AUTOMOTIVE REFERENCE BOOK

MICHIGAN STATE AUTO SCHOOL

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AUTOMOTIVE REFERENCE BOOK

A complete reference book for the use of students of the Michigan State Auto School in conjunction with their courses in automotive construction, operation, maintenance and repairing

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FIRST EDITION

PREFACE

This reference book is the result of ten years experience in teaching and training men who desire to educate themselves thoroughly for positions in the automotive industries. The teaching of the subjects of our courses is highly specialized and requires a type of book, that, as far as we have been able to learn, has never been published.

The fault of most text books lies in their being either too technical for the majority of students, or on the other hand incomplete, although claiming the virtue of simplicity. This reference book has been especially prepared by our staff for the benefit of the student receiving practical instruction in our school. It is intended for the beginner or the expert, but not for use as an engineering text.

No book of itself is sufficient to train a man in the automobile or allied industries. To gain the full benefit of such a book as this, it must be used in conjunction with the training and equipment provided in our classrooms, laboratories and shops.

The plan of our instruction is to alternate theory and practice. The material in the book has been classified under four headings—Engines, Chassis, Elements of Electricity and Advanced Electricity—in order that the theory in each section may be completely explained and then followed by a period of actual shop practice. We have gone thoroughly into the various subjects treated but the simplicity of the text matter will be apparent to everyone. We are constantly adding equipment and improving our instruction in order to conform with the continuous developments in manufacturing and service.

The drawings illustrating the text matter are reproductions of large charts especially prepared by our staff for use in our class work.

Grateful acknowledgment is made to the service managers, production managers and other executives of automobile and tractor companies for their co-operation and appreciation of our efforts to establish and maintain the highest standards in the conduct of our school.

MICHIGAN STATE AUTO SCHOOL, INC.,

By Arthur G. Zeller,

October 1, 1921. Pres. and Gen. Manager.

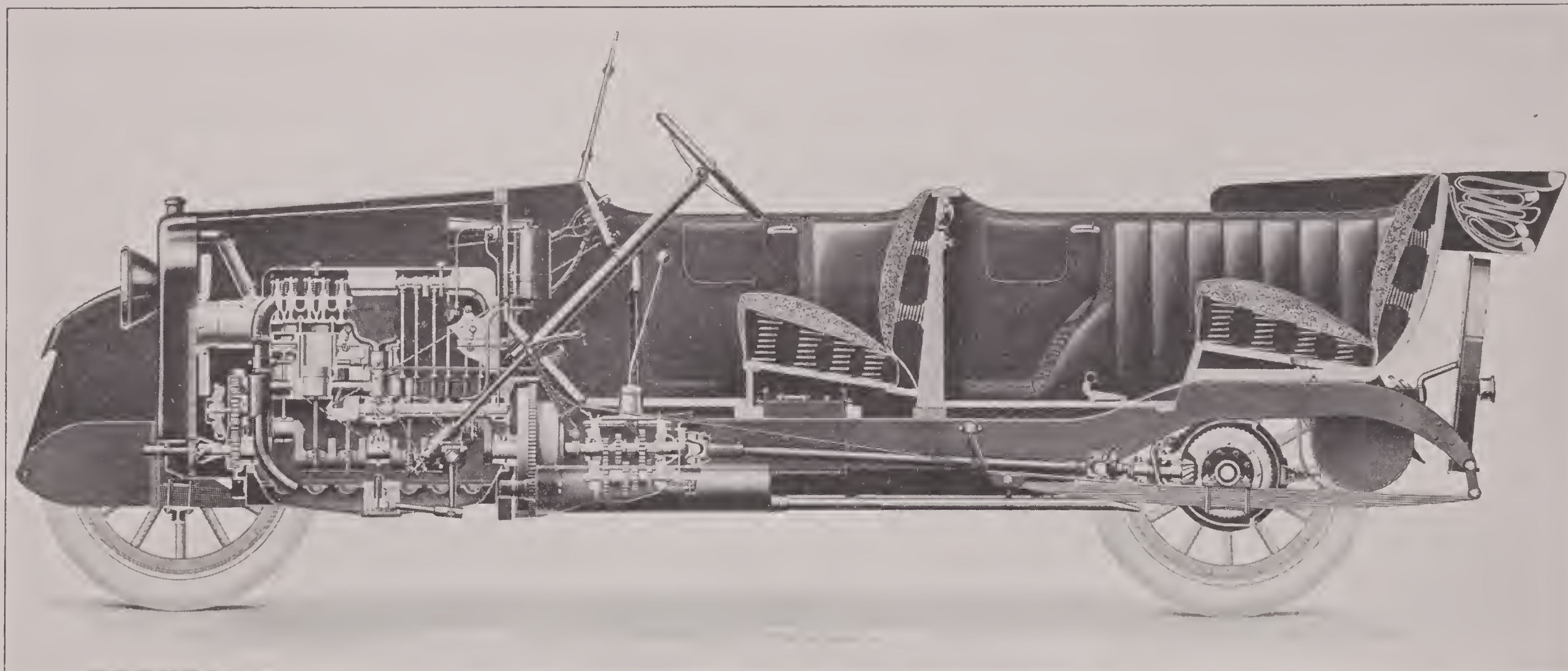


FIG. 1.

A LONGITUDINAL SECTIONAL VIEW OF A MODERN AUTOMOBILE

INTERNAL COMBUSTION ENGINES

HISTORY

The history of the Internal Combustion Engine dates back some two hundred years, but it was not until 1826 that any progress was made and then only in an experimental way. At that time Brown invented what was known as the "Gas Vacuum Engine."

Brown's engine was probably the first which did real work. It was clumsy and unwieldly, and soon had its place among the experiments and failures of that period. No approach to active explosive effect in a cylinder was reached until about 1838, and the years following immediately after. Barnett, in England, was the first to compress a mixture before exploding it. This was about 1860. Many patents were issued in Europe and in this country, but progress was spasmodic and its practical introduction for power purposes was slow. Subsequent to 1860, practical improvements were produced in France, which were brought to the United States in 1862. This was followed by Beau de Rocha's idea (the four stroke cycle principle) which he developed through a long series of experiments and trials. Later, two engineers named Otto and Langdon took up Beau de Rocha's idea and developed the first practical internal combustion engine. In 1870 improvements were advancing at a steady rate. but largely in valve gear and precision of governing for variable loads.

The early idea that slow combustion was necessary proved a detriment to advancement. A suggestion of Beau de Rocha's in 1862 dispelled these ideas and brought forth the truth. His experience taught that the rapidity of action in both combustion and expansion was the basis of success in explosive engines. The application of the gasoline and oil engines to marine and automobile propulsion had a most stimulating effect in developing ways and means of applying it. The automobile has been the main incentive in recent years.

Kerosene oil engines have, however, been tardy in their development, due to the low volatility of the fuel, but are now being perfected and will take a prominent place for a great many power purposes within the range of their application.

DESCRIPTION AND FUNDAMENTAL PRINCIPLES

The "internal combustion engine" is an engine in which heat energy is converted into mechanical energy, by the "combustion" of a gas or volatilized fluid directly in the engine. This is in contrast with the steam engine which may be termed an "external combustion engine" since the heat energy of the fuel is transmitted to the water in the boiler and the water acts as a carrier, conveying the heat energy to the engine where it is converted into mechanical energy.

Combustion means the burning of a substance, uniting with the oxygen of the air, forming gases. When this burning takes place with extreme rapidity and under the proper conditions an "explosion" occurs and a large amount of heat is generated. The effect of heat on gases in a closed receptacle is to make them expand, and it is the pressure and power due to this expansion that is utilized to operate the internal combustion engine. By the combustion of the fuel directly in the engine, higher temperatures are obtained, resulting in a much greater efficiency.

In the gasoline engine, the explosion is made to occur in a closed cylinder, and the expansion pressure utilized to move a plug or piston, the motion of which is transmitted through the engine parts to the point where the power can be used.

To make the movement of the piston continuous requires the repeated production of explosions in the cylinder. This calls for supplying new charges of gas, providing the means for exploding them under proper conditions, and removing the burned gases.

There are two principal systems for performing this series of operations in keeping a gas engine running. The systems, or series of operations, are called "cycles." Engines are classified according to the number of strokes it takes to complete a cycle, and thus we have the "four stroke cycle engine" and "two stroke cycle engine."

The term cycle means a complete course or series of events beginning at any one point, continuing always in the same order and returning to the starting point. A cycle of operations in the gas engine consists of supplying

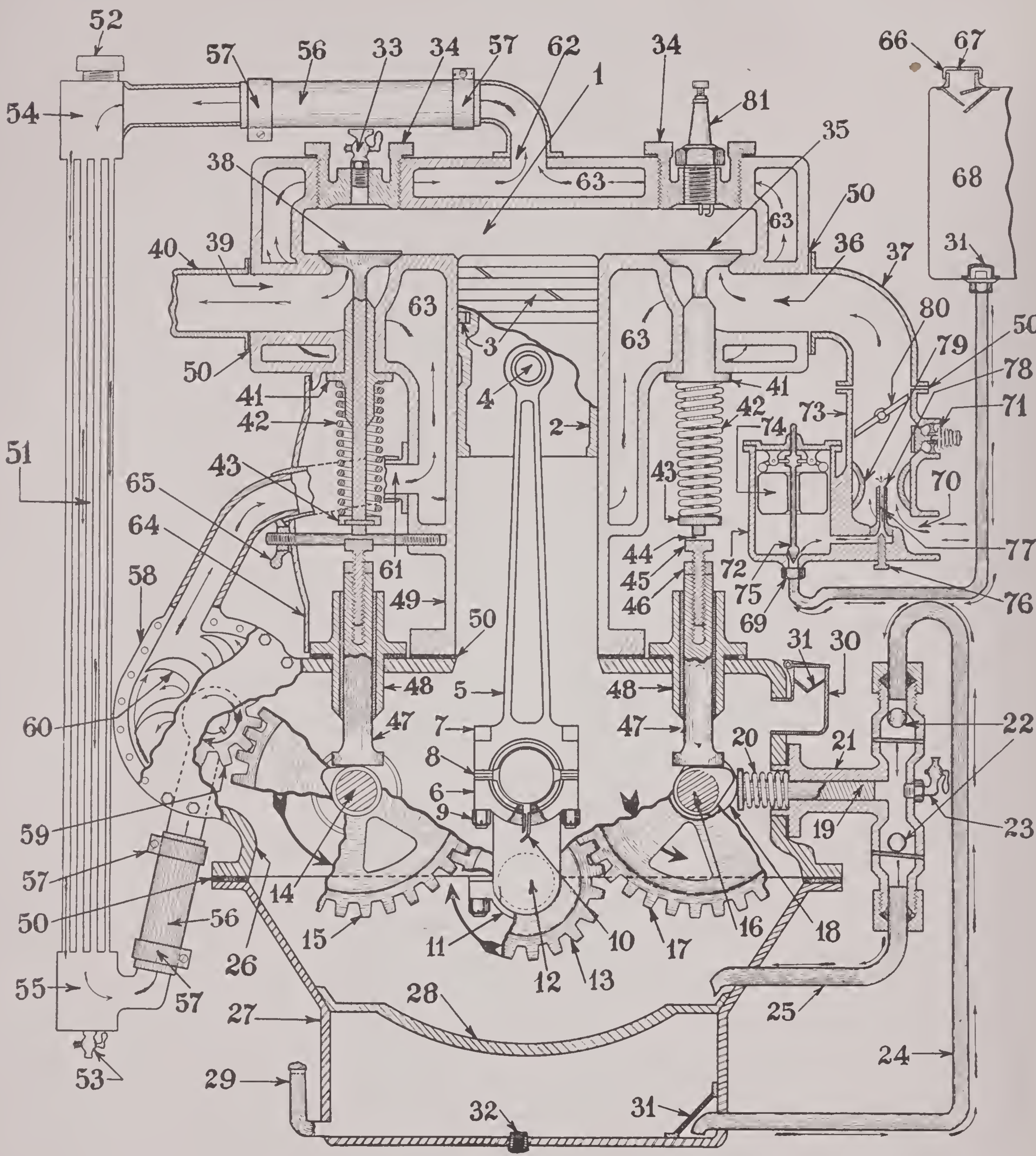


FIG. 2

T-HEAD FOUR STROKE CYCLE ENGINE

the fresh charge of gas, the compression, ignition and expansion of the charge, and exhausting of the burned gases.

FOUR STROKE CYCLE ENGINE

The parts involved in the construction of a four stroke cycle engine are:

Cylinder	Cams
Cylinder Head	Inlet Valve
Piston	Exhaust Valve
Piston Rings	Valve Tappet
Piston Pin	Valve Spring
Connecting Rod	Water Jacket
Crankshaft	Inlet Manifold
Main Bearings	Exhaust Manifold
Crankcase	Flywheel
Timing Gears	Carburetor
Camshaft	Spark Plug

Functions of the Principal Parts

The cylinder is a hollow stationary casting smoothly machined inside, in which the explosion takes place. The piston is a carefully fitted movable plug which receives the force of the explosion. It moves back and forth in the cylinder, and this reciprocating motion is transmitted to the connecting rod, by means of which it is converted into a rotating motion through the means of a crankshaft. This shaft is connected to the transmission system to drive the car.

The inlet valve controls the opening through which the fresh charge of gas is admitted to the cylinder. The exhaust valve controls the opening through which the burned gases leave the cylinder. Both valves are actuated by the valve tappets, these in turn being operated by cams on a camshaft which is driven from the crankshaft through the timing gears. The flywheel is a heavy balance wheel to keep the engine running between the power impulses. When the piston and crank are at the top extremity of their travel the position is called the "top dead center" (T. D. C.) and when at the lower extremity of travel it is called the "bottom dead center" (B. D. C.). The distance the piston travels in the cylinder from one extremity to the other is called the "stroke" of the engine and the movement causes the crankshaft to rotate one-half a revolution.

"Four Stroke Cycle" can now be understood to mean that it requires four strokes of the piston or two revolutions of the crankshaft (720 degrees circular travel) to complete the cycle of operations.

The four strokes are called:

1. Suction or Intake Stroke.
2. Compression Stroke.
3. Impulse or Power Stroke.
4. Exhaust Stroke.

Fig. 4 shows the positions of the principal parts of the engine in these four strokes. At (A) on the intake stroke, the piston is moving downward carried by the momentum of the flywheel or power applied to crankshaft; the exhaust valve is closed and the inlet valve open. The downward movement of the piston causes

FIG. 2

T-HEAD FOUR STROKE CYCLE ENGINE

1. Combustion chamber.
2. Piston.
3. Piston ring.
4. Piston pin or wrist pin.
5. Connecting rod.
6. Connecting rod cap.
7. Connecting rod bolts.
8. Shims.
9. Castle nuts.
10. Oil dipper.
11. Main bearing cap.
12. Crankshaft.
13. Crankshaft timing gear or master gear.
14. Exhaust camshaft.
15. Exhaust camshaft timing gear.
16. Inlet camshaft.
17. Inlet camshaft timing gear.
18. Eccentric.
19. Plunger. } Oil pump.
20. Plunger spring. } Oil pump.
21. Housing. } Oil pump.
22. Check valves. } Oil pump.
23. Pet cock. } Oil pump.
24. Inlet line.
25. Outlet line.
26. Crankcase.
27. Oil pan.
28. Oil trough.
29. Oil level gauge.
30. Oil filler and breather pipe.
31. Screen.
32. Oil pan drain plug.
33. Pet cock.
34. Port plug.
35. Inlet valve.
36. Inlet port.
37. Inlet manifold.
38. Exhaust valve.
39. Exhaust port.
40. Exhaust manifold.
41. Valve stem guide.
42. Valve spring.
43. Valve spring retainer.
44. Clearance.
45. Clearance adjuster.
46. Clearance adjuster lock nut.
47. Tappet.
48. Tappet guide.
49. Cylinder.
50. Gasket.
51. Radiator.
52. Filler cap.
53. Drain cock.
54. Upper chamber.
55. Lower chamber.
56. Hose connection.
57. Hose clamp.
58. Water pump housing.
59. Water pump drive gear.
60. Water pump impellers.
61. Water inlet to water jacket.
62. Water outlet to water jacket.
63. Water jacket.
64. Valve cover or inspection plate.
65. Wing or thumb nut.
66. Fuel tank filler cap.
67. Air vent.
68. Fuel tank.
69. Fuel inlet to carburetor.
70. Main air inlet.
71. Auxiliary air inlet, valve and spring.
72. Float chamber.
73. Mixing chamber.
74. Float.
75. Float needle valve.
76. Fuel adjusting valve.
77. Fuel jet.
78. Spray nozzle.
79. Venturi tube.
80. Throttle or butterfly valve.
81. Spark plug.

a vacuum in the cylinder, making the pressure lower than that of the atmosphere outside. The atmospheric pressure then forces air into the cylinder to replace the air displaced by the piston and to balance the two pressures. As the air enters, it passes through the carburetor picking up some of the fuel, forming a vapor or gas, which is represented as entering through the inlet valve.

At (B), just after the piston and crank have passed the bottom dead center the inlet valve closes, and the piston moving upward compresses the charge of gas entrapped in the cylinder. The gas is compressed in order that it may be in a more compact mass when ignited, which condition aids in developing rapid and vigorous burning, producing great heat and consequent high pressure. It also confines the gas to a smaller space when the temperature is highest thus avoiding some loss by radiation of the heat through the walls which hold it.

Just before the piston reaches the top dead center the gas is ignited, usually by an electric spark. The heat due to the burning of the gas causes it to expand and develops a very high pressure which forces the piston down as shown at (C), imparting the impulse to the crankshaft.

Before the piston reaches the bottom dead center again, the exhaust valve opens and the burned gases begin to escape, due to their being at a higher pressure than the atmosphere. The upward movement of the piston shown at (D) caused by the momentum of the flywheel, aids in clearing the cylinder of the burned gases, until the exhaust valve closes as the piston passes the top dead center again, when the whole cycle of operation begins its repetition.

EXPANSION PRINCIPLE OF THE INTERNAL COMBUSTION ENGINE

One of the scientific laws of gases states that the volume, pressure and temperature of any mass of gas are so closely related that no one of those properties can be changed without affecting one or both of the others. If the volume is kept constant, an increase in temperature will increase the pressure; a decrease in volume will increase temperature and pressure; or an increase in pressure or temperature would tend to increase the volume. These facts are the basis upon which the internal combustion engine operates.

During the compression stroke the charge of gas is decreased in volume and its temperature rises and the pressure increases. The instant the gas is ignited the temperature is again increased which tends to make the gas expand. At that moment the gas, being confined in the cylinder, is prevented from expanding so the pressure begins to increase until it is sufficient to move the piston.

This can be demonstrated by taking a metallic can, sealing up its opening and then heating it to raise the temperature a considerable amount. The can will begin to bulge due to the fact that the air or gas inside is expanding from the increase in temperature. If the temperature is still further increased the can will burst because, the walls of the can having limited the amount of expansion, the pressure will increase until it reaches an amount greater than the construction of the can will withstand.

All substances do not have the same combustion properties. Some burn quickly and some very slowly. Powder, for instance, burns with extreme rapidity, while kerosene or gaso-

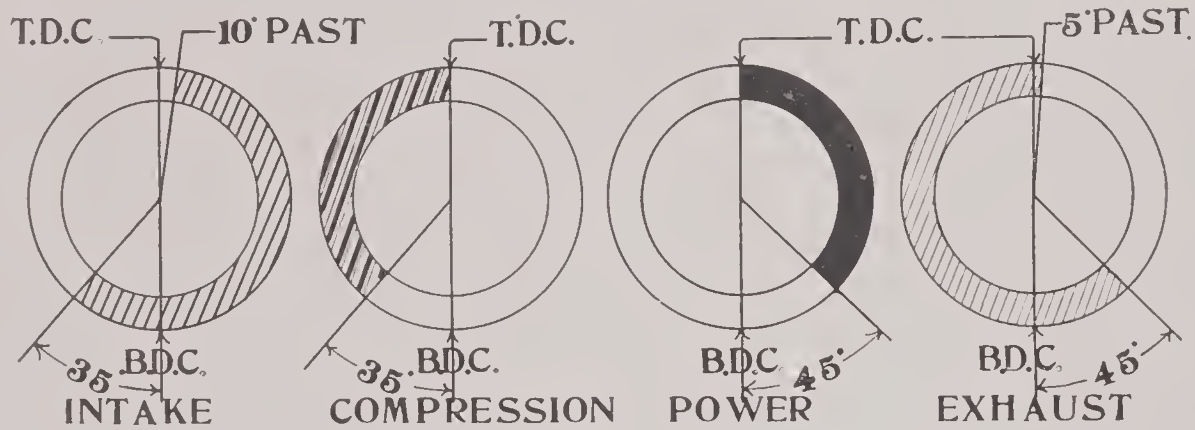


FIG. 3

CYCLE OF OPERATIONS

This figure shows the approximate crankshaft positions at the start and finish of each of the four strokes. The shading shows the length of the strokes with these valve openings and closings, the crankshaft turning in a clockwise direction.

The position of the crankshaft at the start and finish of each stroke is represented by the lines at the end of the shading.

The length of the stroke varies in different engines.

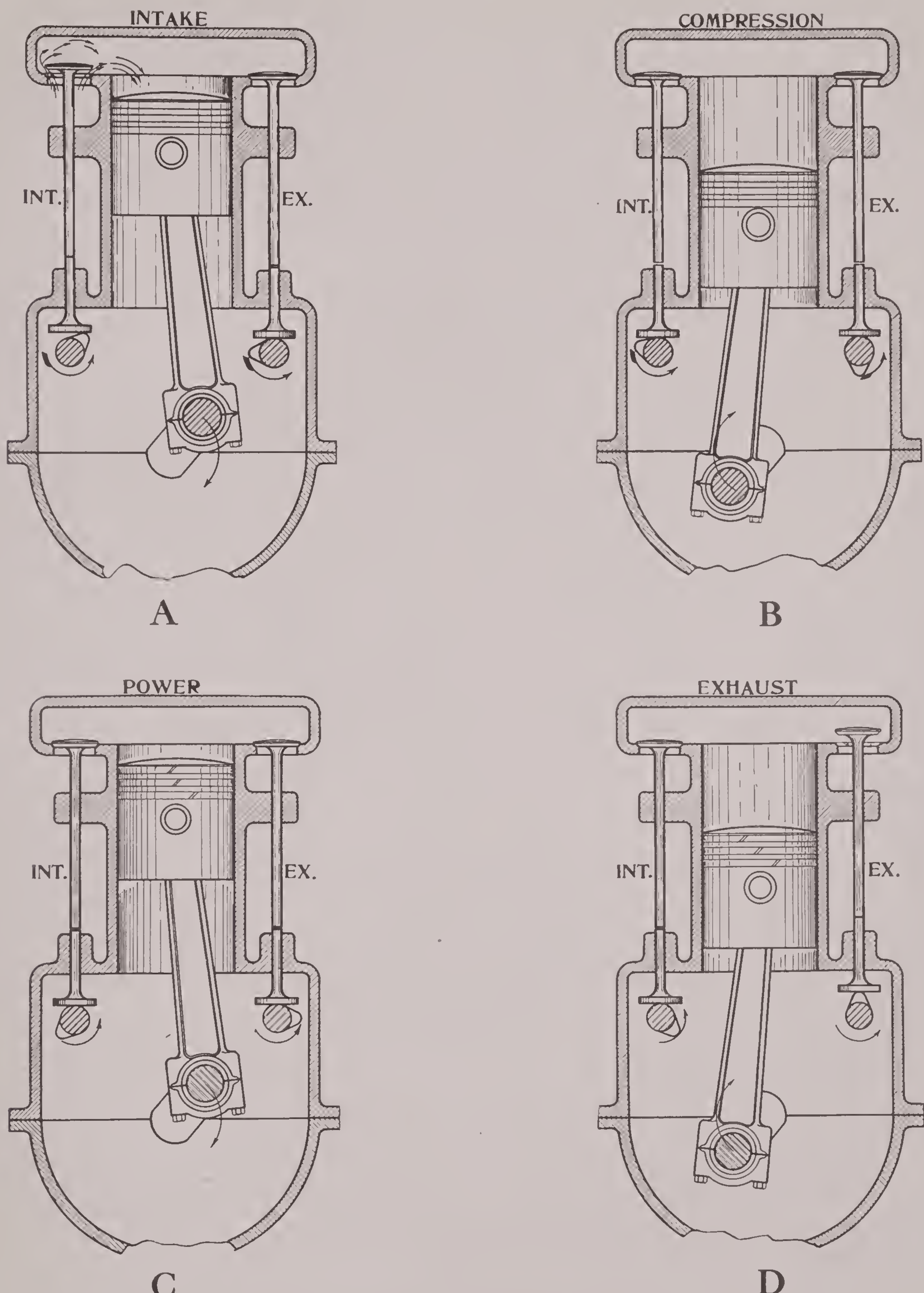


FIG. 4.

ENGINE OPERATIONS

These illustrations show the relative positions of the crankshaft, piston, cams, and valves as the various strokes begin.

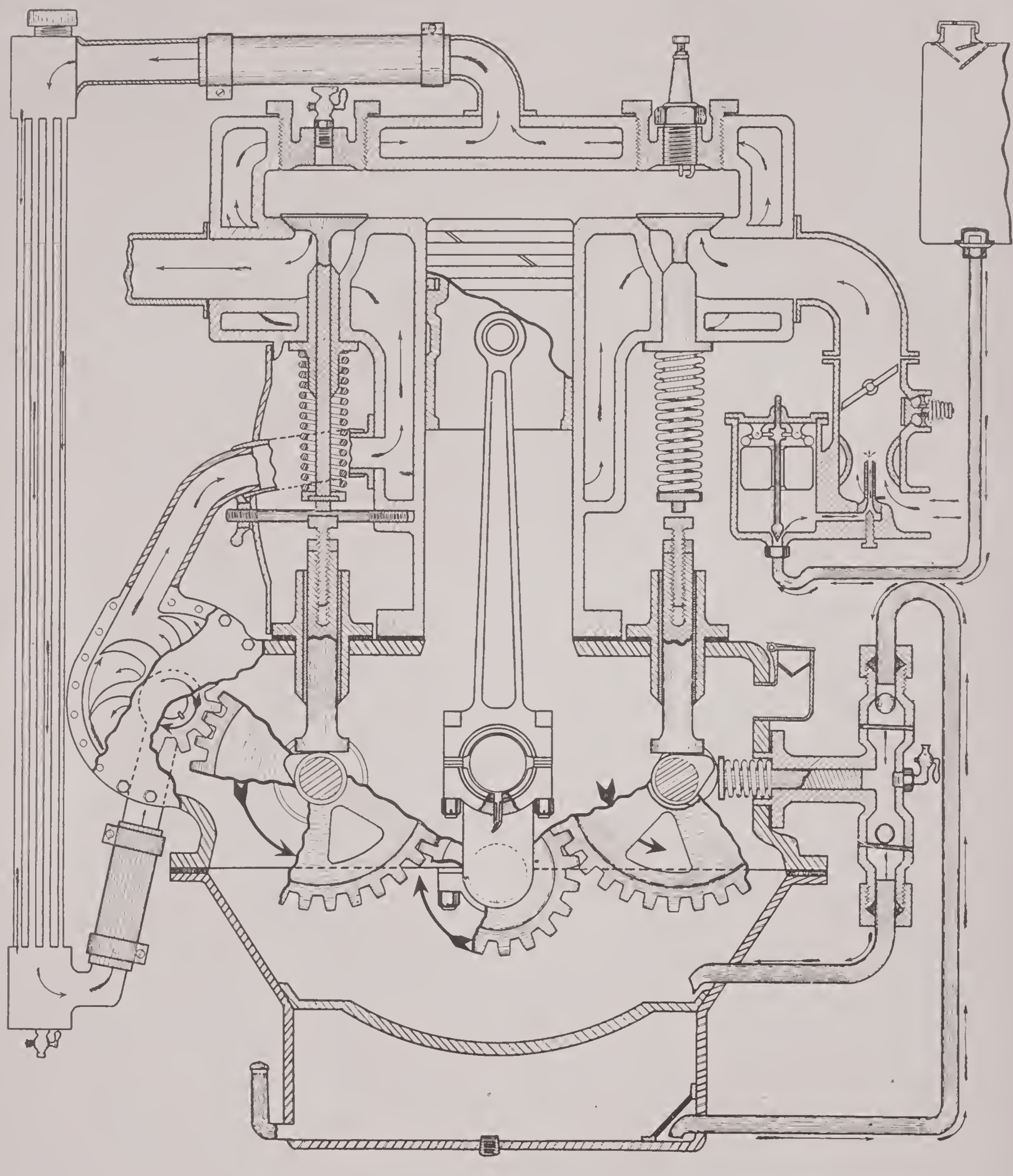


Fig. 5

T-HEAD FOUR STROKE CYCLE ENGINE

This figure shows the complete assembly of a single cylinder T-head engine, with its accessories.

line burn slower. This difference in the rate of combustion has much to do with the power available. The quick burning substances or fuels indicate a rapid temperature rise and quick expansion; the less inflammable fuels, burning more slowly, require more time for transmitting the power of the expanding gas.

In present practice the fuel charge is compressed to between 70 and 80 pounds gauge pressure. The higher the compression the greater the power obtained and the higher the fuel economy, but when the compression exceeds a certain limit there is danger of trouble from overheating of the cylinder and from "self-ignition" or "pre-ignition" due to the heat generated by compression.

The following figures show what temperature the gases reach under the influence of compression pressures, the temperature before compressing being 60 degrees Fahrenheit in each case:

Compression to	Temperature attained.
30 lbs. (gauge)	258 degrees F.
60 lbs.	373 degrees F.
90 lbs.	490 degrees F.

This shows that an increase in compression will cause an increase in the temperature of the gases without the application of any other heat. If the normal operating temperature of the engine is added to this, it would be possible to raise the temperature of the gases to a very high point, sufficient to pre-ignite them.

The temperature of combustion is approximately 2500 degrees to 3000 degrees Fahrenheit. These temperatures are considerably below the theoretical temperature of combustions, but many conditions are present to cause this difference. If such a high temperature was allowed to continue, the metal parts of the engine would bind or "seize," since metals expand in the same manner as gases when heat is applied, except that the amount of expansion is less and it varies in different metals.

To prevent the engine from attaining this excessive temperature, a circulation of air or water around the cylinder is provided to carry away a portion of the heat. Here then are two agencies apparently working against each other both of which are necessary. The higher the combustion temperature of the fuel, the more power available. Hence it is the problem of the automobile engineer to design the engine in such a manner as to dissipate the excessive heat sufficient to protect the materials used and yet allow the fullest value to be extracted from the fuel.

This problem involves the size and shape of the combustion chamber,—the portion of the cylinder in which the gas is exploded,—as well as the type of cooling system. The most common cooling method used is water-cooling; a jacket is provided to allow the water to circulate around the cylinder where it is exposed to the high temperature. Great care must be used to see that the cooling system is always filled with water. In any cooling system however, much of the heat value of the fuel is carried away without its rendering any useful work, which reduces materially the power delivered by the engine.

In the lower portion of the crankcase there is provided a sump or reservoir containing lubricating oil. As the crankshaft rotates, a spoon or dipper on the connecting rod comes in contact with the oil. As it travels upward it throws or splashes oil into the engine, lubricating the cylinder wall, piston, piston rings, piston pin and bearings. All moving surfaces in the interior of the engine are lubricated from this source.

THERMAL EFFICIENCY

In addition to the loss of heat through the cooling system, other conditions, some of them peculiar to the gas engine, combine to reduce the efficiency of its operation. The internal friction of the engine itself consumes a certain amount of power; the low grade of fuel combined with inlet manifold design, and the impossibility of designing a carburetor suitable for all load and speed conditions causes some fuel to enter the cylinder in liquid form, unvaporized; also the exhaust gases leave the cylinder before all of the available heat energy has been given up.

The efficiency of an engine is determined by comparing the amount of energy put into it with the amount of energy it delivers in the form of work. The ratio between the number of heat units supplied in the fuel and the useful work actually performed expressed in heat units, is called the "Thermal Efficiency." The gas engine is the most efficient type of heat engine. In some designs the efficiency is as high as 35%, while in the average automobile engine it is approximately 17% to 20%. The losses vary in different engines, but they may be divided approximately as follows, using the total amount of fuel supplied as 100%:

Friction	13%
Exhaust	30%
Cooling	40%
Power available	17%
Total	100%

DEFINITIONS
INTERNAL COMBUSTION ENGINE TERMS

Bore is the internal finished diameter of the cylinder.

Stroke is the distance moved by the piston from one extreme end of its travel to the other, or from top dead center to bottom dead center positions. The stroke is always twice the radial distance from the center of the crankshaft to the center of the crank pin.

Combustion Chamber is the name given to the space in which the gaseous fuel is ignited and exploded. It includes all the clearance space above the piston when it is on top dead center.

Linear Velocity is the combination of units of distance and units of time. It is the rate of motion and is expressed in "feet per minute" or "feet per second."

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

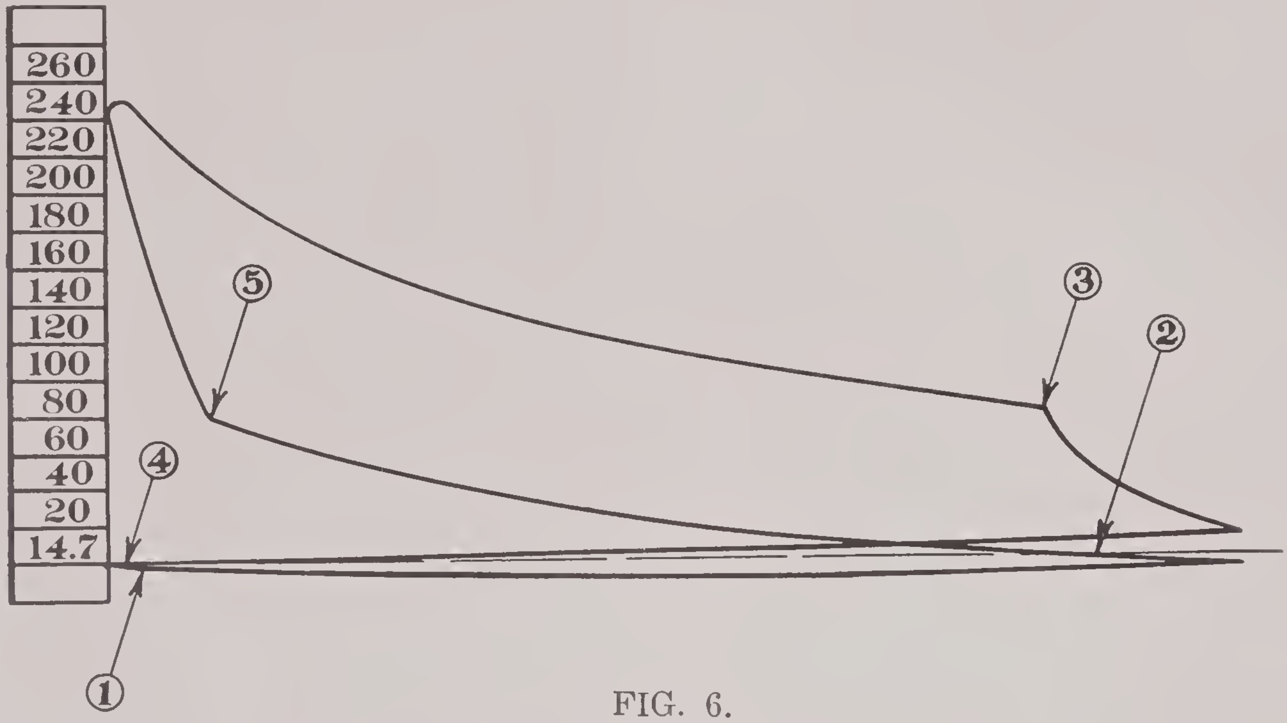


FIG. 6.

INDICATOR CARD, INTERNAL COMBUSTION ENGINE

An indicator card showing the mean effective pressure readings of a typical engine.

1. Inlet valve opening.
2. Inlet valve closing.
3. Exhaust valve opening.
4. Exhaust valve closing.
5. Ignition.

The average temperature at end of the intake stroke is about 260° F. and at the end of the compression stroke is about 850° F.

The temperature during the power stroke rises to as high as 3000° F. and at the start of the exhaust stroke the temperature is about 1000° F. At the end of the exhaust stroke the temperature is about 300° F.

Displacement is the volume displaced by the piston in moving the length of the stroke. To calculate the displacement, multiply the cross sectional area of the cylinder in square inches by the stroke in inches, as expressed in formula, Displacement (cubic inches) = area $\times$ stroke.

For example, the displacement of an engine with 4 inch bore and 5 inch stroke would be;

Area $= D^2 \times .7854 = 4 \times 4 \times .7854 = 12.566$ sq. in.
Stroke $= 5$ in.

$12.566 \times 5 = 62.83$ cubic inches. Ans.

Volumetric Clearance is all the space above the piston when it is on top dead center, including valve pockets, etc., and is expressed in terms of displacement. The clearance percentage equals the clearance volume divided by the displacement.

Circular or Angular Velocity is given in revolutions per minute (R. P. M.) or degrees per minute.

Piston Speed is the summation of the distances traversed by the piston in its up and down movement in a certain period of time. It is the velocity at which the piston is moving. Thus, in an engine with 5 inch stroke making 600 R. P. M. or 1200 strokes per minute the piston speed would be

$$\frac{1200 \times 5}{12} = 500 \text{ ft. per minute.}$$

Pressure expresses the force acting upon a certain area. It is usually calculated as acting upon a unit area and expressed in "pounds per square inch."

Work is the combination of the units of weight or force and distance. It is the overcoming of resistance (usually measured in pounds) through a certain distance. It is calculated by multiplying the moving force, in pounds, by the distance moved, in feet.

The unit of work is the amount of work done by a force of one pound moving through a distance of one foot and is called the "foot-pound."

Power is the rate at which work is done. The most common unit of power is the horse-power (H. P.) and was established by James Watt as the power of a strong draft horse and used by him to measure the power of steam engines. Power equals work (in foot pounds) divided by the time. One H. P. equals 33,000 foot pounds per minute.

The indicated horse-power (I. H. P.) is the horse-power actually developed within the cylinder, and may be calculated from an indicator card, the engine dimensions and the speed of the engine at the time the indicator card was taken. The mean effective pressure (M. E. P.) is determined from the indicator card and represents the average of the pressures at the different positions of the piston.

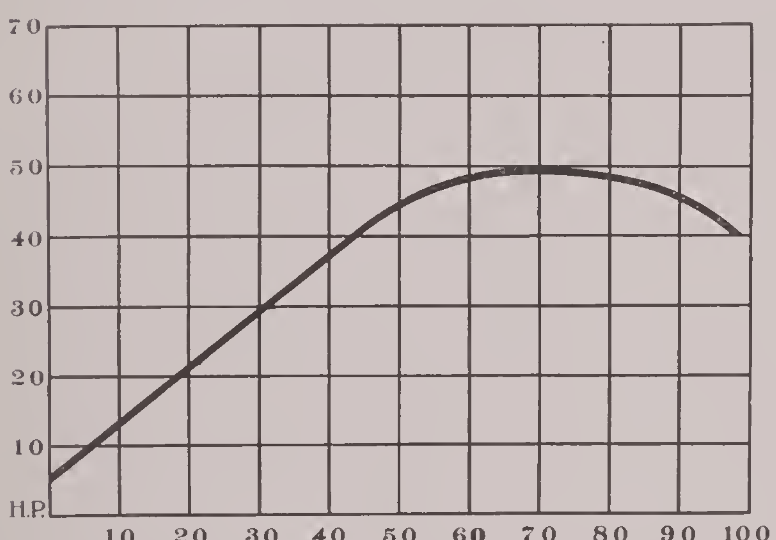


FIG. 7.

COMPRESSION CHART

This chart shows that as the compression is raised the power developed increases until the point of pre-ignition is reached.

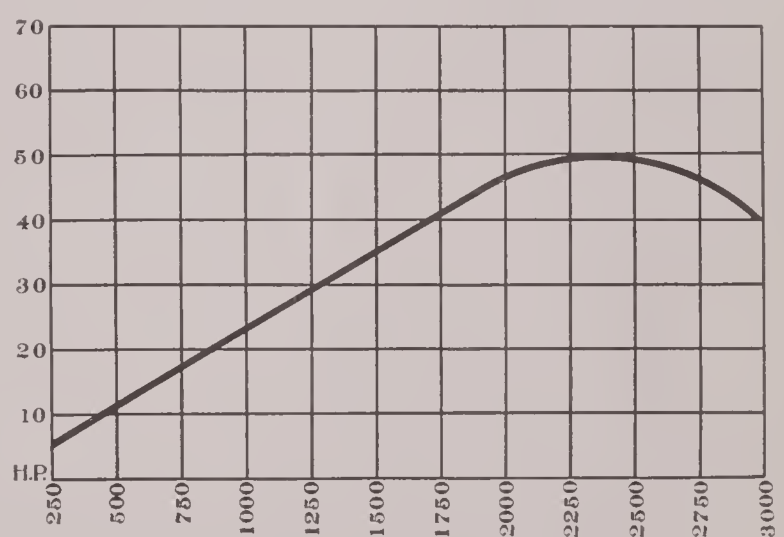


FIG 8.

POWER CHART

This chart shows that as the engine speed is increased the power developed is also increased, until the maximum power is developed.

The horse-power formula is:

$$\text{I. H. P.} = \frac{PLANX}{33000}$$

in which P = M. E. P.
L = Length of stroke in feet.
A = Area of piston in sq. in.
N = R. P. M.
X = Number of impulses per revolution.

For example:–Calculate the I. H. P. of a 4 cylinder, 4 stroke cycle engine with 4 inch bore and 5 inch stroke. Indicator card shows M. E. P. = 90 lbs. per sq. in.; engine running 2000 R. P. M. Then

P = 90
L = 5/12
A = $4^2 \times .7854 = 12.566$
N = 2000
X = 2

$$\text{I.H.P} = \frac{90 \times 5/12 \times 12.566 \times 2000 \times 2}{33000} = 57.12 \text{ Ans.}$$

In practical work the brake horse-power (B. H. P.) rate is used instead of the I. H. P. The B. H. P. is obtained by a dynamometer test or Prony Brake test. The B. H. P. is the horse-power that is delivered by the crankshaft for useful work.

By substituting certain assumed values in the above formula, the automobile engineers have developed a shorter formula which is generally accepted in the approximate rating of automobile engines. The formula was formerly known as the A. L. A. M. (American Licensed Automobile Manufacturers) formula, but has been adopted by the National Automobile Chamber of Commerce, The Society of Automotive Engineers and the Royal Automobile Club of Great Britain. This formula is based on an M. E. P. of 90 lbs. per sq. in., any combination of stroke and R. P. M. that gives a piston speed of 1000 feet per minute, and is written

$$\frac{D^2 \times N}{2.5}$$

in which D = the diameter of the cylinder in inches and N = the number of cylinders. Using the same example as before, a 4 cylinder, 4 stroke cycle engine with 4 inch bore,

$$D = 4$$
$$N = 4$$

$$\text{Then H. P.} = \frac{D^2 \times N}{2.5} = \frac{4^2 \times 4}{2.5} = 25.6 \text{ Ans.}$$

This would be the approximate horsepower developed by that engine when running at 1200 R. P. M., the engine speed which would give a piston speed of 1000 feet per minute. This same engine would probably develop a much higher horsepower at its maximum speed, for the horse-power increases as the engine speed increases until the maximum power point is passed.

Torque is a twisting or turning force. When used in reference to the engine it is the effort or pull in pounds exerted by the crankshaft at a certain radius. In a sense, it is independent of the power of the engine, for the torque may be low and yet if the engine speed is high the horsepower will be high. The Prony Brake test is determining the horse-power by measuring the torque.

Density is the comparison of weight and volume. It is the weight per unit of volume.

Specific Gravity is the comparison of the density of a substance with the density of water, or the weight of the substance compared with the weight of an equal volume of pure water at a temperature of 39.2 degrees F. The specific gravity of gases is determined by comparing their weights with the weight of air.

Specific Heat is the ratio between the heat required to raise the temperature of a certain weight of any substance one degree, and the heat required to raise the same weight of water from 62 degrees to 63 degrees F.

Calorific Value is the amount of heat given up by a unit quantity of any fuel that is burned under proper conditions. It varies in different fuels. A good general figure to use for the average gasoline of today is 20,000 B. T. U. (British Thermal Units) per pound.

The B. T. U. is the unit of heat, and is the amount required to raise the temperature of one pound of pure water from 62 degrees to 63 degrees F.

The Mechanical Equivalent of heat is the amount of mechanical energy equivalent to the heat energy in one B. T. U. Heat and energy being mutually convertible, one B. T. U. = 778 foot-pounds. Since one H. P. = 33,000 foot-pounds per minute, one H. P. = 2545 B. T. U. per hour.

Scavenging is the process of clearing the cylinder of the burned gases.

Flame Propogation is the rapidity of combustion or spreading of the flame through the gaseous mixture after it has been ignited. It is affected both by the quality of the mixture and the compression pressure. For certain compression pressures and certain fuels there is one proportion of mixture at which the flame spreads the fastest. Even a slight deviation from that proportion will make a marked difference in the velocity of propogation, the power, and the thermal efficiency of the engine. Weak compression or an excess of air or of gas will retard the velocity of the flame spreading and require the spark to be advanced to obtain proper results.

Pre-ignition is the premature explosion of the gas in the cylinder. It may be caused by too high compression, ignition spark too early, or carbon deposit in the cylinder.

CYLINDERS

Types

There are four types of cylinder construction, named from the form in which the casting is made,—T-head, L-head, I-head, F-head.

In the T-head type the inlet and exhaust valves are placed on opposite sides of the cylinder, making a large combustion chamber, projecting both sides of the cylinder. This results in an excessive amount of surface being exposed to the cooling medium, and causes a loss of power in the fuel mixture, also using a greater amount of fuel than other types of cylinders to develop a given horse-power. This type is but little used, only 2½% of passenger car engines and 4½% of truck engines being T-head.

In the L-head type, both valves are on the same side of the cylinder, thus reducing the size of the combustion chamber about one half. Although not the best, this arrangement is a decided advantage over the T-head from a standpoint of thermal efficiency, for the reason that it has a smaller amount of surface exposed to the cooling medium. It also has the mechanical advantage of requiring but one camshaft, instead of two as on the T-head. All the cams are placed on the one shaft and driven by one set of gears. About 66% of the engines used in passenger cars and 87% of those used in trucks today are of L-head type.

The valve-in-head or I-type gives the highest thermal efficiency, because of small combustion chamber, all of it directly over piston head. The elimination of the side pockets of the L and T-head type has removed the dead spaces where ineffective gases may remain. The valve arrangements are about equally divided between inclined valves and straight or perpendicular valves. The valves are actuated by rocker arms which receive their motion through push rods from a camshaft located as in the other type, or by an overhead camshaft driven from the crankshaft through a series of bevel gears. About 24% of passenger car engines are of this type.

The F-head cylinder is a compromise, to obtain some of the advantages of the T and L-head. The inlet valve is placed in the head and the exhaust valve at the side. This results in better scavenging of the cylinder, reduces the size of the combustion chamber to approximately that of the L-head cylinder and yet allows large valves to be used as in the T-head cylinder. The thermal efficiency is no better than that of the L-head.

Material and Construction.

The most common material used in cylinder construction is cast iron with a heavy content of graphite, making it a very good wear resisting material. Graphite has a tendency to lubricate, which reduces the percentage of wear at a high temperature. Some cylinder blocks are constructed of aluminum with steel or cast iron sleeves pressed or threaded into the aluminum block. Others are constructed of steel, such as the aircraft engine where the cylinders are machined both on the inside and outside and the water jacket is brazed or welded to the cylinder. The reason for this is that in a casting the cylinder walls and other parts may not be of the same uniform cross section. If not the same, when the tempera-

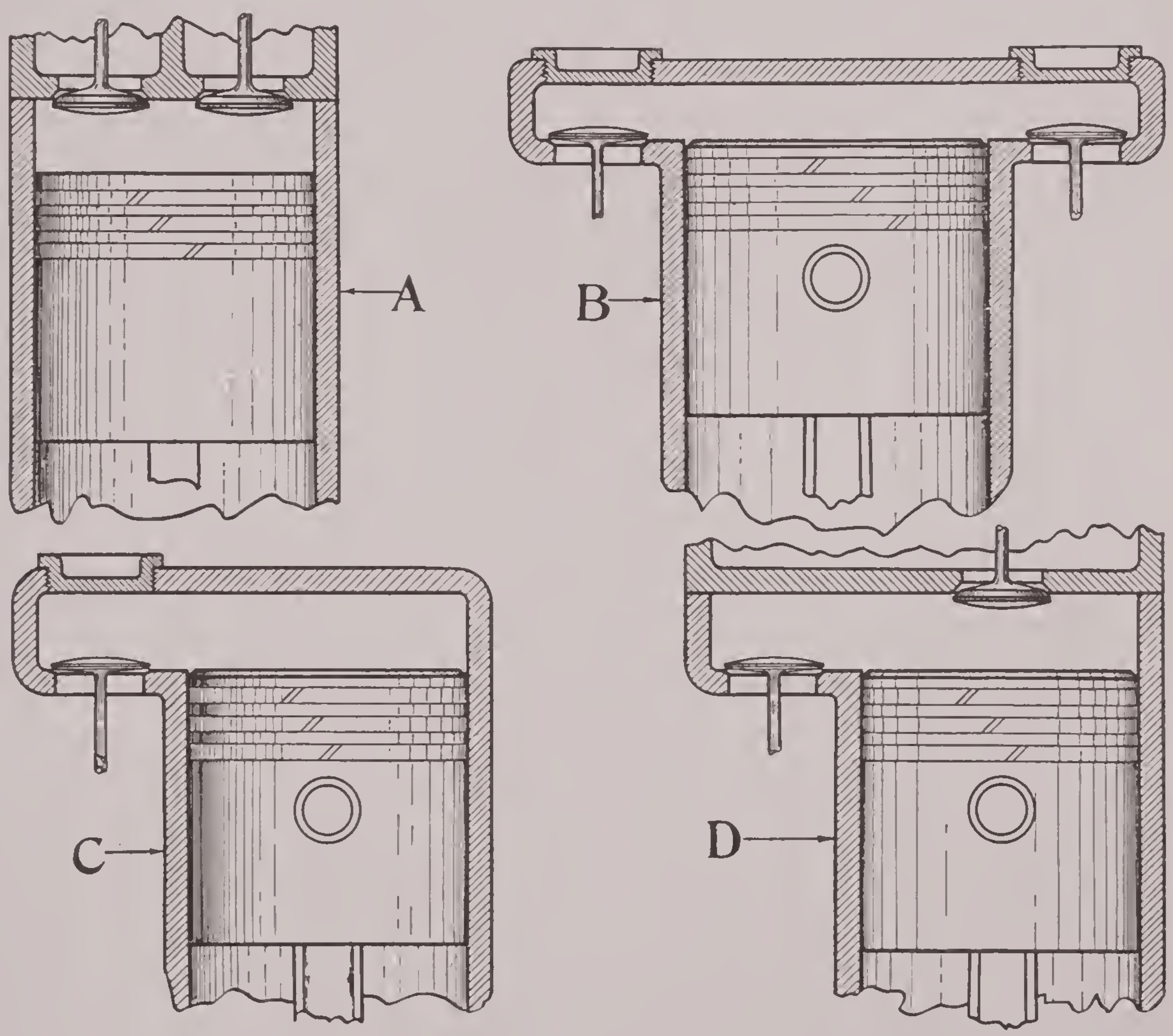


FIG. 9

TYPES OF CYLINDER AND VALVE ARRANGEMENTS

This figure shows some of the various shapes of combustion chambers and arrangements of valves. Illustration (A) represents the I-head cylinder having both valves in the head of the cylinder over the piston, being operated by one camshaft.

Illustration (B) represents the T-head cylinder, having the inlet and exhaust valves on opposite sides of the combustion chamber, being operated by two camshafts.

Illustration (C) represents the L-head cylinder, having the inlet and exhaust valves on the same side, being operated by one camshaft.

Illustration (D) represents the F-head cylinder, having one valve mounted at the side and one in the head, both operated by one camshaft.

ture rises the expansion will not be the same in all parts of the cylinder, causing the cylinders to warp. The cylinders of the aircraft engine, in order to minimize this unequal expansion, are machined on the inside and outside. Steel cylinders are not used to any extent in automotive construction, since they are more expensive and less serviceable. Cast iron is used almost entirely.

Cylinder heads are usually constructed of cast iron and are as a rule cast with the water jacket incorporated in the head itself. This is done by placing cores inside of the mould before the cylinder head is cast.

The cylinder head joint is made air tight by the use of a gasket. This gasket consists of two layers of thin sheet copper which cover a sheet of asbestos. The head is held down by bolts or studs. These bolts are not plain cold rolled steel, but are, as a rule, heat-treated alloy steel. Where the head is not removable, an arrangement of port plugs is provided for easy access to the valves. The port plugs are screwed into threaded holes on the top of the engine, generally directly above the valves. The port plugs are set on a gasket in order that an air tight connection may be made. In some cases, the port plugs are held down by clamps. The same type gasket is used for the port plug as under the cylinder head. Cover the port plug threads with graphite and grease so that they will be air tight when screwed down and can be easily removed.

Finishing

The cylinder walls are finished in several ways. The block is first cast in sand molds made from a pattern, then placed on a boring machine and the cylinder is bored out to the required size, perfectly round and straight. The various methods of finishing the barrel or bore are for the purpose of obtaining as smooth a surface as possible thereby reducing the development of friction.

After the boring, two processes are used to finish the inner surface to accurate size and leave a very smooth surface. The first is reaming. The cylinder is bored to a diameter a fraction of an inch smaller than required, and then the reamer, a fluted boring tool ground accurately to size, is run through leaving a smooth surface of correct dimensions.

The other process is grinding. This is by far the best method of finishing the interior wall, for the reason that it is done with high speed wheels and the rough effect is not left in the barrel as it is with the slower operating tools. The grinding wheels are not affected by the hard spots in the metal as are the cutting tools, therefore a uniform job is insured when finished.

Troubles and Repairs

The more common interior cylinder troubles are cylinder scores or cylinder warped and out of round. These troubles are all corrected by one of the following processes: Boring, grinding, reaming or lapping. The lapping, however, cannot be used to correct scored and warped cylinders without first boring, grinding or reaming. Tools must be used to straighten up the job and then merely smoothen by lapping. These repairs invariably necessitate new pistons and rings, as the size of the cylinder barrel is enlarged considerably.

For lapping, use an old piston with the rings removed, and with a grinding compound on the surface of the piston, place it in the cylinder, then force the piston up and down in a reciprocating and rotary movement, using a stroke the full length of the cylinder wall. After the cylinder wall is polished down smooth, take the new oversize piston, the head of which can just be started in the bottom of the cylinder, apply the grinding compound, and by turning it back and forth, gradually work the piston through. Then remove the piston and the lapping compound and measure the clearance. If the clearance is not sufficient, replace compound and proceed as formerly, using full length strokes until sufficient clearance is obtained, and then the rings may be fitted.

The more common outside troubles to cylinder blocks are cracked water jackets. The jackets are, as a rule, cast in one piece with the cylinder blocks. The most common method of repairing is the salting, rusting, or crystalizing process.

If the crack is not very large and has not been cracked too long, it may be repaired by placing a 20% solution of Copper Sulphate (Blue Vitriol) in a squirt can, and squirt it into the crack. This will cause crystals to form within the crack.

Dissolve about one pound of chloride of sodium, or common table salt, in about three gallons of water. Pour this in the water outlet at the top of cylinder, after stopping up the water inlet at the bottom. Allow the solution to stand above the level of the crack until the leak stops. This solution will only affect the freshly exposed metal in the crack, causing rust.

Dissolve one pound of sal ammoniac crystals in five gallons of water and pour this into the water jacket the same as in the above case. This will also cause rust to form in the crack stopping the leak.

Any of the above solutions will soon rust the crack so that the jacket will hold water, until such a time as the engine is run without water or allowed to become heated above the normal operating temperature. This may be caused by lack of cooling water or lubrication. Where the crack is large or old, these solutions will be ineffective. To repair, clean off the surface about one inch on each side of the crack. With a small sharp cold chisel cut a small "V" shaped trench along with the crack. Rub the surface well with a piece of copper, and then clean the surface well with raw muriatic acid, apply soldering salts and tin the surface, and then apply hard solder until the crack is well filled. Dress down smooth and paint.

Where the crack is large and hard to solder, it may be repaired by drilling a row of small holes about one-half inch apart in the crack. Use a blow torch to heat the metal around the crack and small holes. Take ordinary copper rivets and drive them into the holes in the crack while hot. The cylinder jackets when cooling contract so that the rivets will be held firmly in place. Now take a cape chisel or narrow cold chisel and groove the crack about 1/16″ deep. Clean thoroughly with raw muriatic acid or any other cleaning acid that will penetrate to all parts where the solder should reach. Heat with blow torch and then apply hard solder in such quantity as to form a mound over the crack. Dress the surface with a file or with a grindstone and paint to cover all traces of the work.

Probably the best method, although the least desirable for the repairing of water jackets, is welding or brazing. It may result in warping and cracking. Unless properly pre-heated this invariably necessitates reboring of the barrel if an accurate job is desired. Due to the fact that the cross sectional area of the cylinder walls is not the same all the way through, the expansion will be greater at some points, and less at others, causing the cylinder walls to become out of round or to warp. This will require reboring in order that the engine will have a true cylinder barrel.

Carbon Deposit

The formation of carbon in the combustion chamber is one of the causes of engine knocking. The deposit of carbon may be caused by (1) an excessive amount of lubricating oil getting into the combustion chamber; (2) by using low grade fuel, or (3) too rich a mixture.

In the first cause, the lubricating oil works up by the piston, and since it contains some of the same elements as are in the fuel, the excessive heat tends to break it up or destroy it, the lighter parts passing off as a vapor, leaving the carbon to cook or bake on to the surfaces of the combustion chamber. With the other two causes, incomplete combustion leaves a certain amount of carbon from the fuel in the cylinders, which hardens or cakes on to the surfaces from exposure to the high temperatures.

The combustion chamber should be finished as smooth as possible as there is less tendency for carbon to adhere to a smooth surface. The deposits of carbon reduce the size of the combustion chamber, causing a higher compression pressure and a corresponding increase in temperature. Carbon also holds the heat, preventing it from radiating properly to the cooling medium. These conditions may result in a temperature sufficiently high to cause premature ignition of the gas. Carbon deposit will also cause the spark plugs to become fouled, resulting in a failure of the plug to deliver the necessary spark for igniting the charge of fuel.

Carbon may be removed by several different methods. It may be partly removed by adding water to the mixture, a little at a time, when the engine is hot and running at high speed. This water must be introduced slowly and above the spray nozzle in the carburetor, otherwise the engine will stop.

Another method is to remove the spark plugs or open the petcocks and with a squirt can place a few spoonfuls of kerosene into each cylinder. Then with the ignition off, spin the engine over fast, allowing this kerosene to be thrown around, saturating the entire surface of the combustion chamber. Allow the kerosene to remain in the cylinder over night. The next morning when the engine is started the carbon that is dissolved will pass out with the exhaust gases.

After this deposit remains in the combustion chamber for some time it will form in such a hard scale that the above methods may not be effective. If that is the case, remove the port plugs or cylinder head and scrape this deposit out. At the same time it is usually necessary to grind the valves. Carbon may also be removed by burning it out with an oxygen torch, but care must be taken not to overheat or cause the piston or cylinder to become out of round from unequal expansion. Scraping the carbon is preferable.

If the combustion chamber is too small, there may be premature explosions when the engine is running slowly on a hard pull. The mixture is ignited from the high temperature that is caused by the increased compression. This is termed a compression knock and may be overcome by replacing the cylinder head gasket with a thicker one or by placing a fiber gasket underneath the cylinder, if the cylinder is removable from the crankcase.

Having the spark advanced too much will also cause ignition of the gases before the piston reaches top dead center, resulting in a knock termed, spark knock.

PISTONS

The piston serves a triple function. It forms the movable wall of the combustion chamber, allowing its volume to be increased or decreased. It receives the force of the explosion pressure and transmits that pressure to the connecting rod and also acts as a crosshead, transmitting the angular thrust of the connecting rod to the cylinder wall.

Since the pressure in the combustion chamber is sometimes as high as 400 lbs. per square inch, it is necessary to provide some means of making the piston gas tight. The piston head heats more than the cylinder wall, because it is not cooled by the water jacket; the head end of the piston heats more than the open end because it is exposed to the heat of the burning gases. These facts, and the difference in expansion due to these varying temperatures, make it impossible to finish the piston itself tight enough to form the proper seal. This is accomplished by using flexible split metallic rings, called piston rings, three or four of them being placed in grooves turned on the outer circumference of the piston to receive them. These rings expand and contract with the changes in temperature, are made so as to exert a pressure against the cylinder wall over their entire surface, and with the aid of the lubricating oil, they maintain practically an airtight seal between the combustion chamber and the crankcase. This is termed the "compression seal" and its purpose is to keep the fuel mixture in the combustion chamber during compression and after its ignition.

