees the length of the intake, compression, power, and exhaust strokes.

The timing values given in this diagram represent popular or general practice, but it should be remembered that different engines require widely varying valve timing, according to their design, speed of rotation, compression used, fuel efficiency, etc.

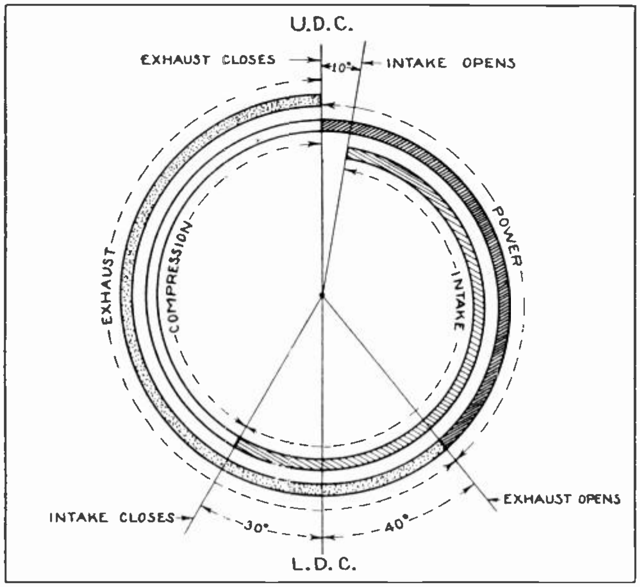


Fig. 5. Diagram illustrating valve timing or showing the points at which the valves open and close, and also showing the degrees of open and closed periods during each revolution of the crank.

4. PRINCIPLES OF CARBURETION

The purpose of the carburetor on an automobile engine is to supply the proper mixture of gasoline vapor and air for fuel to be burned in the cylinders. The carburetor also provides a means of controlling the speed and power output of the engine by admitting more or less fuel under the control of a throttle valve.

Raw gasoline will not burn in the cylinders, so the function of the carburetor is to mix a spray or jet of gasoline with a proper amount of air to provide combustible fuel.

Fig. 6 is a diagram showing a sectional view of a simple elementary type of carburetor. The gasoline enters the fuel bowl through a small tube or pipe from the gas tank, vacuum tank, or fuel pump. The float in the fuel bowl automatically keeps the gasoline at the proper level in the bowl by shutting off the flow from the pipe whenever the float rises high enough. From the fuel bowl the gasoline is drawn through either the high-speed jet or low-speed jet,

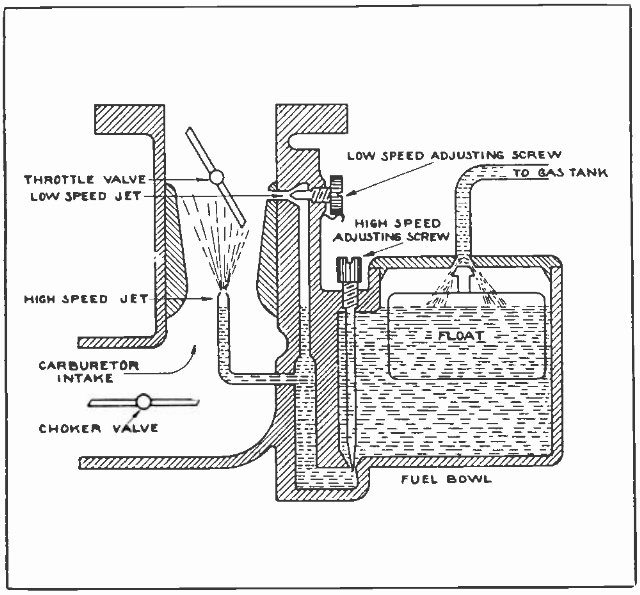


Fig. 6. Diagram showing a sectional view and the operating principles of a simple carburetor used for supplying the proper mixture of gasoline and air for fuel to the engine.

according to the speed at which the engine is operating. Note the positions of these jets in Fig. 6.

As long as the engine operates at moderate or high speeds, the rapidly repeated intake strokes of the pistons in the various cylinders maintain a practically constant suction, which draws a steady stream of air in through the carburetor barrel and intake manifold. This air, rushing upward through the narrow or restricted opening in the carburetor barrel, sucks gasoline from the high-speed jet in the form of a fine sray which mixes thoroughly with the air, and passes on into the cylinders as combustible fuel as long as the throttle valve is open.

When the throttle valve is closed it cuts off the supply of gasoline from the high-speed jet and creates a higher vacuum or suction above the valve. This raises the gasoline and draws it from the low-speed jet for idling or low speed operation of the engine.

For satisfactory engine operation the proper mixture or proportion of fuel and air must be maintained at all times. If there is too much gasoline the mixture is said to be too "rich", and this will cause irregular operation and may stop the engine entirely. **An excessively rich mixture is generally indicated by heavy, black smoke coming from the exhaust pipe.**

If, on the other hand, there is too little gasoline and too much air, the **mixture is said to be too "lean", and the engine will misfire and lack power.**

For average conditions a mixture consisting of about sixteen parts of air to one part of gasoline (by weight) gives the best results. A mixture of less than seven parts of air to one of gasoline is too rich to burn at all, while at the other extreme more than twenty parts of air to one of gasoline will cause the engine to misfire and develop very little power.

When starting up a cold engine a rich fuel mixture is required, and to obtain this a choker valve in the lower end of the carburetor barrel is partly closed in order to shut off part of the air and create a higher suction at the fuel jets and draw more gasoline. As soon as the engine is running smoothly and slightly warmed up, this choker valve should be opened to again thin the fuel mixture and prevent fouling of the spark plugs and cylinders.

From the preceding explanation of carburetor principles it is easy to see the importance of correct carburetion or carburetor adjustment for smooth and efficient operation of an internal combustion engine.

The adjustments for the high-speed and low-speed jets are made by adjustable needle valves which control the flow of gasoline to each jet. The one marked "low-speed adjustment" controls the flow of fuel issuing from the jet located in the carburetor barrel above the throttle valve, and which is generally known as the idling jet. This jet supplies the fuel up to speeds of about twenty miles per hour in high gear.

As the throttle is opened farther than this it breaks the high suction at the upper jet and will not draw the gasoline up to this level any longer. From this point on the fuel is supplied by the lower jet for the higher speeds.

Fig. 7 shows a photograph of a modern carburetor of a dual type design, for use on 8-cylinder engines. You will note the fuel bowl on the left and the air intake opening on the right. The openings which connect with the intake manifold on the engine are shown on the top. The adjusting screws for both the high-speed and low-speed jets can be clearly seen in this view. You can also see the levers which operate the throttle and choker valves.

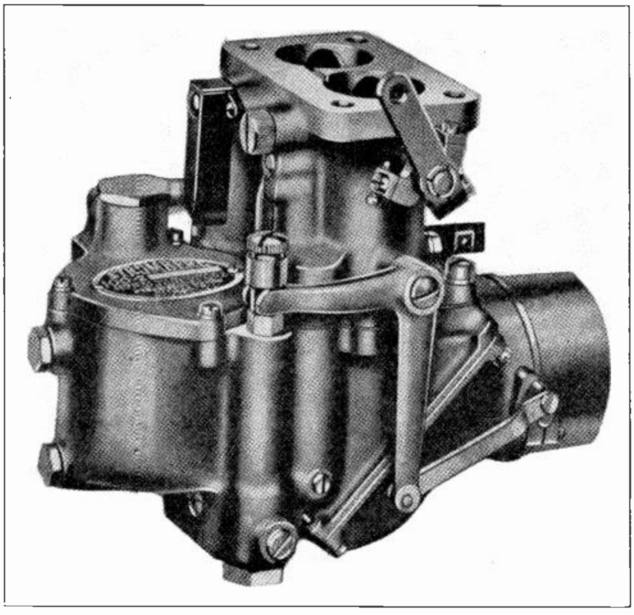


Fig. 7. Photograph view of a double or twin barrel carburetor with some of the operating levers and adjustments in plain view.

Improper carburetor adjustment will often cause faulty and irregular operation of the engine that is sometimes blamed upon the ignition or valve timing; so, when "tuning" an engine one should make sure that the carburetor is properly adjusted for smooth operation.

5. FUEL COMBUSTION and SPARK ADVANCE AND RETARD

When the fuel charge that is supplied to the cylinders by the carburetor is ignited by a spark from the plug it requires a very small fraction of a second for the flame to spread throughout the entire charge in the combustion chamber. In other words, the combustion of the gasoline vapor is not actually an instantaneous explosion, but instead requires a certain small period of time after the charge is ignited before combustion is complete.

The period of time required between ignition and the complete combustion of the fuel depends on the amount of compression, the type of fuel used, the shape of the combustion chamber, location of the spark plug, etc. On an average, this time period is about .003 of a second.

In order to obtain maximum pressure on the piston the ignition spark should be timed so that combustion will be completed just when the piston is on upper dead center. Because of the short period of time between ignition and complete combustion **the spark must, therefore, occur at some point slightly ahead of the upper dead center position** or just before the piston reaches this point.

This is known as **advancing the spark**, and is very important in obtaining maximum speed and power for modern automobile engines, because at the speed these engines operate the piston will travel a considerable distance in even as small a period of time as .003 of a second. Just how far the spark should be advanced depends upon the operating speed of the engine, the degree of compression used, and the grade of fuel.

As the amount of spark advance depends upon the engine speed, it is generally necessary to advance and retard the spark according to the speed at which the car or engine is being operated. This enables one to obtain the maximum power both at low speeds, such as when climbing steep hills, and also at high speeds on good level roads.

Ordinarily the spark is so timed that during low-speed operation of the engine ignition will occur when the piston is at U.D.C. The spark is then advanced as the speed of the engine is increased. This is usually accomplished by rotating the ignition timing device or distributor, and thus causing the spark to occur a little earlier with regard to the piston stroke.

On some cars this spark adjustment is made by hand from a control on the steering wheel, while on many of the modern automobiles it is made automatically by a sort of governing arrangement which operates whenever the engine changes speed.

Excessive spark advance will cause the engine to knock while insufficient advance will result in a loss of power and overheating of the engine.

Generally the best position of spark advance for any certain speed is reached when a little more advance will cause the engine to knock. The amount of spark advance varies from 15 to 60 degrees in different types of pleasure cars, according to the design of the engine.

The method of adjusting the spark advance and retard mechanism will be covered later in connection with ignition distributors.

6. ARRANGEMENT OF VALVES

One of the most important things in gasoline engine design, and one that has a material effect on their efficiency and operating characteristics is the shape of the combustion chamber and the arrangement of the valves. The valves which admit the fuel and discharge the burned gases from the cylinder may be placed either alongside the cylinder as in "side valve" engines or they may be in the cylinder head as in "overhead valve" engines.

Fig. 8 shows the four different valve arrangements, giving both side sectional views of the cylinder and top views looking down on the cylinder and valves. At "A" both valves are located in

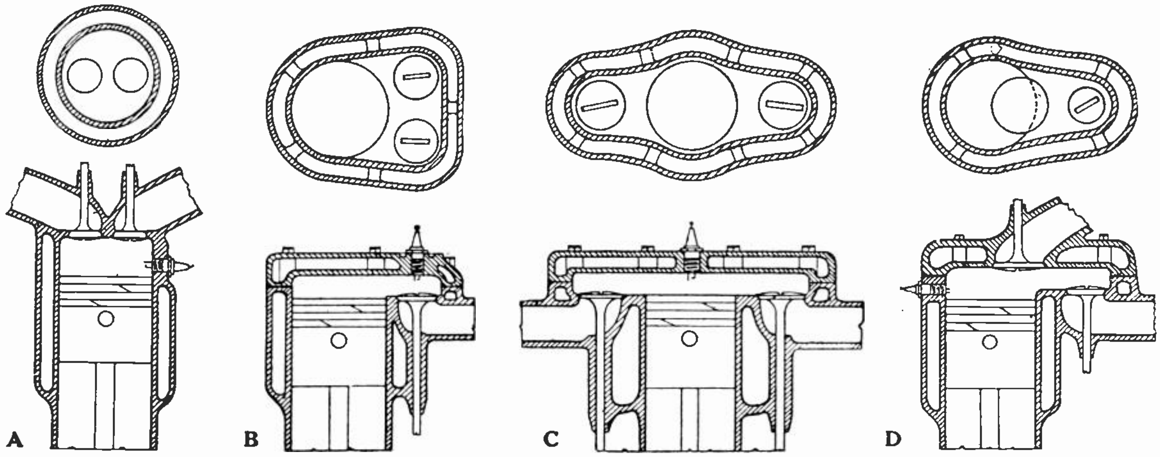


Fig. 8. The above diagrams show the location and arrangement of valves with respect to the cylinder in various types of automobile engines

the cylinder head above the piston. An engine of this type is known as the "overhead valve" type.

"B" shows a cylinder of a side valve engine in which all of the valves are placed on one side of the engine. Engines of this type are commonly called "L-head" engines because the combustion chamber and cylinder form a sort of inverted L shape.

At "C" is shown one cylinder of a "T-head" engine in which the exhaust valves are located on one side of the engine and the intake valves on the other.

At "D" is shown the valve arrangement for what is called an "F-head" engine, which uses a combination of the first two types, the intake valves being located in the head and the exhaust valves on the side.

Fig. 9 shows an end view of an engine with overhead valves. The cam shaft shown at the left of the connecting rod operates a long push rod which in turn operates a rocker arm at the top of the engine. The right-hand end of this rocker arm opens the valve by pushing it downward into the combustion chamber.

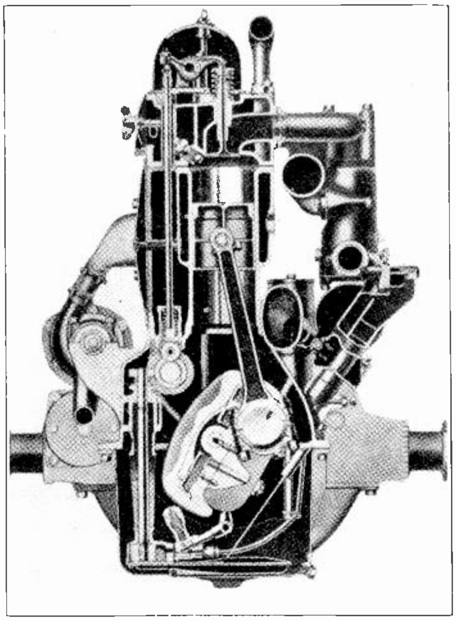


Fig. 9. End and sectional view of a Buick engine showing the overhead valve construction, the method of operating valves by means of long push rods, and overhead rocker arms.

Probably 80% of modern automotive engines are of the L-head type and most of the remainder use the overhead type. One decided advantage of both the L-head and overhead valve types of engines is that all valves are arranged in one line, and therefore only one cam shaft is required to operate all of the valves. This results in a very definite arrangement of the valves from the front to the rear of the engine.

In Fig. 10 you will note that the first and last valves are exhaust valves and the intermediate ones are arranged in alternate pairs of intakes and ex-

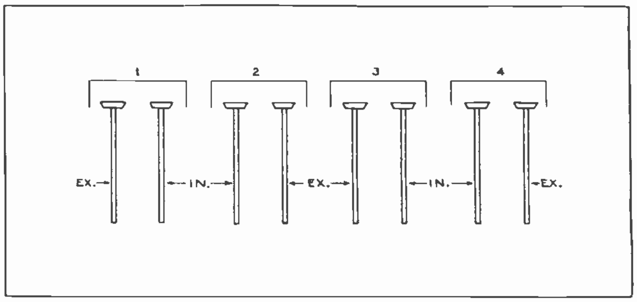


Fig. 10. This simple sketch shows the order or arrangement of exhaust and intake valves which is used on practically all automobile engines. Knowing this arrangement will be a great help in locating certain valves when timing an engine.

hausts. While this sketch shows the valves for a 4-cylinder engine the same arrangement is used regardless of the number of cylinders as long as they are all in one line. This valve arrangement provides a convenient means for setting the engine on U.D.C. when timing the ignition.

In order to obtain even torque and better balance in automobile engines the crank shafts are generally made so that the pistons move up and down in pairs, the first and last piston always moving up and down together. The two pistons of any pair, however, are always on different parts of the cycle.

For example, when the last piston is moving up on exhaust the first is coming up on compression, and when the last piston arrives at U.D.C. position the last valve on the engine will close, as it is an exhaust valve. Therefore, when the last valve on the engine closes, No. 1 piston is on upper dead center on the compression stroke and the engine is set on the timing position or ready for the spark to occur in No. 1 cylinder. This method is particularly applicable to overhead valve engines and is a very good rule to remember.

No. 1. Cylinder on an automobile engine is always the one next to the radiator or on the cranking end, the remainder of the cylinders are numbered in order from here back to the flywheel end.

7. MULTIPLE CYLINDER ENGINES

A single-cylinder, four-stroke-cycle engine receives only one power impulse for every two revolutions of the crank shaft, as four strokes are required to complete the cycle and only one of these strokes is a power stroke. In single-cylinder engines, therefore, a rather heavy impulse is required on the power stroke in order to build up sufficient momentum to keep the engine turning through the three idle strokes which follow.

Due to the severe strain imposed on the engines by this heavy power impulse such engines had to be very strongly constructed, and as a result both the stationary and moving parts were excessively heavy. In addition, they required a very heavy flywheel, capable of storing sufficient energy on the power stroke to keep the engine running at approximately constant speed through the rest of the cycle.

Such engines cannot run at high speeds without severe vibration, and this disadvantage along with the excessive weight has led to the production of multiple-cylinder engines which provide more frequent power impulses, run more smoothly, and have greater flexibility and lighter weight for a given power output.

The greater the number of cylinders the more frequently the power impulses occur and the more even is the flow of power applied to the crank shaft. For a given power output the size and weight of the moving parts of the engine become less as the number of cylinders increases, and this makes possible higher engine speeds and higher efficiencies.

On any engine with more than four cylinders there is no point in the rotation where the engine is not receiving power from the expanding gases on one or another of the power strokes.

For the above reasons six and eight-cylinder engines are the most popular for automobiles, although a number of "fours" are still being built. Twelve and sixteen-cylinder engines are also used and deliver extremely smooth power to drive the car.

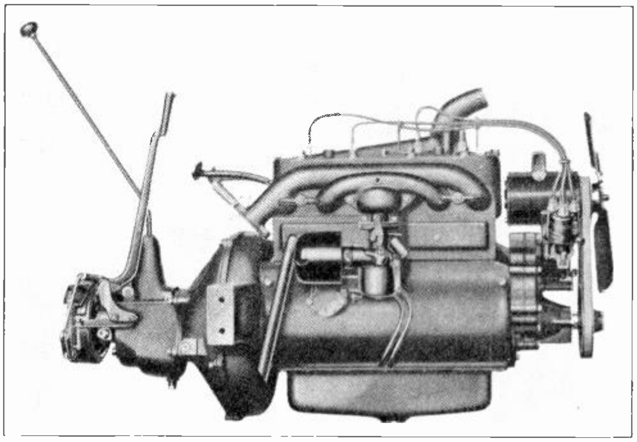


Fig. 11. Side view of a four-cylinder automobile engine used by the Chrysler Plymouth automobile. Note the position of the carburetor, intake and exhaust manifolds and spark plugs.

8. FOUR-CYLINDER ENGINES. FIRING ORDER

Fig. 11 shows a side view of a four-cylinder engine.

Any four-stroke-cycle engine fires all cylinders in two revolutions of the crank shaft, or 720° of crank rotation. Therefore, the angle between the power impulses of a four-cylinder engine of this type will be 720 ÷ 4, or 180°.

The crank shaft for the four-cylinder engine is designed so that the pistons travel up and down in pairs, 1 and 4 traveling up and down together and 2 and 3 traveling together. In this manner, when 1 and 4 are at upper dead center 2 and 3 are at lower dead center, as the crank throws to which they are attached are 180° apart. See Fig. 12, which shows a sketch of the pistons and crank shaft of an ordinary four-cylinder engine.

Fig. 12-A is a sectional view of a four-cylinder engine, showing the crank shaft and other important parts.

When piston No. 1 is moved to L.D.C. on its power stroke the crank shaft has turned 180° from the point of ignition, and at this time another power stroke should commence in one of the other cylinders. At this time pistons 2 and 3 will be at U.D.C., and the one that is fired will depend on the design of the cam shaft, as the operation of the valves will cause one of these pistons to be up on compression stroke and the other on exhaust stroke. If 3 fires after 1 it must be followed by 4, and then by 2, so the **firing order** of the engine in this case will be 1-3-4-2.

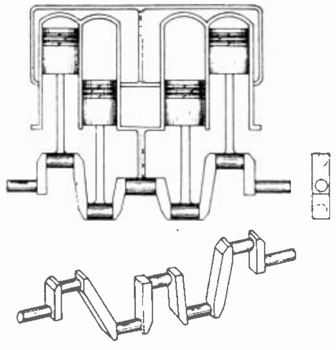


Fig. 12. Sketch showing the design of the crank shaft and arrangement of pistons in a four-cylinder engine.

If the cam shaft is arranged so that No. 2 cylinder fires after 1, then the firing order will be 1-2-4-3. These are the only two firing orders used on four-cylinder automobile engines. The last firing order mentioned is used on both the Ford and four-cylinder Chevrolet engines.

It is very important to know the firing order of various engines on which one may be working, in

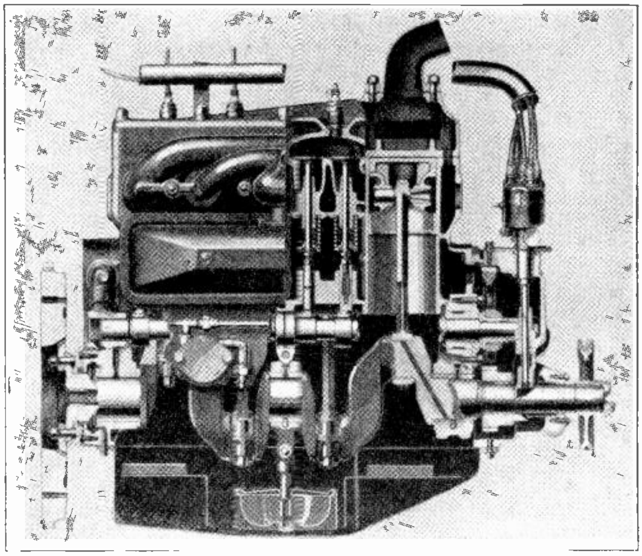


Fig. 12-A. Side sectional view of Chrysler Plymouth four-cylinder engine showing the shape of the crank shaft and arrangement of pistons, valves, etc.

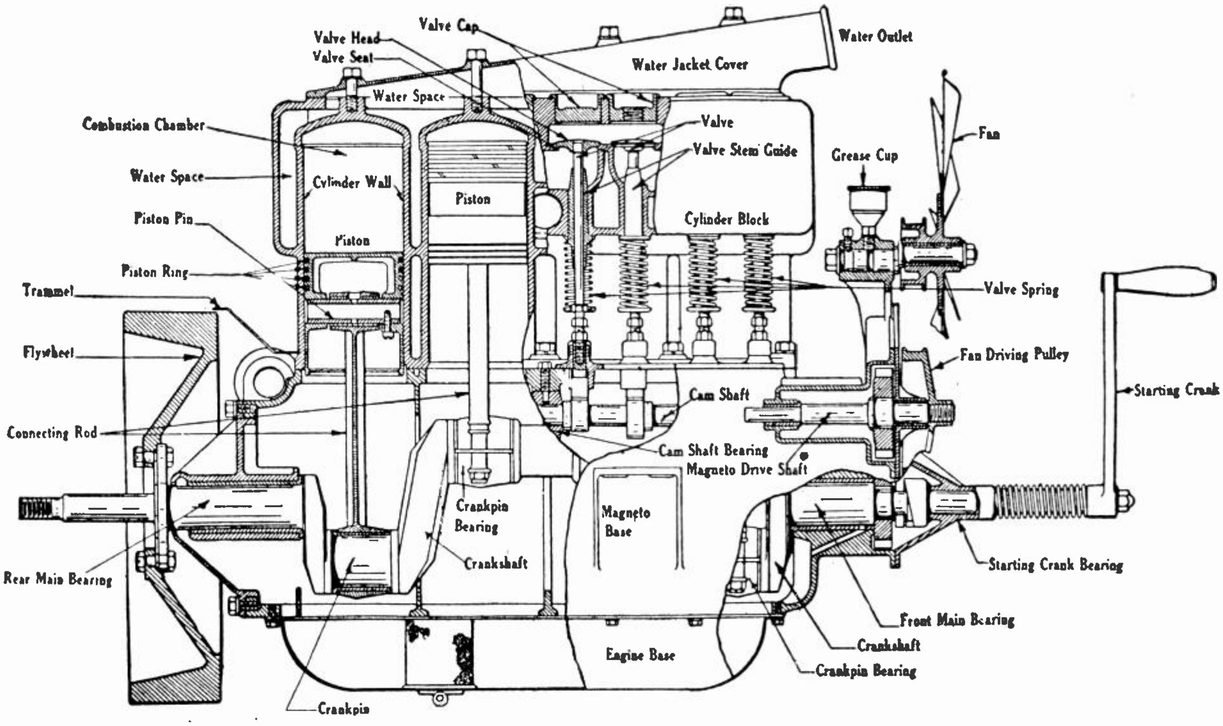


Fig. 13. This diagram shows a sectional view and a number of the important parts of a heavy-duty four-cylinder engine. Note the names by which each of these parts are called. Also note the water jacket around the cylinders for cooling them and carrying away the heat developed by combustion.

order to be able to properly connect the ignition wires from the distributor to the spark plugs,

Firing orders of various engines can be obtained from the manufacturers or dealers, and garages and ignition service stations generally carry a book which gives the firing orders for all of the common types of engines. The method for determining the firing orders by checking directly on the engine will be explained a little later.

Fig. 13 shows a sectional view of a heavy-duty four-cylinder engine and gives the names of many of the important parts. Examine this figure carefully.

9. SIX-CYLINDER ENGINES. FIRING ORDER

Six-cylinder engines are generally preferred to four-cylinder types as the power strokes overlap each other and occur more frequently, or at smaller angles in the revolutions of the crank shaft. As six-cylinder engines of the four-stroke-cycle type fire all cylinders in only two revolutions of a crank, or in 720°, their power strokes will be $720 \div 6$, or 120° apart.

The cranks are arranged at this angle so that they project out at three different points around the crank shaft. This is shown in the small sketch at the right in Fig. 14 which shows the arrangement of the crank throws and pistons in a six-cylinder engine.

By referring to the lower view of the crank shaft in this figure you will note that the cranks are also arranged in pairs, so that pistons 1 and 6 will move up and down together, 2 and 5 together, and 3 and 4 together. Remember, however, that no two pistons which travel up and down together are on the same part of the cycle at the same time, as when one is going up on its compression stroke the other piston is going up on its exhaust stroke.

By referring back to Fig. 3 an excellent view of a six-cylinder crank shaft can be seen. This view shows quite clearly the position of the cranks with respect to each other, and also shows the main bearings of the crank shaft.

In Fig. 14 four of the pistons seem to be at about the same position, part way between the lower and upper ends of the stroke; but by noting the position of the crank throws in the lower view of the crank shaft you will find that if pistons 2 and 5 are traveling downward at this point, pistons 3 and 4 will be traveling upward.

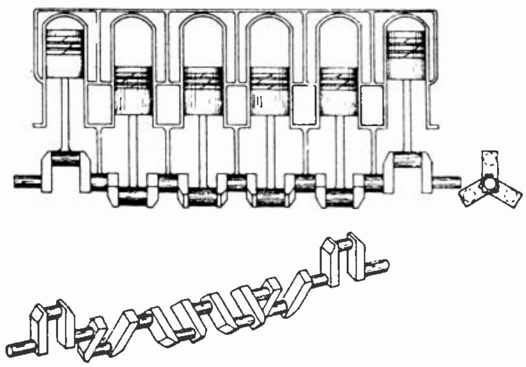


Fig. 14. Diagram showing the design of the crank shaft and the arrangement of pistons for a six-cylinder engine. Note that the cranks are arranged in pairs 120° apart around the shaft.

Because of their more frequently occurring power impulses six-cylinder engines deliver much smoother power than four-cylinder types. There are several firing orders possible with six-cylinder engines having crank shaft arrangements such as shown in Fig. 14, but the only two firing orders which are used are as follows: 1-5-3-6-2-4, or 1-4-2-6-3-5; these having been adopted as more or less standard by various engine manufacturers.

Firing in the proper order is very important in balancing the internal forces in the engine, but has no effect on the interval between power impulses, as this is determined by the design of the crank shaft.

By this time you can, no doubt, readily see the great importance of the firing order in wiring the ignition system of an engine; because if the distributor wires were connected wrongly to the spark plugs the sparks would occur at the wrong time in the cylinders, and the engine would misfire, operate irregularly, and deliver very low power; or possibly not even start.

For example, if the spark occured in a cylinder when the piston came up on exhaust stroke instead of compression stroke there would be no fuel mixture present at the time of the spark and therefore no explosion.

Fig. 15 shows a side-view of a modern six-cylinder engine with sections of the casing cut away to show some of the important parts. No. 1 cylinder is completely open, showing a sectional view of the piston, wrist pin, connecting rod, etc. No. 2 cylinder is arranged to show a sectional view of the exhaust and intake valves, valve guides, valve springs, push rods, and a section of the cam shaft.

On the left end of the engine are shown the flywheel, clutch, and transmission. The distributor, high-tension ignition wires, and spark plugs are shown on top of the engine.

10. EIGHT-CYLINDER ENGINES. FIRING ORDER

The decided advantages of the engines with a greater number of cylinders, both in smooth power performance and in reduced manufacturing cost per horsepower, have resulted in a definite trend toward the construction of engines of this type, and quite a number of the latest automobiles are equipped with "straight-eight" engines. This term "straight-eight" refers to engines having eight cylinders in line. There are other very popular eight-cylinder engines which are of the V-type and which will be discussed later.

The straight-eight engine produces a remarkably smooth torque, as its power impulses occur every 90°, or $720 \div 8$. Fig 16 shows an eight-cylinder engine of this type. Practically all of the recently built straight-eight engines use the firing order: 1-6-2-5-8-3-7-4.

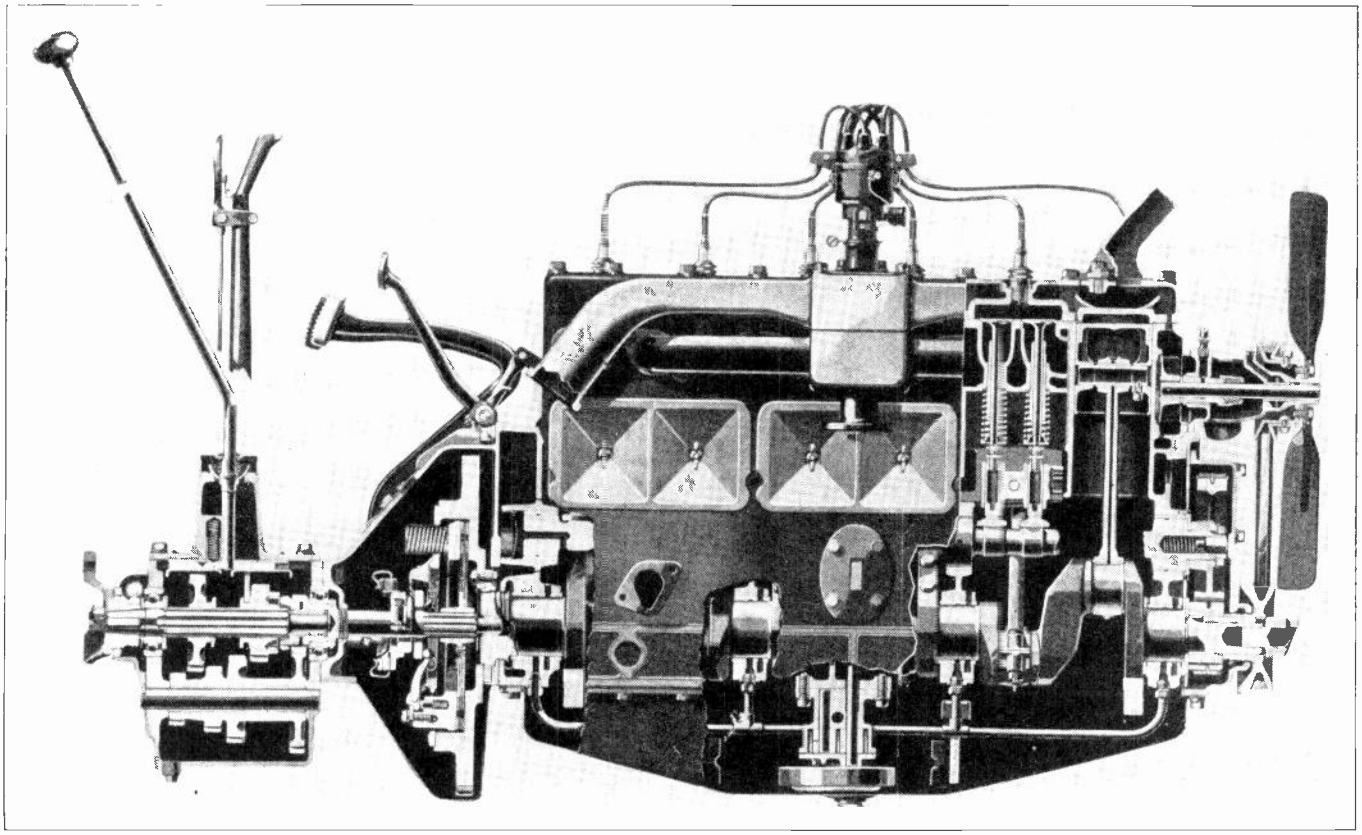


Fig. 15. An excellent side sectional view of a six-cylinder Oldsmobile engine cut away to show the crank shaft, pistons, connecting rods, valves, push rods, cam shaft, flywheel, clutch and transmission. Also note the position of the distributor and spark plugs on top of the engine. Courtesy Oldsmobile Mfg. Co.