The shape of the piston head has considerable effect upon the thermal efficiency of the engine. The ideal form would be a concave head, as this would concentrate the heat of combustion in the center of the combustion chamber, away from the cylinder walls, where it would be radiated to the water jacket. However, this shape is of weak construction and also gathers carbon readily, so is not used. In present practice the heads are flat or convex and finished smooth.

To provide for the uneven expansion of the piston and the cylinder walls and to allow for lubrication, a certain amount of clearance is allowed between the two. The cylinder is bored to exact even dimensions and the piston finished a certain amount smaller. The average practice is to allow .002″ to .003″ per inch of diameter at the piston head, and .001″ to .0015″ per inch of diameter at the open end. This clearance varies with different metals used and also on different designs of engines and the purposes for which they are to be used.

There are usually three piston rings used above the piston pin and perhaps one below. The lower ring acts more as an oil carrier. The grooves are finished about .0005″ wider than the ring and are deep enough to insure the ring not touching the bottom of the groove at any point after the piston and ring have been inserted in the cylinder.

There is sometimes an oil groove below the bottom ring with holes drilled through the piston wall, so that as the piston moves downward the ring will act as a scraper, scraping the oil into the groove, where it will flow through the holes and drop back into the crankcase. The grooves act as oil carriers to keep a film of oil on the cylinder walls both for lubrication and to form a seal between the piston ring and cylinder wall.

In multiple cylinder engines all the pistons should be of exactly the same weight. If one piston is heavier or lighter than the others it causes an unbalanced condition which results in an excessive vibration and unnecessary wear on the bearings.

The piston pin which forms the connection between the piston and the connecting rod is carried in bearings in the walls of the piston. These bearings are provided with bronze bushings which are pressed into place if the piston pin is designed to move in them. In some pistons the pin is made fast in the bearings and the connecting rod moves on the pin, in which case there are no bushings in the bearings in the piston.

The distance from the top of the piston to the center of the piston pin should be the same on all pistons in an engine. Should these distances vary, the compression would be unequal and cause vibration.

Material

The piston is usually made of cast iron, the grade of material being somewhat softer than used in the cylinder, so that the wear will come upon the piston, which is easier and cheaper to replace. Much experimenting is now being done with an aluminum alloy, the advantage being its light weight, which is of considerable value in eliminating vibration. In the reciprocating motion of the piston its weight has to be started and stopped twice in every revolution. Power is used in starting this weight, but of more importance is the vibration caused by overcoming the energy stored up in the moving parts after they are in motion. The aluminum piston has another advantage in the fact that carbon will not adhere to it as readily. It also radiates heat much more rapidly than cast iron and will therefore be cooler than the iron piston, a condition which permits higher compression pressures. Aluminum expands more than cast iron when heated so that a larger clearance is necessary, the usual practice being to allow about twice the amount used on cast iron pistons. The aluminum piston may have a tendency to slap and knock when cold on account of this extra clearance, but when the engine heats up to running temperature the fit will be the same as with cast iron.

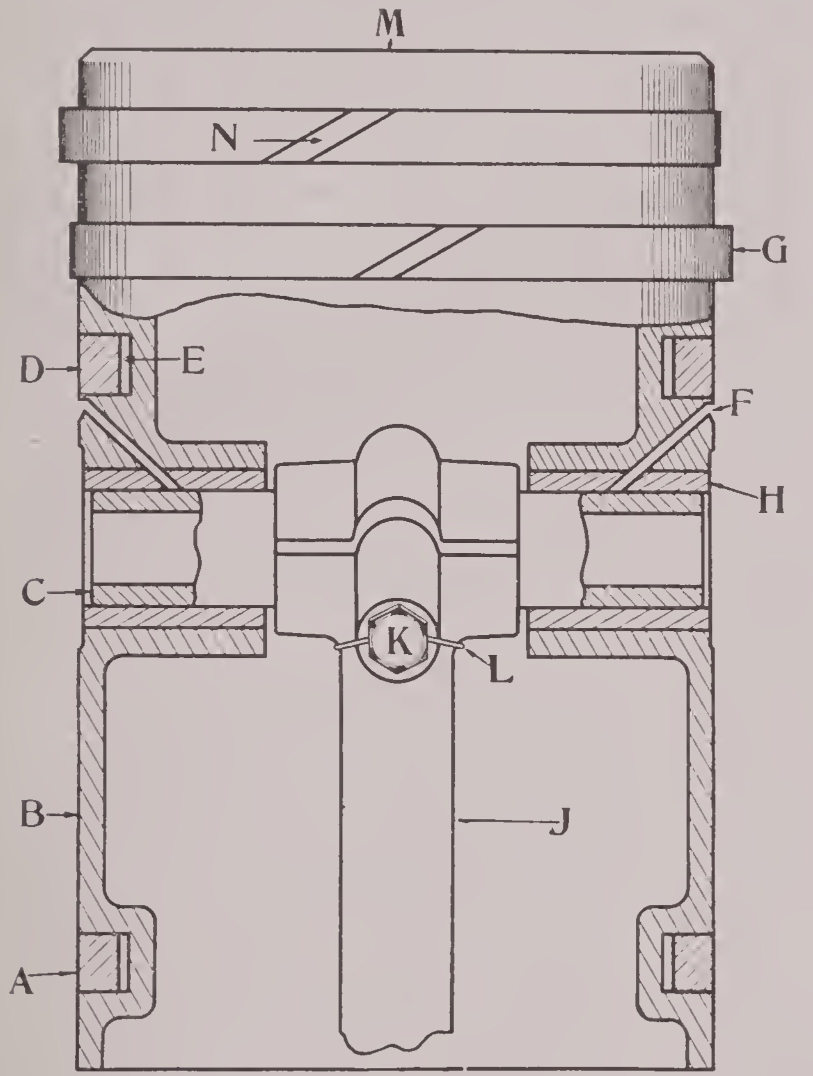


FIG. 10

PISTON

A. Lower piston ring.
B. Piston skirt.
C. Piston pin.
D. Cross section of piston ring.
E. Clearance about 1/32″.
F. Oil hole.
G. Piston ring.
H. Piston pin bushing.
J. Connecting rod.
K. Clamping screw.
L. Safety wire.
M. Piston head.
N. Piston ring gap.

The piston pin is clamped rigidly into the connecting rod. The piston pin bushing is pressed into the piston bosses. The third ring scrapes the excessive oil off the cylinder wall and forces it through the oil holes to the piston pin which lubricates the pin. Oil holes may be drilled in a like manner and convey the oil to the inside of the piston, which prevents an excessive amount of oil from being carried into the combustion chamber.

PISTON RINGS

Material

Piston rings are made of cast iron, high in graphite, which tends to reduce wear especially at high temperature. They are also made somewhat softer than the cast iron used in the cylinder walls, so that if there

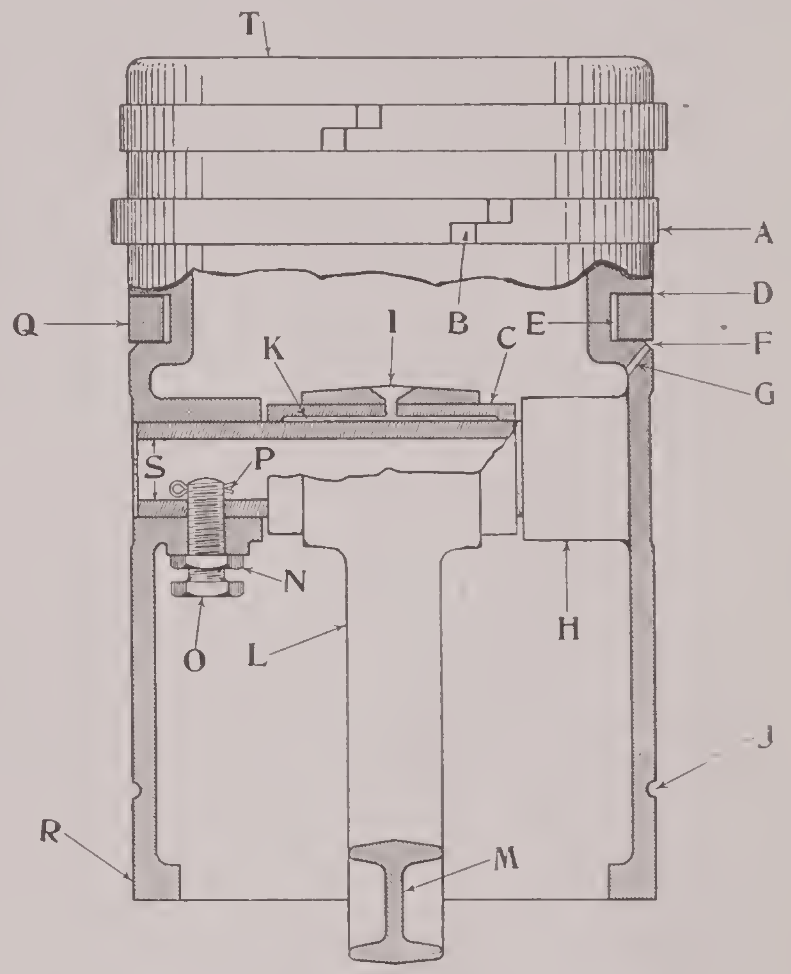


FIG. 11

PISTON

A. Piston ring.
B. Piston ring gap.
C. Piston pin bushing (bronze).
D. Clearance from .005″ to .001″.
E. Clearance about 1/32″.
F. Oil relief groove.
G. Oil hole.
H. Piston pin boss.
I. Oil hole.
J. Oil groove.
K. Oil groove.
L. Connecting rod.
M. Cross section of connecting rod.
N. Lock nut.
O. Piston pin locking screw.
P. Cotter pin.
Q. Cross section of ring.
R. Piston skirt.
S. Piston pin.
T. Piston head.

The piston pin is locked rigidly into the piston bosses. A bronze bushing is pressed into the connecting rod. The bearing is lubricated by the oil striking the head of the piston and dropping downward into the oil hole. The oil groove acts as a reservoir, maintaining a film of oil on the bearing surface.

is any wear it will come on the small rings, which can be easily replaced. Cast iron also has a good spring effect, a natural tension, and when heated will therefore retain its spring tension better than steel or some other metal that would have to be tempered. Cast iron is also low in expansion, allowing the rings to be fitted tightly enough in the grooves to prevent a loss of compression when the engine is cold, and still not expand enough to stick when the engine is hot.

These rings should fit freely enough into their grooves to allow them to expand and contract and have at all times only the tension of the ring holding them against the cylinder wall. When fitting new rings they are given about .0005″ clearance in the groove. If a ring binds in its groove there will be a loss of compression and excessive wear when the engine is hot. When the rings wear until they are loose in their grooves they will cause a knock or slap.

The type of cut in a ring determines how closely the ends of the ring may be fitted. The principle of a leak proof ring is to close the cut or joint to prevent the fuel from going down into the crankcase and to prevent the oil from being drawn up into the combustion chamber. A certain amount of clearance must be allowed in this cut for expansion as the rings heat up, due to the fact that a ring will expand in its circumference, closing the gap. On a plain ring of three inch diameter, the clearance allowed is usually .005″, and for every inch larger in diameter, allow .001″ more clearance. On the so-called leak proof rings, there should be more clearance allowed.

Ring Fitting

To fit these rings, place the ring in the lower end of the cylinder and push it down about two inches with the piston, so that the ring will be properly aligned with the cylinder wall. Then take a thickness gauge and try the clearance in the cut. If the clearance is less than .005″ on a 3″ ring, remove the ring from the cylinder and file the ends. Care should be taken not to remove too much metal, otherwise there will be a loss of compression and a continuous fouling of the spark plug by the oil being drawn up through the cut. When replacing with new rings get the rings the same size as the cylinder. Rings can be obtained in steps of .005″ larger than standard sizes, either in the diameters or the width.

Rings are not always made straight on the surface that engages with the cylinder wall, but may be tapered. The reason for this is that the rings going up and down will scrape the excessive oil off the cylinder wall. The upper ring is usually placed so that the widest part of the ring is towards the top to help scrape some of the oil up for lubrication of the upper rim. The center and lower rings are usually reversed, with the widest part of the rings down, to scrape excessive oil from the cylinder wall. When fitting rings, always see that there is clearance back of the ring—usually about 1/32″—so there will be no chance of the ring riding on the bottom of the ring groove.

PISTON PINS

Material and Design

Piston pins are usually made of high grade steel, heat treated and hardened, of a tubular type, or with a hole drilled through the center to make them light. After the pins are hardened, they are ground to as high a finish as possible. The piston pins are locked either in the piston or the connecting rod. Where the pin is locked in the piston, the upper or piston pin end of the connecting rod has a bronze bushing pressed into it to act as a bearing, and where the pin is locked in the connecting rod by a clamping device, the bearings of the pin are in the piston.

Fitting Piston Pins

Piston pin bearings are usually made of bronze and pressed in, so that if they should wear too loose they can be removed and new ones installed. These bushings must fit in the piston or in the connecting rod very tightly, and should be reamed out with an expansion reamer to the same size as the pin. This will give a snug fit, just tight enough so that it may be pushed through with the palm of the hand without any play. The piston pin is lubricated either by the splash and spray from the interior of the engine or may be lubricated from the chamfer made in the lower ring groove which has holes drilled in it, leading to the piston pin bearings. Again, in the full force feed oiling system the connecting rod has a tube soldered onto it leading up to the piston pin, thus lubricating the pin under pressure.

When reaming piston pin bushings that are placed into the piston, care must be taken to turn the reamer straight through from one bushing into the other. Never ream one side and then turn the piston around and ream the other. The reason for reaming these bushings in this manner is to insure the holes being absolutely in line.

A great many engines are ruined through carelessness in failing to lock the piston pin securely. The pin may be held by a bolt screwed into the piston, with a lock nut and cotter pin to prevent it from working loose, or it may be held in the connecting rod by the clamping lug and clamping screw. These screws are always doubly locked both by the tension of the fit and then with a cotter pin, or lock wire. Should these bolts become loose and drop out, they may get between the moving parts and break the crankcase wall or spring the camshaft or crankshaft. If this occurs, the pin will work out of the piston against the side of the cylinder wall, and as the piston moves up and down, the hardened pin will score or groove the cylinder walls. These grooves in the cylinder walls allow the mixture to get by, causing a decrease in compression and temperature, condensation of fuel, mixing of fuel with the lubricating oil in the crankcase, causing the engine to wear faster and giving less power.

The compression pressure is depended upon to help vaporize the fuel, consequently when there is a loss in compression, the fuel is not fully vaporized. Some of the fuel taken into the combustion chamber will not burn, but will pass through the scores down into the crankcase and dilute the lubricating oil. These scores will necessitate reboring, installing oversize pistons and oversize rings. When the piston pin becomes worn in its bearings it will knock very loudly. When the bushings become loose, they will also cause a knock. The piston pins can be ordered in different standard sizes for a particular type engine in steps of .005″ oversize.

CONNECTING RODS

Material and Construction

Connecting rods are usually made of high grade alloy steel, heat treated to toughen them and increase their strength.

The upper end of the connecting rod carries the piston pin, and the lower end fastens around the crank pin on the crankshaft. The

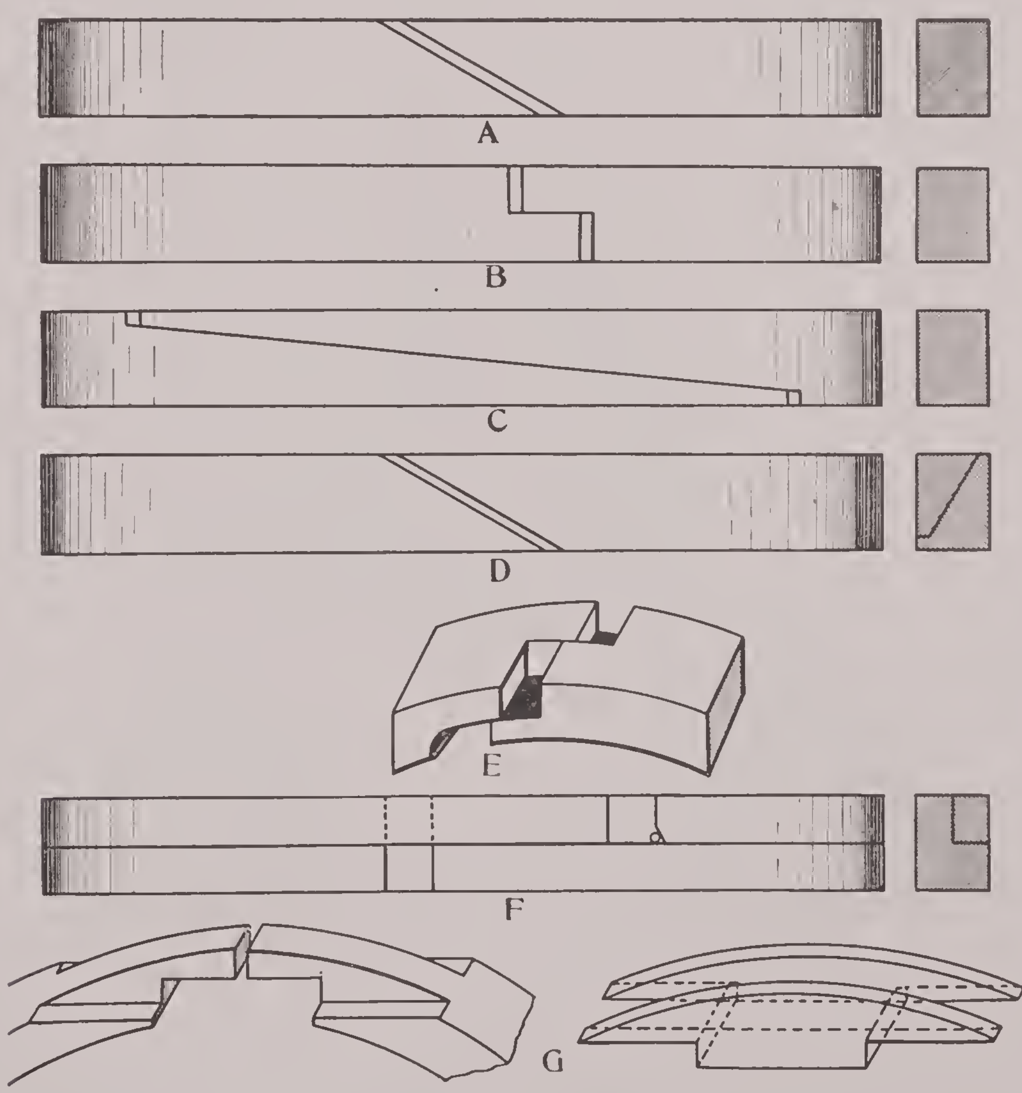


FIG. 12

PISTON RINGS

A. One piece ring (Diagonal cut).
B. One piece ring (Step cut).
C. One piece ring (Long Diagonal cut).
D. Two piece (Diagonal cut).
E. One piece (Special step cut).
F. Two piece (Dowel pinned type).
G. Two piece (Insert type).

lower end is a divided bearing, the connecting rod proper and the connecting rod cap. It is essential that the center line of the piston pin hole and the center line of the crank pin hole should be parallel. The connecting rods at times may become sprung, either through play of the crankshaft, burning out bearings and running loose, or they may have a natural tendency to warp. It is necessary to check the alignment of these holes, especially after re-scraping bearings or replacing with new ones. Both the piston pin bushing and the crank pin bearing are replaceable.

Connecting rods in multiple cylinder engines should be as light as possible and all the rods in any engine should weigh approximately the same to within the fraction of an ounce. Connecting rods that are unequal in weight result in an unbalanced condition, causing vibration, knocking and pounding, which affects the bearings.

The bearings placed in the connecting rod and in the cap will loosen up at times, due to wear. They may be all babbitt, or they may be a bronze backed, babbitt lined bearing. Usually the babbitt is die cast and compressed when hot. The bearings may be held in with either dowel pins, rivets, or screws. Bearings are usually ordered from the manufacturer of the engine, giving the number and type of the engine. The connecting rod cap may either fit directly against the connecting rod proper or may have spacing shims or liners. The shims are placed there so that as the bearing wears, a thin shim can be removed and the cap tightened, to take the play out of the loose bearing, when the bearing is not worn enough to require replacement. Use care in removing shims to be sure that an equal number of the

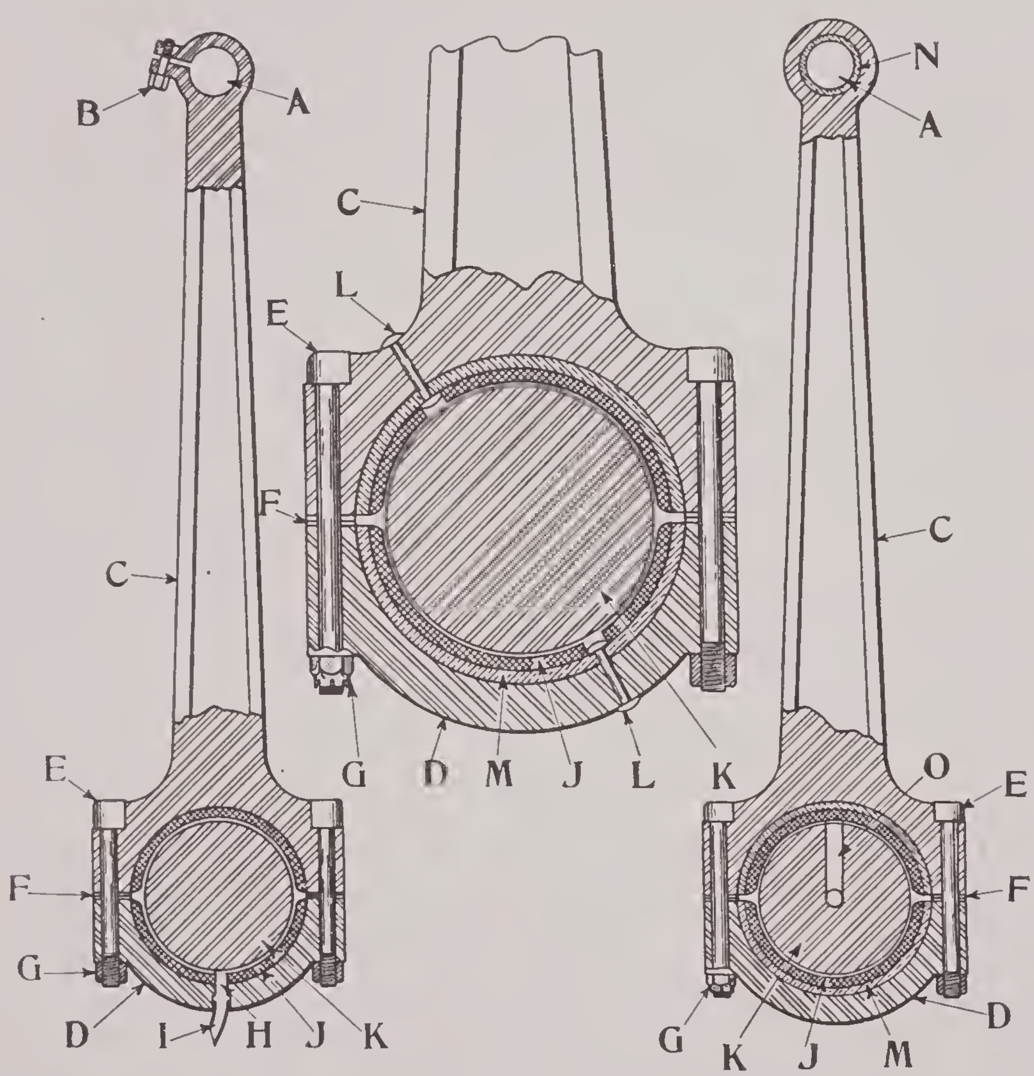


FIG. 13

CONNECTING RODS

A. Piston pin hole.
B. Clamping screw.
C. Connecting rod.
D. Connecting rod cap.
E. Connecting rod bolts.
F. Shims.
G. Castle nuts.
H. Oil hole.
I. Oil dipper.
J. Babbit bearing.
K. Crank pins.
L. Dowel pins.
M. Bronze bearing.
N. Piston pin bushing (bronze).
O. Oil hole.

same thickness are taken from each side of the bearing. Some connecting rods will not have spacing shims, especially in an engine where the pressure oiling system is used. Care must be taken when placing these shims on the rods, that they do not come in contact with the crank pin surface.

The connecting rod cap may be held on to the connecting rod proper by either two or four bolts. These bolts are usually made of heat treated alloy steel, and are very tough. Care should be taken when replacing connecting rod bolts, never to put in a soft steel bolt as it is liable to break.

Bearing Fitting

After fitting the bearings into the connecting rod and cap, fit the bearing to the crank pin for end play. There should be a small amount of end play in this bearing to allow for lubrication and prevent it from cutting ridges on the crank pin. Usually when fitting new bearings, they are given from .002″ to .004″ end play. They may come in the right width, or they may come too wide for the crank pin, necessitating extra fitting. After checking up for end play, see that the bearing does not rest on the fillets of the crank pin. These fillets are the rounded corners at the ends of the crank pin, where the crank pin connects onto the crank cheeks. After making sure that the connecting rod is not resting on the fillets, dress the connecting rod off close to the edge where it fastens onto the cap. With few exceptions a bearing should never fit flush at the edge where it fastens together. This space is allowed as an oil retainer and also for the babbitt that is worn off to collect in, usually being about 1/64″ deep, and about 1/8″ down on the bearing surface.

Scrape the babbitt off with a bearing scraper. Place the necessary number of shims

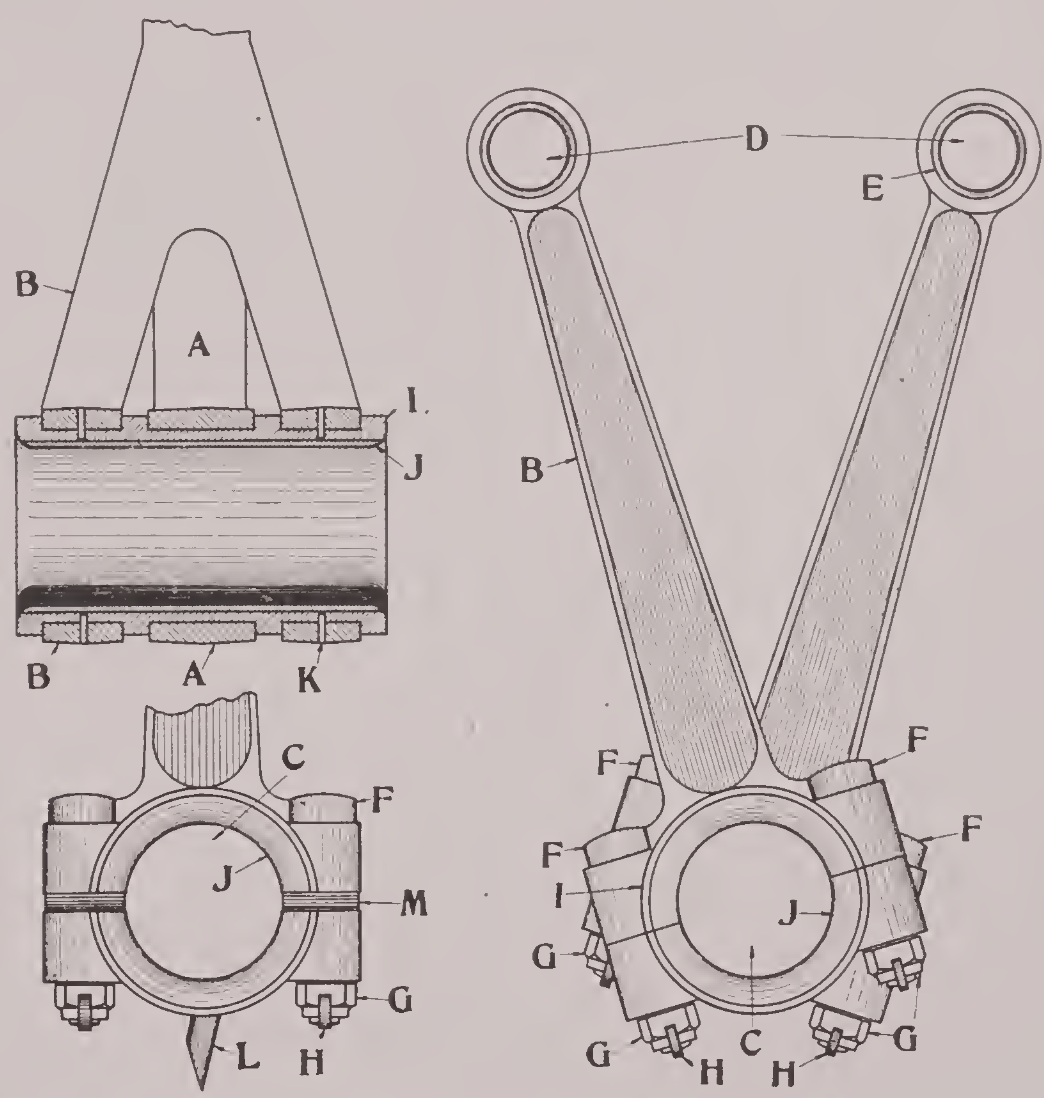


FIG. 14

CONNECTING RODS

A. Blade rod.
B. Fork rod.
C. Crank pin hole.
D. Piston pin hole.
E. Piston pin bushing (bronze).
F. Connecting rod bolts.
G. Castle nuts.
H. Cotter pin.
I. Bronze bearing.
J. Babbitt bearing.
K. Dowel pins.
L. Oil dipper.
M. Shims.

between the connecting rod cap and the connecting rod, so that the connecting rod will fit the same as when assembled into the engine, with all bolts drawn tight. Have just enough tension so that the weight of the connecting rod will swing it down if placed in a horizontal position. Never, when scraping bearings, fit a bearing tighter than it would be fitted into the engine. If the bearing should fit tighter it would spring it out of round, and when the bearing is fastened around the crank pin it will not have a full bearing surface. After fastening the connecting rod on the crank pin, work the connecting rod back and forth a few times to make an impression on the babbitt surface. The spots on the babbitt that are caused by rubbing the crankshaft are the high spots, and will appear bright when removed, or by placing Prussian blue on the crank pin, the high spots will appear blue when the rod and cap is removed.

A bearing may appear to be machined accurately, but still there may be a variation in the machining or variable hardness in the metal, and also the bearing may spring as it is placed in the connecting rod. The result is that the bearing will not fit evenly all over.

These bearings are designed with a certain length and diameter, and have a certain area, to withstand the pressures and prevent excessive wear under operating conditions. Use must be made of all this area when fitting the bearing, therefore the bearings should be scraped down to a uniform bearing surface. Remove the connecting rods from the crank pin and notice the spots that are polished on the babbitt metal. These are the spots that are rubbing. If the bearing only touches in a few spots, it will be necessary to scrape these high spots down to have a greater amount of the surface in contact with the crank pin.

Use a very sharp bearing scraper that

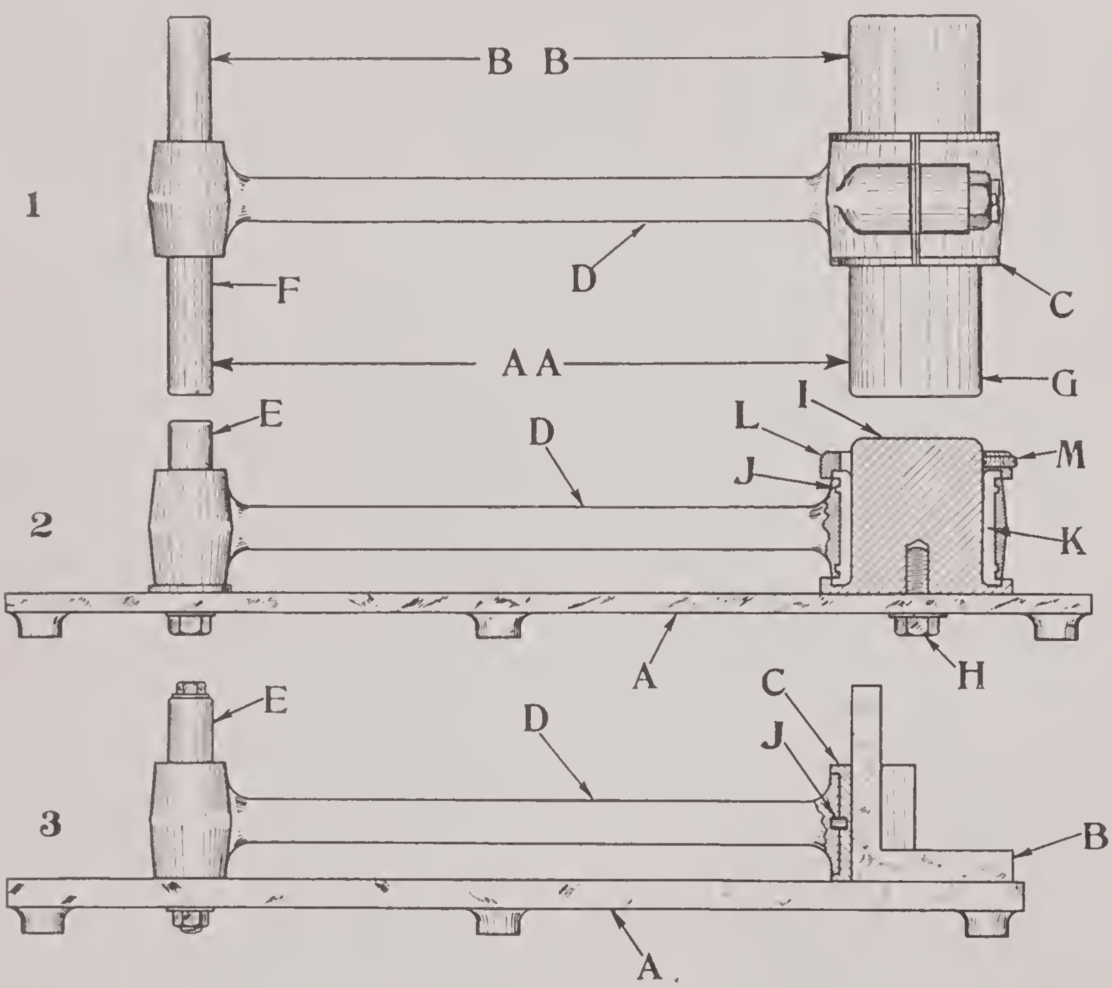


FIG. 15

BABBITTING AND CONNECTING ROD TESTING FIXTURES

1—C. Babbitt bearing.
D. Connecting rod.
F. Piston pin.
G. Metal shaft.
AA. BB. } Equal distances.
2—A. Fixture.
D. Connecting rod.
E. Piston pin.
H. Bolt.
I. Metal plug.
J. Anchor holes.
K. Babbitt space.
L. Iron collar.
M. Set screw.
3—A. Fixture.
B. Square.
C. Babbitt bearing.
D. Connecting rod.
E. Piston pin.
J. Dowel pin.

has been honed on an oil stone. Dress down the high spots on the bearing, replace the connecting rod on the crankshaft and proceed as formerly, working it back and forth to obtain an impression. When scraping the bearing it will be noticed that the bearing surface becomes larger; that is, more spots are showing on the bearing, and as the spots increase, gradually let up on the heavy scraping and scrape more lightly. Care must be taken to scrape only the exact spots that show bright or blue. Do not scrape around the spot, as that will be cutting the grooves deeper and deeper, and no bearing will be obtained.

The connecting rod should be held by hand, resting it against the chest, resting the fingers on the bearing and using very short strokes. It will take considerable time and practice to accomplish a good job of scraping, but an improvement will be noticed each time, and better knowledge will be obtained of when to scrape hard and when to scrape light.

Alignment

After scraping the bearing, the alignment should be checked in two ways. First, clamp the piston pin on to a surface plate and test it with a square to be sure it is perpendicular. Then place the connecting rod on the pin and check the crank pin bearing with the square. (See Fig. 15-3.) If it is out of alignment, the rod may be held in a vice and sprung with the aid of a wrench, using care not to spring it too far so that it will have to be sprung back. Too much bending tends to weaken the steel. Never heat a connecting rod as this also weakens the steel by destroying the value of the heat treatment given to toughen it. If the rod is bent too much to be straightened cold, replace with a new one.

The final checking of alignment should be made with the rods on the crankshaft, and the pistons attached, as shown in Fig. 16. The bore of the cylinder is always square with the surface which joins the crankcase. The connecting rod bearings must be fitted so that the piston pin is parallel with this finished surface, as at AA-BB, and the two squares A and B show that the piston is also absolutely true.

A long connecting rod eliminates side thrust

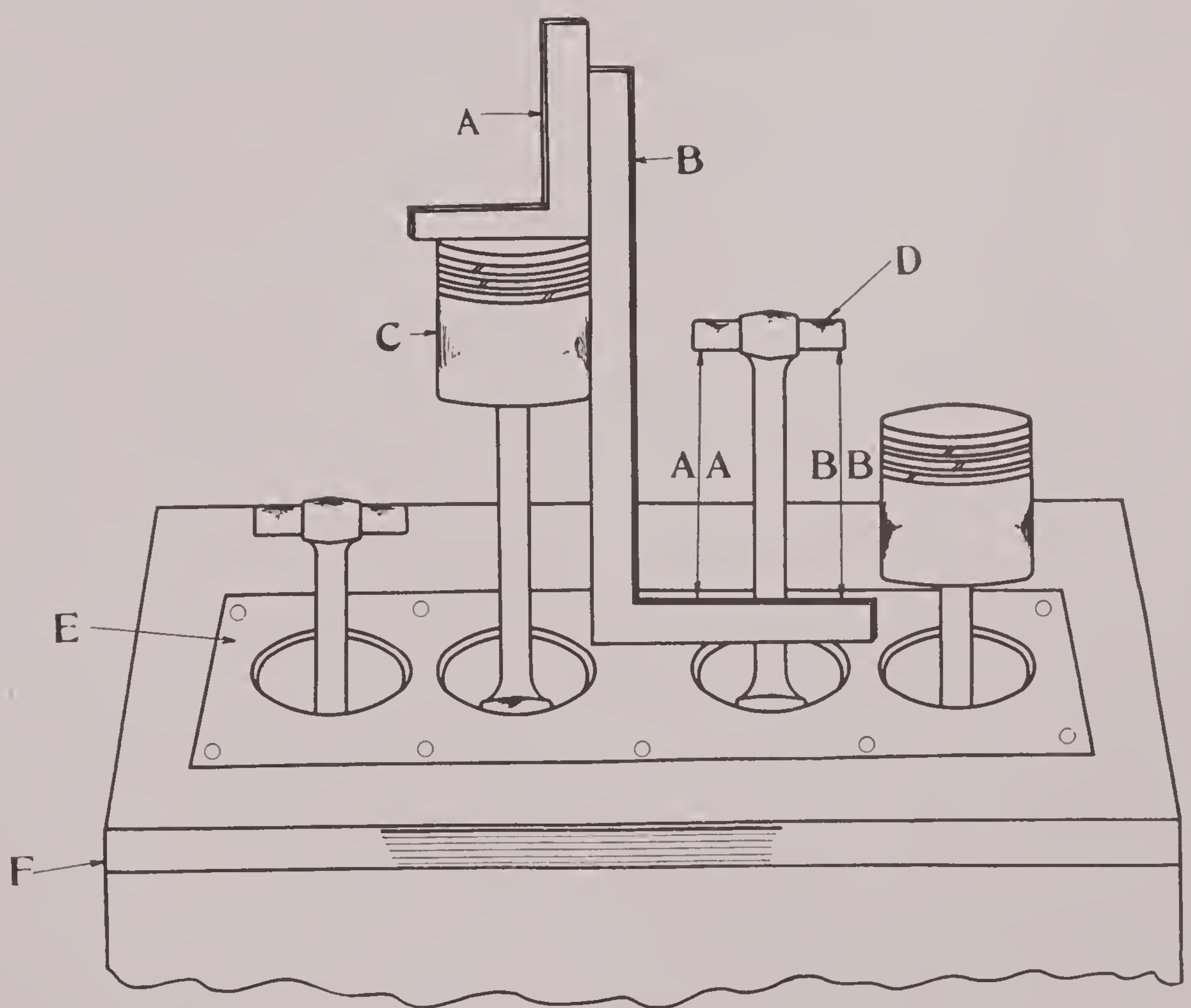


FIG. 16

CHECKING THE ALIGNMENT OF CONNECTING RODS AND PISTONS

A. Square.
B. Square.
C. Piston.
D. Piston pin.
E. Machined surface.
F. Crankcase.
AA.-BB. Equal distances.

on the cylinder walls. This side thrust causes excessive wear on the cylinder wall, on the piston, on the piston pin bearings and crank pin bearing.

In racing engines, where thrust and speed is excessive, the distance between piston pin and crank pin centers is usually about twice the piston stroke. In general practice the rods may be somewhat shorter, as the long rod makes the whole engine high and heavy.

The crank pin should be perfectly round, smooth, and straight. It will wear out of round through the continuous pounding. If it is necessary to tighten the crank pin bearing frequently it may be caused by the crank pin being out of round or by the piston pin and crank pin holes not being in proper alignment.

When replacing the connecting rod in the engine while assembling, place it on the crank pin in the same position as when scraping, as the crank pin may be tapered. When fastening the connecting rod into the engine while assembling, always tighten the nuts enough that there is no chance of their becoming loose, using a suitable size socket wrench, made especially for this purpose. If the connecting rod should fit too tightly, NEVER BACK UP ON THE NUT to make the bearing fit properly. Either remove the cap and put in a thicker shim or else dress a little more from the bearing. Lock the castle nuts, which are provided for that purpose, with a cotter pin; press the cotter pin in place and lock. It is very essential that these bolts should not become loose. If the connecting rod has the least chance to pound, all the strain will come on the bolt and nut and the bolt will break, allowing the connecting rod to be forced through the side of the crankcase by the whirling crankshaft. A piston pin bearing or crank pin bearing that becomes loose will cause a knock. These bearings should be kept fairly snug, and if they become so loose that they will pound, they should be tightened immediately, otherwise they may break the connecting rod, the cap or the bolts. When a bearing becomes loose it will pound the crank pin out of round, or when the holding bolts and nuts become loose, it will break the bolts.

Aircraft engine connecting rods and bearings are usually fitted looser. The reason for this is that through the tremendous friction resulting from the high speed and high bearing pressure there is more heat generated. This will cause expansion, and if clearance is not allowed for this expansion the friction and the heat will be greater, consequently the bearings will burn out, or the rod will break at the weakest point. Many connecting rods have broken through bearings freezing or expanding until they seize the crank pin.

On all bearings, there should be enough clearance allowed for expansion, and for a film of oil between the bearing surfaces. This oil reduces wear. A connecting rod bearing if fitted too tightly will wear the crank pin rough and out of round. Where no shims are provided for the fitting of bearings, it is necessary to scrape the bearings to a good fit, while scraping for a good bearing surface. When crank pins are lubricated by pressure system, usually no shims are used in the connecting rod as they would allow oil to be forced out instead of covering the surface of the bearing. Bearing surfaces have oil grooves or oil retainers, except where the oil comes onto the bearing under a high pressure, so that as the crank pin revolves, it will always have oil upon it, either from the oil pipes directly, or from the dipper, as in the splash system. Where the connecting rods have dippers, dipping down into the oil trough, there will be a hole in the connecting rod cap bearings with oil grooves to distribute the oil over the bearing surface. These oil dippers should not dip into the oil more than from 1/16″ to 3/32″. If they dip deeper, the cylinder walls receive too much oil.

V type engines sometimes have a yoke connecting rod assembly, made up of two connecting rods; one is the fork rod or outer rod holding the bronze backed, babbitt lined bearing; the other is the blade rod, which fits on the outside of the bronze bearing. From the assembly, it is seen that there are two bearing surfaces to be fitted.

Fit the bearing into the fork rod first, the same as in the ordinary connecting rod, then proceed with the scraping as formerly. After the bearing is scraped so that the rod and the cap fit snugly together with the connecting rod bolts pulled up as tightly as possible and with the proper fit, then proceed with the fitting of the blade rod. This blade rod has no babbitt bushing on the inside, but fits directly on the outside of the bearing held into the fork rod. Care must be taken not to pinch this bearing with the blade rod. The blade rod should fit free with a nice rubbing fit. With an oilstone dress the bronze down to the correct fit. Sometimes shims are placed between the blade rod and its cap, but it is not advisable. The yoke type rod is lubricated either by splash or pressure.

In some V-type engines two rods side by side are used instead of the yoke type. In this case, the cylinders are not directly opposite each other, but staggered. These rods are fitted to the bearings same as any single rod. The hinged cap on the connecting rod is seldom used in automobile practice, as it has not proven successful.

Use of Soft Metal Bearings on Crankshafts

The connecting rod bearings and main bearings are made of babbitt for several reasons.

Babbitt containing a certain percent of antimony is very low in expansion. This will allow the bearing to be fitted tightly enough to prevent a knock when the engine is cold and still not expand enough to grip when the engine is hot. Babbitt also containing certain percentages of tin and copper in addition to antimony is a soft bearing metal that will protect the crank pin from excessive wear. That is, when the bearing is fitted too tightly, is overheated and expands from lack of proper lubrication, the wear always comes on the babbit instead of crank pin. This is preferable, because the bearing is much easier, quicker and cheaper to replace and refit than the crankshaft.

CRANKSHAFTS

The crankshaft is probably subjected to the greatest strain of any part of the engine, since practically the entire duty of transmitting the power of the engine to the driving wheels devolves upon it. The three most important stresses are, that due to the pressure arising from the explosion, that due to the momentum of the reciprocating parts, and that due to the centrifugal force. It is a comparatively expensive part of the engine, requiring very accurate machine work.

Material and Construction

The material used for the construction of crankshafts is usually high grade alloy steel, heat treated to increase the strength. They are usually forged under a big drop hammer to the proper shape, roughly, then turned and finished evenly and smooth. Some crankshafts are made from a solid billet, blocked out, turned and finished all over. This, however, is an expensive process in automobile engine construction.

The crank pin is offset from the center line of the main bearings to allow for an upward and downward movement of the piston. The distance from the center of the crank pin to the center of the main bearings is one-half the length of the stroke.

Static and Dynamic Balancing

On account of the construction and shape of the crankshaft and the effects of the forces acting upon it, the shaft must be accurately balanced both statically and dynamically.

Static balance means that if there is no one point on the crankshaft heavier than any other, after it is finished, it can be laid upon two parallel knife edges that have been carefully adjusted to horizontal position, and it will not move or rotate. But even though the crankshaft has perfect static balance it may not have perfect dynamic balance. Crankshafts of different construction will be out of balance at different speeds, even though the static balance is perfect.

The crankshaft should be balanced at the average engine speed used in operating the car and to do this properly it is put in a testing machine and run at the normal engine speed. The centrifugal force due to the crank pin revolving around the center of the crankshaft would only tend to pull the shaft from the bearing in all directions, causing wear on the bearings. If the shaft is out of balance, however, it will set up vibration and cause pounding and excessive wearing of the bearings. To overcome this a counterbalance is fastened on by bolts and dowel pins or forged integral with the shaft. The weight of the counterbalance is designed to offset the centrifugal force developed in each crank pin, first from its own weight and the weight of the crank cheeks, and second from the weight of the reciprocating parts attached to it.

Another effect of this unbalanced condition is to cause the crank pins to creep toward each other as the centrifugal force springs the shaft. An exaggerated example of this creeping may be seen in the buffing wheel as the felt layers gather toward the center when the wheel is speeded up. This action brings undue strains on the bearings, tends to throw them out of alignment, and the binding of the bearings will use up some of the power to overcome the increased friction. The more main bearings on the crankshaft the less will be the creeping action in the shaft.

Repairing

Multiple cylinder crankshafts which are long, having in some instances as many as seven main bearings, are very difficult to keep straight, if one is careless in the handling of them. Never stand a crankshaft on end, which, on account of the open space between the crank pins, gives the crankshaft a chance to sag. In sagging it pulls the main bearings out of line. Never drop a crankshaft down on its end; always lay it down carefully and flat. If the crankshaft should be sprung a few thousandths of an inch, pulling up on the bearings will not make it all right. A crankshaft so adjusted will have a tendency to whip and wear the main bearings loose continuously.

After removing the crankshaft from the engine, if it is not to be placed back immediately, cover the bearings by wrapping oily rags around them to prevent metals of different kinds falling on the bearing surfaces, also to prevent the bearing surfaces from rusting.

A crankshaft that is sprung should be straightened and reground, as a crankshaft that is out of line with the main bearings will continually wear the main bearings loose, causing a very heavy pound on sudden acceleration and application of the load. Crankshafts may be readily straightened when placed between lathe centers or under a press. In case of a connecting rod breaking or any other part breaking and jamming on the inside of the engine as happens at times, it will put a twist in the crankshaft, which cannot be removed by ordinary straightening. Straighten the crankshaft as accurately as possible and then have it reground, which requires fitting it into smaller bearings. Should the crank pin become out of round from wear and pounding it will be necessary to regrind this in a grinding machine, although there are some hand tools made for straightening and truing crank pins.

If no spacing shims are allowed between the main bearing cap and the main bearing, it is necessary to scrape the bearings down to the proper fit, besides having a good bearing surface. The bolts holding the main bearings are usually heat treated, having fine threads, and are locked by castellated nuts, provided for a cotter pin lock, or a safety wire. It is necessary that these bolts and nuts be locked. Either a cotter pin or safety wire should be used for this purpose.

Alignment

To check a sprung crankshaft, place it between the centers of a lathe or in a chuck and run the crankshaft in a steady rest, resting an indicator on the bearing surface. This indicator will indicate the point at which the crankshaft is sprung out of line and the number of thousandths of an inch that it is out. To check the accuracy and circularity of the main bearings or the crank pin use a micrometer. This is an instrument that will measure in thousandths, or ten-thousandths of an inch, and will show whether the crank pin is out of round or tapered. The crankshaft is mounted in the crankcase in babbit bearings, similar to the ones used in the connecting rods, to reduce friction and wear.

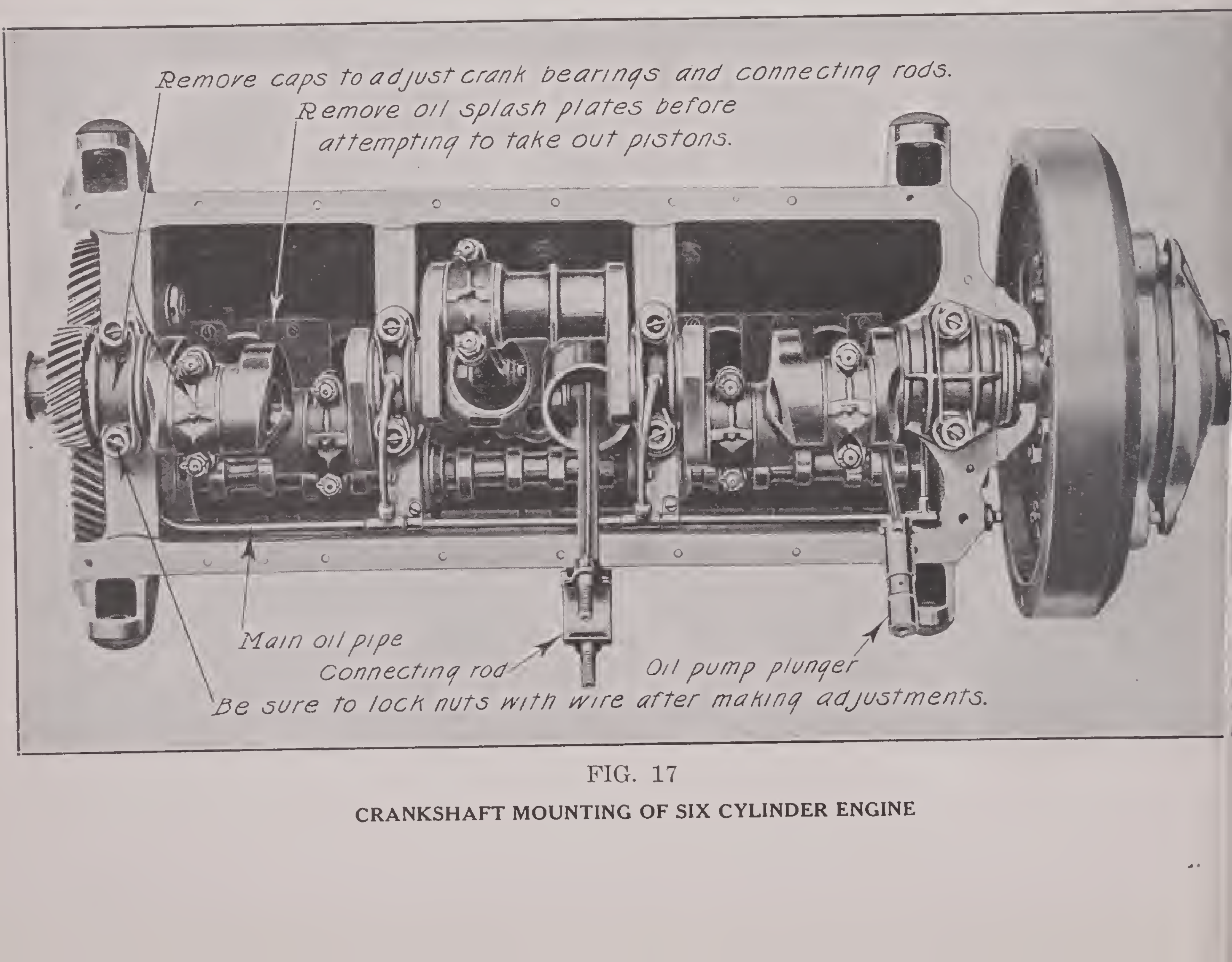


FIG. 17

CRANKSHAFT MOUNTING OF SIX CYLINDER ENGINE

Pouring Bearings

Both the main bearings of the crankshaft and the connecting rod bearings that fit on the crank pin may have to be poured. Bearings are poured where there are no die cast bearings available to replace them. When pouring connecting rod bearings it is necessary to make up a fixture with a pin the same size as the piston pin and a plug the same size as the crank pin, fastened onto a plate. After fastening a connecting rod onto this fixture it will be necessary to pre-heat the jig and connecting rod. Babbitt should not be poured into a cold fixture because it will chill and not flow readily causing blow holes and cracked bearing surfaces. After these fixtures are heated up, pack whatever openings there are with either clay or powdered asbestos mixed with oil. Meanwhile heat up the babbitt in a ladle. The babbitt used should be of a high grade, high speed, bearing metal. Heat it in the ladle enough so that it will just char a soft pine stick, then pour the babbitt into the mold as rapidly as possible. After the babbitt has cooled in the connecting rod, remove the connecting rod and press the plug out. Then split the bearing with a hack saw and proceed with the scraping and dressing down.

Main bearings are poured usually in the same manner, excepting that the crankshaft itself can be used. Rest the crankshaft on jacks, line it up with a surface gauge and indicator so that the surface of the crankshaft is parallel to the surface of the crankcase, checking up the gear centers at the same time, then heat the bearings on the crankshaft so that they are warm. Seal up whatever openings there may be with fire clay or asbestos mixed with oil and then pour the hot babbitt into the bearings one after the other. When it is cooled, remove the crankshaft and scrape these bearings down to a good fit and a good bearing surface.

Fit shims in between the caps and the main bearings, otherwise when the babbitt is poured into the cap it will fuse on to the metal in the crankcase and the whole bearing will have to be melted out. The shims should be a thin metal or fabric shim, fitting against the crankshaft. After fitting in the shims, heat up the crankshaft and caps again, plug whatever opening there may be, pour one cap after the other, and when they are cool, remove them, and scrape in each cap separately and replace the shims with the correct size metal shims and see that they do not come in contact with the crankshaft. Care must be taken when pre-heating a rod or crankshaft not to get it too hot, destroying the heat treatment.

Fitting of Bearings

After replacing the bearings in the crank case for the crankshaft to revolve in, it will be necessary to scrape these bearings in order to utilize the full bearing surface. This is done in about the same manner as in scraping the connecting rod bearings. That is, the first operation will be to fit the crankshaft into the bearings for end play.

Remove the bearing caps and place the crankshaft in the crankcase bearings. There should be from .002″ to .004″ end play to allow for expansion. If not enough clearance is allowed for expansion, the crankshaft will cut the metal from the bearings and perhaps from the crankshaft proper, roughening the surface and causing excessive wear. The amount of clearance allowed for end play varies on different engines, depending on the speed, pressure and general power developed by the engine, but in automobile practice it is usually from .002″ to .004″. After checking up this end play, check up the different fillets to see that the crankshaft is not riding on these, because if the crankshaft is riding it cannot come down on the bearing surface.

There is a thrust bearing always provided on the crankshaft. This may be a ball thrust bearing, or the shoulder of the main bearing. Either the center bearing or, if on a multiple bearing crankshaft, one of the end bearings close to the flywheel will have a shoulder somewhat wider than the others. This shoulder is provided to take the crankshaft end thrust. It is not adjustable, and in case of wear, the whole bearing must be replaced. After checking up for end play and for riding on the fillets, then proceed with the scraping.

The first thing to accomplish is to align the bearings, therefore do not scrape the bearing caps until all the bearings that are mounted in the crankcase are finished, especially on a multiple cylinder engine where there are several bearings. If one bearing should be higher than the others and the cap should be tightened down on the crankshaft, it would spring the shaft. Lay the crankshaft in the bearings, turn the crankshaft back and forth, getting an impression on the different bearings. Then scrape the bearings until a good surface is obtained on all of them, at least from a 75% to 80% bearing.

Dress the bearings on the edge where the caps fasten on the bearing support, to allow it to act as an oil retainer and also allow space for the babbitt to collect as it wears. As the bearing surface improves under the scraping, do not scrape as heavily, but lightly, so as to obtain a good bearing surface. After the bearings have a good surface and the crankshaft rests upon all the bearings with the same pressure, then scrape the caps. Fit the caps the same as with the connecting rod caps, for end play and to prevent riding on the fillets. Then proceed with one cap at a time, scraping that cap to a good bearing surface.

The life of the bearings in an engine always depends upon the finish and the area of the bearing surface. Care should be taken not to fit the bearings too tight, because a certain amount of clearance must be allowed for a film of oil, but if pains are taken in scraping a good bearing surface, a bearing will not have to fit so tightly as one that is improperly scraped. A bearing run without oil, or fitted too tightly, will cut and wear excessively. Some crankshaft main bearings have shims between the cap and crankcase to take up the wear.

Clearance

After the crankshaft is set up and has a good bearing surface, it should be free enough so that it can be turned by hand, not necessarily spinning around, but enough so that it can be turned freely. Aircraft and racing engine crankshafts usually fit looser to allow for greater expansion. The amount of play allowed is usually taken up by expansion and a film of oil. A tight bearing will not allow the oil to get onto the surface unless it has the pressure oiling system, and as so few automobiles have the pressure oiling system, it is very essential that great care should be used in fitting the bearings. Always take into consideration the oiling system that provides the oil for the bearings. That will help to determine the clearance to allow on the bearings.

VALVES

Types and Materials

The two types of valves that are mostly used are the sleeve valve, as used in the Knight engine, and the poppet valve. Considerable experimenting has been done on the rotary valve, but it has not proven successful on account of the expansion and difficulty in lubricating the exhaust valve.

The poppet valve is constructed of different kinds of materials. There is the cast iron head valve, with a steel stem; the all-nickel steel valve, and the tungsten steel head with the nickel steel stem. The latter valve is generally used for the exhaust. The reason for the use of these different materials is that the material must resist warping and withstand the heat. Cast iron is one of the most successful materials used for valves, from the warping standpoint, but it will not stand the excessive heat generated in the racing or the aircraft engine, it having a tendency to burn. The tungsten steel valve will withstand heat and resist warping.

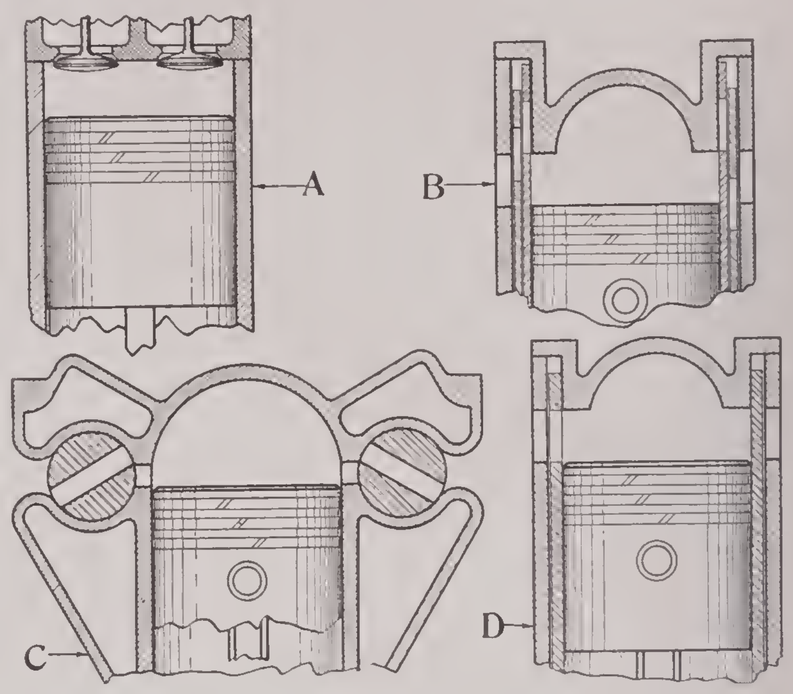


FIG. 18

TYPES OF VALVES

A. Poppet valve.
B. Sliding sleeve valves.
C. Rotary tube valves.
D. Rotary sleeve valves.

The purpose of the valves is to allow the fuel to enter the combustion chamber at a certain time and to allow the exhaust or burned gases to escape at a certain time; and still when the piston is on the compression stroke and on the power stroke, these valves must seal the combustion chamber. No matter how true or how accurate the surface of either of the valves, or the seat in the cylinder is machined, there will be some unevenness there, which makes it necessary to frequently grind the valves into a perfect seat.

Troubles and Repairs

Valves sometimes warp, due to carbon packing underneath the seat, or excessive heat, making regrinding necessary. A leaking inlet valve may cause a back fire through the carburetor. Also there will be a loss of compression on the compression stroke, a general decrease in the efficiency through a drop in temperature due to the loss of compression. Unequal compression in the different cylinders of the multiple cylinder engine will result in increased vibration. If the exhaust valve should leak it causes a general loss of compression but no backfire.

Valve stems can be obtained in oversizes, in steps of .005″ larger than the standard size. It is necessary that the valve stems fit the guide closely with a little clearance allowed for expansion. When fitting the valves, the exhaust valve stem should have .002″ of an inch clearance, while the inlet valve stem should have .001″ clearance, depending entirely upon the speed the engine runs. Aircraft engine valve stems are usually fitted looser than the valve stems in automobile engines. An inlet valve stem that is worn too much will cause an engine to miss fire at low engine speed, because when the piston goes down on the suction stroke with the inlet valve open and the throttle valve partially closed, as it will be at that speed, the inlet manifold and combustion chamber are under a high vacuum. This vacuum will draw air in through the worn valve stem guide, making the mixture to become too lean and cause backfiring through the carburetor. This can be tested by squirting some gasoline around the valve stem and as the piston goes down on the suction stroke it will draw this gasoline into the combustion chamber with the air, making the mixture richer or in the right proportion causing the engine to fire properly again.

Valve Grinding

When grinding valves, remove all free carbon that is burned into the valves and valve seat and combustion chamber. Then be sure that the end of the valve stem is not resting on the tappet, otherwise it will be impossible to grind the seat. Use fine valve grinding compound, place a small amount on the face of the valve, drop the valve on the seat with a light spring underneath the valve head to lift it when the pressure is taken off the top of the valve. Use a screw driver or a prong made to fit the valve and turn the valve back and forth about a quarter of a revolution. Repeat this several times. Lift the valve by removing the pressure, turn it around about a quarter of a revolution to to pick out a new spot, then push the valve down onto the seat and turn it back and forth again as before. Care must be taken not to bear down too hard on the valve, otherwise ridges will be cut in it. A valve will grind in somewhat faster by having just a slight amount of pressure, moving it back and forth about a quarter of a revolution and continuously changing to a new spot on the seat so as to keep it round.

Prussian blue can be used to check the accuracy of the valve surface. Remove all grinding compound from the valve and seat, put a small amount of Prussian blue on the valve face, wipe it off so there is just a faint coloring, then drop the valve down on the seat and turn it back and forth a few times. Lift the valve and see whether the correct blue impression has been made on the seat in the cylinder. It should show an impression all the way round; or use a soft pencil and mark the valve after it has been cleaned, drop the valve in the seat, again moving it back and forth. If the marks are erased all the way around it shows the valve to be seating properly. Then place the pencil marks on the seat in the cylinder and proceed as before. This is to check the seat in the cylinder, as the former process was to check the valve face. Should the test prove that the valve has a good seat, put some oil on the valve face and polish it by moving it back and forth as formerly. Place the valve back in the cylinder after removing all valve grinding compound placing the proper spring under the valve. Then readjust the clearance at the end of the valve stem to the proper dimensions given later. If any particles of this valve grinding compound should remain in the combustion chamber, it will work onto the cylinder wall and mar the finish, cutting the piston rings and cylinders, thus resulting in a loss of compression. Always replace the valve in the seat to which it was ground.

Clearance

The clearance at the end of the valve stem above the tappet is allowed for expansion. As the engine heats up the valves will heat up. If no clearance was allowed for expansion the valves would not seat. This clearance varies on different engines. Aircraft engines require sometimes as much as 1/32″ clearance. Average clearances at the end of the valve stem are about .002″ to .004″ on the automobile engine. The clearance depends upon the heat developed by the engine. If too much clearance is allowed at the end of the valve stem, it will cause a knock and on a multiple cylinder engine if all the valves should have too much clearance it makes a noise that is very annoying. If the inlet valve should not have enough clearance at the end of the stem, it would cause a backfire by the valve not seating, also causing a general loss of compression. If the exhaust valve does not seat properly by having too little clearance at the end of the valve stem, there will be a general loss of compression, causing vibration, and perhaps the cylinder would misfire.

The various automobile manufacturers specify certain clearances for their engines when they are cold. But there is a general rule that can be applied to any engine for clearances at the end of the valve stem. This clearance is adjusted by the adjusting screw in the top of the tappet which is held in place by a lock nut.

Rule: Rough set all the tappets to about .020″. Start the engine and allow it to run until it reaches its normal operating temperature. Then adjust the inlet valve clearance to .002″ and the exhaust to .004″. It is noticeable that when the engine cools off the clearance is greater, but it is necessary to have that much clearance there to allow for the expansion. This rule will hold true on any engine if the engine is heated up to its normal running temperature before making final adjustments. Then check up the clearance when the engine is cold and that will determine the amount of expansion there is to the valve stems.

After the clearance at the end of the valve stem has been adjusted properly, the lock nut should be locked securely. It will be noticed that as the lock nut is tightened it will move the adjusting screw upward considerably, perhaps for .003″ or .004″. This is due to the play of the screw in the thread in the top of the tappet. Allowance for this should be made when adjusting the clearance. Always test the clearance after the lock nut is tightened.

Should a valve become warped or bent so badly that it cannot be ground, it may be necessary to reface it in a grinding machine as is used for the Tungsten steel valve. A cast iron valve can be refaced in a lathe or with a special hand facing tool, such as is commonly used in garages. If the guide for the valve stem is removable, the old guide may be pressed out and a new one pressed in. Some engines have no removable valve stem guides. It will then be necessary to ream the hole larger with an expansion reamer and put in a larger valve. With the removable guides all that is necessary is to replace the guide and use a standard valve.

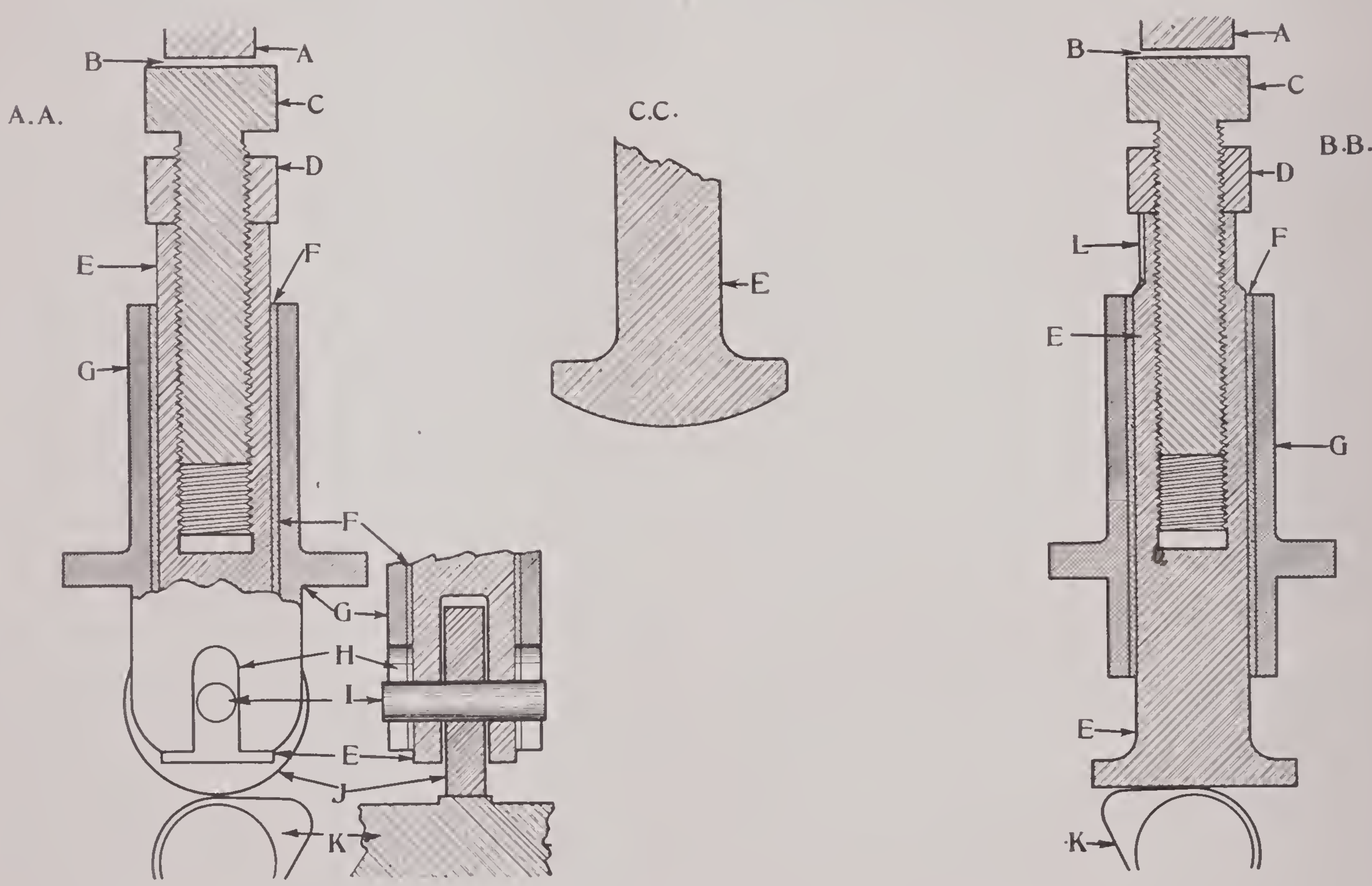


FIG. 19

TAPPETS OR CAM FOLLOWERS

A.A. Roller type.
B.B. Mushroom type—Flat head.
C.C. Mushroom type—Oval head.
A. Valve stem.
B. Clearance.
C. Clearance adjusting screw.
D. Locknut.
E. Tappet.
F. Bronze bushing.
G. Tappet guide.
H. Roller pin guide.
I. Roller pin.
J. Roller.
K. Camshaft.
L. Flattened portion of tappet for adjusting.

TAPPETS OR CAM FOLLOWERS

Types.

There are several types of tappets. The materials used are, as a rule, heat treated steel, ground and machined to a very smooth surface. These tappets are fitted with screws for the purpose of adjusting valve clearances. The method of adjustment varies with the make, but in all cases is for the purpose of allowing valves to come to a full seat before the tension is released on the tappet. The tappets are equipped with some device for locking the adjusting screw so that when the engine is in operation, continuous pounding upon the tappets will not loosen the screws and change the relative adjustment of the valves. The device used for locking is usually a simple jam nut. The top of the tappet is drilled and threaded, into which screws an ordinary hardened cap screw. The lock nut is placed on the upper threads of the cap screw.

Tappet guides are generally bushed with bronze bushings. Occasionally they are simply a part of the crank case. They are lubricated through oil grooves or oil outlets through the crank case. However, the entire valve chamber may be lubricated by splash. The oil dipper throws the oil through the upper portion of the engine. These tappets sometimes become worn and have a tendency to make a very objectionable knock. The knock is not dangerous, but will cause an unnecessary amount of noise and wear.

A push rod is a continuation of the tappet, connected to the rocker arms, valve lifters or roller arms, which operate directly on the valve stems. This is most commonly used in overhead, or I-type engines. The material used in push rods is, as a rule, heat treated steel, being ground and accurately finished to length. The push rods tend to rattle and knock if their sides become worn. They are lubricated much in the same way as tappets. Clearance for push rods or tappets in their guides should not be over .001″.

ROCKER ARMS

The purpose of the rocker arm is to make the overhead connection between the push rod and valves. This rocker arm is usually a steel forging, having its fulcrum or bearing at the rocker arm post, and usually employing a bronze bearing on the inside. Remove the bearing when worn and replace with a new one. Some engines have the rocker arm mounted on annular ball bearings. The rocker arm pin is usually made of alloy steel, hardened and ground to reduce the wear and friction to a minimum. The outer end of the rocker arm that connects to the push rod may have a hinge joint with the clearance adjusting nut below the hinge. This hinge joint necessitates a hinge pin which is also hardened and ground. Sometimes the upper end of the push rod is rounded off similar to a ball, with a concave receptacle at the outer end of the rocker arm, making a so-called ball and socket type bearing. The end of the rocker arm that operates the valve may be just a flat surface, so that it slides on the end of the valve stem, or it may have a roller on the end, operating on a hardened pin. The roller is usually made of high carbon steel, heat treated and ground to reduce wear and insure accuracy.

VALVE SPRINGS

The valve springs of both inlet and exhaust valves are held onto the valve stem by a spring cup, or retainer, which is a grooved receptacle to center the spring and hold it. This spring cup may be held on the valve stem by any one of several methods. One is by screwing the valve spring cup onto the valve stem and then locking it with a cotter pin. Another is by having a groove cut in the valve stem, a key inserted and held in place by the lower side of the retainer. Another, which is most common, is by a horseshoe washer, fitting into a groove cut around the valve stem. To replace these valve springs or remove them from the valves, turn the flywheel so that the tappet comes down on the lowest part of the cam. Use a valve lifter, which is a forked bar suspended by a chain or in some other simple manner, place it under the spring cup, lift the retainer upward, remove the lock and let the spring down. Then remove the valve from the chamber and lift the spring out of place. The same process is followed when replacing valve springs except that the operations are reversed. Place the valve spring into place first with the retainer underneath, then drop the valve into place. Get the valve lifter underneath the retainer, lifting the spring, retainer and spring upward, insert the lock into the groove or slot and then let the retainer down onto the retainer lock.

Usually both valve springs have the same tension, although it is not necessary that they should have. Spring pressure is usually about thirty-five pounds; it may be more or less, depending upon the amount of suction desired in the combustion chamber and also upon the speed at which the engine runs. The spring under all conditions, either exhaust or inlet, should always be stiff enough or of high enough pressure to keep the valve and tappet riding on the cam at the high engine speeds, otherwise when the valve closes with a weak spring, the crankshaft will have passed the proper closing point.

Racing engines require considerably more spring pressure on both valves. The inlet spring pressure need not be quite as much as the exhaust, because the inlet valve does not have a tendency to be drawn away from its seat, during intake stroke, as it is already open. As the piston goes down on the intake stroke if the exhaust spring should be weak, the exhaust valve will be drawn away from its seat by the suction of the piston, and burnt gases will be drawn back into the combustion chamber, weakening the new charge, causing a general loss of power and misfiring. The inlet spring need only be strong enough so

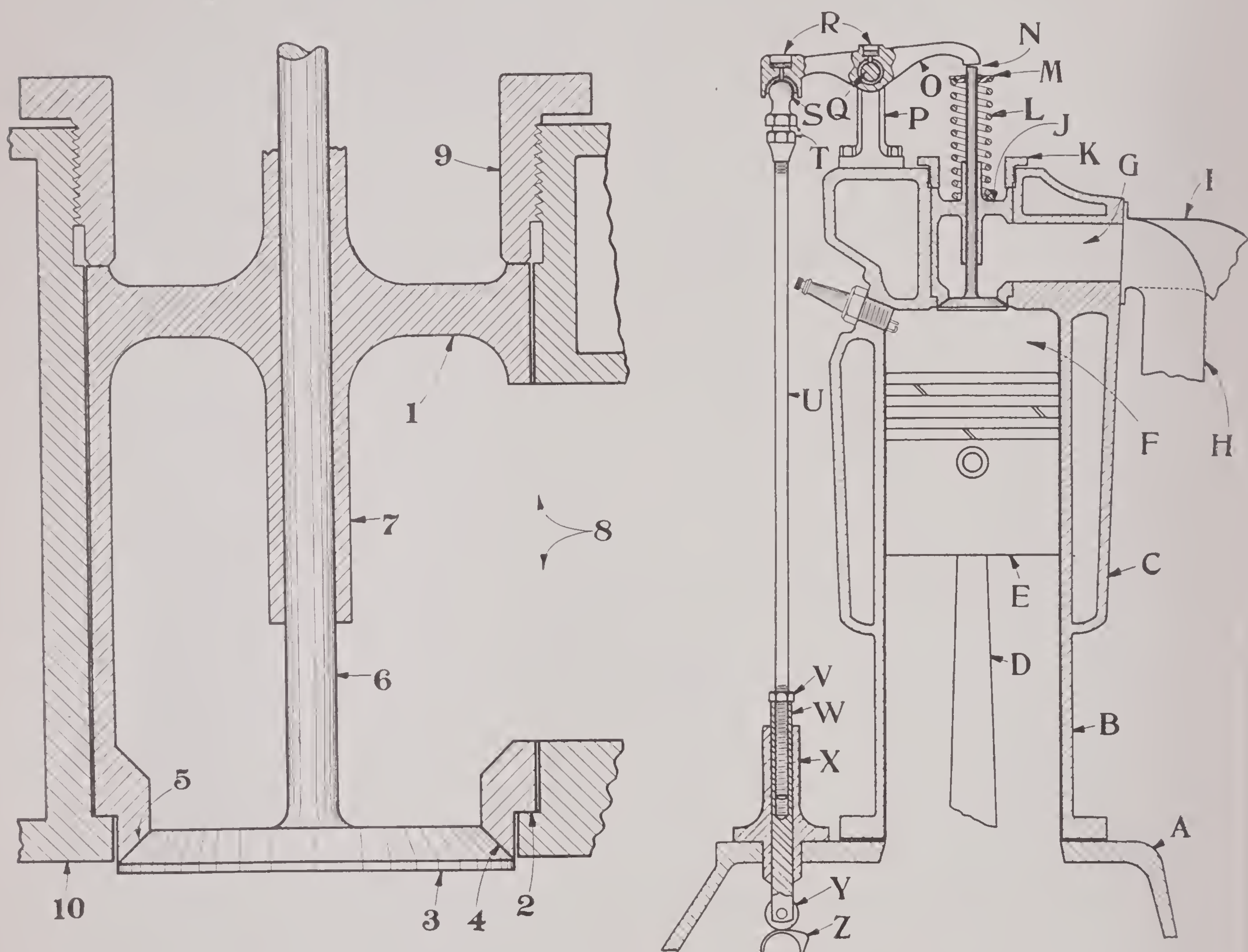


FIG. 20

I-HEAD CYLINDER AND DETAIL OF VALVE CAGE ASSEMBLY

1. Valve cage.
2. Cage seat.
3. Valve head.
4. Valve seat.
5. Valve face.
6. Valve stem.
7. Valve stem guide.
8. Port.
9. Cage nut.
10. Cylinder head.

A. Crankcase.
B. Cylinder.
C. Water jacket.
D. Connecting rod.
E. Piston.
F. Combustion chamber.
G. Port.
H. Inlet manifold.
I. Exhaust manifold.
J. Valve cage.
K. Cage nut.
L. Valve spring.
M. Valve spring retainer.
O. Rocker arm.
P. Rocker arm post.
Q. Rocker arm shaft and bearing.
R. Oil holes and retaining felts.
S. Ball and socket joint.
T. Push rod adjustment.
U. Push rod.
V. Lock nut.
W. Tappet.
X. Tappet guide.
Y. Tappet roller.
Z. Cam.

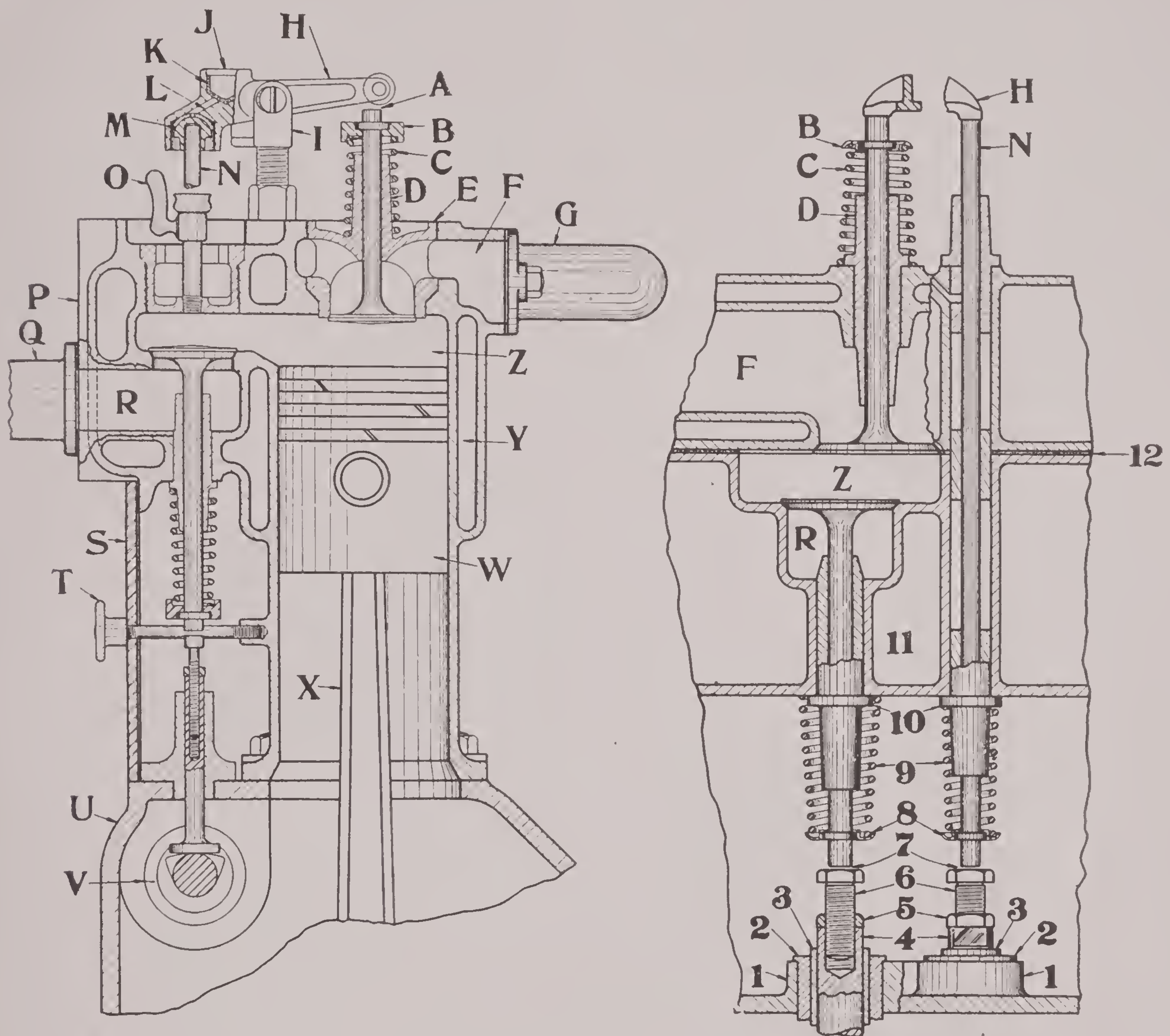


FIG. 21

F-HEAD CYLINDER SHOWING TWO DIFFERENT TYPES OF VALVE MOUNTING

A. Clearance.
B. Valve spring retainer.
C. Valve spring.
D. Valve stem guide.
E. Cage.
F. Inlet port.
G. Inlet manifold.
H. Rocker arm.
I. Rocker ărm post.
J. Oil reservoir.
K. Felt oil retainer.
L. Oil hole.
M. Ball and socket bearing.
N. Push rod.
O. Pet cock.
P. Cylinder head.
Q. Exhaust manifold.
R. Exhaust port.
S. Valve inspection plate.
T. Inspection plate retaining nut.
U. Crankcase.
V. Camshaft and bearing.
W. Piston.
X. Connecting rod.
Y. Water jacket.
Z. Combustion chamber.

1. Crankcase.
2. Tappet guide.
3. Tappet bushing.
4. Tappet.
5. Lock nut.
6. Clearance adjusting nut.
7. Clearance.
8. Valve spring retainer.
9. Valve spring.
10. Valve stem and push rod guide.
11. Water jacket.
12. Cylinder head gasket.

that the valve stem and tappet will always ride on the cam. Generally the exhaust valve spring has the more pressure, so if the inlet spring has the same pressure as the exhaust there is more than sufficient spring pressure on the inlet, causing a slight loss of power. On engines where the valve springs are of different lengths, the longest spring or the one with the most pressure is the exhaust.

The automatic inlet valve is not opened by a cam, but by the suction of the piston, and is closed by a light spring. This light spring allows the valve to be drawn away from its seat on the suction stroke, and as the suction decreases the valve will gradually seat itself aided by the spring. Then the piston moving up on the compression stroke with both valves closed, compresses the mixture. The spring tension required on the valve is small and has therefore perhaps 1/8″ or 3/16″ lift. The valve chatters considerably on its seat; it is not a very practical valve to use in automobile practice, being very noisy.

VALVE CAGES AS USED IN OVERHEAD ENGINES

The valve cage may be used on either the I or the F-head engine in connection with the overhead valve. These cages are used so that the valves may be readily removed for regrinding. If the valves are set directly in the head of the cylinder on the I-head where the head is not removable, it would be necessary to remove the whole cylinder

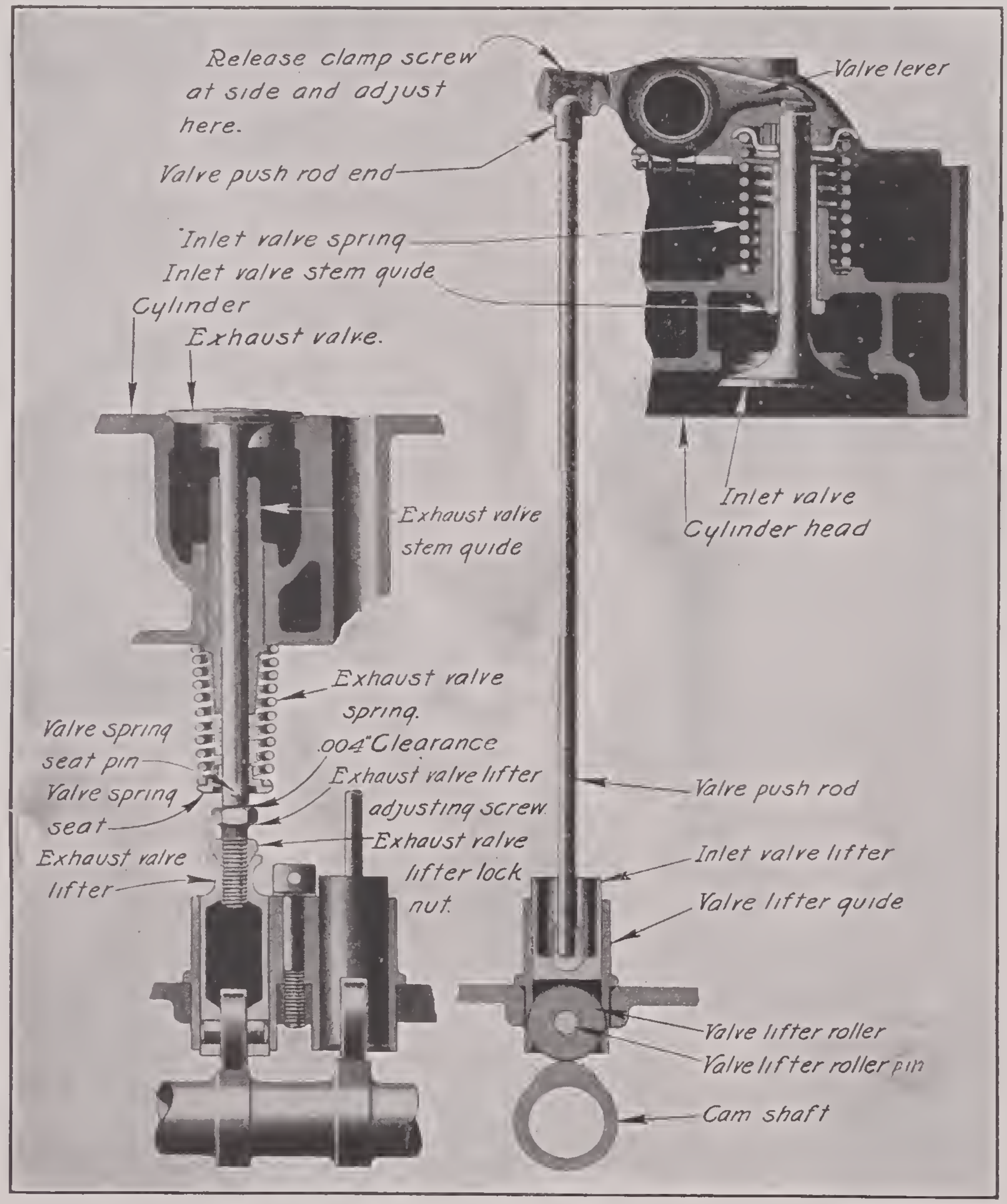


FIG. 22.

VALVE OPERATING MECHANISM OF A TYPICAL F-HEAD CYLINDER

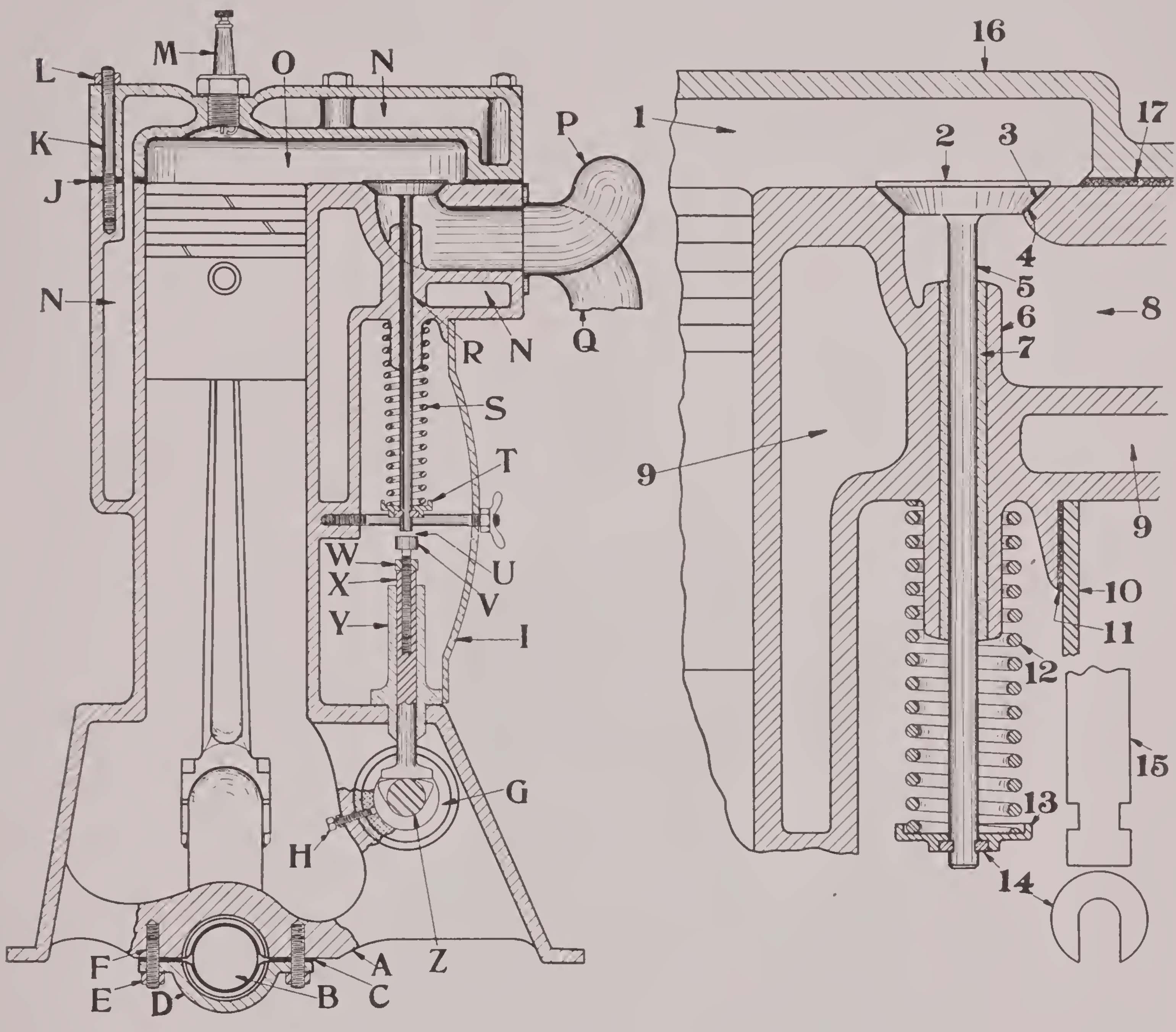


FIG. 23

L-HEAD ENGINE SHOWING AN ENLARGED VIEW OF VALVE ASSEMBLY

A. Crankcase.
B. Crankshaft.
C. Shims.
D. Main bearing cap.
E. Main bearing adjusting nut.
F. Main bearing stud.
G. Camshaft bearing.
H. Camshaft bearing lock.
I. Valve cover plate.
J. Cylinder head gasket.
K. Cylinder head stud.
L. Cylinder head nut.
M. Spark plug.
N. Water jacket.
O. Combustion chamber.
P. Exhaust manifold.
Q. Inlet manifold.
R. Valve stem guide.
S. Valve spring.
T. Valve spring retainer.
U. Clearance.
V. Clearance adjusting screw.
W. Lock nut.
X. Tappet.
Y. Tappet guide.
Z. Camshaft.
1. Combustion chamber.
2. Valve head.
3. Valve seat.
4. Valve face.
5. Valve stem.
6. Valve stem guide.
7. Valve stem bushing.
8. Port.
9. Water jacket.
10. Valve cover plate.
11. Gasket.
12. Valve spring.
13. Valve spring retainer.
14. Horse shoe washer.
15. Valve stem.
16. Cylinder head.
17. Cylinder head gasket.

block from the engine to regrind the valve, but by placing the valves in a cage and holding the cage in with a nut, or by screwing the cage onto a seat, it eliminates removing the whole cylinder to regrind the valves. These valve cages are either threaded into the cylinder or held down with a nut against a machined seat or gasket. The valve must be ground to a seat in the cage. Sometimes the cage requires grinding.

Care must be taken in placing the cage into the cylinder that the port holes are in line with the ports in the cylinders, otherwise the passage is obstructed, or partially obstructed, causing a loss of power and perhaps misfiring in the cylinder. These valve cages are made of cast iron, having the valve stem guides reamed to the correct fit. The valve cage is used successfully on automobile engines, but not with racing or aircraft engines, the reason being that the heat in the automobile engine is not as great as it is in a racing or an aircraft engine. The cage not being used on the latter engines, it is then necessary to remove the cylinder to regrind the valves.

If the inlet valve cage leaks at its seat, the piston while going down on the suction stroke draws in excessive air making the mixture too

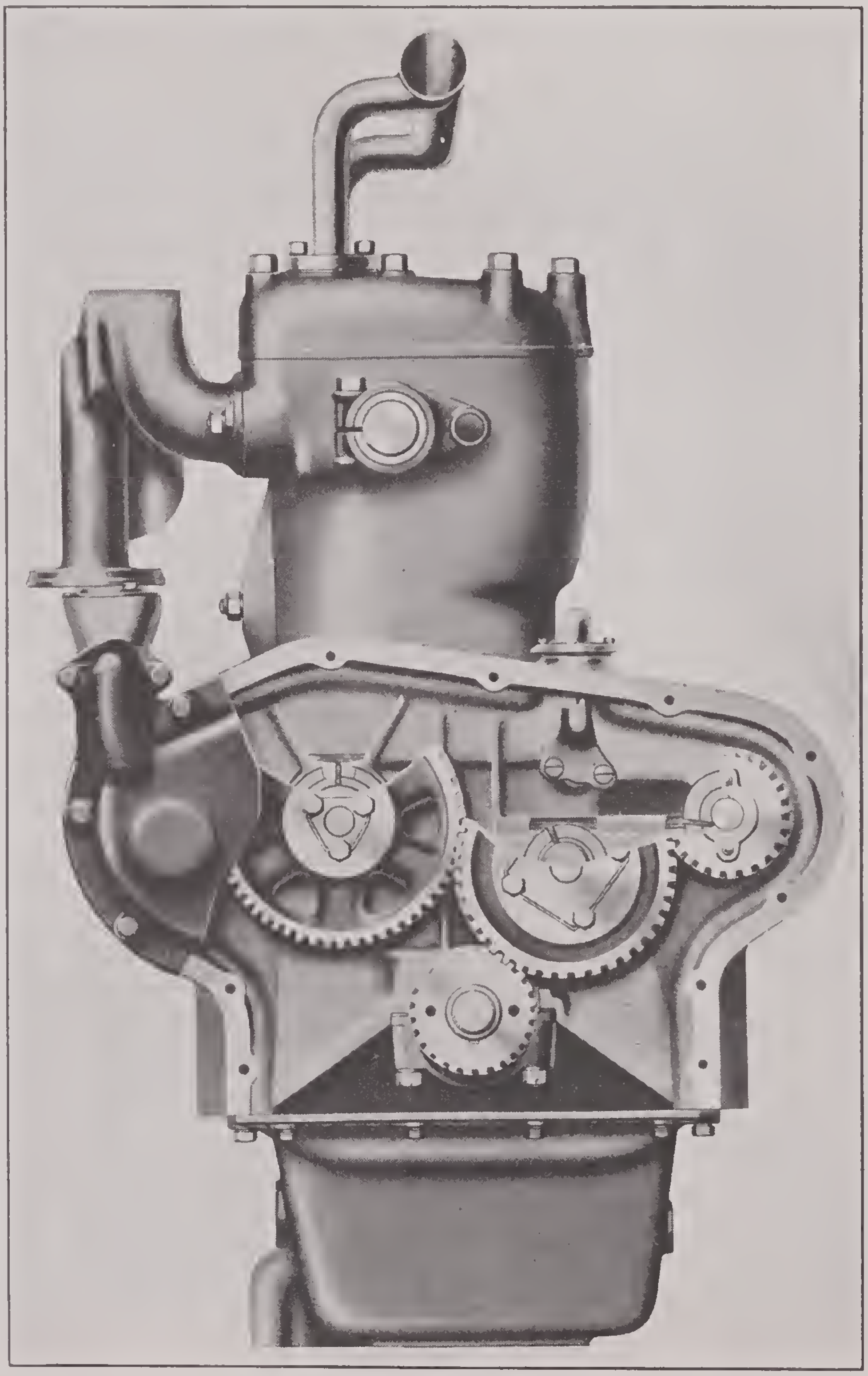


FIG. 24

GENERATOR AND CAMSHAFT DRIVE

lean, causing misfiring and backfiring, while the exhaust port when it leaks, causes a hissing noise, loss of compression, efficiency and power.

VALVE SPRING COMPARTMENTS

The compartment where the valve springs are located, is on the outside of the cylinder casting, with a cover fastening onto the cylinder, having a gasket to prevent leakage. This chamber has an opening into the crank case to allow the vapor from the crank case to lubricate the tappets and valve stems. The covers are generally held on with a long stud which is fastened to the cylinder casting. The gasket is usually make of cork. On the multiple cylinder engine one cover plate may enclose all of the valves, although some engines

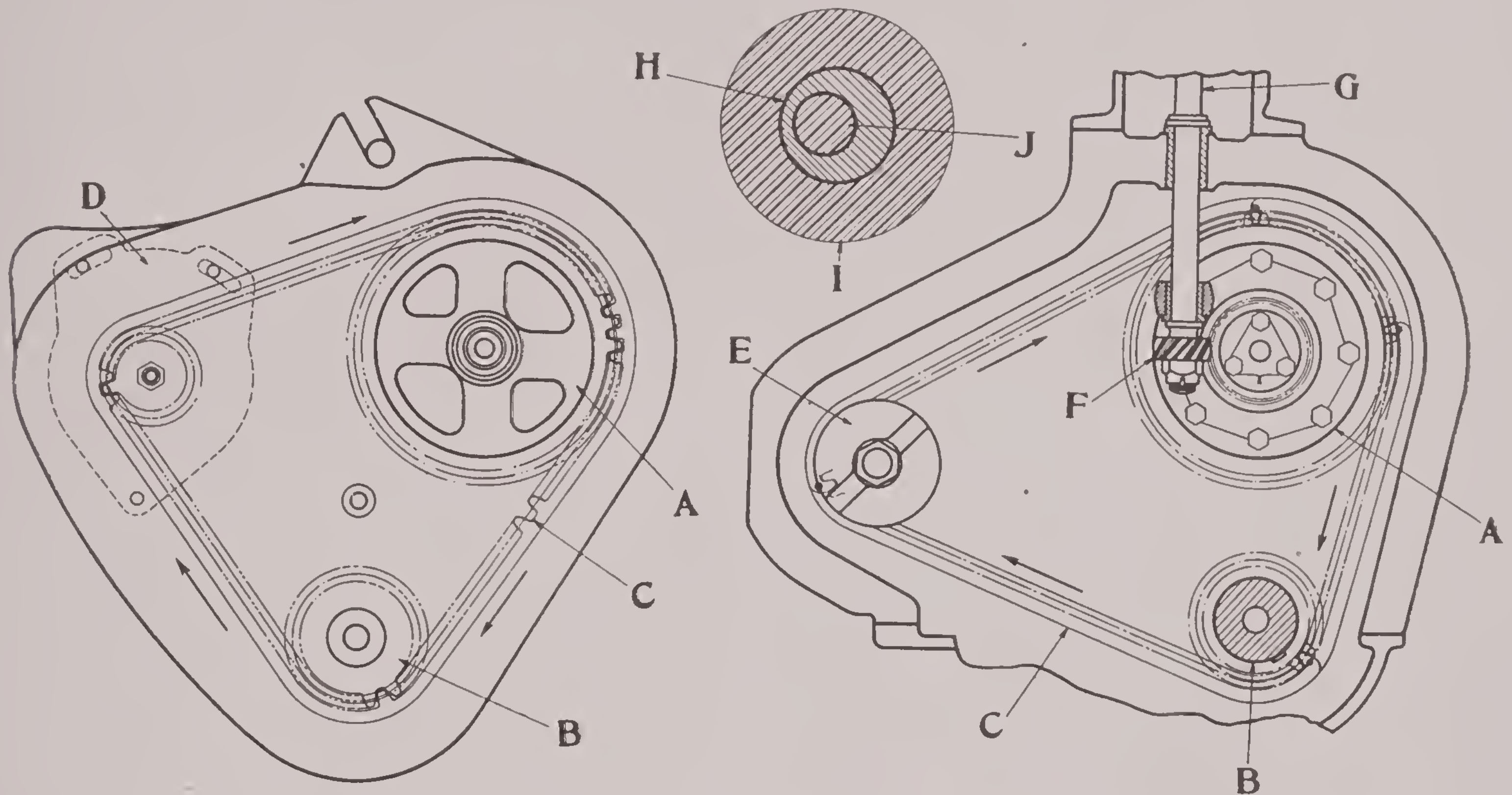


FIG. 25.

CHAIN DRIVE AND METHODS OF ADJUSTMENT

This figure shows the chain drive for the camshaft and the generator, and the method of removing the slack in the chain.

With the chain drive, all the shafts turn in the same direction. In the illustration to the left, (D) represents the generator mounting which is pivoted at the bottom and slotted at the top, so that it may be swung either to the right or left, for the purpose of adjusting the tension of the chain (C). (A) represents the camshaft sprocket and (B) the crankshaft sprocket. In the illustration at the right (E) represents the generator sprocket; the generator hub (H) is mounted in the gear case (I). (J) represents the generator shaft set off center, so that when the generator is turned it will swing the shaft inward or outward.

(A) represents the camshaft sprocket and (B) represents the crankshaft sprocket. (C) represents the chain. (F) represents the spiral gear that drives the ignition distributor shaft (G).

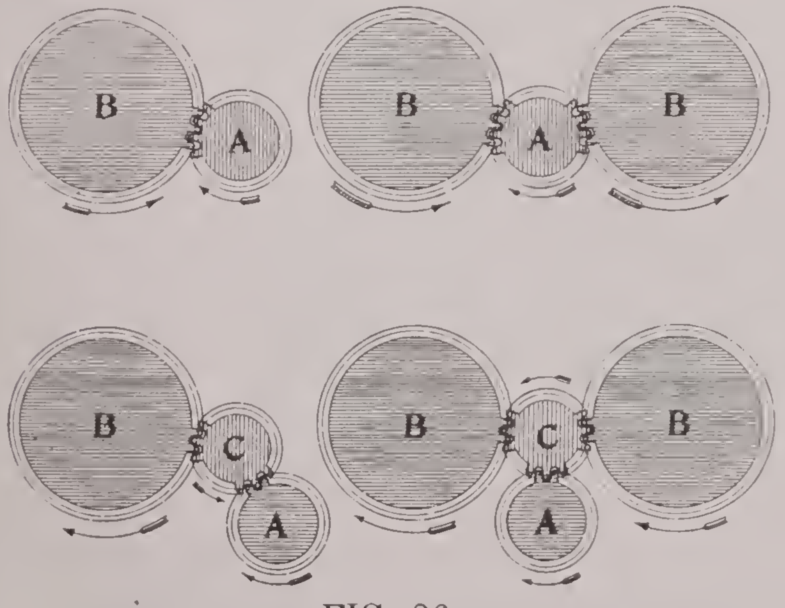


FIG. 26.

DIRECTION OF ROTATION OF TIMING GEARS

This figure shows the different gear arrangements on 4 cycle engines.

The direction of rotation of the timing gears and the number of gears in the gear train must be known to properly time the camshaft.

When there is no idler gear between the crankshaft and camshaft timing gears, the gears revolve in opposite directions.

When there is an idler gear between the crankshaft and camshaft timing gears, the timing gears revolve in the same direction.

A. Crankshaft timing gear or master gear.
B. Camshaft timing gear.
C. Idler gear.

have two or more cover plates for the spring compartment.

CAMSHAFT AND ECCENTRIC SHAFT

The camshaft is a shaft used to lift the valves from their seats at the proper time. The cams are either placed on the camshaft and held tight with keys or pins, or forged integral with the shafts, and then ground to the proper degree of accuracy. The eccentric shaft is a shaft that is used in the sleeve valve engine to move the sleeves up and down, causing the ports to be uncovered. Either a camshaft or an eccentric shaft is used in the four stroke cycle engine, and revolves one-half as fast as the crankshaft, or while the crankshaft is turning two complete revolutions the camshaft turns one. This is because the four stroke cycle engine requires two revolutions of the crankshaft to complete the cycle of operations. The gear or sprocket on the camshaft has twice as many teeth as the gear or sprocket on the crankshaft. The gears or sprockets are fastened onto the end of the camshaft with bolts or keys. These gears must have a small amount of backlash or clearance, where the teeth mesh with each other. This clearance is from .002″ to .004″, just enough play to allow for expansion, and for any unevenness in the contour of the teeth.

The camshaft revolves in bearings made of bronze or babbitt metal which are mounted or pressed into the crankcase. These bearings must be in line with one another so as to allow the shaft to revolve freely. The camshaft is usually about .001″ smaller than the bearing and should have very little end play, preferably from .002″ to .004″. It is made of steel, heat treated, hardened and accurately ground.

The part of the cam that has a true radius, concentric with the shaft, is called the heel, while the part of the cam that is used to raise the valves is called the toe. On engines where the intake, or suction stroke, is 205° long, crankshaft travel, the toe of the cam is 102½° long, because the camshaft travels one-half as fast as the crankshaft. If the exhaust stroke is 230° long, the exhaust cam toe will be 115° long. The toe or lift of the cam governs the height the valve is lifted from its seat, the length of time the valve is held open (the stroke) and the speed of the opening and closing of the individual valve.

The camshaft for a single cylinder engine

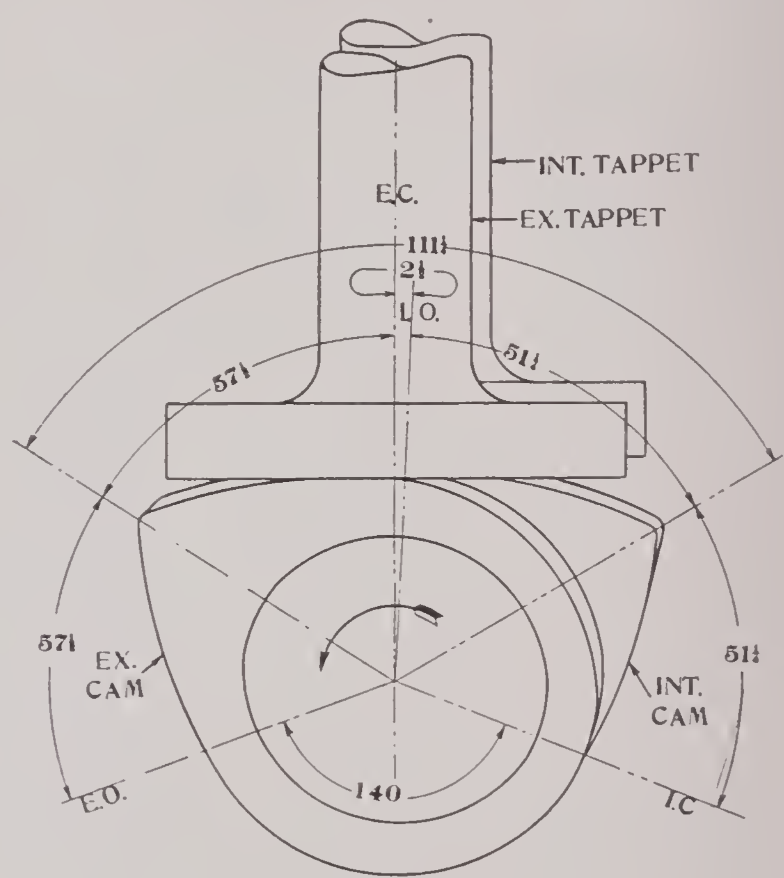


FIG. 27

EXHAUST AND INLET CAMS—RELATIONSHIP

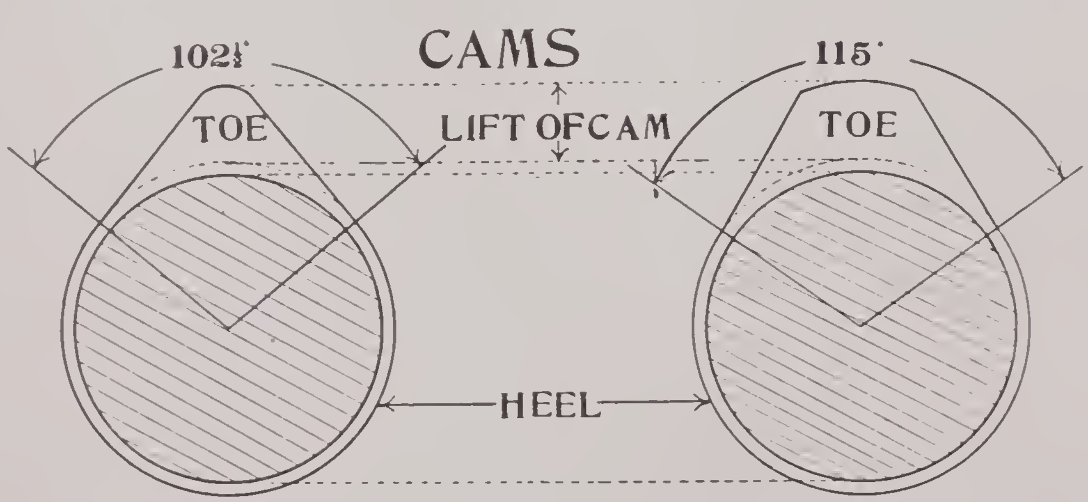


FIG. 28

This figure shows the design of an inlet cam for an engine having the intake stroke 205° long and an exhaust cam for an exhaust stroke 230° long. As the camshafts in the four stroke cycle engine revolve at one half crankshaft speed the toe of the cams are just one half the length of the crankshaft travel in degrees.

with both valves operated mechanically has two cams on it. On multiple cylinder engines the order in which the cams are placed on the camshaft governs the order in which the valves open and the cylinders fire. The cylinders are numbered 1, 2, 3, etc., beginning at the front or cranking end of the engine, and the order in which they fire is called the firing order of the engine. Then to find the firing order of an engine, it is necessary to determine the order in which the cams are set on the camshaft or the order in which the valves open, remembering that the valves open just twice as many degrees apart crankshaft travel as they do camshaft travel. Knowing this to be true then, to determine the number of degrees apart the cams are set on the camshaft, divide the number of degrees apart the cylinders fire, crankshaft travel, by two.

Example: In a 4-cylinder engine the cylinders fire 180° apart crankshaft travel, and all inlet or exhaust cams are set 90° apart on the camshaft. If this engine should have a 1-2-4-3 firing order, number 1 and 4 cylinders would fire 360° apart crankshaft travel, 180° apart camshaft travel, and number 1 and 4 cams, either inlet or exhaust, would be set 180° apart.

INLET VALVE OPENING AND CLOSING

The degrees which are considered in this explanation will be the position that the crankshaft is in when the valves either open or close. The valve opening and closing points are not standard, for the reason that there are several conditions that are considered in determining these points, such as speed of the engine, fuel, size and lift of valves, size of the combustion chamber, stroke, shape of inlet manifold, inlet port, exhaust port, diameter and length of exhaust pipe.

The suction stroke is determined by the opening and closing of the inlet valve. As long as the inlet valve remains open the piston is on the intake stroke. The inlet valve opens when the crankshaft is about 10° past top dead center, and closes when the crankshaft reaches a point approximately 35° past bottom dead center. Some inlet valves open on dead center, or may open as late as 30° past top dead center. Some inlet valves close as early as 15° past bottom dead center and others as late as 45° past bottom dead center. The reason for closing the inlet valves so late after the piston has started upward, is that the gases, coming in during the suction stroke, attain a certain momentum. The faster the piston goes down on the suction stroke, the greater will be the velocity of the gases rushing into the combustion chamber. When the pressure of the gases rushing in equals the pressure formed by the piston moving upwards, the inlet valve should close. On high speed engines the inlet valve is held open

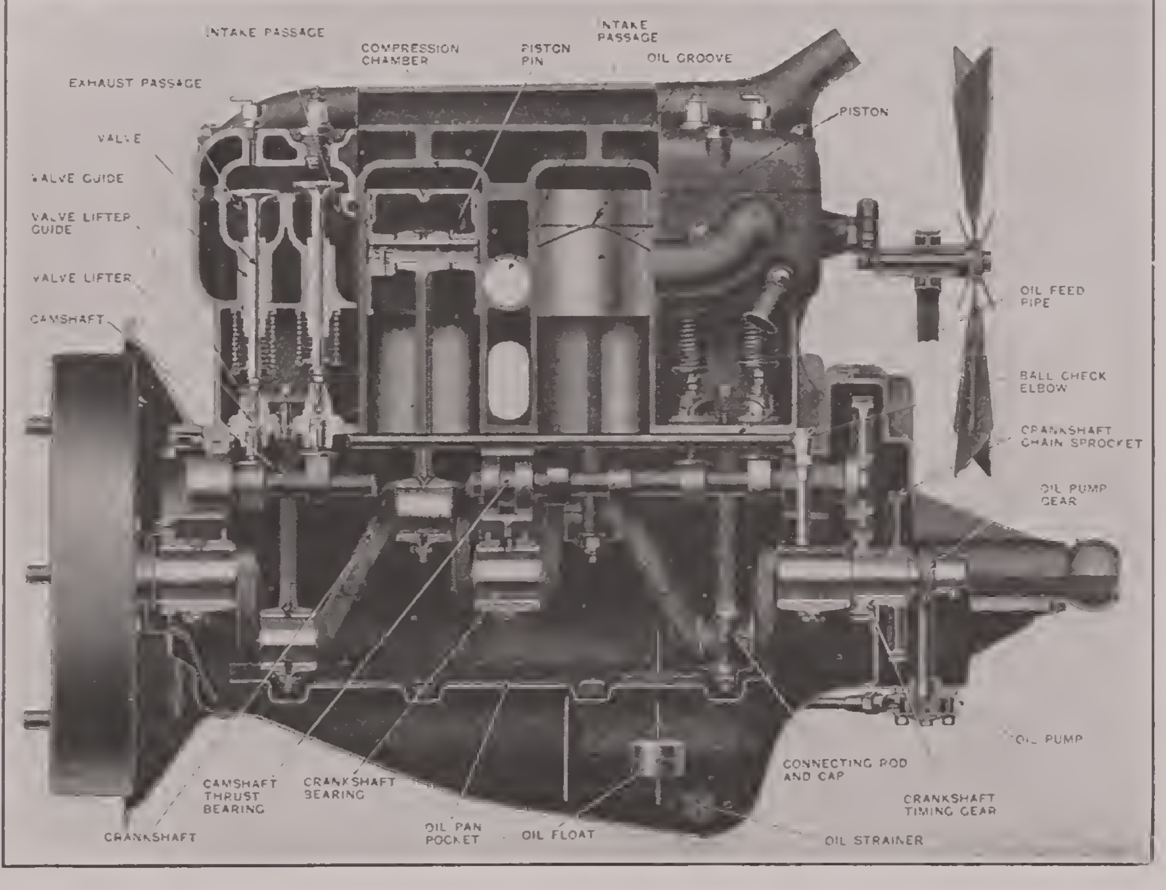


FIG. 29

CAMSHAFT MOUNTING, FOUR CYLINDER ENGINE

longer, due to the greater velocity of the incoming gases, while on the low speed engine the inlet valve is closed earlier because of the lower velocity of the incoming gases.

Theoretically the valve timing is not perfect for all engine speeds, but the valve timing that is used is the one that has been experimented with at the average speed of the car so as to give the highest efficiency. The inlet valve usually opens a few degrees after the exhaust valve has closed so that the piston will move downward a trifle with both valves closed and form a partial vacuum in the combustion chamber. This vacuum, as the inlet valve opens, will draw the gases in much faster than if it had been open when the suction started. The speed of the gases rushing through the inlet manifold helps to properly vaporize the fuel.

EXHAUST VALVE OPENING AND CLOSING

The exhaust valve usually opens about 45 before bottom dead center, although this opening will vary a few degrees either way, depending upon the speed of the engine and the back pressure in the cylinder and the exhaust pipe. The exhaust valve closes when the piston reaches top dead center or a few degrees past. The size and lift of the exhaust valve and the back pressure generally determine the point of opening, because if the exhaust valve should open too late on a high speed engine, for instance, the piston as it moves up on the exhaust stroke would have to work against the pressure that is in the combustion chamber and in the exhaust manifold. By allowing the gases to escape from the cylinder earlier this pressure is relieved.