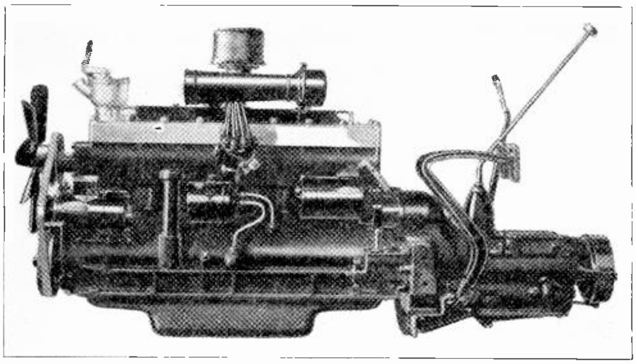


Fig. 16. Modern "line eight" automobile engine with eight cylinders in line. Engines of this type are very extensively used on modern cars and deliver extremely smooth power. Courtesy Chrysler Motors Corp.

Straight-eight engines are used by Chrysler, Marmon, Packard, Buick, Studebaker, and other manufacturers of popular cars.

V-type eight-cylinder engines have their cylinders arranged in two rows or "banks" of four each, as shown in Fig. 17. Engines of this type are used in Lincoln, Cadillac-LaSalle, and Oldsmobile-Viking cars.

The firing order of a V-type engine alternates consecutively, firing first one cylinder on the right bank and then one on the left bank, and so on down the bank, following this arrangement as closely as the design of the crank shaft will permit.

In the calier types of V-eight's crank shafts similar to those used in four-cylinder engines were employed, having two pistons one from each bank connected to each crank throw, as shown in Fig. 18.

The firing order for this type of engine is either 1R- 4L- 2R- 3L- 4R- 1L- 3R- 2L; or 1R- 4L- 3R- 2L- 4R- 1L- 2R- 3L. The letters "L" and "R" denote cylinders on the left and right banks, as viewed from the drivers seat, and always keep in mind that **number one cylinder is the one nearest the radiator.**

Most of the more modern V-eight's use a crank shaft with the cranks arranged 90° apart instead of 180°, and thus obtain still better balance and smoother operation. Engines of this type are used by the Cadillac-LaSalle and Oldsmobile-Viking cars.

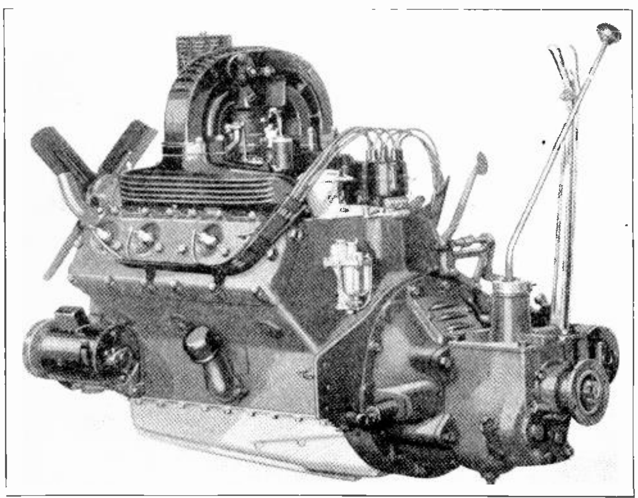


Fig. 17. V-type, eight-cylinder engine with cylinders arranged in two banks of four each. Carefully compare the construction of this engine with the "line eight" type shown in Fig. 16. Courtesy Oldsmobile Viking Mfg. Co.

They require a different firing order from the earlier type V-eight's. The firing order of the Cadillac-LaSalle engine is: 1 L- 4 R- 4 L- 2 L- 3 R- 3 L- 2 R- 1 R.

The firing order of the Oldsmobile Viking is: 1R- 1L- 4R- 2R- 2L- 3R- 3L- 4L.

The firing order of the Lincoln is: 1R- 4L- 2R- 3L- 4R- 1L- 3R- 2L.

Fig. 19 shows a photo of a crank shaft such as used in these later type V engines, and Fig. 20 shows an excellent sectional end-view or a modern V-eight engine. In the foreground can be clearly seen the crank shaft with its counter-balancing weights and two connecting rods attached to the one crank. Note the position of each of the pistons attached to this crank and observe that one of the pistons is at the extreme outer end of its stroke, or U.D.C., while the other piston on the left is approximately midway on its downward stroke. Also note the position of the spark plugs and valves in the combustion chambers.

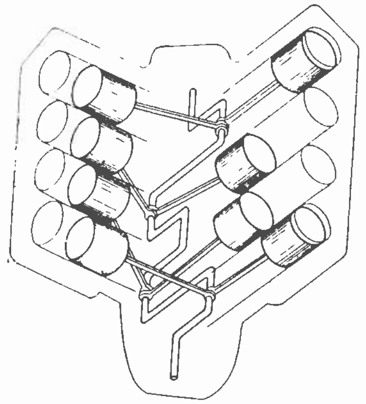


Fig. 18. Diagram showing the type of crank shaft and arrangement of pistons used with V-type, eight-cylinder engines.

The end of the cam shaft can be seen located between the cylinders. The cams of this shaft operate short rocker arms, which in turn press against the valve stems to operate the valves in the proper order. The carburetor, air filter, and intake and exhaust manifolds are shown above the engine in this view.

One of the later types of multiple-cylinder engines is the Cadillac V-16, which is in reality two straight-eight's mounted at an angle of 45° to each other. This engine delivers remarkably smooth power and a tremendous amount of horsepower for its weight, and is a very good example of the weight reduction possible with an increase in the number of cylinders. The weight of this engine is only 25% greater than that of the Cadillac Eight, but its horsepower is double.

The firing order of the V-16 is: 1 L- 4 R- 5 L- 7 R- 2 L- 3 R- 6 L- 1 R- 8 L- 5 R- 4 L- 2 R- 7 L- 6 R- 3 L- 8 R.

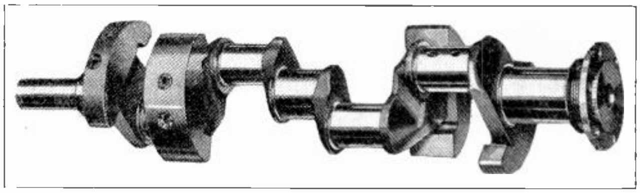


Fig. 19. Photograph of crank shaft used with V-type, eight-cylinder engines. Note that there are only four cranks, each of which have two connecting rods from pistons in opposite banks connected to them.

11. DETERMINING FIRING ORDERS BY TEST

In case the firing order of any engine is not known it may be quickly determined by any one of several methods. The simplest and most popular of these is the **compression method.**

We know that each piston must move up on its compression stroke just before its cylinder is fired, and the order in which these compression strokes occur in the different cylinders must be the same as the firing order. Keeping this fact in mind, the firing order may be quickly and accurately determined in the following manner.

Remove all spark plugs and seal the plug hole in cylinder No. 1 with a piece of paper or waste. Then slowly crank the engine until the paper blows out. Stop cranking at this point and seal the remaining spark plug holes, and then slowly turn the crank, noting the order in which the remaining wads are blown from the cylinders. This will indicate the firing order.

As each successive wad is blown from the cylinder a chalk mark may be put near that plug opening denoting the number of the wad blown—as 1, 2, 3, 4, etc. When all cylinders are marked the firing order can be read from cylinder 1 to the last cylinder.

Keep in mind that the firing order of an engine cannot be changed, as it is determined by the design of the crank shaft and cam shaft. These would have to be changed before the firing order could be altered.

Another method of determining the firing order—and one that is sometimes more convenient than that just given, particularly when the engine is of the overhead valve type—makes use of the fact that the valves open and close in the same order as the firing order.

When the intake valve closes on No. 1 cylinder the piston is rising on the compression stroke. Since the compression stroke takes place in each of the different cylinders in the same order as the firing order, the order in which the intake valves close must be the firing order.

To determine the firing order by this method, first locate the intake valve of each cylinder and then rotate the engine slowly until the intake valve on No. 1 cylinder closes. The next intake valve to close will be located at the cylinder that follows No. 1 in the firing order, or the one which fires second.

Continue turning the crank slowly and note the order in which the remaining intake valves close. This will show the firing order.

The same procedure could be used with the exhaust valves if desired.

12. IGNITION SYSTEMS. PRINCIPLES

As previously explained, the purpose of the ignition system on an automobile engine is to provide a means of setting fire to or igniting the fuel charge in the combustion chamber each time the piston comes to T. D. C. on the compression stroke.

A number of different methods of igniting the gas charge in internal combustion engines have been tried, but electrical ignition has proved to be the most positive and reliable for the high engine speeds required in automotive service.

Many modern automobile engines rotate at speeds of about 4000 RPM and require from 200 to 300 sparks per second, depending upon the number of cylinders. Electrical ignition is the only type capable of giving sufficient instantaneous heat to ignite fuel charges at such speeds, and has the added advantage of being easily and accurately controlled.

The important parts of a common electrical ignition system are:

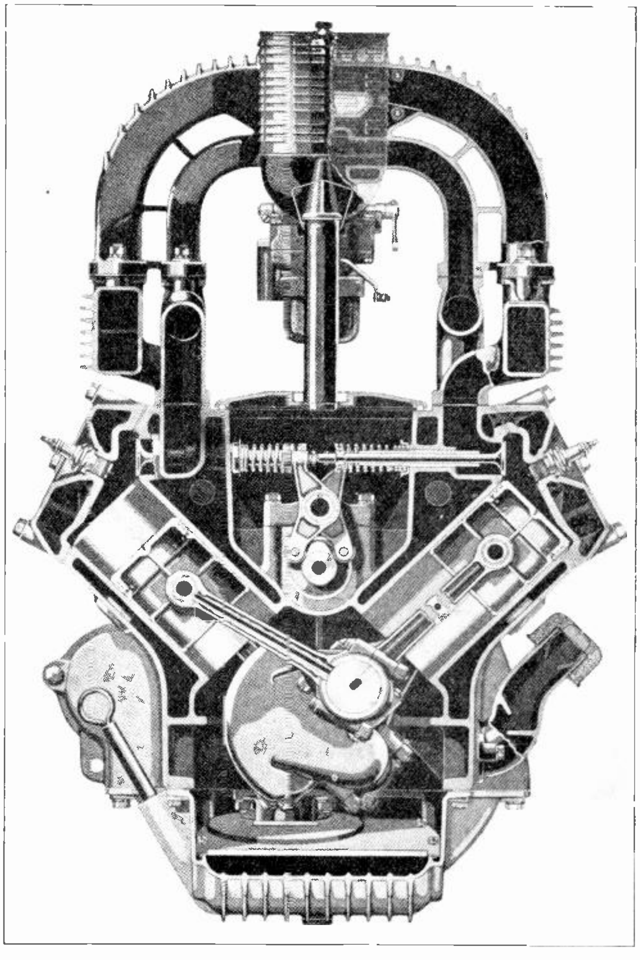


Fig. 20. An excellent end sectional view of a modern V-type, eight-cylinder engine. Note carefully the arrangement of the pistons, valves, cam shaft, rocker arms, spark plugs, carburetor, and intake and exhaust manifolds. Courtesy Oldsmobile Viking Mfg. Co.

1. **A battery** or **generator** for a source of current supply.
2. **A spark coil** or **magneto** to produce high-voltage sparks at certain regular intervals.
3. **Spark plugs** to introduce the sparks into the combustion chamber of the engine.
4. **A distributor** to direct the high-voltage current to the spark plugs in the correct order.
5. A means of varying the time of the spark with relation to the piston position.

Each of these devices will be explained in the following paragraphs.

13. STORAGE BATTERIES

Storage batteries are commonly used as the source of current for ignition and other uses on modern automobiles. The majority of these batteries are the three-cell, six-volt type, but some are of the twelve-volt type.

Fig. 21 shows a common type six-volt storage battery in a rubber case, with the connector straps and terminal posts showing on top of the battery.

Storage batteries provide a convenient small portable device for supplying electricity for ignition, lights, horn, starting motor, etc. These batteries are fully charged when installed in a new car, and are then kept charged by current supplied from a low-voltage generator which is driven directly from the engine as long as it is running. This prevents the battery running down or discharging and eliminates the necessity of removing it from the car for frequent recharging.

The combination of this battery and generator provide a dependable supply of low-voltage energy as long as the generator charging rate is properly maintained and the battery is not abused or used excessively when the engine is not running. Both storage batteries and generators for automobiles will be discussed more fully in later paragraphs.

Fig. 21. Common three-cell, six-volt storage battery of the type extensively used to supplv current to ignition and lighting systems on automobiles.

14. IGNITION COILS

Electrical ignition is accomplished by forcing a spark across a small air gap in the combustion chamber. The voltage required to break down the resistance of this air gap and form a spark will depend principally upon the length of the gap and the degree of compression. With a compression pressure of about 80 lbs. per square inch and a spark gap length of about .030 inch, the voltage required to produce the spark will range from 6000 to 10,000 volts. These values of compression and spark gap length represent common practice in modern automobile engines.

We can readily see that the six-volt energy supplied by the battery will not be of high enough potential to break down the gap and form a spark, and that this voltage will need to be increased or stepped up considerably for ignition purposes. To accomplish this we use a special type of direct current transformer called an **ignition coil.**

Fig. 22. High-tension ignition coil such as used for supplying high voltage impulses to the spark plugs on the ignition systems of automobiles. The heavily insulated bushing on the top of the coil is where the high voltage lead connects.

Fig. 22 shows a high-tension ignition coil such as used with many automobiles. In this figure the coil and core are shown enclosed within a waterproof case which is attached to a bracket for convenient mounting on the engine.

An ignition coil consists essentially of a soft iron core which is laminated or built up of a bundle of soft iron wires and on which are wound two separate windings called a primary and secondary. The

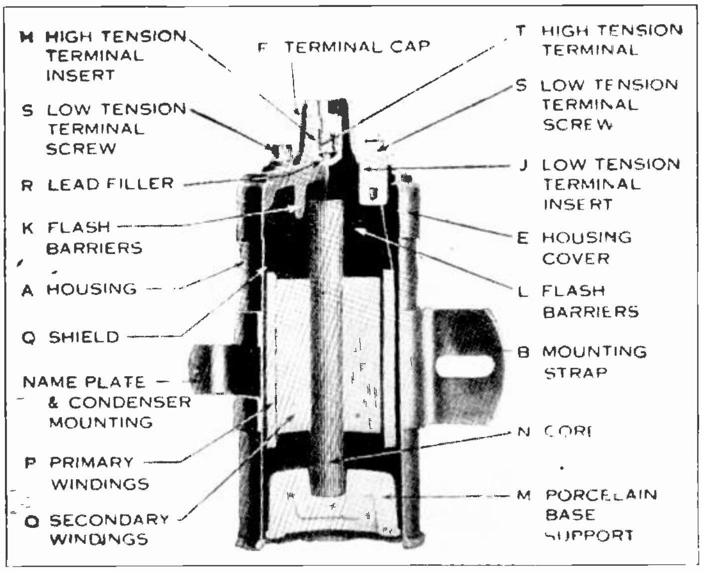


Fig. 23. Diagram showing a sectional view of an ignition coil and the location and names of each of the important parts.

primary winding generally consists of about 200 turns of No. 18 wire and is connected in series with the battery and a make and break contact or **interrupter.** The secondary winding generally consists of about 12,000 turns of No. 36 wire and is connected in series with the spark plug gap.

Fig. 23 is a sectional view of an ignition coil, showing the position of the core and coils within the case and also giving the names of the more important parts.

You already know that with a transformer of this type, when alternating current or pulsating current is passed through the primary winding consisting of a smaller number of turns, a much higher voltage will be induced in the secondary winding because of its greater number of turns. As the current supplied by the automobile battery or generator is D. C., it is necessary to provide some form of make and break device in the primary circuit of the ignition coil, in order to cause the variation of the current and magnetic flux necessary for the induction of the high voltage in the secondary.

Fig. 24 is a diagram showing some of the essential parts and the operating principles of a modern battery ignition system. When the switch, SW., and the contacts, A, of the interrupter are closed, current will flow from the positive terminal of the battery, through the primary winding of the ignition coil, through the interrupter contacts; then, through the grounded connections and metal frame of the car, back to the battery.

This flow of current sets up a strong magnetic field around the iron core of the ignition coil. As the engine operates, the cam (C) is caused to rotate and each of its projections bump the movable spring contact, causing the circuit to be momentarily opened at "A".

Each time the circuit is thus opened the magnetic flux around the core in the ignition coil collapses and induces a momentary high voltage in the secondary winding. You will note that one end of this secondary coil is connected to the primary terminal and has a circuit back through the battery to ground, G. The other end of the high-tension winding goes directly to the spark plug, so that the high voltage will flash across the spark plug points in the form of a hot spark; then from the shell of the plug to the ground connection, G2, and back through the metal frame of the engine to the grounded battery terminal, and on to the start of the secondary coil. This completes the high-tension circuit for one plug.

The voltage induced in the secondary winding of the coil not only depends upon the number of turns in the secondary and the amount of flux set up by the primary, but also depends upon the speed of flux collapse around the coil and core when the breaker points open the circuit.

When the primary circuit is open the current flow does not stop instantly because of the effect of self-induction in the windings. The collapsing flux induces a rather high voltage in the turns of the primary winding, and tends to maintain a current flow in the form of an arc across contacts A for a small fraction of a second after these contacts are open.

This tends to slow up the flux collapse and thereby reduce the voltage induced in the secondary. The arc that is caused at the breaker points by this self-induction would also tend to burn and damage the surface of these points if something were not done to quickly extinguish the arc.

15. IGNITION CONDENSERS

To eliminate the arc at the breaker points and also to counteract the tendency of current to flow after the primary circuit is broken, a device known as an **ignition condenser** is used.

In Fig. 24 this condenser is shown at "C", and is connected directly across or in a parallel with the contact points at "A".

These condensers consist of a number of layers or small sheets of tinfoil separated by sheets of insulating material, usually paraffin paper or mica. Alternate tinfoil sheets are connected together forming

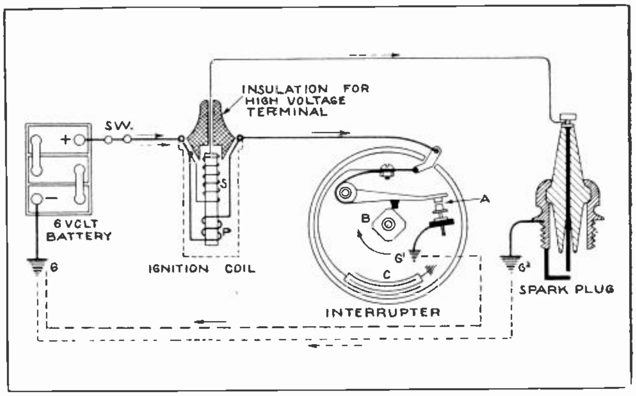


Fig. 24. This simple sketch shows both the primary and secondary circuits of a battery type ignition system. Trace the primary current through the heavy wire and ground connections, and the secondary current through the light wire, spark plug, and ground connections.

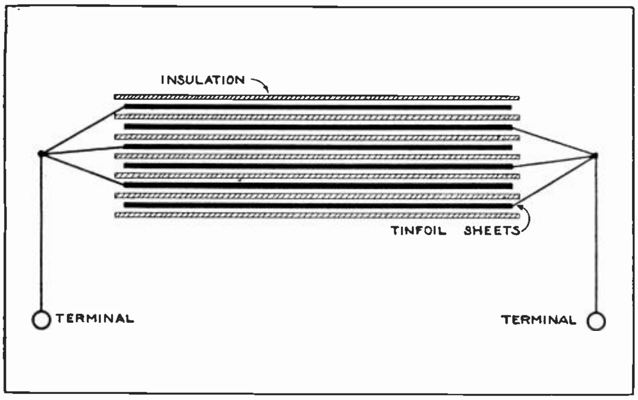


Fig. 25. Diagram showing the construction of a simple condenser with groups of conducting sheets separated by sheets of insulation. In ignition systems it is very important that this insulation be in good condition and have no shorts or grounds.

one terminal of the condenser, and the remaining sheets form the other terminal, as shown in Fig. 25.

With the condenser connected across the points as shown in Fig. 24, when the points open the primary circuit the self-induced voltage which tends to keep current flowing through the primary is absorbed by the condenser. This induced voltage, which at times reaches an instantaneous value of 200 volts, charges the condenser instead of forming an arc at the breaker points.

The charged condenser then applies a back voltage to the primary coil and circuit, thus effecting an almost immediate stoppage of current flow and greatly speeding up the demagnetization of the iron core.

This increase in the speed of flux collapse greatly increases the voltage induced in the secondary and applied to form the spark at the plug points. In fact, a coil with a good condenser of the correct capacity may often produce a spark ten times as great as a coil without any condenser. If the condenser is defective the ignition system will not operate.

In addition to this great improvement in the ignition itself, the condenser greatly increases the life of the breaker contacts and enables them to operate for long periods without attention, by almost entirely eliminating the arc when these points open the primary circuit.

16. EFFECTS OF SELF-INDUCTION

A fact that has a very important effect upon the operation of ignition coils is that it requires a small fraction of a second for the current in the primary coil to build up to full value after the breaker points are closed. This is also due to the counter-voltage of self-induction. The time required for the current to build up to maximum value depends upon the design of the coil and the self-induction of the primary circuit.

This becomes a very important factor, particularly with high-speed engines with a large number of cylinders, because, as already mentioned, it may be necessary for the breaker points to open and close several hundred times per second. If there is not sufficient time between the closing and opening of the breaker points for the primary current to build up to full value, then when the points are opened there is less flux to collapse across the secondary turns, and there will be less induced voltage in the secondary and at the spark plug points.

An ordinary ignition coil may require approximately .012 of a second for its primary current to build up to full value after the points are closed. By changing the design of the coil and providing a magnetic circuit of lower reluctance and a primary winding with less turns, it is possible to reduce the amount of self-induction in the winding and thereby speed up the action of the coil.

Referring to Fig. 26 and carefully comparing the curves for the fast and slow ignition coils, you will note that on the coil design for fast operation the current can build up to its full value of approximately 6 amperes in a time of .006 second; while the slow coil requires approximately .012 second, or twice as much time, to build up to its maximum current.

From this we can see that the design or speed of operation of ignition coils is very important and must be considered when changing or replacing coils, particularly on high-speed engines.

A slow speed coil would require the breaker contacts to be closed for nearly .012 second in order to build up full current and obtain a good spark on each break, and with high-speed engines the period during which the breaker points remain closed may be considerably less than .006 second.

This matter of speed or time lag in the operation of ignition coils also explains why the sparks supplied by the battery ignition system become weaker as the engine approaches higher speeds; because, as the speed increases, the period of time during which the breaker contacts remain closed becomes less.

17. IGNITION COIL RESISTANCE

Decreasing the number of turns in the primary winding of an ignition coil to speed up the action of the coil has the undesirable effect of reducing the primary resistance to a point that will cause it to take an excessive current at low engine speeds when the breaker points are allowed to remain closed for

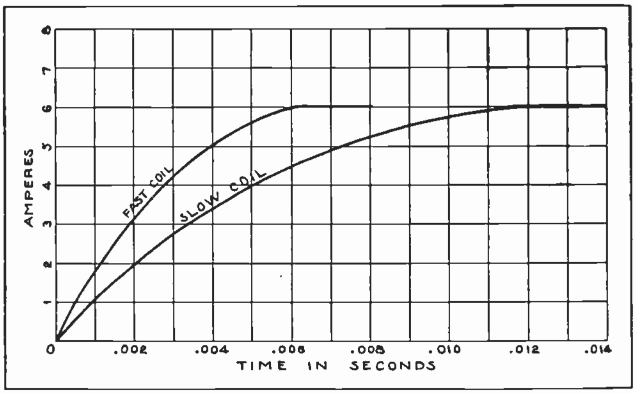


Fig. 26. The above curves show the difference in time required for different types of coils to build up their full primary current after the breaker points close.

longer periods. This tends to cause the coil to overheat.

To prevent this a current-limiting resistance is connected in series with the primary winding of the ignition coil. This resistance is made of material of such a nature that its resistance increases with its current and temperature.

When the engine is operating at high speed and the breaker points are closed only for very short periods the current flow through the primary and the resistance is less. This allows the resistance unit to remain cool and keeps its resistance low, so that it does not interfere much with the flow of current through the coil primary.

As the engine speed is reduced and the breaker points are closed for longer periods, allowing the coil to draw a heavier current, this increased current raises the temperature of the resistance unit, causing its resistance in ohms to increase and thus limiting the primary current to the proper value to prevent overheating of the winding and coil.

This small resistance unit also protects the coil from burning out in case the ignition switch is left turned on when the engine is stopped, and also during the periods of high voltage which may occur due to faults in the generator.

Excess current from either of these causes will heat up the resistance element to a point where its resistance becomes very high, thus limiting the current flow and protecting the coil.

In case the switch is left on too long or the generator fault is not removed, the resistance unit may be burned out and thus open the circuit; but this unit is much easier and cheaper to replace than a burned out coil would be.

These primary resistance units are generally wound on small porcelain or asbestos insulators and are mounted right on the ignition coil.

18. VIBRATING-TYPE IGNITION COIL

Some of the earlier types of ignition systems, a few of which are still in use on older cars, use the vibrator-type spark coil. On these coils the circuit is made and broken by a magnetically operated armature and a set of contacts attached directly to the end of the coil, instead of being broken by the breaker points in the distributor as with modern ignition systems.

Fig. 27 shows a coil of this type mounted in a wooden box equipped with spring contacts and screw terminals for completing the circuits through the ignition wires. When this coil is connected in the ignition circuit the current enters the terminal marked "connect to switch" and flows around the primary winding, through the vibrator contacts, to the terminal marked "connect to commutator".

From this point it flows through the timer or "commutator", and back to the battery. When the current flows through the coil the iron core becomes magnetized and pulls down the steel spring or armature to which the lower contact is attached, thus breaking the primary circuit and inducing the high voltage in the secondary.

Breaking the circuit by demagnetizing the core allows the spring to move up and again close the contacts, thus repeating the operation very rapidly as long as the primary circuit is completed by the timer.

These contacts when properly adjusted vibrate with a speed of 200 breaks per second or more. To prevent the contacts from opening before the coil is fully magnetized, the upper contact is also mounted on a spring and tends to follow the lower contact down a short distance when it is attracted to the core.

This action continues until the upper spring strikes a stop on the under side of the adjusting bar; and at this point a quick, snappy break is effected.

The vibrator can be adjusted by turning the nut at the end of the adjustment bar, thus varying the distance between the spring and the iron core. Coils of this type are used extensively on model T Fords, but are now considered obsolete.

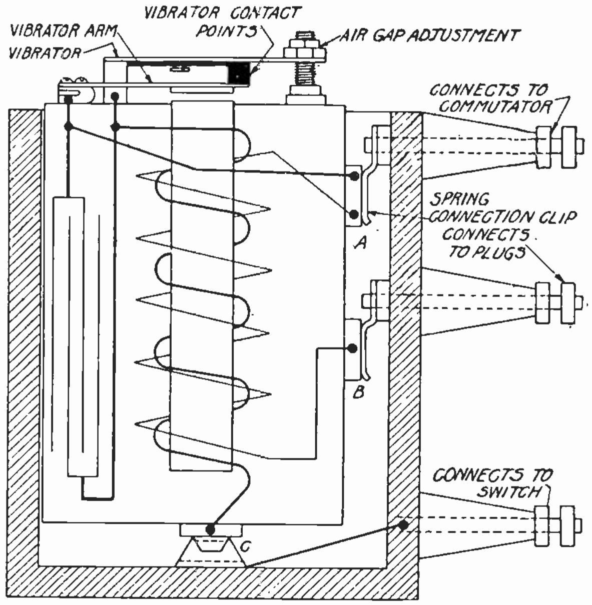


Fig. 27. Diagram of a vibrating type spark coil such as used on older model Fords and single-cylinder gasoline engines. Note the location of the condenser and trace out both primary and secondary circuits carefully.

Fig. 28 shows a wiring diagram of the ignition equipment for the old model T Ford. You will note that these systems used four seperate spark coils, one for each cylinder, and that the current from the battery was supplied to the primary of each spark coil at the proper time by means of the timer, or "commutator".

By tracing out this diagram you will find that current flows from the positive terminal of the battery to the switch which is used for connecting the ignition system to either the battery or the magneto after the engine is running. From the switch the current is supplied to a common bus or battery connection which feeds to all primary windings of the ignition coils.

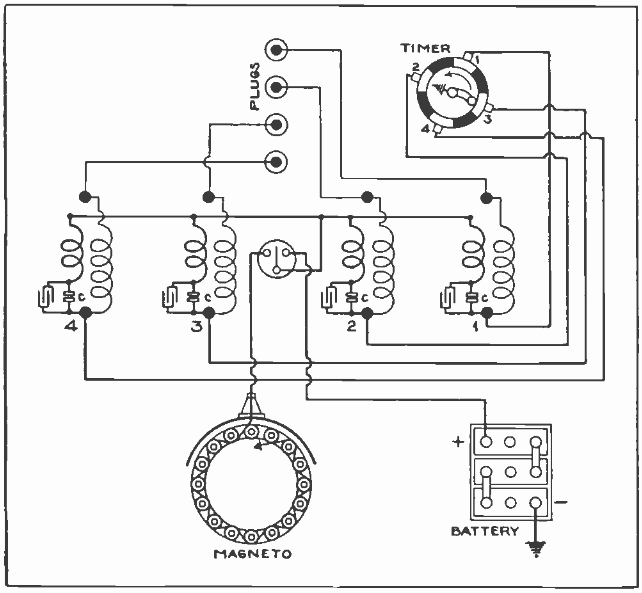


Fig. 28. Wiring diagram of the ignition systems used on the Model T or older type Fords.

Tracing the circuit of coil 3, the current would flow through the primary, then through the vibrator contacts, C, and out along the wire to terminal 3 on the timer; then through the rotor or movable arm of the timer to ground. From the ground connection it returns to the grounded negative of the battery, thus completing the circuit for this coil.

As the timer arm rotates counter-clockwise, as shown by the arrow, it closes the circuits to the primaries of the various coils in the order 1, 2, 4, 3. As each coil is excited in turn it delivers a spark from its secondary directly to the spark plug to which it is connected.

From this we find that systems of this type use four ignition coils instead of one coil as used by modern systems. The vibrating contacts on these coils also have a tendency to wear out or become burned and blackened, so that they require more or less frequent attention.

Note that the timer, which at the proper instant supplies the current to the various coils in order to create sparks at the right time in the different cells, is located in the primary circuit to the coils.

Modern ignition systems use a distributor in the secondary circuit and this will be explained in later paragraphs.

19. SPARK PLUGS

In order to introduce the ignition sparks inside the cylinders or combustion chambers, some highly insulated heat-resisting device is needed to carry the high voltage through the metal cylinder-head to the spark point located inside. For this purpose **spark plugs** are used.

Spark plugs are made in a number of different types, but in general they consist of a threaded metal shell which screws into the opening in the cylinder-head and which contains the electrodes or spark gap terminals, and a heavy porcelain or mica insulator which has the high-voltage terminal run through its center. The outer end of this insulated high-voltage terminal is equipped with a nut or clip for attaching the high-tension ignition wire.

Fig. 29 shows several different styles of spark plugs, and Fig. 30 shows sectional views of several plugs with each of the various parts marked and named. Examine this figure very carefully until you are sure you are thoroughly familiar with the construction of these devices.

Because of the very severe conditions under which spark plugs operate they must be carefully designed both as to materials and shape, and it is also very important to use the proper plugs when replacing old ones in an engine. The porcelain insulator for the center electrode must be a good insulator capable of withstanding at least 8000 volts or more, and should maintain its insulating qualities at very high temperatures. Under certain conditions this insulator may be subjected to temperatures of over 3000° F.

If this insulator cracks or breaks down in any way the high voltage will leak from the center electrode directly to the shell of the plug and be grounded to the engine without passing across the spark terminals or electrodes inside the cylinder. Porcelain is used almost entirely for insulation in spark plugs made by leading manufacturers.

The metal used for the electrodes themselves should have a rate of expansion approximately equal to that of the insulation, so that it will not crack the insulator with changes of temperature and will not loosen and allow leakage of the compression or expanding fuel gases. This metal should also be of such a nature that it will not be rapidly burned away

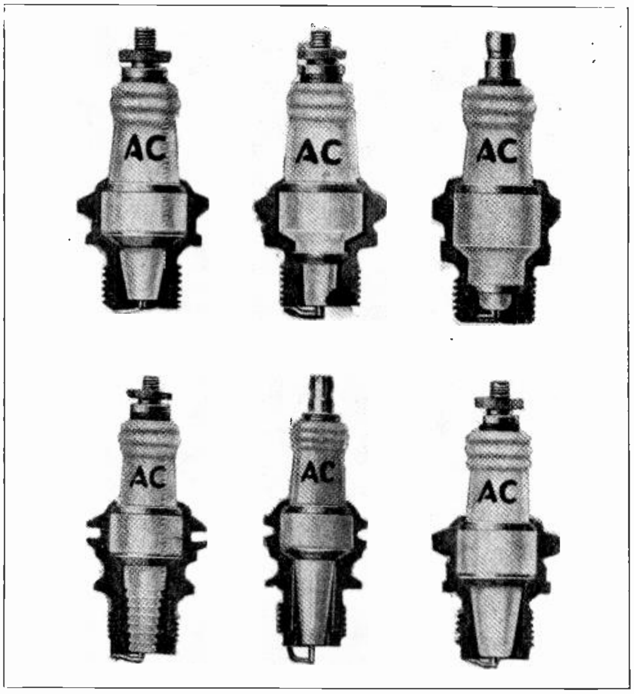


Fig. 29. Above are sectional views of several types of spark plugs showing their construction and the arrangement of the metal and porcelain parts, as well as the electrodes or points.

by repeated sparks, and it should not distort or change the length of the spark gap appreciably with various changes in temperature. The metal generally used for these electrodes is a nickle alloy.

The spark plug shells are made of steel and they are threaded on their lower ends to fit tightly into the threaded openings in the cylinder head and also to allow the plugs to be conveniently removed for cleaning, adjustment, or replacement.

If the plug points become badly fouled with carbon, it may tend to short circuit them and reduce the heat of the spark. In such cases the plugs should be removed and scraped clean. If the points become bent or badly burned away this may interfere with the efficiency of the spark and ignition of the fuel mixture, and such points should be adjusted or the plug replaced with a new one.

The top or outer end of the porcelain insulator should be kept free from dirt and moisture; otherwise the high-voltage energy may leak from the connection terminal down over the surface of the insulator to the metal plug shell, instead of flashing across the points inside the cylinder as it should.

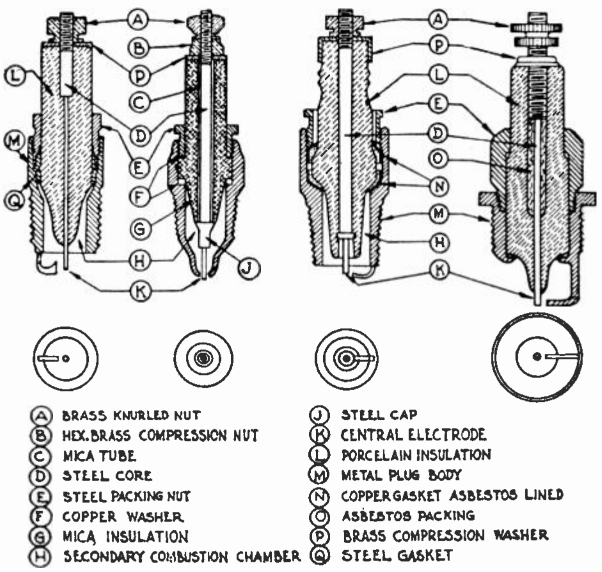


Fig. 30. This diagram also shows sectional views of several different spark plugs and gives the names of the various parts.

20. SELECTION OF PROPER TYPE PLUGS

There are two different sizes of spark plugs used in automobile engines and these are classified according to the type of threads used on the plug shell, and according to the diameter of the threaded portion of the shell.

The S.A.E. plug, so called because it has been declared standard by the Society of Automotive Engineers, has a diameter of 7/8 of an inch at the threaded portion and is still used by the majority of automobile manufacturers. The other type of plug is known as the "metric" plug, because it uses metric threads and has a diameter across the threads of 18 millimeters (approximately 11/16 of an inch).

Due to the definite tendency toward higher compressions and higher operating temperatures in modern engines, the metric plug is coming into favor with engine manufacturers. Its smaller diameter results in less distance between the plug points and the water-cooled metal of the engine, and this means that the heat from the plug points is dissipated more quickly, thus enabling the plug to run cooler at very high engine temperatures.

When changing spark plugs in an engine, the manufacturer's recommendations should always be followed; that is, plugs should be replaced with those of the same type as originally supplied.

Extreme operating conditions may occasionally make it necessary to change the type of plugs, but in general this should not be done. One reason for using the same type of plugs is that the thickness of metal in the cylinder head varies with different engines, so various engines require longer or shorter plug bodies below the threaded portions in order to locate the points in the best igniting position in the combustion chamber.

Spark plug bodies are made in three different lengths—short, medium, and long. If a long bodied plug is used in an engine built for short plugs the lower end of the plug will extend too far into the combustion chamber, as shown at the left of Fig. 31, and it may be bumped and damaged by a moving valve or the top of the piston. This will also cause the plug points to overheat and may cause pre-ignition or early firing.

On the other hand, if a plug that is too short is used the points will be located in a pocket above the combustion chamber, as shown in the center view in Fig. 31. There is a tendency for dead gas to lie in this pocket and cause such a plug to misfire. This position of the plug points will often cause them to become badly fouled with carbon. In a few cases of extreme operating conditions short plugs may be temporarily used to avoid overheating and other troubles.

On the right in Fig. 31 is a plug of the proper length with its lower end just flush with the upper surface of the combustion chamber, and with the electrodes or spark points projecting about 3/16 of an inch into the chamber.

The distance or spacing between spark plug points has a very definite effect upon the performance of the engine. Incorrect setting of these points will often cause irregular operation and sometimes complete failure of an engine.

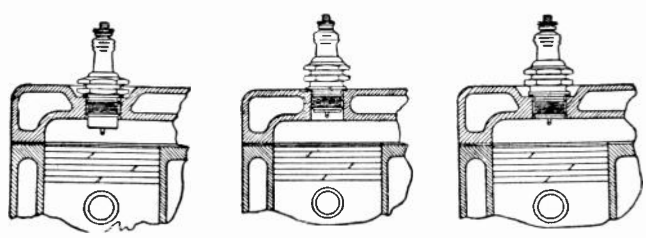


Fig. 31. The above sketches show spark plugs improperly fitted to the cylinder on the left and properly fitted in the cylinder on the right.

For normal compressions a gap of approximately .030 inch gives best results. High-compression engines will usually operate more satisfactorily with a shorter plug gap of about .025 inch for engines with compression pressure exceeding 80 lbs. per square inch.

In many cases the exact proper setting can only be determined by experiment or test, the best setting depending upon the running speed at which perfect performance is desired. For example, good low-speed operation can best be obtained with a rather wide gap setting while at very high speeds best performance is often obtained by closing up the plug gap slightly.

21. DISTRIBUTORS

On a modern ignition system the ignition coil produces the high-voltage impulses at the right time by the operation of breaker points or an interrupter such as was shown in Fig. 24. To deliver these high-voltage impulses to the proper spark plugs or to the cylinders in their proper firing order a device called a **distributor** is used.

The diagram in Fig. 32 illustrates the operation of this distributor. The rotor, R, is driven by a direct connection to the engine, so that it always revolves at a definite speed with respect to the engine speed. This rotor arm is connected to the high-tension lead from the ignition coil; so that as it revolves it delivers the spark impulse to the spark plugs in the various cylinders in the order in which they are connected to the stationary contacts in the distributor cap, which is made of insulating material.

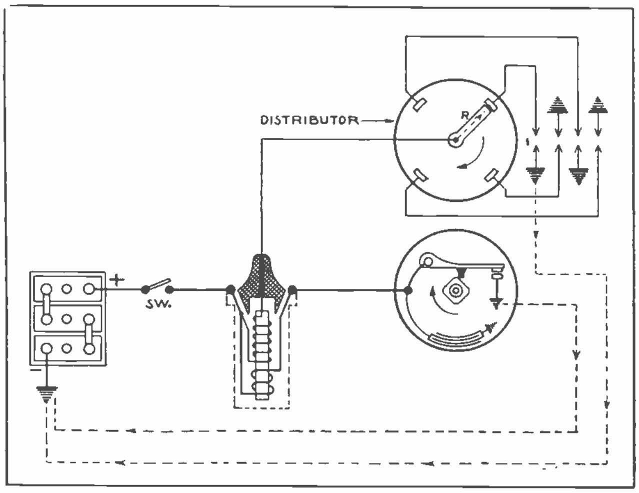


Fig. 32. Diagram of a battery ignition system showing both the primary circuit through the breaker points and the secondary circuit through the distributor arm contacts to the spark plugs.

The current flows from the distributor wires through the center electrodes of the various plugs; then across the spark gaps to the plug shells, which, of course, are grounded to the engine and allow the current to flow back through the engine and frame to the grounded terminal of the battery, and then to the return of the ignition coil secondary.

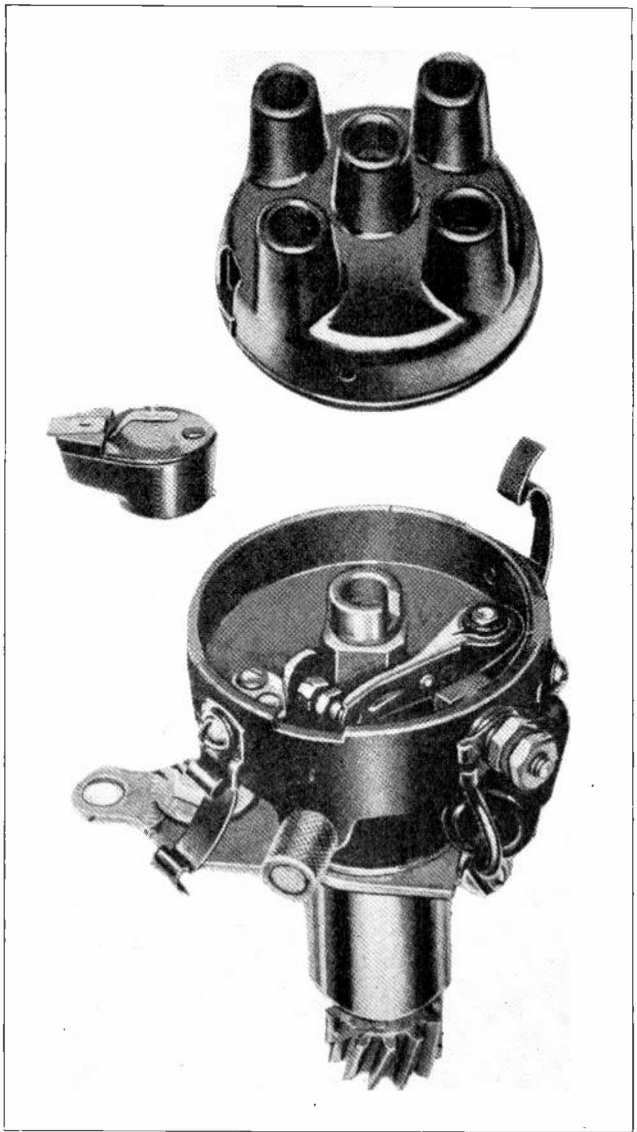


Fig. 33. This view shows a distributor with the high tension cap and rotor removed so that the primary breaker points and cam can be clearly seen in the distributor housing.

The term "distributor" is generally applied to the complete unit which contains both the interrupter points and the distributor rotor and contacts.

Fig. 33 shows a photograph of a distributor with the "cap" or "head" removed. This cap is shown at the upper right with its terminals for connecting the high-tension ignition wires. The one high-voltage wire from the ignition coil always connects to the center terminal of these caps, while the spark plug wires connect to the outer terminals in the proper order.

This distributor cap or head is made of bakelite or a compound of high insulating quality. On the inner side of the cap are located metal electrodes or stationary contacts for each terminal. The small rotor shown at the upper left fits on the top of the distributor shaft directly above the cam and rotates when the engine is running, delivering high-voltage impulses to the plugs through the stationary contacts in the distributor caps as it passes them.

In the lower part of Fig. 33 is shown the interrupter mechanism with the breaker points and cam in plain view. The small metal lever projecting to the left and fitted with a round eye is for shifting the distributor to advance or retard the spark by moving the breaker points a slight distance around the cam.

Fig. 34 is a top view of a distributor with the cap removed to show the breaker arm or contact lever, breaker contacts, cam, and condenser more clearly. The arm for shifting the breaker mechanism to advance and retard the spark is also shown in this view.

The number of sparks generated per revolution of the distributor shaft will depend upon the number of corners or projections on the cam. If the cam is four-cornered four sparks will be produced, and if the cam is six-cornered six sparks will be produced for each revolution.

As any automotive engine fires all cylinders in two revolutions of the crank shaft and the distributor is built to generate the sparks required for all cylinders in one revolution of the distributor shaft, the distributor therefore must be geared to the engine so that it rotates at one-half engine speed. This rule applies to all automotive engines.

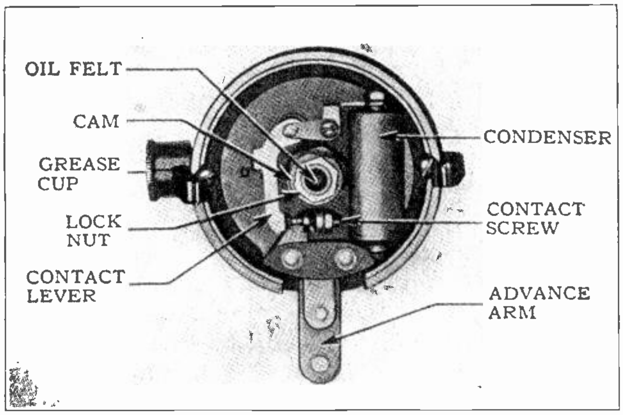


Fig. 34. Top view of the breaker mechanism and condenser of an ignition distributor. Note the names of the various parts.

22. METHODS OF ADVANCING THE SPARK

We have already mentioned the necessity for advancing the spark to obtain earlier ignition of the fuel charge and maximum power and efficiency when the engine is operating at very high speeds. There are two general methods used for advancing and retarding this spark through shifting the breaker plate or housing around the cam in the distributor.

These methods are the **manual control**, or hand-operated method, and the **automatic control** obtained by means of governor weights which advance the spark automatically with an increase of engine speed and without any attention from the drivers.

The manual method advances the spark by moving either the breaker plate or the entire distributor housing to shift the breaker contacts a slight distance around the cam. Moving the breaker contacts in the opposite direction to cam rotation causes the contacts to open sooner and advance the spark; while moving the housing or breaker in the direction of rotation of the cam will retard the spark. This movement is generally obtained by the driver moving a small lever attached to the steering wheel and connected through a rod to the lever on the side of the distributor.

Efficient engine operation requires a gradual advance of the spark as the engine speed is increased and a proportional retarding of the spark as the engine speed is reduced. It is practically impossible to meet this condition by hand operation, but the spark advance and retard can be much more rapidly regulated by automatic control.

Automatic spark advance is generally accomplished by shifting the position of the cam with relation to the distributor shaft. The cam is mounted in such a manner that it can be moved around the shaft a slight distance in either direction.

The operating mechanism consists of a set of weights which are attached to and rotate with the distributor shaft. As the speed of the shaft increases with an increase in engine speed, centrifugal force causes the weights to move outward from the shaft, the amount of this movement being proportional to the speed of the engine.

The governor weights are attached to the cam so that they cause it to shift around the shaft in the direction of rotation as the weights fly outward, thus advancing the spark. When the speed is decreased the weights are drawn in by springs and

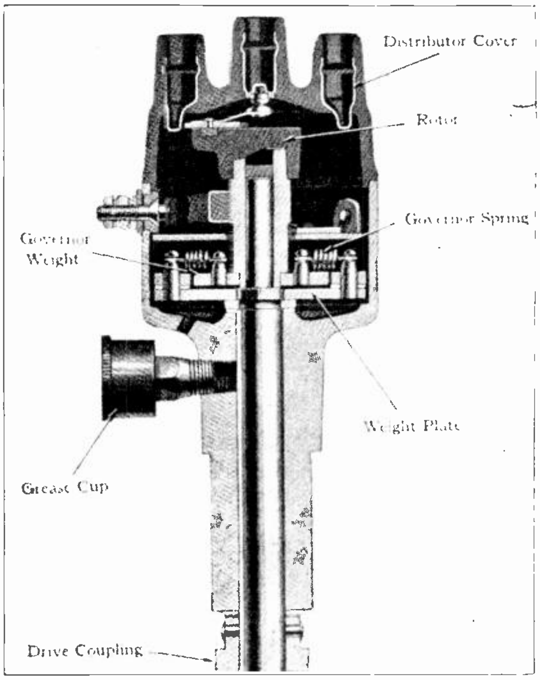


Fig. 35. Side sectional view through a distributor with automatic spark advance mechanism shown in the lower part and secondary rotor and contacts shown in the upper part.

the cam gradually moves back against the direction of rotation and retards the spark.

Fig. 35 shows a sectional view of a distributor in which the governor weights and springs can be seen in the lower part of the housing. Directly above these are located the cam and breaker points, and in the top of the distributor a rotor can be seen. The rotor has a permanent sliding contact connection with the center terminal of the distributor cap, while the metal tip of the rotor arm delivers a high-voltage impulse through a very short gap to the terminals of the spark plug wires as it passes them.

Fig. 36 shows a distributor of the automatic spark-advance type, with the cap and breaker element removed and the governor unit raised up out of the housing to show the weights and springs clearly. A loose cam is shown directly above the governor unit. When this cam is set in place on the shaft the wings on each side of its lower end fit over the pins on the governor weights; and, as these weights are thrown out or drawn in, the pins shift the position of the cam with respect to that of the shaft, thus effecting smooth and automatic adjustment of the spark with various engine speeds.

23. TIMING THE IGNITION

Timing the ignition means setting the distributor so that it supplies the spark to the correct cylinder at the right time; that is, not too late or too early.

The methods used to accomplish this vary somewhat with differences in distributor design; but the general procedure should be as follows:

1. Set the engine with No. 1 piston at U.D.C. on the compression stroke.
2. Move the spark lever to the full retard position.
3. Adjust the breaker contacts so that they are .020 inch apart when fully open.
4. Loosen the screw or nut which locks the advance lever to the housing.
5. Turn the distributor housing until the rotor arm comes in line with the contact on the cap that is connected to the spark plug in No. 1 cylinder.
6. Adjust the housing so that the breaker contacts are just beginning to open.
7. Lock the advance lever screw.

On some distributors the spark lever is riveted to the housing and cannot be moved. In such cases timing is effected by adjusting the cam on top of the shaft to a point where the rotor is lined up with segment 1 on the distributor cap as the breaker contacts are just opening. The cam is then locked in position by the locking screw or lock nut.

After the ignition has been timed, it is a good plan to carefully check the wires in the distributor cap to see that they are correctly connected. To do this the firing order of the engine and the direction of rotation of the rotor arm must be known.

The firing order is usually stamped on some part

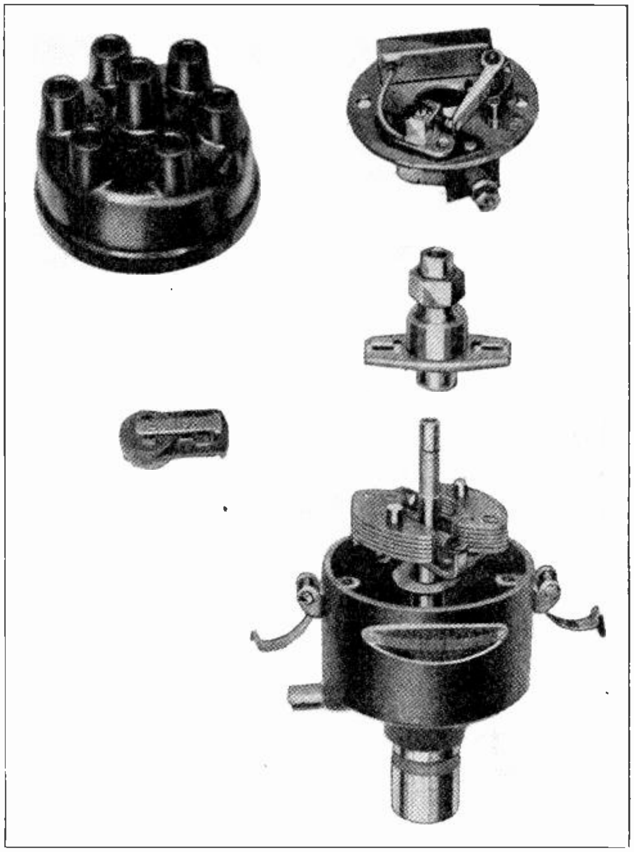


Fig. 36. Disassembled view of a distributor with automatic spark advance, showing the governor weights in the view at the lower right.

of the engine; but, if not, it can be readily determined by the methods explained in previous articles.

For example, on a six-cylinder engine with the firing order 1-5-3-6-2-4, No. 5 cylinder fires immediately after No. 1 and the wire from No. 5 spark plug should connect to the distributor cap segment that the rotor arm passes next after No. 1. The wire from No. 3 cylinder should connect to the next segment. And so on until they are all attached in the proper order. This method applies to all distributors using a single rotor arm.

24. SETTING THE ENGINE ON UPPER DEAD CENTER

One of the easiest methods of setting No. 1 piston on U.D.C. and one that can be applied to all side valve engines, is the "spark plug leakage" method. Unscrew the plug in cylinder No. 1 a few turns so that air can leak past its threads. Then pour into the recess around the plug just enough oil to seal this air leak. A couple of shots from an oil can will generally be sufficient.

Next, crank the engine slowly until bubbles are seen coming through the oil, which means that the piston is coming up on the compression stroke. Now bump the crank around just a little bit at a time and at each movement watch for the bubbles. When a point is finally reached where no bubbles arise when the crank is moved, that will be U.D.C.

The above method cannot be used on overhead valve engines as the plugs are generally screwed into the side of the cylinder instead of the top. With engines of this type the U.D.C. for cylinder No. 1 can be found by watching the valves and is reached just at the time the exhaust valve of the last cylinder closes or seats. This point can be determined by slipping a small piece of paper between the valve stem and rocker arm. As long as the rocker arm is holding the valve open against the tension of the spring the paper will be held firmly in place; but just as soon as the valve seats or closes, this tension will be removed from the paper and it will slip out if lightly pulled upon.

Remember that it is the **exhaust valve** in the **last cylinder** which is to be observed to determine **upper dead center** for **No. 1 cylinder.**

25. SPECIAL IGNITION SYSTEMS FOR HIGH-SPEED ENGINES

Some of the high-speed, high-compression engines used on late model automobiles require specially designed ignition systems for maximum operating efficiency. This can be better understood if we consider the fact that a six-cylinder engine using a six-cornered cam in the distributor and rotating at 3000 R.P.M. will have its breaker contacts opening 150 times per second, and these contacts remain closed only for about .004 second each time after making the primary circuit. These periods will be still shorter on a high-speed eight-cylinder engine.

In order to secure satisfactory operation at such speeds the ignition coil must be fast enough in action to build up its current during the short period of contact closure, and the breaker must do its work very accurately.

During the very short period that the contacts are closed a good contact without chatter or vibration must be made; otherwise the coil will not have time to completely magnetize and a very weak spark or complete miss will be the result.

26. DOUBLE OR "DUAL" IGNITION

To reduce the period of time required to burn the fuel charge and insure more complete combustion at high speeds, some engines are now being equipped with two ignition systems which operate together to supply two sparks to each cylinder.

These sparks occur at the same instant at different points in the combustion chamber, thus spreading the flame more quickly through the entire fuel charge.

The advantages claimed for the dual system are increased horsepower and efficiency, and also greater dependability because there are two separate ignition systems. If one should fail the engine can still be run on the other.

Fig. 37 shows a simple diagram of the coils, breaker, and high-tension leads to the distributor of such a system. From this diagram you can see that there are simply two separate sets of breaker points,

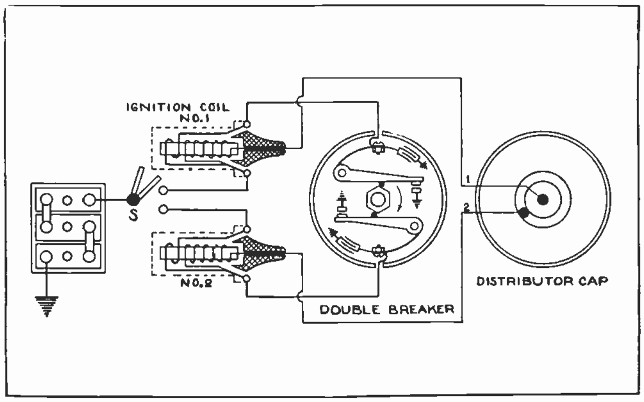


Fig. 37. This diagram shows the parts and connections of a dual ignition system used for firing two plugs in each cylinder. See the rest of this system in Fig. 38 below.

condensers, ignition coils, and high-tension leads to the distributor.

The only point at which these two systems are connected together is at the ignition switch, S; and, even though the two breaker arms are both operated by the same cam, they are electrically insulated or separated from each other.

Both breaker contacts are caused to open at the same time by the cam, and this causes a collapse of flux in both coils at the same time, in turn causing them to send high-voltage impulses to the two distributor terminals at the same instant. From this point the two impulses are delivered separately to the two spark plugs located in opposite sides of the combustion chamber.

Early types of double ignition systems used two separate distributor units, but these were later combined into one by changing the design of the rotor arm and distributor cap.

In Fig. 38 is shown a diagram of the connections from the distributor head to a six-cylinder engine equipped with dual ignition. The distributor cap has 14 terminals, 12 of which connect to the spark plugs, and the other 2 are connected to the high-tension terminals of the ignition coils.

The rotor arm for such a distributor really con-

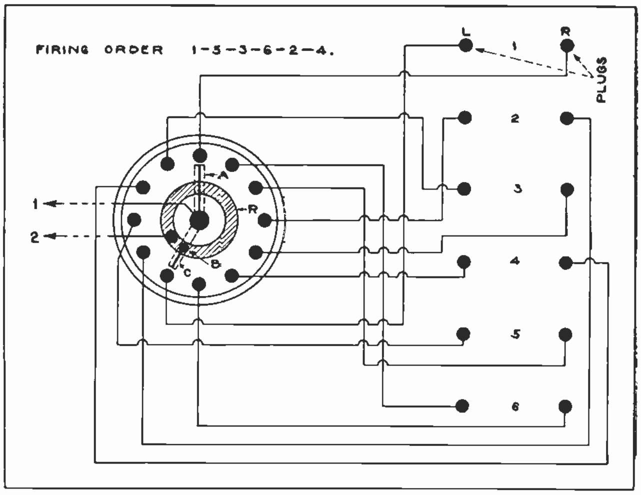


Fig. 38. Diagram showing distributor rotor arms and high voltage leads from the distributor cap to the spark plugs of a six-cylinder engine with a dual ignition.

sists of two arms electrically insulated from each other and rigidly connected together at an angle as shown in the figure. One arm conducts current from coil 1 to the spark plugs on one side of the engine. The other arm supplies current from the other coil to the plugs on the opposite side of the engine.

The high-tension lead from coil 2 connects to a conducting ring or slip ring, R, imbedded in the insulation material of the cap. From this ring the current is collected by a small carbon brush, B, that is mounted on the upper side of No. 2 rotor arm. From this point it travels along the arm to the plug segments on the cap and then to the spark plugs.

Six double sparks occur during each revolution of the distributor which means that sparks are produced every 60° of shaft travel, or 360 ÷ 6. However, the angle between the segments is only 30°, or 360 ÷ 12, and from this it can be seen that the rotor arm, A, for example, doesn't fire at every terminal it passes, but only at every other one. The same applies to rotor arm, C.

From the diagram you will note that when A is in position to fire any certain cylinder, C is in line with the segment which connects to the opposite plug in the same cylinder.

To obtain the best results from a double ignition system the sparks should occur at exactly the same time, and if they do not the breaker contacts should be adjusted so that they both open at the same instant.

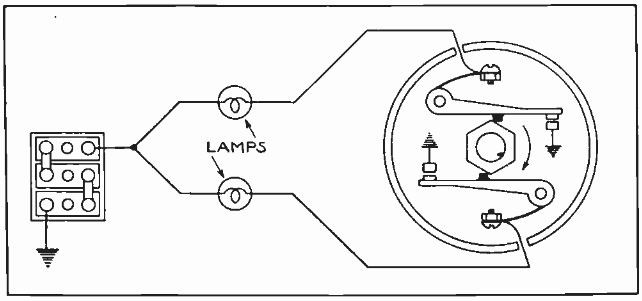


Fig. 39. This sketch shows the method of using test lamps for synchronizing breaker points of a dual ignition system.

To synchronize these breaker contacts, connect a six-volt test lamp in series with each set and a battery. Then rotate the distributor shaft very slowly until one light goes out. Now adjust the other set of contacts which are still closed so that the second light goes out. If both contacts are correctly set both lights will go out at the same instant when the distributor shaft is slowly turned.

Fig. 39 shows the methods of connecting lamps for synchronizing and adjusting the breaker points of a double ignition system.

27. SPECIAL DISTRIBUTORS FOR EIGHT-CYLINDER ENGINES

On account of the high operating speeds of modern eight-cylinder engines and because of the fact that every ignition coil requires a certain definite fraction of a second to fully magnetize its iron core, ordinary distributors have been replaced by specially designed units to meet high-speed requirements.

On earlier types of eight-cylinder distributors an eight-cornered cam and a single set of breaker contacts were used. This arrangement did not give good ignition at high speeds, as the period of contact closure was too short to allow the coil to become fully magnetized.

With eight-cylinder engines eight sparks must be produced in one complete revolution of the distributor shaft and cam, or one spark must occur for every 45° of shaft rotation, or 360 ÷ 8. This means that the breaker contacts must open and close once in every 45°.

After the contacts have opened the insulated cam follower which is mounted on the movable breaker arm has to travel over the corner of the cam and down the other side before the contacts are closed again. For this reason the contacts are held open for a longer period than is necessary. This results in the contacts being closed for only 20° out of each 45° of rotation, and being open for the remaining 25°.

As the contacts need to be open for only 10° to effect a clean break of the primary current, we can see that 20° of opening is unnecessary. What is required, then, for high-speed eight-cylinder engines is a distributor which will open the contacts for 10° to allow them to remain closed for the balance of the 45° interval during which each break must occur.

This has been accomplished by using distributors equipped with a four-lobe cam and two breaker arms which are mounted at an angle of 45° to each other, as shown in the center view in Fig. 40. With this arrangement the breaker arms are raised one at a time or alternately at 45° intervals so that one set of contacts closes 10° after the other set opens.

As both sets of contacts are connected in parallel in the primary circuit, the circuit is kept closed except for the 10° intervals during which both contacts happen to be open.

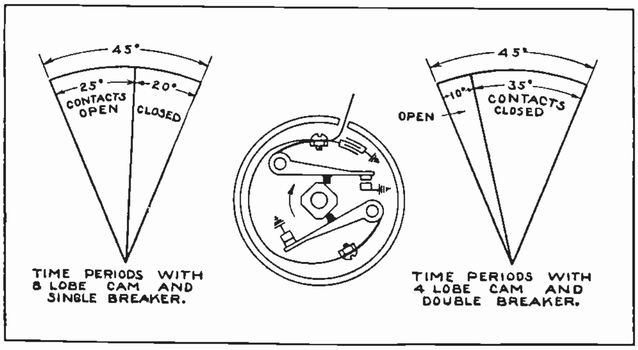


Fig. 40. Diagram showing construction of breaker mechanism for high-speed distributor and also showing periods of time which contacts remain open and closed with both single breaker and double breaker distributors.

As each set opens four times in one revolution of the distributor shaft and also opens at a point 45° from the opening of the other set, eight sparks per revolution are obtained, thus providing the proper number of sparks for an eight-cylinder engine.

Keep in mind that with this type of distributor when either set of contacts opens the other set is still open for another 10°; so, even though the contacts are in parallel, this effects a complete opening in the circuit for a period of 10° once during each 45°.

The sketch on the left in Fig. 40 shows 45° of the rotation of the old type distributor, illustrating the 25° period during which the contacts are open and the 20° period during which they are closed.

The sketch on the right in Fig. 40 shows a 45° period of the rotation of the new type distributor. In this sketch you will note that the contacts are open for only 10° and are closed for 35°, thus giving the ignition coil much more time to build up maximum flux and resulting in much better sparks at high speed.

The top view in Fig. 41 shows one of the double-breaker-arm, high-speed distributors in use with a single ignition coil on an eight-cylinder engine, and in the lower view in this figure a distributor of the same type is shown in use with two separate ignition coils, one of which is used with each set of breaker points.

With this system the distributor contact arms are not connected in parallel, but each one is connected to its own coil and each coil only produces a spark for every other plug or cylinder. This only requires the coils to operate at the same speed as for a four-cylinder engine and therefore gives them plenty of time to build up to full magnetization in the period during which the contacts are closed.

It also allows the coils to operate at a much lower temperature.

So we can see that this arrangement accomplishes the same result as the distributor and connection in the top view.

With either of the types of distributors shown in Fig. 41 each set of breaker contacts fires only every other cylinder, or one set firing four cylinders and the other set firing the remaining four.

For example, if the firing order of an engine is 1-6-2-5-8-3-7-4 one set of breaker contacts would fire cylinders 1-2-8-7, the other set firing cylinders 6-5-3-4. Therefore, if each cylinder is to get its spark at the correct time the angle between breaker openings must be exactly 45°. Any variation from this angle would mean that four of the cylinders would fire later in the piston stroke than the other four, and this would result in loss of power and poor, uneven engine performance.