The exhaust valve may close on either top

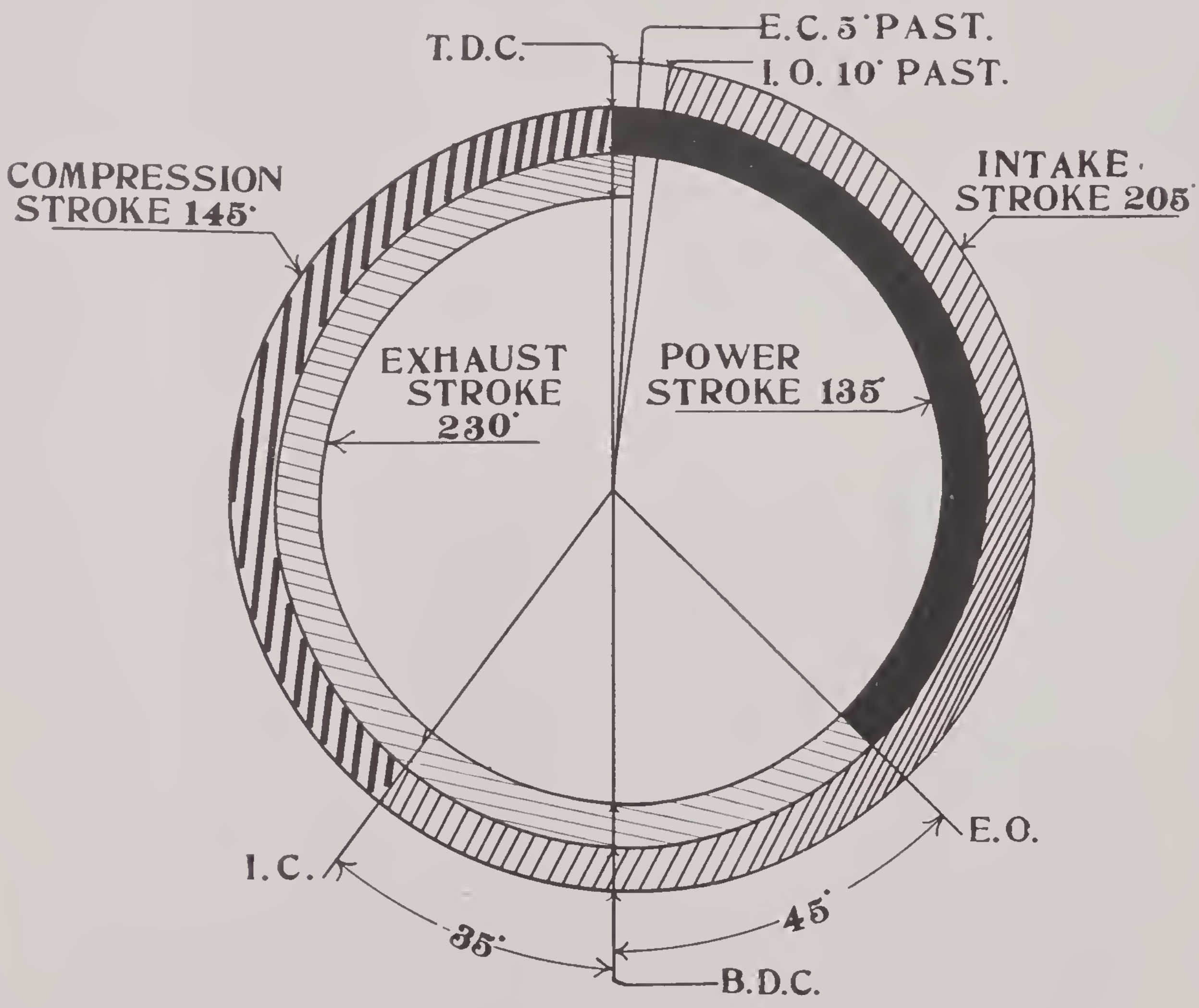


FIG. 30

CYCLE OF OPERATIONS

This figure shows the combination of the four strokes and in the order in which they occur in an engine with crankshaft turning in a clockwise direction.

Assuming that both valves are closed as the crankshaft reaches a point 10° past top dead center, the inlet valve starts to open and the piston moves downward on the intake stroke. This valve remains open during 205° of crankshaft travel until a point 35° past bottom dead center, at which point the inlet valve closes.

The piston moves upward (both valves being closed) during the next 145° of crankshaft travel, until it reaches top dead center, at which time the spark occurs.

The piston is forced down on the power stroke during the next 135° of crankshaft travel, to a point 45° before bottom dead center, at which time the exhaust valve opens.

The exhaust valve remains open until 5° past top dead center or during 230° of crankshaft travel.

After the exhaust valve closes there is 5° of crankshaft travel before the inlet valve opens again.

dead center or a few degrees past, which may be necessary to insure all the burned gases having left the cylinder. With the general variation in the opening and closing of the valves it can be seen that the four strokes will be of different lengths. Consequently, the cams will be made differently. For instance, in the valve opening and closing just given, the exhaust stroke is about 230° long, while the intake stroke is about 205° long, necessitating different shape cams for the inlet and for the exhaust.

The ideal type of cam for maximum power, is one that opens the valves to the wide open point as soon as possible, holds them open as long as possible, then closes them quickly. A cam of this type operates very noisily. Cams on automobile engines are usually made with a slight curve ground on the toe. The shape of the tappet, or cam follower that rides on the cam has considerable to do with the speed at which the valves open and close. A tappet with a roller riding on the cam will be one of the slowest acting tappets, but the quietest, while a tappet that is flat on the bottom will open very quickly but is noisy. In automobile engine construction it is necessary to sacrifice some of the maximum efficiency to obtain quietness.

MANIFOLDS

Material and Construction

The inlet manifold is designed with two important considerations: first, to give each cylinder the same quantity of fuel, and second, to insure the mixture being equally well vaporized when entering each cylinder. With the fuels used today, a great portion of it passes through the manifold as a mist suspended in the air current. Since the velocity of the air depends upon the speed of the engine, the size and shape of the manifold has much to do with the mixing of the gases. Bends, sharp corners and rough surfaces on the interior of the manifold have a tendency to retard the fuel mixture and cause condensation.

The inlet manifold is made of aluminum, malleable or cast iron, and a part of it is sometimes cast integral with the cylinders, where the cylinders are in block. It may also be cast integral with the exhaust manifold so that the incoming gases may come in contact with the hot walls of the exhaust passages, heating them and causing them to vaporize more thoroughly. It may be water jacketed allowing a circulation of hot water around it, or it may be oil jacketed, serving two purposes, to heat the gases and also cool the oil that circulates around it. The fuel may be mixed in the carburetor with hot air drawn from around the exhaust pipe. All these heaters, hot spots and hot air tubes have a tendency to improve the thermal efficiency of the engine by warming up and vaporizing the fuel better. When the gas is cold and taken into the cylinder in a partially vaporized state the unvaporized portion does not burn, but is lost or wasted, washing the lubricating oil from the cylinder wall, getting down into the crankcase, mixing with the oil, spoiling its efficiency as a lubricant and causing loss of compression and power.

When the air velocity is high, it chills the manifold enough to cause frost to form on the exterior on damp cold days. This is not an indication of a poor mixture; it has only to do with the atmospheric conditions outside the manifold.

The principal considerations with the exhaust manifold are to take the exhaust gases away from the cylinder as quickly as possible and to make it of such size as to avoid any back pressure in the cylinder. The quicker the exhaust gases are expelled the less heat they will give up to the cylinder casting. It is seldom cast integral with the cylinders but is bolted on with long studs and clamp arms.

A gasket usually made of a sheet of asbestos between two sheets of copper is used to take up the unevenness between the face of the manifolds and the cylinders.

Troubles and Repairs

The inlet manifold gaskets must be air tight, otherwise when the piston moves down on the suction stroke it will draw air in through these openings, making the mixture too lean and causing misfiring and possibly backfiring through the carburetor. To test an inlet manifold for a leak, run the engine as slowly as possible. With a priming can squirt gasoline on the various joints, or any point where a leak is suspected. As the gasoline is squirted on a joint where air is drawn in, the gasoline will be drawn in, enrichening the mixture, allowing the cylinder to fire again, causing the engine to run faster. If the gasoline is squirted on a joint that does not leak, it will have no affect on the running of the engine.

In time carbon will obstruct the passages in the exhaust manifold due to the burned gases passing through, necessitating cleaning. The back pressure caused by the formation of carbon is effective on the top of the piston, having a tendency to hold it back when the piston comes up on the exhaust stroke, causing a loss of power. These manifolds may crack, and if they do it will necessitate welding. If the casting warps in the welding process the flange surfaces may require refinishing. Care must be taken not to have the gasoline supply line too close to the exhaust manifold. In case of leakage the gasoline would be ignited, and set fire to the car. Insulate the exhaust manifold at this point with asbestos.

VALVE CHAMBERS OR PORTS

The valve chamber leading either to the inlet valve or exhaust valve may feed to two or more cylinders, with the valve closing off each separate cylinder. These passages should be as smooth as possible and with few curves and obstructions. The inlet manifold when clamped onto the cylinder at the valve chamber should line up with the port, otherwise the passage is obstructed, interfering with the free flowing of the gas.

FLYWHEELS

The purpose of the flywheel is to store up the energy imparted to the crankshaft by the explosion in the cylinder and keep the shaft turning between the impulses so that the turning force may be substantially uniform.

With a single cylinder four stroke cycle engine, the power is applied for only one stroke and there are three idle strokes. Thus the flywheel stores up some of the mechanical energy developed during the power stroke and gives it up in keeping the shaft turning until the next power stroke. As the number of cylinders is increased, the impulses occur oftener and a smaller amount of weight is required in the flywheel to keep the shaft turning.

Using the weight of flywheel required for a single cylinder engine as 100%, the weights for other engines are approximately as follows:

Single	100%
Two cylinder	80%
Four cylinder	44%
Six cylinder	22%
Eight cylinder	11%
Twelve cylinder	4%

These weights are usually exceeded in actual practice to facilitate starting the engine and car. The centrifugal force and road clearance are important in determining the diameter.

Material and Construction

Flywheels are generally made of cast iron, and are machined all over to balance them. They are mounted on the end of the crankshaft on the face of a flange, and are held onto this flange with either bolts or studs, which are locked by safety wires or cotter pins. The flywheel usually has marks on the circumference such as: "D. C." (Dead Center), "E. O." (Exhaust Opening), "E. C." (Exhaust Closing), "I. O." (Inlet Opening), and "I. C." (Inlet Closing).

When bolting the flywheel onto the crankshaft, care should be taken that the marks line up properly with the crankshaft, because this flange may have four, six, or eight holes in it. This allows four, six, or eight different positions for the flywheel, consequently the marks on the flywheel may not line up with the crankshaft, causing a great deal of trouble when timing the camshaft. Care should be taken when bolting the flywheel to the crankshaft that no dirt rests between the surfaces, otherwise the flywheel will wobble and vibrate causing the bearings to wear. Some flywheels are keyed to the tapered end of the crankshaft, but this method of fastening is not as successful on account of the small diameter of the shaft, allowing the flywheel to continuously work loose and pound.

The flywheel is also used as the clutch mounting for either the cone clutch or the disc clutch. The flywheel may have gear teeth machined on the circumference for the electric starter, or may have a steel gear pressed on it for the same purpose.

VALVE TIMING, T-HEAD ENGINE

As the T-head engine has two camshafts it is necessary to time each shaft separately. Time the exhaust camshaft first and then the inlet camshaft. Considering a single cylinder engine; with the tappets on the heel of the cam, adjust the exhaust valve clearance to .004″ and the inlet valve to .002″. Set the crankshaft 5° past T. D. C. Turn the exhaust camshaft in its direction of rotation until the exhaust valve just closes, which can be determined by placing a thin piece of paper between the end of the tappet and exhaust valve stem and when the paper becomes free the valve is just seating. Lock the gear onto the camshaft, then turn the crankshaft forward about 5° and turn the inlet camshaft in its direction of rotation until the inlet valve is just opening, then lock the inlet camshaft gear in place.

This places the piston on the end of the exhaust stroke and the start of the intake.

Valve Timing of Engine with Automatic Inlet Valves

To time the camshaft of an engine with automatic inlet valves, it is only necessary to time the exhaust camshaft. With the crankshaft or flywheel a few degrees past top dead center, turn the exhaust camshaft in its direction of rotation until the exhaust valve just closes, mesh the gears and lock in place.

To Determine the Inlet from the Exhaust Valve by Their Movement

Referring back to the valve openings and closings: The inlet valve opened just as the exhaust valve closed, or within a few degrees crankshaft travel from that point, while when the exhaust valve opened, the inlet valve did not close at that point. Turn the engine over and watch the action of the valves. When one valve closes and the other valve opens at the same time or immediately after, the one that closes is the exhaust, and the one that opens is the inlet.

To Determine the Firing Point

Open the priming cup or remove the spark plug; turn the engine over until compression is felt in the cylinder, then put a wire on the top of the piston and turn the crankshaft over until the piston reaches top dead center. This will be T. D. C. compression or firing point. Another method of setting the piston on the firing point is to crank the engine over until the inlet valve just closes. The crankshaft is now about 145° from the firing point; open the priming cup and place a wire on the head of the piston, turn the flywheel over until the piston reaches top dead center, or the "T. D. C." mark on the flywheel lines up with the indicator, thus putting it on the firing point.

CYLINDER CASTINGS AS USED ON MULTIPLE CYLINDER ENGINE

Cylinders may be cast separately, or in pairs,

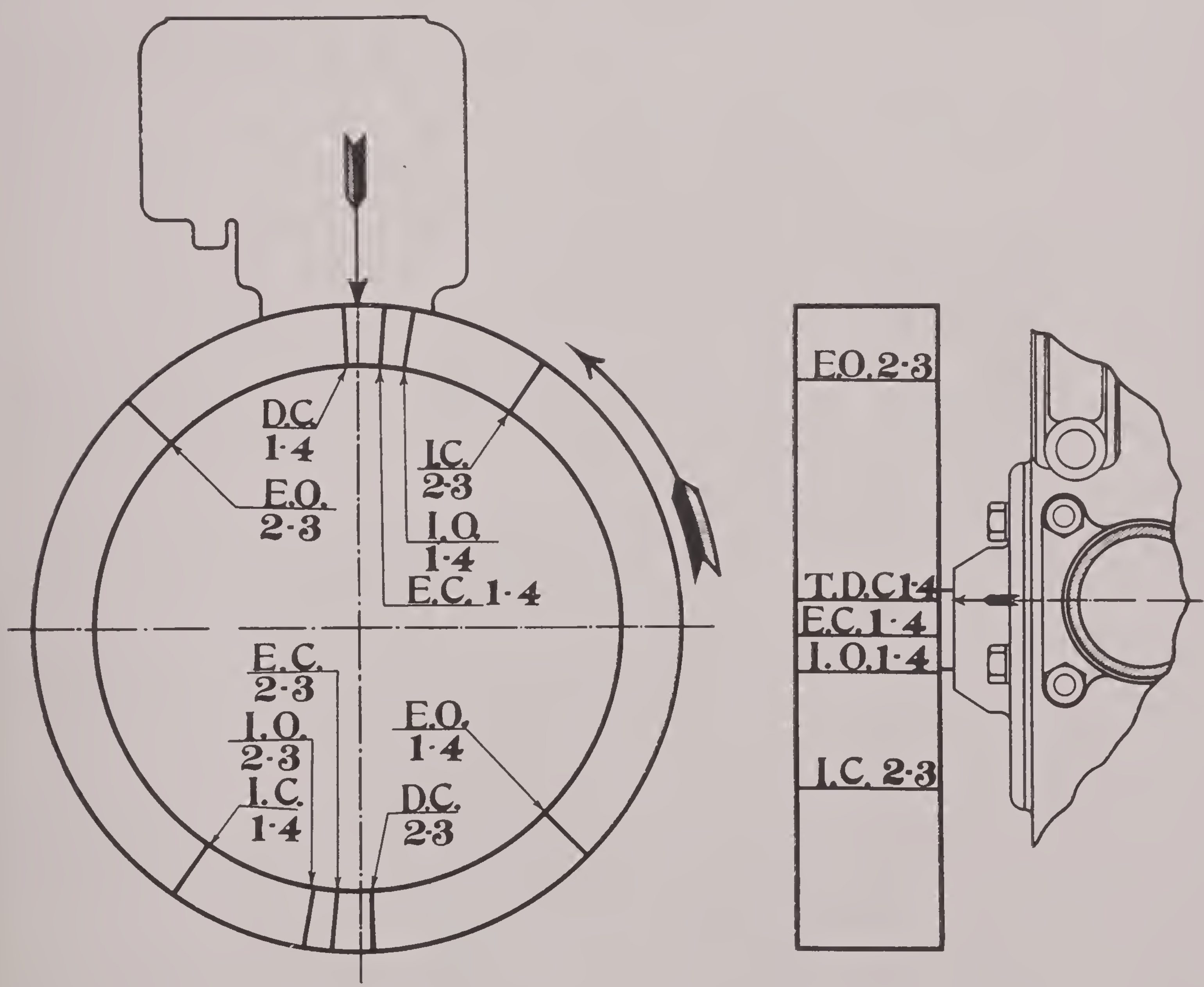


FIG. 31

FOUR CYLINDER FLYWHEEL MARKS

D.C. Dead center.
E.O. Exhaust opens.
E.C. Exhaust closes.
I.C. Inlet closes.
I.O. Inlet opens.

or there may be four cylinders cast in block, separate from the crankcase, but fastened to same with studs, having a paper gasket between. In some constructions the cylinder block may have the upper half of the crankcase cast integral, eliminating the gasket and the machining of these surfaces. Where the cylinders are separate there are numerous joints and fittings to make the connections between the various cylinders which necessitates extra machining on both the fittings and the cylinders.

GENERAL PRINCIPLES OF OPERATION, MULTIPLE CYLINDER ENGINES

In any four stroke cycle engine, after a certain cylinder fires, that same cylinder will not fire again until the crankshaft completes two revolutions, or 720°. After firing, the piston must perform a cycle of operations; consisting of Power, Exhaust, Intake and Compression strokes.

On any four stroke cycle engine regardless of the number of cylinders, all cylinders will fire during two revolutions of the crankshaft, or 720°.

There are three things that determine the distance apart of the explosions in a multiple cylinder engine; — the angle between the cranks, the angle between the cylinders, and the number of cylinders.

In automobile engines if the cylinders and crank throws are set standard, the explosions will occur uniformly, or at regular intervals. In order to find the distance apart the explosions occur, divide 720° by the number of cylinders. A four cylinder engine will fire every 180°; a six, every 120°; an eight, every 90°; and a twelve, every 60°.

When speaking of No. 1 spark plug, it refers to the spark plug in No. 1 cylinder; No. 4 exhaust valve, the exhaust valve in No. 4 cylinder, etc. Consider the firing point as being T. D. C. compression. Firing point retard may be anywhere from T. D. C. to 10° past, while the firing point in advance may be anywhere from 25° before T. D. C. to T. D. C. This will vary more or less on different engines. In automobile engines two pistons move together and will be 360° apart in operation. For example: In a four cylinder engine No. 1 and No. 4 move together, that is, when No. 1 is on T. D. C., No. 4 will be there also. If No. 1 was on T. D. C. compression (firing point) No. 4 would be on T. D. C. exhaust—360° from the firing point. When the explosion occurs, No. 1 will start moving down on Power stroke. Since there are only two different operations performed on the downward movement of the piston—Power and Intake—and since both pistons do not perform the same operation at the same time, No. 4 would be moving down on intake. When two pistons are considered that move together it is found that if their crankshaft throws are anywhere from 10° past to 135° past T. D. C., one will be on Power, the other on Intake. When the crankshaft throws are between 45° before and 35° past B. D. C., one will be on exhaust, the other on intake. When the crank throws are between 35° past B. D. C. and T. D. C., one will be on compression and the other on exhaust. When one fires, the other will be on exhaust. When the inlet valve opens in one the other will be on Power. When the exhaust valve opens in one the inlet will be open on the other. When the inlet valve closes in one, the other will be on exhaust. When the exhaust valve closes in one the other will be on Power.

Based on the average valve settings, as shown in Fig. 30, the duration of the strokes will be:

Intake	205°
Compression	145°
Power	135°
Exhaust	230°
Lap	5°
Total	720°

When timing the ignition, always time from T. D. C. flywheel mark, or piston position,—not by the valve closings, as they vary on almost every engine.

Timing the Valves Or Setting the Camshaft

The valves may be timed by either flywheel marks or piston position, and timed to the opening or closing of either the inlet or the exhaust valve in any cylinder. Timing by the flywheel marks is preferable, because that will give the exact timing for that individual engine, provided the flywheel marks are correctly located.

Care must be taken when timing any camshaft that the camshaft and crankshaft are turned in the same direction that they revolve when the engine is running.

Checking the Flywheel Marks

If the flywheel marks are correct, when two pistons reach T. D. C. their relative mark should line up with the indicator. For example: when No. 1 and No. 4 pistons are on T. D. C., the flywheel mark "D. C. 1-4" should line up with the indicator.

Establishing An Indicator

Where there is no indicator stamped or fastened on the crankcase, one can be established by cranking the engine over until two pistons reach T. D. C. If Nos. 1 and 4 are taken, then place a mark on the crankcase that will point to, or be in line with "D. C. 1-4" mark on the flywheel.

ESTABLISHING FLYWHEEL MARKS

Where the flywheel is not marked, the timing marks may be established provided the valve openings and closings are known. If the flywheel has a circumference of 36 inches, it can be divided into 360 equal spaces and one inch will represent 10°; one half inch, 5 , etc.

Consider a four cylinder engine for example. Crank the engine over until Nos. 1 and 4 pistons reach T. D. C., then place a mark on the flywheel in line with the indicator. This mark will represent dead center for Nos. 1 and 4 "D. C. 1-4." That is, any time that mark lines up with the indicator, Nos. 1 and 4 pistons will be at their highest point of travel.

Turn the flywheel 5° farther in its direction of rotation and place a mark on the flywheel

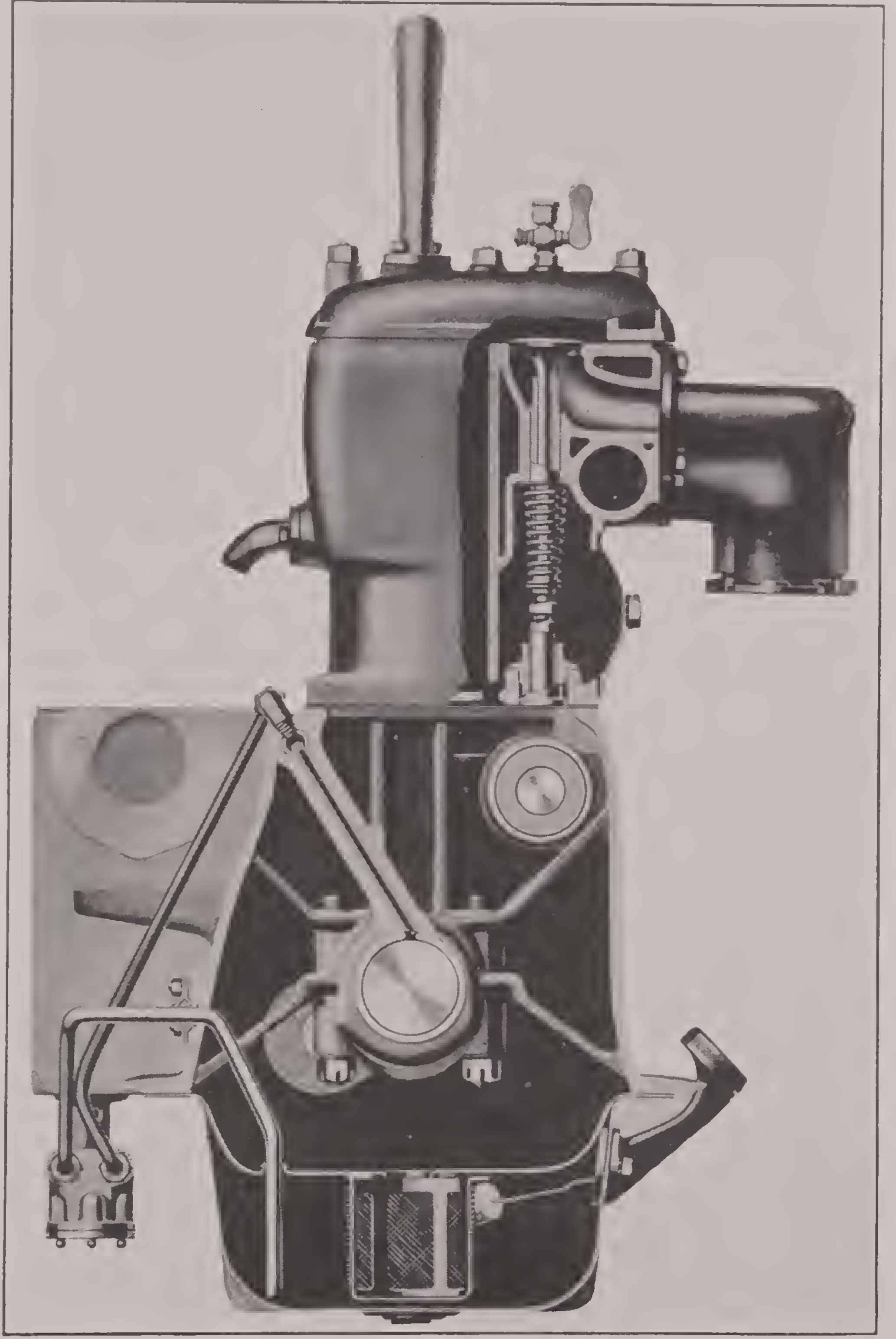


FIG. 32

FOUR CYLINDER ENGINE (END VIEW)

in line with the indicator. This will represent exhaust closing, Nos. 1 and 4 "E. C. 1-4." That is, when that mark lines up with the indicator, Nos. 1 and 4 pistons will be in the correct position for the exhaust valve to close. Turn the flywheel another 5° in its direction of rotation and place a mark on it in line with the indicator. This will represent the inlet valve opening position (10° past T. D. C.). That is, when the mark "I. O. 1-4" lines up with the indicator, Nos. 1 and 4 pistons will be in the correct position for the inlet valve to open.

CRANKSHAFTS FOR TWO CYLINDER FOUR STROKE CYCLE ENGINES

The crankshaft may have either two or three main bearings depending upon the general construction. The crank pins may be set opposite one another, 180° apart, or both crank pins may be in the same plane, that is both together. The arrangements of these crank pins and the setting of the cylinders determine

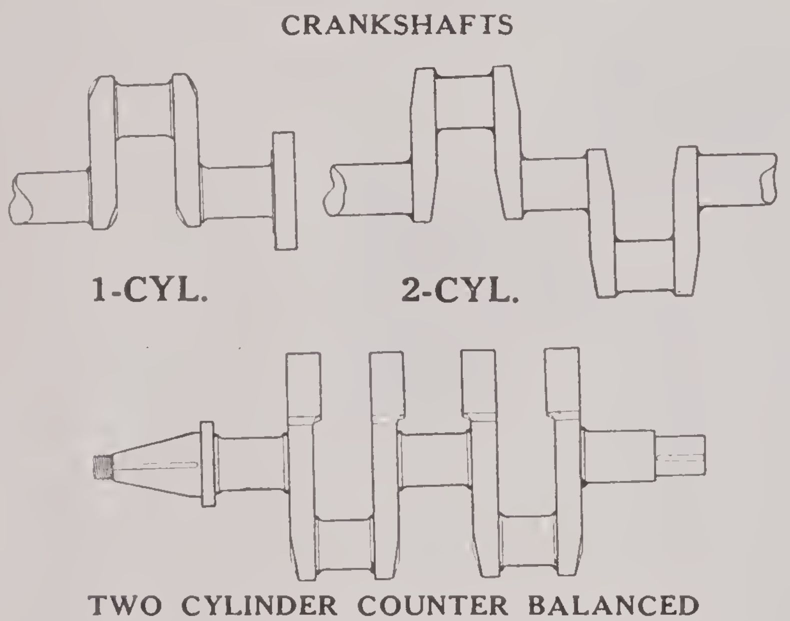


FIG. 33

the distance apart the cylinders fire in crankshaft travel. The two cylinder engine is built in two types, one where both cylinders are in the same plane, and the other, the opposed type. In the opposed type the cylinders are set opposite one another. Motorcycle engines have the cylinders set about 22½° from a vertical line, causing them to fire unevenly.

Consider a two cylinder vertical engine, using a crankshaft with the crank throws set 180° apart. It requires 720° crankshaft travel to perform the cycle of operations. Both cylinders should fire in two revolutions of the crankshaft. In this type of engine when number one piston is on top dead center compression or firing point, number two piston will be on bottom dead center, hence, the crankshaft must turn 180° before number two piston reaches the firing point. When number two fires, number one is on bottom dead center on the exhaust stroke, having completed 180° of its travel. Number one swings 180° to top dead center, just completing the exhaust stroke, necessitating another complete revolution, or 360°, before it is ready to fire. So after number two cylinder has fired number one piston will travel 540° before it is ready to fire again. Number one and number two cylinders fired 180° apart, and number two and number one fired 540° apart, giving the full 720° travel. A two cylinder engine of this design is not very practical, causing considerable vibration through the variable firing. This vibration causes pounding on the bearings and general wear, besides general vibration in the installation.

Consider the crankshaft again where the crank throws are set 180° apart in an opposed engine. On this engine both pistons are on top dead center at the same time. On a two cylinder engine, in order to have the explosions occur at equal intervals, an explosion must occur every 360°. Considering the right hand cylinder as firing, the left hand cylinder is on top dead center at the end of the exhaust stroke, 360° from its firing point. In the next 360° travel, number two or the left hand cylinder will be firing and number one will be at the end of the exhaust stroke, just 360° from its firing point. An engine of this type is evenly balanced, because the explosions occur at equal intervals.

Consider the two cylinder vertical engine with both crank throws in the same plane. When number one is on top dead center, firing point, number two is also on top dead center, but at the end of the exhaust stroke. If number one is firing, then 360° later, crankshaft travel, number two will fire, number one will be at the end of the exhaust stroke. The explosions occur every 360°, or at equal intervals.

The two cylinder engine is used mostly on marine, tractor, or stationary work.

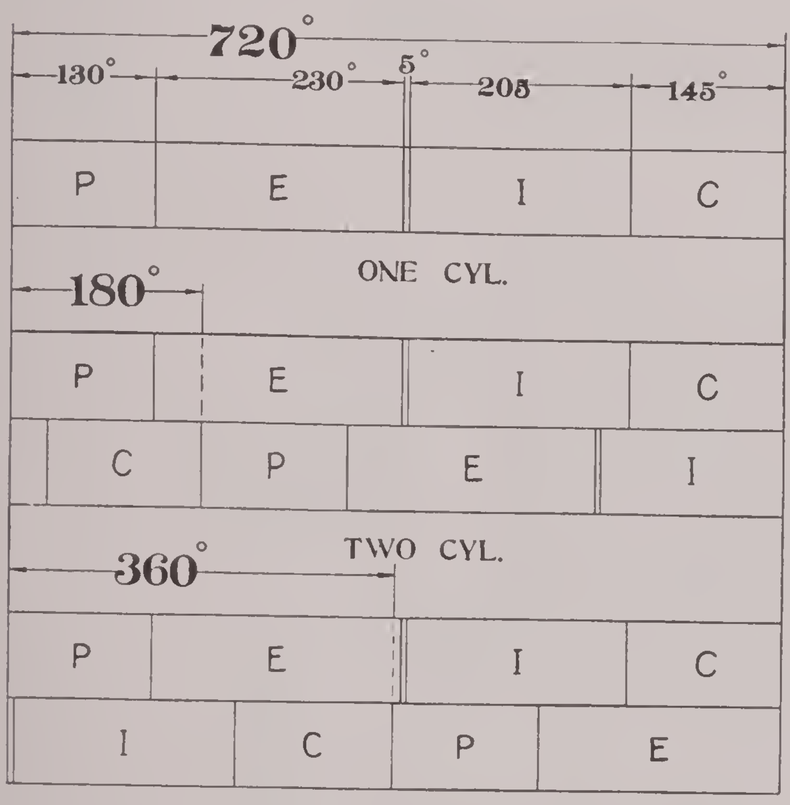
Timing Camshaft on Two Cylinder Engine

To time the camshaft on any multiple cylinder engine, it is only necessary to time the cams to one cylinder; the remaining cams are automatically timed as they are on the same camshaft. The shape of the crankshaft, the placing of cylinders and the way the camshaft is made determines the firing order.

For instance, consider the two cylinder engine with both crank throws on top dead center at the same time. Every 360° crankshaft travel an exhaust valve will open, but as the camshaft travel is one-half as fast as the crankshaft, the exhaust cams will be placed on the shaft 180° apart and the same with the inlet cams.

To time the camshaft on a two cylinder engine, adjust exhaust valve tappet to .004″ clearance, turn the flywheel until the indicator lines up with the "E. C." mark. The crank pins are now a few degrees past top dead center. Turn the camshaft in its direction of rotation until number one exhaust valve just closes, then mesh the gears and lock them in place.

If it is an L-head engine with the valves on the same side, the inlet will be timed. If it is a T-head engine, after timing the exhaust valve



POWER CHART

FIG. 34

it will be necessary to turn the crankshaft forward a few degrees, then turn the inlet camshaft in its direction of rotation until number one inlet valve just starts to open. Mesh the gears and lock in place. Number one is on the end of the exhaust stroke, starting on the intake, and number two will now be on the firing point, if the spark is fully retarded.

To set number one on the firing point for timing the ignition, crank the engine over until number one inlet valve just closes. Open the priming cup, place a wire on the head of the piston, then crank the engine over in its direction of rotation about three-eighths of a turn or until the wire reaches the highest point of its travel. Number one is now on the firing point in full retard.

Setting by Compression: Crank the engine over until compression is felt in number one cylinder. Place a wire on the top of the piston, crank it over until the piston reaches top dead center, and number one will be on the firing point, in full retard.

To Determine Which Cylinder Is Misfiring

The pet cock on the engine can be opened and the sound of the explosion heard or the flame can be seen. When the engine has no pet cocks, other methods must be used. The temperature of the spark plug when the engine is stopped may be used to determine this. Another method is, when the engine is running, take a screw driver, rest it on the cylinder and lean it over on the spark plug. This is what is termed shorting, or short circuiting the spark plug, giving a path of less resistance for the current than through the spark plug. Short circuiting a plug in a cylinder that is firing will slow down the speed of the engine. The engine will slow down and speed up as you move the screw driver back and forth onto a firing plug. When a plug is shorted in a cylinder that is not firing, it makes no difference in the running of the engine because that cylinder is dead.

THREE CYLINDER FOUR STROKE CYCLE ENGINES

The crank pins are spaced 120° apart. As the first cylinder that fires must be ready to fire again in the next 720° travel and it being necessary to have the explosions occur at equal intervals, the cylinders will fire every 240°, giving three power impulses every 720° crankshaft travel. This engine is used in marine work, but is no longer applied to automobiles.

FOUR CYLINDER FOUR STROKE CYCLE ENGINES

The crank pins are spaced 180° apart, having Nos. 1 and 4 crank pins in line and Nos. 2 and 3 in line, but 180° from Nos. 1-4. The number of main bearings on the crankshafts in the four cylinder engine varies. It may be either a two, three or five bearing crankshaft. All four cylinder crankshafts have the crank pins spaced exactly the same; the only differences are in the arrangement and number of main bearings. The less the number of main bearings, the more the crankshaft will spring and the heavier it must be.

A four cylinder engine of the T-head type has one exhaust camshaft and one inlet camshaft, each camshaft having four valve operating cams which are either forged integral with the shaft or keyed on. The four cylinder F, L or I-head engine has all the cams on one shaft, inlet cams being usually a different shape from the exhaust cams. On a four cylinder engine in order to have all four cylinders fire in two complete revolutions of the crankshaft and to have them occur at equal intervals they must fire every 180°. When all four cylinders have fired, number one must be ready to fire again. Firing every 180° crankshaft travel, and as the camshaft travels one-half as fast as the crankshaft, the exhaust cams are placed 90° apart, and the inlet cams are placed 90° apart. The order in which they open and close the valves will determine the firing order.

Consider a four cylinder engine, with Nos. 1-4 pistons on T. D. C.; either one of these two could be fired, depending on the position of the cams. Consider that No. 1 is firing. When No. 1 is firing, Nos. 2 and 3 are on bottom dead center, so the crankshaft will swing 180°, bringing Nos. 2-3 up, and the last closing of the inlet valve will determine which one of these two cylinders will fire next. Consider that No. 2 came up on the compression stroke. If No. 2 followed No. 1 on the compression stroke the firing order will start 1-2. The

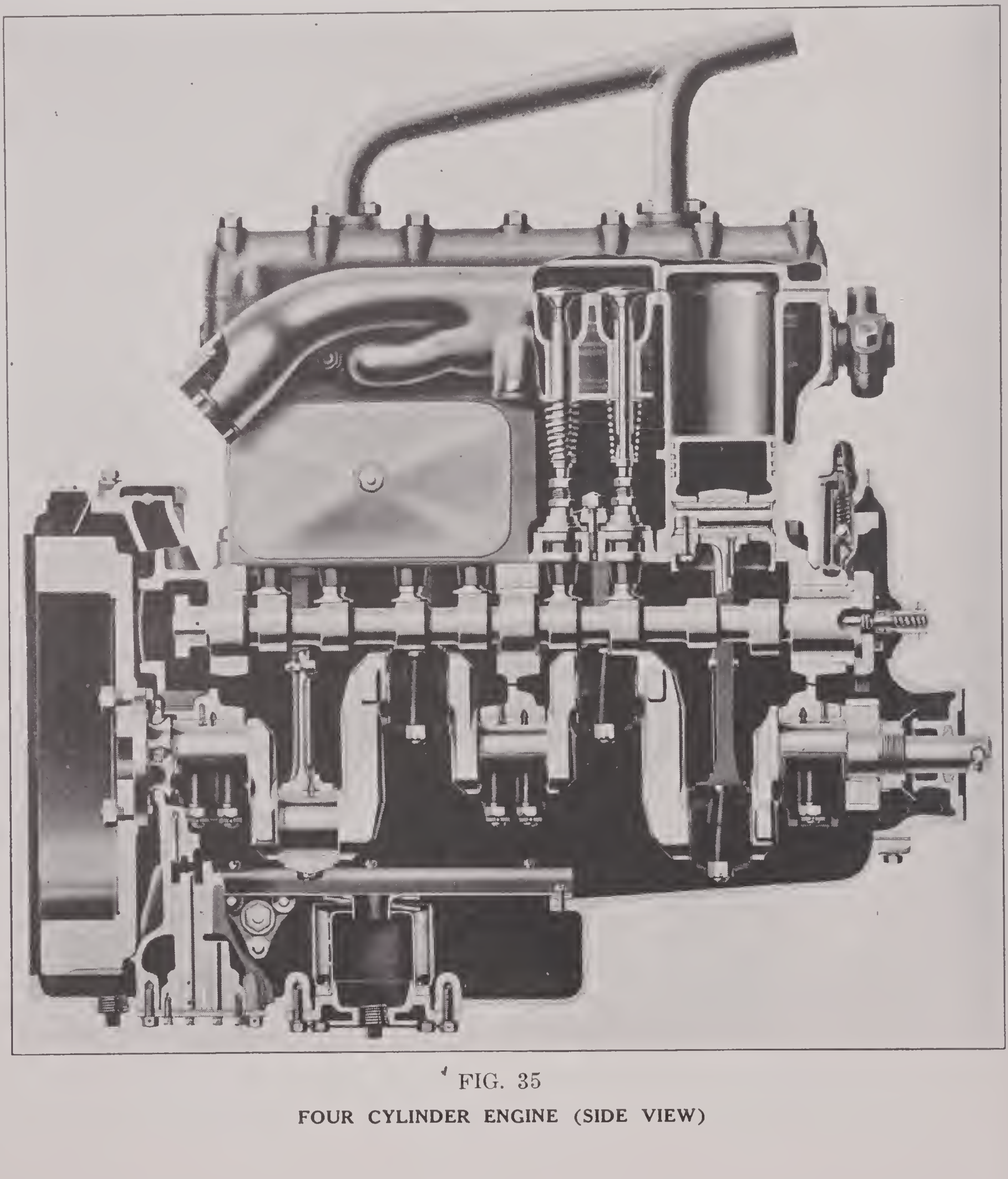


FIG. 35

FOUR CYLINDER ENGINE (SIDE VIEW)

crankshaft will swing another 180° having completed 360° of its travel, bringing Nos. 1-4 up on top dead center. The last time they were on top dead center, No. 1 fired and is now on the end of the exhaust stroke, so No. 4 fires. This gives a firing order thus far of 1-2-4. The crankshaft swings another 180°, bringing Nos. 2-3 up. The last time they were up, No. 2 fired and is now on the end of the exhaust stroke, so No. 3 fires. This gives a firing order of 1-2-4-3.

Again, consider Nos. 1-4 on T. D. C. and No. 1 firing. The crankshaft will turn 180°, bringing Nos. 2-3 up. If No. 3 came up on compression, it follows No. 1 in firing. Turn the crankshaft another 180° bringing Nos. 1-4 up, and as No. 1 fired the last time it will be on the end of exhaust stroke putting No. 4 on the firing point. Turn the crankshaft another 180°, bringing Nos. 2-3 up. No. 3 will be on the end of the exhaust stroke, putting No. 2 on the firing point. So the firing order will be 1-3-4-2. These are the two standard four cylinder firing orders: **1-2-4-3; 1-3-4-2.**

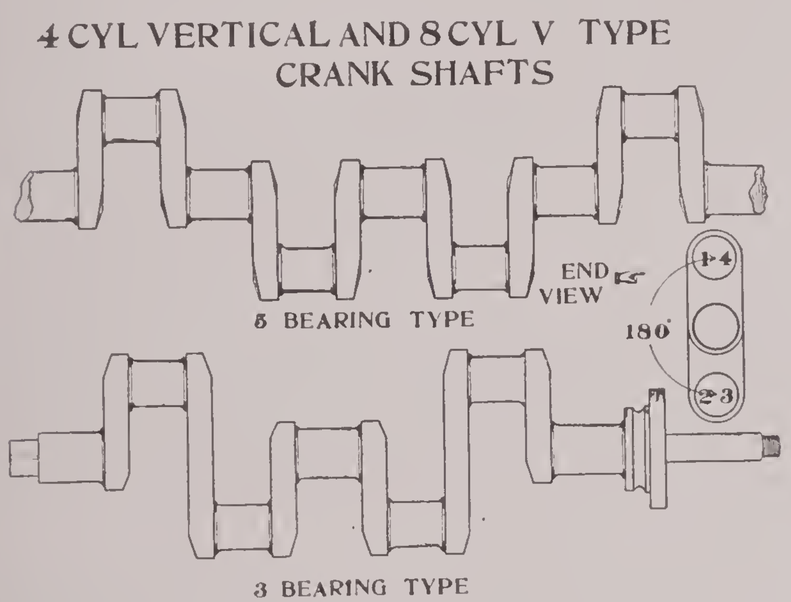


FIG. 36

One standard firing order has no advantage over the other, and considering either end of the engine as number one, it does not make any difference in the firing order. Either end could be considered number one. If it has a 1-2-4-3 firing order, it will be the same from both ends.

The standard method of numbering cylinders is from the cranking end.

Determining the Firing Order by the Movement of the Valves

Choose the inlet valves in No. 1 and No. 2 cylinders. Crank the engine over until No. 1 inlet valve just closes, then watch No. 2. If in the next half revolution of the flywheel, No. 2 inlet valve closes, the firing order is 1-2-4-3. If No. 2 does not follow No. 1, the firing order is 1-3-4-2. It is only necessary to watch the closing of the two inlet valves.

Either the openings or closings could be followed but as the closing of the inlet valves determine the compression and the firing it is easily remembered. To determine the firing order by compression, open No. 1 and No. 2 pet cocks, or remove the spark plugs from Nos. 1 and 2 cylinders; crank the engine over until compression is felt in No. 1 cylinder. Then place your hand over the opening in No. 2 cylinder and if compression is felt in No. 2 half a revolution or 180° after No. 1, the firing order is 1-2-4-3. But if No. 2 does not follow No. 1 on compression in the next 180°, the firing order is 1-3-4-2.

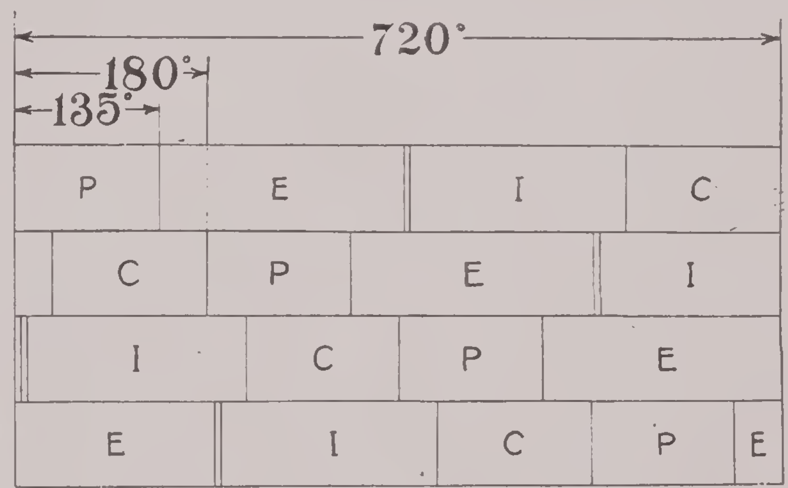


FIG. 37

FOUR CYLINDER POWER CHART

Timing Camshaft on T-Head Four Cylinder Engine

It is necessary to time to one cylinder only. Adjust No. 4 inlet and exhaust valves to .002″ and .004″ clearance respectively. Crank the engine over until the flywheel mark "E. C. 1-4" lines up with the indicator. Then turn the exhaust camshaft in its direction of rotation until No. 4 exhaust valve just closes, then mesh the gears and lock in place. Turn the flywheel a few degrees until the mark "I. O. 1-4" lines up with the indicator. Then turn the inlet camshaft in its direction of rotation until No. 4 inlet valve just starts to open. Mesh the gears and lock in place. No. 4 is now on the end of the exhaust stroke and the beginning of the intake, and No. 1 is approximately on the firing point. Care must be taken to turn the camshafts in their direction of rotation. If camshafts are driven from the crankshaft by a chain, the camshafts turn in the same direction as the crankshaft, but if driven by a gear, they turn in the opposite direction, excepting where there is an idler gear between the crankshaft and camshaft gears.

Timing Camshaft on L, I, or F-Head Engine

Adjust No. 4 exhaust valve to .004″ clearance. Crank the engine over until Nos. 1-4 crank throws are about 5° past top dead center, or the flywheel mark "E. C. 1-4" just lines up with the indicator, or until Nos. 1-4 pistons reach T. D. C. and just start down, not more than 1/32″. Turn the camshaft in its direction of rotation until No. 4 exhaust valve just closes, then mesh the gears and lock in place. This brings the other valves into time with their respective pistons. The inlet cams are placed on the same shaft and necessitate no other timing. No. 4 is now on the end of the exhaust stroke and the beginning of intake, which be on the firing point, with retarded spark.

Finding the firing order on the L-head engine is the same as on the T-head.

To set No. 1 on the firing point, crank the engine over until No. 4 exhaust valve just closes, which puts No. 1 at the beginning of the power stroke. Another method is to crank the engine over until No. 1 inlet valve closes, then open the pet cock and put a wire down on the head of the piston and turn the engine over until No. 1 reaches T. D. C. It will then be on the firing point, with retarded spark.

To determine which cylinder is misfiring when the engine is running, it can be tested by the pet cock, or the screw driver method (grounding or shorting out spark plugs). If, when one is shorted, a difference in the running of the engine is noticed, a plug has been shorted in a live cylinder, but when there is no difference in the running of the engine, a plug has been shorted in a cylinder that was not firing.

SIX CYLINDER ENGINE CRANKSHAFTS

A six cylinder crankshaft may have either three, five or seven main bearings. The more bearings there are the more rigidly the crankshaft is held, the less wearing of the bearings and the less danger of breaking. The crankshaft is so constructed that Nos. 1 and 6 crank pins are in line, Nos. 2 and 5 are in line, and Nos. 3 and 4 are in line. These three groups of crank pins are spaced exactly 120° apart. When No. 1 piston is on top dead center, No. 6 will be in the same position, then Nos. 2 and 5 come up together, followed by Nos. 3 and 4. Turning the crankshaft in one direction of rotation, it is noticeable that after Nos. 1-6 have moved up, Nos. 2-5 will follow, then Nos. 3-4. Turn the crankshaft end for end and turn it in the same direction of rotation as before, then when Nos. 1-6 move up, Nos. 3-4 will follow, then Nos. 2-5. When the crankshaft is made with Nos. 2-5 following Nos. 1-6, it is called a right hand crankshaft. When Nos. 3-4 follow Nos. 1-6, it is called a left hand crankshaft. This will make a difference in the firing order, as well as the order in which the cams are placed on the camshaft.

All six cylinders must fire in two revolutions of the crankshaft, so that after the first cylinder has fired and made two complete revolutions it is ready to fire again. The explosions should occur at equal intervals, or as close to it as possible to reduce vibration, so to have all six explosions occur in two revolutions, they should occur 120° apart.

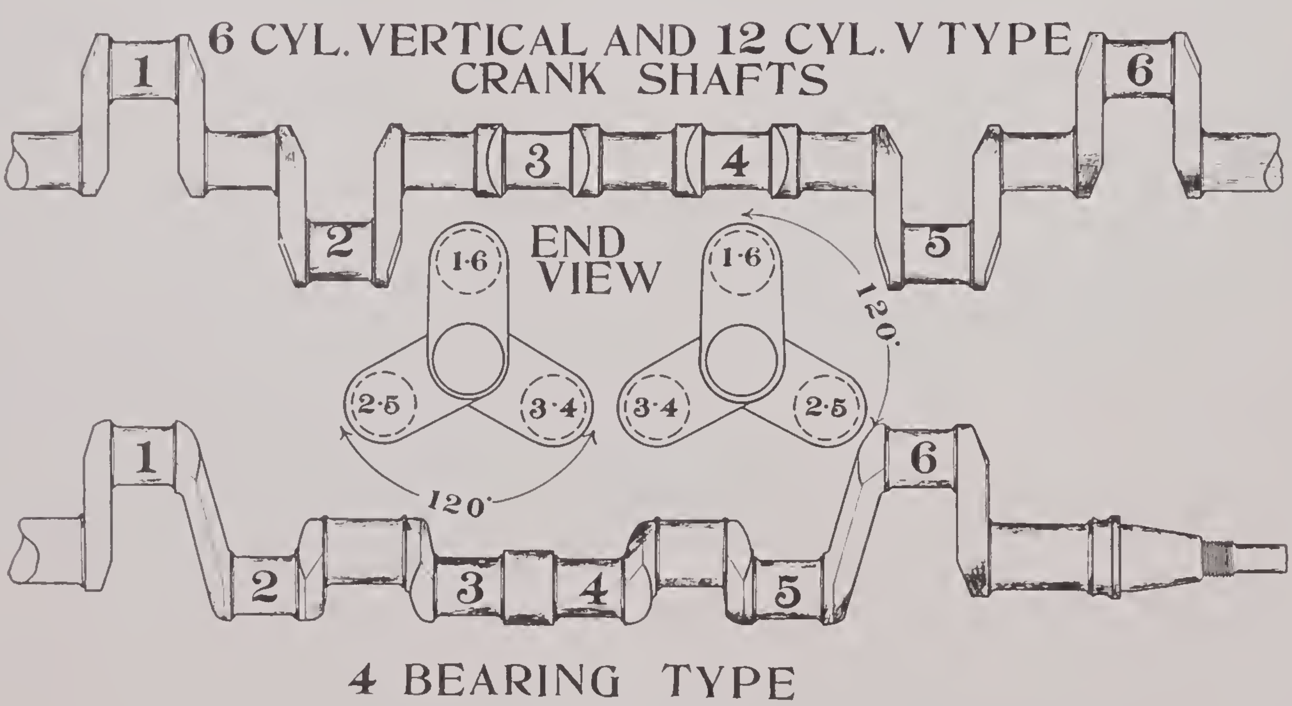


FIG. 38

Six Cylinder Firing Orders

There are eight possible firing orders for the six cylinder engine, but engineers have eliminated six and have kept the two best firing orders from a vibration, balance and carburetion standpoint. The two standard firing orders are:

1-5-3-6-2-4

1-4-2-6-3-5

The other six possible firing orders for the six cylinder engine are:

1-4-5-6-3-2

1-3-5-6-4-2

1-3-2-6-4-5

1-5-4-6-2-3

1-2-4-6-5-3

1-2-3-6-5-4

In the six cylinder firing orders not standard, two pistons on one end of the engine follow one another in firing, and on some engines with certain type inlet manifolds it will cause enrichening of the mixture, through having on one end, two explosions 120° apart and then an interval of 360°, while with the two standard firing orders, if a divided inlet manifold is used, with one branch leading to each end of the engine, there will be a suction in each direction every 240°.

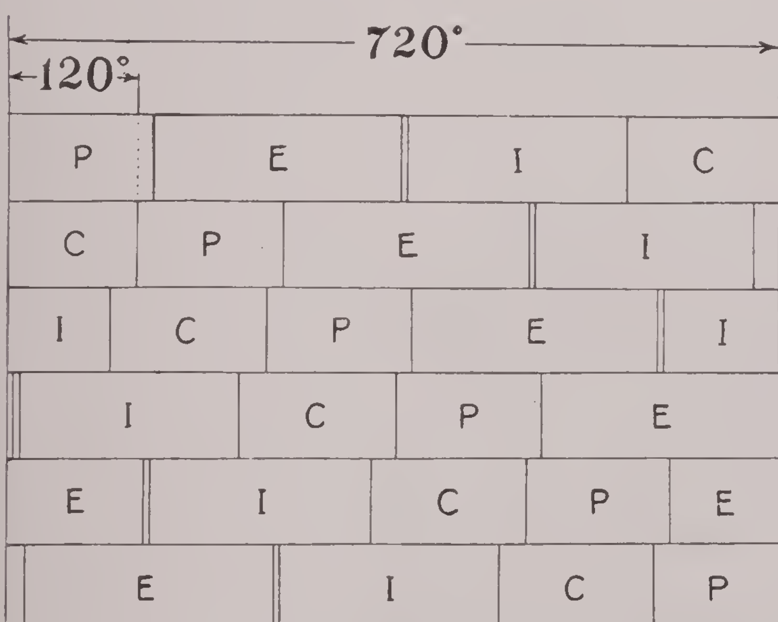


FIG. 39

SIX CYLINDER POWER CHART

Standard Six Cylinder Firing Orders

Consider Nos. 1-6 on T. D. C., with Nos. 2-5 following. No. 1 will fire and No. 6 is on the end of the exhaust stroke. The crankshaft turns 120°, bringing Nos. 2-5 up, and No. 5 will fire. The crankshaft turns another 120°, bringing Nos. 3-4 up. No. 3 being on the front of the center line of the engine, should fire next. When No. 3 is firing, No. 4 is on top dead center at the end of the exhaust stroke. Firing order thus far is 1-5-3. Crankshaft swings another 120°, bringing Nos. 1-6 up again. As No. 1 fired last time, No. 6 will fire this time. In another 120° Nos. 2-5 are up. No. 5 fired last time, so No. 2 will fire this time. In the next 120°, Nos. 3-4 are up. No. 3 fired last time, so No. 4 will fire this time. The firing order is:

1-5-3-6-2-4

This gives an explosion every 120°. The cams must be arranged in the same order. No. 5 exhaust cam follows No. 1, and as the camshaft revolves one-half as fast as the crankshaft and the explosions are 120° apart crankshaft travel, Nos. 1-5 exhaust cams are 60° apart, then No. 3 is 60° from No. 5. The shape of the crankshaft on the six cylinder engine determines the opening and closing of the valves and the firing order.

To find the firing order of a 6 cylinder engine, if it is not known, first select the inlet

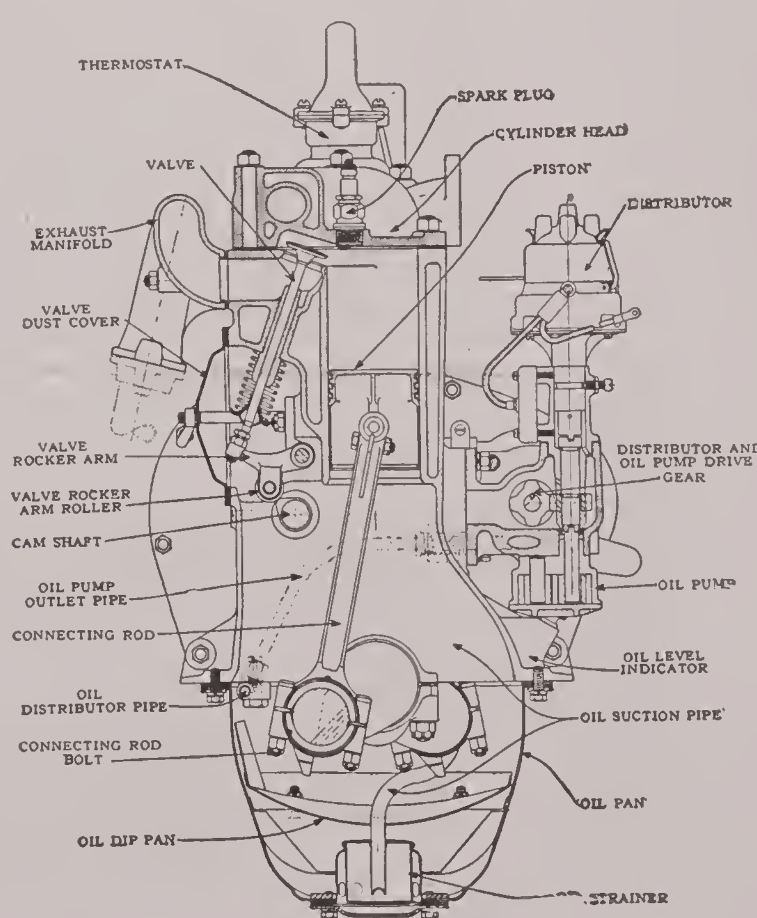


FIG. 40

SECTIONAL END VIEW, SIX CYLINDER L-HEAD ENGINE

valves in Nos. 1-4 cylinders, then crank the engine over until No. 1 inlet valve closes, and if No. 4 inlet valve closes 120° or 1/3 revolution later, the firing order is 1-4-2-6-3-5. If No. 4 inlet valve does not close 120° after No. 1, the firing order is 1-5-3-6-2-4. Or, if compression is felt in No. 4 120° after it is felt in No. 1, the firing order is 1-4-2-6-3-5. If not, the firing order is 1-5-3-6-2-4. Or, crank the engine over until No. 1 piston reaches T. D. C. If No. 2 piston moves to T. D. C. 120° later, the firing order is 1-5-3-6-2-4. If not, it is 1-4-2-6-3-5.

Timing Camshafts on Six Cylinder T-Head Engines

Adjust No. 6 exhaust valve to .004″ clearance and No. 6 inlet valve to .002″ clearance. Crank the engine over until the flywheel mark "E. C. 1-6" lines up with the indicator, assuming that the flywheel is fastened onto the crankshaft correctly, then turn the exhaust camshaft in its direction of rotation until No. 6 exhaust valve just closes. Mesh the gears and lock in place. Turn the flywheel a few degrees until the mark "I. O. 1-6" lines up with the indicator. Turn the inlet camshaft in its direction of rotation until No. 6 inlet valve just starts to open, then mesh the gears and lock in place. No. 6 is now on the end of the exhaust stroke and beginning the intake; No. 1 is on the firing point. Or, crank the engine over until Nos. 1-6 pistons reach T. D. C. and move down not more than 1/32″. Turn the exhaust camshaft in its direction of rotation until No. 6 exhaust valve just closes. Mesh the gears and lock. Turn the flywheel a few degrees in its direction of rotation, then turn the inlet camshaft in its direction of rotation until No. 6 inlet valve just starts to open. Mesh the gears and lock in place.

To put No. 1 on the firing point on the six cylinder engine, crank the engine over until No. 6 exhaust valve just closes. Then No. 1 will be just a few degrees past T. D. C. on the firing point. No. 1 can be set on the firing point, by observing the inlet valve closing, then by placing a wire on the head of the piston and cranking the engine over until the piston reaches T. D. C. or the wire reaches the highest point of its travel, or until the flywheel mark "1-6 D. C." lines up with the indicator.

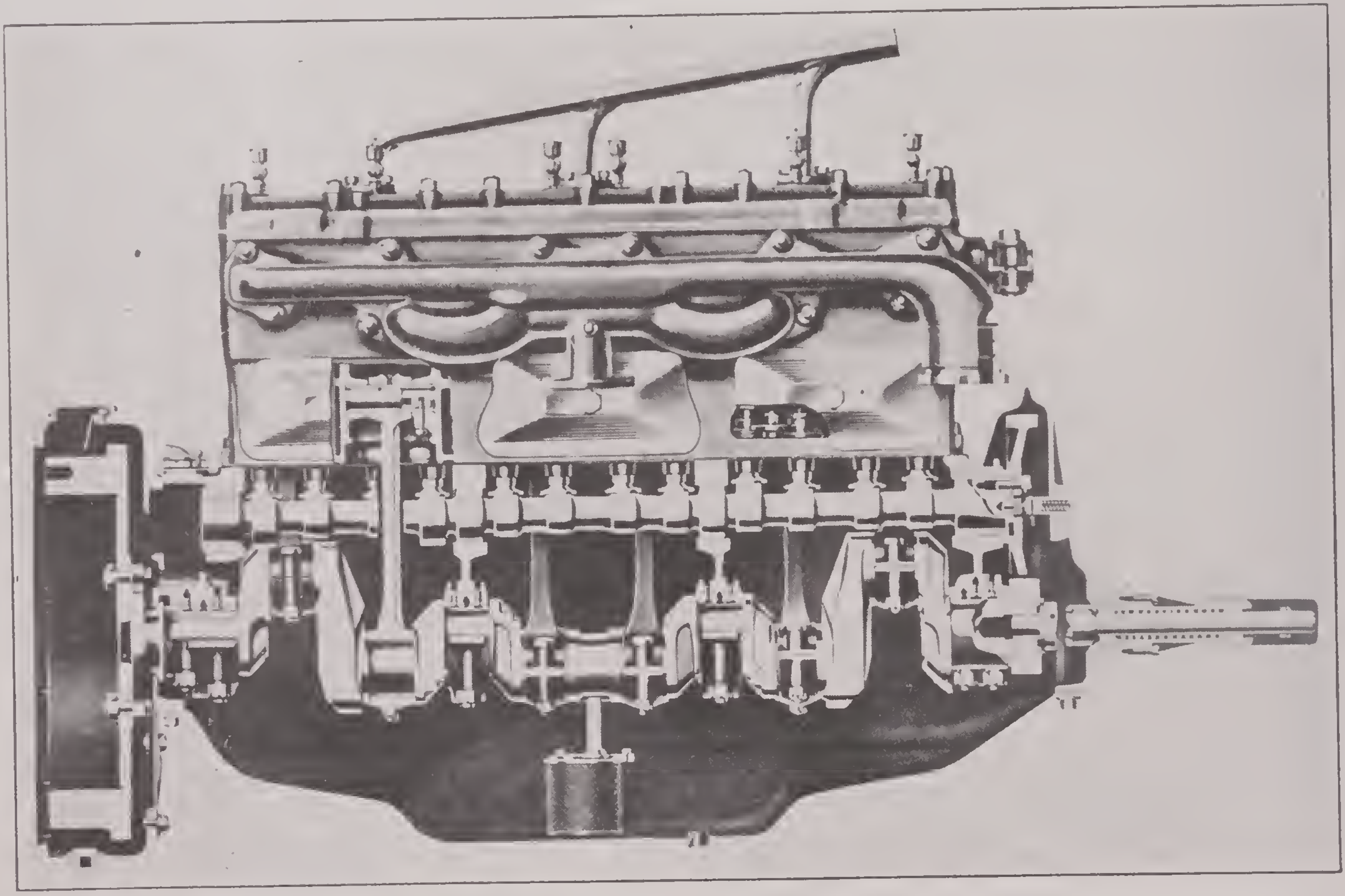


FIG. 41

CUT OPEN SIDE VIEW OF L-HEAD ENGINE

Timing Camshaft on Six Cylinder L, I or F-Head Engines

Adjust No. 6 exhaust valve to .004″ clearance. Crank the engine over until the flywheel mark "1-6 E. C." lines up with the indicator. or until Nos. 1-6 pistons reach T. D. C. and move down not more than 1/32″. Turn the camshaft in its direction of rotation until No. 6 exhaust valve just closes, then mesh the gears and lock.

The firing order can be found the same on this type of engine as on the T-head engine, by watching either the opening or closing of the valves. To set No. 1 on the firing point: After the inlet valve in No. 1 seats, bring the piston to T. D. C., or bring the flywheel mark "1-6 D. C." in line with the indicator. By watching the inlet valve on No. 1 until it closes, it is positive that No. 1 is just going up on compression, so that when the flywheel mark "1-6 D. C." lines up with the indicator, No. 6 is on the end of the exhaust stroke and No. 1 is on the end of the compression stroke just ready to fire.

EIGHT CYLINDER V TYPE ENGINE CRANKSHAFT

The crankshaft used in the eight cylinder V type engine is of the same design as in the four cylinder, with the crank throws set 180°

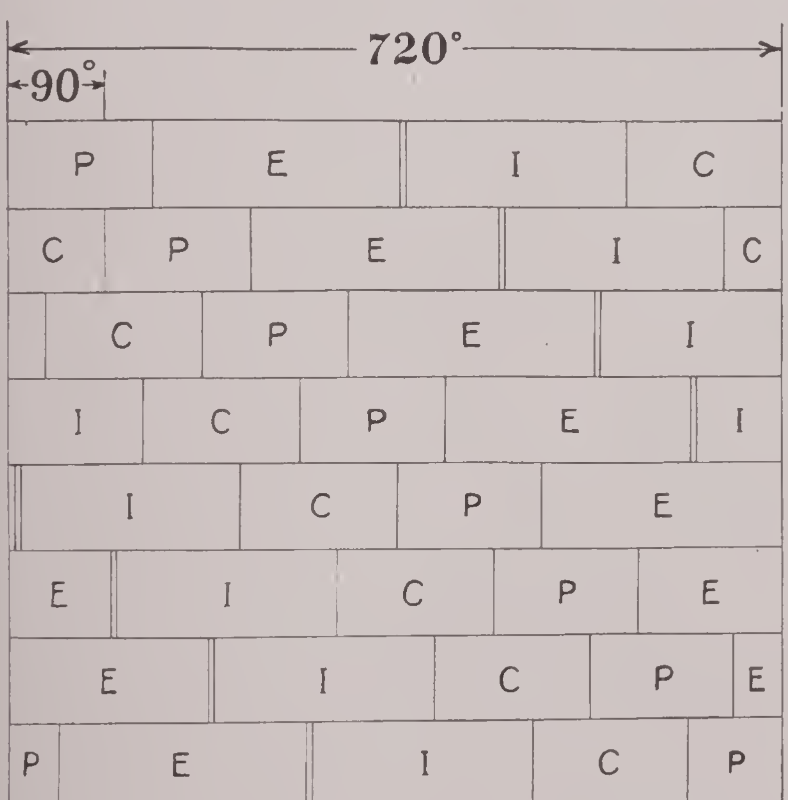


FIG. 42

EIGHT CYLINDER POWER CHART

apart. There are only four crank throws on this crankshaft, Nos. 1-4 are in line, as are also Nos. 2-3. On eight cylinder engines all eight explosions occur in two revolutions of the crankshaft, thus the explosions are 90° apart, for even firing. There are some engines made that do not fire every 90°. This may cause increased vibration at low speed, depending upon the number of degrees that the explosions vary from 90°. The cylinders are arranged in V shape, that is, four cylinders on each side, the V being at an angle of 90°, which brings a crank throw up every 90°, first in the right hand block and then in the left hand block. No. 1 cylinder is at the cranking end. The right cylinder block is on the right side and the left cylinder block is on the left side when viewed from the operator's seat. In no V type engines do two cylinders fire in the same block in succession. It fires first in one block and then in the other block. Consider the crankshaft turning over from the right hand block to the left hand block. There will be a cylinder firing in the left hand block every 180°, crankshaft travel, likewise in the right hand block. Thus when the explosions alternate from one to the other, they occur at 90° intervals. If the ignition was cut off on either the right or left hand block, the engine would run as a four cylinder engine, firing every 180°. There are four eight cylinder firing orders, any one of which may be used on V type engines.

Consider Nos. 1R-4R as being up on top dead center. 1R fires, and the crankshaft swinging 90° brings 1L and 4L on T. D. C. Either one could be fired, but to prevent excessive vibration of the engine, it is preferable to fire them diagonally across to the opposite end. That would bring 4L on the firing point; the firing order thus far is 1R-4L. Then the crankshaft swings 90° farther, bringing 2R and 3R up. Either of the four cylinder firing orders may be employed, 1-2-4-3 or 1-3-4-2, so consider 2R to fire next. Crankshaft swings another 90° and brings 2L and 3L on top. The second one from the rear fires as 4L fired first, that will make 3L fire after 2R. Then the crankshaft swings another 90°, 1R and 4R are on T. D. C. the second time, and as 1R fired the last time 4R fires this time. The crankshaft swings another 90° and 1L and 4L are on T. D. C., and as 4L fired the last time 1L must fire now. Another 90° brings 2R and 3R up. 3R is on the firing point as 2R fired the last time, and is now on the exhaust stroke. The crankshaft travels another 90° and 2L and 3L are on top. 2L is on the firing point, because 3L is just finishing up the exhaust stroke. This gives a firing order of:

1R-4L-2R-3L-4R-1L-3R-2L

The other eight cylinder firing orders are, as follows:

1R-4L-3R-2L-4R-1L-2R-3L
1R-1L-2R-2L-4R-4L-3R-3L
1R-1L-3R-3L-4R-4L-2R-2L

The last two are seldom used in automobile engines, but are used in some aircraft engines. They have a tendency to cause more or less vibration. By firing from one end of the engine to the other prevents the swaying vibration.

To Find the Firing Order

To find the firing order of an eight cylinder V type engine by observing the closing of the inlet valves, first watch 1R inlet valve close, then in the next 90° crankshaft travel, 4L inlet valve should close. If it does not 1L will follow 1R. Consider that 4L does follow 1R. Then in the next 90° crankshaft travel 2R inlet should close. If it does, the firing order will begin 1R-4L-2R, but if 2R does not follow 4L, 3R will, and the firing order begins 1R-4L-3R. It is only necessary on the eight cylinder V type engine to determine the first three valve closings, because the second one determines whether the engine fires directly across or diagonally. The third one determines whether it has a 1-2 firing order, or a 1-3 firing order.

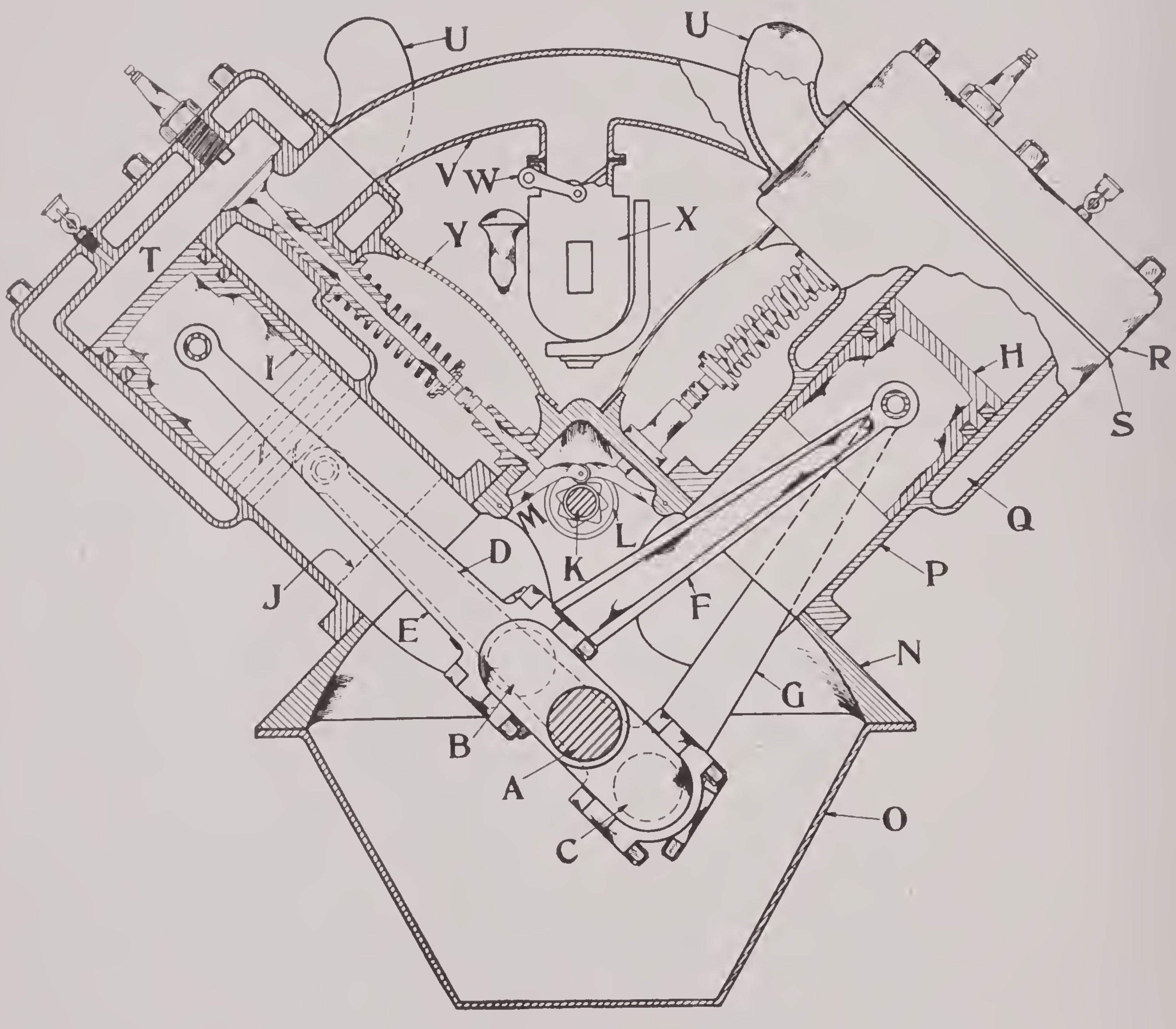


FIG. 43

EIGHT CYLINDER V TYPE ENGINE

A. Crankshaft main bearing.
B. 1-4 Crank pins.
C. 2-3 Crank pins.
D. 2-3 R. Connecting rods.
E. 1-4 R. Connecting rods.
F. 1-4 L. Connecting rods.
G. 2-3 L. Connecting rods.
H. 1-2-3-4 L. Pistons.
I. 1-4 R. Pistons.
J. 2-3 R. Pistons.
K. Camshaft.
L. Camshaft bearing.
M. Rocker arm.
N. Crankcase.
O. Oil pan.
P. Cylinder.
Q. Water jacket.
R. Cylinder head.
S. Cylinder head gasket.
T. Combustion chamber.
U. Exhaust manifold.
V. Inlet manifold.
W. Throttle arm.
X. Carburetor.
Y. Valve cover plate.

The firing order can also be found by the compression method and as it is understood that the closing of the inlet valve determines the compression stroke, either method can be used. The compression method is necessary though on the sleeve valve engines since the valves cannot be seen.

Timing Camshaft on Eight Cylinder V Type Engines

Adjust No. 4R exhaust valve to .004″ clearance. Crank the engine over until the flywheel mark "E. C. 1R-4R," lines up with the indicator, or until 1R-4R pistons reach T. D. C. and move down not more than 1/32″. Turn the camshaft in its direction of rotation until No. 4R exhaust valve just seats. No. 1R is on the firing point. No. 1R can be put on the firing point also by watching for the closing of the inlet valve, then crank the engine over until the flywheel mark "D. C. 1R-4R" lines up with the indicator. As the explosions occur 90° apart, the camshaft traveling one-half crankshaft speed, the exhaust cams are spaced 45° apart, and the inlet cams the same, thus opening the valves 45° apart camshaft travel or 90° apart crankshaft travel.

Some eight cylinder V type engines have sixteen cams, or one inlet cam for each inlet valve, and one exhaust cam for each exhaust valve, while some are built with the camshaft having only eight cams, four exhaust and four inlet. In the latter type, each cam operates a valve on both the right and left hand blocks, necessitating a special rocker arm arrangement in the crankcase. (See Fig. 45.)

To Test for a Misfiring Cylinder

On eight or twelve cylinder V type engines, it is necessary to cut off one block entirely to test for misfiring. Then find the misfiring cylinder by the screw driver method. If upon cutting off one block it is noticed that the block that is running is firing in all four cylinders, disconnect this one and connect the other, trying each cylinder separately to find which one

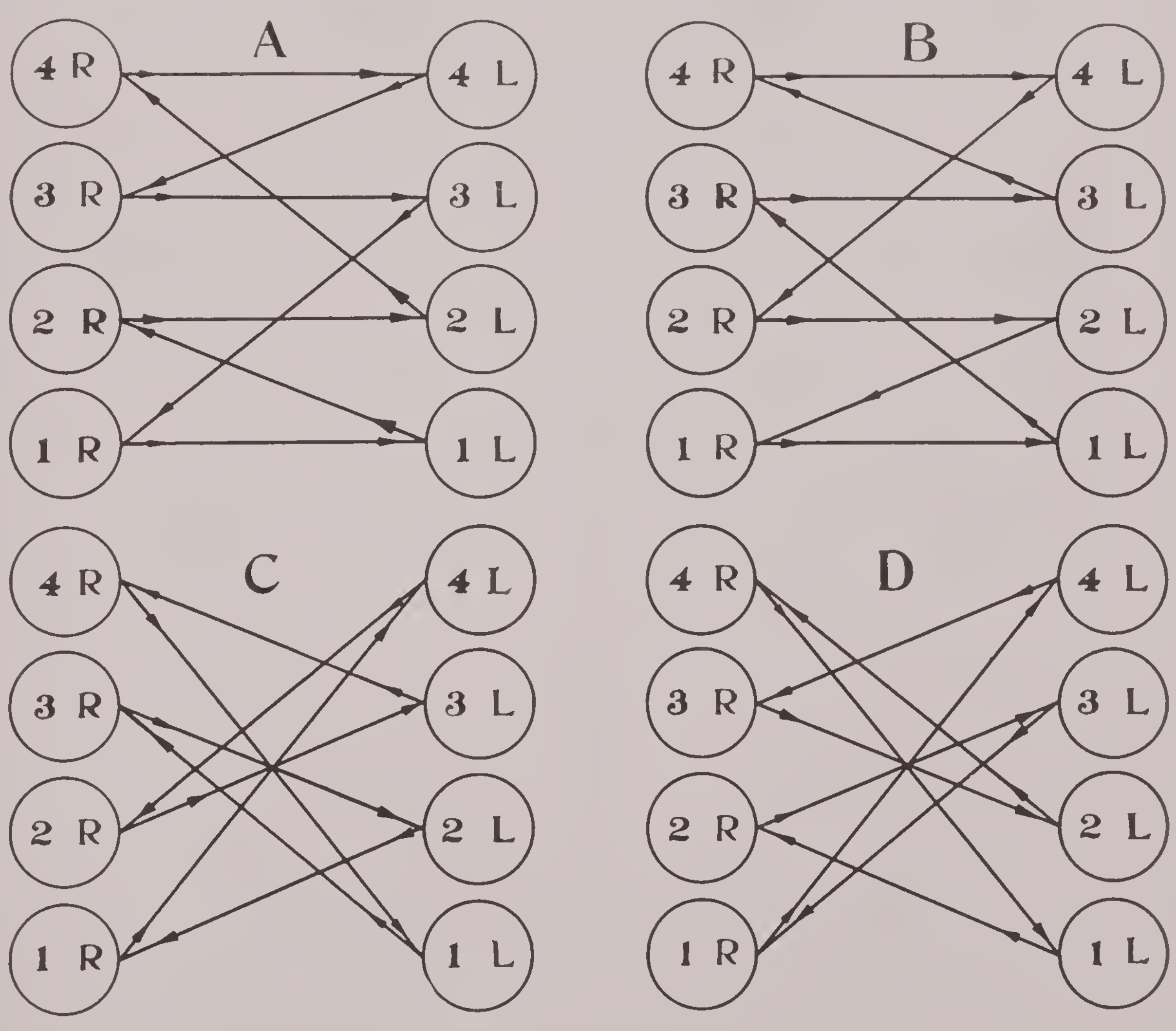


FIG. 44

EIGHT CYLINDER V TYPE ENGINE

FIRING ORDERS

A. 1R—1L—2R—2L—4R—4L—3R—3L.
B. 1R—1L—3R—3L—4R—4L—2R—2L.
C. 1R—4L—2R—3L—4R—1L—3R—2L.
D. 1R—4L—3R—2L—4R—1L—2R—3L.

is misfiring. This is necessary because of the short lap between the explosions.

EIGHT CYLINDER VERTICAL ENGINE

In the eight cylinder vertical engine the cylinders are set in line, and its principles of operation are the same as if there were two four cylinder engines placed together end to end, with the crankshafts coupled so that the throws form right angles, or in such a manner that 90° after Nos. 1-4 reach T. D. C. in one half of the engine Nos. 1-4 in the other half of the engine will be on T. D. C. The same standard four cylinder firing order is used in each half of the engine with the explosions alternating from one end to the other.

In the eight cylinder vertical engines, the cylinders are numbered 1-2-3-, etc., from the cranking end, the same as in the other vertical engines. The crank throws are set 90° apart so that every 90° two pistons will reach T. D. C. This gives an explosion every 90°, with all cylinders firing in 720°. Nos. 1-4 pistons move together, also Nos. 2-3, the same as in a four cylinder engine. Nos. 5-8 move together and Nos. 6-7.

Firing Orders

The two most probable firing orders are:

1-5-2-6-4-8-3-7
1-5-3-7-4-8-2-6

To find the firing order, watch the order of valve closings, or the order of compression.

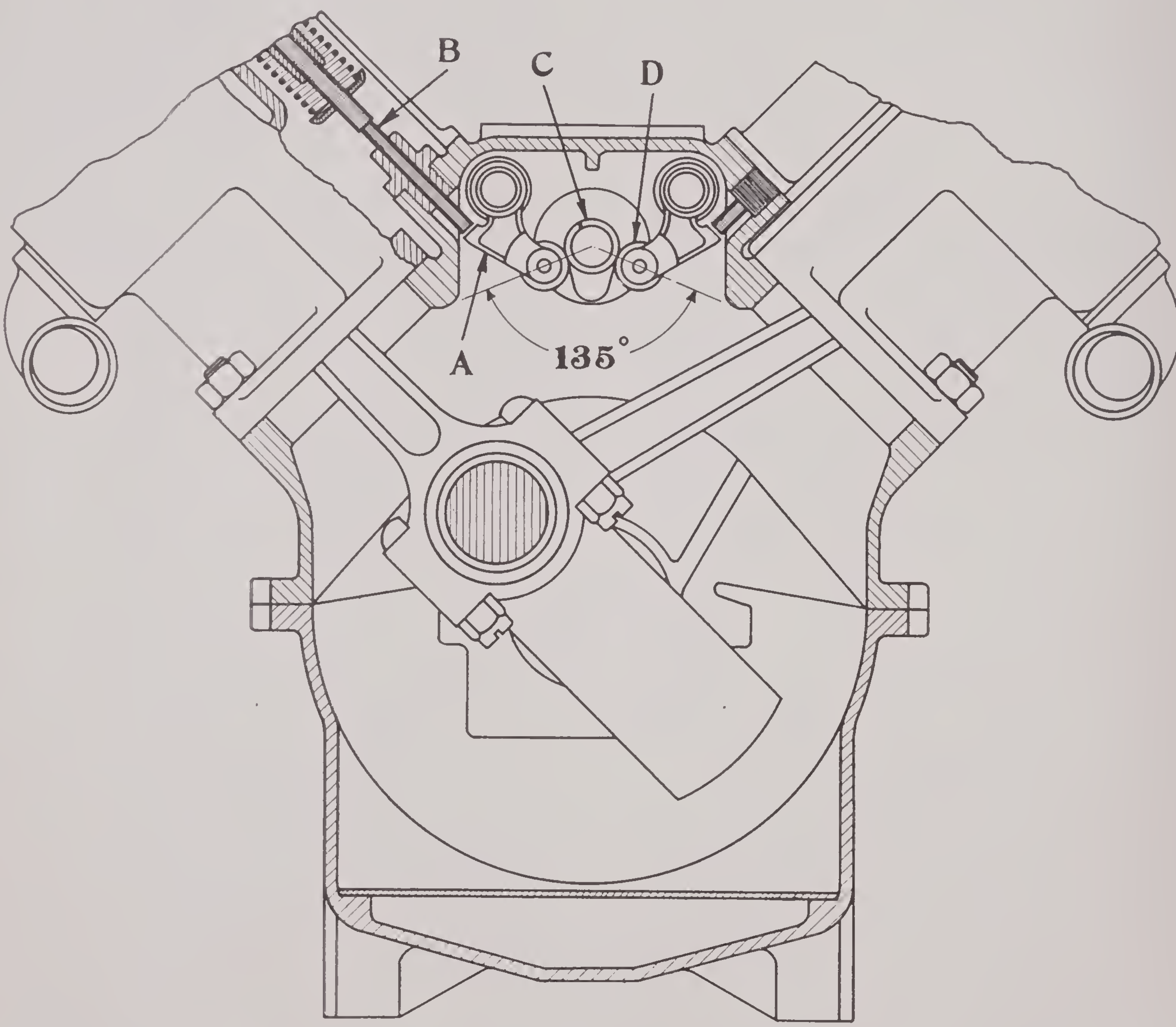


FIG. 45

ROCKER ARM ARRANGEMENT, EIGHT CYLINDER V TYPE ENGINE WITH EIGHT CAMS

A. Rocker arm.
B. Tappet.
C. Camshaft.
D. Roller.

Timing

In timing the valves, use the same method as in any other engine. Crank the engine over until the flywheel mark "E. C. 1-4" lines up with the indicator, or until Nos. 1-4 pistons reach T. D. C. and move down not more than 1/32″. Turn the camshaft in its direction of rotation until No. 4 exhaust valve just closes. Mesh the gears and lock in place.

TWELVE CYLINDER V TYPE ENGINE

The crankshaft used in this engine is the same as the six cylinder crankshaft, excepting that the crank pin bearings are somewhat longer. There may be either a three, five or seven bearing crankshaft in the twelve cylinder engine, depending upon the design of the engine. In the twelve cylinder engine, all twelve cylinders must fire in two revolutions,

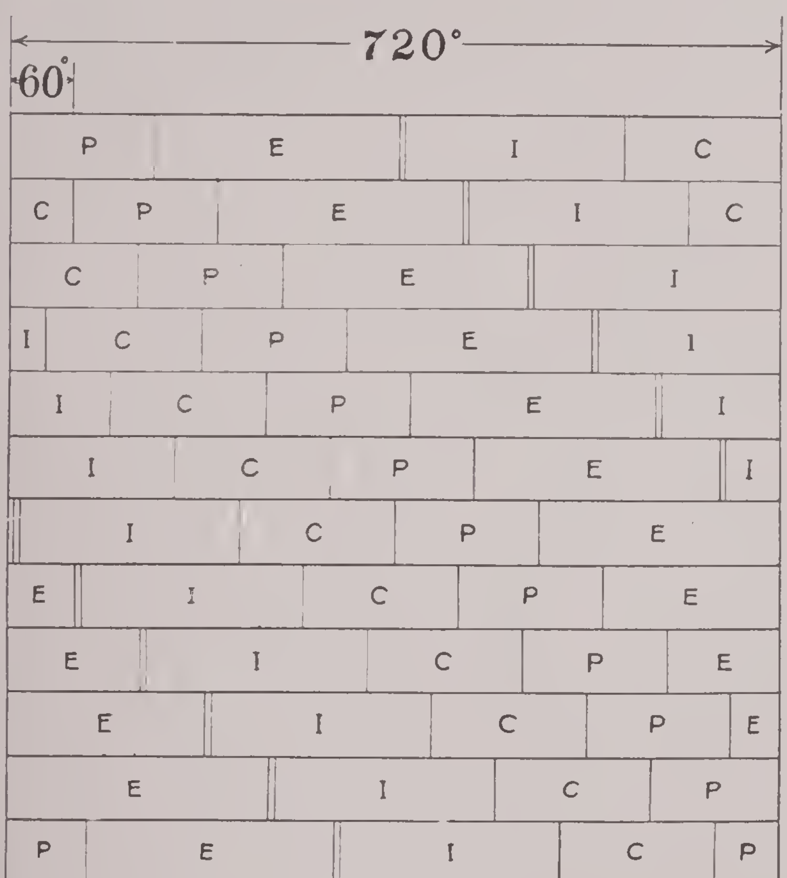


FIG. 46

TWELVE CYLINDER POWER CHART

so to have the explosions occur at equal intervals it is necessary to have one explosion every 60° crankshaft travel. On the V type engine where the explosions occur every 60°, the cylinders are placed at an angle of 60° on the crankcase, but there are some twelve cylinder engines that do not fire every 60°. For instance, the Liberty aircraft engine fires at unequal intervals of 75° and 45°. On this engine the cylinders are placed at an angle of 45°. As in the eight cylinder V type engine, where the four cylinder firing order is used in each block, the twelve cylinder engine using a six cylinder crankshaft has a standard six cylinder firing order in each block. The twelve cylinder V type engine fires either diagonally or directly across. The firing orders are:

1R-6L-4R-3L-2R-5L-6R-1L-3R-4L-5R-2L
1R-6L-5R-2L-3R-4L-6R-1L-2R-5L-4R-3L
1R-1L-4R-4L-2R-2L-6R-6L-3R-3L-5R-5L
1R-1L-5R-5L-3R-3L-6R-6L-2R-2L-4R-4L

The last two firing orders fire from the right to the left hand block directly across. This is seldom if ever found. In the first firing order given, when No. 1R is on T. D. C., No. 6R is on T. D. C. at the same time, so when No. 1R fires, No. 6R will be on the end of the exhaust stroke. Then the crankshaft swings over and brings No. 1L and No. 6L on T. D. C., so it can fire either directly across from No. 1R or diagonally, the latter of which is the most preferable. So No. 6L will follow No. 1R. Then in the next 60°, Nos. 3R and 4R will move up on T. D. C. No. 4R fires, then in the next 60°, Nos. 3L-4L reach T. D. C. and No. 3L will fire. Then in the next 60°, Nos. 2R-5R reaches T. D. C., so No. 2R will fire next. Swing the crankshaft another 60° and that will bring Nos. 2L-5L up, and No. 5L will fire next. In the next 60° Nos. 1R-6R are up, and as No. 1-R fired the last time, No. 6R must fire. Then in another 60° No. 1L-6L are up. No. 6L fired the last time, so No. 1L must fire. The next 60° of crankshaft travel brings Nos. 3R-4R up, and No. 4R having fired the last time, No. 3R will fire this time. In the next 60° Nos. 3L-4L reach T. D. C., and as No. 3L fired last time, No. 4L will fire. In another 60° Nos. 2R-5R will reach T. D. C., and No. 2R firing last time, No. 5R will fire. Swing the shaft another 60° and Nos. 2L-5L will reach T. D. C. As No. 5L fired last, No. 2L will fire this time. This will give the firing order:

1R-6L-4R-3L-2R-5L-6R-1L-3R-4L-5R-2L

Timing Camshaft on Twelve Cylinder Sixty Degree V Type Engine

Adjust No. 6R exhaust valve to .004″ clearance. Crank the engine over until flywheel mark "E. C. 1R-6R" lines up with the indicator, or until Nos. 1R-6R pistons reach T. D. C. and move down not more than 1/32″. Turn the camshaft over in its direction of rotation until No. 6R exhaust valve just closes. Then mesh the gears or chain and lock in place. No. 1R is now on firing point retard. No. 1R can be set on the firing point by watching No. 1R inlet valve close and then bring the piston to T. D. C. or the flywheel mark "1R-6R T. D. C." in line with the indicator.

To Find Firing Order of Twelve Cylinder V Type Engine

Crank the engine over until No. 1R inlet valve just closes. Then No. 6L inlet valve should close next, and if it does the firing order is diagonal, but if it does not, the firing order is directly across. Then in the next 60° of crankshaft travel No. 4R should close and if it does the firing order starts 1R-6L-4R, but if No. 4R does not follow No. 6L, the firing order is 1R-6L-5R, the same as in the six cylinder firing order.

Crank the engine over until No. 1R piston reaches T. D. C. If No. 2R piston moves to T. D. C. 120° or 1/3 revolution later, the firing order starts 1R-6L-5R. If No. 2R does not reach T. D. C. 120° after No. 1R, the firing order starts 1R-6L-4R.

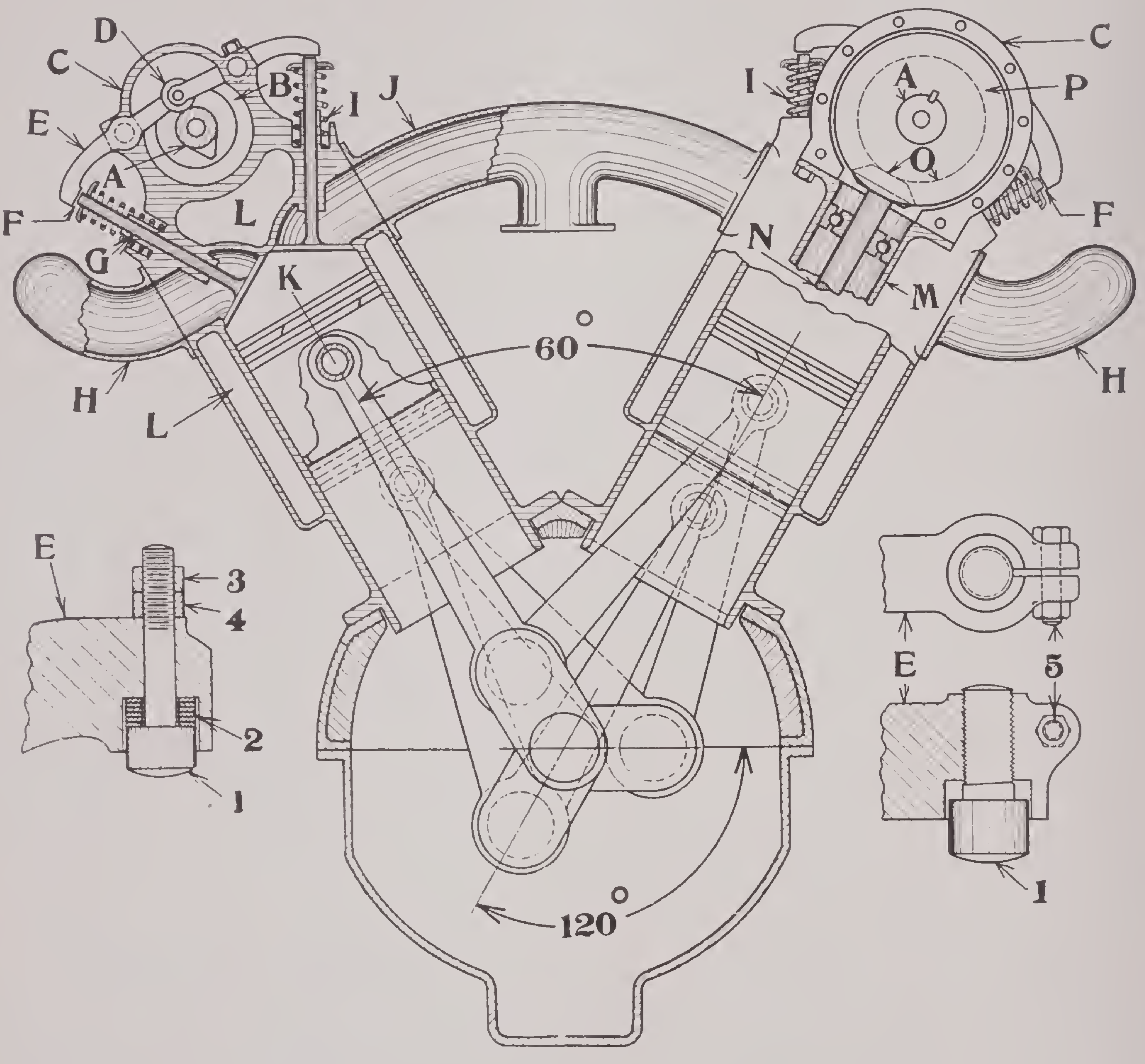


FIG. 47

TWELVE CYLINDER V TYPE ENGINE

A. Camshaft.
B. Camshaft bearing.
C. Camshaft housing.
D. Roller.
E. Rocker arm.
F. Clearance.
G. Valve stem guide.
H. Exhaust manifold.
I. Valve spring.
J. Inlet manifold.
K. Combustion chamber.
L. Water jacket.
M. Vertical shaft housing.
N. Vertical shaft.
O. Bevel drive gears.
P. Bevel driven gear.
1. Clearance adjusting screw.
2. Spacing shims.
3. Jam nut.
4. Lock nut.
5. Clamping bolt.

To Find Which Cylinder Is Misfiring

Cut off the ignition on one block, then short out the plugs one at a time until the cylinder that is misfiring is located. In shorting out a plug in a cylinder that is dead it will make no difference in the running of the engine, while if a plug is shorted in a cylinder that is firing it slows down the engine.

Timing Camshaft on Twelve Cylinder Sixty Degree V Type Engine Overhead Camshafts

To time the camshafts on engines using two overhead camshafts, crank the engine over until the flywheel mark "E. C. 1R-6R" lines up with the indicator. Have 6R and 1L exhaust valves adjusted to .004″ clearance. Turn the right hand camshaft in its direction of rotation, until No. 6R exhaust valve just closes, mesh the gears and lock in place. Turn the flywheel over in its direction of rotation about 60° or until flywheel mark "E. C. 1L-6L" lines up with the indicator. Then turn the left hand camshaft in its direction of rotation until No. 1L exhaust valve just closes, then mesh the gears and lock in place. No. 6L is on firing point retard, and No. 1R will be 60° past the firing point. On these engines it is necessary to know the firing orders to be able to time them properly.

KNIGHT SLEEVE VALVE ENGINE

In the Knight engine, the valve operating mechanism consists of thin cast iron sleeves placed within the cylinders. They control the port opening and closing, or strokes. This type of engine was invented by Charles Y. Knight, an American Engineer, who received very little encouragement from American manufacturers. European manufacturers, however, recognized the good features of this design and several prominent European cars use this type engine. It is now used in this country on models of Willys Knight, Stearns Knight, Handley

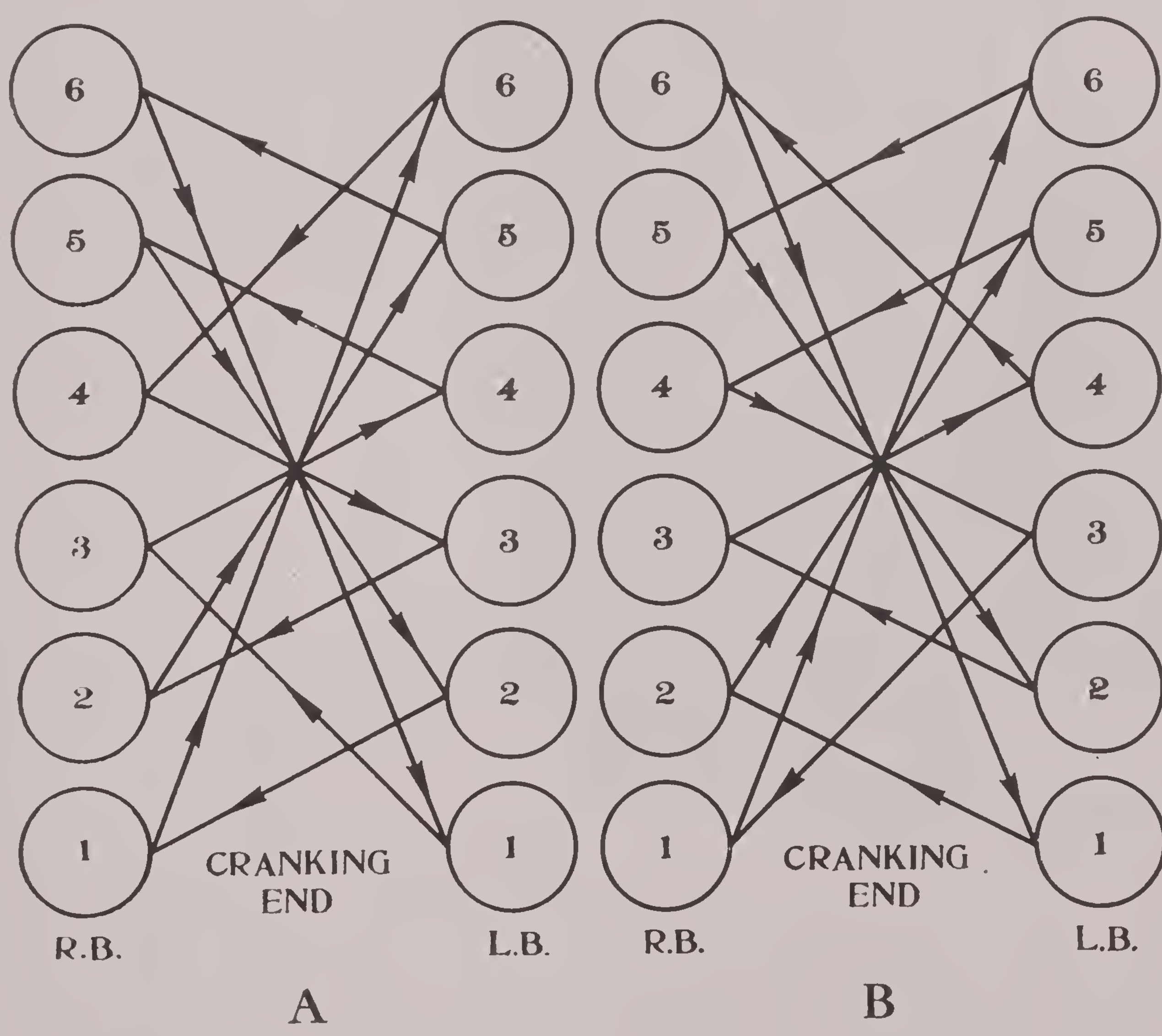


FIG. 48

TWELVE CYLINDER V TYPE FIRING ORDERS

A. 1R—6L—4R—3L—2R—5L—6R—1L—3R—4L—5R—2L
B. 1R—6L—5R—2L—3R—4L—6R—1L—2R—5L—4R—3L

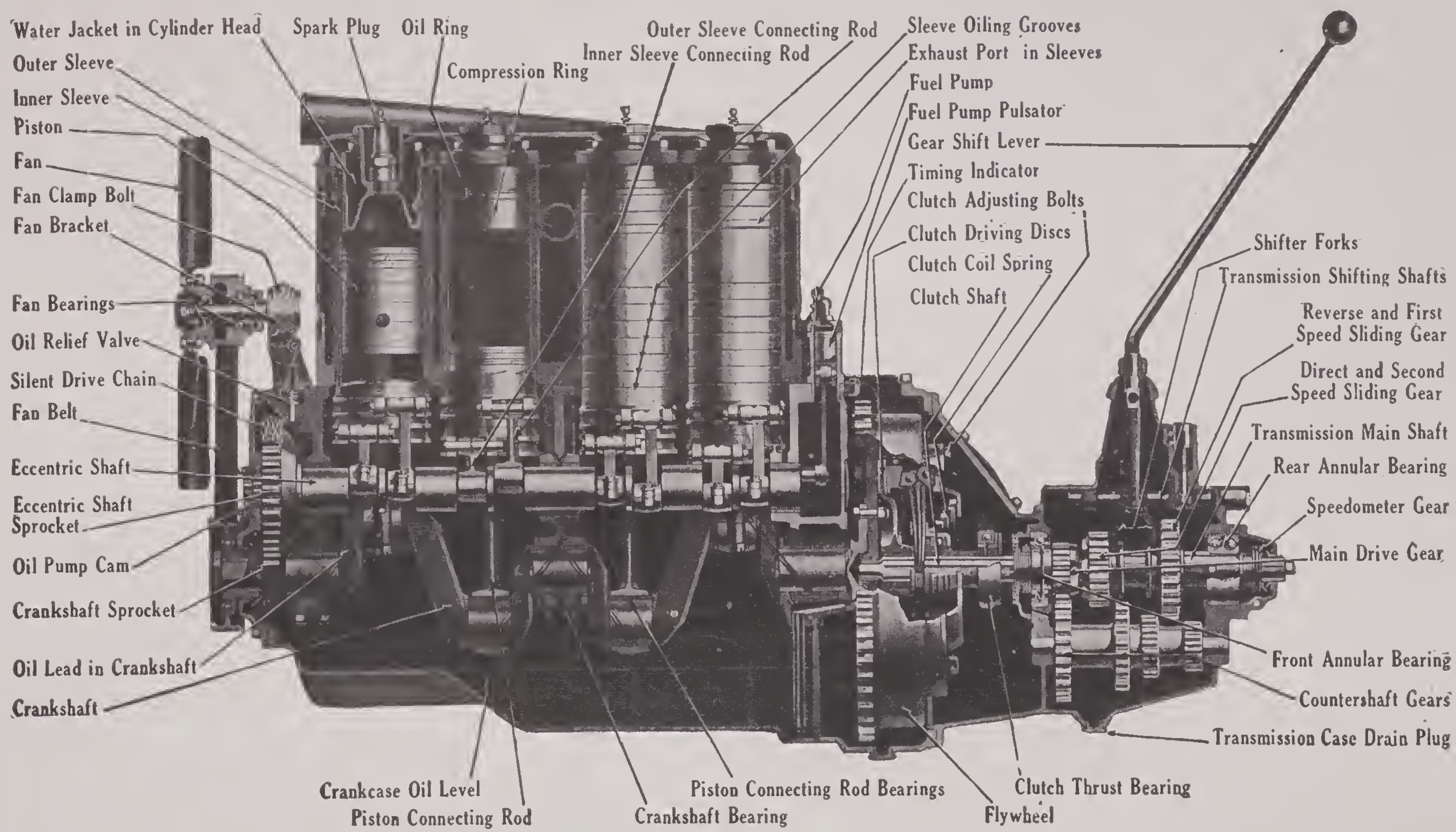


FIG. 49

CUT AWAY VIEW OF FOUR CYLINDER SLEEVE VALVE ENGINE, SINGLE SPRING DRY PLATE CLUTCH, THREE SPEED SELECTIVE TYPE TRANSMISSION, MOUNTED IN UNIT

Note: A special feature of this particular make of sleeve valve engine is the fuel pump, located at the rear right hand side. It is inserted in the gasoline line between the gasoline supply tank and the carburetor, and is connected to a pulsator which is attached to and operated by the eccentric shaft of the engine.

When the engine is running, the air in the pulsator is being continually expanded and contracted, which action alternately draws fuel into the pump and forces it into the carburetor. When the supply of fuel exceeds the demand, a float-operated valve prevents pumping until more fuel is needed.

The fuel pump supplies fuel in any quantity under the pressure desired, at any engine speed, irrespective of throttle opening.

Knight, and R. and V. Knight (formerly the Moline Knight), in units of 4, 6 and 8 cylinders.

Operation

The operating principles of this engine are practically the same as in any four stroke cycle engine, the only difference being in the method of admitting and exhausting the gases from the cylinder. The cylinders are usually cast in block. Near the top of each cylinder are two ports which are connected with the inlet and exhaust manifolds respectively. The cylinder is waterjacketed, and inside of this member and interposed between the cylinder and piston are two thin cast iron sleeves, extending from the crankcase to the top of the combustion chamber. These sleeves are actuated or moved up and down by small connecting rods, which are driven by an eccentric shaft. The eccentric shaft is driven from the crankshaft by a silent chain or gears, at one-half crankshaft speed.

The sleeves have large slots which line up with the openings or ports in the cylinder wall, allowing the gases to enter and exhaust at approximately the same time and in the same relation to the movement and position of the crankshaft and piston as in the poppet valve engine. The travel of the sleeves is comparatively small, their velocity being about 1/10 that of the piston. The openings in the sleeves are wide enough so that the gases can enter and exhaust more quickly than in the poppet valve engine. These openings are not obstructed by a valve head which has a tendency to break up and retard the movement of the gases when entering and leaving the cylinder.

Some of the advantages claimed by the manufacturers of this engine are: smooth running, quietness of operation especially at high speeds, greater flexibility, and the ability to retain its compression longer than the poppet type, because carbon forming on the surface of the sleeves improves the compression, while carbon forming on the face of poppet valves will prevent them from seating properly, resulting in a loss of compression.

The sleeves are lubricated in the same manner as the piston and cylinder wall, by an oil vapor from the crankcase. To insure more equal distribution of the oil over the surface of the sleeves, oil holes and spiral oil grooves are provided.

The action and operation of the sleeve valve engine is positive at all speeds. In the poppet valve engine, the tappet will not always follow the contour of the cam at high speed, hence, the action is sometimes erratic.

The combustion chamber in a sleeve valve engine is one of the most efficient of any design used. The inside of the combustion chamber is machined accurately and smoothly. This gives uniform compression, and has less tendency for carbon deposit to form. It is an engine that improves with use. This is true only in this way; due to the great surface area of the

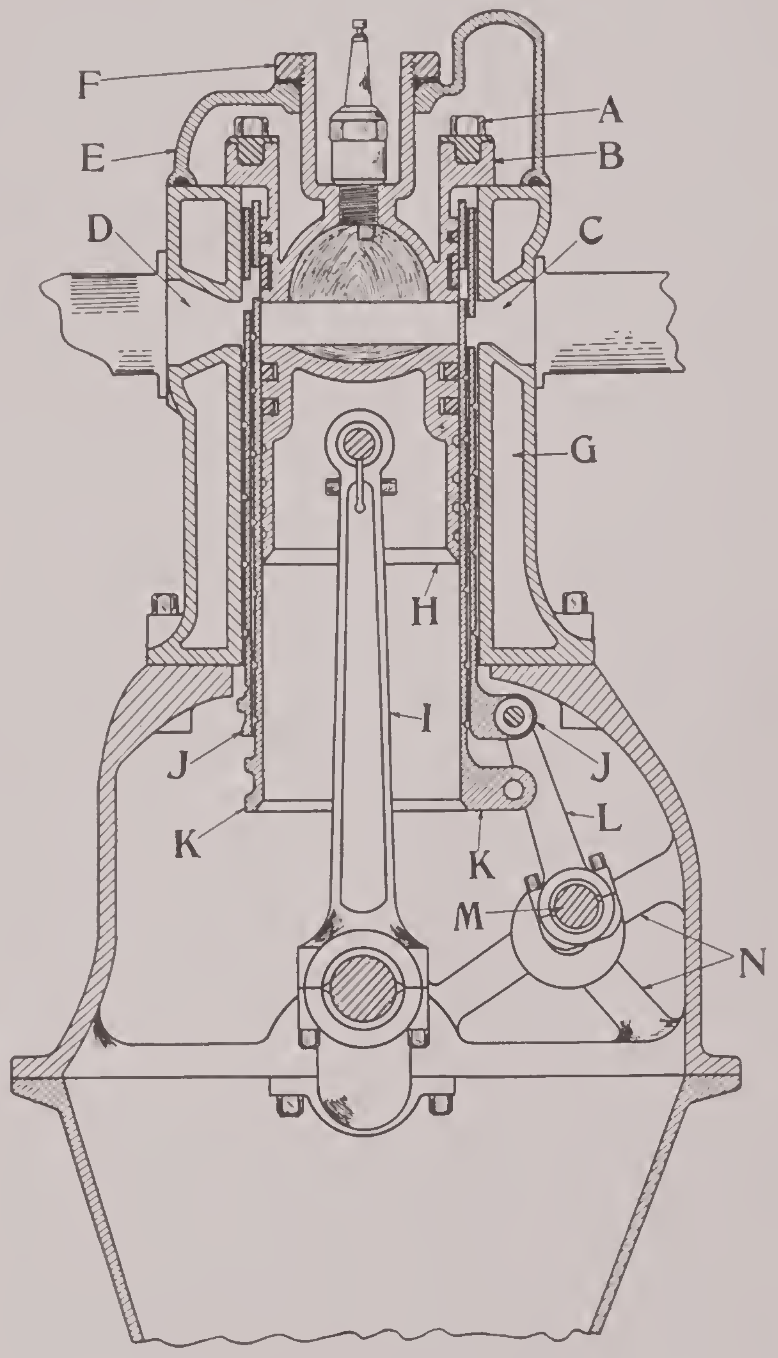


FIG. 50

SLEEVE VALVE ENGINE

A. Cylinder head bolt.
B. Cylinder head.
C. Exhaust port.
D. Inlet port.
E. Removable water jacket.
F. Nut.
G. Water space.
H. Piston.
I. Connecting rod.
J. Outer sleeve.
K. Inner sleeve.
L. Outer sleeve connecting rod.
M. Eccentric shaft.
N. Eccentric shaft mounting.

sleeves, it is impossible to machine these accurately enough to hold the maximum compression. When these sleeves are new there is a tendency for the lubricating oil to work up through the uneven surface of the sleeves and the mixture will move down in the same way. But eventually, the high spots will wear down, and the lubricating oil and condensed mixture collecting in the low spots will be burned by the heat from the combustion chamber, so that these sleeves will in time wear into a more even surface.

Some of the disadvantages claimed by other manufacturers are; this type of engine due to its design is not suitable for racing engines, aircraft engines, tractors, etc., or for any purpose that demands a constant load at a wide open throttle. That is, if the sleeves are given clearance sufficient to hold the compression when the engine is cold, at high speeds or at high temperature the sleeves will start scoring and cutting from expansion. If the sleeves are given enough clearance to prevent excessive friction at high speeds or temperature, the clearance will be so great when the engine is cold that it is impossible to hold maximum compression. But for automobile use, where the speed and load is variable, where a constant load and wide open throttle are not used to any great extent, the sleeve valve engine is very satisfactory.

If the sleeves become worn they cannot be rebored, as they are too thin. It is necessary to replace with new sleeves and pistons of the original size. The new sleeves will, in time, wear in to the proper clearance.

Finding Firing Orders

To find the firing order of a sleeve valve engine, use the compression method. If it is a four cylinder engine, crank the engine over until compression is felt in No. 1 cylinder, and if compression is felt in No. 2, 180° or one-half a revolution later, the firing order is 1-2-4-3. If compression is not felt in No. 2, then the firing order is 1-3-4-2.

Setting Eccentric Shaft

If in a six cylinder engine, remove the spark plug and exhaust manifold from No. 6 cylinder, crank the engine over until the flywheel mark "E. C. 1-6" lines up with the indicator, or until Nos. 1-6 pistons reach T. D. C. and move down not more than 1/32″. Place a light down in No. 6 spark plug hole. Without moving the crankshaft, turn the eccentric shaft in its direction of rotation until the light that is seen through the open exhaust port is just shut off; at this point the exhaust port is closing. Mesh the gears or connect the chain around the sprockets.

To Place No. 1 on Firing Point

After feeling compression in No. 1 cylinder, turn the crankshaft until No. 1 piston reaches T. D. C. This will be T. D. C. compression, or the firing point.

SPARK PLUGS

The spark plugs are constructed of several different materials. The shell is usually made of steel, and has a thread cut on it for screwing into the cylinder; the threaded portion may be tapered to insure a tight fit in cylinder. The metric size seats on a copper and asbestos gasket; this plug is used mostly in foreign, aircraft, or motorcycle engines. The S. A. E. standard plug has a 7/8″—18 thread base and seats on a copper and asbestos gasket to prevent leakage. The porcelain that is used in plugs is of a kind that will stand high pressure and high temperature without cracking. If the porcelain should be cracked, the spark will jump through the broken porcelain over to the shell instead of jumping the gap in the end of plug that is in the cylinder. The resistance of the gap at the end of the electrodes is greater under compression than it is under atmospheric pressure. Many of the plugs will fire at the points or gap when they are laid out in the open, but under compression the spark will jump through a slight crack in the porcelain. To test the plugs, increase the gap to about a quarter of an inch, then test, and if it will jump a quarter inch gap under atmospheric pressure, it will function properly under compression. The gap between the center electrode to which the wire is connected from the distributor, and the electrode which is fastened onto the shell, varies on different engines, depending upon the ignition system used. A clearance of approximately .025″ to .030″ will be sufficient on the average automobile engine.

The porcelains may be held in the shell by a nut, with gaskets between to prevent leakage, or there may be part of the shell shoulder rolled down on top of the porcelain to prevent leakage. Where the nut is used the porcelain can be replaced. The spark plug should be kept clean by cleaning with kerosene and scraping out thoroughly.

The spark plug is generally placed in the cylinder as close to the inlet valve as possible, so that the inrushing gases will wash off the carbon and oil or whatever formation there may be on the electrodes. Where the hole that the spark plug fits into is very deep, the extension plug should be used, because of the burned gases that would stay in this pocket and prevent fresh gases from coming in contact with the electrodes, causing hard starting and misfiring. Some engines have double ignition systems, using two spark plugs in the cylinder placed at different points. This gives an increase in power. From the instant that the gases ignite until they are fully burning, there is a loss of time. Consequently, if there are two spark plugs to ignite the gases at different points in the cylinder and both igniting at the same time, the gases will burn a great deal faster. Most aircraft engines use the double ignition for this reason and also as a precaution, so that if one plug fails, there is another in the cylinder to fire. Keep the spark plug points adjusted uniformly to prevent uneven explosions and vibration of the engine.

Spark plugs are divided into two different types. One is the petticoat, or hollow type, where the center electrodes project through the hollow porcelain, not being imbedded in the end of it. The other is the conical type where the electrode extends through the porcelain about 1/8″. This conical type is preferable on high compression engines, because the compression would have a tendency to heat the electrode too readily if it was exposed to the heat, causing pre-ignition. Some spark plugs have numerous points, or electrodes, but one is all that is necessary, because the spark will only jump one gap and if one should become shorted it will prevent the others from working. So with two electrodes and as short as possible, the less trouble there will be. The electrode on the shell should be bent downward and then up, so any oil forming on it will run down onto the depression, keeping the oil away from the gap to prevent fouling. (See Fig. 245, Electrical section.)

CRANKCASE

Various materials are used in the construction of crankcases, the most common of which are cast iron and aluminum. Some are made of bronze, but are not used in automobile construction. The purpose of the crankcase is for mounting the crankshaft, camshaft and cylinders, and enclosing the same with their bearings to allow for lubrication without loss of oil. The crankcase may be cast integral with the cylinders or may be separate. The oil pan is fastened to the bottom of the crankcase. The gear housing or gear casing is cast integral with the crankcase, requiring a cover to enclose the gears. This cover fastens onto the gear housing with bolts or screws with a thin paper or cork gasket between. Use shellac on one side of the gasket and graphite on the other to prevent injuring it when removing.

The crankcase may have a breather tube, either cast integral with it or fastened separate. This breather tube serves as the oil filler tube providing a place to pour oil into the crankcase and has baffle plates within to prevent the oil from splashing out. There must be an opening in the crankcase to allow the heat to pass out, otherwise the bearings may burn out through overheating and thinning down of the oil under the high temperature. As the pistons come down they have a tendency to force this hot vapor out.

Crankcases may become cracked as a result of a connecting rod breaking, necessitating welding. When welding the crankcase, whether aluminum or cast iron, it is necessary to preheat the casting to prevent further cracking and excessive warping. Notwithstanding these precautions, the casting may warp to a certain extent, necessitating remachining the cylinder and oil pan surface, to prevent oil leakage. The crankcase may have mounted upon it the ignition drive bracket, starting motor bracket, or generator bracket.

OIL PAN

The oil pan may be a sheet steel stamping or a light aluminum casting. The purpose of this oil pan is to act as an oil reservoir and furnish a mounting for the oil pump and oil level indicator. It may have troughs into which the connecting rods splash. It is held to the crankcase proper by studs or cap screws, with a cork or felt gasket between the two surfaces to prevent oil leakage. The oil level indicator indicates the amount of oil that is in the reservoir.

COOLING SYSTEMS

The great heat developed within the combustion chamber, in addition to the heat of friction between the piston and cylinder, would cause the metals to bind or seize, the lubricating oil to decompose, and possibly cause premature explosions, if there was not some means provided for cooling the engine. At the same time, since the efficiency of the engine depends upon its ability to utilize the greatest number of heat units generated in the combustion chamber, it is evident the more heat units transferred to the cooling agent, the less the efficiency of the engine. Therefore the design and operation of the cooling system is very important.

There are two types of cooling systems, one using a current of air circulating around the engine, and the other using a water jacket, the water being kept in circulation and cooled by exposure to cooler air currents.

AIR COOLING SYSTEM

Air cooled engine cylinders have the walls constructed somewhat lighter than on the water cooled type, for the purpose of radiating

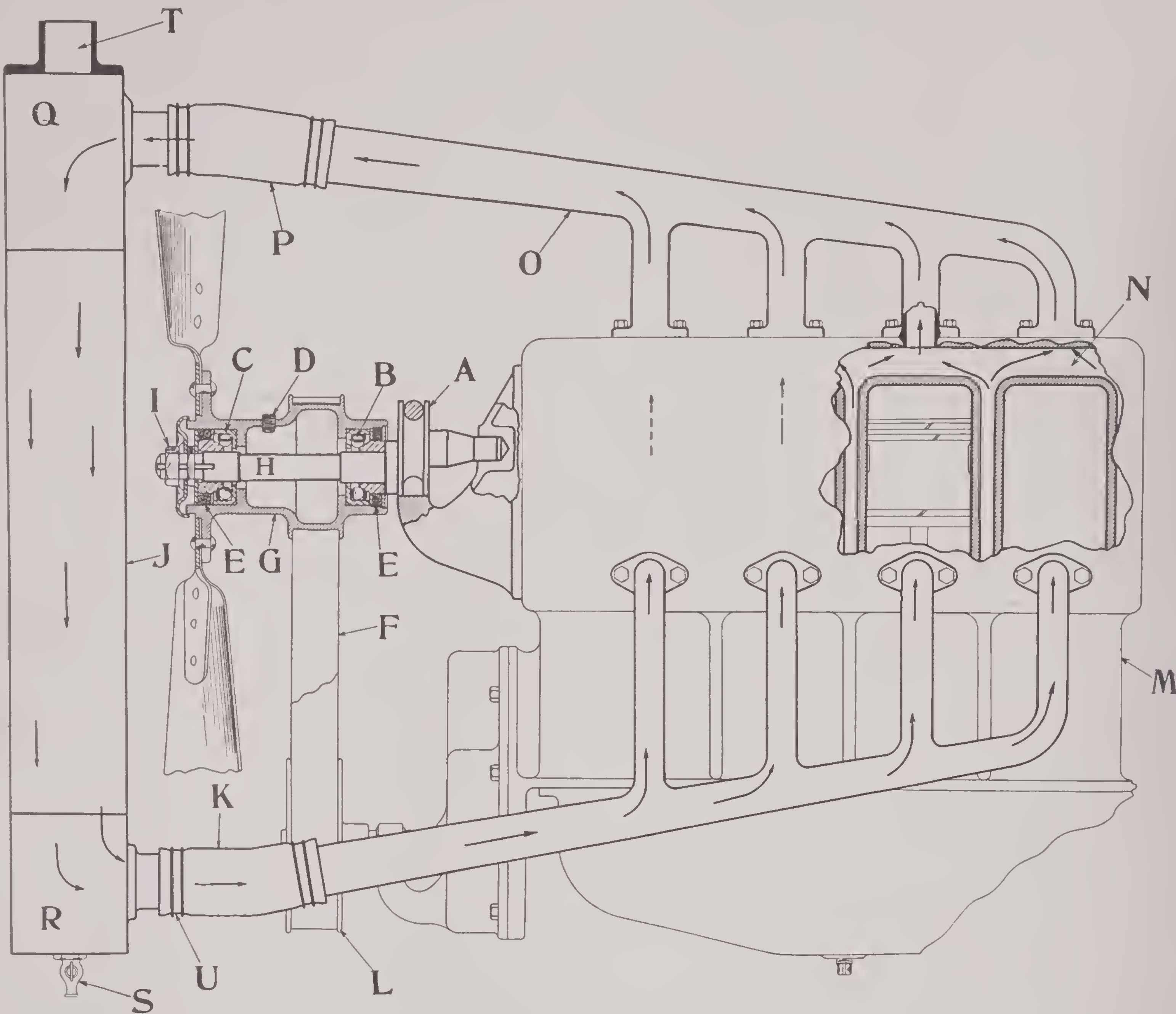


FIG. 51

THERMO-SYPHON COOLING SYSTEM
TYPICAL FAN MOUNTING

The arrows indicate the water circulation. The water is caused to circulate by the difference between the temperature of the water in the water jackets and the water in the radiator.