To check the setting of breakers of this type a six-volt test lamp can be connected in series with the contacts. With a system such as shown in the

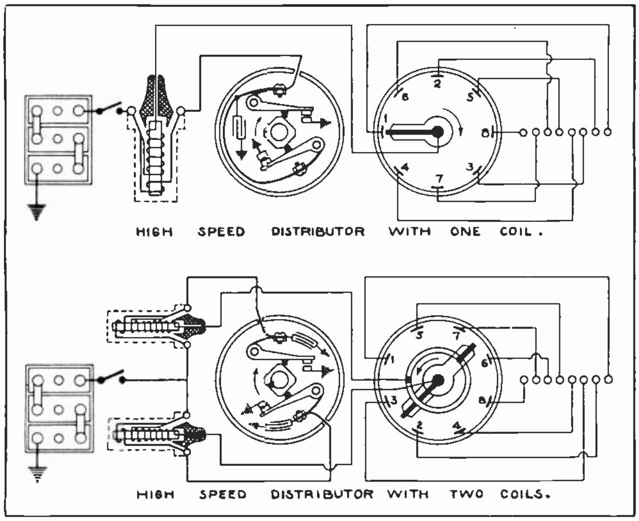


Fig. 41. The top diagram shows the connections for a high-speed distributor using one coil on an eight-cylinder engine. Below is shown the same type breaker using two coils and a slightly different arrangement of the secondary rotor arms and distributor cap contacts.

upper view in Fig. 41, only one test lamp is necessary in the primary lead to the distributor. With the other system shown in the lower view in Fig. 41 two test lamps should be used, one connected in each of the primary leads to the separate sets of breaker contacts.

Then turn the distributor shaft very slowly by cranking the engine until the light goes out. Mark the position of the rotor arm on the edge of the distributor housing at this exact point. Then slowly turn the distributor again to the point where the light goes out once more. Mark this position of the rotor arm, and the space between the two points marked should be exactly 45° of the circle around the housing. Special gauges for accurately measuring this angle and instructions for their use can be obtained from the manufacturers of these special distributors.

In the case of the first system mentioned where one test lamp only is used the marks should be made at two points where this lamp goes out. In the case of the second system the first mark will be made where one lamp goes out and the second mark where the opposite lamp goes out.

28. IGNITION LOCKS

All automobiles are equipped with a key switch to close the primary ignition circuit when the engine is to be started and during running, and to open this circuit when the engine is to be stopped and the car to be left standing. Key switches of this type make it difficult for anyone but the owner of the car to turn on the ignition to start the engine and thereby tend to prevent automobile thefts. However, ordinary ignition switches can be quite easily wired around by anyone knowing something about electricity or ignition circuits, and for this reason such switches do not give very complete protection from theft.

Many of the later types of cars are equipped with special ignition locks and primary wiring that is a great deal more difficult to tamper with. Cars so equipped are therefore more nearly theft proof.

Fig. 42 shows a diagram of a system of this type. By examining this sketch you will note that when the ignition switch is turned off it not only breaks the primary ignition circuit, but also grounds the wire which leads to the insulated movable arm of the breaker contacts. As the stationary breaker point is already grounded, this short circuits the breaker points, thus making it impossible for them to open the circuit and create a spark even if the ignition switch is shorted out with an extra wire.

The wire leading from the ignition lock or switch to the distributor is enclosed in heavy, steel-armored cable, to make it very difficult to cut this wire and release the locked short on the breaker points. Locks of this type are, of course, not absolutely theftproof but they make it so much more difficult for a car to be tampered with that they afford a great deal of additional protection against theft of the car.

In the case of trouble in an ignition system it may be necessary to test the switch to determine whether the fault is located in it or not. To test these lock switches use a six-volt battery and a head light bulb connected in series with a set of test points or leads.

To make the test proceed as follows: Turn the engine until the breaker contacts are fully open and then remove the coil wire from the switch terminal, T. Next place one test point on the insulated or movable breaker arm and the other on the switch terminal. With the switch turned on the lamp should light and with the switch off the lamp should not light.

Then place one test point on the insulated breaker arm and the other on the lock case. With the switch off or locked the lamp should light. With the switch turned on or unlocked the lamp should not light. If the lamp lights with the switch in the "on" position, the insulated breaker arm has become grounded due to defective insulation, the condenser is grounded, or there is a ground in the lock itself.

Disconnect the condenser and repeat the test. If the lamp does not light now the condenser is defective. If the lamp does light, disconnect the breaker arm and repeat the test again. If this puts the lamp out the breaker arm was grounded. If the lamp still remains lighted the trouble is undoubtedly in the lock, and will necessitate removing the lock to disassemble and test it.

29. TROUBLE-SHOOTING ON IGNITION SYSTEMS

In order for an automobile engine to start readily and operate satisfactorily throughout its entire speed range it must have fuel of the correct mixture, good compression, and a good spark or ignition.

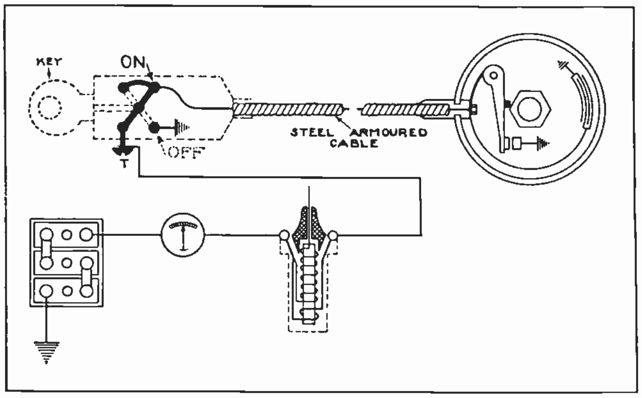


Fig. 42. The above sketch shows the primary ignition circuit through a special ignition lock switch and cable. Study the principles of this circuit carefully while reading the accompanying explanation.

Failure of any of these will result in poor performance or may prevent the engine starting at all.

When checking to locate troubles and causes of poor operation or refusal to start, the automobile trouble-shooter will generally commence with the ignition system, partly because it is one of the easiest things to check and also because trouble more frequently develops in the ignition than any other part of the engine.

Ignition systems and devices have been greatly improved in the last few years, but because of the number of small parts necessary in these systems and the delicate nature of some of these parts, there are numerous possibilities of small troubles developing which may interfere with the operation of the engine.

When we also consider the fact that the ignition devices and wiring of the systems are subjected to very extreme service conditions due to the severe vibration, dirt and dust, engine heat, and oil which the ignition devices and wiring are subjected to, we can understand better why some of these troubles occur.

We should also consider the fact that on an automobile ignition system there are used both extremely low-voltage circuits and extremely high-voltage circuits. In the six-volt circuits to the primary of the ignition coil and to the starting motor, lights, horn, etc., the slightest loose connection or resistance in the circuit will greatly interfere with the current flow.

In the high-voltage circuits from the ignition coil and distributor to the spark plugs, the slightest defect in the insulation will allow leakage or grounding of this energy.

It is estimated that approximately 75% of the ordinary engine failures encountered by the service man are due to ignition faults. However, as many engine failures are due only to an empty gasoline tank, clogged fuel line, choked or flooded carburetor, leaky vacuum tank or fuel pump, loose intake manifold or poor compression, it pays to keep these things in mind and not overlook them before going into any elaborate overhauling or repairs to the ignition system.

It is so easy to check to see whether the gas tank is empty or not, or whether gasoline is reaching the carburetor, and also to check the engine compression by merely turning the engine slowly with the crank, that every electrical service man should watch for these troubles and know how to check them. Keeping these possible troubles in mind, as well as those that may occur in the electrical system, may also save you considerable time and money with your own car when it fails to operate properly out on the highway.

If the compression of an engine is poor because of leakage past the piston rings or through poorly fitting valves, the engine will operate irregularly because of loss of part of the fuel charge on such cylinders and loss of power or misfiring due to the low pressure of the fuel charge.

Therefore, it is necessary for smooth operation of the engine that the pistons and valves be in good condition to maintain good and uniform compression in all cylinders.

If the intake manifold or carburetor connections are loose the suction on the carburetor jet may not be sufficient to raise the proper amount of fuel, or the amount of extra air drawn in through these openings may be great enough to make the fuel mixture so "lean" that it will not fire properly.

In electrical trouble-shooting on an automobile engine two of the most important things are **careful and close observation of the wiring and parts of the system,** and **the use of a definite systematic method of testing each part of the system.**

Very often electrical troubles are caused by loose connections, broken wires, defective insulation, or faults in some of the devices which can be easily seen by carefully checking over the system. There is probably no single rule or method of trouble-shooting that will apply to all cases, because of the various types of equipment used and the varying trouble indications that may sometimes be produced by the same fault.

One very good general rule, however, is **to start at the unit which appears to cause the trouble and work from that point back toward the battery.**

For example, with a failure in the ignition system start at the spark plugs and check from there back from the high-tension wire to the distributor. Check the distributor for faults both in the high-tension and low-tension circuits, and then if the fault is still not located, check the wiring back to the ignition coil.

Next check from the ignition coil to the ignition switch; and so on, making sure before leaving any particular point that the system is O. K. up to that point and cannot be the cause of the trouble.

Some of the various defects which commonly occur in ignition systems and also their symptons and remedies will be discussed in following paragraphs.

30. COMMON ELECTRICAL TROUBLES AND REMEDIES

First, let us suppose that an automobile engine will not start. One of the first things to check in this case, after making sure that there is fuel in the carburetor is the battery.

Try to operate the starting motor and if the starter turns the engine over quite lively the battery is O. K. If the engine turns over sluggishly or not at all the battery should be checked for low-voltage, low gravity of the acid, or loose connections. The tests for voltage and acid conditions will be covered more fully in the section on Storage Batteries.

Very often starter trouble and weak ignition are a result of loose connections at the battery terminals. Because of the very heavy currents required at low-voltage to operate the starting motor, the battery connections should be very securely tightened and the terminal posts and connecting clamps should be well cleaned. Otherwise the small amount of resistance placed in the circuit by dirty or loose connections will cause so great a voltage drop during the flow of the heavy starting currents that the starting motor will not develop sufficient torque to turn the engine.

Even if it does turn the engine the voltage drop during operation of the starting motor may be great enough to reduce the current flowing to the ignition coil and produce sparks too feeble to ignite the fuel mixture.

Battery connections may be good enough so that the lights and horn will operate alright when the car is standing idle, but yet not good enough to supply sufficient current to the starting motor and ignition coil to start the engine.

One of the reasons why an engine that will not start when being slowly turned over by the starter can often be started by cranking, is that when the starting motor is left out of service it allows the battery to supply more current to the ignition coil and produces a hot enough spark to ignite the gasoline mixture when the engine is cranked.

31. TROUBLE AT SPARK PLUGS

After the battery and its connections prove to be O. K., next test for a good healthy spark at the plugs. Remove one of the high-tension wires from its plug terminal and hold it about one-fourth of an inch away from the engine as at "A" in Fig. 43, to see if a good spark can be obtained when the engine is turned over.

If regular and healthy sparks can be obtained in this manner from each plug wire, the trouble is either in the plugs themselves or the ignition is out of time.

In judging the spark obtained on such tests remember that a thin, weak, threadlike, blue spark may not be sufficient to ignite the gasoline mixture in the cylinder, and also remember that a spark plug will jump considerably farther in open air than it will under compression inside the cylinder. In order to dependably ignite the fuel mixture, the spark should be hot and fiery appearing, or "fat" as it is often called. It is not alone the voltage of the spark that ignites the gasoline mixture but also the amount of current and the heat developed that make a good spark.

If good hot sparks can be obtained from all of the plug wires and yet the engine will not start, remove the plugs and examine them. If they are dirty or carbonized they should be cleaned and the points should be checked to see that they are set about .030 inch apart. If any of the plugs have cracked insulators or the points are badly burned away, they should be replaced.

Also be sure to see that the outer ends of the plug porcelains are clean and free from dirt and moisture, as sometimes a layer of moisture or damp dirt will allow the spark to creep along the surface of the porcelain and short circuit to the plug shell in this manner, rather than jump across the plug points inside the cylinder. Carefully wiping the plugs with a clean cloth or a cloth dampened with kerosene will generally remedy this.

Very often a car that has become water-soaked in a heavy rainstorm or has had snow blown in through the radiator and melted on the plugs will refuse to start because of the combination of water and dirt on the surface of these insulators.

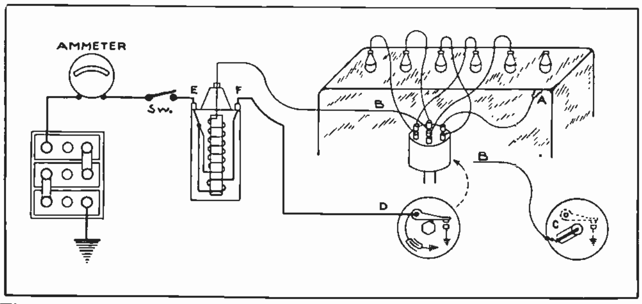


Fig. 43. Sketch illustrating methods of testing for ignition troubles. Refer to this sketch frequently while reading the paragraphs on this subject.

32. DISTRIBUTOR TROUBLES

If the plugs are in good condition and receiving good sparks and the engine still doesn't start, check the timing. Crank the engine around to bring No. 1 piston at U.D.C. on the compression stroke. Then retard the spark lever and remove the distributor cap.

The rotor arm should be in line with the contact on the cap that is connected to cylinder No. 1, and the breaker points should just be opening. If this condition is not found then retime the ignition as explained in an earlier article.

If no sparks are obtained when a plug wire is held near the engine, pull the high-tension coil lead, B, from the center terminal of the distributor cap and hold it close to the engine. If a hot spark jumps regularly to the engine with this test, the trouble is in the distributor cap, rotor arm, or plug wires; because you have proved that the ignition impulses are being delivered from the coil to the distributor but are not getting from the distributor to the plugs.

In this case remove the distributor cap and hold the high-tension coil lead close to the **rotor arm,** as at "C" in the small illustration in Fig. 43. Make and break the circuit at the interrupter points, and if a spark jumps to the rotor it is defective and should be replaced. If the rotor is O. K. examine the distributor cap. If it is wet, dirty, or oily it should be thoroughly cleaned with gasoline and a cloth. If the cap is cracked or burned it should be replaced.

In the type of distributor caps now in general use the end of the rotor arm doesn't make actual rubbing contact with the cap terminals but instead allows the spark to jump through a very small air gap as it passes from the rotor arm to the cap contacts. This spark in time burns away the contacts and forms upon them a scale which has a very high resistance and may weaken the spark to a point where it can no longer ignite the fuel charge.

To remedy this, remove the scale with emery cloth or sandpaper. If the contacts are badly burned away the air gap will be too great and the cap and arm should be changed.

If the high-tension section of the distributor has been carefully checked and found to be in good condition, carefully inspect the high-tension wires leading from the distributor cap to the plugs. These wires are heavily insulated with rubber and are generally protected by an additional coating of varnished braid, as they must carry the very high voltage impulses to the plugs without allowing leakage or grounding to the metal parts of the engine which they are near to and often come in contact with.

The insulation of these wires is subjected to very severe conditions, due to heat of the engine and the oil which is often thrown upon them and is very damaging to the insulating qualities of rubber. Leakage through the insulation of one of these wires would not be likely to interfere with the starting of the engine, although it would probably cause missing when the engine is operating.

However, if several of these wires should become grounded or leak badly it might prevent the engine from starting. If these wires are found to have cracked or brittle insulation, or if the rubber has become soft and mushy due to the action of oil, and particularly if sparks or leaks are detected along the surface of these wires, then they should be replaced.

33. BREAKER POINT TROUBLES AND DEFECTIVE CONDENSERS

If no spark can be obtained from the high-tension wire of the ignition coil when the engine is cranked or when the breaker points are opened, the breaker contacts should be carefully inspected to see that they make good contact when closed and that they are separated the proper distance (.020 inch) when fully open.

The surfaces of these contacts very often become burned or dirty, and a very small amount of dirt or blackening can increase their contact resistance to such an extent that the primary of the ignition coil will not receive anywhere near enough current. Small particles of grit or sand stuck to one of these points may prevent the engine starting.

Dirty breaker-contacts can be cleaned by drawing a piece of fine sandpaper through them, with a light pressure applied to hold the contact surfaces against the rough side of the paper. They can also be cleaned by use of a thin breaker point file. Contacts that are badly burned or pitted should be replaced, as the cost of new contacts is very cheap compared to the trouble bad contacts may cause.

To determine whether these contacts are properly making the primary circuit to the coil, snap them apart and watch for a small spark as they open. If this spark occurs it indicates that primary current is flowing through them. The trouble with the system is then likely to be in the condenser or coil.

Bad sparking and heating of the breaker contacts generally indicates an open-circuited condenser. A shorted condenser will prevent current flowing through the breaker points at all. A good way to check the condenser is to disconnect it and hook in another one that is known to be good. If the breaker points and condenser are proven to be O.K. then the trouble is probably in the ignition coil and the coil should be removed and tested.

34. TROUBLE TESTS ON IGNITION COIL AND PRIMARY WIRING

If the coil tests O.K. then carefully check the primary circuit for high resistance caused by poor contacts or loose connections. If the coil delivers no spark when the primary circuit is broken the failure may be caused by a ground between the coil and the breaker arm, or by the breaker arm being grounded, the condenser grounded, or an open circuit somewhere between the distributor and the battery.

Disconnect the primary wire, D, from the distributor and touch it to the engine, and if a flash is obtained it proves that this wire is good and is carrying current from the battery to the distributor, and that the trouble is probably in the breaker arm.

Disconnect the condenser and touch the primary wire to the distributor arm while the breaker contacts are open. If this produces a flash the arm is grounded. Repeat this test on the insulated terminal of the condenser and if a flash is produced it indicates a grounded condenser. If the primary wire, D, fails to produce a flash when touched to the engine it should be disconnected from the coil terminal and replaced by another wire.

If the new wire gives a flash when touched to the engine the original wire must have been grounded or open. If no flash can be obtained with the new wire then remove the other wire from the opposite primary coil terminal, E, and touch it to the engine.

If a flash is obtained in this manner it proves that current was supplied from the battery to the primary of the coil and that the ignition trouble is probably in the coil.

This trouble is likely to be a burned out resistance element, a burned out primary coil, or a grounded coil. With the wire, D, between the coil and the distributor connected and the breaker points closed, or with a direct ground connection from coil terminal F to the engine, if no flash can be obtained on the other coil terminal it indicates an open circuit such as a burned out resistance or burned out primary.

With the connection entirely removed from terminal F, or the distributor side of the coil, if the lead touched to the other side produces a flash it indicates that the coil is grounded. If no flash can be obtained when touching to the engine the end of the wire which has been removed from terminal E and should feed current to the coil, this indicates an open circuit, probably due to a fault in the ignition switch or a poor connection at the ammeter, or possibly it is due to a break in the wire underneath the insulation.

The ammeter itself will often give some helpful indications in ignition troubles. If when the breaker contacts are known to be closed the ammeter gives no reading when the ignition switch is turned on, this indicates an open circuit in the primary ignition wiring, or dirty high-resistance breaker contacts.

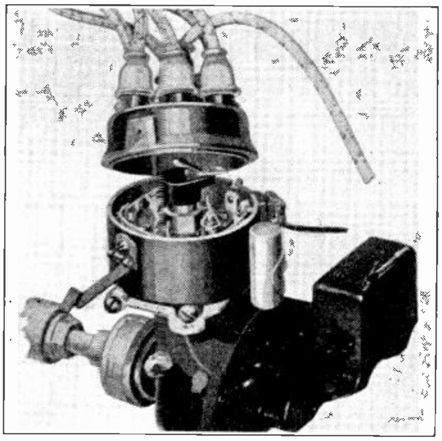


Fig. 43-A. Photograph of distributor with high-tension cap removed showing rotor arm in place and double breaker points beneath. Also note the high-tension wires connected to the cap and the water shields which are placed over the connections.

The open circuit may, of course, be a broken wire, loose connection, or a defective coil or coil resistance. It may also be in the ignition switch itself.

If the ammeter gives an excessive reading or throws the needle clear across the scale when the ignition switch is turned on, this indicates a ground in the primary wiring or one of the devices of this circuit.

From the foregoing explanation we can see that electrical trouble shooting on an automobile ignition system is just a process of systematic elimination. By testing one part at a time in the manner suggested, it is possible to definitely and accurately corner the trouble in whichever part of the device or wiring it may be located.

For this reason it is well to thoroughly study the very simple diagram given in Fig. 43, or the diagram of any particular ignition system on which you may be working, and also to have the circuit well in mind before starting to shoot trouble. You can easily corner any trouble if you know exactly where the current ought to flow to operate the various devices and then check to find just how far it does go along this path.

After the first general inspection to see if any broken or grounded wire or loose connections can be noted, one should avoid jumping from one part of the system to the other but should rather follow the system straight through, testing one part at a time, each in order, as explained.

35. IGNITION TROUBLES THAT CAUSE ENGINE TO MISS

Various faults can occur in ignition systems which, while they do not prevent the engine starting, will cause it to fire very irregularly or miss on certain cylinders and operate with greatly reduced power.

One very common cause of an engine missing is faulty spark plugs. To check the spark plugs, short circuit the plug gap by bridging between the plug terminal and the engine with a screw driver. This grounds the plug and prevents a spark from occurring at its points. When the engine is running and a good plug is shorted in this manner the engine will slow down and run more unevenly than before.

Shorting out a bad plug, however, will have no noticeable effect on the operation of the engine. In this way a bad plug can often be quickly located and adjusted or replaced. This same test, however, might also indicate a cylinder that is not firing because of poor compression due to leaky valves or some other cause, so the test is not always an indication that the plug is bad.

When an engine with many cylinders is being tested in this manner it is sometimes difficult to tell whether a plug is firing or not, as one bad plug in an eight-cylinder engine, for example, would not produce a very noticeable indication or slowing down.

To overcome this and quickly detect the missing cylinder or cylinders, the engine can be run on one-half of its cylinders by removing the plug wires from the spark plugs in the remaining half. While operating in this manner the missing cylinder can be easily and positively located, because of the great difference that will be noticed when one of the good plugs is shorted out.

When a bad plug is found it should be cleaned and adjusted or replaced.

Missing may also be caused by defective insulation on the high-voltage secondary wiring, either between the distributor and the plugs or between the secondary of the coil and the distributor. This can generally be found by carefully inspecting these wires for cracked, softened, or defective insulation, and also by feeling along their surfaces for slight leakage which will produce a shock when the spot is touched.

Sometimes by carefully watching and listening when the engine is running you can detect sparks or light, snapping noises from leakage sparks which are flashing through the insulation on the wires to the metal parts of the engine or to the tube or clamps in which the wires are supported.

When any of these wires begin to leak high-voltage energy, the best remedy is to replace all of them with new ones.

Distributor faults may also be the cause of missing and irregular engine operation. Some of the more common of these faults are breaker contacts dirty, pitted, or improperly adjusted; movable breaker arm sticking in its pivot; untrue breaker cam; distributor shaft wabbling due to worn bearings, or distributor housing loose in its socket.

If the bearings allow the distributor shaft to move off center more than .003 inch they should be replaced. If the engine runs smoothly at low speeds but misses at higher speeds it may be caused by the plug points being set too far apart, breaker contacts set to open too far, insufficient spring tension on the movable breaker arm, worn cam follower, defective condenser, etc.

All battery ignition systems produce weaker sparks at high speeds because of the shorter period of contact closure and less complete magnetization of the coil between breaks. Therefore, anything which tends to further reduce the very short period of time that the coil primary circuit is closed (such as weak breaker springs or worn and lengthened cam follower) will interfere with ignition at high speeds.

Any of the causes of missing previously mentioned might also be responsible for poor engine performance at high speeds.

If the engine lacks power and overheats, the ignition timing should be checked to see that the sparks are not occurring too late or too far retarded.

Late ignition will always decrease the power of an engine and cause it to overheat, and it should be corrected by timing the engine properly as explained in an earlier article.

If the timing is right the carburetor adjustment should be checked. If changing this adjustment fails to "pep" up the engine, next check the valves and see that the clearance between the end of the valve stem and its tappet or rocker arm is correct. This clearance varies with different engines and the manufacturer's recommendation should always be followed when it is known, but if the manufacturer's figure is not known, a clearance of .006 inch for intake valves and .008 inch for exhaust valves will generally give good results.

These settings should be made while the engine is warm and the clearance should be determined by a feeler gauge.

Another possible cause of an overheated or sluggish engine may be improper valve timing.

A good general rule to follow when checking engine trouble is to first check the ignition, then the fuel system, and then the valves, always keeping in mind that any of these can be the cause of the various troubles outlined in this section.

36. HIGH-TENSION MAGNETOS

High-tension magnetos are extensively used in the ignition systems of trucks, tractors, and aeroplane engines. Their principle of operation is almost the same as that of the high-tension ignition coil, except that magnetos generate their own low-voltage primary current instead of receiving it from a battery.

You are already well familiar with the principles of operation of D.C. and A.C. generators, so it is not necessary to go into great detail as to these principles of magnetos.

High-tension magnetos consist of the following important parts:

1. A set of permanent magnets for producing a magnetic field.
2. A rotating iron core or armature on which the coils are wound.
3. A primary winding to generate low-voltage energy, and a secondary winding to step up this voltage.
4. A set of breaker contacts to interrupt the primary circuit and cause the flux to collapse.
5. A condenser to prevent arcing at the breaker contacts and increase the secondary voltage.
6. A distributor to direct the spark impulses out to the different spark plugs.

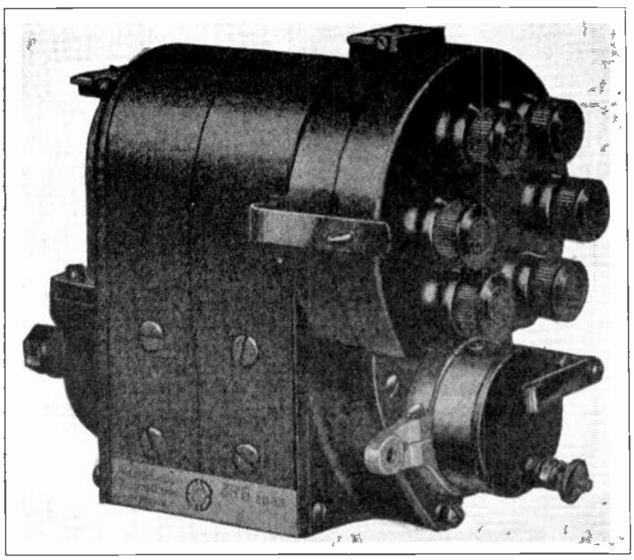


Fig. 44. Photograph of a high tension magneto used for ignition purposes on trucks, busses, tractors, etc. Courtesy Bosch Magneto Corporation.

Fig. 44 shows a common type of magneto for use with six-cylinder engines. The two large horseshoe-shaped permanent magnets which supply the magnetic field can be seen over the body of the magneto. On the lower right-hand end is the housing which contains the breaker points, and on the upper right end is the distributor housing with the terminals for the six spark plug leads clearly shown. On the left end of the magnet is shown a coupling by which its armature is driven by connection to the engine. The armature revolves between pole faces attached to the lower ends of the permanent magnets.

Fig. 44-A shows a magneto armature removed from the housing and field frame. The heavily-insulated primary and secondary coils are shown wound on a simple spool form, or the center leg of the armature core at No. 1.

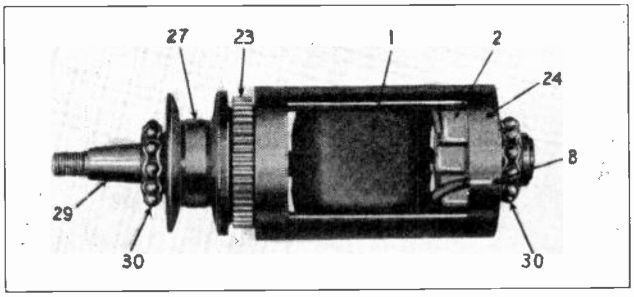


Fig. 44-A. Magneto armature removed from housing to show bearings, slip ring, armature core, windings, and condenser.

At 2 is shown the condenser, which is also contained in the armature. The ground on the iron armature core is shown at 24, and one of the primary leads is grounded or connected to this core at B.

No. 23 is the gear which drives the distributor mechanism, 27 is the insulated slip ring at which the high-voltage energy from the secondary is collected by means of the brush and carried to the distributor.

At 30 are the ball bearings in which the armature rotates, and at 29 is the end of the shaft by which the magneto is coupled to the engine.

37. CIRCUITS AND OPERATING PRINCIPLES

Fig. 45 shows a diagram of the primary and secondary windings of a magneto armature. You will note that the upper end of the primary connects to one side of the condenser and then through the breaker points to ground, while the lower end of the primary connects to the other side of the condenser, and directly to ground. This places the breaker points in series with the primary winding and the condenser directly across the breaker points.

The inner end of the high-voltage secondary coil is connected to the primary and thus obtains a ground connection, while the outer end of the secondary is connected to the insulated slip ring, S, and delivers the high-voltage energy from this ring

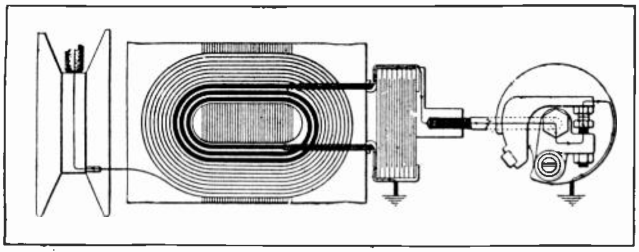


Fig. 45. Diagram of primary and secondary windings of a common magneto armature. This diagram also shows condenser and breaker points on the right and the high tension slip ring on the left. Courtesy Bosch Magneto Corporation.

to a brush and then through the distributor to the spark plugs.

Fig. 46 is a diagram showing the position of a magneto armature between the pole faces of the permanent magnets, and also shows the direction of magnetic flux travel through the armature from the north to the south pole.

With the armature core in its present position, the flux built up between the two field poles is at maximum; but as the core is turned to a point at right angles to its present position it doesn't provide nearly as good a path for the magnetic lines and thus causes a great reduction or sudden collapse of the flux, twice during each revolution.

This collapse and building up of the magnetic field as the armature is rotated causes the magneto to generate low-voltage A. C. in the primary winding. By using in this primary coil circuit a set of breaker contacts to interrupt the current flow just as the field flux is collapsing, the flux around the primary turns is also allowed to collapse, with the result that the double flux collapse induces a very high-voltage impulse in the secondary winding, which consists of a great number of turns of fine wire.

To obtain maximum voltage the primary circuit should be broken just at the point when the greatest amount of voltage and current are being induced in it.

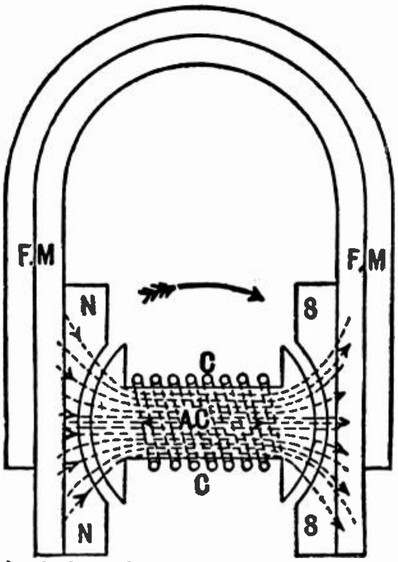


Fig. 46. This sketch shows the position of the armature between the pole pieces of a magneto and shows the path of the flux from the permanent magnetic field.

Referring to Fig. 47 we find that with the magneto armature in a position shown at "A" flux is passing from the north pole downward through the core to the south pole.

If this armature is revolving clockwise we can see that its top and bottom sides are just about ready to break away from the poles they have been passing and approach the opposite poles. As they pull away from the poles the strong magnetic field which was passing through the armature core collapses and shifts over in the opposite position shown at "B". Here the flux is still passing from the north to the south poles of the permanent magnets, but it is now passing upward, or in the reverse direction, through the armature core.

We find, therefore, that the point of maximum flux movement or change, and also the point of maximum voltage generated in the primary, will be just as the magneto armature breaks away from one set of poles and passes on to the next, or while it is moving from the position shown at "A" to that shown at "B".

The maximum voltage will be generated in the primary winding when the armature is in the position shown at "C" in Fig. 47, and this is the point at which the breaker contacts should interrupt the circuit.

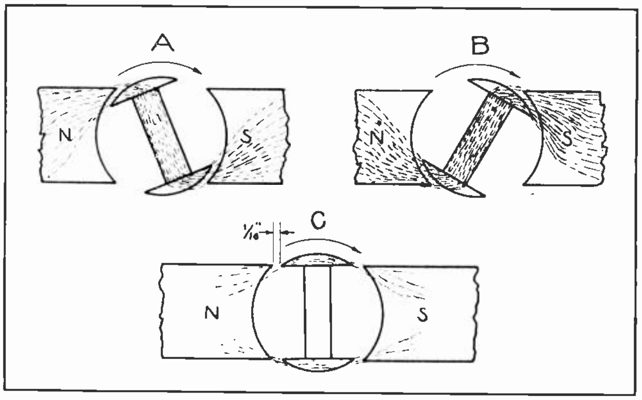


Fig. 47. The above sketches illustrate the shift and collapse of flux as a magneto armature rotates between the field poles to cause the induction of voltage in the armature coils.

Magnetos are so constructed by the manufacturer that when the breaker housing is in the full advance position the breaker contacts will open the primary circuit when the armature is in the position shown at Fig. 47-C, or when the armature tip has left the pole tip by a distance of about 1/16 of an inch.

Any variation from this setting would greatly weaken the spark, and to prevent altering the timing of the breaker contacts when the magneto is taken apart for inspection or repair, a keyway is cut in the armature shaft to receive a key on the breaker plate so that the two will always be locked together in the proper position.

Fig. 48-A shows a diagram of the primary and secondary circuits of an ordinary magneto, and also shows the connections and locations of the various important parts. Trace this circuit carefully and

compare it with Figs. 44 and 45 until you thoroughly understand the general construction and wiring of a magneto.

Note how a number of the circuits are completed by grounding the connections to the armature core and metal parts of the magneto frame. The solid black parts of the sketch indicate the insulating material which separates various metal parts of the magneto and parts of the circuit.

In tracing this circuit you will find that the breaker points are in series with the primary coil and that the condenser is connected across these breaker points. One end of the secondary coil is connected directly to the primary winding to obtain a ground through this low-resistance winding, although in many magnetos it is connected directly to ground at the other end of the primary. The other end of the high-voltage secondary delivers its impulses to the distributor through the insulated collector ring, brush, and conductor rod or pencil. From the distributor the impulses are sent in the proper order by means of a timed rotor to the spark plugs.

38. MAGNETO SAFETY GAPS

Note the safety gap which is connected between the high-tension lead and ground, to protect the secondary winding from excessive voltage strain in case the spark plug gaps become open too far or the secondary lead becomes broken.

As long as the spark plugs remain in proper condition and connected to the secondary leads the magneto needs to build up only about 6000 volts to flash across the 100,000 ohms approximate resistance of the spark plug gaps under compression.

If the resistance of this secondary circuit is increased by a broken secondary wire or the spark plug gaps becoming too widely open, the secondary voltage will rise to an excessive value. This places a very high strain on the insulation of the windings and if allowed to continue will eventually puncture and break down this insulation. As the armature insulation cannot easily be repaired this generally means that the entire armature will have to be replaced.

The safety gap connected in the manner shown is really in parallel with the spark plug gaps in the entire secondary winding to ground. With this gap set at about 5/16 of an inch, 8000 volts will send a spark across it, so the voltage strain on the insulation can never rise above this value, and the possibility of puncture is greatly reduced. Under normal operating conditions the spark will jump the plug gaps, as their resistance is lower than that of the safety gap.

Fig. 48-B shows a simplified wiring diagram quite similar to the one in Fig. 48-A, except that the various parts are shown further apart to make the circuit easier to trace. In this diagram it is very easy to trace the circuit of the primary coil through

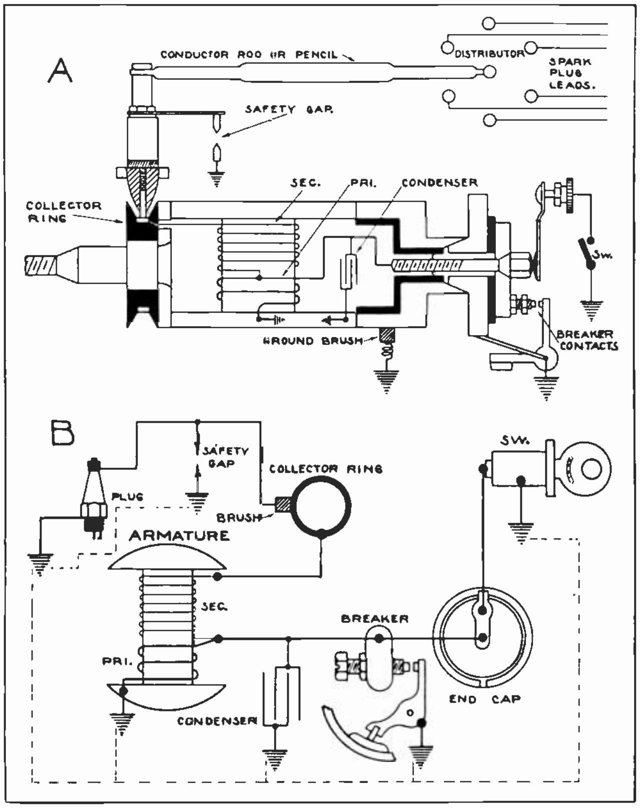


Fig. 48-A. Diagram showing complete primary and secondary circuits of a magneto. B. Another diagram showing a different arrangement of the primary and secondary circuits and important parts of the magneto.

the breaker points and to note that the condenser is connected across these points.

The secondary circuit can also be easily traced through the collector ring, brush, the single spark plug shown, and back through the grounded connections, primary coil, and to the start of the secondary. The dotted lines in this circuit show the ground path created through the metal parts of the magneto by grounding one end of each of the various devices.

39. GROUND BRUSH AND IGNITION SWITCH

Magneto armatures are generally supported in ball bearings, and in order for the secondary current to complete its circuit from the frame to the armature through the grounded connections, the current would ordinarily have to flow through these bearings. This would tend to pit the balls and ball races of the bearings and also to carbonize the grease with which they are lubricated, and thus would result in very rapid wear of the bearings.

To avoid this a small carbon brush is inserted through the base of the magneto and held in contact with the rotating armature by a light spring. This brush is called a **ground brush,** and provides a path of lower resistance than the bearings, so that most of the current will flow through this brush circuit.

To prevent any current at all from flowing through the bearings most manufacturers insulate them from the magneto frame with pressed paper or fibre insulation.

In both Figs. 48-A and B you will note that a grounding switch is used to shut off the magneto and ignition by short-circuiting the breaker points. When these points are short-circuited by the switch they cannot open the primary circuit any longer, and this prevents the sudden collapse of flux and the induction of high-voltage impulses in the secondary, thus stopping the spark.

This is a very effective method of shutting off the ignition to stop the engine and is much more convenient than trying to place a switch to open the primary circuit, as this circuit is all contained within the armature of the magneto itself.

The ignition switch in this case merely grounds the insulated breaker point, thus entirely shorting out the breaker contacts.

40. BREAKER MECHANISM

The breaker assembly of the armature-type magneto consists of five principal parts, as follows:

1. A circular metal breaker-plate which supports the contacts.

2. Contact points, one of which is attached to the breaker plate but insulated from it, and the other mounted on the grounded movable breaker arm.

3. Breaker housing.

4. Steel cams attached to the inside surface of the breaker housing.

5. Fastening screw which holds the breaker plate to the armature and also makes connection between the insulated breaker contact and the ungrounded end of the primary winding.

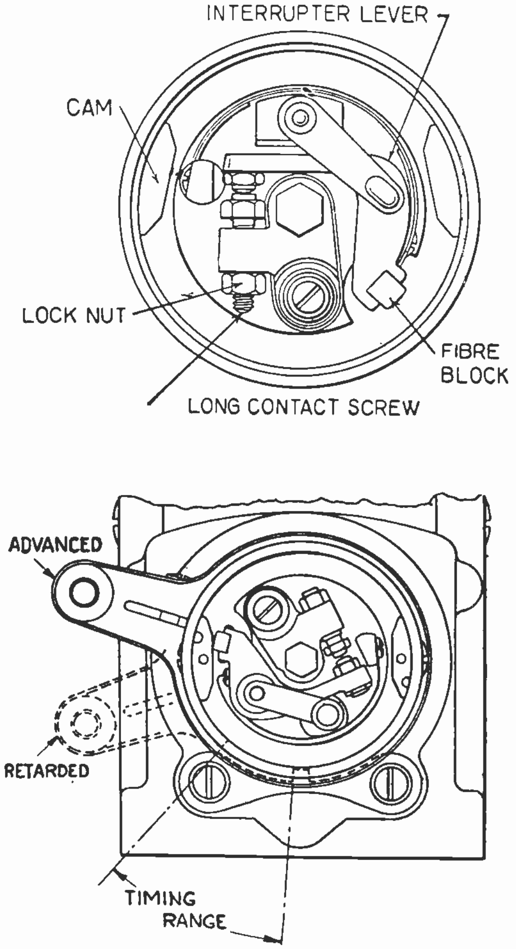


Fig. 49. The top view in this figure clearly shows the breaker mechanism of a magneto. Below is shown another view of a breaker with the points open and the cam under the breaker arm, and also showing the method of advance and retard of the spark by means of a lever on the breaker housing. Courtesy Bosch Magneto Corporation.

The upper view in Fig. 49 shows a diagram of the breaker mechanism of a mageto in which both the stationary and movable contacts can be seen. As the breaker plate and contacts are rotated the fibre block on the outer end of the arm rides over the cams attached to the inside of the breaker housing, thus causing the breaker points to open. When the fibre block drops off the cams the breaker points are closed by the action of a small spring attached to the movable arm.

Contact points are generally tipped with platinum as this metal stands up very well under the continuous sparking and make and break action and doesn't burn or corrode as easily as most other metals.

Magneto contacts are generally set for a maximum opening at .015 of an inch, although certain variations of this gap may be necessary with different magnetos under various operating conditions.

It is just as important to keep these contact surfaces bright and clean and properly fitted as it is with those of interrupters on battery ignition systems. **For efficient ignition, breaker contacts must make a good low-resistance closure in the primary circuit each time they touch, and must make a quick, clean break when they open.**

The lower view in Fig. 49 shows the manner in which the spark of a magneto can be advanced or retarded by shifting the breaker housing and cams by means of the advance lever attached to the side of the housing.

41. DISTRIBUTOR

Magneto distributors are quite similar to those used with battery ignition systems, except that instead of using a small distributor arm, magnetos use a distributor plate which is rotated by means of a gear that is driven from a small gear on the armature shaft.

Fig. 50 shows an end view of a magneto with the distributor cap removed to show the plate and gear. As this plate revolves its metal arm makes contact in rotation with the stationary contacts which are mounted in the cover and connect to the various spark plug leads. Below the distributor gear and plate in Fig. 50 can be seen the breaker housing with the cover removed, showing the breaker points and mechanism inside.

42. SETTING THE DISTRIBUTOR GEAR

In order that the rotating contact or segment will be at the correct position when the breaker contacts open, it is very important that the distributor gear

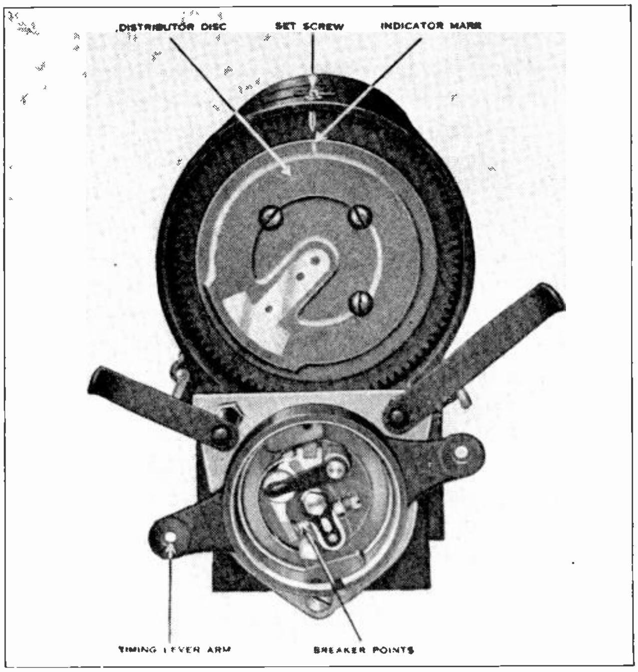


Fig. 50. Photograph of a magneto with covers removed showing the breaker mechanism below and the high voltage distributor disk and contact arm above. Courtesy Eisemann Magneto Corporation.

and its smaller driving gear on the end of the armature be properly meshed together. If these gears are not properly meshed it may result in the rotating brush or segment being at a point midway between the stationary segments when the spark occurs.

This would tend to make the spark jump the gap between the rotating and stationary contacts as well as the plug gap, and in all probability the increased resistance would result in the spark occuring at the safety gap of the magneto or at the wrong plugs of the engine.

To insure proper operation and make it easier to properly set and time the magneto in overhauling, manufacturers generally place small punch marks on the edges of the gears, one mark on the armature gear and two on the distributor gear, as shown in Fig. 51-A.

Magnetos are often arranged so that by making small changes they can be driven either clockwise or anticlockwise, according to the most convenient

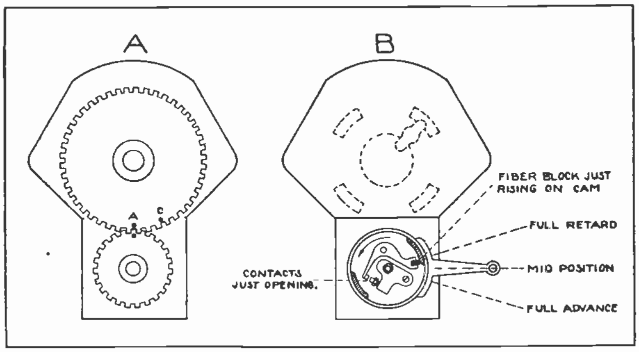


Fig. 51. A shows method of properly timing or setting the distributor gears by means of marks on their edges. B shows breaker arm in proper position, spark advance lever and breaker points both in proper position for timing the magneto.

connection to the engine. If the magneto is for clockwise rotation, the C mark on the distributor gear should line up with the mark on the armature gear when meshing the gears together. If the magneto is to be driven anticlockwise, the A mark on the distributor gear should be lined up with the mark on the armature gear.

The direction of magneto rotation is always designated as clockwise or anticlockwise when facing the drive end of the magneto. The direction of rotation for which the magneto is intended is generally marked by an arrow on the oil cover over the drive end bearing.

Sometimes a magneto is found which has already been overhauled several times and on which the original marks may have been obscured or scratched off, and other marks may have been made by the men who previously overhauled the magneto.

As these marks cannot be depended upon, the gears should be carefully meshed or set by the following procedure and as illustrated in Fig. 51-B. Set the breaker housing in mid position, half way between full advance and full retard. **Turn the magneto armature in the normal direction of rotation until the fibre block on the breaker arm is just moving up on the cam and opening the contacts. Then rotate the distributor gear to a point where the brush is in the middle of the segment, as shown.** Now, while making sure that the armature and distributor gear maintain these positions, move the gears into mesh with each other.

To check the setting move the breaker housing to the full retard position and, turning the magneto armature in the correct direction of rotation, see if the brush is still on the segment with the breaker contacts open. Make the same test with the breaker housing in the full advance position. The brush should be on the segment in both positions.

Magnetos are made with distributors for various numbers of cylinders, according to the types of engines they are to operate with. The upper view in Fig. 52 shows a complete wiring diagram of a magneto connected to the plugs of a four-cylinder engine, while the lower view in this figure shows another magneto connected to the plugs of a six-cylinder engine.

The arrangement of the distributor brushes and segments and also of the primary connections are slightly different in these two diagrams, but the circuits and principles are in general the same. In both diagrams the breaker contacts are shown in the circuits of the primary coils, and the high-voltage secondary circuit is shown leading from the collector ring through the brush to the distributor, and from the distributor contacts to the plugs, which in turn are grounded to complete the circuit back to the magneto frame.

The ground circuit and connections in each case are shown by the dotted lines. The wires leading

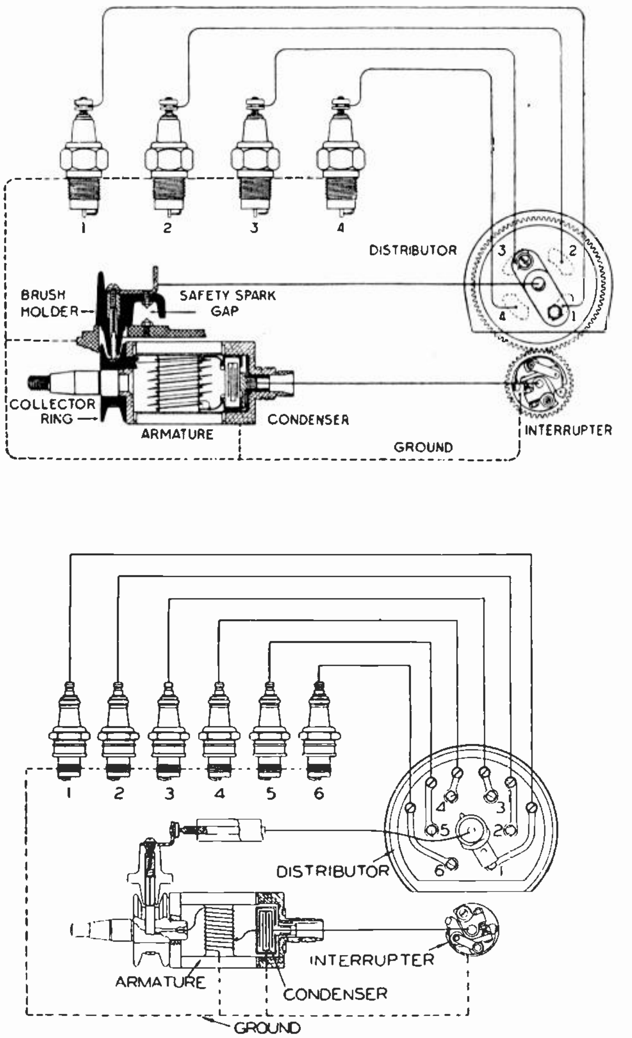


Fig. 52. The upper view shows complete primary and secondary circuits of a magneto with the high tension leads connected from the distributor to the spark plugs of a four-cylinder engine. The lower view shows the circuits of a magneto for use with six-cylinder engines. Note that the spark plugs are lined up numerically in these figures and are not in their proper order on the engine.

from the distributor terminals to the spark plugs in this figure are connected to the plugs according to their firing order, and the rows of plugs are arranged this way also and **not in their actual positions** on the engine.

43. TIMING A MAGNETO TO THE ENGINE

When connecting a new magneto to an engine or when reinstalling one that has been taken off for repairing or overhauling, the magneto should be carefully timed to the engine in the following manner, which you will note is very similar to the method used for battery ignition systems.

Set the engine so that No. 1 piston is at top dead center on the compression stroke. Fully retard the magneto breaker housing and turn the magneto armature in the normal direction of rotation until the distributor brush is on segment No. 1 of the distributor cap and the breaker contacts are just beginning to open.

Then connect the magneto to the engine through the drive coupling, being very careful not to allow the armature or distributor to change position while making the connection. Some magneto manufacturers place on the distributor disk or gear a mark which when lined up with a mark or screw on the distributor housing indicates that the distributor brush or rotating segment is in position to contact with the stationary segment which connects to No. 1 cylinder. These marks can be seen by referring to Fig. 50.

Fig. 53 shows a sectional view of one type of magneto, giving the names of the various parts. Examine each part very carefully and make sure that you understand the function of all of the important parts which have been explained in the preceding paragraphs.

You will note in this figure that the ground brush is located in the revolving breaker plate and rubs against the metal collar or frame of the magneto in the back of the breaker housing. In this position the brush not only makes a good return for the grounded secondary current, but also makes a positive ground connection from the rotating breaker mechanism to the magneto frame, to make more certain the shorting or grounding action of the ignition switch when the magneto is turned off.

The path of the high-tension energy can be traced from the upper right-hand end of the secondary coil to the collector ring, collector brush, up through the metal strip imbedded in the insulation of the distributor cap to the center distributor brush, across the rotating strip on the distributor disk, and out of the upper distributor brush to the spark plug wire. Only one of the outer brushes that connect to the spark plugs is shown in this view.

Fig. 54 shows another sectional view of a different type of magneto and, while the construction is different in some respects, you will note that the general arrangement and principles are the same. Note the position of the oil holes and the ground brush shown in this figure.

44. DISASSEMBLING MAGNETOS

The exact procedure for taking apart a magneto to make repairs or for overhauling will vary somewhat with different types of magnetos and detailed instructions for these can be obtained from the manufacturer of any certain magneto.

The following general rules, however, will prove to be very helpful and any magneto can be disassembled by this method with a little care and observation on the part of the workman so as not to overlook other small details.

First remove the breaker housing and distributor cap. Then remove the breaker plate by taking out the holding screw. Next remove in order the magnets, high-tension collector plug, high-tension pencil or conductor bar, ground brush, bearing plate at the interrupter end, distributor gear, and then the armature.

It is very important to remember that **the armature should be removed last,** for if this rule is **not**

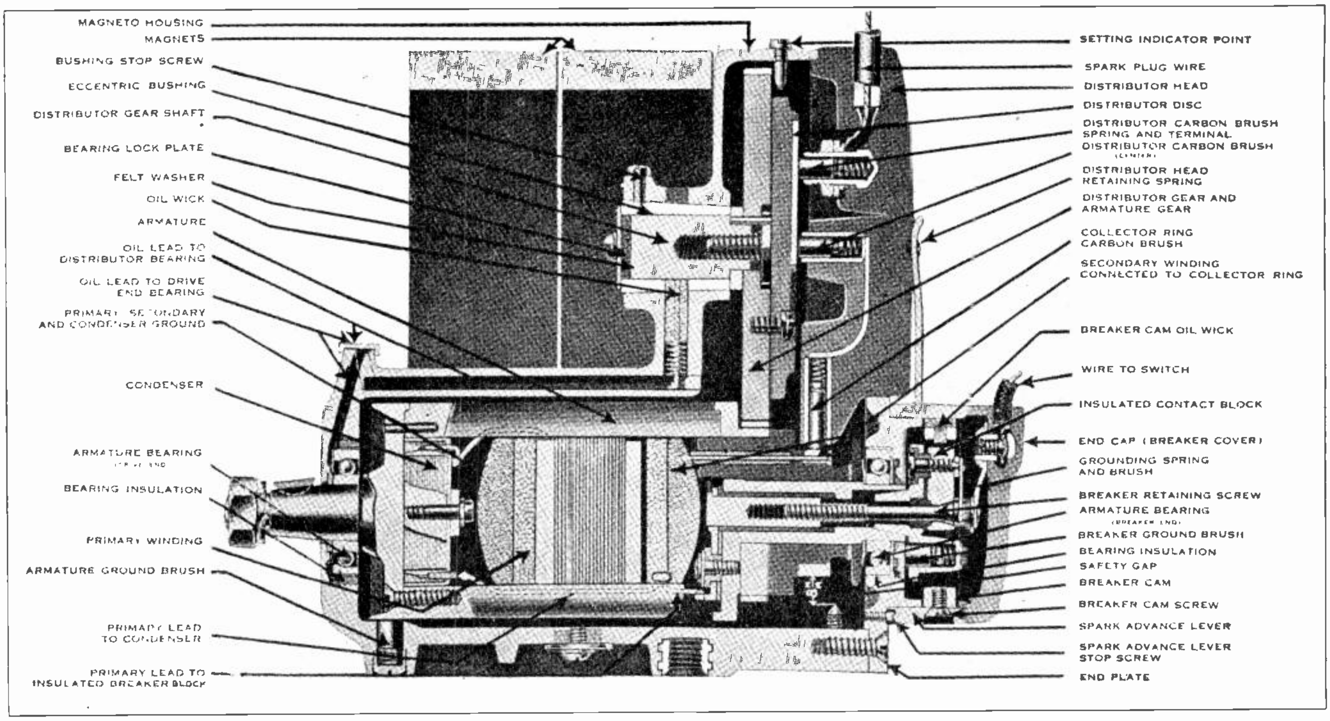


Fig. 53. This excellent sectional view of a magneto shows the arrangement and names of all the important parts. Examine each part very carefully and compare with instruction describing various magneto parts. Courtesy Eisemann Magneto Corp.

followed it may result in cracked collector ring insulation and broken ground brushes.

To reassemble the magneto follow the same procedure in the reverse order. Extreme care should be used not to batter, scratch, or damage any of the finely machined metal parts and not to crack or injure the molded insulation.

When removing field magnets their magnetic circuits should be kept closed by slipping an iron bar or keeper across the pole ends before completely removing them from the pole shoes. This bar should be left on the field magnets as long as they are off the magneto, in order to prevent weakening the poles, which will occur if the magnetic circuit is broken and left open.

Magneto magnets can be easily recharged by means of a powerful electro-magnet operated from a storage battery or other source of D.C. When fully magnetized the average magneto magnet should lift about 20 lbs.

In replacing these magnets be careful to get all like poles on one side. It doesn't matter which side the north or south poles are on as long as all north poles are kept together and south poles together. If some of the poles are reversed the magnetic flux will short directly between adjacent poles and will not pass across the armature gap between the pole pieces. This results in no field or a very weak field across the coils and practically no induction or spark.

Like poles can easily be determined by holding the magnets side by side or end to end in a position so that their poles tend to repel.

Field magnets should not be banged around or handled roughly when they are off the magneto, as such treatment causes them to lose their charge. The armature should also be very carefully handled in order not to damage the insulation on the coils or harm the bearings.

On some magnetos when the distributor gear and shaft are put back in place the end of the shaft may catch upon an oil wick in the lower side of its bearing. This wick can be held down with the end of a screw driver or other slender metal tool inserted in the back end of the bearings while the shaft is pushed in the front end.

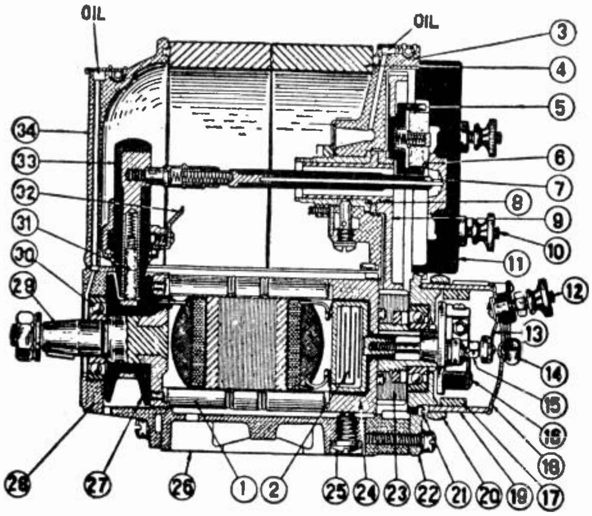
45. MAGNETO TROUBLES AND CARE. RECHARGING FIELD MAGNETS

Some of the common magneto troubles which may be the cause of an engine missing or starting hard, or complete failure of the ignition system, are as follows:

When the field magnets become weak it will cause very poor sparks at low engine speeds and make the engine start hard. The magnets should be removed as previously explained and recharged by holding or rubbing their poles in contact with the poles of a powerful electro-magnet.

Regular magnet chargers can be purchased for this work or a very effective charger can be made by winding about 500 turns of No. 14 magnet wire on each of two soft iron cores about two or three inches in diameter and six inches long and bolting the bottom ends of these cores securely to a soft iron plate to form a keeper for a closed magnetic circuit across their ends. See Fig. 55.

With these coils connected in series in a manner to create unlike poles at the top ends of the electro-



1. Armature wound core
NOTE: Complete armature consists of parts indicated by the following numbers: 29, 1, 2, 24 and 27.
2. Condenser
3. Gear housing
4. Magnet
5. Distributor brush holder
6. Distributor brush
7. Conducting bar
8. Distributor gear bearing
9. Distributor gear
10. Distributor plate terminal screw
11. Distributor plate
12. End cap terminal nut
13. End cap contact spring with brush
14. End cap holding post and spring
15. Interrupter fastening screw
16. Interrupter complete
17. Interrupter cam
18. Magneto end cap
19. Interrupter housing
20. Timing arm
21. Interrupter housing stop screw
22. Rear end plate
23. Armature gear
24. Armature flange—condenser end
25. Grounding brush with holding screw
26. Base plate
27. Collector ring
28. Shaft end plate
29. Driving shaft and flange
30. Ball bearing—either end
31. Collector brush
32. Safety gap electrode
33. Collector brush holder
34. Waterproof hood

NOTE: The numbers given above are for reference only. Do not use these reference numbers when ordering parts.

Fig. 54. Diagram showing sectional view and names of important parts of a magneto of somewhat different type than the one shown in Fig. 53. Courtesy Bosch Magneto Corporation.

magnet and then connected to a six-volt storage battery, a very powerful magnetic field will be set up across the open pole ends.

For added convenience these ends can also have small square pieces of soft iron bolted to them, in order to make a broader surface for the ends of the horseshoe magnets to contact with. If the inner edges of these pole pieces are made 1 to 1½ inches apart and the outer edges from 7 to 8 inches apart, they will accommodate almost any of the ordinary sized magneto magnets.

Care should be taken to place the horseshoe magnet on the charging magnet in the proper position to strengthen the poles it already has, rather than to reverse them and build them up in the opposite direction. The proper polarity can easily be determined by suspending the horseshoe magnet above the electro-magnet when the current is turned on. If the horseshoe magnet is free to turn its poles will be attracted to the proper poles of the electro-magnet.

The charging magnet should be bolted to a bench in a vertical position so that the horseshoe magnet can be rubbed or rocked across the ends of the electro-magnet poles for several seconds with the current turned on.

When removing the magneto magnets from the charger always remember to place the iron keeper or bars across their ends first. A fully-charged magnet should pull about 20 lbs. on an iron bar attached to a small spring scale, as previously mentioned.

During the test and after the magnet poles are in contact with the scale bar, the temporary keeper bar should be removed in order to get maximum pull. It should, however, be placed on the magneto magnet again before removing it from the scale to replace it on the magneto, otherwise a great deal of the charge will be lost.

46. BREAKER TROUBLES

If the breaker points on a magneto are set too close or if they are dirty and not making a good contact, it will probably cause the engine to miss, particularly at low speeds. By means of a thin gauge obtainable for this purpose the breaker points should be kept set to open the proper distance. As previously stated, the maximum gap or opening between these points should be about .014 or .015 of an inch.

The contact surfaces should be kept clean and bright and should meet squarely when they are closed. If the platinum tips or surfaces of the breaker points have been burned off or filed off, the points should be replaced with new ones, because efficient operation cannot be obtained with points that are badly burned or those that have had the contact metal ground away.

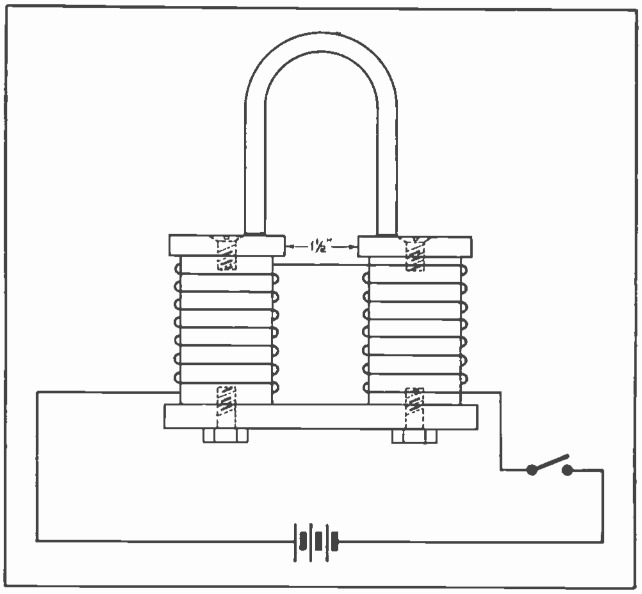


Fig. 55. This sketch shows the method of constructing a simple electro-magnet for recharging field magnets of magnetos.

If the points are only slightly burned or blackened they can be dressed off with fine sandpaper drawn between the contacts when they are pressed lightly together. They can also be dressed or resurfaced with a fine breaker-point file. These files should be carefully used because if not they can do more harm than good.

One should never hold the file rigidly in the hand or attempt to file one contact at a time. Instead, the file should be held between the contacts by pressing them lightly together against the file surfaces. Then draw the file easily back and forth, always allowing its surfaces to align with those of the contacts which are pressed against it.

Sometimes the stationary contact becomes loose or the pivot of the movable arm becomes worn or loose, and either of these will result in faulty ignition. When found in this condition they should be tightened or replaced.

If the spring tension on the movable breaker arm becomes weak or if this arm is allowed to bind on its pivot, the engine will miss at high speed. The correct tension on the breaker arm should be approximately 16 ounces when the contacts are closed. A temporary repair or increase in spring tension may be effected by bending the spring or shortening it until a new one can be obtained.

47. CONDENSER, ARMATURE, SLIP RING, AND DISTRIBUTOR TROUBLES

An open-circuited condenser will generally cause excessive arcing and severe burning of the contacts and greatly reduce the high-tension spark. If the condenser is shorted it will also prevent the magneto operating, because it shorts out the breaker contacts and prevents the opening of the primary circuit.

The only remedy for a condenser that is actually open or grounded inside is to replace it with a new one. A ground in the armature windings due to defective insulation may result in weak ignition and missing, or in complete failure of the engine. Unless the trouble is right in one of the leads or connections of the coils, the best remedy is to replace the magneto armature with a new one.

If the insulating rings or material on each side of the collector ring become oily and dirty it will allow the high voltage to creep over the surface and to ground. In such cases the rings should be carefully washed with gasoline and well dried before being put back in service.

These rings or insulating barriers sometimes become cracked or punctured and in some cases must be replaced with new ones. To remove a damaged ring, first pull the inner bearing race off the armature shaft. Then stand the armature on end with the collector ring down and apply a little alcohol to dissolve the varnish which cements the secondary lead to the ring. Be careful not to drop any alcohol on the winding insulation, as it will ruin it.

When the varnish is soft the secondary lead can easily be removed, after which the ring is pulled off the shaft with a special puller. If such a puller is not available expand the ring by immersing it in hot water, after which it can generally be tapped off with a hammer or sometimes pulled off by hand.

Distributor plates and caps sometimes become dirty or carbonized and should then be carefully washed out with gasoline and dried with a clean cloth. Never use sandpaper to clean blackened surfaces of the distributor plate, as this roughens the surface and makes it collect additional dirt much more rapidly.

The magneto ground brush should always make good contact with the rotating armature, and if it doesn't the armature should be cleaned and a new brush installed when necessary.