A. Fan mounting and belt adjustment.
B. Inner bearing.
C. Outer bearing.
D. Oil plug.
E. Felt oil retaining washers.
F. Fan belt.
G. Fan hub.
H. Fan shaft.
I. Adjusting nut.
J. Radiator.
K. Lower hose connection.
L. Fan belt drive pulley.
M. Cylinder block.
N. Water jacket.
O. Water outlet manifold.
P. Upper hose connection.
Q. Upper chamber.
R. Lower chamber.
S. Drain cock.
T. Radiator filler tube.
U. Hose clamps.

the heat more rapidly. These cylinders have fins cast on their exterior to help dissipate the heat. The air cooled engine has higher thermal efficiency than the water cooled engine. Running at a higher temperature, less heat is radiated or taken away from the combustion chamber. This reduces the loss by cooling and leaves more to be converted into power, and under normal conditions an air cooled engine will give good service. They are not very successful when used to produce maximum power continuously, as the fins will not radiate the heat fast enough. A fan is used to draw an air blast around the cylinders for proper cooling. Air cooled engines, because of the higher temperatures necessitate greater clearance on all bearing surfaces including valve stems, connecting rods, crank pin bearings, tappets, etc.

Due to the fact that the cylinder expands more than in the water cooled type less clearance will be required on the piston. On the old type aluminum alloy piston used in the Franklin, about .011″ and .003″ clearance was allowed. But on the new pistons that are being used at present (long type) only about .005″ and .002″ are allowed. This prevents any chance of a piston slap when the engine is cold, but will sometimes slap after the engine heats up to normal operating temperature. If the pistons are fitted tight enough to prevent slapping at high speeds they may seize at lower speeds.

The general practice in fitting piston pins in this type engine is to heat the pistons by placing them in hot oil, then fit the piston pins to a snug pressing fit with the palm of the hand. If they are fitted when cold, as in a water cooled engine, a knock may develop, when the engine is hot. This will be caused by the piston expanding more than the piston pin.

WATER COOLING SYSTEM

In the water cooling system a circulation of water through the water jacket and radiator is maintained to keep the cylinders cool. There are two types of water cooling systems, thermo-syphon and pump circulation.

Thermo-Syphon Type

With the thermo-syphon cooling system, there is no pump or other mechanical device to circulate the water through the engine and radiator. The thermo-syphon cooling system works on the principle of hot water being lighter than cold water, or by the difference in the weight of water at different temperatures. Water at 39° F. temperature weighs 62.4 lbs. per cubic foot, while water at a temperature of 212° F. weighs 59.8 lbs. per cubic foot. It is this difference in the weight of the water at different temperatures that causes the water to circulate through the system. As the engine heats up, the water in the water-jacket will be heated, the hot water will rise to the top and pass over into the radiator practically being forced by the cooler water entering the bottom of the water jacket from the bottom of the radiator. Air currents acting upon and passing through the radiator cool the water in it, causing the cooler water to settle to the bottom of the radiator where it is ready to enter the water jacket again, thus making a constant circulation of water through the cooling system.

This system does not cool high speed or heavy duty engines sufficiently, the water not passing through the radiator fast enough. On the thermo-syphon cooling system there will be no circulation of the water until there is a considerable difference between the temperature of the water in the lower radiator chamber and the water in the jackets of the engine. The water inlet and outlet hose connections on the thermo-syphon system are considerably larger than on the pump circulating system and should be kept free at all times.

Pump Circulation Type

The type of pump that is used to circulate the water depends upon the type of the engine and its application. Marine engines of the smaller type use the plunger pump to circulate the water, while the larger marine engines use the gear pump. A pump of these types is necessary because the water must be drawn a considerable distance.

On automobile engines the radiator being about the same height as the engine, demands only a circulating pump. This circulating pump does not require any suction, being connected between the radiator and engine and using the impellers to force the water through.

On this system, the instant the engine starts, the water begins to circulate, consequently it will take an engine with a cooling system of this type longer to heat up to its correct running condition than one with the thermo-syphon system. This system prevents the engine from overheating more than the thermo-syphon. The radiator is generally connected to the pump by hose, and there is an outlet hose from the top of the cylinder to the top of the radiator. If these hose connections become clogged in any manner, there is a tendency to stop some of the water from circulating and cooling, consequently causing overheating of the engine.

Where the pump circulating system is employed a method is sometimes provided to retard the circulation until the engine heats up. In some instances shutters are provided at

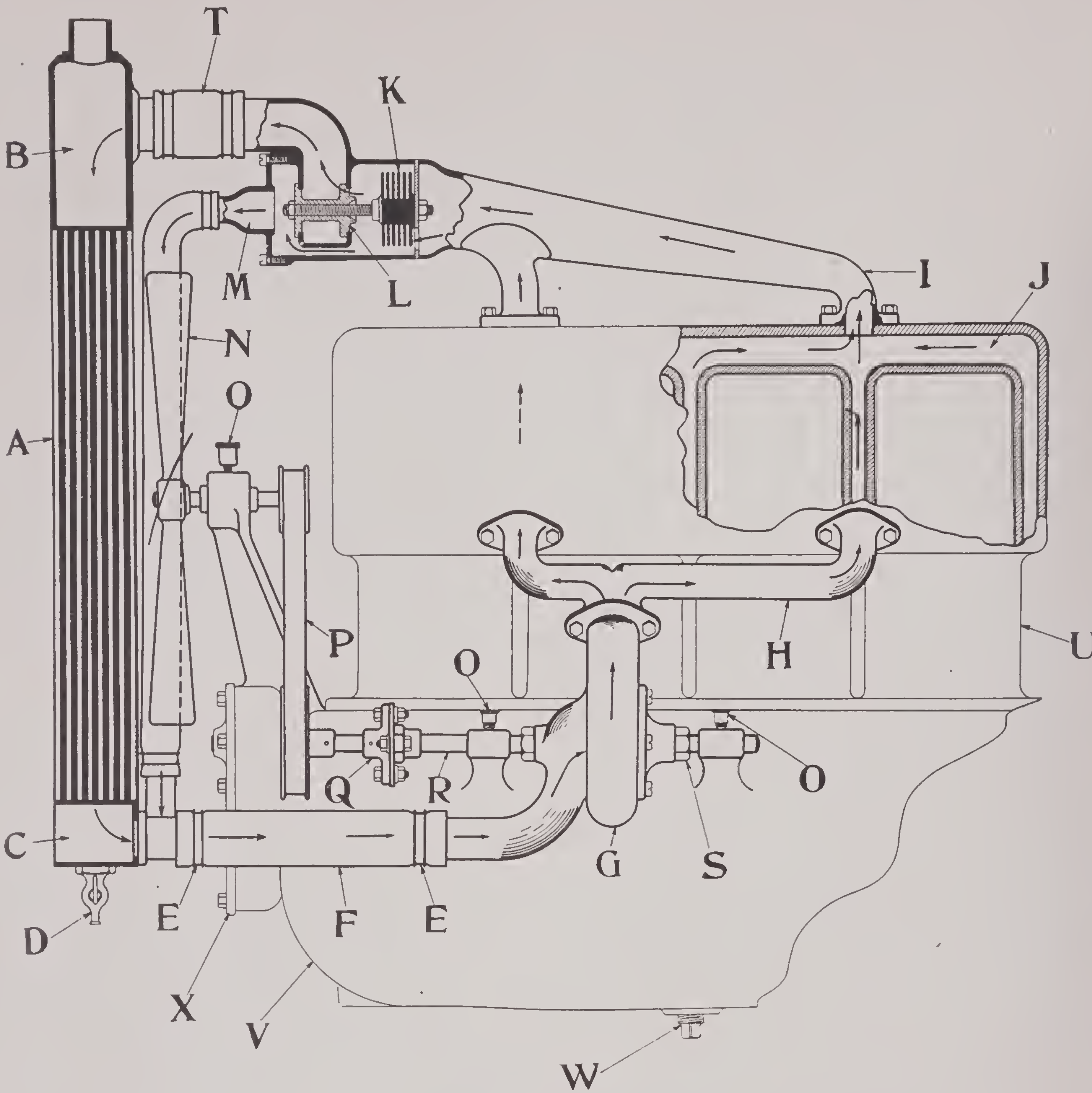


FIG. 52

CIRCULATING WATER COOLING SYSTEM
THERMOSTATIC CONTROL

A. Radiator tubes.
B. Upper chamber.
C. Lower chamber.
D. Drain cock.
E. Hose clamp.
F. Hose.
G. Water pump.
H. Water inlet manifold.
I. Water outlet manifold.
J. Water jacket.
K. Thermostat.
L. Valve.
M. Water by-pass.
N. Fan.
O. Grease cups.
P. Fan belt.
Q. Flexible coupling.
R. Water pump shaft.
S. Packing nut.
T. Hose.
U. Cylinder block.
V. Oil pan.
W. Drain plug.
X. Gear case cover.

The purpose of the thermostat in the cooling system is to regulate the flow of the water to the radiator so as to allow the engine to heat to the normal operating temperature as soon as possible and keep the water at approximately an even temperature. When the engine first starts and the water is cold, the water passes through the passage (M) back to the pump without having passed through the radiator. The water continues to circulate in this way until it reaches a predetermined temperature. This temperature is sufficient to cause the thermostat (K) to expand and open the passage into the radiator.

This passage remains open while the temperature of the water remains above that at which the thermostat operates. Should the temperature of the water decrease, the thermostat will contract, closing the passage to the radiator, again allowing the water to heat.

The use of the thermostat tends to increase the efficiency of the engine by allowing it to heat more rapidly and keeping it nearer a constant temperature, thus preventing condensation of the fuel, eliminating carbon and fouling of spark plugs.

the front of the radiator, which regulate the amount of air that passes through it. These shutters may be controlled by hand from the dash, through an operating rod and bell crank, or may be connected to the throttle control lever. When the engine is running slowly the shutters are practically closed. When the throttle valve is opened, giving an increase in speed and a rise in temperature, the shutters will be opened to provide more rapid cooling of the water.

These shutters may also be controlled automatically by a thermostatic regulator. When the water is cold the regulator contracts and holds the shutters closed, but as the water heats, the regulator expands, opening the shutters. This same type regulator may be used with a valve to regulate the circulation of the water instead of the air. The regulator controls certain valves so that when the water is cold it circulates only through the engine and as the water heats, the regulator expanding opens the valves, allowing the water to circulate through the radiator.

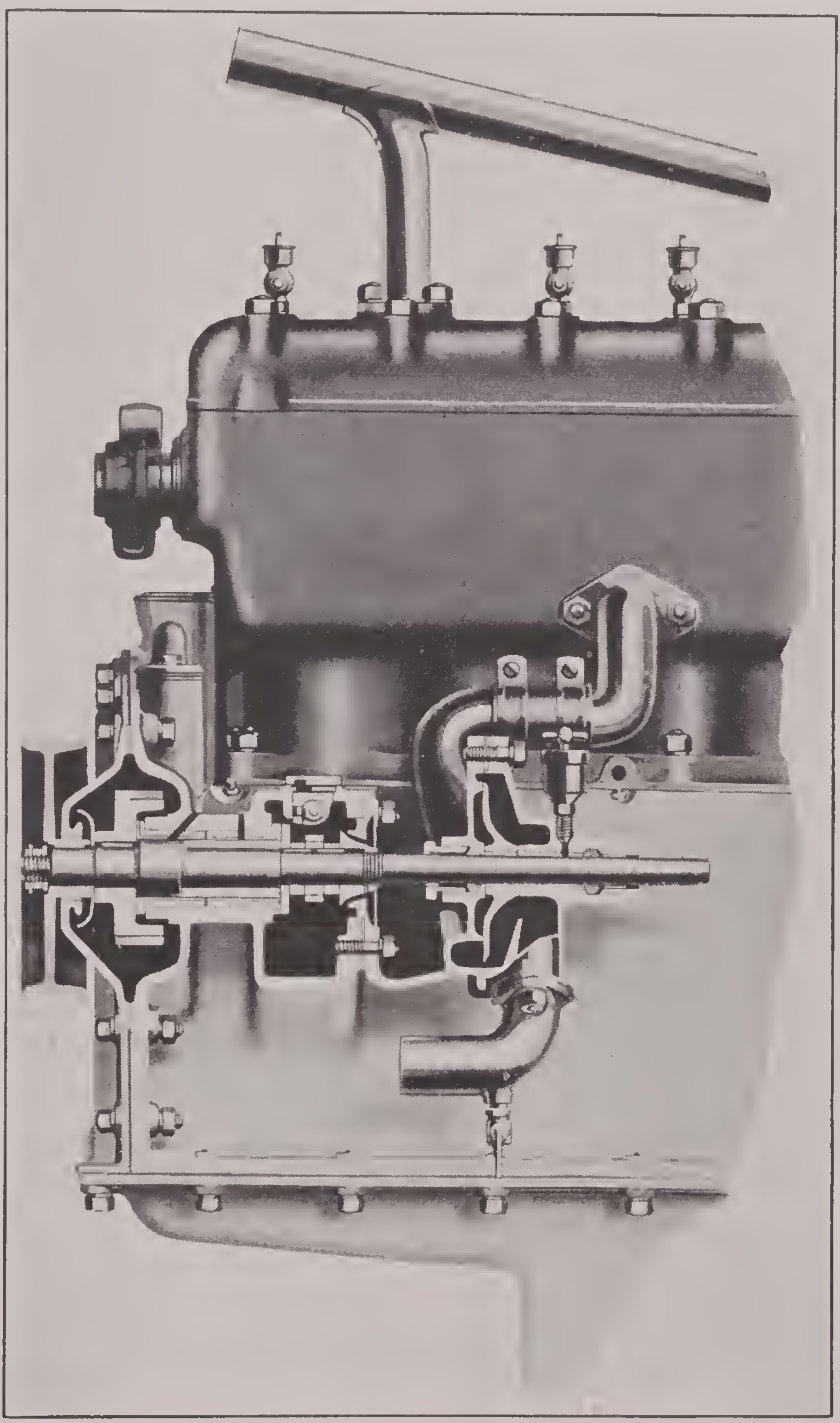


FIG. 53

PUMP SHAFT AND DRIVE

WATER PUMPS

Water pumps used on the internal combustion engine may be either the plunger pump, or the gear pump, as explained under lubrication systems, in which they are more commonly used. The centrifugal circulating pump is the type most used on the present day automobile engines. This water pump may be driven by a gear and shaft from the generator, or the pump shaft may drive the generator. The impeller has blades sloping outward to give the water a centrifugal or outward whirling action. The outlet is on the outer diameter of the housing and the inlet near the center. The pump circulates the water from the bottom of the radiator through the water jackets of the engine into the top of the radiator, where it is cooled by the air currents passing through the radiator as it flows down to the bottom chamber again. The water pump usually has two packing nuts to prevent water from leaking by the revolving shaft. These packing nuts should be packed with candle wick or braided cotton, made especially for this purpose and well graphited. The bronze bearings are generally lubricated from grease cups, requiring one or two turns once a week. These bearings can be replaced when worn. The impeller can also be replaced, being mounted on the shaft and held in position by a pin or key. Sometimes this pin may become sheared off necessitating replacing with a new pin or key. (See Figs. 2, 5 and 53 for sketch and mounting of centrifugal pump.)

WATER MANIFOLDS

Both the inlet and outlet water manifolds may be made of cast iron, bronze or aluminum. The purpose of these manifolds is to provide the water connection between the pump and the cylinders and between the cylinders and the top of the radiator. On a cylinder cast in block there will be but one inlet into the cylinder, while on the multiple block engine each block requires an inlet from this manifold. A manifold may be held on by studs and nuts, or by cap screws with a gasket between the two surfaces. These surfaces are machined, and the asbestos gasket placed in between to prevent leakage, or to make up any unevenness in the surface.

RADIATORS

The principal types of radiators are the honey comb or cellular, and the tubular. The cellular radiator is constructed of either diamond or square shape cells, with the water passing through very small spaces surrounding them. The tubular type has thin vertical tubes for the water to pass down through. This space is usually larger than the circulating space on the cellular type. The thickness of the tubes or the cells determines to a great extent the efficiency of the cooling system. The thinner the metal, the better the heat will radiate. The radiator is constructed with two chambers, one the upper and the other the lower, connected either by tubes or cells.

The water leaves the lower chamber and passes into the cylinder either by the aid of a pump or on the thermo-syphon principle. As the water becomes cooler it becomes heavier, and this causes it to drop more rapidly. The radiator is subjected to considerable vibration, consequently it is necessary to provide some type of shock absorber. The radiator is sometimes set on felt packing or plates to absorb this shock, preventing breaking of the soldered joints. In the lowest point of the radiator there is usually a drain cock provided. The purpose of this drain cock is to drain the water from the radiator and water jackets of the engine. A radiator should never be painted because this paint acts as an insulation between the cold air and the surface of the cooling tube, preventing the cold air from coming in direct contact with the surface, thereby hindering proper radiation.

Troubles

In time, scale will form throughout the interior of the cooling system in both the water jackets and the radiator. This scale prevents the water from coming in direct contact with the radiating surfaces of the radiator, causing the engine to overheat, resulting in a general loss of efficiency. This scale can be removed by using either a lye or muriatic acid solution.

When using the lye solution, remove the rubber hose connections, stop up the water outlet at the bottom of radiator and the water inlet at the bottom of water jackets. Dissolve three one pound cans of lye in five gallons of hot water and pour into the cooling system, letting it stand about five hours. Drain and flush the cooling system with a stream from a hose. Replace hose connections and refill with clean soft water.

When using the muriatic acid solution, it will also be necessary to remove the rubber hose connections. Mix 1 part of commercial muriatic acid with 7 parts of soft water, pour into cooling system and let stand for about twenty-four hours. Drain, flush, and refill with clean soft water. The engine should not be run when these solutions are in the cooling system. Always use soft water or rain water in the cooling system if possible.

The scale which forms in the cooling system is a lime or mineral deposit. Most all well water or hard water contains more or less mineral matter, this matter being either in suspension or solution, and will form a scale deposit in the radiator tubes and water jackets. Where an anti-freezing solution is used that contains some salt as a basis, such as calcium-chloride, this circulating through the cooling system may deposit solid matter in the form of crystals on the inner surface of the cooling walls.

Anti-freezing solutions containing glycerine, may have a chemical action, due to the acid sometimes found in the cheap commercial grades of glycerine used for this purpose. This chemical action causes deterioration of the water jacket walls and also helps to cause a deposit. The glycerine solution will also affect the rubber hose.

Anti-Freezing Solutions

To lower the freezing point of water to prevent freezing in cold weather, various solutions may be used. Among those more commonly used are; common salt, alcohol, glycerine, and calcium chloride. Each of these have certain advantages and disadvantages.

An alkaline solution, such as the salt and calcium chloride, produces a distinct electrolytic action similar to an electric battery, wherever two dissimilar metals are used in the cooling system, such as the brass tubing of the radiator and the solder at the joints, or the aluminum pump housing and the steel impellers. These solutions will also have a tendency to leave crystals or an incrustation as the water evaporates. The alcohol solution affects none of the system, but evaporates very rapidly. The glycerine solution affects the rubber hose.

Of the above named substances, perhaps alcohol is the preferable one, since it will not affect the metals or rubber and will not form deposits of foreign matter, also will not freeze at known temperatures and has no electrolytic effect. But the boiling point of alcohol is very low, and this will cause it to evaporate at a temperature less than the boiling point of water.

One of the best mixtures, is a solution of water, alcohol and glycerine. The addition of glycerine will reduce the liability of evaporation to a large extent and raise the boiling point.

Freezing Points
Water and Alcohol

Water 95%—Alcohol 5% — Freezing point, 25° F.

Water 75%—Alcohol 25% — Freezing point, zero.

Water 60%—Alcohol 40% — Freezing point, 20° below zero.

Water, Alcohol and Glycerine

Water 90%—Alcohol-Glycerine 10%—Freezing point, 25° F.

Water 75%—Alcohol-Glycerine 25%—Freezing point, 10° F.

Water 70%—Alcohol-Glycerine 30%—Freezing point, 5° below zero.

Water 60%—Alcohol-Glycerine 40%—Freezing point, 15° below zero.

LUBRICATION

The purpose of a lubricant on any bearing surface is to keep metal away from metal. With a film of oil between two bearing surfaces, the bearing surfaces ride upon the oil instead of upon each other, which reduces the friction and the wear. Therefore, there must always be some clearance between any two bearing surfaces to allow for expansion of the metals when heated and also for the film of oil. Lubricating oil in the internal combustion engine serves three distinct purposes; **general lubrication of all bearings, compression seal and cooling.** Without sufficient lubricating oil on the various bearings the friction will increase, causing high temperatures, general overheating of the bearings, and as the oil becomes hotter and thinner, it lubricates less than before. The film of oil between the piston and cylinder wall fills the clearance space and forms a seal to assist in keeping the compressed gases within the combustion chamber. Without this seal it would be impossible to maintain the compression pressures necessary for efficient combustion.

New bearing surfaces of any type or description when placed under a magnifying glass appear to be a mass of high and low spots, no matter how well they may be ground or finished. The lubricating oil that comes onto the bearing surfaces prevents these high spots from coming in contact with one another, allowing the high spots to gradually wear off, thereby smoothening the surface and reducing the friction. If the bearings were run without a lubricant or with excessive pressure before they are worn smooth, it would cause undue friction between the metals, developing heat, tearing these high spots off and roughening the bearing surfaces. When the bearing surfaces become roughened, the bearing can no longer be kept tight.

Under all conditions use the brand of oil recommended by the engine manufacturers. The manufacturers have made extensive experiments with various brands and bodies of oils best suited to their engines, and their recommendations should be followed as nearly as possible. The oiling system employed predetermines the weight or density of oil to be ing rod bearings is thrown by the rapid rotation of the shaft up onto the lower ends of the sleeves and pistons. Circular grooves in the sleeves gather the oil, and aided by the suction, the oil passes from groove to groove and through small perforations, lubricating the surface of the sleeves and pistons. The oil pressure is automatically regulated by a by-pass valve which is controlled from the throttle. That is, as the throttle is opened, the cam forces the valve inward which causes the spring to hold the by-pass valve tighter against its seat. When the throttle valve is in a closed position the cam moves around and allows the oil pressure to force the valve away from its seat. This prevents an excessive pressure at low speeds.

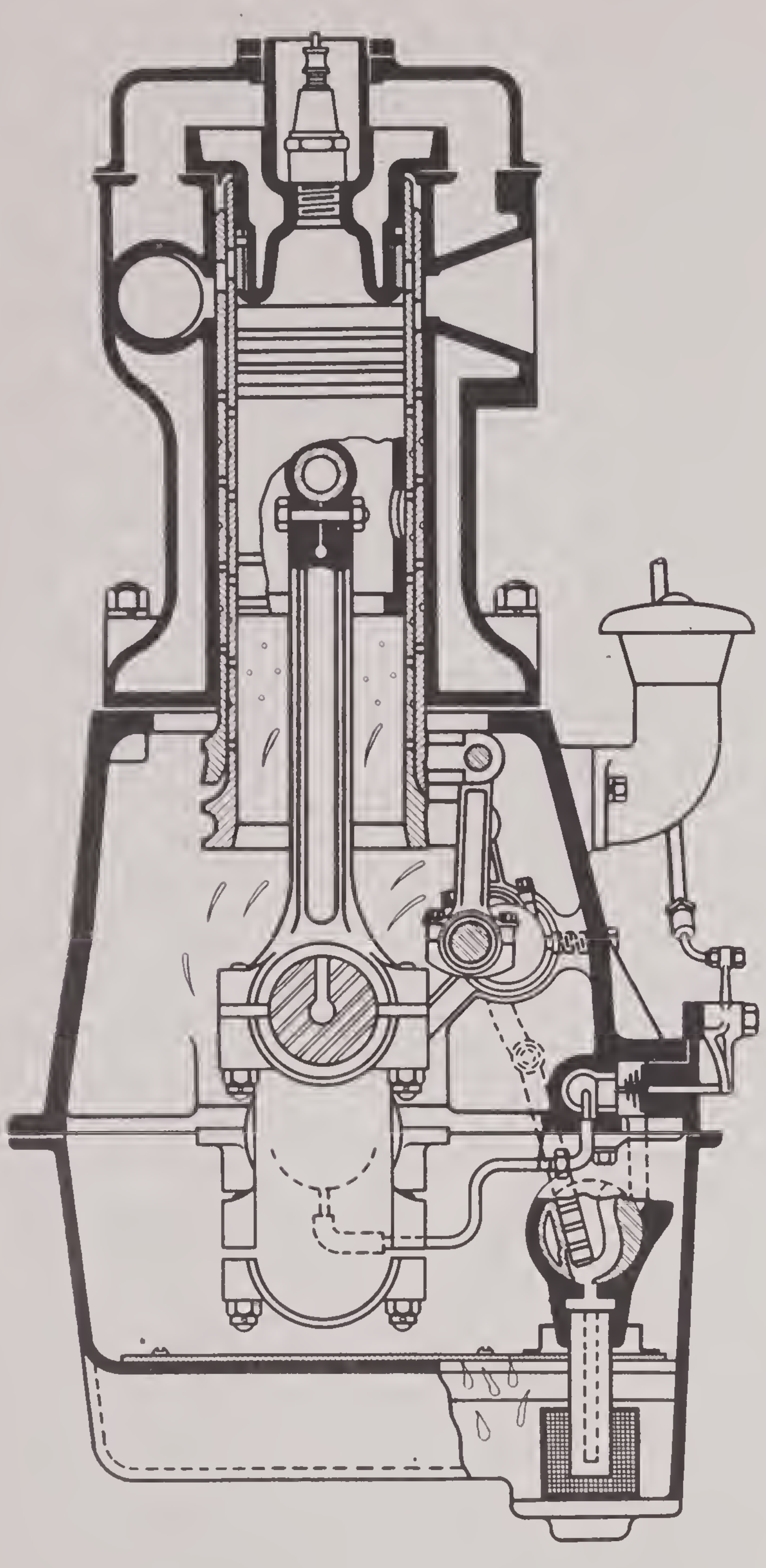


FIG. 54.

FORCE FEED LUBRICATING SYSTEM SLEEVE VALVE ENGINE

This system employs a plunger pump mounted on an oscillating shaft. A sleeve rod mounted around the eccentric shaft through its connection with the plunger, moves the plunger back and forth, and up and down. As the plunger moves up drawing the oil from the sump into the pump shaft, the shaft moves to the right. When the plunger reaches its highest point of travel the shaft turns clockwise enough to close the inlet at the bottom and open the outlet at the top. The plunger moves down and forces the oil out of the shaft, by the by-pass pressure regulator, to the main bearings of the crankshaft, through drilled holes in the crankshaft to the rod bearings. The overflow of oil from the connect-

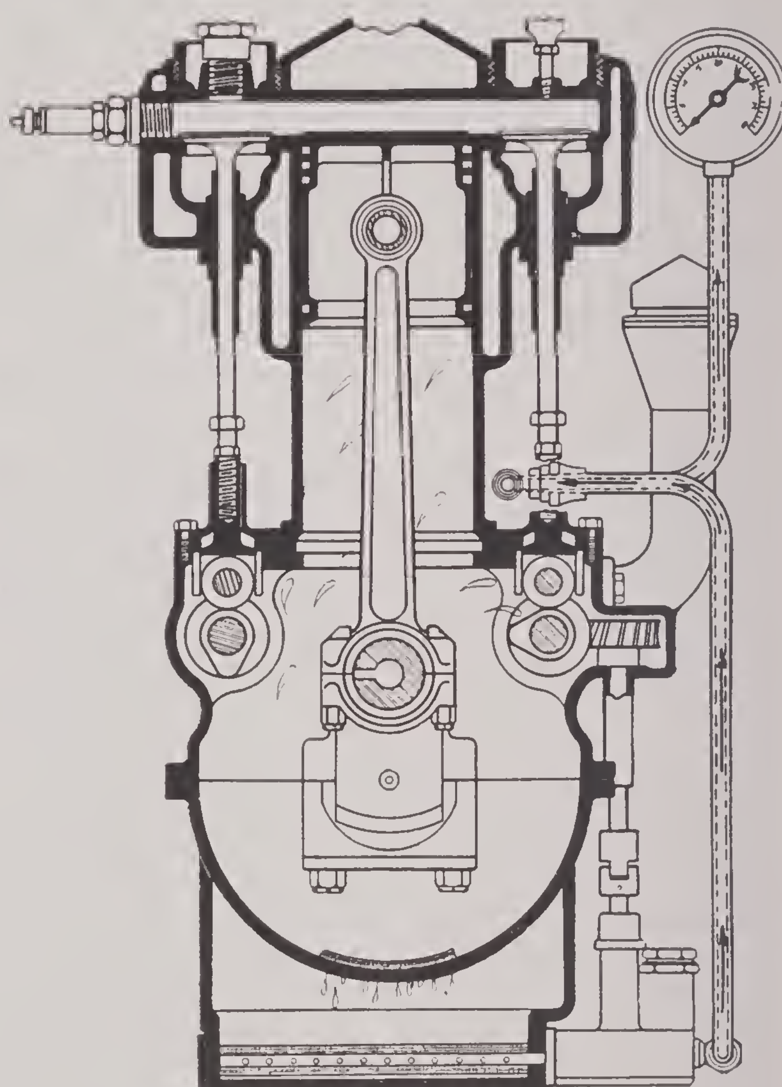


FIG. 55.

FORCE FEED SYSTEM—T-HEAD ENGINE

A gear pump located outside the engine draws the oil from the oil sump and forces it through a tube to a pipe through the crankcase, which conducts the oil to the main bearings. The oil is forced into the center of the crankshaft and through a drilled hole to the crank pin bearing of the connecting rod.

used, thus a splash oiling system has not sufficient pressure to force heavy oils through the bearing clearances and a lighter oil is necessary, while with a pressure system the heavier bodied oils can be used.

In aircraft engines, racing engines, or engines where the temperature rises very rapidly, oils of fairly heavy body should be used, as the flash or burning point is higher. These heavier oils do not break down as readily under high temperature as the lighter oils. On a heavy duty, constant speed or high speed engine the temperature on the interior of the combustion chamber is very high, while on the automobile where the engine is working under a variable load, the temperature never becomes as high. Hence, it is not necessary to employ the heavy oils. The heavy oil causes a drag in the bearings and increases the carbon deposit, if the operating temperature is low. The oil used must have a clinging tendency, to resist being forced from between the bearing surfaces.

The most practical and best oils to use in the internal combustion engine are the mineral oils, because they withstand the heat and high pressures with which they come in contact. Vegetable or animal oils have a certain acid effect on the metals and also gum up readily, producing friction in the engine and preventing perfect lubrication.

A certain amount of this oil burns or bakes onto the walls of the combustion chamber and the head of the piston. This deposits a certain amount of carbon residue which makes the combustion chamber smaller and results in an increase in temperature through having higher compression, thereby sometimes causing a premature explosion.

This carbon deposit does not remain red hot so there is no tendency to back fire from this cause. It will cause the explosions or the expansion to occur more rapidly so that a partial expansion will occur before the piston is on T. D. C. If the engine should become overheated and enough carbon has been deposited in the combustion chamber, it will continue to run due to the high compression, even without the aid of an igniting spark. When the piston comes up on the compression stroke, if the temperature reaches the igniting point, the charge is ignited.

When the engine is first started, being quite cold, a large per cent of the fuel taken into the combustion chamber may condense or turn back into the form of gasoline. This gasoline washes the lubricating oil from the cylinder walls, allowing the gasoline to pass down into the crankcase mixing with the lubricating oil, diluting it and making it unfit for use. Lubricating oil diluted with gasoline or kerosene does not lubricate the bearings properly, consequently when the lubricating oil becomes diluted it will cause the bearings to cut and wear.

Considerable carbon will work down into the crankcase with the oil, making the oil very dark, which is an indication that it should be changed.

The method of lubrication varies, depending upon the speed, load, and heat generated by the engine. Production is also taken into consideration and final cost of the engine. Proper lubrication of the engine cannot be over emphasized.

The importance of lubrication may be judged from the fact that actual service records, covering a period of almost two years, show that 90% of all repair bills, outside of wrecks and faulty material, were traced either directly or indirectly to improper lubrication.

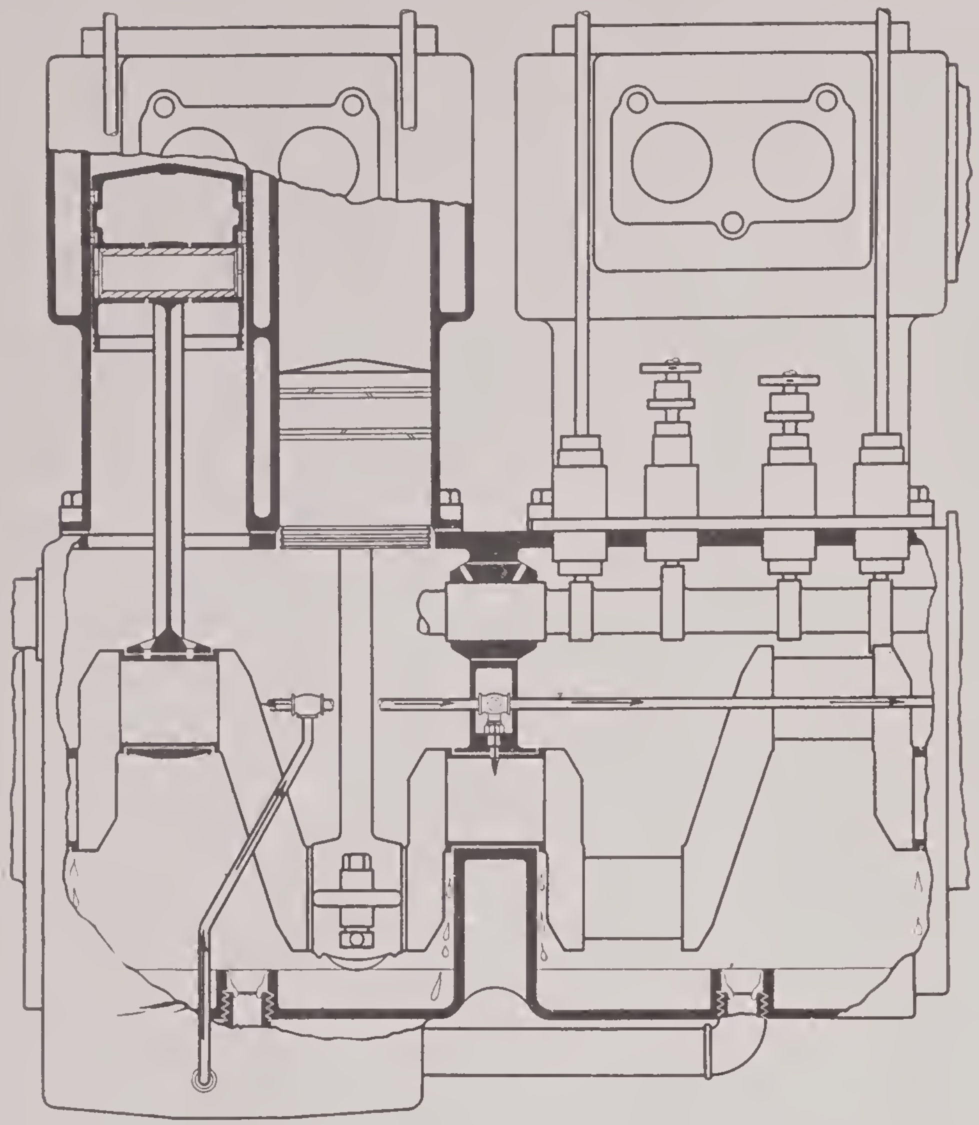
Proper lubrication is obtained by allowing enough clearance at every bearing surface, so that as the engine heats up and the various moving parts reach their maximum expansion under normal running conditions, there will be enough clearance to provide for a film of oil, which will prevent one bearing surface from coming in contact with the other.

Oil must be supplied on every bearing surface at all times and the oil must be clean and of the correct grade as required by that engine. Never allow the oil to get below the correct oil level in the sump, and see that the pump is operating so that the oil is delivered to the bearings. This, on the average car, can be determined by observing the pressure or sight feed on the dash.

The correct grade of oil can be determined either from the manufacturer's recommendation or from a chart of recommendations furnished and obtained directly from reliable oil companies. The chart will recommend the correct grade of oil to be used both winter and summer for practically every make and model of car on the market. These recommendations are correct, since they have been determined from laboratory and dyamometer tests, in which the running temperature of the oil at different points in the engine, the temperature and pressure on the different bearings, the design of the engine, its purpose and the type of lubrication system have been taken into consideration.

Buy the correct grade of oil in sealed cans or drums with the name of the manufacturer on the container.

Due to dilution from unvaporized fuel and to sediment which may collect in the oil sump, tubes, troughs and bearings, it is necessary, about once every five hundred to one thousand



FORCE FEED AND SPLASH SYSTEM

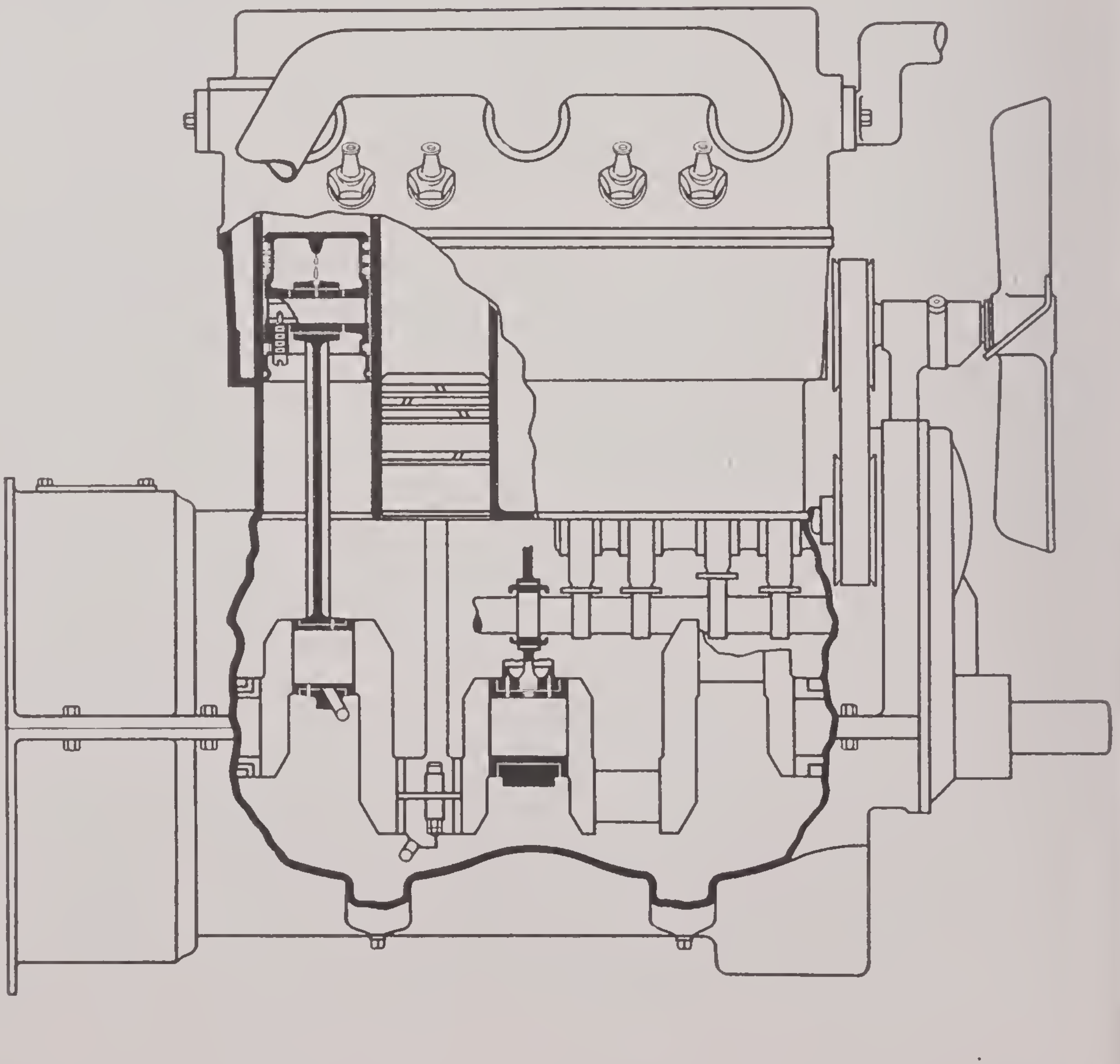
FIG. 56.
(At Left)

In this system a plunger pump circulates the oil onto the main bearings under pressure. The pump also circulates the oil to troughs underneath the rod bearings. These troughs are extra wide and are made a part of the oil pan. Surplus oil in the troughs will overflow and drain through the outside pipes back to the oil sump.

SPLASH CIRCULATING SYSTEM

FIG. 57.
(At Right)

In this oiling system the oil is circulated by a pump to an indicator on the instrument board, then into the troughs underneath the connecting rods. The rods splash the oil onto the different bearings. This sketch shows a construction where two troughs supply the oil for four rods.



miles to drain the dirty oil from the crankcase. Replace with kerosene and run the engine slowly under its own power not more than one-half minute. Drain the crankcase again, remove the oil pan, scrape and clean the sediment from the oil pan, spin the engine over by hand forcing the kerosene out of the pump, tubes and bearings and allow the engine to remain open for some time. These precautions will prevent any kerosene from remaining in the engine which will dilute the new oil. Then replace oil pan and refill with new clean oil. Do not fill the oil sump above the maximum oil level, indicated by a petcock or level gauge.

On some engines the oil may need to be changed more often. Before removing the oil, allow the engine to run until the oil reaches the lower oil level. Always refill the oil reservoir with fresh oil. Mixing fresh oil with the old oil will spoil the lubricating qualities of the new oil.

Before trying to start the engine, pour a small quantity of oil on the head of each piston, spin the engine over allowing the oil to work down to replace the oil that was washed away from around the rings. This oil is necessary in order to have compression. Never allow the engine to overheat to such an extent that the oil will be forced from the bearings by unusual expansion.

LUBRICATING SYSTEMS

One of the first lubricating systems used was the plain splash system, where the oil was poured into the crankcase and the connecting rods splashed in it. If the oil was at too low a level, the connecting rods could not splash it and the bearings would burn out. Or if too much oil was put in the crankcase, the connecting rods would splash too much oil onto the cylinder walls, so that an excessive amount would be carried into the combustion chamber and foul the spark plugs. A mechanical oiler was used with this system to keep the oil level constant, but as the engine would labor and heat up, it would use more oil and the mechan-

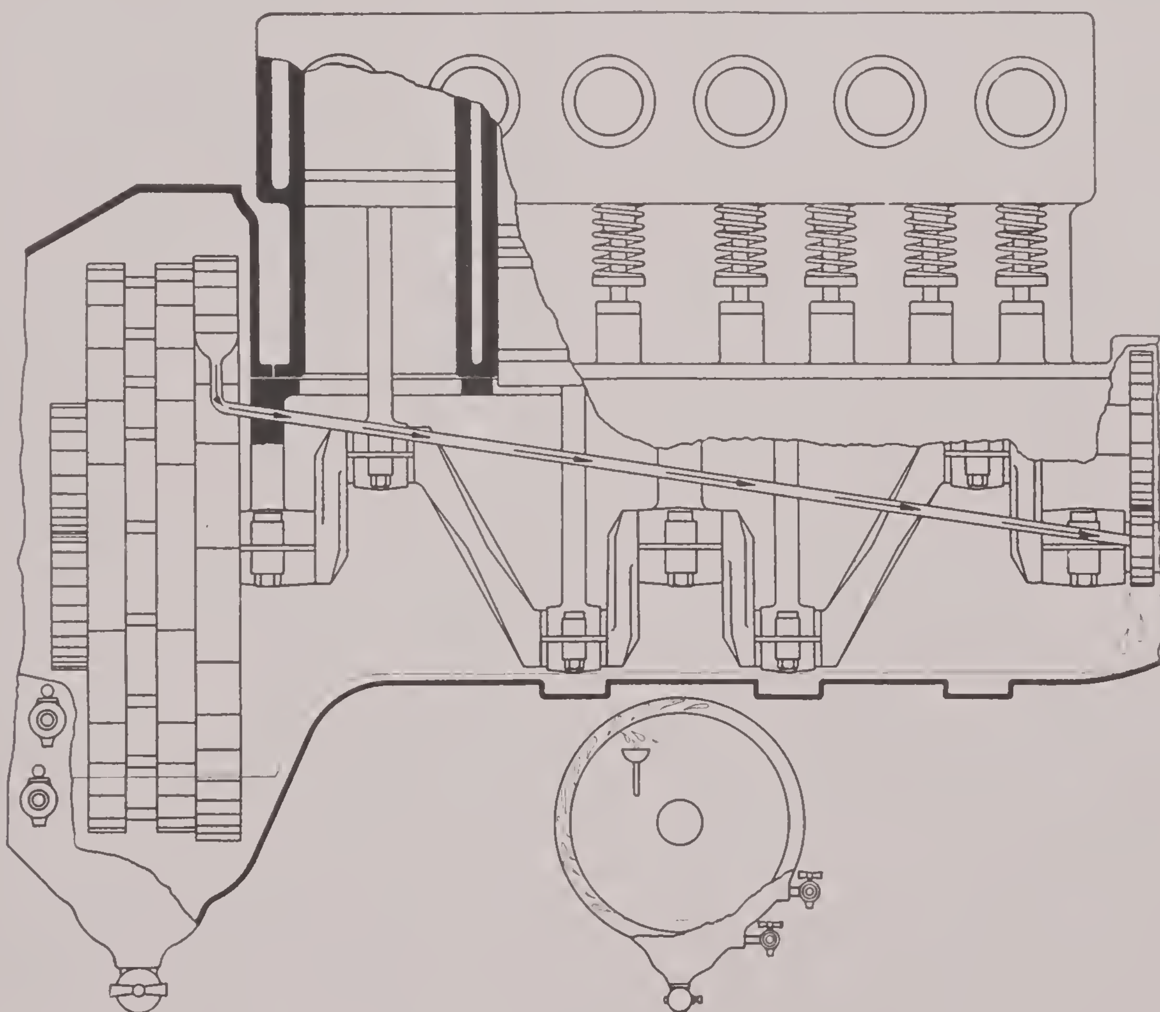


FIG. 58.

SPLASH CIRCULATING SYSTEM (FORD)

In this oiling system the oil is picked up from the oil sump by the revolving flywheel and dropped into the funnel at the end of the oil pipe. The oil flows through this pipe to the timing gears and then into the troughs where the connecting rods dip. As the troughs fill, the oil overflows into the oil sump. When the connecting rods splash the oil out of the troughs it is thrown onto the cylinder walls, piston pin bearings, crankshaft, camshaft bearings and tappets.

ical oiler would not keep the level high enough. The result was burned out bearings and scored cylinder walls.

SPLASH CIRCULATING SYSTEM (FORD)

The oil in this system is circulated by the flywheel, being carried to a funnel shaped tube, through which it is distributed to the different bearings and gears. The oil flows into troughs directly underneath the connecting rods where they splash it. The oil fills the troughs, then overflows and runs down into the oil sump. The main bearings, camshaft, piston, piston pins, and tappets are lubricated by the oil that is splashed and whirled around by the connecting rod, and also by the oil vapor in the crankcase, but as the pressure increases on these bearings, it forces the oil out, causing them to wear very rapidly.

SPLASH CIRCULATING OILING SYSTEM

In this oiling system there is a mechanically operated pump circulating the oil to the troughs for the connecting rods. The oil splashed by the connecting rods lubricates

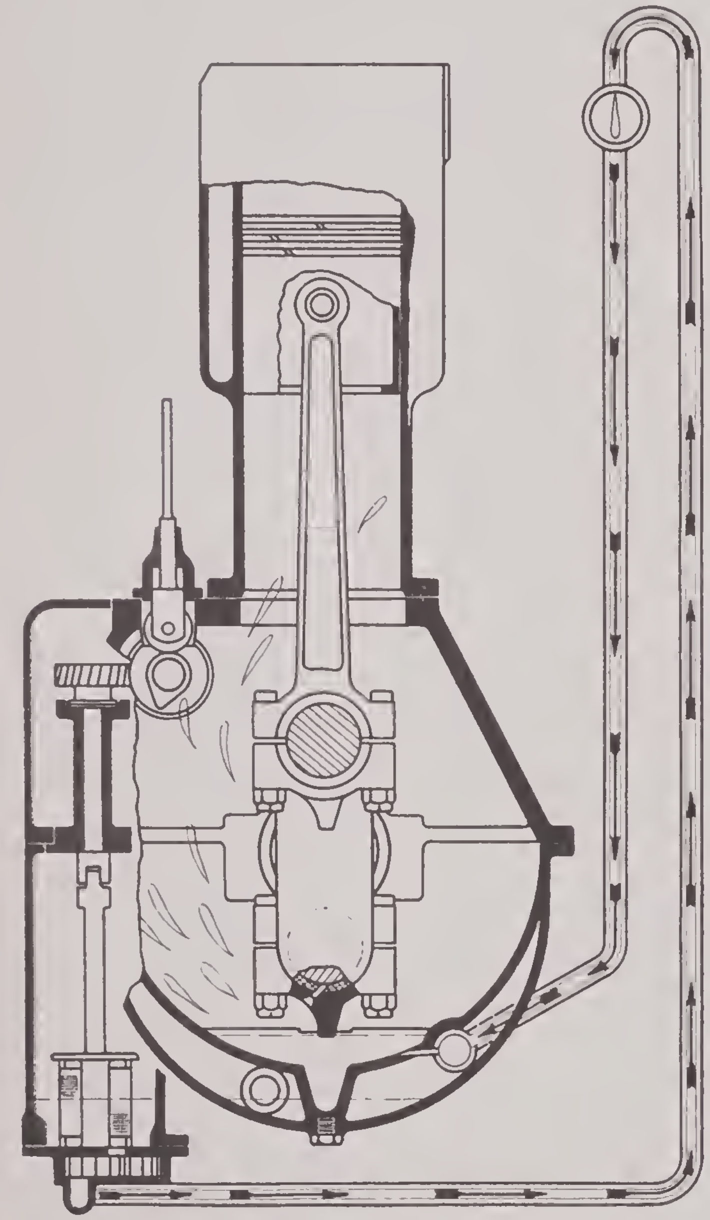


FIG. 59.

SPLASH CIRCULATING SYSTEM

In this oiling system the oil is circulated by a pump, to an indicator on the instrument board, then into the troughs under the connecting rods. The connecting rods dip into the oil in the troughs splashing the oil onto the main bearings, pistons, piston pins, tappets, and camshaft bearings.

The oil then flows into the oil sump to be circulated again by the pump.

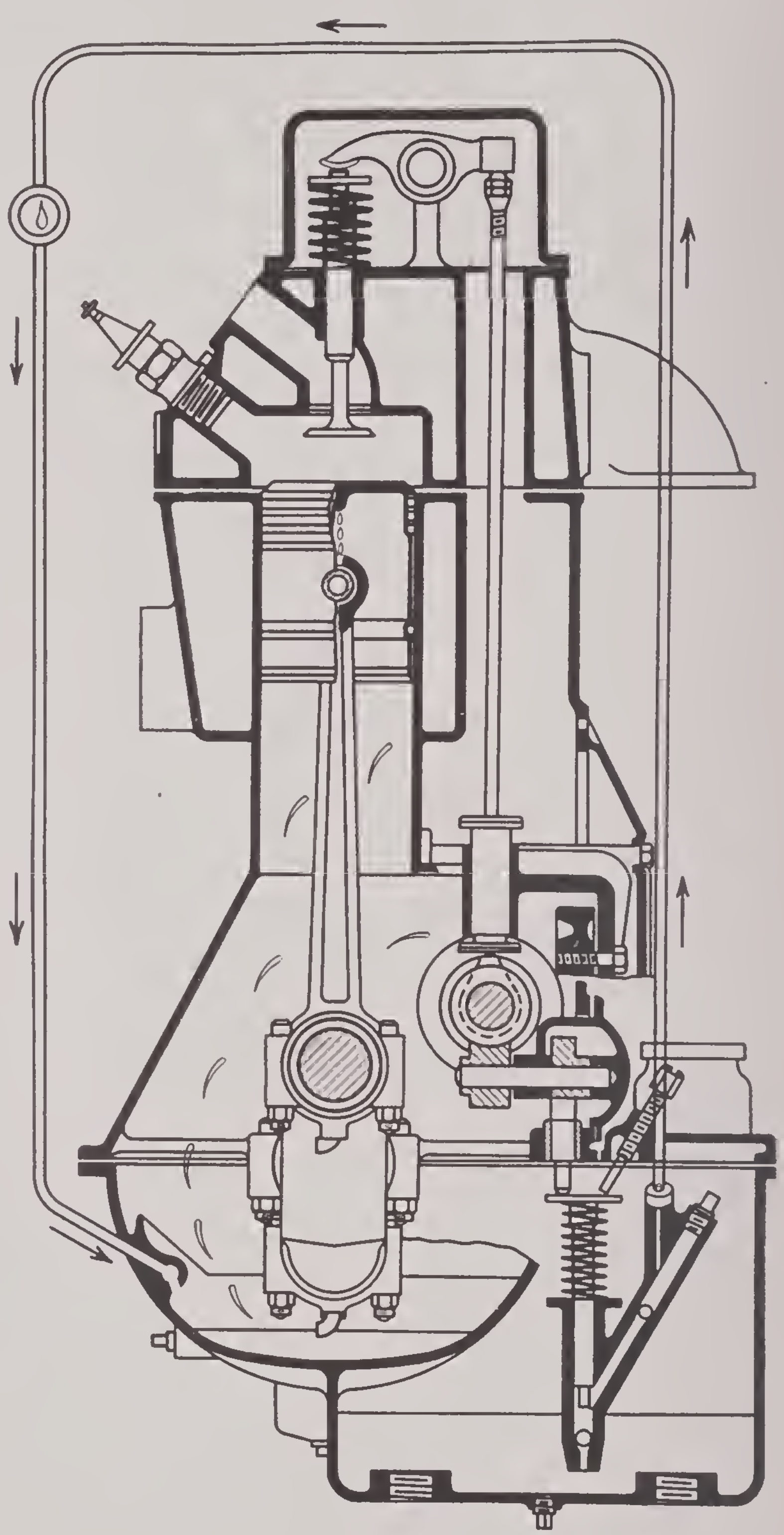


FIG. 60.

FORCE FEED AND SPLASH SYSTEM

In this system the pump circulates the oil onto the main bearings under pressure. The oil is thrown from the oil troughs by the connecting rods onto the pistons, piston pins, tappets, and camshaft. From there it flows into the troughs below the connecting rods; the connecting rod bearings are oiled by dipping into the troughs.

the piston, piston pin, camshaft, tappets, and the main bearings, then it overflows the troughs and drops into the oil sump to be circulated again by the pump. The circulating pump keeps the oil at a constant level at all times in the troughs. The connecting rods dip approximately 3/32″ into this oil. If they dip deeper, it will flood the cylinder walls, causing the spark plugs to foul, and also causing excessive carbon formation. Some type of indicator is used to indicate whether or not the oil is being circulated. A pressure gauge may be used, but on account of the oil pipes being open where they lead into the oil troughs, the pressure indicated will be very low. There are sight feed indicators used where the driver can see the oil passing through the glass tube. The oil level gauge which is placed in the pan indicates the amount of oil that is in the oil sump.

FORCE FEED AND SPLASH OILING SYSTEM

On this oiling system a mechanically operated pump of either the plunger or the gear type may be used to circulate the oil. The connecting rods receive the oil by dipping into the troughs, while the main bearings on the crankshaft are lubricated under pressure. The oil pipe leads directly onto the bearings, so with the heavy pressure, it can be seen that the oil will reach all the bearing surfaces more readily than if it came on by gravity.

The pressure gauge will indicate a higher

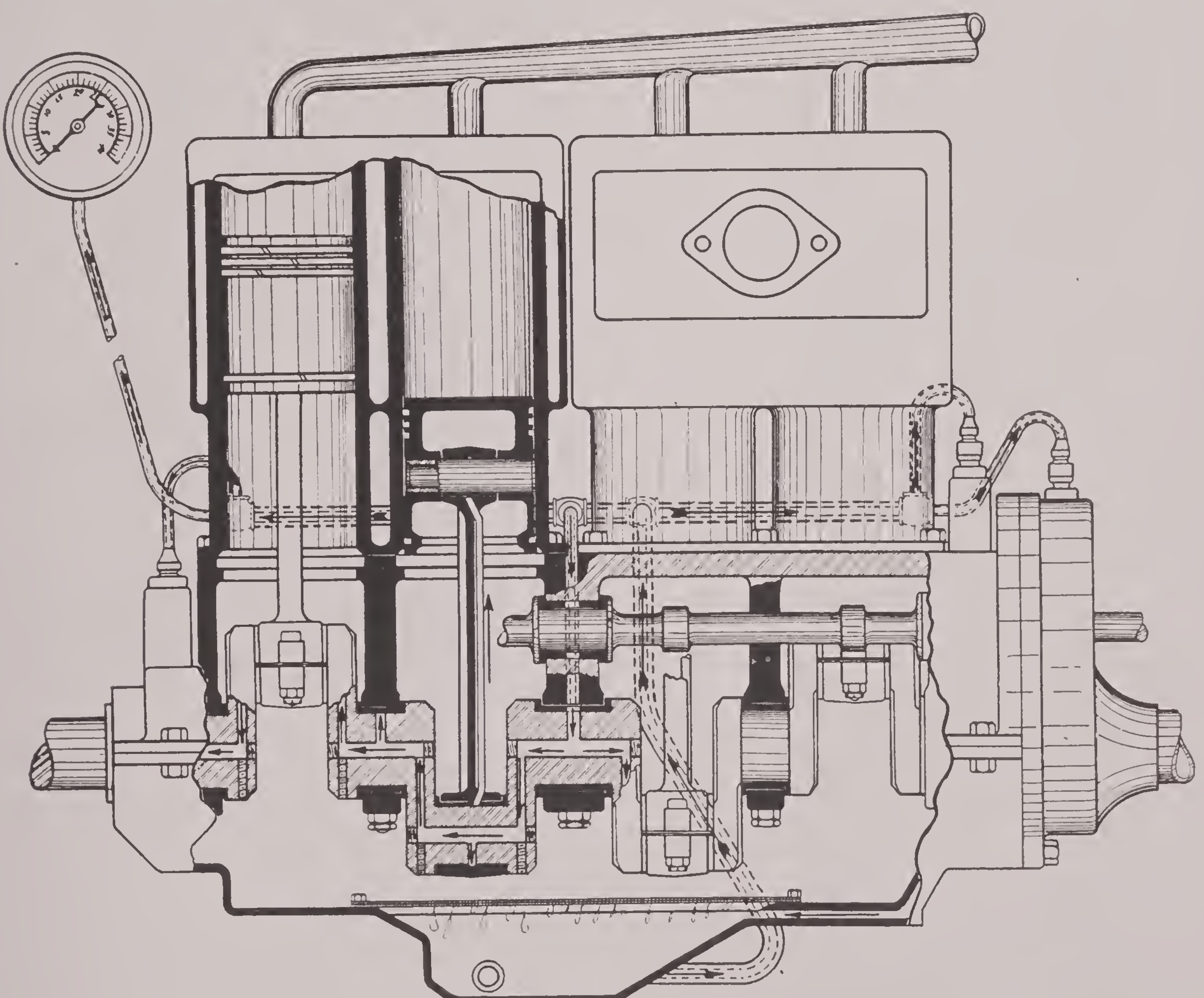


FIG. 61.