Some of the other faults which may cause defective magneto operation and for which the remedies can be clearly seen are: Wrong timing, wrong breaker plate, incorrect meshing of armature and distributor gears, cracked distributor cap, broken distributor brush, worn bearings, wrong direction of rotation of armature, etc.

Magnetos are supposed to operate in one direction only, but the direction of rotation can be reversed if necessary in many magnetos by changing the breaker plate for one made for opposite rotation and resetting the meshing of the armature and distributor gears as previously explained.

It is a good plan to check and clean the distributor and interrupter mechanisms of magnetos and readjust the breaker points after every 1000 miles of operation on trucks and busses, or after every 100 hours of operation on tractors and stationary engines.

Cleaning and adjustment are required more often than this on aeroplane engines where the ignition is extremely important.

At these intervals the magnetos should also receive one or two drops of good light machine oil in each of the oil openings. Be very careful not to oil them excessively because too much oil is very often the cause of magneto trouble due to damaged insulation or collection of excessive dirt.

48. STARTING MOTORS

One of the greatest conveniences provided by electricity on the modern automobile is the electric starter which eliminates the necessity of cranking the engine by hand as with former types of cars. The electric starter which turns the engine over at a mere touch of the starting switch is so much quicker, safer, and more convenient that everyone wants their starter to be in good condition at all times.

Electric starters are very rugged and simple devices, and do not often get out of order, but there are a few simple faults which do occasionally occur that interfere with their proper operation. These troubles can be easily corrected by an experienced service man.

As it requires considerable torque to turn the automobile engine over rapidly when starting, and particularly when the oil is cold and stiff, series motors are used for this work. You have already learned that series motors have an excellent starting torque characteristic. The series D.C. motors used for automobile starters are constructed and operated on the same general principles as those you have already covered in the D.C. Power Sections of this Set.

The principal difference between power motors and those used for starting automobiles is that the automobile starting motor is smaller and is designed for operation on 6 or 12 volts.

Fig. 56 shows a starting motor with the brushes and a commutator on the right end and the driving pinion that meshes with the flywheel gear of the engine on the left end.

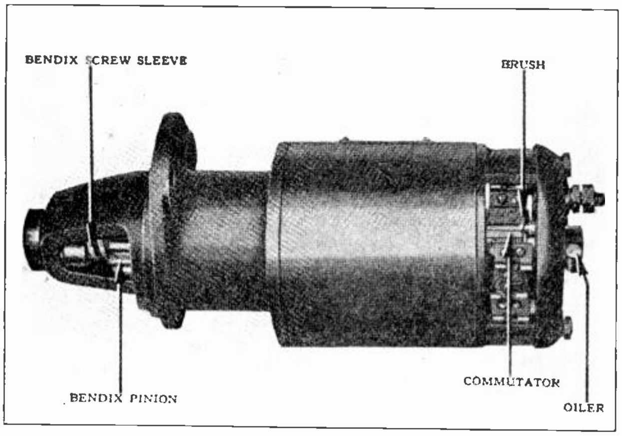


Fig. 56. Photo of common type of automobile starting motor, the commutator and brushes shown on the right and driving pinion on the left.

Fig. 57 shows the location of the starting motor mounted on the engine near the right-hand end, near the flywheel. In this view you will note that the starting motor housing is bolted securely to the flywheel housing. The shaft and driving pinion of the starting motor project through into the flywheel housing to mesh with the teeth of the flywheel gear and turn the engine over when the starting motor switch is closed. The switch in this case is mounted on top of the starting motor where it is operated by a small lever and a pedal which projects through the floorboard of the car.

Starting motors consist of the following principal parts:

1. Cylindrical field frame.
2. Armature.
3. Brushes and brush rigging.
4. End plates in which the bearings are supported.
5. Mechanism used to connect and disconnect the motor armature to the engine flywheel.

As starting motors operate on very low voltage and require heavy currents, both their armatures and fields are wound with very heavy conductors,

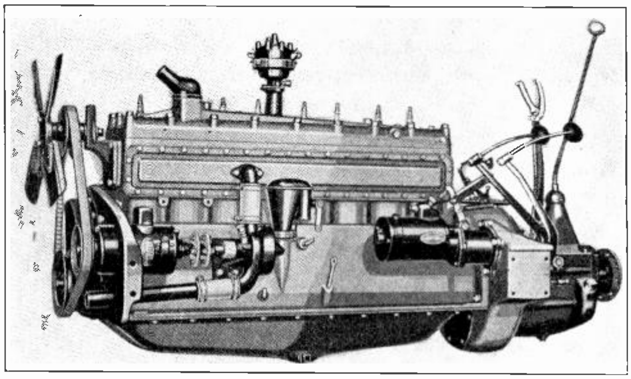


Fig. 57. Side view of an eight-cylinder Studebaker engine showing location of starting motor attached to the flywheel housing on the right.

generally in the form of copper bars or strips. This makes their construction very rugged and tends to eliminate troubles due to short circuits, grounds, and defective insulation which occur more frequently with smaller insulated wires.

The commutator and brushes of starting motors, however, are necessarily rather small and are sometimes sources of trouble on account of the very heavy currents they are required to carry.

Starting motors are made to develop from approximately one-half to one horse power, according to the size of the automobile engine they are to operate. At six volts this results in very heavy operating currents ranging from 100 to 200 amperes when the starter is turning the engine over at about 125 RPM.

During the first instant of operation, however, when the starter is just getting the engine in motion starting currents may run as high as 400 or 500 amperes for a fraction of a second.

From this we can see the necessity of having tight connections and a good low-resistance circuit from the battery to the starter, and through the brushes and windings of the starter itself.

Fig. 58 shows a simple circuit-diagram of the field and armature connections of a series starting motor of the four-pole type. You will note that the motor only has one connection terminal, which is

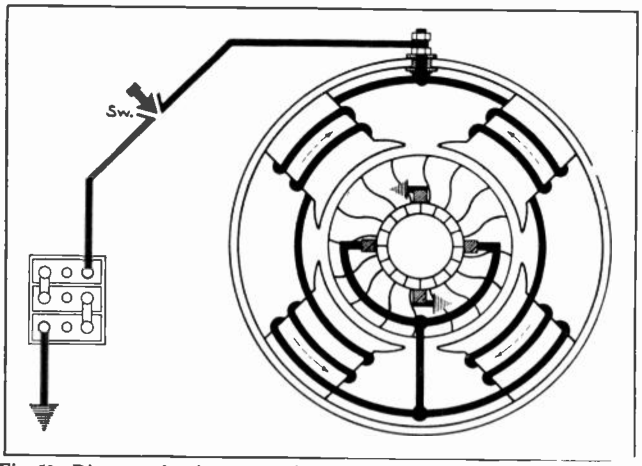


Fig. 58. Diagram showing connections of series wound automobile starting motor. Carefully trace the circuit from the battery through the switch, field coils, armature, and from the grounded brushes back to the battery.

insulated from the frame and feeds the battery current through the field coils and armature in series. Two of the brushes are grounded, thus giving the armature current its return to the other side of the battery, which is also grounded.

The upper view in Fig. 59 shows the commutator end of a starting motor with the cover and brush-holder mechanism removed. Note the arrangement of the brushes, one set of which is grounded to the metal cover, and also note the heavy armature bar conductors attached to the commutator. The large leads projecting from the field frame are those of the series field coils. The insulated connection terminal by means of which the heavy starter cable is attached to the motor can be seen on the lower left corner of the field frame.

In the lower view the opposite end of the starter is shown, and the heavy armature conductors can again be seen projecting from the frame. This view also shows the special pinion and coupling arrangement by which the starting motor is connected to the engine flywheel.

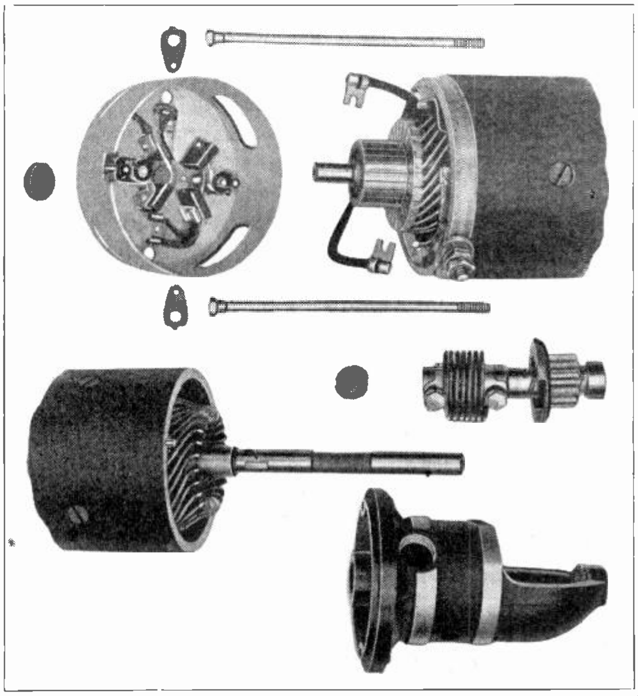


Fig. 59. Disassembled view of a starting motor showing commutator end and brushes above, and drive end with Bendix drive and pinion below.

49. BENDIX DRIVE FOR STARTERS

When the electric starter on an automobile is brought into use it must momentarily connect with the engine flywheel in order to turn the engine, but as soon as the engine is started and running under its own power, the starter must be immediately disconnected, or it would otherwise be driven at an excessive speed, because of the high gear ratio between the starter and the engine flywheel.

This gear ratio is generally about 15 to 1 and enables the starter to crank the engine at a speed of about 125 RPM. When the engine is running under its own power, however, the normal speed will range from 500 to 3500 RPM, which you can readily see would drive the starter at a terrific rate if it were left connected to the flywheel.

To avoid this requires some form of device which will automatically and reliably connect the starting motor to the engine flywheel when it is desired to start the engine, and quickly disconnect it as soon as the engine begins to run under its own power.

One of the most popular arrangements developed for this purpose is known as the **Bendix drive,** which is shown in Fig. 60. This device connects to the end of the starter armature and consists of a coarsely threaded sleeve mounted on the end of the armature shaft, a small gear or pinion which has threads cut in its inner surface to correspond with those on the sleeve over which the pinion fits, a strong coil spring, and the necessary studs to attach the assembly to the drive head.

Fig. 61 shows a sectional view photo of a starting motor with the Bendix drive attached to its armature. Keep in mind that the drive head or left end of this Bendix drive is rigidly attached to the armature shaft and the rest of the assembly is driven through the coil spring.

When current is sent through the motor by pressing the starter switch, the armature almost immediately goes up to a speed of about 4,000 r.p.m. As the small gear has a certain amount of weight its inertia, tends to prevent its accelerating with the

Fig. 60. Photograph view of Bendix drive mechanism showing spring, sleeve, and pinion.

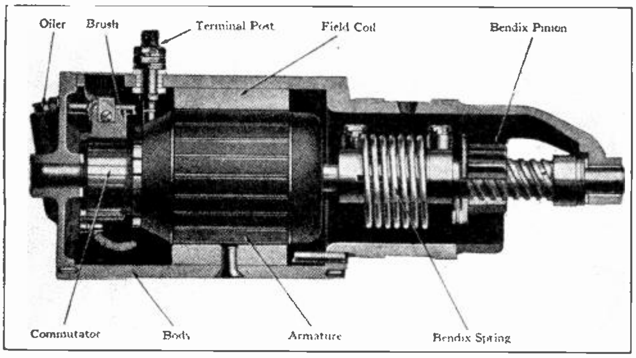


Fig. 61. Sectional view of an automobile starting motor showing commutator and brushes on the left and Bendix drive on the right. Examine this figure carefully while reading the explaining paragraphs.

motor, and as it is loose on the threaded sleeve it tends to turn slower than the sleeve, which causes the threads to force it outward to engage the teeth of the flywheel. The coil spring then absorbs the shock as the motor starts to crank the engine.

As soon as the engine starts to run under its own power the speed of the flywheel tends to exceed that of the starter gear and causes it to revolve faster than the drive sleeve, so that the threads force the gear back toward the starting motor and out of mesh with the flywheel teeth.

To avoid the possibility of the small pinion or gear revolving and creeping along the threaded sleeve due to car vibration and thus possibly engaging the flywheel when the engine is running, the gear has attached to it a flange one side of which is much heavier than the other. This heavy side tends to hang downward and prevents the gear from revolving except when the starting motor operates it.

In addition to this weighted flange, an added precaution is provided in the form of a small stop pin which can be seen in the lower edge of the flange in Fig. 61.

When the pinion gear is thrown to the idle position this little pin is forced by a light spring into a shallow groove in the driving head, thus holding the gear in this retarded position.

Two of the great advantages of the Bendix drive are its very simple construction and the fact that it allows the starting motor to come up to full speed before connecting it to the engine, thus giving the motor a tremendous "break away" or initial starting torque to crank the engine.

50. MANUAL PINION SHIFTS

Another method that is quite commonly used for engaging the starter pinion with the flywheel gear is known as the **manual shift.** With this system the pinion is attached to the starter pedal by a lever arrangement which, during the first downward movement of the starter pedal shoves the pinion into mesh with the flywheel gear.

Further movement of the pedal operates the starter switch, starting the motor and cranking the engine. Just as soon as the engine starts the foot should be removed from the pedal to allow the strong spring which returns the pedal to normal position to also withdraw the pinion from the flywheel gear.

Starters of this type generally also have in the pinion a form of slipping clutch arrangement which will prevent the motor from rotating at excessive speeds in case the pinion should stick or jam in the meshed position when the engine starts.

Fig. 62 shows a starter with the manual-type shift mounted on the transmission of an engine and with a section of the flywheel casing cut away to show the manner in which the gears are meshed. Note attached to the starter pedal the lever which first moves the small gear into place and then presses the starter switch, which is located on top of the motor.

Fig. 63 shows a starting switch of the foot-operated type for mounting in the floorboard of the car. The connections from the battery to the starting switch, and also from the starting switch to the terminal of the starting motor, are made with heavy stranded copper cable which is equipped with soldered lugs to secure low-resistance connections to the battery, switch, and motor terminals.

It is very important to see that the lugs of this starter cable are well soldered to the conductor, and that they are securely tightened to all terminal connections. When you consider that it is necessary for the 6-volt battery to send several hundred amperes through this circuit, you can readily see that the slightest amount of looseness in these terminal connections, or even a thin layer of dirt or corrosion at such terminals, would create enough resistance to greatly interfere with efficient starter operation. Even a small fraction of an ohm would cause too much voltage drop at the starter. For example, 1/50 of an ohm in a circuit carrying 200 amperes would cause a voltage drop of 1/50 x 200, or

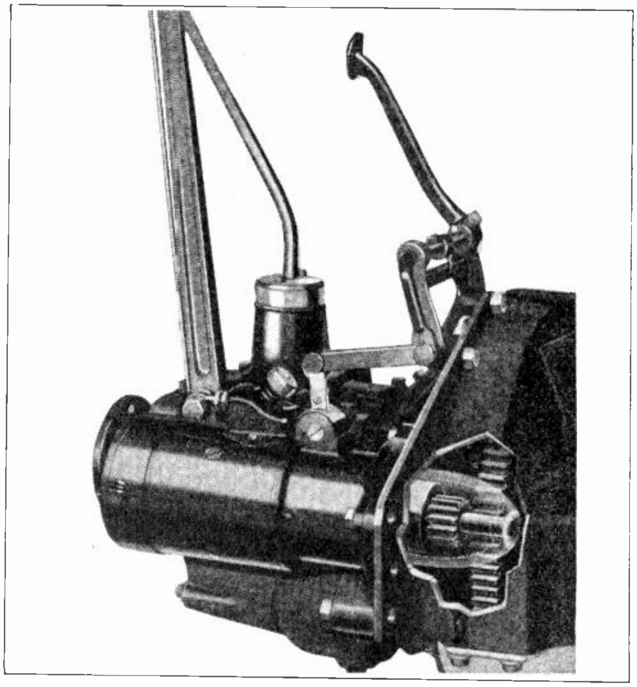


Fig. 62. This view shows method of meshing the starter pinion with the flywheel gear by means of the starter pedal which operates both the gear and starter switch.

4 volts, thus leaving only 2 volts effective pressure at the starter brushes.

For this same reason it is very important to keep the contacts of the starting switch clean and in good condition and the switch properly operating, to avoid unnecessary resistance at this point. These contacts sometimes become burned and pitted, due to making and breaking the heavy current circuit, and they then require scraping and polishing to provide a bright, new surface.

51. STARTER TROUBLES AND REMEDIES

Because of the very rugged electrical construction of starting motors, troubles of an electrical nature are not very often encountered within the motor itself. In most cases electrical troubles will be found to be at the commutator, brushes, brush holders, or leads. This fact should be kept well in mind by the trouble shooter or ignition service man.

When the starting motor gives trouble, it is generally in the form of low cranking torque or complete failure of the motor. It should be kept in mind that satisfactory operation of the starter depends not only on the condition of the motor itself, but also on the condition of the battery, connecting cables, and starter switch, and one should carefully check each of these items before spending the time necessary to remove the starting motor for thorough inspection or overhauling.

52. LOW VOLTAGE AT STARTING MOTOR

If the starting motor fails to crank the engine properly, a good test to determine the cause of the trouble is to switch on the lights and press the starter pedal. If the lights are extinguished when the starter switch is closed, the trouble is generally due to a loose or dirty connection in the starter circuit. Carefully check the battery terminals, cell connectors, and ground connection.

To help locate the trouble, hold the starter switch closed for about one-half a minute and this will cause the loose connection to heat up so that it can be readily located by feeling along the different parts of the circuit with the hand.

If the lights gradually dim down and go out when the starter switch is closed, this generally indicates a dead battery. The battery should be removed from the car and tested with a high rate discharge test, which will be explained later in the Battery Section.

53. MECHANICAL TROUBLES

If, when the starter switch is closed, the lights dim slightly, but do not go out, it generally indicates mechanical trouble, which may be either in the engine or the starter and is causing an overload on the starting motor. Crank the engine by hand to see if it is unusually tight, as might be the result of cold, heavy oil, tight bearings, etc.

Sometimes the starter pinion becomes jammed or locked just as it starts to mesh with the flywheel gear. The pinion can usually be released by putting the car in high gear and rocking it back and forth to disengage the pinion. If none of these troubles seem to be present, then remove the starting motor and check it for a bent armature shaft or loose bearings.

Sometimes the starter may stick because of loose bearings which allow the armature to rub the pole pieces and lock magnetically when current is applied.

If, when the starter switch is pressed, the lights do not dim at all, there is probably an open somewhere in the starter circuit. This trouble will generally be found at the starter switch or at a loose cable connection, or sometimes at brushes stuck in the brush holders so that they do not rest upon the commutator. An extremely dirty commutator or brushes may also give this indication.

If the starting motor operates and spins at high speed without cranking the engine, it may be due to hardened or gummed oil on the Bendix sleeve which prevents the pinion from traveling into mesh with the flywheel gear. Washing off the threaded sleeve and parts with a brush and gasoline will generally cure this trouble.

Sometimes the Bendix spring or studs become broken or there may be several teeth broken out of the flywheel, thus preventing the starter pinion from meshing at a certain point. If the starter uses a manual pinion shift, check carefully for disconnections or excessive play in the pedal rods or levers.

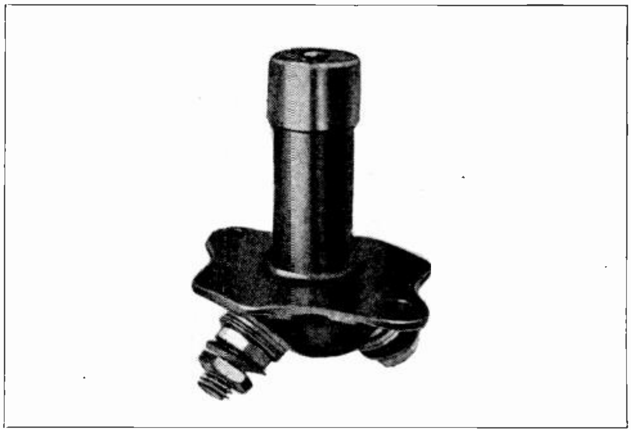


Fig. 63. Starter switch for mounting on the floorboard and connecting in series with the lead from the battery to the starting motor.

If, when the starter is operated. a loud clashing or banging noise occurs when the pinion meshes with the flywheel, check the bolts that hold the starter to the flywheel housing to see that they are tight. If this doesn't remedy the trouble, move the starter and examine the teeth on the flywheel gear.

The edges of the teeth on both the flywheel and pinion gears are beveled to allow them to engage with each other easily. If these teeth are badly burred, due to rotating with only the entering edges meshed, noisy starter operation will result. This condition can only be remedied by replacing the gears.

Burred teeth are generally caused by improper alignment of the pinion, which may be due to a bent armature shaft, worn starter bearings, or loose starter. Clashing may also be caused at times by the threaded Bendix sleeve sticking or "freezing" to the armature shaft, and thus preventing the slight lateral movement which is necessary for silent gear meshing.

To correct this trouble, the Bendix drive should be removed and disassembled and the armature shaft carefully polished with fine emery cloth. Any rust should also be removed from the inside of the Bendix sleeve. Then apply a little light oil and reassemble.

When the starting motor cranks the engine very slowly, the trouble may be due to short circuits or high-resistance connections in the motor, or loose connections and high resistance at the starter switch or cable. If the switch gets hot, remove it and look for burned contacts. Also inspect the switch for possible defects in the insulation. Examine the starter cable carefully for loose connections or for damaged insulation where it rubs against the car frame and may have become grounded.

The starting motor should be carefully checked for poor brush contact, weak brush-spring tension, dirty commutator or brushes, or unsoldered field or armature connections.

If the trouble is still not located, the armature, field, and brushes can be tested for grounds. A weak battery may also cause the starter to crank the engine very slowly.

53. ELECTRICAL AND MECHANICAL TROUBLES IN MOTOR

If no trouble can be located at the battery, starting switch, or cable and there appears to be electrical trouble within the starting motor, it should be taken apart and carefully examined for both mechanical and electrical defects, such as the following:

Armature rubbing on the pole shoes, worn bearings, bent shaft, broken brushes or brushes stuck in the brush holders, loose connections to the brushes or field coils, grounded cable terminal, poor brush-spring tension, loose connections between commutator bars and armature leads due to solder having been melted and thrown out of the commutator risers, high resistance in the field circuit caused by solder melting and running out of the joints between field coils, etc.

Always remember that anything that increases the resistance of the motor or its circuit will greatly decrease its torque. The mistake that is sometimes made by inexperienced or untrained automobile service men is that of replacing worn starter brushes with brushes of the wrong grade or material.

In order to be of sufficiently low resistance, the brushes for starting motors are made of carbon and powdered copper, the copper content being the greater portion of the material used in these brushes. If these brushes are replaced with ordinary carbon or carbon graphite brushes, their resistance will be altogether too high for use on such heavy currents at low voltage.

Sometimes wrong brushes of this type become red-hot when the starting motor circuit is closed, but they will not allow enough current to flow to start the engine.

You are already familiar with the methods of testing field coils or armature windings for grounds, shorts, opens, etc., as covered in the Sections on Armature Winding and Motor Repairs.

An ordinary 110-volt test lamp can be used very conveniently for checking for these faults on starting motors. The brush holders should also be checked to see that those which are supposed to be insulated have not become grounded to the starting motor frame.

After a starting motor has been repaired and overhauled it can be thoroughly tested before it is replaced on the car by means of a regular garage test bench such as is used in most medium and large-sized garages or automotive electrical service stations.

On these benches the starting motor is securely clamped in a special vise and a spring scale and lever arrangement are attached to the shaft to measure its torque when battery voltage is applied.

While in the Automotive Department of your shop course, be sure to get plenty of actual practice in overhauling, repairing, and testing starting motors, and in the use of test bench equipment.

54. AUTOMOTIVE GENERATORS

As stated in an earlier article in this section, the generator is a very important piece of the electrical equipment on a modern automobile. With the extensive use of electric current for lights, ignition, horn, starting motor, and various other purposes, any ordinary-sized battery would soon become discharged if there were no means for supplying it with current.

The length of the battery discharge could, of course, be prolonged by using batteries of larger sizes, but as this would add considerable weight and additional expense, it is much more practical to equip each car with a small low-voltage D. C. generator to keep the battery charged, and also to supply the current for various uses and prevent drain on the battery when the engine is running at normal speed.

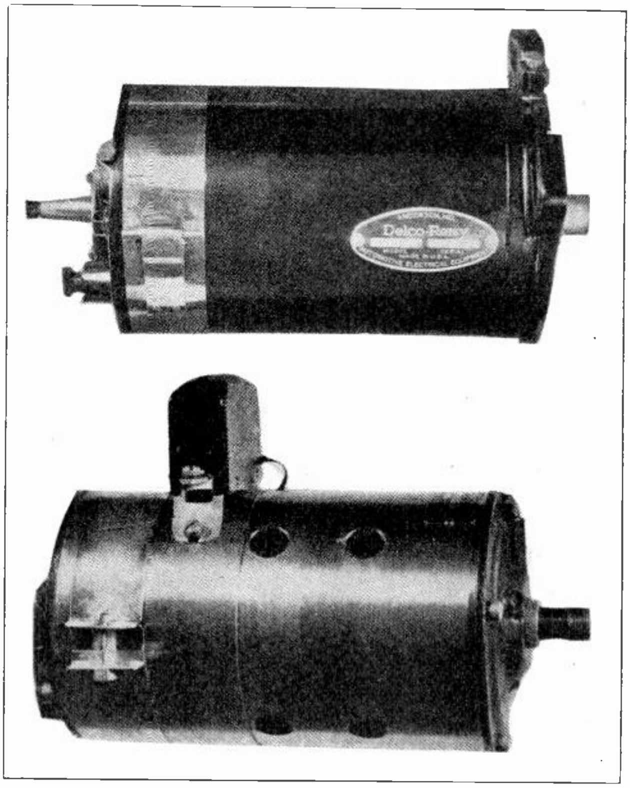


Fig. 64. Photograph views of two types of automobile generators. Note the metal band on the left end of each generator which can be removed for access to the brushes and commutator. Also note the cut-out mounted on top of the generator.

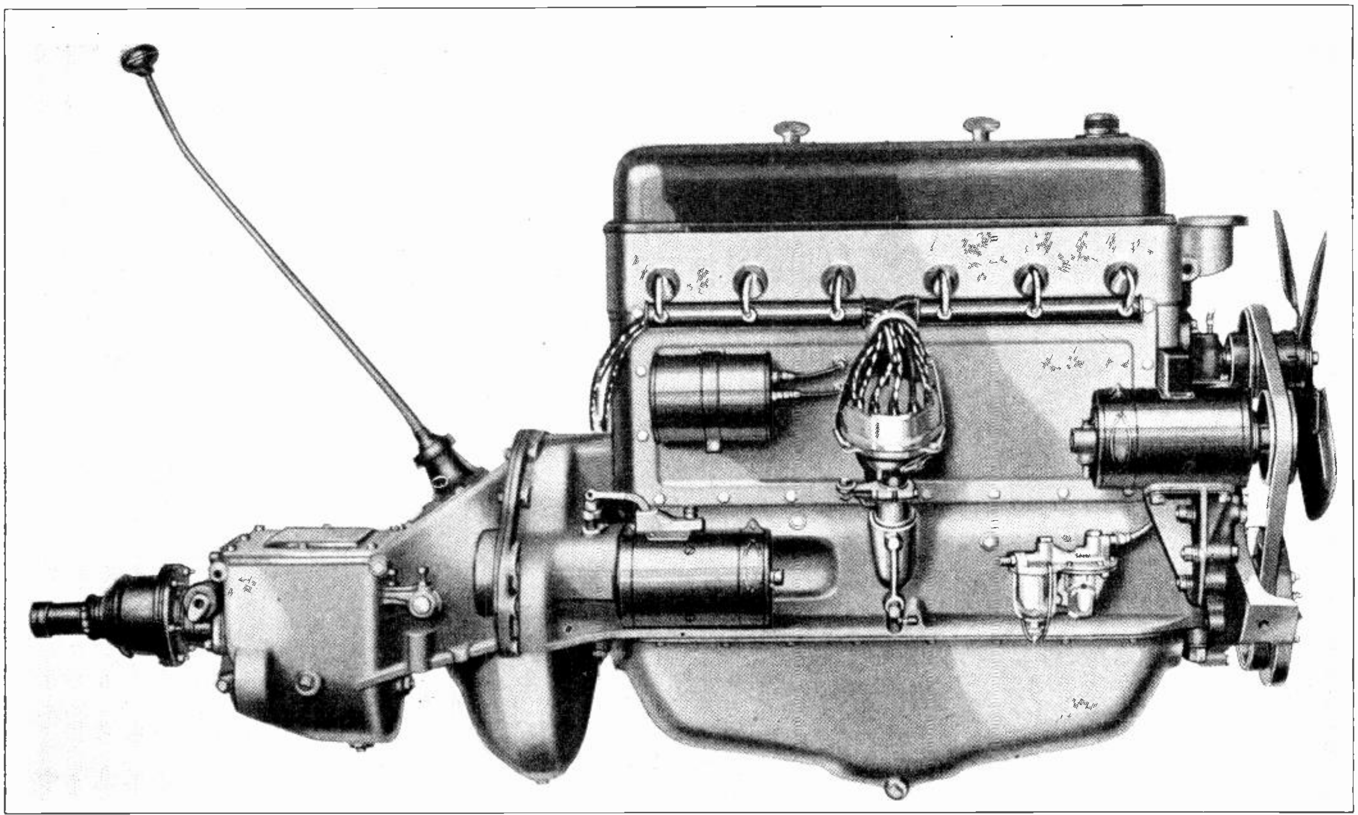


Fig. 65. Side view of a six-cylinder Nash engine showing the location of the starting motor, generator, double ignition distributor, and fuel pump. Note the generator driving belt which drives both the generator and fan.

For this purpose a small shunt-wound D. C. generator is connected to the engine by means of a chain, belt, or gear, and is driven at a speed of about one and a half times engine speed, producing from 6 to 8 volts within the normal speed range of the engine.

Fig. 64 shows two very common types of automobile generators, and Fig. 65 shows a generator attached to a bracket and mounted upon the engine at the right-hand end. In this figure you will note the 'V" belt used to drive the generator and fan.

The general construction and operating principles of D. C. generators have been thoroughly covered in the previous section on D. C. power equipment, and the principles of automobile generators are very much the same. Because of the peculiar conditions under which they operate, however, there are certain special features in their design that are very important and interesting to consider.

For example, a generator must be capable of rotating at very high speeds without injury, as it may often be revolved at speeds of 6,000 r.p.m. or over. Another special feature is the very interesting voltage control, which has been developed to enable the generator to produce high enough voltage to charge the battery and supply current when the car is operating at comparatively low speeds and yet prevent the generator from developing excessive voltage and charging currents at high speeds. When we consider that it is desired to have the generator commence charging the battery at a speed of about 12 miles per hour and yet not charge excessively or develop too high voltage at speeds of even 60 or 70 miles an hour, this voltage regulation is quite an accomplishment.

Another feature of the automobile generator is the convenient means provided for adjusting or changing the charging rate so that it can be set to suit various driving conditions.

55. THIRD BRUSH REGULATION

One of the most commonly used and popular types of automobile generators which fulfills the above requirements is known as the "third brush" type, because it uses a small third or auxiliary brush to regulate the voltage at different speeds.

This brush is connected to one end of the field winding and is placed in such a position on the commutator that it tends to decrease the field voltage and current when the generator speed increases, and so prevents the armature voltage and current from rising above the limit for which the brush is set.

The location and connection of this third brush is shown in Fig. 66.

You have already learned in an earlier section on D. C. motors and generators that when the armature windings are carrying current there is set up around them a strong magnetic field which tends to distort the lines from the field poles, and cause the pole flux to shift around the pole faces in the direction of rotation. This armature reaction results in weakening the flux at one pole tip and strengthening it at the other, as shown at Fig. 66.

In this diagram the coils A to G are under one field pole and will have generated in them a voltage propor-

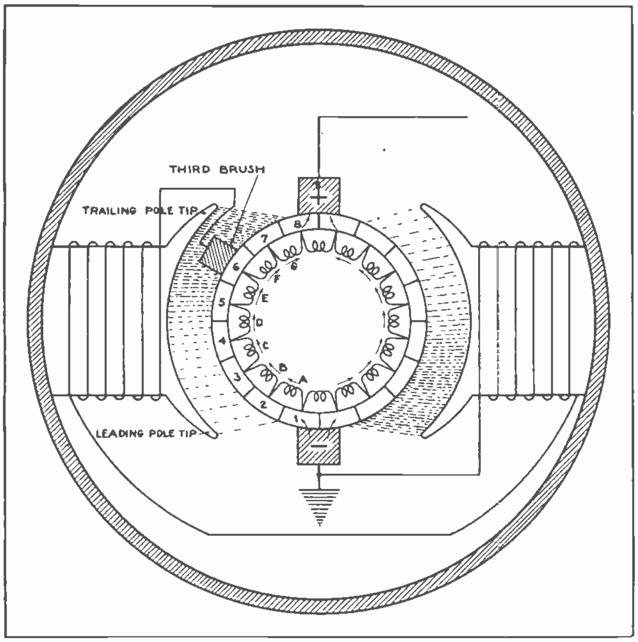


Fig. 66. Diagram showing the armature reaction, field distortion, and principles of third brush voltage regulation on an automobile generator.

tional to the speed at which they are rotated and to the strength of the magnetic field of the generator. Assuming that each coil generates 1 volt, the voltage between adjacent commutator bars will be 1 volt; and the voltage between the main brushes will be the sum of the voltages generated in the separate coils in one side of the winding, or in this case 7 volts.

Note that the two sides of the armature winding form two parallel paths from the negative to positive brush. With a pressure of 1 volt between bars, the voltage applied to the field coils which are connected between the negative brush and third brush will be 5 volts.

This voltage doesn't remain constant, but varies with the shifting of the field flux due to the change of current load in the armature conductors. For example, if the armature develops a certain voltage and delivers a current of 10 amperes at a speed of about 1,800 r.p.m., then if the speed is increased the voltage and current will tend to increase.

A slight increase in the armature current increases the field distortion, moving the more dense field flux farther toward the pole tips. This weakens the field through which coils A, B, C, D, and E are moving thus reducing the voltage applied to the field, cutting down the total generator field strength, and tending to prevent the voltage at the main brushes from rising in proportion with the increase of speed.

In actual practice this third brush method of voltage regulation allows the charging rate to gradually increase up to generator speeds of about 1,800 r.p.m., at which point the correct relation between armature current and field voltage is obtained. From this point the charging rate gradually falls off as the speed is increased above this limit. This is generally a desirable feature, particularly in the summer time, when the car may often be operated for long periods at high speeds, as it protects the battery from being overcharged and the generator from overheating.

As the voltage applied to the field varies immediately with any change of generator speed and armature current, resulting in a change of field distortion, this regulation is entirely automatic and maintains a fairly steady voltage even with sudden variations in the engine speed.

56. ADJUSTING CHARGING RATE

To adjust the charging rate of a generator of this type, all that is necessary is to slightly shift the position of the third brush on the commutator to include more or less bars between it and the negative brush.

You can readily see that if the third brush in Fig. 66 were shifted farther to the right it would include more armature coils in the field circuit and supply higher voltage to the field, thus causing the generator to develop higher armature voltage at the main brushes and increase the charging rate.

On the other hand, if the brush were shifted to the left to cut out part of the winding between it and the negative brush, there would be less voltage applied to the field coils, and the generator voltage and charging rate would be decreased.

The third brush is generally arranged with a set screw which normally holds it securely in one position, but which can be loosened to allow the brush to be shifted, either by lightly tapping against the holder with a screwdriver or by the adjustment of an auxiliary shifting screw. This provides a convenient method of increasing the charging rate during winter months when the engine starts hard, due to cold, stiff oil and therefore requires considerably more starting current. This is also the season when the daylight hours are

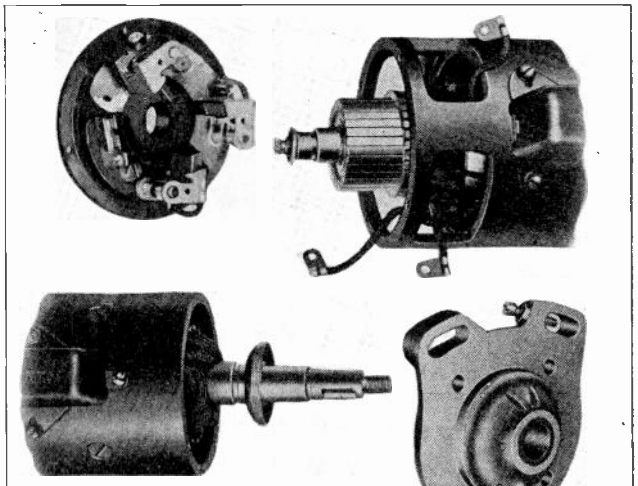


Fig. 67. Disassembled view of an automobile generator showing commutator and brushes above, drive end of generator in the center, and small views of field coils and armature below.

shorter and the headlights are used a great deal more on an average.

In the summer time, to prevent overcharging the battery, the generator charging rate should be cut down by adjusting the third brush. This is particularly true when the car is being used on long trips at high speeds, as the battery would otherwise be overcharged and overheated, and the generator would also tend to overheat due to the continuous high operating current through its armature.

It is important to know by merely looking at the generator in which direction to shift the third brush. To **increase the charging rate,** the brush should be shifted **in the direction of rotation** of the commutator, and **to decrease the charging rate** the brush should be shifted in the **direction opposite to that of commutator rotation.**

The upper view in Fig. 67 shows the commutator end of an automobile generator with the end-plate and brush rigging removed. The two large brushes placed at right angles to each other are the main brushes and the smaller brush is the third brush, or voltage regulating brush.

The center view in this figure shows the opposite end of the generator, opened up to show the end of the armature winding and the drive shaft by which the unit is coupled to the **engine.**

At the bottom of this figure are shown four field coils and an armature completely removed from the generator frame.

Fig. 68 shows a set of curves which indicate the variations in voltage and current at different engine speeds and for generators operating both cold and hot. Note the difference in the operating current due to the increased resistance of the generator windings after the unit has been operating for some time and is warmed up.

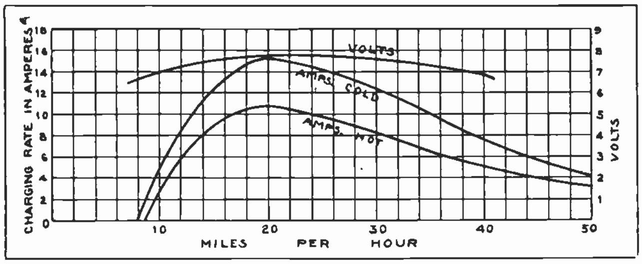


Fig. 68. These curves show the variation in generator voltage and charging current with changes of car speed and variations in generator temperature.

57. GENERATOR CUT-OUTS

In order to prevent the battery discharging back through the generator when the engine speed falls too low to allow the generator to develop a voltage equal to that of the battery, a device known as a **reverse current cut-out** is commonly used.

This device is simply a magnetically operated switch or relay equipped with both a series and shunt winding and a set of contacts, as shown in Fig. 69. The cut-out is generally mounted on top of the generator, as shown in Fig. 69 and also on the photographic view of the lower generator in Fig. 64.

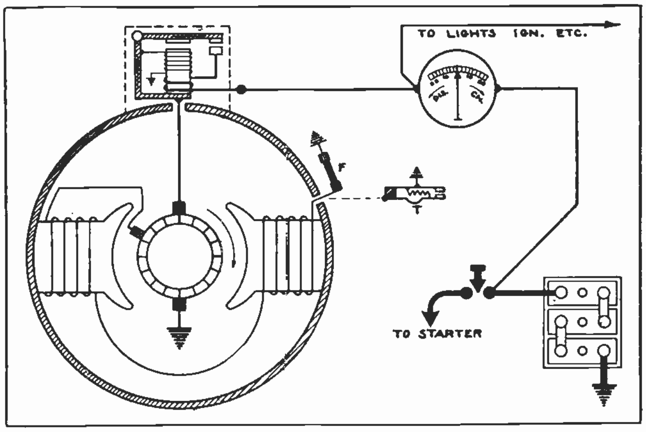


Fig. 69. This diagram shows the connection of an automobile generator and complete charging circuit, including the cut-out, ammeter, battery and field protective devices.

The shunt winding consists of a good many turns of fine wire and is connected directly across the main generator brushes, as can be noted by carefully tracing the circuit from the top brush of the generator in Fig. 69 up through the cut-out frame and shunt coil to ground, by which it returns to the lower brush of the generator. This means that the strength of the shunt coil will always be proportional to the voltage output of the generator.

When the generator voltage rises to about 7 volts the shunt coil becomes strong enough to magnetize the core and attract the armature, closing the contacts in the charging circuits through the ammeter to the battery. This charging current flows through the series coil consisting of a few turns of heavy wire, and this coil is wound so that the current flows in the same direction as through the shunt coil, thus adding the magnetic strength of the series coil to that of the shunt coil and holding the contacts firmly closed.

Whenever the generator speed falls below a certain value, its voltage drops below that of the battery and the battery commences to discharge back through it. This discharge current flowing through the series coil in the opposite direction sets up a magnetic field which opposes that of the shunt coil and demagnetizes the core, allowing the spring to pull the armature back and open the contacts.

A reverse current or discharge current of not over 2 amperes should be sufficient to release the cut-out contacts. These cut-outs not only prevent the battery from discharging through the generator at low speeds, but also prevent the generator from being overheated and burned out in case the engine was stopped and the battery discharged a heavy flow of current through the generator armature in an attempt to motorize the generator, which, of course, is connected rigidly to the engine and cannot be turned because of insufficient torque to rotate the engine.

Fig. 70 shows two types of cut-outs, one with the cover removed showing the coil and contacts.

By referring to Fig. 69 again you will note that the ammeter is connected in series with the generator and the battery so that it will register the current flowing to the battery by a movement of the needle over the side of the scale marked "Charge." This instrument will also register the flow of current out of the battery whenever the battery is discharging through the lights and other equipment.

The ammeter should always be observed when looking for battery or generator troubles, because it gives a good indication of possible reasons for the battery being discharged or overcharged due to too low or too high charging rates, and will also indicate sticking contacts in the cut-out by showing a very heavy discharge when the engine is stopped. Note that the starter connection is taken off the battery in such a manner that this very heavy current doesn't flow through the ammeter.

58. FIELD PROTECTION

Since the third-brush generator depends upon the current flowing through the armature to produce the field distortion necessary for voltage regulation, we can readily see that if the charging current were interrupted it would entirely destroy the regulating action of the generator.

In fact, if the battery becomes disconnected or the charging circuit open, the generator voltage may rise to 30 or 40 volts, because of insufficient current flowing through the armature to distort the field and keep the voltage reduced in those coils between the third brush and the grounded main brush.

With the field flux in a normal, evenly-distributed position over the pole face these coils would generate much higher voltage, excite the field much more strongly, and allow the generator to develop sufficient voltage to quickly burn out the field coils.

To prevent this, field protection is generally provided either in the form of a fuse or a thermostatic cut-out placed in series with the field windings.

In Fig. 69 the fuse is shown at "F" in the grounded field lead.

If the field current rises above the normal value of approximately 5 amperes this fuse will blow and the generator will become dead. Another method of field protection and one that is rapidly replacing the fuse for this purpose is the **thermostatic cut-out,** such as shown at "T" in Fig. 69.

These devices consist of simply a set of contact points, a small resistance, and a spring-like blade made of two dissimilar metals welded together so that when they become overheated they warp in a manner with which you are already familiar.

With this thermostat connected as shown by the dotted lines to the field terminal, in place of the fuse, whenever an excessive current flows through the generator its temperature increases and the strip becomes heated and warps, opening the contacts and thus inserting the small resistance in the field circuit and reducing the charging rate about 40%.

As soon as the temperature in the generator drops enough to allow the strips to cool off the contacts automatically close and bring the generator back into normal operating condition. This device is also a precaution against the generator overheating.

For maximum life of the generator insulation the temperature inside the unit should not exceed 180° F., so the thermostat is designed to open the cut-out points at this temperature and thus reduce the charging rate by inserting resistance in the field.

When the generator cools off again the contacts close and allow the charging current to again rise to normal value. We can see, therefore, that the thermostatic cut-out not only protects the field winding from burning out due to excessive voltage, but also protects the generator against overheating due to heavy charging currents and high engine temperatures.

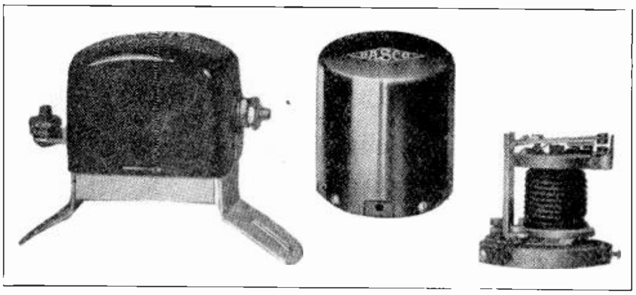


Fig. 70. This view shows two types of generator cut-outs and the one on the right has a cover removed showing the coil and contacts.

59. GENERATOR TROUBLES AND REMEDIES

The generating circuit consists of a generator, cut-out, ammeter, and battery, and the wires which connect these units together. So whenever the battery doesn't charge properly the trouble may be in any of these devices or wires of this circuit.

Normally the generator begins charging the battery at a car speed of about 12 miles per hour and reaches its maximum output at about 25 miles per hour. If the battery doesn't charge properly or the generator performance is not satisfactory the generating system should be checked over until the trouble is found and remedied.

Some of the more common troubles encountered are as follows:

If the generator doesn't charge at any speed it may be due to faults in the generator itself or to a defective cut-out, open circuits or grounds somewhat in the charging circuit, or defective drive where the generator connects to the engine.

A good place to start tracing the trouble is at the cut-out. Remove the insulated wire from the cut-out and touch it to the car frame or engine. If a flash results there is no break or opening in the charging circuit, but if no flash is obtained the circuit should be checked for loose or broken wires.

If the circuit is O. K. start the engine and remove the cut-out cover, and see if the contacts close when the engine is accelerated. If they do not, close them by hand and if the generator then charges the battery the cut-out must be defective.

Quite often the shunt winding will be found to be burned out and in this case the cut-out should be replaced with a new one.

If with the engine running at moderate speed the generator doesn't charge after the cut-out contacts are closed by hand remove the cut-out from the circuit and connect the generator directly to the battery. If the generator now charges there must be a ground in the cut-out and this unit should be replaced or repaired.

Sometimes the cut-out contacts may be found burned or dirty so that they do not close the charging circuit to the battery. In this case they should be carefully cleaned with fine sandpaper.

A defective field protection device may also prevent the generator from charging. If a fuse is used for this protection see whether or not it is blown, and if not see that it is making good contact with the fuse clips.

If the generator is equipped with a thermostat examine this device carefully for dirty or pitted contacts or bent spring blade. If the thermostat is defective it should be adjusted or replaced.

If no trouble can be located in any of the above devices or in the wiring of the generator circuit then the fault is likely to be in the generator itself and it should be removed, and carefully tested.

If the generator charges but at a very low rate it may be due to a loose drive belt, poor brush contact, high resistance in the field circuit because of loose or dirty connections, improper setting of the third brush, or partial short circuits in the winding. The remedies for each of these troubles can be clearly seen without further explanation.

If the generator charges at too high a rate when the car is run at high speed this may be caused by a grounded third brush; or, in case the generator has been recently repaired, the field leads may have been connected wrong. Where one end of the field is connected to the ungrounded main brush the grounding of the third brush will cause the generator to operate as a straight shunt-wound machine and the regulating action of the third brush is eliminated.

If the generator charges when the car operates at low speeds but the charging current falls to zero at high speeds, this is usually the result of poor brush contact, which may be caused by burned or glazed commutator surface, commutator out of round, high mica, loose bearings allowing the commutator to vibrate, weak brush-spring tension, worn or dirty brushes, or brushes stuck in the holders.

If the commutator is out of round or has a very rough surface it should be turned down in a lathe and the mica should then be carefully undercut. The brushes should be sanded in, as explained in the D. C. Motor and Generator Sections, to see that their faces properly fit the commutator and are clean and free from gum or dirt.

Be careful to see that the brush springs are at the proper tension and that the brushes do not stick in the holders.

If the generator overheats badly it may be due to shorted armature coils, or to the armature laminations having been burred together by rubbing on the pole faces, or by rough handling while being repaired.

Burred laminations promote eddy currents which overheat the core and the trouble can be corrected by taking a very light coat off from the core in a lathe or by replacing the armature.

A loose connection in the charging circuit causing high field voltage will also result in the generator overheating; and wrong setting of the third brush allowing an excessive charging rate may be another cause.

If the generator voltage is too high and causes the lights to flare or burn out this is generally due to loose or dirty connections in the charging circuit. High resistance in this circuit prevents the normal flow of current through the armature of the generator and thereby prevents field distortion and the voltage regulating action of the third brush. So an open circuit or loose connection at the battery, ammeter, or anywhere in the generating circuit will cause excessive voltage and may result in a burned out field winding if it is not quickly corrected. In such cases all connections should be carefully cleaned and tightened.

When the generator brushes squeal during operation at certain speeds or at all speeds this may be remedied by cleaning the commutator and sanding off the faces of the brushes; or, in case it is caused by hard brushes, by boiling them for a few minutes in paraffin wax. If the trouble cannot be corrected in this manner replace the brushes with those recommended by the manufacurer.

When testing a generator for internal troubles first take the machine apart and carefully examine it for mechanical defects or any electrical troubles which can be noted. Then test the armature for opens, shorts, or grounds, as previously explained in the section on Armature Winding and Testing.

Next test the fields for the same troubles. Test each of the brush holders for possible grounds due to defective insulation, check the commutator to see that its surface is clean, that there is no high mica, and no short circuited bars. Check the brushes to see that they are all properly fitted, have the right spring tension, and move freely in the holders.

Replace any defective parts before reassembling the generator.

60. LIGHTING EQUIPMENT

The lights are a very important part of every modern automobile, as it is impossible to drive safely on unlighted country highways without two good headlights; and these headlights provide a great safety feature by indicating the position and approximate speed of an approaching car even on lighted streets and highways.

The headlights of a modern automobile should illuminate the road surface for several hundred feet ahead of the car, in order to enable the driver to see people or obstructions in the road in time to bring the car to a full stop from the high speeds at which modern cars are commonly operated.

In order to avoid "blinding" an approaching driver, the headlights should throw definite beams of light which can be kept down on the road surface and below the level of the eyes of other drivers.

Electric lights meet these requirements very nicely by supplying a concentrated beam of high candle power that can be quickly and easily focused and controlled. Therefore, electric lighting is now used without exception on all modern automobiles.

The headlights are generally provided with a dimming device which enables them to be dimmed or their beams to be dropped lower when meeting another car, and then brightened or the beams raised for vision farther ahead on a dark country road.

In addition to the headlights, most cars are equipped with cowl lights, tail light, stop light, dash light, and dome light, while some have additional small convenience lights at various places in the car.

Cowl lights are small lights located one on each side of the body of the car just in front of the wind shield. These lights can be left on when the car is parked and they serve to show the position of the car to another driver. They are much smaller and require a great deal less battery current than would be used if the headlights were left on. Cowl lights can also be used for driving the car on well lighted streets or roadways.

A tail light is very essential to indicate the rear of the car to a driver approaching from behind and also to illuminate the license plate as required by state laws. The tail light should always be kept in good condition so that it shows a distinct red light to the rear of the car, as this affords a great amount of protection from rear end collisions both when the car is in operation and when parked. A car should never be operated or left parked without a good tail light.

The stop light is a more recently developed light which goes on when the brake is pressed and indicates to a following driver that the car ahead is about to slow down or stop. Stop lights also afford a great amount of protection to the rear ends of automobiles; and, for reasons of one's own safety as well as courtesy to fellow drivers, cars should never be operated without a good stop light.

The purpose of the dash light or lights is to illuminate the various instruments on the dash or instrument board of the automobile, enabling the driver to see his speedometer and the meters and instruments which indicate various conditions, such as engine temperature, fuel level, oil pressure charging rate, etc.

Dome lights illuminate the interior of the car and are particularly convenient when getting in and out of the car at night, or whenever one desires to see within the interior of the car. Dome lights, however, should not be left on when a car is driven along a dark highway as they interfere with the view of the road ahead.

All automobile lamps are designed to operate at low voltage, generally six volts, and are connected to the battery through the ammeter and conveniently located switches.

The bulbs for the various lights are designed with filaments of various resistance and wattages according to the amount of light required. The headlights, of course, are the larger and the various other lights use smaller bulbs.

A single-wire system is now in general use for the wiring of automobile lights, and the other terminal of each light socket is grounded so that the current returns through the car frame to the grounded terminal of the battery. This arrangement greatly simplifies and reduces the cost of wiring systems, and also lessens the possibilities of trouble in the circuits.

Many people are inclined to operate their cars with one or more defective lights because they do not realize the importance of lights as a safety feature, or do not realize how easily and cheaply lights can all be kept in good condition. It is a simple matter for the experienced or trained service man to quickly locate and repair almost any trouble in the lighting system, and every attempt should be made to encourage customers to have defective lights repaired or replaced immediately and keep them in good condition at all times.

61. HEADLIGHTS

Headlights, as previously mentioned, are the most important of any lights on the automobile. Headlights are carefully designed to project the light beams on the roadway in the proper manner to give the driver a good view of its surface some distance ahead and to avoid glare in the eyes of approaching drivers.

Each headlight consists of the following important parts: Electric light bulb which supplies the light; reflector which controls and concentrates the light beam; lamp housing in which the bulb and reflector are supported; bulb adjusting devices used to focus the light; front glass or lens; and lamp standard or bracket which attaches the headlight to the car.

Fig. 71 is a diagram showing a sectional view of a headlight and in which each of the above parts can be noted.

The lamp housings are made in various styles and shapes to fit the design of the car, and the reflectors are made of silvered metal of the proper shape to gather all the light rays thrown backward and sidewise from the bulb and concentrate them forward in one beam upon the road surface.

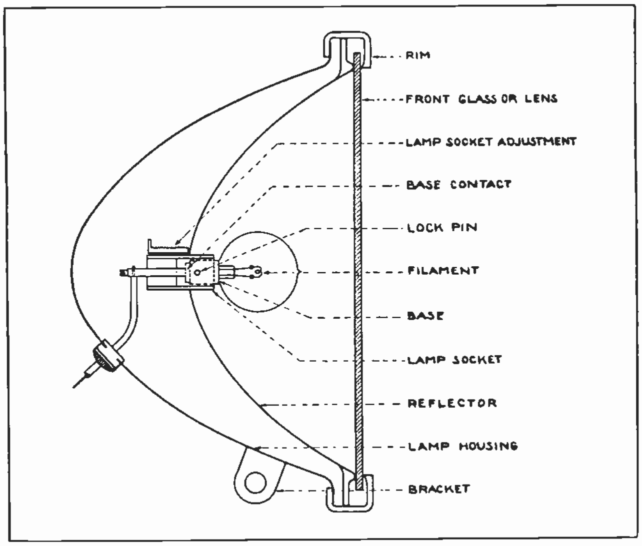


Fig. 71. Diagram showing the construction of a common type of automobile headlight. Note that the lamp socket is adjustable for focusing the light rays properly with the reflector.

Headlight lenses are of various types, some having specially cut or ground glass with ribs or corrugations to aid in directing or diffusing the light as desired.

The lamp adjusting device allows the bulb to be moved either forward or backward in the socket to **adjust the focus of the light** beam and make it broader or narrower.

Automobile headlight bulbs are constructed quite similarly to regular incandescent light bulbs, with which you are already familiar, except that their **filaments are** designed for lower voltage and are therefore made of lower resistance and to take heavier currents in order to produce the desired wattage. These bulbs have a concentrated filament which produces the light from a source of a very small area, thus making it easy to focus and direct with the reflector and lens.

The bulbs are small, ranging in diameter from about an inch to an inch and a half, and are secured to a metal base or ferrule by means of which they are held into the socket and connected to the electric circuit.

Some headlight bulbs are of the single filament type but most of those used on recent makes of cars are of the double filament type, having two separate filaments located one above the other and either of which can be turned on at will by the light switch.

One filament is used for directing a bright beam a long distance down the road, while the other is used for directing a beam of less brilliancy slightly downward and at a spot on the road closer to the front of the car. This latter filament is used when meeting another driver and helps to further reduce the blinding glare in his eyes.

On single filament lamps one end of the filament is connected to the outer metal ferrule of the lamp base which is grounded to the lamp housing when the lamp is placed in the socket. The other filament lead is insulated and connected to a small terminal in the base of the socket by which it makes contact with a spring terminal attached to the insulated light wire leading from the battery and switch to the lamps.

Double filament bulbs have one end of each filament grounded to the ferrule and the other two ends brought to separate insulated contacts in the lamp base.

On the left in Fig. 72 are shown two headlight bulbs, one of the double filament and one of the single filament type; and on the right are shown two of the smaller bulbs such as are used for dash lights, tail lights, etc.

62. DIMMING OF HEADLIGHTS

As mentioned before, it is desirable to provide some means of dimming or dropping the headlight beams when meeting another driver, and thus avoiding throwing in his eyes a glaring light which would make it impossible for him to see the road or the exact location of the approaching car.

There are in general use two common methods of dimming; one by using a resistance that is cut in series with single filament bulbs, and the other and more popular method of using double filament bulbs.

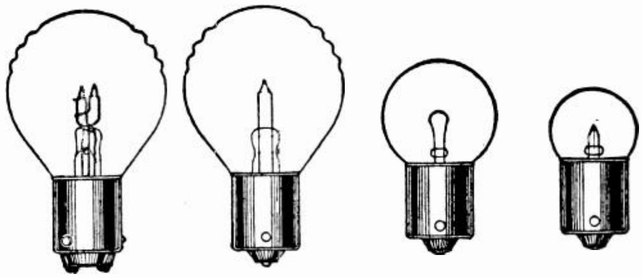


Fig. 72. Several types of double and single filament bulbs used for headlights and other lights on automobiles.

Fig. 73-A shows a diagram of the wiring for headlights using the resistance method. When the switch is at the left in the position shown, the resistance is in series with the bulb filaments and reduces their current and light output. When the switch is moved to the right the resistance is cut out, bringing the bulbs up to full brilliancy.

In Fig. 73-B is shown the wiring for the double-filament type lamps. When the switch is on the left contact the lower wattage upper filaments of the lamp are in use. These filaments being located somewhat above the center of the reflector cause the beam to be thrown downward and closer to the front of the car. When the switch is thrown to the right-hand contact the heavier wattage lower filaments are in use, and as these filaments are in the center of the reflector their light beams are thrown slightly higher and farther ahead along the road.

The smaller or dimmer filament is generally of 21 candle power, (C.P.) and the larger filament or main headlight filament of 32 C.P.

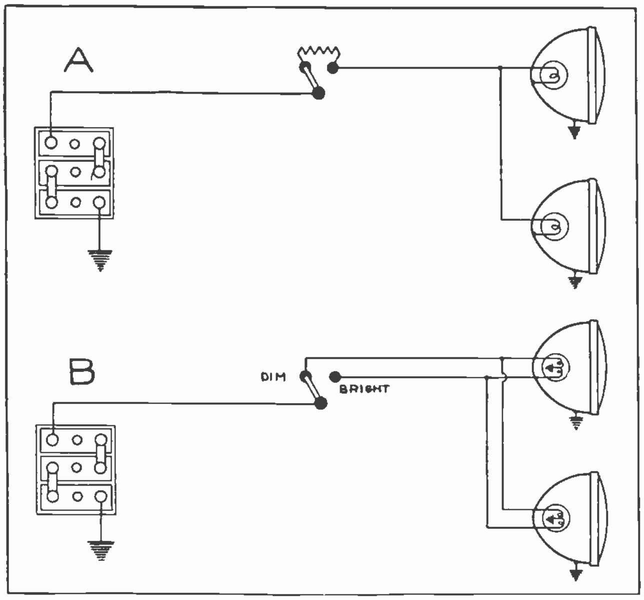


Fig. 73. A. Diagram showing resistance method of headlight dimming. B. Double filament method of dimming or "dropping" headlight beams.

The light switch for turning headlights on and off and for dimming them was formerly located on the dash of automobiles, but on modern cars it is generally located either on the steering wheel or column; or a foot switch is placed near the clutch pedal. Either of these arrangements is much more convenient than the dash switch for reaching the switch and dimming the lights when necessary.

63. LIGHTING SWITCHES

The upper view in Fig. 74 shows several types of operating levers for lighting switches and below are shown the switch contacts mounted on the insulating base of the switch. When the switch levers are mounted on the dash the switch mechanism and contacts are generally mounted directly behind them. When the switch levers are mounted on the top of the steering column the switch mechanism is generally mounted on the lower end of the column and operated by a long rod which runs from the lever down through the column.

The switch-lever positions are generally marked according to the lights that are turned on in each position, such as cowl or side, bright or head, dim, off, on, etc. The stationary contacts on the switch bases are also usually marked, so that it is an easy matter to connect the various light wires to the switch.

One of the contacts is connected directly to the battery. When the switch is turned on the contact fingers slide around to close circuits from the battery contact to the various sets of lights, according to the position the switch is placed in.

In case the switch contacts are not marked the battery terminal can be located by testing with a piece of wire grounded to the frame of the car. The battery terminal is the one which will give a flash when touched with this grounded wire and with the switch in the **off** position.

Now connect one end of the test wire to the battery terminal and try out the remaining contacts with the other end, and note the results. When the end of the wire is touched to the headlight contact the headlights will light; and if the tail light contact is touched this lamp will light, etc., and in this manner the different terminals can be quickly and easily located.

If a switch has been removed for repairs and all the wires are disconnected they can be tested out and connected up as follows:

Touch to the car frame each of the wires that connect to the switch until one is found which gives a flash. That is the live wire from the battery and should be connected to the battery contact on the switch. Touch the remaining wires on the battery contact until the tail light wire is found by the tail light burning when a certain wire is touched. Then connect this wire to the contact marked "tail light," or to the one which will give a light when the switch is on in any position. The tail light is generally switched on when any of the other lights are on.

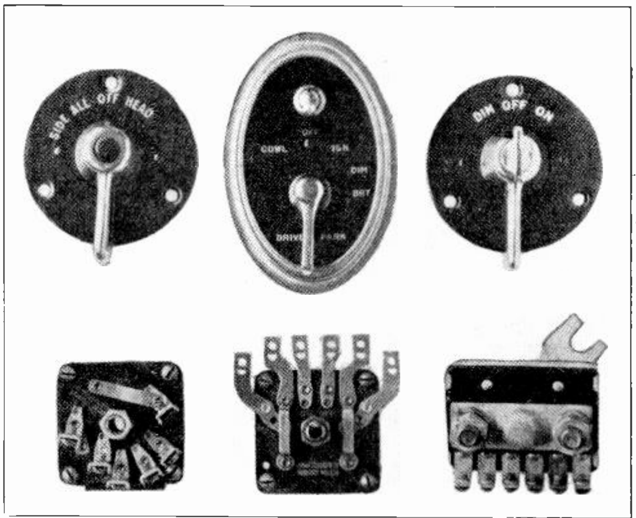


Fig. 74. At the top of this figure are shown several types of light switches and below are shown the backs of the switches with their various contacts for the different light circuits.

The wires to the other lights can be found in the same manner and connected to the properly marked switch contacts or to the contacts which will give a light when the switch lever is in the proper position for whichever light is being connected.

The stop light is generally controlled by a small switch located under the floorboards of the car and operated by a wire and spring attached to the brake pedal.

Dome lights and other convenience lights around the car are generally operated by small snap or push button switches located in convenient places.

The dash light on modern cars is generally switched on whenever the headlights or other driving lights are on. In some cases it is left off when only the parking lights are on, and in other cases it is equipped with a special snap switch of its own so that it can be turned off when desired.

Dash lights are sometimes connected in series with the tail light, so they will go out and warn the driver any time the tail light burns out.

64. TROUBLES IN LIGHTING SYSTEMS

The electric wiring on an automobile is comparatively simple and the wires are usually partly visible, so generally no complicated testing or elaborate test instruments are required to check the system for such common troubles as opens, shorts, grounds, loose connections, etc.

A simple low-voltage test lamp made up with a six-volt bulb or a low reading voltmeter is often very convenient. However, in the majority of cases a screw driver and a short piece of test wire are all that is necessary to locate troubles.

Some of the more common troubles and remedies of automobile lights are covered in the following paragraphs.

If all of the lights fail to light when the switch is turned on, check to see if the main fuse is burned out. and if it is not, see that it is making good contact with the fuse clips.

If a circuit breaker is used, check to see if the contacts are dirty or pitted, or if the plunger is sticking.

Test with a short test wire from the battery terminal on the switch to ground or to some metal part of the car, and if a flash is obtained this indicates that battery current is reaching the switch and that the trouble is very likely in the switch itself. By removing and checking the switch the loose, dirty, or bent contacts can generally be located.

If no flash results when the battery contact on the switch is grounded with the test wire, check for a broken wire between the switch and battery or for a burned out ammeter.

Failure of all lights might also be caused by all of the bulbs being burned out due to a surge of high voltage from the generator, but this is very unlikely as all the lights will not usually burn out at once and such a surge would be noticeable if they did.

If at any time during the operation of the car the lights all brighten up considerably, shut off the engine immediately and check for a loose connection in the generator charging circuit, since this is the most probable cause of an increase in generator voltage as previously explained.

65. HEADLIGHTS FAIL

If the headlights do not light up but all of the other lights do, the trouble will be in the headlight bulbs or the headlight circuit somewhere.

If the lighting system is one in which each of the light circuits is separately fused, examine the headlight fuses first. Next remove the insulated plug which leads to the lamp housing and connects to the bulb socket, and touch this plug to the back of the lamp housing or car frame. If no flash occurs it indicates a break between the headlight and the battery, probably in the switch but possibly in the wire.

If no flash is obtained when this terminal is grounded, test next with a wire from the headlight contact on the switch to ground, and if no flash occurs here connect the test wire from the battery terminal on the switch to the headlight contact. If the lights then burn the trouble is proved to be in the switch.

Remove the switch and check for dirty, burned, or pitted contacts and switch fingers. Also see if the contact fingers have lost their spring tension due to overheating. The switch lever must be in the headlight position while making these tests.

If a flash was seen when the insulated headlight plug was touched to the car frame, the trouble must be in the headlight. Remove the lens and examine the bulb or test it, and if it is burned out, replace it. If the bulb is all right, the trouble may be due to the fact that the contact on the insulated plug is not making good contact to the bulb. It may also be caused by rust forming between the reflector—in which one end of the light filament is grounded—and the lamp housing, or between the lamp housing and the car frame.