FULL FORCE FEED SYSTEM

Oil is forced by the pump direct to the crankshaft bearings and by means of drilled holes in the crank webs, to the crank pins, then through the oil pipe attached to the connecting rods, to the piston pins.

The pistons and cylinders are lubricated by the oil thrown from the lower end of the connecting rods. The oil then returns to the sump and is again circulated.

This is the only oiling system in which the oil is forced onto the piston pin under pressure.

pressure on this than on the previous system. To prevent the bearings from receiving excessive oil there is a by-pass provided in the outlet so that when the pressure reaches a predetermined point, a safety valve, which is adjustable, will open and allow the excessive oil to pass back into the oil sump without going onto the bearings. This also prevents excessive oil from reaching the cylinder wall.

FORCE FEED OILING SYSTEM

On the pressure oiling system, a mechanically operated pump draws the oil from the oil sump, circulates it through pipes to the main bearings on the crankshaft. The crankshaft is drilled, the holes leading to the crank

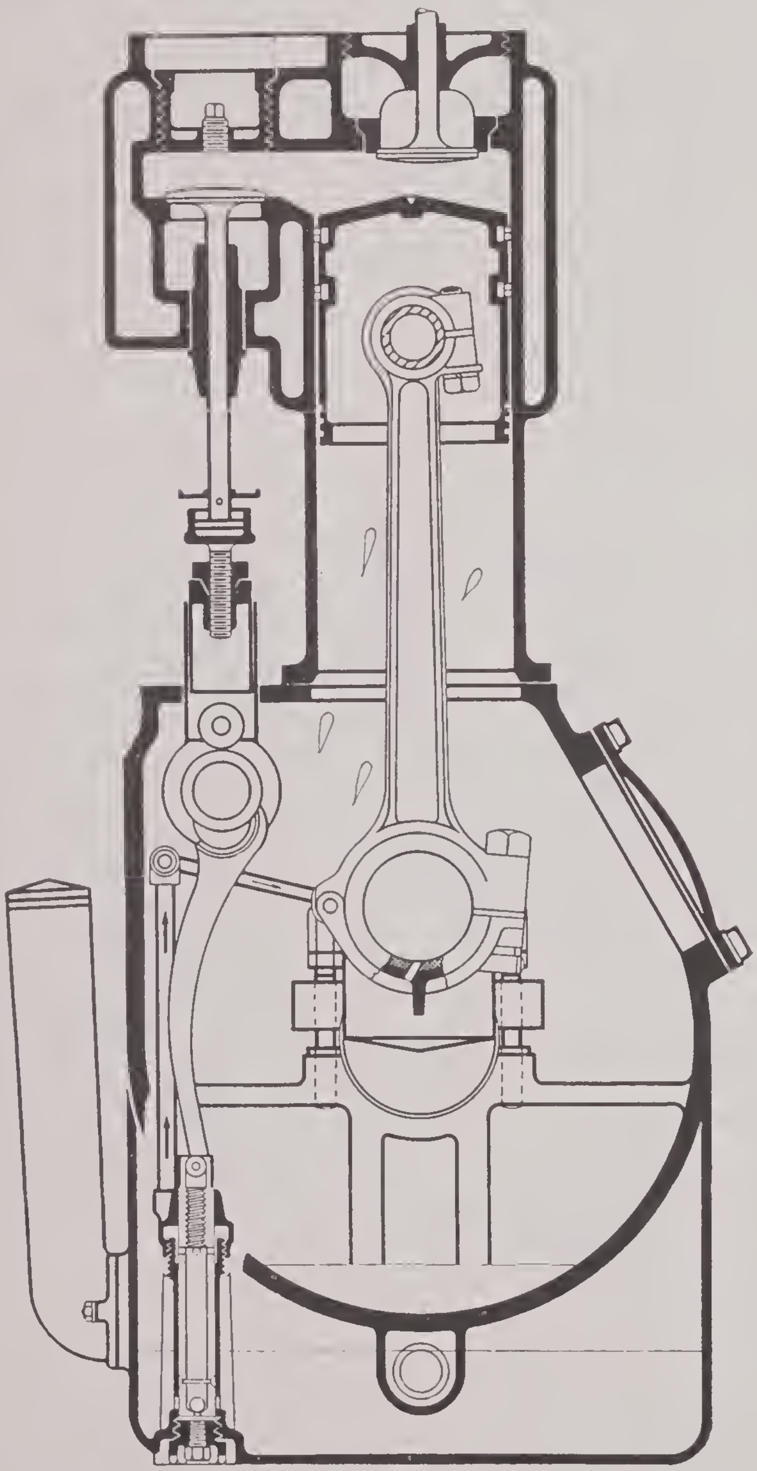


FIG. 63.

FORCE FEED AND SPLASH SYSTEM

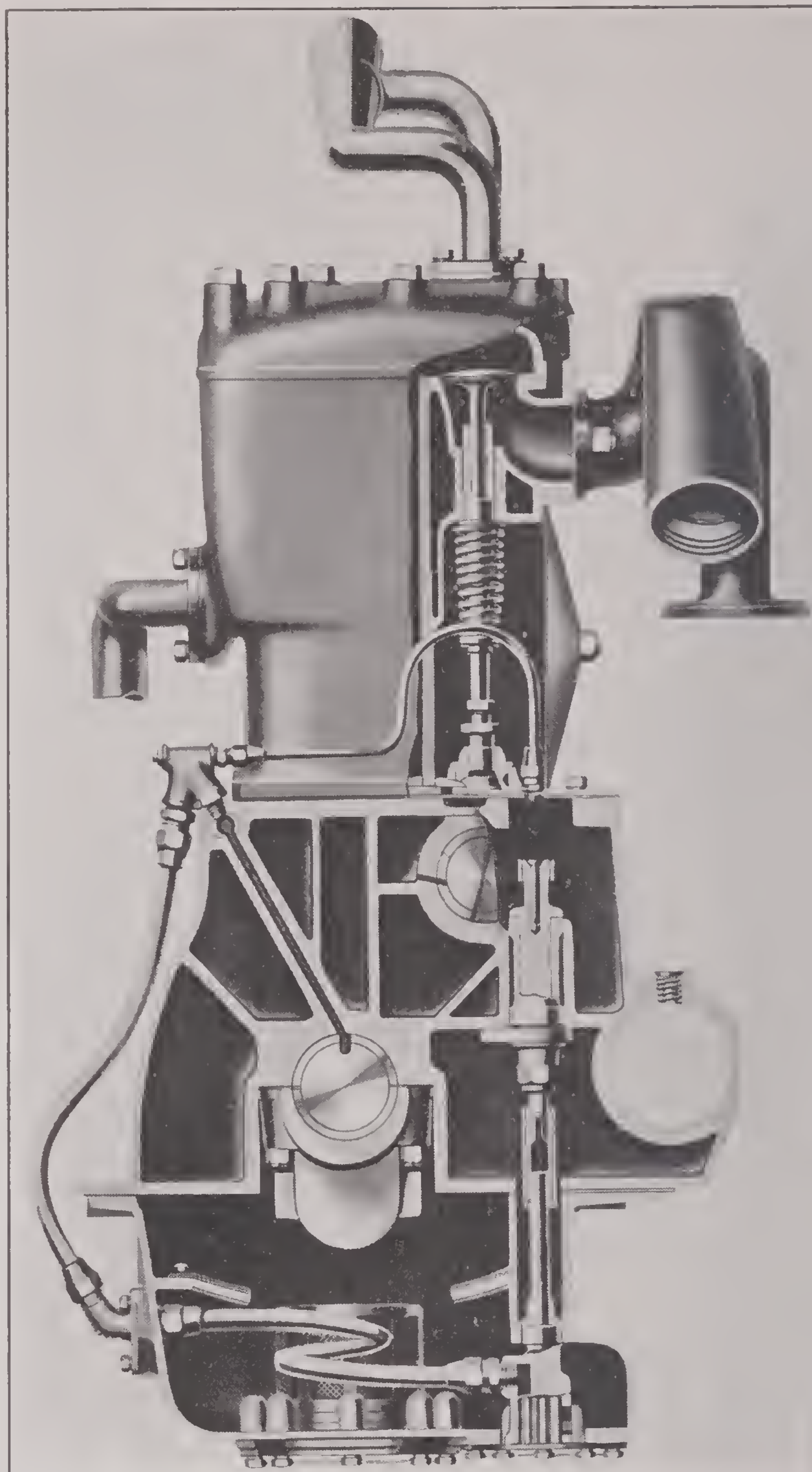


FIG. 62.

FORCE FEED LUBRICATING SYSTEM

The oil is drawn from the oil sump into the pump and is carried around by the teeth on the gears and forced out to a pipe through the crankcase. The oil passes through this pipe to the main bearings, then through drilled holes in the crankshaft to the rod bearings. Through another pipe the oil is forced into a recess located around and above the camshaft. From there the oil feeds by gravity to the camshaft bearings and timing gears. The piston, piston pin and cylinder walls, etc., are lubricated by the oil vapor which is thrown around by the rod bearings.

The extra oil drains back into the oil sump where it is again circulated through the engine. The connecting rods do not dip in the oil.

With this construction the oil screen can be removed and cleaned, also the pump can be removed and adjustments or replacements made without removing the oil pan.

pin bearings, so that when the oil from the oil pipe comes onto the main bearings it lubricates the main bearings, then as each small hole that is drilled in the crankshaft comes in line with the oil pipe, the oil, being under high pressure, is forced into the hollow crankshaft and through it onto the crank pin bearings.

The regulating by-pass is more essential on this system than on the others, to prevent excessive oil from getting onto the cylinder walls. Where the pressure oiling system is used the connecting rods and main bearings are usually not fitted with shims, as the oil would get by the shims and flood the cylinders. Some pressure oiling systems are constructed with a tube fastened onto the connecting rod, which leads from the crank pin bearing up to the piston pin, so that when the hole in the crank pin lines up with this tube the oil will be forced up through the tube onto the piston pin. The latter system is called the full force feed oiling system.

Some manufacturers have improved on this system by lubricating the camshaft bearings under pressure; or the oil may first be forced through a hollow camshaft, lubricating its bearings and then forced onto the main bearings and connecting rods. With the full pressure oiling system, the bearings retain their proper fit for a longer period, because at all times there is a positive feed of oil to the bearings. The pressure usually carried in the full pressure oiling system is about thirty pounds, although on racing and aircraft engines the pressure may be as high as one hundred pounds.

Oil Level Regulation

On some engines the oil troughs are hinged and their position is governed by the different engine speeds; so that as the engine speeds up the connecting rods will dip deeper into the oil, and as the engine slows down they will

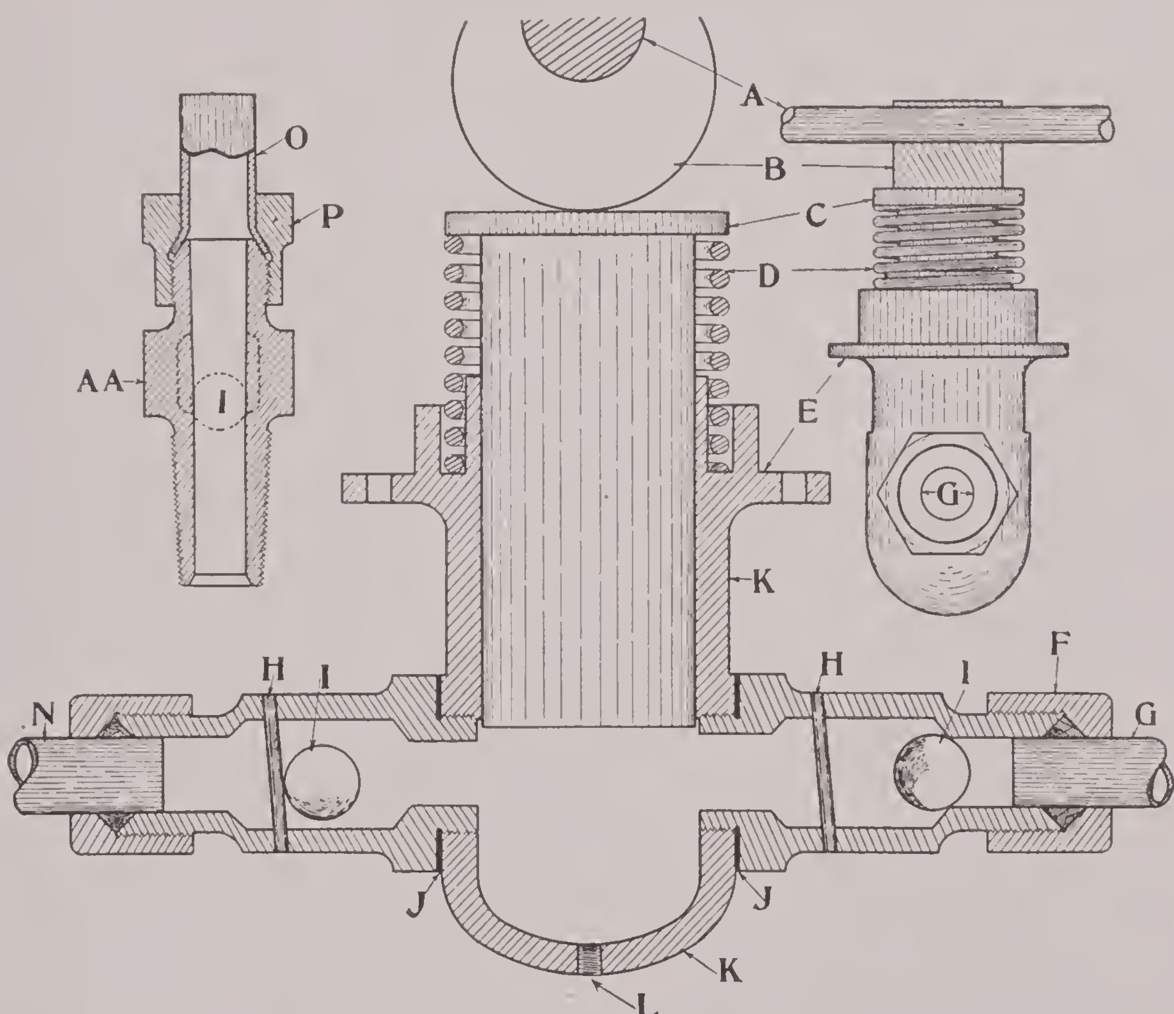


FIG. 64.

PLUNGER OIL PUMP

A. Camshaft.
B. Eccentric.
C. Plunger or piston.
D. Plunger spring.
E. Pump housing flange.
F. Packing gland nut.
G. Inlet pipe.
H. Ball check valve stop pin.
I. Ball check valves.
J. Gaskets.
K. Pump housing.
L. Opening for drain cock.
N. Outlet pipe.
O. Copper tubing.
P. Coupling nut.
AA. Flared tube coupling.

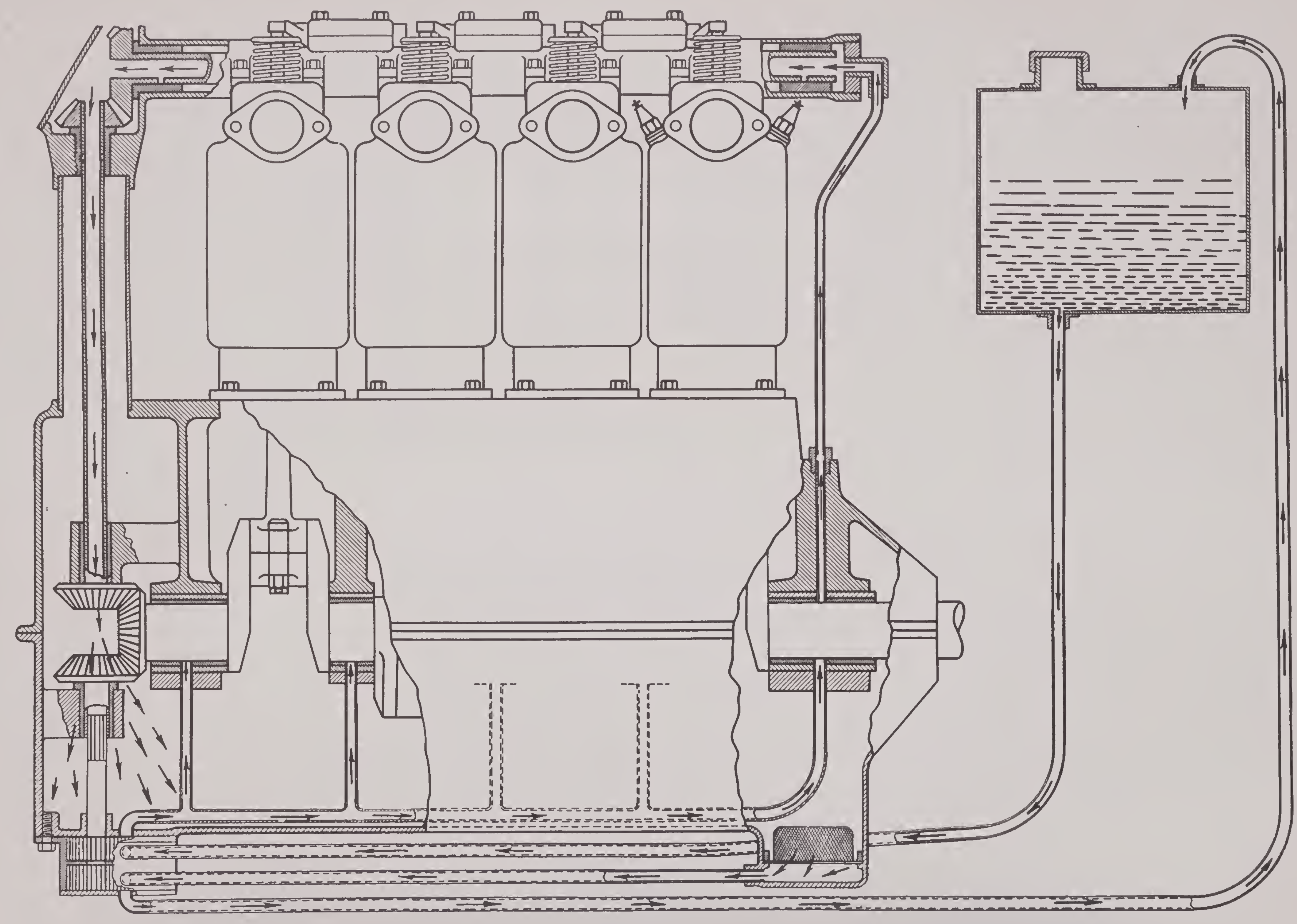


FIG. 65.
FORCE FEED OILING SYSTEM—DRY SUMP

(See next page)

FORCE FEED OILING SYSTEM—DRY SUMP

FIG. 65.

(See Opposite Page)

In this system the oil is drawn from the tank by the upper pump and distributed through the feed pipe to the main bearings under pressure and then through the hollow crankshaft onto the connecting rod bearings. The oil is then thrown onto the cylinder walls and piston pins. The extra oil drops down into the oil sump. An oil pipe carries some of the oil into the hollow overhead camshaft and through small holes onto its bearings. The extra oil passes through the camshaft housing onto the bevel timing gears and down through the vertical shaft and housing onto the lower bevel gears, then into the oil sump. From there the oil passes through the screen and into the lower pump which forces it up into the tank again.

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not dip as deeply. There is an oil level gauge provided on the oil pans to indicate the amount of oil that is in the crankcase. Always keep the oil above the low level mark, but never above the high level mark. Should the oil be above the high level mark, the connecting rods would dip too deep into the oil, flooding the cylinders and causing the spark plugs to foul and misfire.

OIL PUMPS

The purpose of the oil pump in the internal combustion engine is to circulate the oil to the different bearings in the engine where it will overflow and drop back into the oil sump to be circulated again. The oil pumps that are used are of two distinct types, the plunger pump and the gear pump. The plunger pump necessitates a reciprocating drive, while the gear pump necessitates a revolving drive.

Plunger Pump

The plunger pump is the easier to install and does not necessitate gears. It is usually driven from the camshaft by means of an

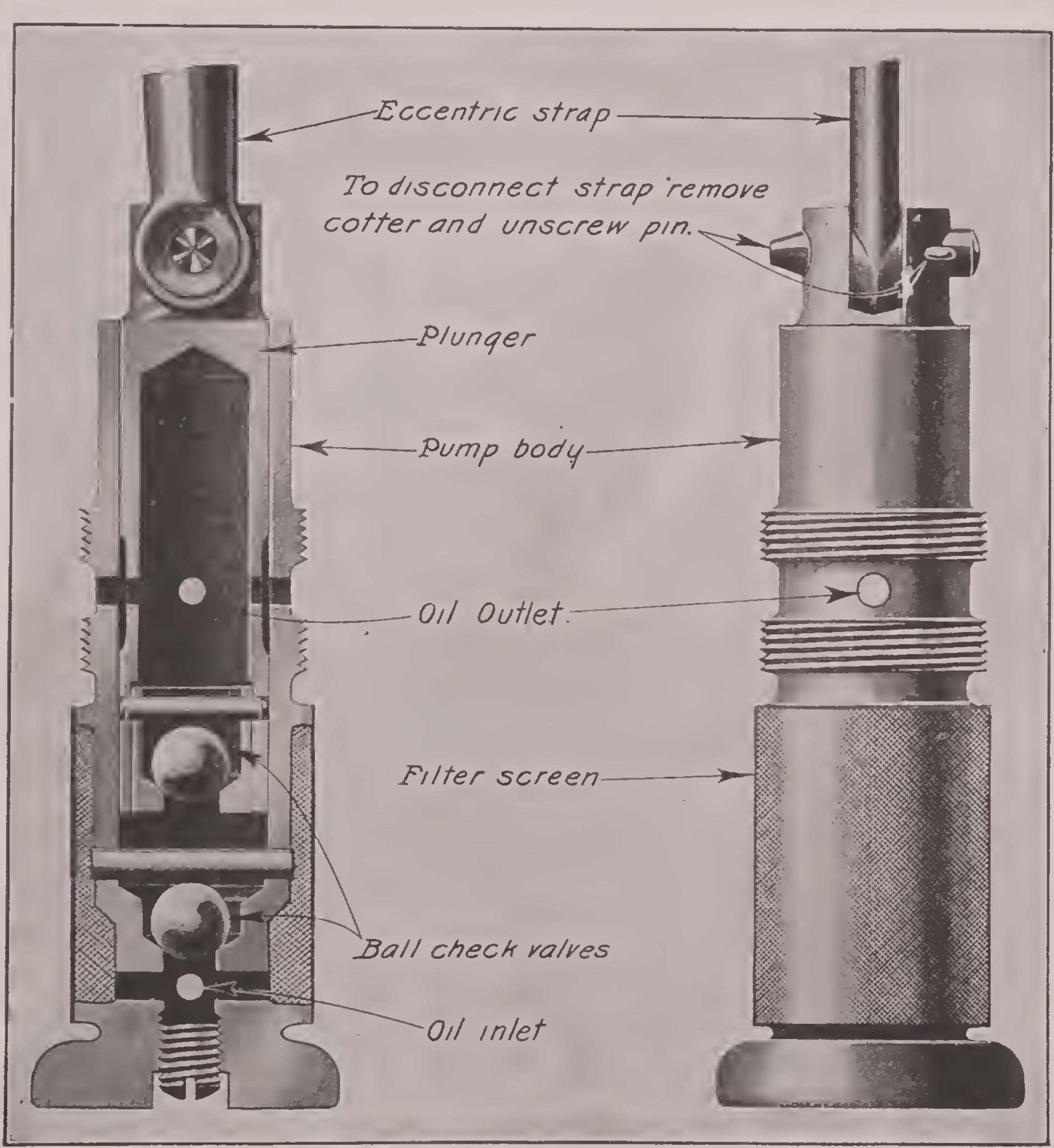

FIG. 66.

PLUNGER OIL PUMP

eccentric. This eccentric is round, but being set off the center of the camshaft imparts a reciprocating motion to the plunger. The plunger sets into the pump body, fitting snugly, and has a stiff spring resting against a shoulder on it to keep it against the eccentric. The eccentric forces the plunger down while the spring forces it up as the eccentric revolves. There may be either one or two check valves in the pump. One allows the oil to enter the pump, the other allows it to flow out. These pumps should be placed down in the oil, or at least below the oil level, otherwise at times they may drain, necessitating priming before starting. They may be placed on the side of the crankcase as close to the camshaft as possible. In assemblies of this kind it is advisable when the engine starts, to see that pressure is registered on the pressure gauge, or that the oil is circulating through the sight feed on the dash. Oil pipes leading to and away from the pump should be air tight, especially on the inlet. If this pipe leaks the pump will draw air instead of oil. The plunger should be a snug fit in the housing.

Gear Pump

The gear pump has two gears on the interior and is driven by a shaft. The capacity of a gear pump depends upon the speed at which it is driven, the width of the face of the gears, the number of teeth in the gears, and the spacing of the teeth, also the closeness with which the gears fit the housing. It is the space between the teeth that acts as the oil conveyors. The oil is carried from the oil inlet around the outside of the gears to the opposite side and then forced out the outlet. A gear pump will circulate a greater quantity of oil than the plunger pump, but will not draw oil as far. The plunger pump is the better suction pump of the two. Keep the pump shaft and the gears fitting snugly in the housing to prevent leakage. The

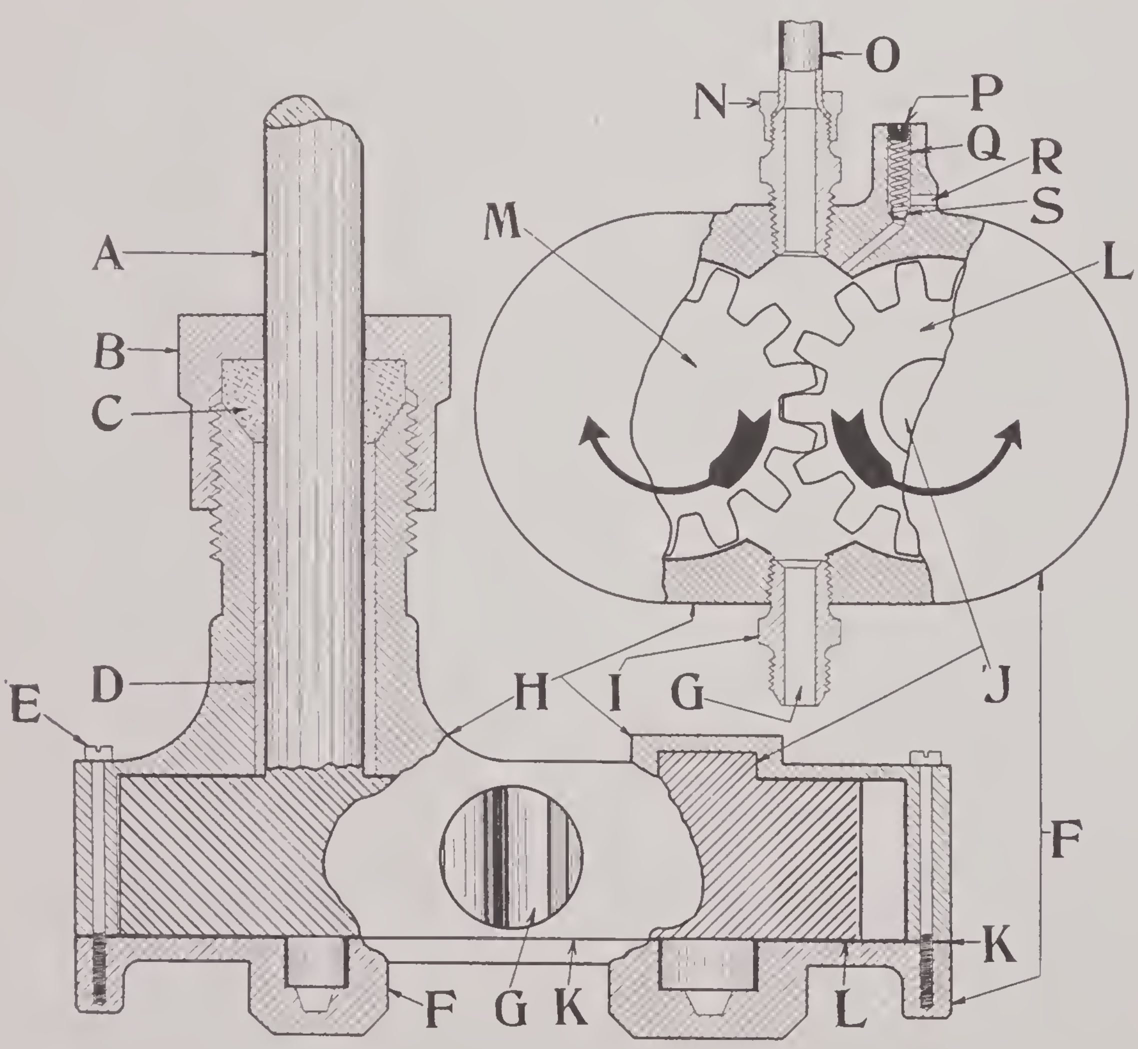

FIG. 67.

GEAR OIL PUMP

A. Pumpshaft.
B. Packing nut.
C. Packing.
D. Removable bushing.
E. Body screw.
F. Pump base.
G. Oil inlet.
H. Pump body.
I. Coupling.
J. Idler gear pin.
K. Gasket.
L. Idler gear.
M. Drive gear.
N. Coupling nut.
O. Outlet pipe.
P. Pressure regulating screw.
Q. By-pass valve spring.
R. By-pass outlet.
S. By-pass valve.

heavier the oil the higher the pressure will be. If the oil pump should be on the exterior of the engine, it will necessitate a packing box or packing nut to prevent the oil from being forced out around the pump shaft. This packing nut should be packed with candle wick or braided cotton, made especially for this purpose and well saturated with graphite. The graphite prevents the shaft from wearing excessively and also will keep the packing soft. Adjust the packing nut just tight enough to prevent leakage.

FUEL SYSTEM

There are several types of fuel systems used to feed the gasoline from the main gasoline supply tank to the carburetor. The simplest and best known is the gravity system. In the gravity system the gasoline tank is placed above the carburetor so that the gasoline level in the float chamber can be kept constant by the weight of the liquid. There are baffle plates provided on the interior of the tank to prevent splashing of the gasoline. To allow the gasoline to flow down into the carburetor, it is necessary that a hole be drilled in the filler cap as an air vent so that air may enter the tank as the gasoline flows out. If no vent is provided the gasoline will not flow.

Where the main gasoline tank is lower than the carburetor either a pressure or vacuum system is necessary. The tank being lower, the gasoline must be lifted to supply the carburetor. In the pressure system the pressure must not be above five pounds, as any pressure above may force the float needle valve in the carburetor away from its seat and the gasoline would overflow the spray nozzle. The gasoline would then be picked up by the inrushing air making the mixture too rich and cause misfiring.

There is a safety valve provided either in the tank or close to the pressure pump, by which the pressure can be regulated. When the pressure reaches the point to which the valve has been adjusted the valve will open and allow the excessive air to escape. The pump used for this pressure system is usually a plunger pump and driven by the engine.

The filler cap of the main gasoline tank in the pressure system has no holes drilled in it but seats on a gasket to make the tank air tight. An auxiliary hand pump and pressure gauge are usually provided. If for some rea-

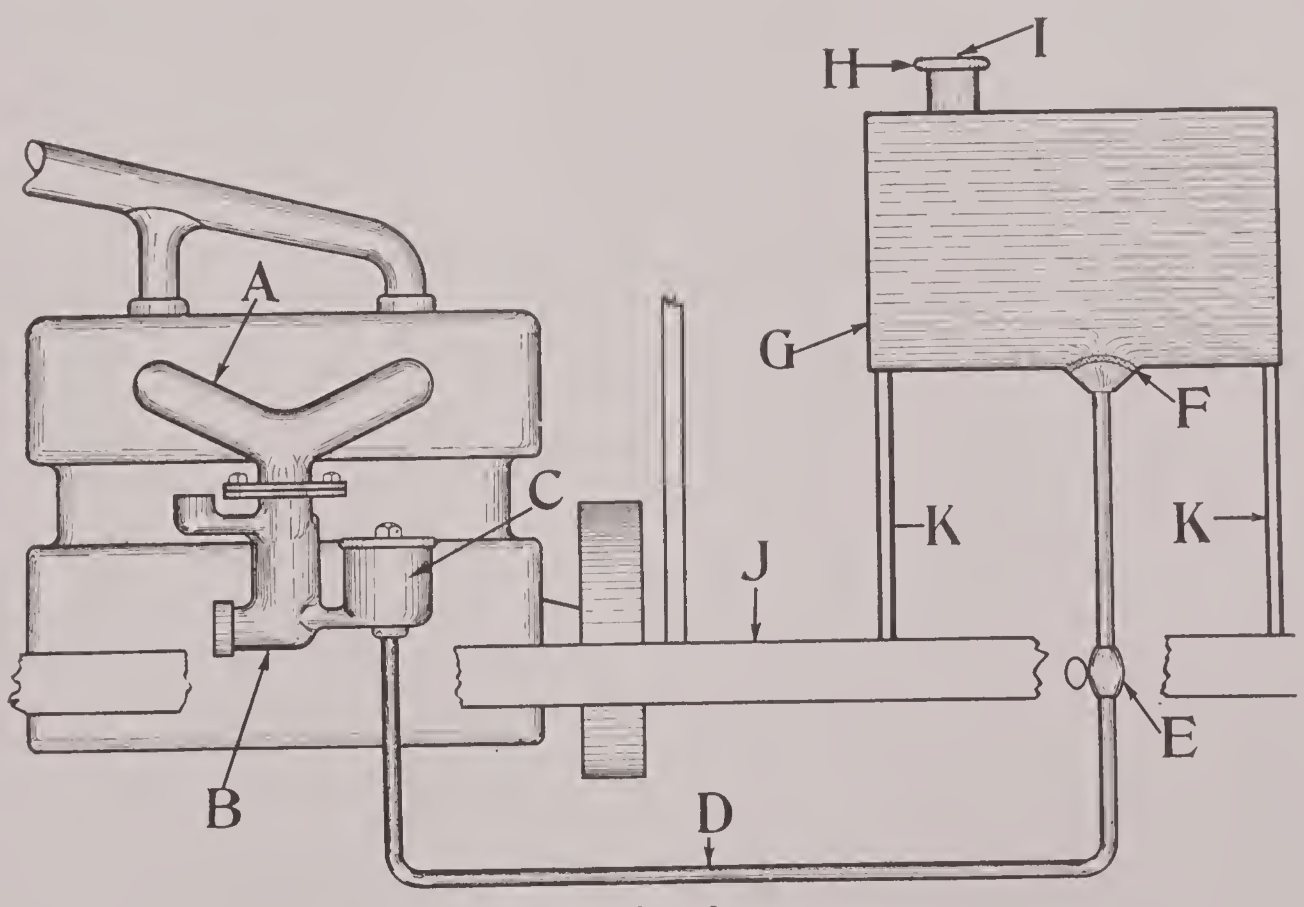

FIG. 68.

GRAVITY FUEL SYSTEM

A. Inlet manifold.
B. Carburetor.
C. Float chamber.
D. Fuel pipe.
E. Shut off valve.
F. Screen.
G. Fuel tank.
H. Filler cap.
I. Air vent hole.
J. Car frame.
K. Fuel tank supports.

son the pressure drops too low, the hand pump may be employed to restore or maintain the necessary pressure.

Another fuel system is the vacuum system. One of the vacuum systems depends upon the vacuum that is produced in the inlet manifold to draw the gasoline from the main supply tank, which may be located below the carburetor level. This type of vacuum system works very successfully on the automobile engine, but not as successfully on high speed engines, or any engine that runs at a constant speed on a wide open throttle, because when the throttle valve of the carburetor is wide open, the vacuum in the inlet manifold decreases and will draw less gasoline at the time when the engine needs the most.

The gasoline tank on the vacuum system must have an air vent in the filler cap. There must be no air leaks in the pipes. On the pressure system air would escape through the leaks instead of entering the tank, but on the vacuum system air will be drawn through the pipes instead of gasoline.

In the gasoline line there is a strainer to prevent dirt from passing into the tank and into the carburetor. This dirt would plug up the passages, causing the mixture to be too lean, and may prevent the engine from running. There is usually a sediment chamber provided in the gasoline line so that dirt of any kind that passes through the pipes will settle in it. This chamber and screen should be removed occasionally and the dirt cleaned out. Dirt in the gasoline line may cause the engine to misfire or back-fire through the carburetor.

VACUUM TANK

The vacuum tank commonly used on automobiles consists of two chambers, the upper

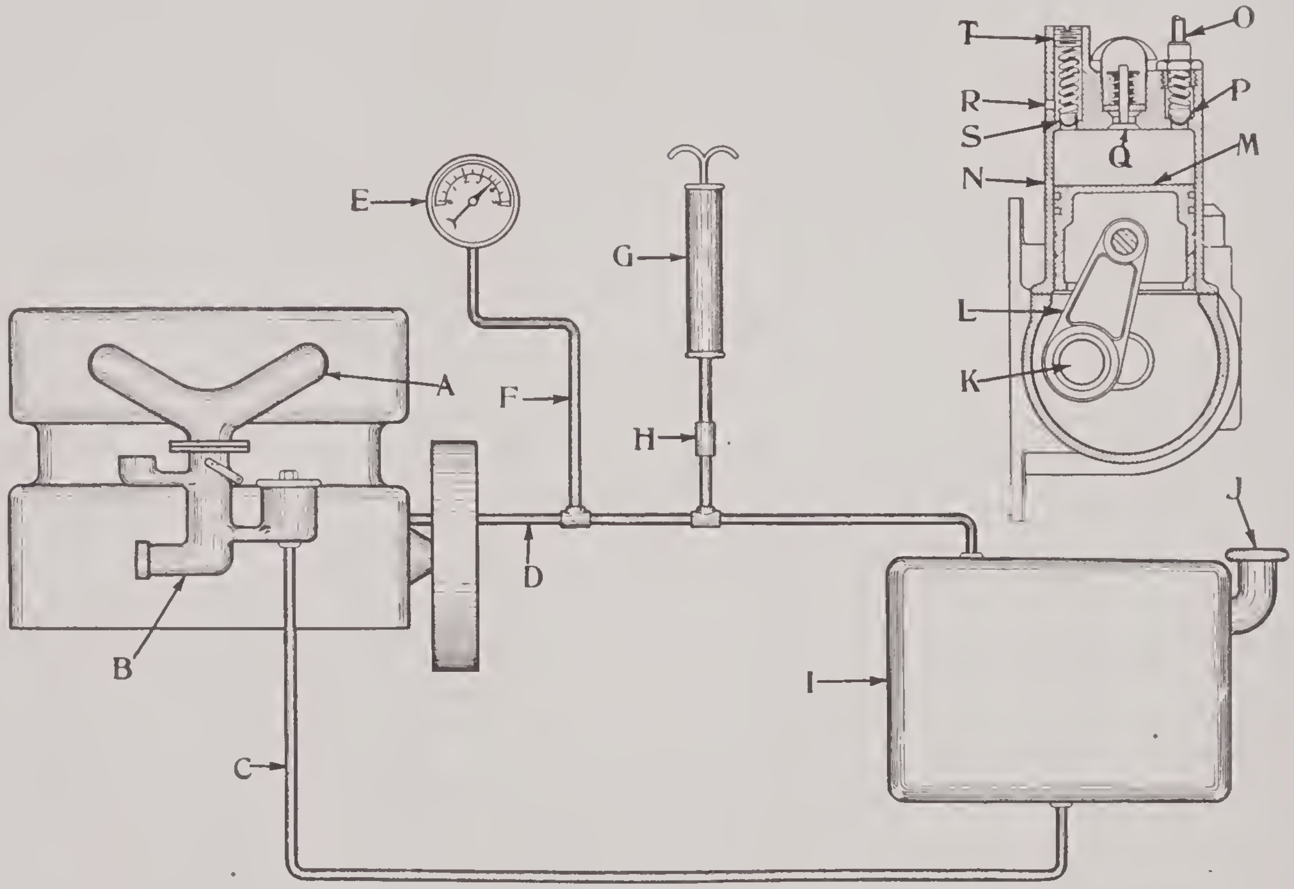

FIG. 69.

PRESSURE FUEL SYSTEM

A. Inlet manifold.
B. Carburetor.
C. Fuel pipe.
D. Air pipe from pressure pump.
E. Pressure gauge.
F. Air pipe.
G. Hand air pump.
H. Check valve.
I. Fuel tank.
J. Filler cap.
K. Pump crankshaft.
L. Connecting rod.
M. Piston.
N. Cylinder.
O. Air pipe to the fuel tank.
P. Check valve.
Q. Air inlet valve.
R. Relief port.
S. Safety valve.
T. Pressure regulating screw.

For this fuel system to operate properly it is necessary for all joints and connections to be air tight. The required pressure is about five pounds. This pressure is maintained by the air pump driven by the engine. The hand pump (G) is used to force air into the tank to supply enough gasoline to the carburetor to start the engine or maintain the necessary pressure. Pressure regulator (T) is provided to keep the pressure in the tank constant, which is necessary as the carburetors will not operate under a higher pressure.

and lower, the upper acting as a filling chamber and the lower acting as a gravity supply tank. The upper chamber has four openings in the top and contains the float and operating mechanism. From one opening a pipe extends back to the gasoline tank at the rear of the car. This is the gasoline inlet. From another opening a pipe leads to the inlet manifold which allows the vacuum to extend into the upper chamber. In the third opening is a pipe, bent in the form of a half circle, which allows air at atmospheric pressure to enter the two chambers. Into the fourth opening a filler plug is threaded.

The lower chamber is usually provided with three openings; one at the top and two at the bottom. This chamber supplies the gasoline by gravity to the carburetor as it is required. The lower chamber must be under atmospheric pressure at all times, to allow the fuel to flow

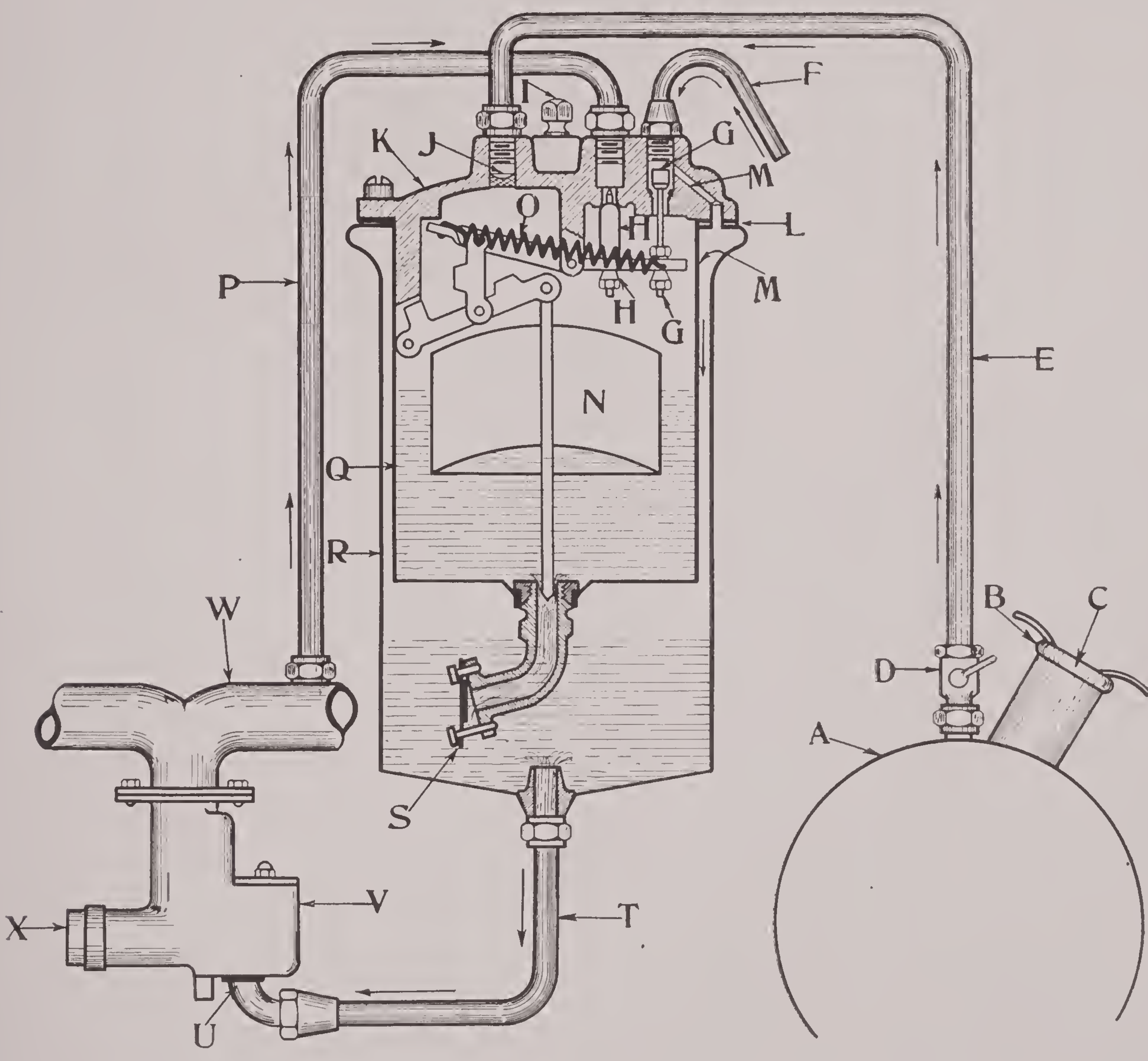

FIG. 70.

VACUUM FUEL SYSTEM WITH AN ENLARGED VIEW OF VACUUM TANK

A. Main fuel tank.
B. Filler cap.
C. Vent hole.
D. Valve.
E. Fuel pipe.
F. Vent pipe.
G. Atmospheric valve.
H. Vacuum valve.
I. Filler plug.
J. Screen.
K. Cover.
L. Gasket.
M. Air passage.
N. Metal float.
O. Toggle springs.
P. Vacuum pipe.
Q. Upper chamber or vacuum tank.
R. Lower chamber or gravity tank.
S. Flapper valve.
T. Fuel pipe to carburetor.
U. Fuel inlet to carburetor.
V. Float chamber.
W. Inlet manifold.
X. Carburetor air inlet.

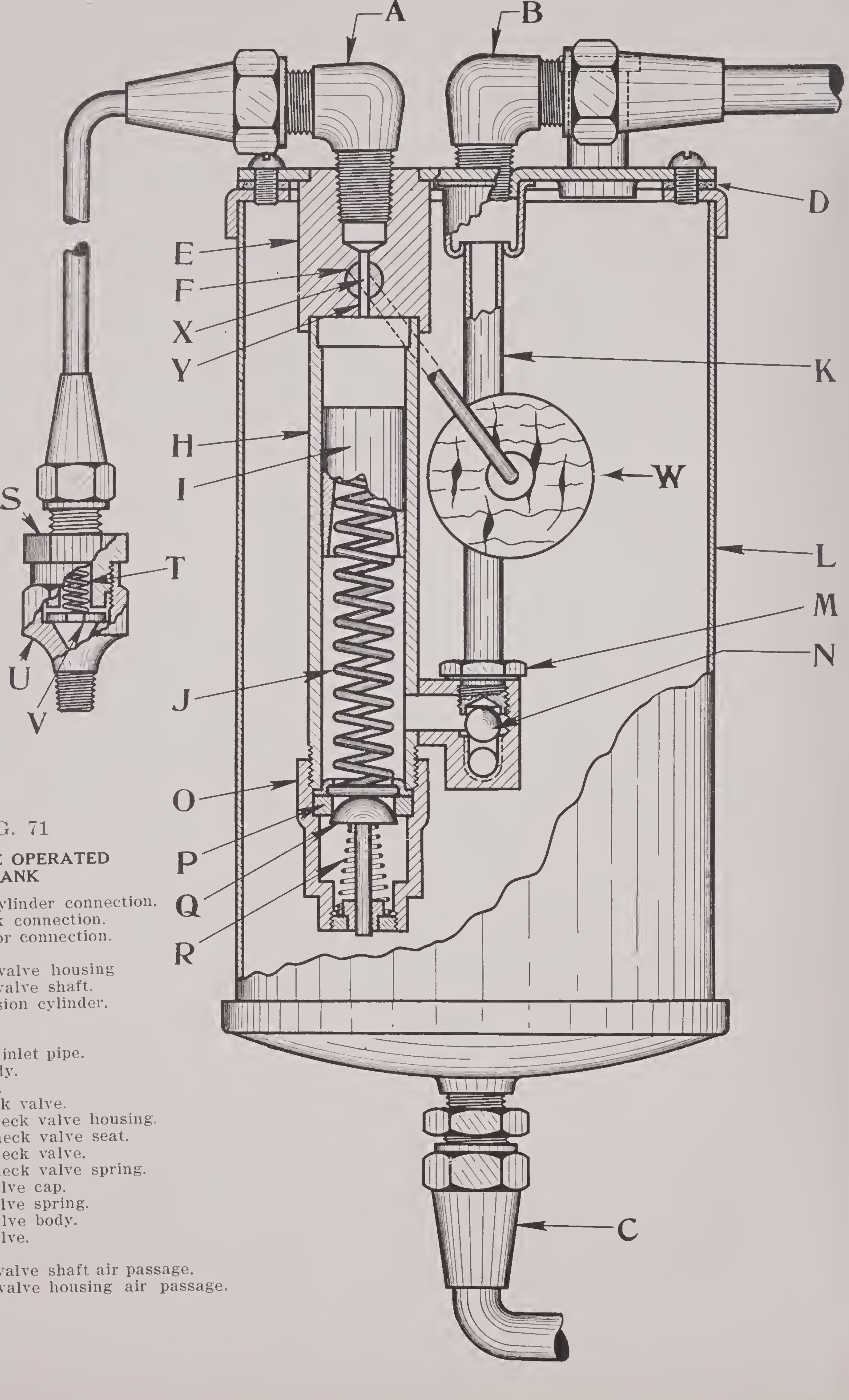

FIG. 71

PRESSURE OPERATED TANK

A. Engine cylinder connection.
B. Fuel tank connection.
C. Carburetor connection.
D. Gasket.
E. Shut-off valve housing
F. Shut-off valve shaft.
H. Compression cylinder.
I. Piston.
J. Spring.
K. Gasoline inlet pipe.
L. Tank body.
M. Lock nut.
N. Ball check valve.
O. Outlet check valve housing.
P. Outlet check valve seat.
Q. Outlet check valve.
R. Outlet check valve spring.
S. Check valve cap.
T. Check valve spring.
U. Check valve body.
V. Check valve.
W. Float.
X. Shut-off valve shaft air passage.
Y. Shut-off valve housing air passage.

from it by gravity. Atmospheric pressure is maintained through the space between the two chambers, and an air passage which connects the lower chamber to the air vent that enters the upper chamber. From one of the openings at the bottom of the lower chamber, a pipe leads to the carburetor and in the other opening a drain plug or valve may be provided.

Operation

(See Fig. 70)

Consider that the float (N) is at the bottom with the atmospheric valve (G) closed and the vacuum valve (H) open. The suction from the manifold produces a vacuum which draws the gasoline from the gasoline tank through the fuel pipe (E) into the upper chamber. As the gasoline level rises in the upper chamber, the float (N) moves up and acting through levers and springs opens the atmospheric valve (G) and closes the vacuum valve (H). Since the suction is now cut off, the gasoline in the upper chamber will flow into the lower chamber by gravity, due to atmospheric pressure in both chambers. When the gasoline level lowers to a certain point, the float mechanism will close the atmospheric valve again and open the vacuum valve. The vacuum produced in the upper chamber will now draw the gasoline from the gasoline tank into the upper chamber, as before.

Troubles

In the vacuum tank, if the float is punctured or stuck-down and does not move up when the gasoline reaches its maximum level, the air valve will remain closed and the vacuum valve open, and the gasoline from the main fuel tank will continue to be drawn into the upper chamber, then into the manifold, flooding the cylinders with gasoline.

If the connections are not air tight, or if the air valve does not seat properly, the suction from the manifold will draw air from the outside instead of gasoline from the tank, causing backfiring in the carburetor and misfiring due to a lean mixture. Back-firing in the inlet manifold may cause the gasoline to be forced out through the air vent at the top of the tank.

The vacuum valve prevents air from entering the inlet manifold through the upper chamber during the time the gasoline is flowing from the upper to the lower chamber, thus preventing a lean mixture or back-firing.

Sometimes when the car stands idle the gasoline will drain from the vacuum tank, due to loose connections or obstructions under the carburetor float needle valve. When this occurs it is necessary to prime the tank before starting. This is accomplished on some cars by a hand pump, while in others it is accomplished by removing the primer plug and pouring in sufficient gasoline.

PRESSURE OPERATED TANK

The pressure operated tank was designed to be used in place of the conventional vacuum tank in a vacuum fuel system. The vacuum tank, operated by the negative pressure or vacuum in the inlet manifold above the throttle valve, has a tendency to keep an insufficient supply of gasoline in the tank at the higher engine speeds. At the high speeds when the engine demands the maximum amount of gasoline, there is a minimum negative pressure or vacuum in the manifold, which results in a sluggish action of the vacuum tank. The pressure operated tank is actuated by the combustion pressure in the cylinder and will operate and supply gasoline in direct proportion to the engine speed.

Operation

(See Fig. 71)

The check valve body (U) is threaded into the cylinder head. The pipe from (B) extends back to the main fuel tank at the rear of the chassis. The main tank has an air vent so that it is at atmospheric pressure. The small tank has an air vent also, and being mounted above the carburetor allows the gasoline to flow by gravity to the float chamber of the carburetor, through the connection at (C).

When the float (W) is down, the air passages (X) and (Y) are in line, so that the explosive pressure from the combustion chamber acts upon the piston (I), forcing it downward and compressing the spring (J). At the completion of the power and exhaust strokes, when the pressure in the combustion chamber lowers to that of the atmosphere, the spring (J) forces the piston (I) upward, causing a vacuum in the cylinder (H) below the piston. The ball check valve (N) is then forced from its seat by the gasoline in the inlet pipe (K), which is under atmospheric pressure in the main gasoline tank, and rushes in to fill up the cylinder (H) until the pressures are balanced.

The next explosion in the combustion chamber forces the piston (I) downward again, closing the check valve (N) and opening the valve (Q), forcing the gasoline out of the cylinder (H) into the tank. The float (W) rises and falls with the level of gasoline in the tank. As it rises it turns the shut-off valve shaft (F), throwing the air passages (X) and (Y) out of line, shutting off communication between the combustion chamber and the cylinder (H). When the gasoline level lowers enough, the shaft (F) turns until the air passages are in line again, when the operations in the tank are repeated.

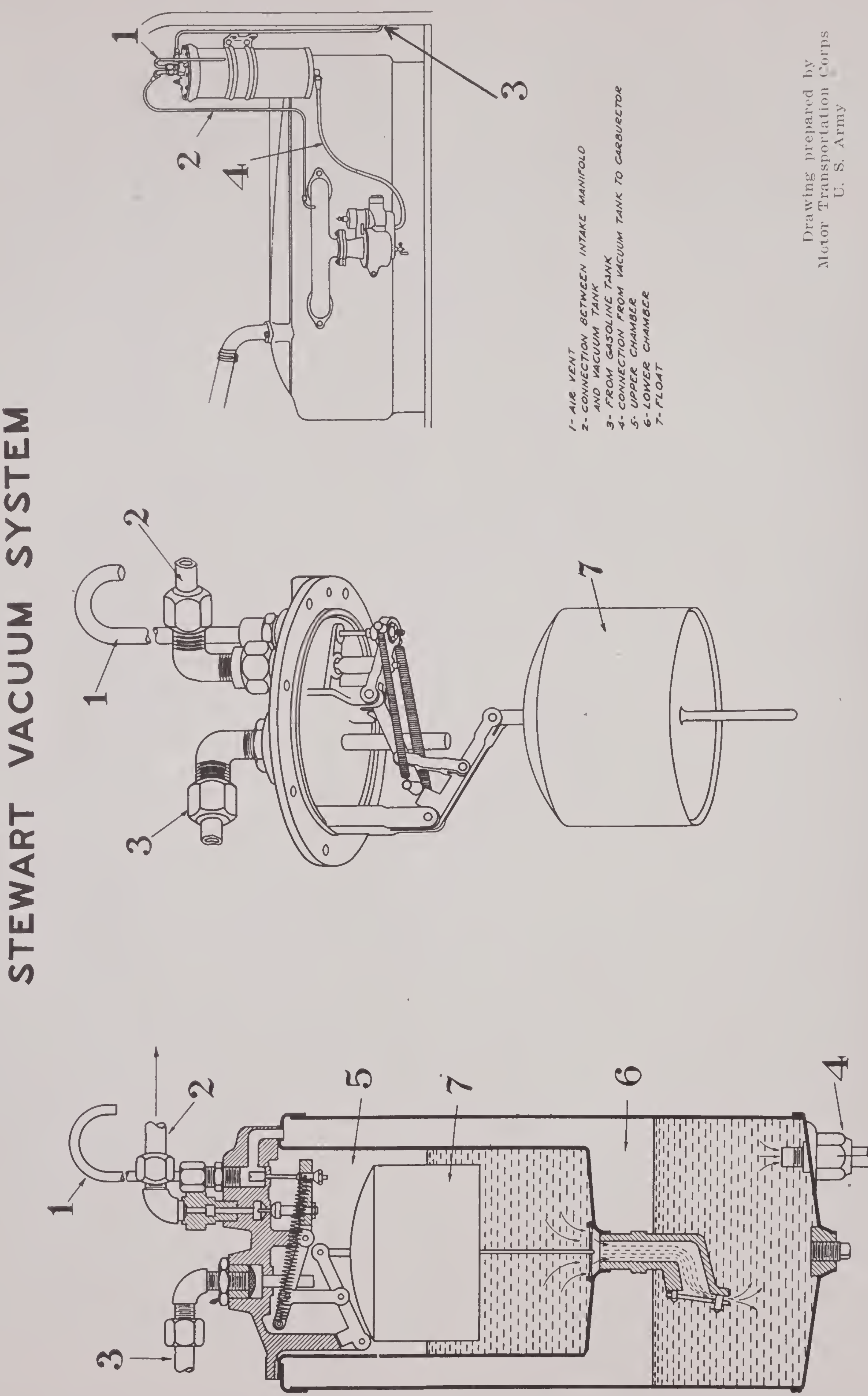
STEWART VACUUM SYSTEM
1
2
3
4
5
6
7
1- AIR VENT
2- CONNECTION BETWEEN INTAKE MANIFOLD AND VACUUM TANK
3- FROM GASOLINE TANK
4- CONNECTION FROM VACUUM TANK TO CARBURETOR
5- UPPER CHAMBER
6- LOWER CHAMBER
7- FLOAT
Drawing prepared by Motor Transportation Corps U. S. Army

FIG. 72.

CARBURETION

The process of carburetion is the combining of the vapors which rapidly evaporate from hydro-carbon liquids with certain proportions of air to form an inflammable gas. The quantities of air required vary with different liquids, as some mixtures burn quicker than others. Mixtures of gasoline and air burn very quickly, in fact the combustion is so rapid that it is practically instantaneous and if caused to occur in a closed receptacle results in an "explosion."

The mixture must be properly proportioned or the rate of burning will vary; if it is too rich or too lean the power of explosion is reduced and the force acting on the piston is decreased. The chemical composition of the fuel determines the proportion of air required. The ordinary gasoline used contains about 84% carbon and 16% hydrogen. Air contains oxygen and nitrogen, and the former combines with the hydrogen and carbon of the fuel to make possible the process of combustion.

In determining the amount of air necessary for the proper mixture, reference is made to the fact that one pound of hydrogen requires eight pounds of oxygen to burn it, and one pound of carbon requires two and one-third pounds of oxygen to burn it. Air contains one part of oxygen to three and a half parts of nitrogen, so for each pound of oxygen needed four and a half pounds of air must be used. Then to insure combustion of one pound of gasoline, nine pounds of air must be supplied to burn the carbon, and six pounds of air to burn the hydrogen. This is a proportion of fifteen pounds of air to one pound of gasoline. At 62 degrees Fahrenheit, about fourteen cubic feet of air will weigh one pound, so that a pound of gasoline will require about two hundred cubic feet of air. This would be the amount required for theoretical combustion, but in general practice about twice that amount is necessary, since the nitrogen, which is the main constituent of the air, acts to deter the burning.

In order to be explosive, gasoline vapor must be combined with definite quantities of air. Rich mixtures ignite quicker, produce more heat and more effective pressure on the piston head. Mixtures varying from one part gasoline and seven parts air to one part gasoline and thirty parts air are the limits of a combustible gas. The correct amount is between twelve and sixteen parts of air to one part of gasoline. The rich mixture (twelve or less to one) results in fuel wasted, leaves a carbon deposit and is shown by black smoky exhaust. The lean mixture (sixteen or more to one) is slow burning, resulting in loss of power, and ignites incoming gas as shown by back-firing in the carburetor; the rich mixture gives the greatest power, while the lean mixture gives the greatest economy.