Rusty or dirty connections at these points mean an open or high-resistance circuit between the grounded terminal and the battery.

To test for an open or high-resistance connection between the reflector and the grounded terminal of the battery, place one end of the test wire on the wire which carries the current to the headlights and touch the other end to the reflector. If no flash is obtained, check for poor contact between the lamp contacts and housing, or between the housing and car frame.

The various other lighting circuits can be tested out in the same manner as outlined for headlights. Check to see if the current is carried through the wire all the way up to the light, and then test for burned-out bulbs and poor grounds between the lamp housing or socket and car frame.

66. FLICKERING AND FLARING OF LIGHTS

Headlights and other lights are sometimes caused to flicker by loose connections in the lighting circuits, and very often this trouble is found to be at the insulated plug which connects to the lamp housings.

The small springs which connect the plug and bulb terminals together either become weak or stuck, or burned and dirty. Sometimes it is only a small amount of corrosion that is responsible for high resistance in the circuit and causes the lights to dim or flicker occasionally.

In this case the trouble may be remedied by merely working the plug back and forth in its socket to rub off the corrosion and brighten the contacts. When the trouble is due to weak contact springs, these springs may be stretched out or the trouble may be remedied by adding a small drop of solder to the bulb contacts, thereby increasing the pressure and tension on the spring contacts.

If the flickering is not due to trouble in the lamps or at the plug connections, then check over the entire circuit, cleaning and tightening any dirty or loose connections; and, if it is necessary, check the switch for loose or burned contacts.

As previously mentioned, flaring lights are generally caused by loose connections in the generator circuit or defects in the generator. In such cases all connections in the generator and charging circuit should first be carefully cleaned and tightened.

If the lights still burn excessively bright, the trouble may be a partially broken wire in the generating circuit or some defect in the generator itself. If the trouble seems to be in the generator, it should be removed and checked for broken wires, poor brush contact, sticking brushes, or grounded third brush.

67. TEST PROCEDURE

When checking the electrical system on a car for faults or troubles, always follow the plan of testing out first those parts of the circuit that are easily accessible and therefore most easily eliminated as possible sources of trouble.

For example, when lights fail, always check the fuses or circuit breaker first before checking over the switch contacts and wiring. Never disassemble the lighting unit to check for bulb and other lamp troubles without first making a test with the light switch on by grounding the plug at the back of the lamp housing to make sure that current is reaching the lamp. If a flash is thus obtained, it indicates that the trouble is in the lamp itself.

If the car lights burn dim, it is generally caused by a weak battery or connections that are loose, corroded, or dirty and of high resistance.

If only certain lights burn dimly, check that circuit carefully, cleaning and retightening any contacts or connections that appear doubtful.

If all lights are dim, the battery and its connections should be checked first of all. Poor contact due to corrosion or rust forming between the terminals of the lamp base and the spring connection to the plug are often the cause of dim lights, and in other cases they are caused by rust forming between the various parts of the lamp housing or between the lamp housing and the car frame where the light obtains its ground circuit.

Sometimes rust or a poor connection between the lamp housing and car frame can be burned out or welded into a better connection by connecting one lead of a battery to the housing and the other to the frame, thus passing a heavy current through this circuit.

If this doesn't work, the housing should be removed and the contact surface sandpapered or scraped clean, and then remounted and securely tightened.

High-resistance connections between the ammeter and battery will cause the lights to flare when the engine is speeded up.

68. SHORT CIRCUITS and CIRCUIT BREAKERS

As a great deal of the wiring on automobiles is run along the metal parts of the frame and held in small clips, and as the frame is used for the other conductor of the circuit, it is quite common to find short circuits resulting from chafed or damaged insulation, allowing the wires to touch the frame or metal parts of the car.

These wires are subjected to very severe service, due to road vibration, dirt and oil accumulating on them, and occasional abuse by careless mechanics working on other parts of the car. Oil tends to rot the rubber insulation, and vibration tends to chafe the insulation off the wires where they rub under the clips or against other metal parts. Sometimes the insulation becomes damaged by being jammed with a heavy tool or metal part during some mechanical repair or overhauling of the car.

To protect the wires in case of such grounds and short circuits, and also to eliminate the fire hazard as much as possible, the lighting and accessory circuits of automobile electric systems are generally protected by fuses or circuit breakers.

Fuses and circuit breakers are never connected in either the generating or ignition circuits. In some cases fuses are used in each separate circuit, while in other cases one main fuse is used to protect all the circuits. In this case the fuse is generally placed on the back of the lighting switch.

The small circuit breakers which are often used in place of fuses are very simple devices consisting of a switch operated by an electro-magnet or solenoid, as shown in Fig. 74-A.

When the normal load current, which is generally under 15 amperes, is flowing through the coil and contacts of the circuit breaker it doesn't create enough magnetism in the coil to lift the plunger and open the circuit; but if the current should rise to a value of 25 amperes or more, due to a short circuit in the wires, it creates sufficient magnetism to raise the plunger, causing it to strike the contacts and break the circuit.

When the contacts are thus opened and the circuit is broken, the coil is demagnetized and allows the core to drop, due to the action of gravity and of a small

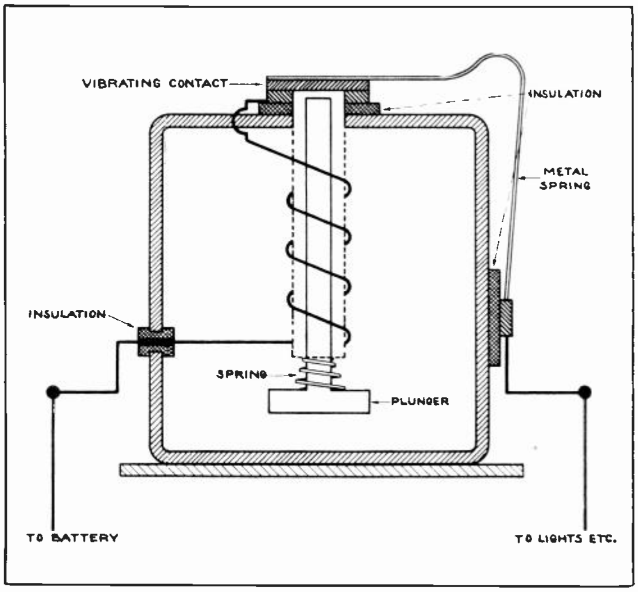


Fig. 74-A. Diagram of a simple magnetic circuit breaker for protecting automobile wiring circuits in case of shorts and grounds.

spring, which also tends to pull it back. This again completes the circuit, magnetizing the coil and once more raising the plunger to break the contacts.

From this we see that the breaker continues to vibrate somewhat on the order of a vibrating bell, thus limiting the current to prevent overheating of the circuits and also making considerable noise to call attention to the fault so that the defective circuit will be switched off and the trouble removed.

69. TESTING FOR SHORTS

When a short occurs in the wiring to the lighting system or horn, it may be either in the wires themselves or at the switches, lamp, socket, connectors, etc. To locate the short, first determine whether a fuse or circuit breaker is used.

If a fuse is used, connect a 21-candle power lamp across the fuse clips to serve as a trouble light. If a circuit breaker is used, just turn on the switch and let the breaker buzz. If the lamp lights or the breaker buzzes with the lighting switch in the "off" position, then look for the trouble in the stop light and accessory circuits.

Disconnect the wire from the stop light switch and if this stops the breaker buzzing or extinguishes the trouble lamp, the fault is in the stop light circuit between the switch and the lamp, and in the majority of cases it will be found in the switch itself.

As the horn is generally connected through the fuse or breaker, the same test should be made on it. Disconnect the wire from the horn to see if the breaker stops or the light goes out. If it does, the fault is in the horn; and if not, the trouble is in the wire. If the fault is in the wire leading from the horn to the button, the horn will blow continuously.

If a short circuit occurs only when the light switch is on, turn the switch lever from one position to the other to determine which part of the circuit the trouble is in.

If the circuit breaker stops buzzing or the trouble lamp burns dimly in certain positions of the switch, it indicates that these circuits are clear, and the trouble lamp burns dimly in such cases because it is in series with the other lights.

If a clear indication is obtained with the switch on all positions except the headlight position, this indicates that the trouble is in the headlight circuit, and you should next remove the plugs which connect the wires to the lamp housings and bulb socket.

If the breaker then stops or the trouble lamp goes out, the short is due to the plug contacts touching the lamp housing in some way. Careful inspection will then generally show where the fault is and the trouble can be remedied by properly adjusting or reinsulating the sockets according to the nature of the fault.

If the trouble lamp remains lighted or the breaker continues to buzz after the plugs have been removed from the lamps, it indicates that the trouble is in the wiring. To locate the exact point, start at the lamp and trace each circuit back, paying particular attention to any point where the wire is secured to the frame by clips. Pulling or moving the wire will often help to locate the trouble, because, if the breaker stops buzzing or the trouble light goes out when the wire is moved to a certain point, the fault is evidently close to that position.

In certain cases where the system is wired with armored cable and the short is hard to locate, it is cheaper to rewire the circuit with new wires than to spend too much time trying to locate the fault.

Sometimes an intermittent short will occur and last just long enough to blow the fuse and then disappear. This is generally caused by a loose wire touching the car frame when the machine is in motion, and this wire may strike against the frame when the car hits a bump. Try to determine what position the switch was in when the short occurred and then carefully inspect that circuit for loose wires, defective insulation, etc.

If the trouble is noticed in all switch positions, the fault is very likely to be in the tail light circuit; while, on the other hand, if the short occurs with the lighting switch off, look for trouble in the stop light and accessory circuits.

70. LEAKY INSULATION

Sometimes a partial short or high-resistance ground will allow a slow leakage of current from the battery that is not enough to blow the fuse or operate the breaker, but will cause the battery to continually run down. Generally this trouble will be indicated by a low reading on the ammeter when all the electrical devices are turned off, but the ammeter would not indicate a fault in the starting circuit or in the wire from the battery to the ammeter.

In some cases the leak may not be great enough even to show a noticeable reading on the ammeter.

To test the system for such leaks, disconnect one of the cables from the battery terminal and connect in the circuit a low-reading voltmeter with a range of 6 to 10 volts. With all switches and electrical devices turned off, the voltmeter shold not give any reading, and if it does a leak is indicated.

First disconnect the stop light wire and see if it causes the meter to read zero, and if it does the leak is in that circuit. If the trouble is not in the stop light circuit, then disconnect the wire which leads from the battery to the ammeter by removing the connection at the meter.

If the voltmeter now reads zero the trouble is in or beyond the ammeter. Next remove the wires from the other ammeter terminal and touch them one by one on the "hot" lead to the battery. When the faulty wire is touched to the battery lead the voltmeter will show a reading, and in this manner the defective circuit can be located. This circuit can then be carefully checked over for defective insulation or leaks. Very often it is easier and cheaper to entirely rewire the circuit.

Of course, one should not assume that such a leak is always the cause of a run-down battery, as it is more often due to too low a charging rate or the car is not being operated enough hours per week or month to keep the battery well charged.

Excessive operation of the starter or driving mostly at night with the lights on, or equipping a car with too many additional electrical accessories will also result in a run-down battery.

Remember that to keep a battery fully charged in the winter, so that it will properly operate both lights and starter, requires a considerably greater charging rate than during the summer months.

With normal driving the winter charging rate should be about twice as great as that for summer use.

From the foregoing explanations of lighting circuit troubles and remedies you can readily see the advantage of having a good general knowledge of electrical principles and circuits, as trouble shooting on the electrical systems of automobiles is simply a matter of definite circuit tracing and testing, the same as with any electrical power or signal devices.

With all the general training that you have had in this line and the knowledge you can obtain from this section on automotive electrical devices and circuits, it should be a very easy matter for you to locate troubles in any part of the wiring system of a car.

71. AUTOMOBILE HORNS

Automobile horns are made in many different types and sizes, but most of them are of two general types as far as their mechanical operation is concerned. One type uses a small motor to drive a notched or toothed wheel that rubs against a pointed button mounted on a diaphragm, as shown in Fig. 74-A.

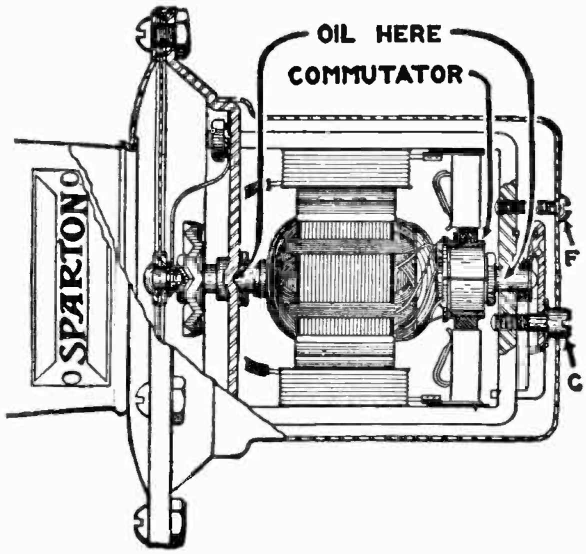


Fig. 75. This diagram shows a cut-away view of a motor-driven automobile horn. Note the notched wheel which vibrates the diaphragm by rubbing on the pointed button at its center.

When the horn button is pressed, current flows through the motor and causes the toothed wheel to rub on the button and vibrate the diaphragm rapidly. This vibration is transmitted out through the horn in the form of air waves or sound.

The other common type of horn uses a magnetic vibrator with one or two electro-magnets and an armature, and operates very much on the principle of an ordinary vibrating bell or buzzer.

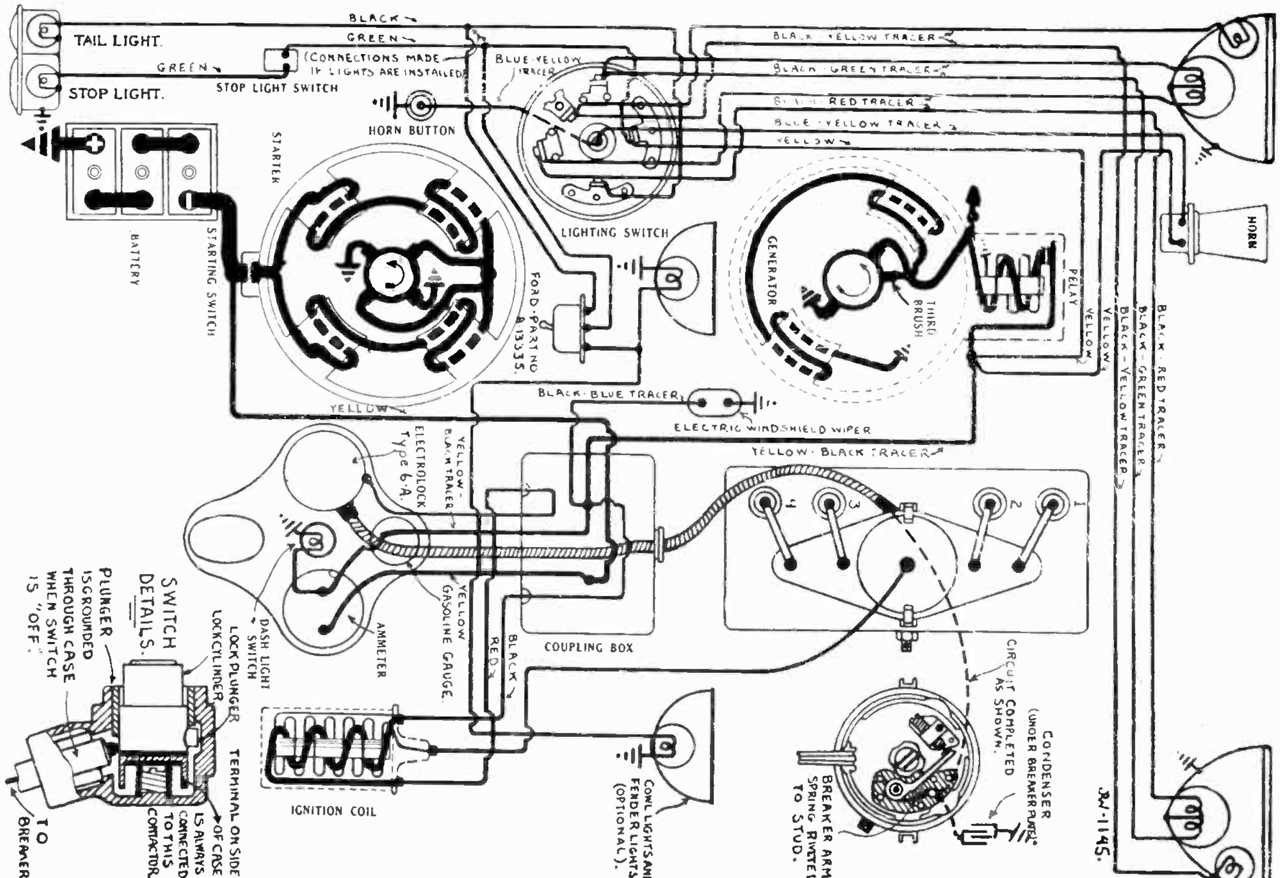


Fig. 76. Complete wiring diagram of Model A Ford car. This diagram shows the wiring for the starter, generator, ignition and lights. Trace out each part of the wiring until you thoroughly understand the entire system. Courtesy National Automotive Service.

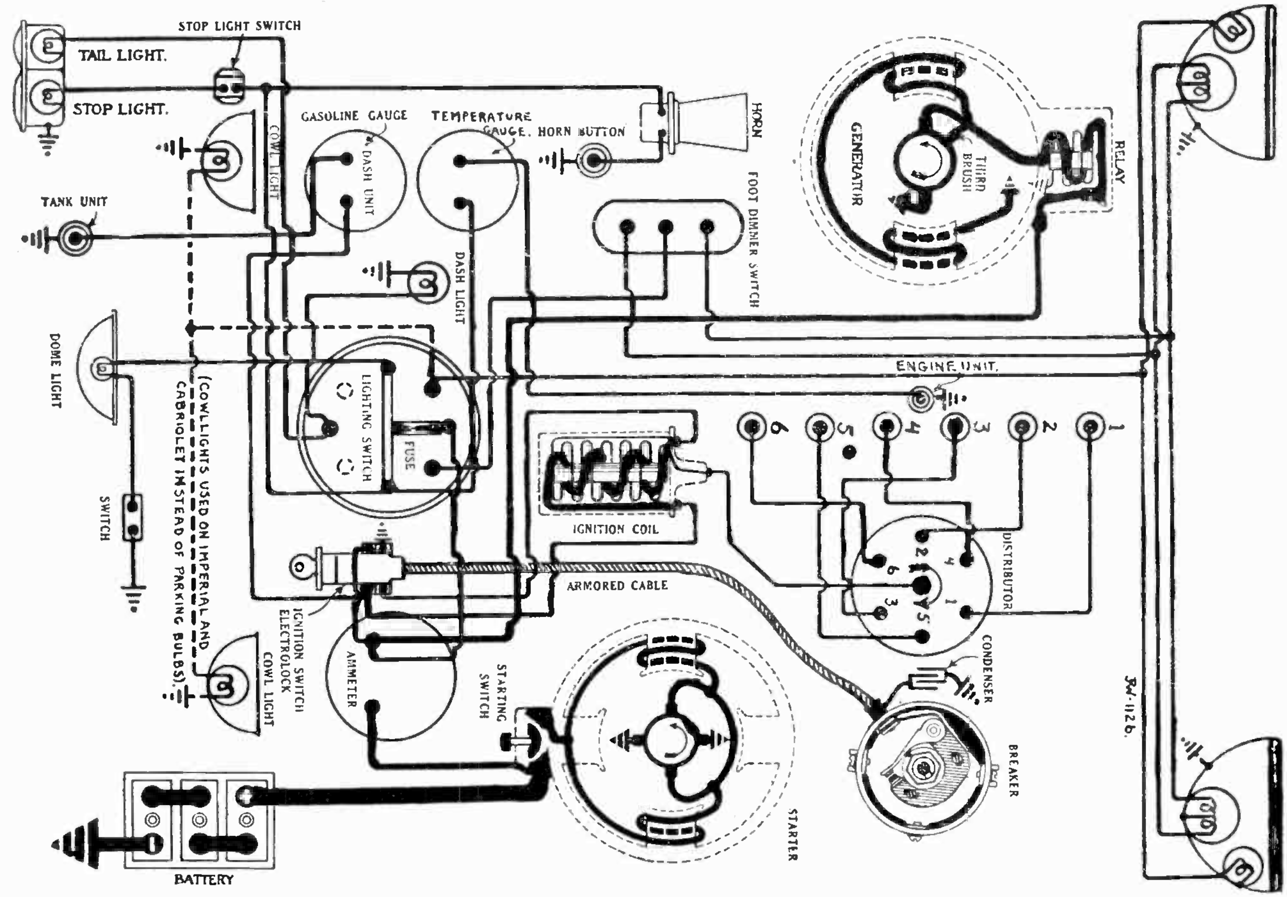


Fig. 77. Complete wiring diagram of 1930 Chevrolet. Note carefully the location and arrangement of all of the electrical devices. Trace the circuits one at a time to become thoroughly familiar with the common types of automobile wiring systems. Courtesy National Automotive Service.

The armatures of automobile horn vibrators are generally much heavier and are fitted with special springs to obtain the loud notes required to be heard in automobile traffic. The different high and low pitched notes are obtained by designing the vibrators or motor wheels for different speeds to get different frequencies of vibration of the horn diaphragm.

The care of motor-type horns is very similar to the care of any small D. C. motor such as those with which you are already familiar. Commutator and brushes generally require the most frequent attention and the bearings should be occasionally lubricated, unless the horn is of a type using ball bearings, or has inside of it permanent lubricating cups which do not require attention for a year or more at a time.

The greater number of troubles affecting horn operation are in the wires leading to the horn or at the horn button, rather than in the horn itself, except perhaps in some of the very cheaper grades.

Care of the vibrating-type horn is similar to the care that would be given any heavy-duty vibrating bell, in that it will possibly require occasional cleaning of the make-and-break contacts or adjustment of the armature spring.

A great many horns are equipped with an adjusting screw either against the back end of the armature shaft or sometimes located down inside of the horn at the center of the diaphragm. By means of this screw the pressure of the diaphragm button against the notched wheel or vibrating armature can be adjusted to slightly change the pitch or note of the horn, or to improve the operation of the horn in case the button or wheel becomes worn away with use.

Some special types of horns are operated by air supplied by a small motor-driven air pump of the rotary type which is built right into the back of the horn. The connections of the horn and horn button to the switch or ammeter terminal are shown in some of the complete wiring diagrams of automobiles.

72. COMPLETE WIRING SYSTEMS

Fig. 76 shows a complete wiring diagram for a 1930 Model A Ford. Note carefully the general arrangement of the various parts and circuits, and trace out each circuit one at a time.

For example, first trace the starting circuit from the battery, through the starting switch and starting motor to ground. Then trace the generator and charging circuit from the generator through the cut-out, ammeter, and battery. Next trace the ignition circuit from the battery through the ignition switch, primary coil winding, breaker points, and back to the battery; and the secondary circuit from the high-tension lead of the coil through the distributor to the spark plugs.

Finally trace out the lighting circuit from the battery

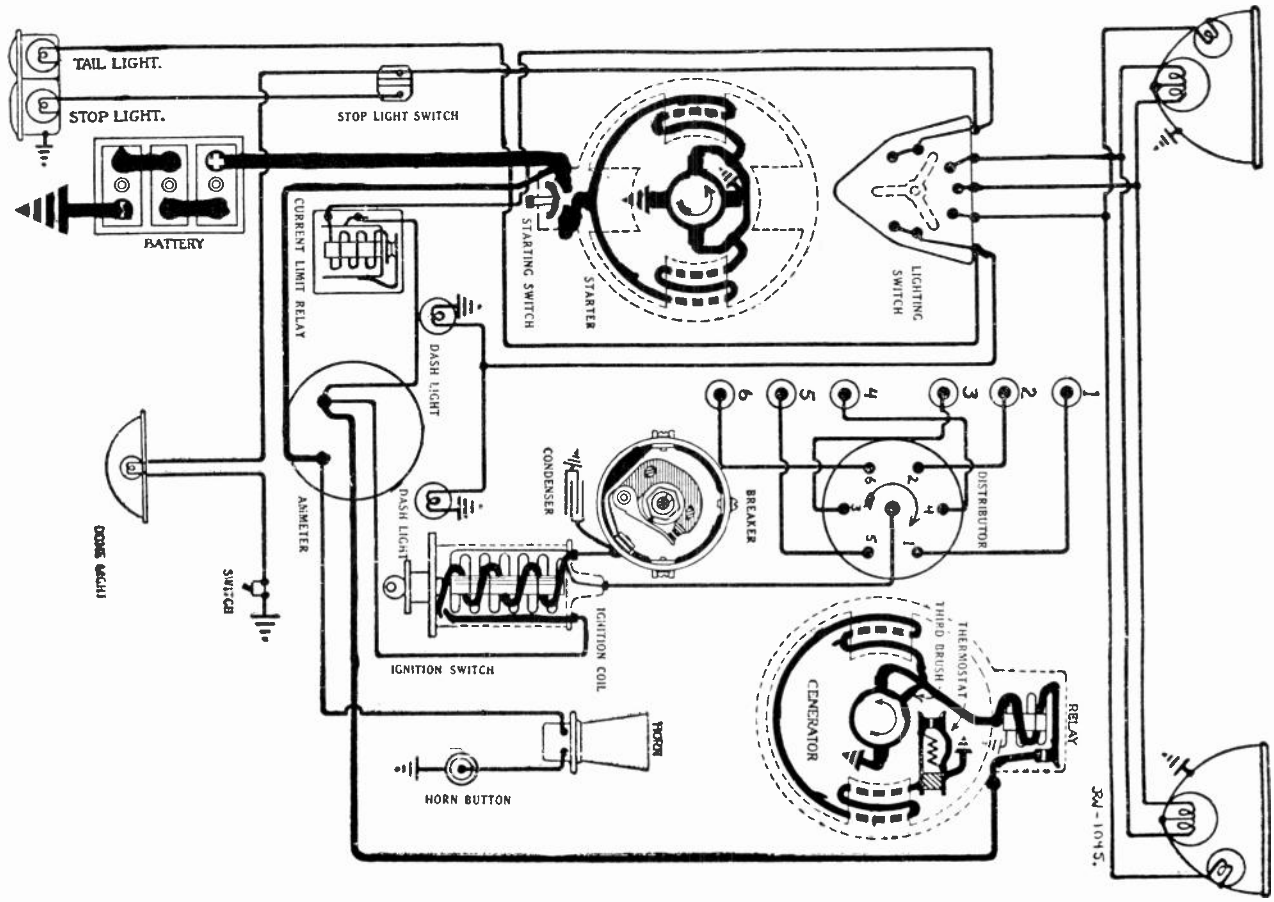


Fig. 78. Wiring diagram of 1930 Oldsmobile car. Note the circuit breaker or current limit relay used for short circuit and overload protection, and also the thermostat overload device for protection to the generator. Courtesy National Automotive Service.

through the ammeter, lighting switch, and to the various lights.

Note that the wires of different parts of the system have insulation with different colored markings, which is a great aid in tracing circuits on the car and shooting trouble in various parts of the system.

Fig. 77 shows the complete wiring diagram and all of the electrical devices for the 1930 model Chevrolet.

The electrical equipment used on these cars is made by the Delco Remy Company, who are one of the larger manufacturers of automotive electrical equipment.

Trace out this circuit very carefully and you will note that although there are some small differences in the arrangement of parts and wires, the general system and principle are very much the same as in Fig. 76.

Fig. 78 shows the complete wiring diagram of a 1930 Oldsmobile, which is also equipped with Delco Remy apparatus.

Fig. 79 shows the wiring system of an eight-cylinder Packard automobile, using two coils and the double breaker contacts.

In addition to the automotive electrical equipment made by the Delco Remy Company of Dayton, Ohio, there is also that supplied by two other leading manufacturers—The Northeast Electric Company, Rochester, N. Y., and the Autolite Corporation of Toledo, Ohio. These concerns make most of the electric devices for automobiles; while magneto ignition systems for trucks, tractors, marine engines, etc., are supplied by the American Bosch Corporation at Springfield, Mass.; Eisemann Magneto Corporation, New York, N. Y.; Sims Magneto Company, Orange, N. J., and several others.

It is a very good plan to keep in mind that special information on various ignition devices or repair parts can always be obtained by writing directly to the manufacturers or by getting in touch with their nearest local distributor.

For those who may wish to specialize in automotive electrical service there are special service manuals or books containing wiring diagrams of practically all cars and trucks manufactured.

These diagrams are very convenient to have on hand when tracing troubles or testing circuits of certain makes of cars, but as these systems are a great deal alike in many respects and are far too numerous to include all of them here, we have just shown a few of the most common types to give you a general idea of complete automobile wiring systems.

The wiring diagram for any certain make of car can generally be obtained without charge from the automobile manufacturers, or we will be glad to supply at any time information as to where you can obtain special books on wiring diagrams for any graduates who may make a specialty of automotive electrical work.

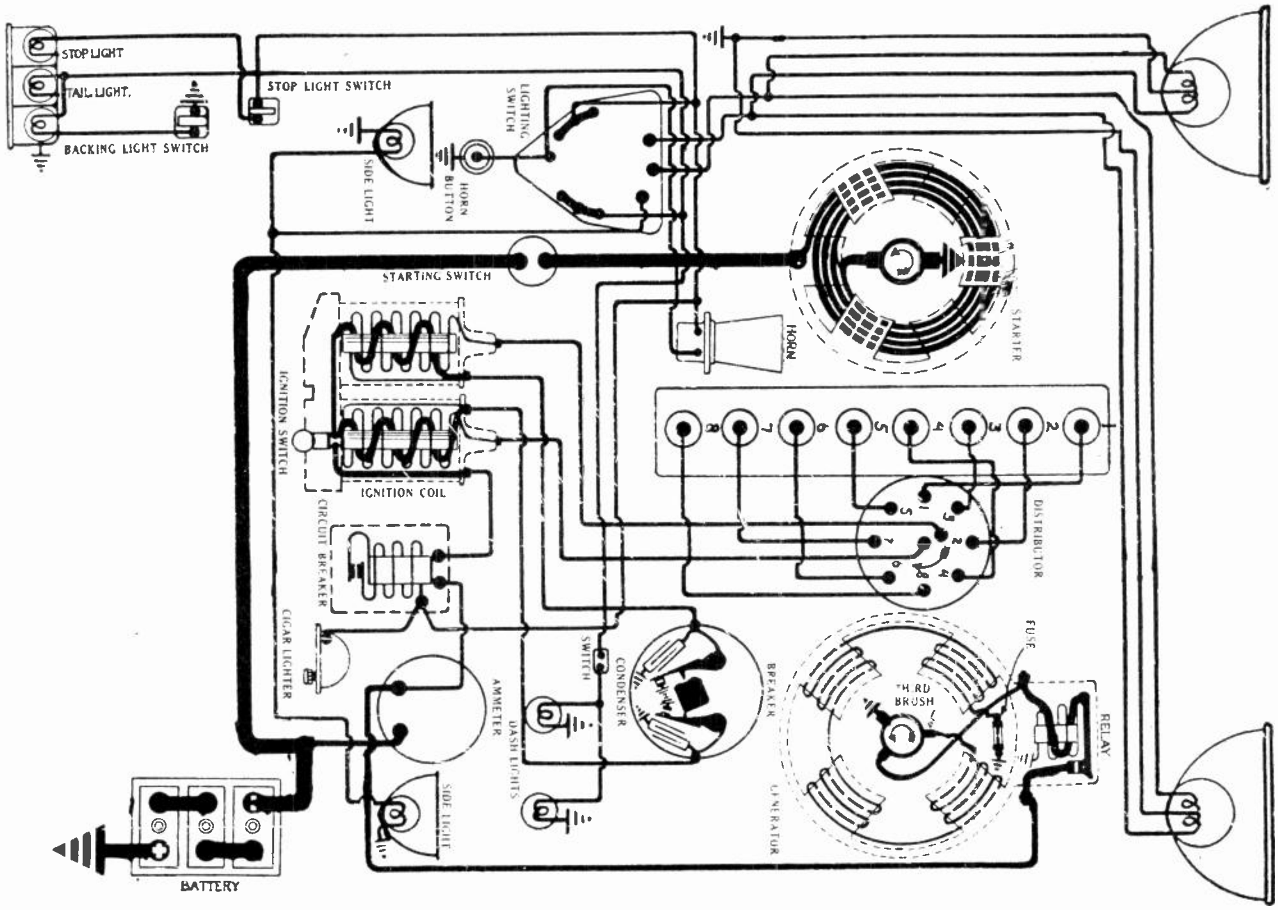


Fig. 79. Complete wiring diagram of an eight-cylinder Packard automobile. Note the two ignition coils and high speed distributor with double breaker arms used on this "line eight' engine. Also note the peculiar field coil construction in the starting motor by which one large coil wire around the motor frame is used to produce alternate poles in the field pole cores. Courtesy National Automotive Service.

Whether or not you make automotive electricity your regular trade or business, remember that to be able to locate and repair electrical troubles on your own car will often come very handy and will save you considerable time and money; and it may also enable you to make extra money on the side by repairing the ignition equipment of someone else's car.

Keep in mind at all times that systematic, thoughtful circuit tracing and testing will locate any electrical trouble that can possibly occur in any part of an automobile ignition or wiring system; and that in a great majority of cases these troubles arise from such simple things as loose connections, shorts or grounds, all of which can be easily repaired by anyone with the general knowledge of electricity that you should have from your course and this reference set.