CARBURETORS

The purpose of the carburetor is to provide means for mixing the air and gasoline in the proportions required by the engine. Practically all the carburetors used at present are of the "spray nozzle" type and make use of the following parts:

- Float chamber
- Float
- Mixing chamber
- Venturi tube
- Float needle valve
- Spray nozzle
- Spray nozzle needle valve
- Main and auxiliary air inlets
- Throttle valve

The current of air is drawn through the mixing chamber, where it mixes with the gasoline. A jet or spray nozzle is located in this chamber to spray the fuel as it is drawn into the air current and thus better vaporize it. The size of the air passage at the point where the spray nozzle is located is reduced by making it of special form called a "venturi tube." The principle of the venturi tube is that when any fluid passes through a tube, the volume passing will be the same at all points if the size is constant. If the size changes at some point, the volume remains the same, while the velocity will be inversely proportional to the area. Thus, in the restricted portion of the air passage in the mixing chamber the air velocity is increased.

As previously stated in explaining the four stroke cycle engine principles, the charge of gas is forced into the cylinder due to the fact that the atmospheric pressure outside is higher than that of the vacuum in the cylinder caused by the downward movement of the piston. The velocity of the entering gases thus depends upon this difference in pressures, which varies with engine speed, and as it slows down it will not pick up as much fuel as when running at a higher speed. The venturi tube was introduced to insure a sufficient supply of gas at the low speed by causing the air to pass the spray nozzle at a velocity that would pick up the necessary amount of fuel.

The main air inlet supplies the air in sufficient quantities for low speeds, but when the engine speed increases, the suction in the mixing chamber increases, picking up so much of the fuel that the mixture becomes too rich. For high speed then, more air is needed and it is supplied through one or more auxiliary air inlets, usually placed above the spray nozzle and below the throttle valve so that the additional supply of air does not affect the spray nozzle.

The auxiliary air valve is adjustable to allow regulation of the amount of air entering the mixing chamber, and is usually operated by the suction of the engine. In some carburetors the auxiliary air valves are arranged to operate the spray nozzle needle valve so that the mixture of air and gasoline may be made more nearly in the proper proportion for the various engine speeds.

An adjustable needle valve is usually placed in the spray nozzle, the purpose of which is to regulate the amount of gasoline that can be drawn from the spray nozzle by the inrushing air.

The breaking up and vaporizing of the fuel depends upon the shape of the spray nozzle and the needle valve. If the valve has a fine and long point on it, the fuel must pass through a longer space, which helps to vaporize it. If the point is blunt, the fuel will pass through a larger space and will not be broken up as thoroughly. The thread on the needle valve is of very fine pitch so that a slight change in the valve does not give too great a change in the mixture. In some cases the valve is adjusted definitely by hand and in other cases its adjustment is automatically provided for in the operation of the auxiliary air valves. When so operated it is called a "metering pin."

Carburetors may have one or more spray nozzles or jets. The jets are small tubes with openings of various specified sizes. The jet is used to make it impossible for the car driver to change the adjustment of the carburetor without obtaining special wrenches. Some carburetors have a single jet for all speeds, while others have low and high speed jets or needle valves.

The purpose of the float chamber is to hold a small quantity of gasoline in close proximity to the spray nozzle and where it can be maintained at a constant level. It takes its

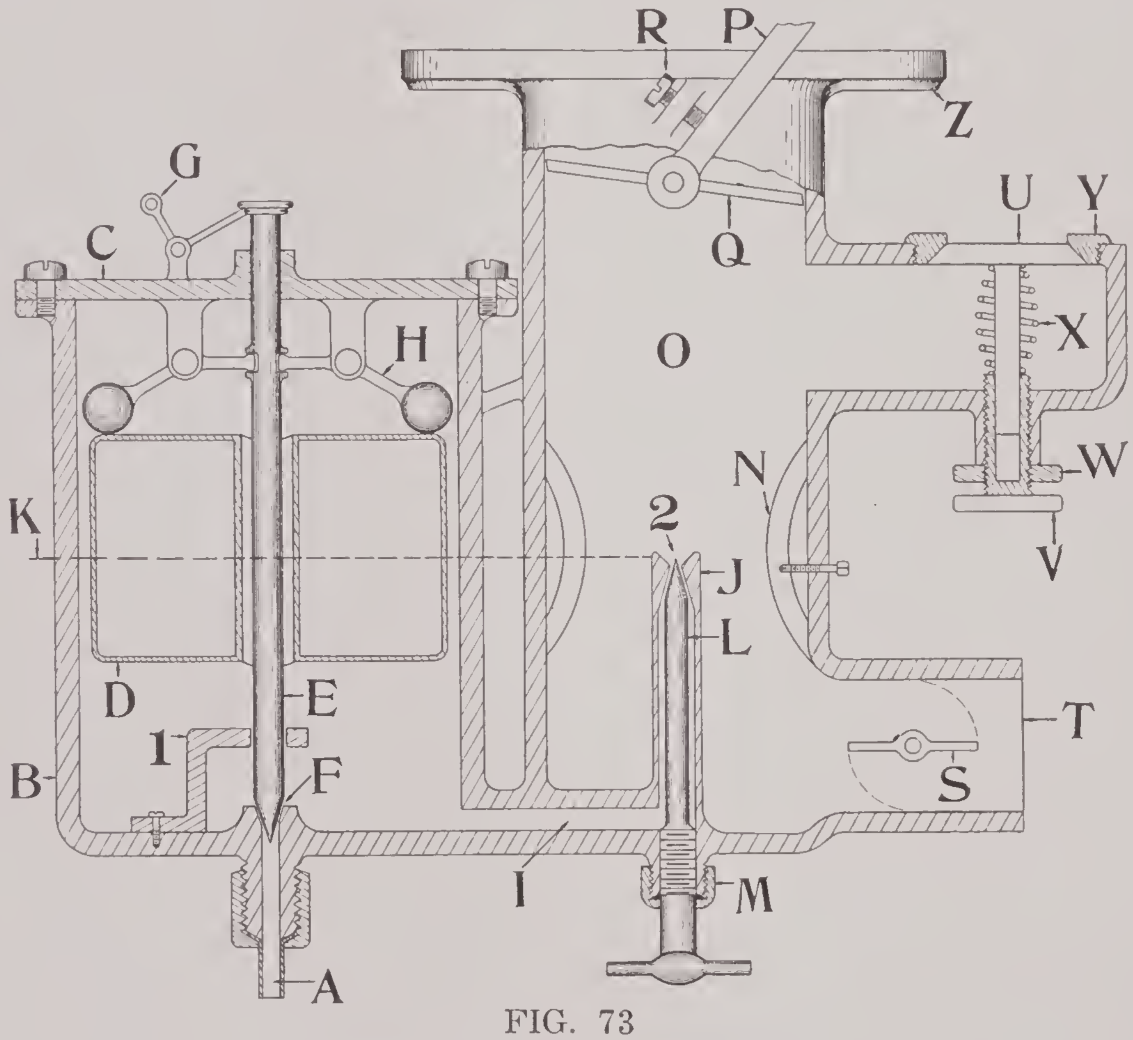

FIG. 73

CARBURETOR—SINGLE JET TYPE

A. Gasoline inlet.
B. Float chamber.
C. Float chamber cover.
D. Float.
E. Float needle valve.
F. Float needle valve seat.
G. Priming lever.
H. Float valve lever arms.
I. Gasoline passage.
J. Gasoline jet.
K. Gasoline level.
L. Gasoline adjusting valve.
M. Packing nut.
N. Venturi tube.
O. Mixing chamber.
P. Throttle valve lever arm.
Q. Throttle or butterfly valve.
R. Stop screw.
S. Choke valve.
T. Main air inlet.
U. Auxiliary air valve.
V. Auxiliary air valve spring adjustment.
W. Lock nut.
X. Auxiliary air valve spring.
Y. Auxiliary air valve seat.
Z. Carburetor flange.

1. Float needle valve guide.
2. Spray nozzle.

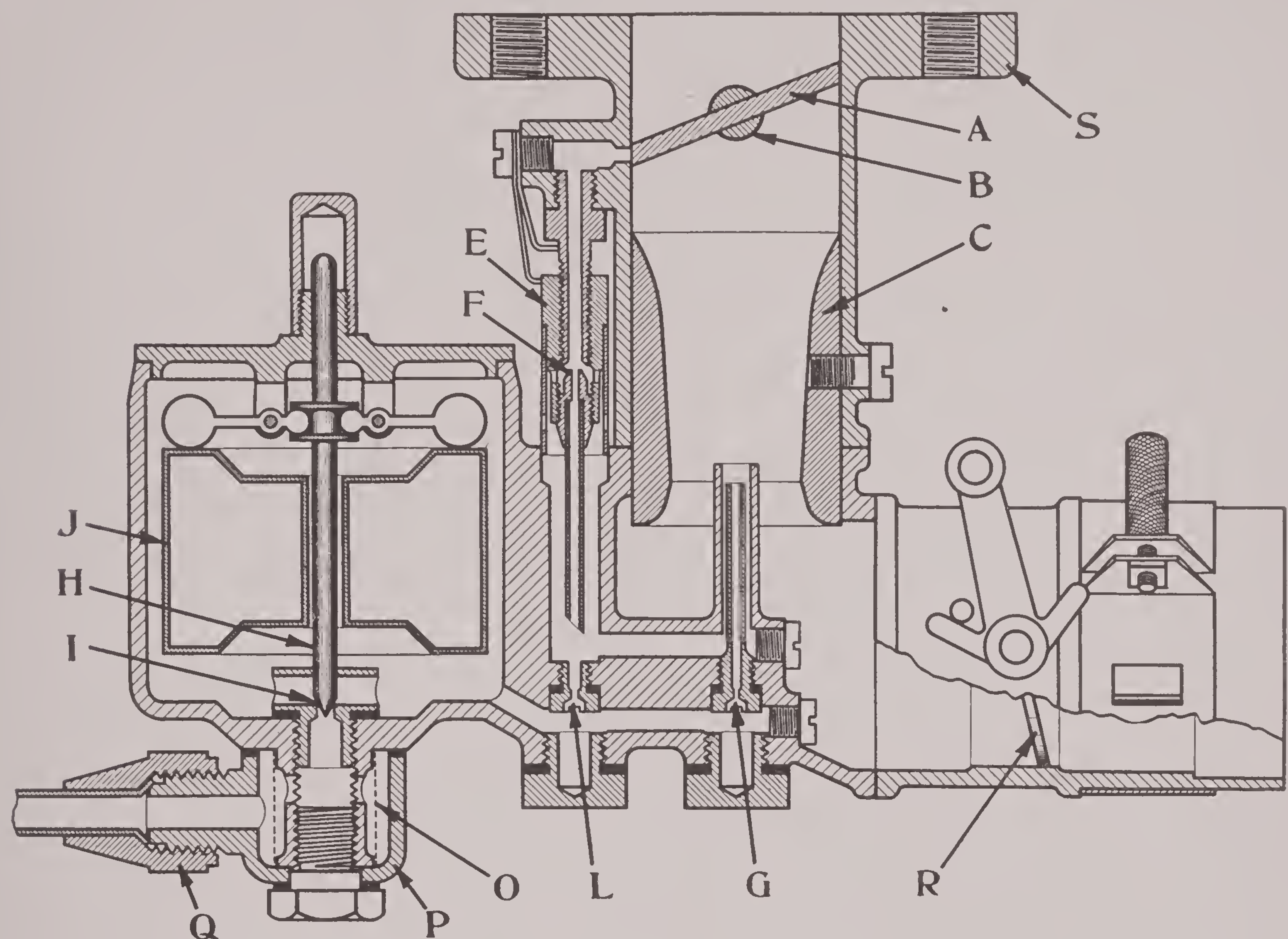

FIG. 74

CARBURETOR, COMPENSATING TYPE ZENITH

A. Throttle valve.
B. Throttle shaft.
C. Venturi or choke tube.
E. Idling device.
F. Air passage.
G. Main jet.
H. Float needle valve.
I. Float needle valve seat.
J. Float.
L. Compensator.
O. Screen.
P. Coupling.
Q. Tube coupling.
R. Choke valve.
S. Flange.

The adjustments on the Zenith carburetor are the venturi or choke tube, main jet, compensating jet and the idling adjustment. The size numbers of these parts constitute the settings. The size numbers are stamped on each part.

The chokes are numbered in millimeters and the jets in hundredths of millimeters.

Troubles

Choke tube too large—The pick up will be defective and cannot be bettered by the use of a larger compensator. Slow speed running will not be very smooth. The engine will have a tendency to load up under a hard pull and at high speed the exhaust will be of variable nature.

Choke tube too small—The effect of a small choke tube is to prevent the engine from taking a full charge with the throttle valve fully opened. The pick up will be very good but it will not be possible to get the maximum speed.

Main jet too large—At high speed it will give the indication of a rich mixture, irregular firing in the muffler, sooting up the spark plugs.

Main jet too small—The mixture will be too lean at high speed. There may be backfiring at high speed.

Compensator too large—Too rich a mixture on a hard pull.

Compensator too small—Too lean a mixture liable to misfire and give jerky action to the car on a hard pull.

Idling adjustment made with the idling screw. If this screw must be run in all the way, put in a larger idling device. If this screw must be run out all the way put in a smaller idling device.

name from the fact that a float is used to operate the valve controlling the flow of gasoline into the chamber. The float rises and falls as the gasoline level varies and is adjusted so that the gasoline will always be kept approximately at the height of the spray nozzle where the air current picks it up. When no air is passing through the mixing chamber, the gasoline level should be 1/32″ to 1/16″ below the top of the spray nozzle. If too high the nozzle will continually overflow and if too low the air current will not pick up sufficient fuel.

The float is made hollow, of very light sheet brass or copper, soldered to make it air tight, or made of cork. If the hollow float leaks it will fill with gasoline and becoming too heavy to float will settle down, holding the needle valve open until the float chamber becomes "flooded" and the gasoline overflows at the spray nozzle. The cork float is painted with three or four coats of shellac to keep the gasoline from getting into it. If this coating wears off, the gasoline will soak into the cork until it becomes "gasoline logged," preventing it from floating and resulting in the flooding of the float chamber as mentioned before.

Different methods are used to connect the float with the needle valve controlling the flow of gasoline into the float chamber. In Fig 73, which illustrates a typical single jet carburetor, there are two float levers pivoted on the float chamber cover, one end of each resting on the float and the other end connected to the float needle valve. As the float rises and falls these levers move with it, thus closing and opening the valve. In Fig. 75 the float and needle valve are secured to a single arm pivoted in the center, the result being the same.

As the gasoline enters the float chamber it passes through one or two fine mesh screens. These screens strain the fuel, preventing particles of dirt or other foreign matter from entering the float chamber. Any dirt or lint that might settle on the float valve seat would prevent the valve from closing and cause the fuel to overflow at the spray nozzle.

Main Air Inlet Heaters

The main air inlet of the carburetor is sometimes provided with a hot air tube, which conveys the hot air from around the exhaust pipe to the air inlet. From there it passes by the spray nozzle, vaporizing the fuel more thoroughly. The carburetor may have a jacket cast around the outside of the mixing chamber through which hot water from the engine is circulated, helping to vaporize the fuel. On some carburetors hot oil may circulate through this jacket.

Throttle Valve

The purpose of the throttle valve is to regulate the amount of the mixture entering the combustion chamber, thus controlling the speed of the engine. It serves the same purpose as a water valve in a water pipe, or of a steam valve in a steam pipe. The valve is operated from the driver's compartment through a series of levers and connecting links.

On the throttle valve lever there is a small screw provided which is called the stop screw. The purpose of this screw is to set the throttle valve so that it will not close entirely, in order to keep the engine running at a slow speed. Sometimes this stop screw is located on the outside of the mixing chamber where the throttle control lever strikes the screw just before the throttle valve closes. This prevents the engine from stopping when the throttle control lever on the steering wheel is in the closed position. **This stop screw is not a carburetor adjustment. Carburetor adjustments are those which regulate the mixture.**

Idling Adjustment

Due to the low suction at low engine speeds, the velocity of the air at the spray nozzle is not great enough to draw the heavy fuel and the fuel that it does draw has not sufficient velocity for proper vaporization. Consequently, at low engine speeds the engine may misfire due to an insufficient amount of fuel being supplied or not properly vaporized. To overcome this, some carburetors are provided with an idling device which allows the fuel to be taken through a by-pass into the mixing chamber at the throttle valve. When the engine is running at slow speed, the vacuum above the throttle valve is very high, while below the throttle valve there is practically no vacuum or suction at all. The fuel taken out of this idling well or by-pass through the small opening under the high vacuum will be vaporized, allowing the engine to fire properly at slow speed. When the throttle valve is opened and the engine speeds up, the suction is not as effective upon the small well, as when the throttle was closed.

Gaskets

Gaskets are made of a compressible material and are placed between two surfaces to overcome unevenness in machining and to prevent leakage. A gasket should be used between carburetor and inlet manifold to prevent air from entering in any other manner than through the proper air inlets. Air leaks at any point above the throttle make it impossible to control the quality of the mixture, making the engine hard to start and hard to control.

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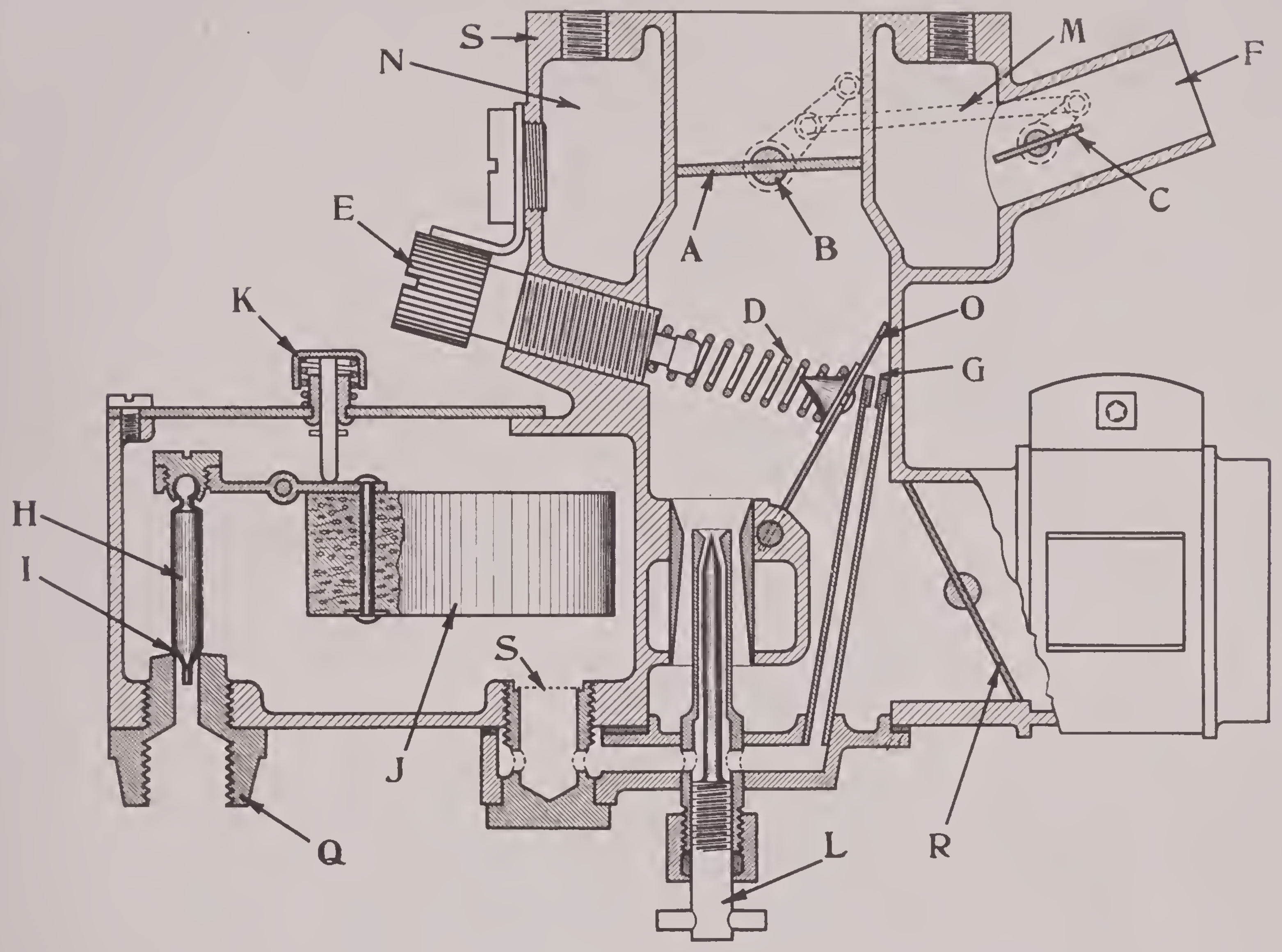


FIG. 75

CARBURETOR, AIR VALVE TYPE

MARVEL

A. Throttle valve.
B. Throttle valve shaft.
C. Heater damper.
D. Air valve spring.
E. High speed air adjustment.
F. Exhaust gas inlet to heater jacket.
G. High speed nozzle.
H. Float needle valve.
I. Float needle valve seat.
J. Float.
K. Primer.
L. Gasoline adjustment (needle valve).
M. Throttle lever and heater damper connections.
N. Heater jacket.
O. Auxiliary air valve.
Q. Gasoline inlet.
R. Choke valve.
S. Screen.

ADJUSTMENT OF MARVEL CARBURETOR

Turn the air adjusting screw inward until the end of the screw is flush with the ratchet. Unscrew the needle valve one turn. Start the engine, then allow it to warm up. Place the spark lever in full retard, adjust needle valve until the engine runs smoothly, then place the spark lever in advance and open the throttle quickly. If the engine skips or stops while accelerating, unscrew the needle valve slightly by turning it to the left until the throttle valve can be opened rapidly without causing the engine to skip or stop.

The air valve adjusting screw need not be further adjusted unless the proper acceleration cannot be obtained. More accurate low speed adjustment can be made by the needle valve with the engine running at low speed and under load. Turn the gasoline adjusting valve (L) clockwise until a backfiring in the carburetor is noted or a misfiring occurs. Then turn the adjustment the other way just enough to prevent misfiring or backfiring. Then speed the engine and when running at normal driving speed under load, turn the air valve or high speed adjustment (E) to the left until a backfiring is noted; turn it the other way just enough to prevent a backfiring. This is the maximum economy adjustment.

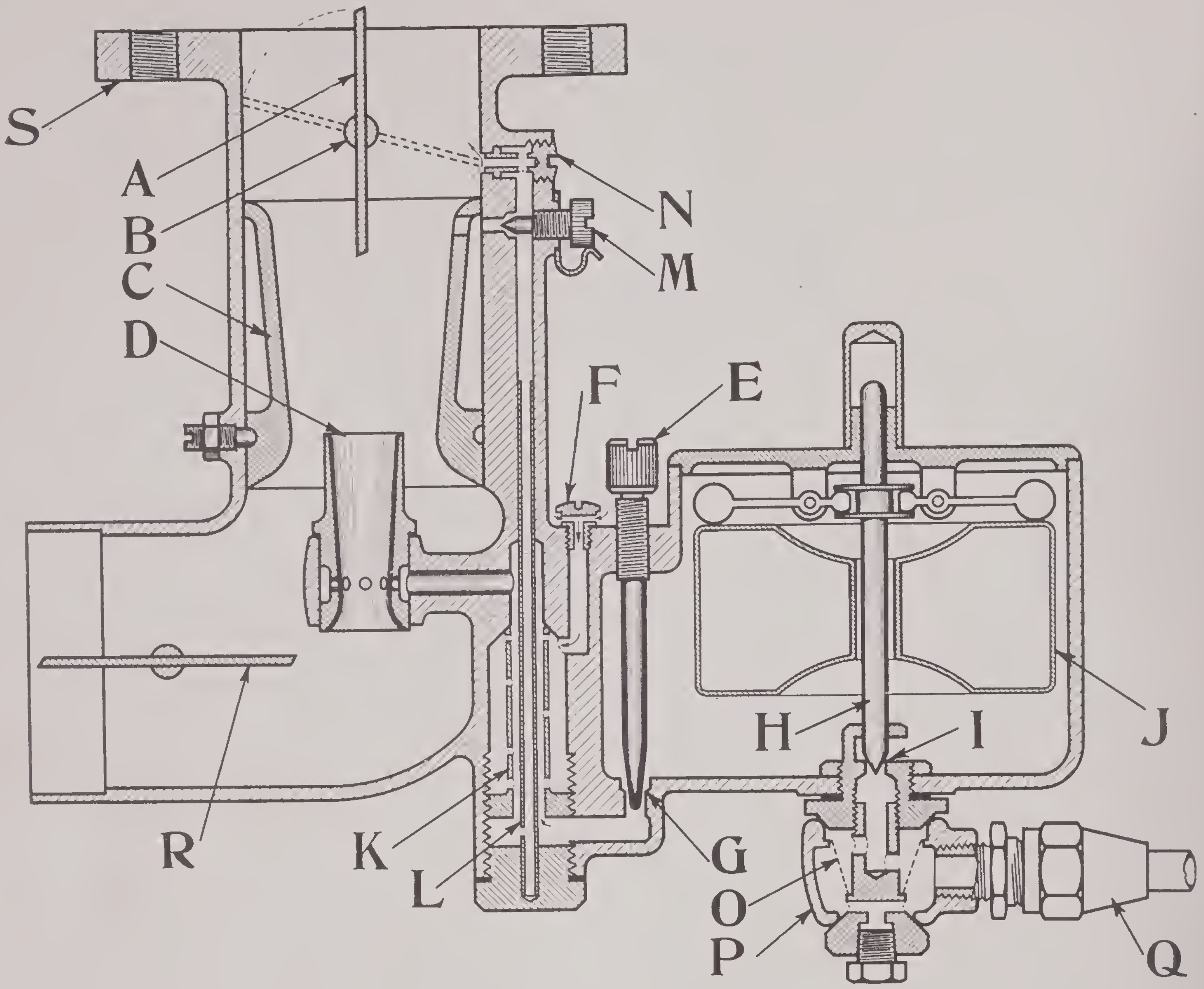


FIG. 76

CARBURETOR, PLAIN TUBE TYPE

STROMBERG

A. Throttle valve.
B. Throttle valve shaft.
C. Large venturi.
D. Small venturi.
E. High speed adjusting needle valve.
F. Air bleeder.
G. Needle valve seat.
H. Float needle valve.
I. Float needle valve seat.
J. Float.
K. Accelerating well.
L. Idling tube.
M. Idling adjustment needle.
N. Idling discharge jet.
O. Strainer.
P. Strainer body.
Q. Gasoline connection.
R. Choke valve.
S. Carburetor flange.

The adjustments on this carburetor are the high speed adjusting screw (E) and the idling adjustment needle (M).

Surrounding and communicating with the tube (L) which conducts the gasoline from the measuring orifice to the jet, is a circular reserve chamber or accelerating well (K). With the engine idling or slowing down, this well fills with gasoline and when the venturi suction is increased by opening the throttle valve or at a faster engine speed, the level in the well goes down and the gasoline thus displaced passes through the holes in (K) to join the flow from (G), thus more than doubling the normal rate of feed. The amount and rate of discharge can be graduated by changing the holes in the top and side of the well.

When the throttle is closed, gasoline is drawn in through the hole in (L) and mixed with air taken in through the hole in the venturi at (M) and discharged into the carburetor at the throttle valve.

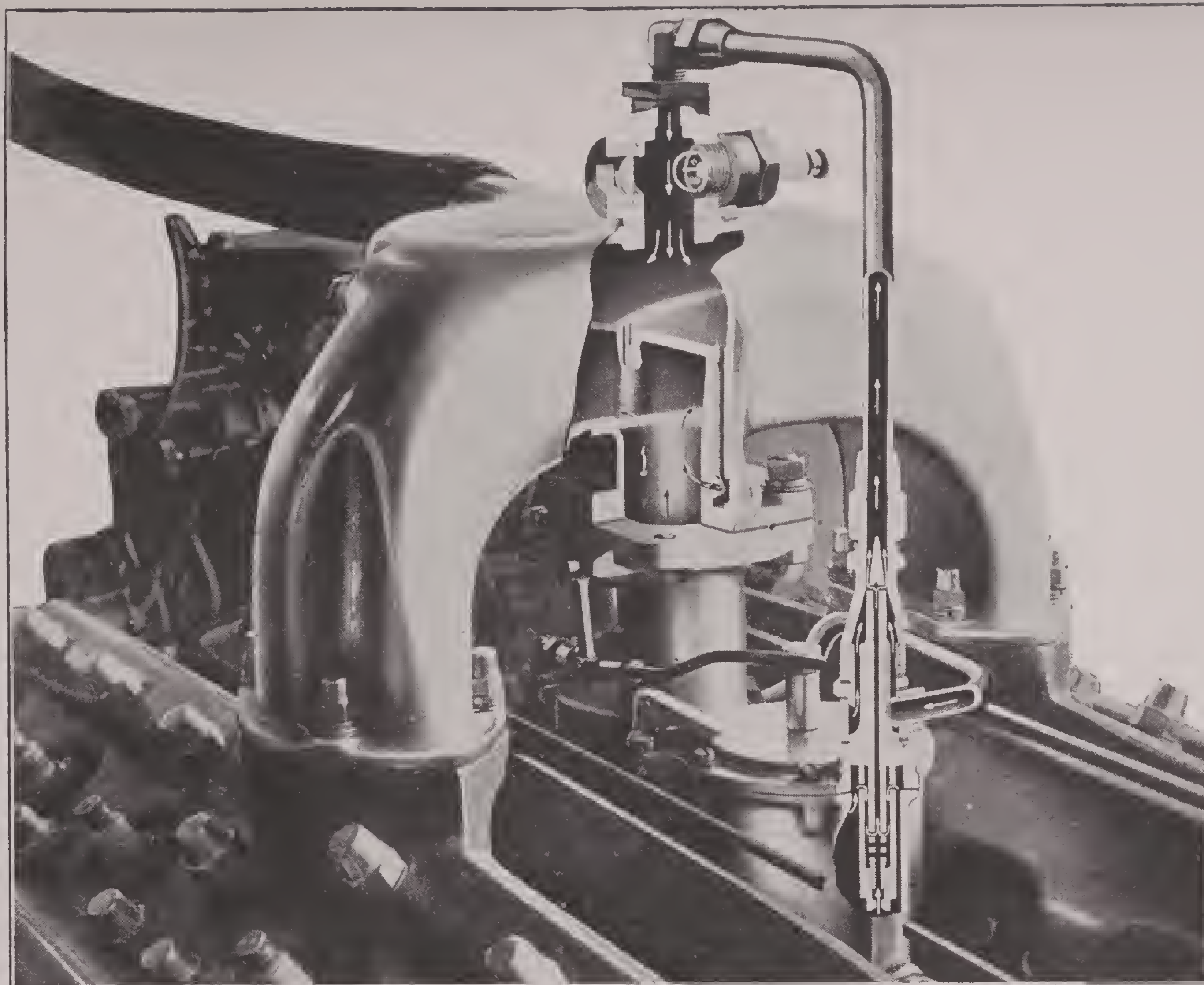


FIG. 77

FUELIZER AS USED ON THE PACKARD CAR

The purpose of this device is to increase the temperature in the interior of the inlet manifold.

The temperature in the manifold is increased from 57° to 120° in less than 30 seconds. This overcomes the condensation of the fuel while the engine is cold, eliminating some of the causes of the carbon formation and the gathering of the fuel in the crankcase.

The pipe leading from the carburetor to the top of the jacketed inlet manifold carries a minute quantity of gas direct from the carburetor to the Fuelizer spark plug.

At this point the gas is ignited and circulates at very high temperature through the Fuelizer chamber which surrounds the inlet manifold.

At the bottom of the Fuelizer chamber are two small holes through which the superheated exhaust of the Fuelizer is permitted to enter directly into the main inlet manifold.

Thus the main inlet manifold temperature is raised by direct mixing with the Fuelizer exhaust, as well as from the heat developed in the Fuelizer chamber.

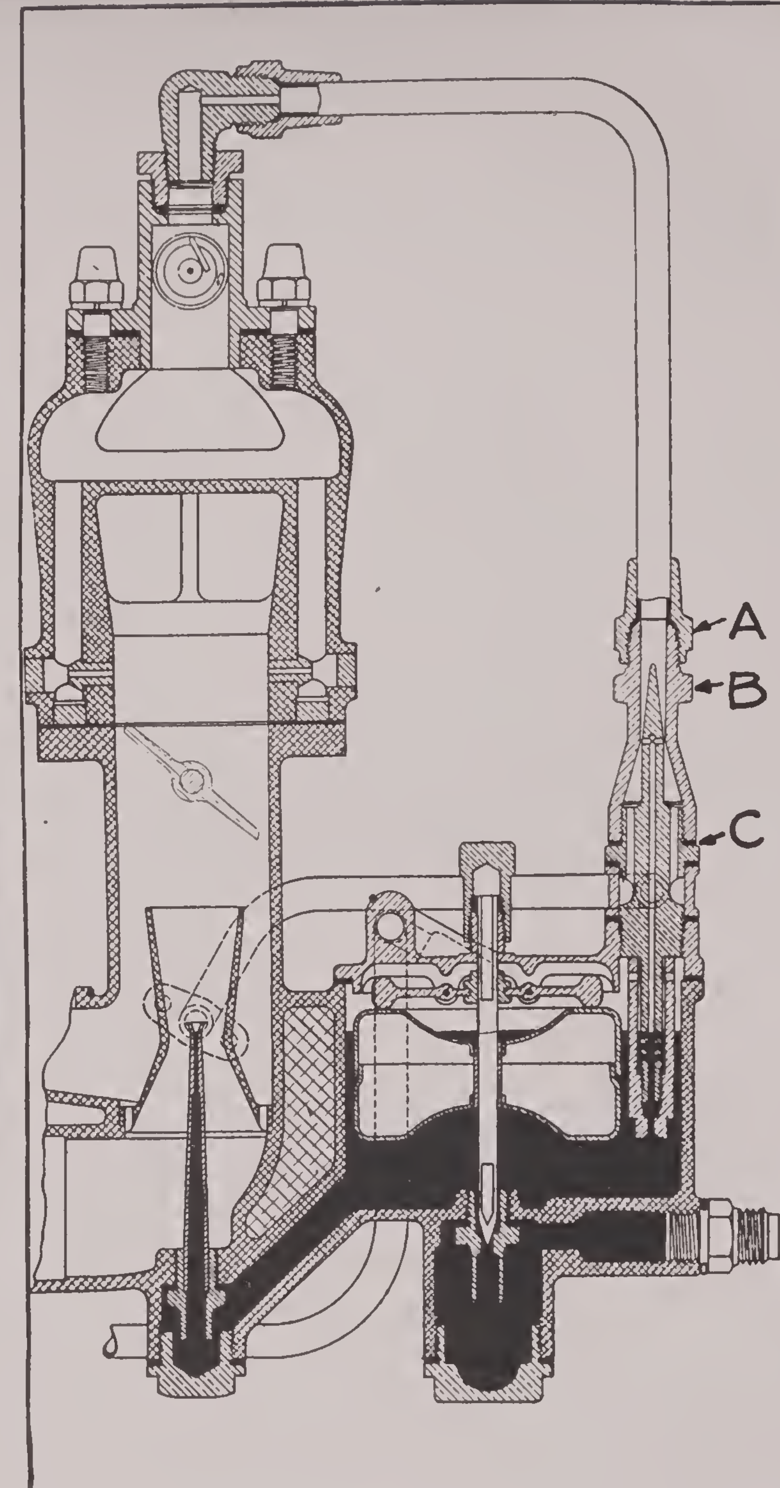


FIG. 78

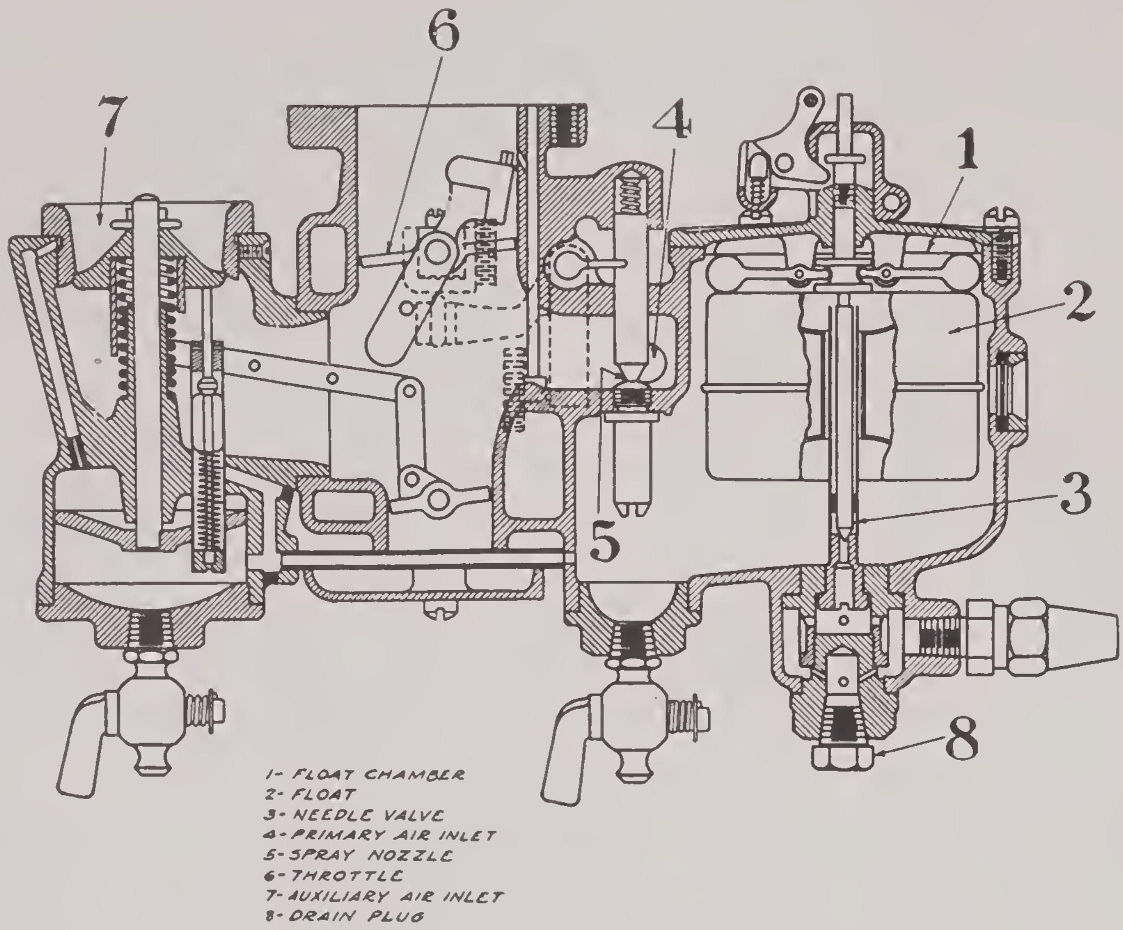


FIG. 79

CARBURETOR, AIR VALVE METERING PIN TYPE RAYFIELD

RAYFIELD CARBURETOR

The model of Rayfield carburetor shown in Fig. 79 supplies the fuel through two different passages. One supplies all the gasoline required when the engine is idling and at low speed. This is through the spray nozzle (5). The additional gasoline required for higher speeds is furnished through a tube which is controlled by a tapered metering pin located under the automatic air valve (7).

This model has three air inlets, the constant or fixed air opening (4) and two automatically controlled air valves, which are interconnected. These two valves operate together to increase the supply of air proportional to the additional gas supply caused by the increased suction of the engine upon acceleration.

A piston attached to the upper automatic air valve (7) operates in a dash-pot or cylinder of gasoline. When the carburetor is in operation the resistance offered to any movement of the piston by the gasoline in the dash-pot prevents a sudden opening of the air valve, thus causing a strong suction on both fuel nozzles as the throttle is opened. When the throttle valve is opened, the vacuum in the mixing chamber tends to draw the air valve away from its seat, opening the other air valve located at the bottom below the throttle, and at the same time moving the metering pin away from its seat and also forcing the piston down. The downward movement of the piston produces a pump action which forces gasoline up through the metering pin tube into the mixing chamber, giving an additional amount of gasoline to mix with the additional air entering through the two auxiliary air inlets.

There are two adjustments on this carburetor, low and high speed, both being fuel adjustments. These adjustments regulate the lift of the metering pin at the spray nozzle. The low speed adjustment is the lower knurled screw. Turning this screw to the right lifts the metering pin from the spray nozzle. The high speed adjustment is the knurled screw on the adjustable cam which is fastened on the throttle shaft. The cam turns with the throttle shaft and does not lift the metering pin until the throttle valve is partially opened. Turning the screw to the right lifts the metering pin away from the spray nozzle.

With the throttle valve closed, the metering pin lifting arm rests on the flat side of the cam, thereby coming back to the low speed adjustment when the throttle valve is closed.

A dash control for easy starting is mounted on the steering column. This control turns the cam which rests against the arm that lifts the metering pin away from the spray nozzle, thereby allowing a rich mixture to be drawn into the cylinder.

When this control is pulled all the way back, a plunger valve opens a by-pass having two openings, one into the throat of the carburetor, the other in the float chamber below the fuel level.

When the engine is cranked and the throttle valve closed, the partial vacuum above the throttle valve will draw a rich charge of gas from the float chamber.

This carburetor is water jacketed, the hot water passing around the mixing chamber assisting in the proper vaporization of the mixture.

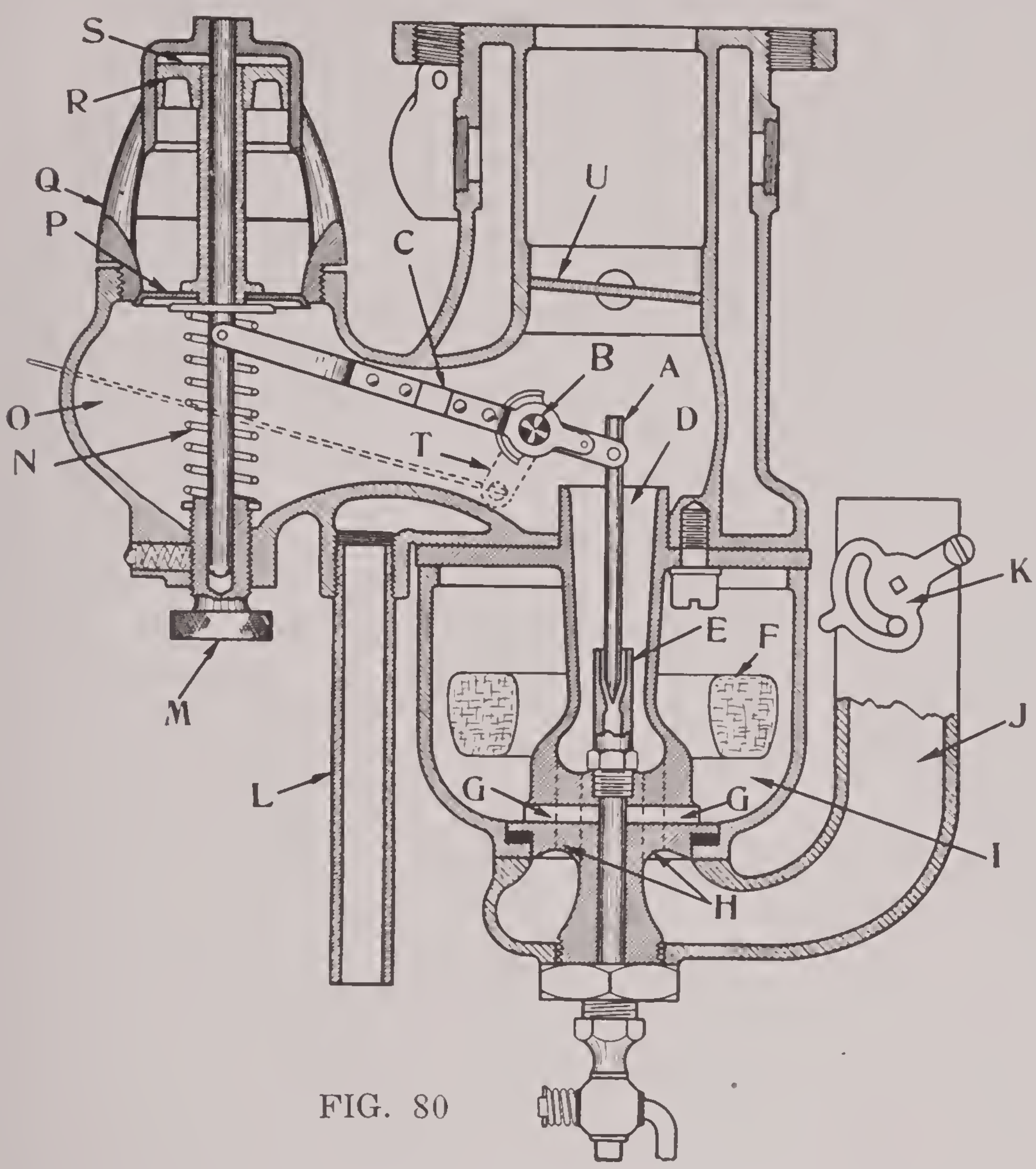


FIG. 80

CARBURETOR, AIR VALVE METERING PIN TYPE SCHEBLER

A. Gasoline needle valve.
B. Needle valve operating lever shaft.
C. Needle valve operating lever.
D. Venturi tube.
E. Spray nozzle.
F. Float.
G. Gasoline passages.
H. Air passages.
I. Float chamber.
J. Main air inlet.
K. Choke valve lever.
L. Exhaust gas outlet.
M. High speed air adjustment.
N. Auxiliary air valve spring.
O. Auxiliary air valve chamber.
P. Auxiliary air valve.
Q. Low speed gasoline adjustment.
R. Plunger.
S. Dash pot.
T. Dash control lever.
U. Throttle valve.

Operation

The gasoline enters the carburetor through the float valve into the float chamber (I), through the passages (G) to the spray nozzle (E).

The vacuum produced by the downward movement of the pistons draws the gasoline from the spray nozzle (E), past the needle valve (A), through the venturi tube (D) and the mixing chamber. At the same time the suction of the pistons draws the air through the air intake (J) and passages (H) into the venturi tube. Thus the gasoline and air entering at high velocity vaporizes more readily while the mixture is passing through the venturi tube. At higher engine speed the increased vacuum in the mixing chamber draws the air valve (P) away from its seat, allowing more air to enter the mixing chamber; and as the needle valve (A) is raised and lowered automatically by the movement of the auxiliary air valve, more or less gasoline is allowed to spray into the mixing chamber. As the air valve moves down it lifts the needle valve (A), acting through the lever (C), admitting more gasoline. The needle valve acts as a metering pin, admitting an increased amount of gasoline in direct proportion to the increased amount of air entering through the auxiliary air valve.

To prevent an erratic action of the air valve when the throttle is suddenly opened or closed, a dash pot is used. Its function is to steady the movement of the air valve and prevent sudden extreme opening or closing and also prevent the air valve from "chattering" due to the intermittent suction developed by the pistons. The air valve (P) is connected directly to a plunger (R) which operates against a cushion of air in the dash pot (S).

Adjustments

With the engine under load at low speed, turn the adjustment (Q) to the left or counter clockwise until the engine backfires or misfires, then turn it to the right until the engine runs evenly.

Advance the spark lever two-thirds to three-fourths of the travel on the sector and open the throttle quickly. If the engine backfires upon this sudden acceleration, turn the adjusting screw (M) to the right until the engine does not backfire upon acceleration, and runs properly at high speeds. When the screw (M) is turned inward the spring (N) is compressed, which increases its tension, holding the air valve (P) tighter against its seat, restricting the amount of air entering by the air valve at high speeds and upon acceleration. When the adjustment (Q) is turned to the left it lowers the needle valve in the nozzle at (E) and decreases the amount of gasoline allowed to enter the mixing chamber.

There is usually a choke lever located either on the dash or steering column. This lever is connected directly with the needle valve by means of an eccentric on (B) in the mixing chamber. When the dash control lever is moved, it acts through a connecting wire and lever (T), which lifts the needle valve (A). When the choke lever is moved all the way back a shoulder on the lever (T) tries to move the lever (C) upward. This causes the air valve (P) to be held against its seat. The result is a rich mixture for starting. As the engine warms up, move the dash choke lever in the opposite direction, gradually lowering the needle valve (A). When the engine is warm, the dash choke lever should be closed, which will not interfere with the regular carburetor adjustments. This carburetor is jacketed to allow the hot exhaust gases to assist in the vaporization of the fuel.

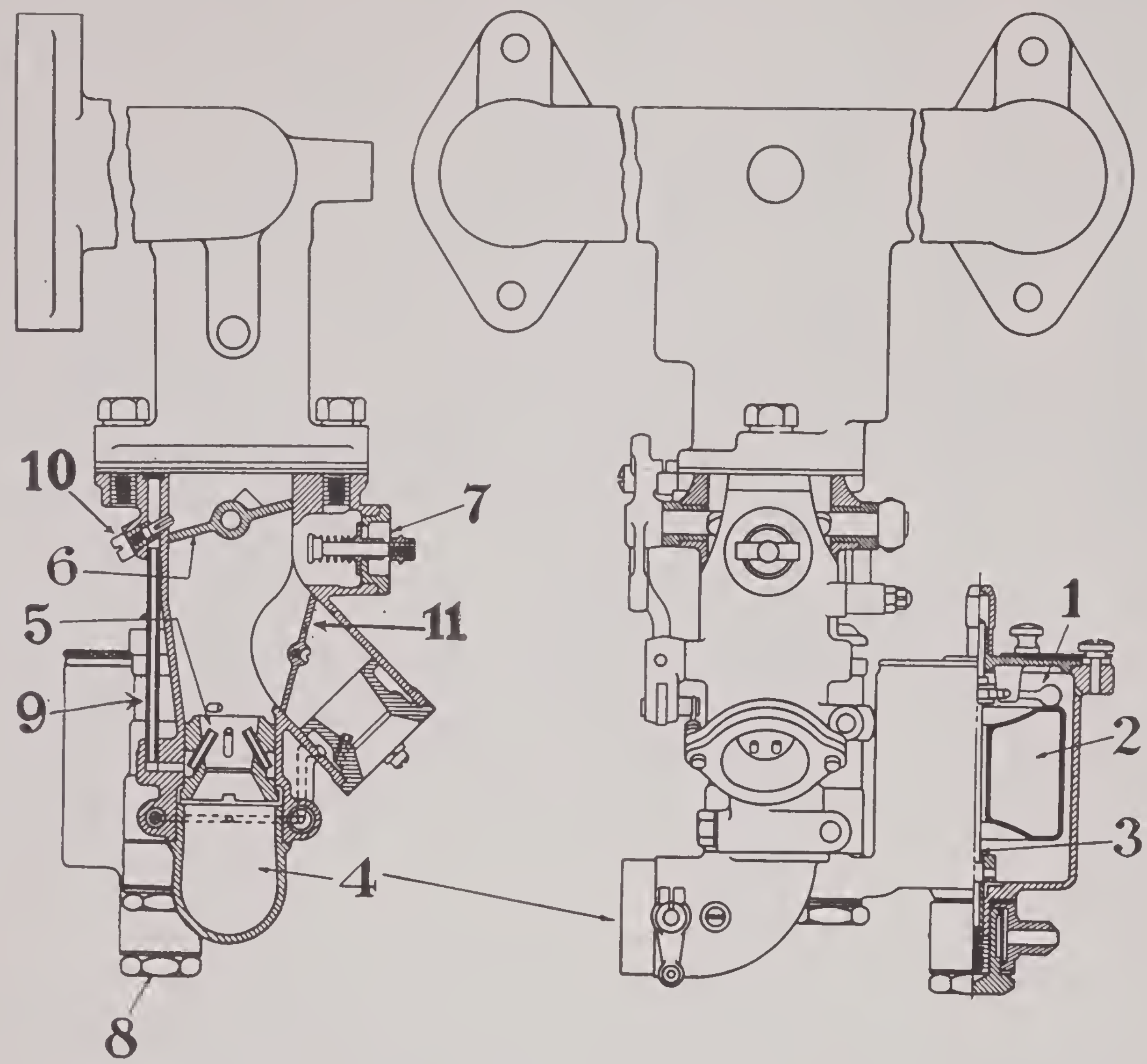


FIG. 81

CARBURETOR, TWO STAGE MULTIPLE JET TYPE BALL AND BALL (TRADE NAME)

1. Float arm.
2. Float.
3. Float needle valve.
4. Main air inlet.
5. Jets.
6. Throttle valve.
7. Auxiliary air valve.
8. Swivel fuel pipe connector.
9. Idling tube.
10. Idling adjusting screw.
11. Lower air valve.

The gasoline level is just below the top of the jets (5). As the throttle valve is opened, the air entering through the main air inlet (4) draws the gasoline from the jets.

There is no low speed adjustment except by changing the size of the venturi and jets.

Connected with the float chamber at the bottom and the mixing chamber at the top is an idling tube (9). When the throttle valve is closed, or practically closed, the high vacuum above the throttle valve draws the gasoline up through the idling tube and into the mixing chamber above the throttle valve. There is a small air opening at the idling adjusting screw, which allows air to enter with the gasoline. This opening is adjustable. On some models of Ball and Ball there is an accelerating well, which is connected to the float chamber at the bottom and the mixing chamber at the top. When the throttle valve is almost closed there is created a vacuum in the top of this tube which draws a plunger upward. The upward movement of the plunger draws gasoline into the lower part of the tube. When the throttle valve is opened suddenly, the vacuum above the throttle valve is lost. The weight of the piston as it moves down in the accelerating tube forces the gasoline out through a jet into the mixing chamber.

The auxiliary air valve (7), which is adjustable only to a limited extent, regulates the mixture at high speeds.

When the throttle valve is opened wide, the lower air valve (11) is opened in the secondary air inlet by a connecting lever. Air entering the mixing chamber through the secondary inlet, causes additional gasoline to be drawn from jets located in this inlet.

CARBURETOR CONDITIONS

Engine Starting and Operation

For easy starting, a choke valve is usually provided in the main air passage. By choking the main inlet of the carburetor the mixing chamber is under a higher vacuum which produces a very rich mixture. Fuels vaporize at a lower temperature in a vacuum than under atmospheric pressure. As this vacuum draws more fuel from the spray nozzle, it makes the engine easier to start.

When choking the main air inlet on a carburetor that is provided with an auxiliary air valve, the high vacuum may draw the auxiliary valve away from its seat, causing the mixture to be too lean, and prevent the starting of the engine. One method of overcoming this is the use of a mechanical device which draws the needle valve away from its seat allowing a rich mixture to be taken into the cylinder. This eliminates the necessity of a choke.

A mixture that is too lean may cause a back-fire through the carburetor, except when starting. A back-fire through the carburetor while cranking the engine is not caused by the mixture being too lean, but may be caused by the ignition not being wired according to the firing order, the camshaft not timed correctly, or the inlet valve not closing. At low engine speeds, or when attempting to start the engine, if the mixture is not rich enough it will not fire at all. Or, if the engine is running slowly and the carburetor is adjusted so that the mixture is too lean, the engine will stop without back-firing.

The back-fire becomes more distinct as the throttle valve is opened and the compression and explosive forces become more powerful. With a lean mixture and a wide open throttle, a back-fire will throw a flame a considerable distance out of the main air inlet of the carburetor, possibly setting fire to the stray gasoline that may have been dripping from it.

A rich mixture is indicated by the variable engine speed, or what is known as galloping or loping, and also by the black smoke which issues from the exhaust. (Blue smoke from the exhaust is an indication that lubricating oil is being burned in the combustion chamber.)

The engine running at various speeds and loads demands various mixtures. More power is required to get a load under motion, and a richer mixture is needed, while as the engine speeds up and gets the load under motion, a rich mixture is no longer required. However, more gasoline will be consumed as the individual cylinders are firing more times per minute.

On carburetors having multiple adjustments, always make the low speed adjustment first. After the low speed adjustments are made, the speed of the engine should be increased and the high speed adjustment made. Never make final adjustments until the engine becomes heated. When the engine becomes heated the vaporization of the fuel that is taken in depends largely upon the heat in the combustion chamber.

When the engine is cold it is noticeable that the mixture is too lean, hence the engine should be run with the choke valve partially closed and gradually opened as it becomes heated. A mixture that is too lean will cause misfiring at low speed, before it causes a back-fire, while a mixture that is rich may cause misfiring. When adjusting a carburetor always adjust it to the running condition of the engine, that is, considering temperature, speed and load.

Continuous dripping of gasoline from the carburetor may be caused by a loose connection where the gasoline pipe connects to the float chamber or by the float needle valve not seating properly in the bottom of the float chamber so that it will not shut off the gasoline properly. To remedy this, the float valve should be reground to its seat with fine valve grinding compound. The arms in the float chamber may be bent, allowing the float to rise too high before it shuts off the gasoline. This will cause the gasoline to overflow at the spray nozzle.

IGNITION

The ignition used on the internal combustion engine may be either magneto or battery ignition. The magneto ignition is divided into several different types such as low tension, low tension dual, high tension, high tension dual, and high tension duplex. The types of battery ignition are either the vibrating spark or the single spark ignition. The driving speed of these ignition devices varies in the different ignition systems. The ignition timer may be driven in connection with the generator or the pump shaft. The distributor must be wired according to the firing order of the engine. The secondary wires must lead to the proper cylinders, otherwise it will cause back-firing through an open inlet valve into the carburetor, and thus prevent starting of the engine.

The ignition can be timed so as to make the spark occur earlier or later. On the ignition device there is usually an advance and retard mechanism provided, which allows the spark to occur on top dead center or a little past when cranking the engine, and earlier as the engine speed increases. This is necessary because of the lapse of time between the occurrence of the spark and the fullest expansion of the gases. The higher the speed of the engine, the greater distance the piston will have moved by the time the burning gas has reached its maximum expansion; therefore, to obtain the maximum power from the fuel, it is necessary to have the fullest expansion occur immediately after the piston passes top dead center. This is accomplished by introducing the spark into the cylinder earlier.

Ignition devices for racing and high speed engines have a spark advance of about 45°, while the average automobile ignition has an advance ranging as high as 20° to 30°. Whether it is necessary to use the full range of advance or not can only be determined by putting the engine through a test. If the spark is advanced too far when cranking, it will cause a kick-back due to a partial expansion occurring before the piston reaches top dead center. When the engine is running and the spark is advanced, the momentum of the flywheel overcomes the force of the explosion until the piston passes top dead center. This premature explosion causes a very decided knock and wearing of the bearings.

It is noticeable that as the engine heats up the spark may have to be slightly retarded. This is due to the fact that after the engine becomes heated, the gases will burn faster than when cold, requiring the spark to be retarded. Also when the car is running up hill or pulling a heavy load the engine has a tendency to knock. This is due to the throttle valve being open wider and the engine drawing in a larger volume of the fuel mixture, which gives a higher compression and greater heating of the fuel. This causes the fuel to ignite and expand before the piston has reached top dead center, the same as when the spark occurs too early. This results in a loss of power and is remedied by retarding the spark. However, the engine should never be run any length of time with the spark fully retarded.

The formation of carbon in the combustion chamber causes a knock, due to high compression and temperature. This premature explosion cannot be prevented by retarding the spark. In cases of this nature the carbon should be removed.

When starting, the spark should occur in full retard on top dead center at the end of the compression stroke, or a trifle after. This will prevent a kick-back or other damage.

ENGINE STARTING DEVICES

One of the common methods of starting the engine is with a hand crank. This hand crank has notches machined on the end to engage with notches machined in either the crankshaft or on the crankshaft nut. The construction of these notches is such, that as the crank is turned in its direction of rotation it will readily turn the engine but as the engine starts, it will have a chance to overrun the starting crank throwing it out of engagement. However, should the engine kick back, as a result of the spark being advanced too far, it will drive the starting crank in the opposite direction, often breaking the arm of the operator and doing other damage.

Modern automobile engines are provided with an electric starting motor. The starting motor is mechanically connected to the crankshaft or flywheel by means of a sliding gear drive, or through a chain and sprockets, or may be automatically connected by means of a Bendix drive.

The source of current used to turn the starting motor is a storage battery provided for this purpose. The storage battery is kept in a charged condition by means of an electric generator driven by the engine. In some instances the same device is used for charging the battery that is used for cranking the engine, being termed a motor-generator. If the engine should not start within a reasonable length of time, it is not advisable to use the electric motor for too long a period. The battery will discharge rapidly, because the current flows from the battery through the electric motor at a high rate.

TWO STROKE CYCLE ENGINES

On a two stroke cycle engine, it requires two strokes of the piston to complete a cycle of operations, one downward and one upward movement.

Every time a piston reaches top dead center an explosion occurs. The explosions are not as powerful in this engine as they are in the four stroke cycle engine of equal displacement due to various reasons. One is that the piston does not have sufficient time to take in a full charge of fuel; another is that the fuel taken into the cylinder is not vaporized as thoroughly; and third, as the exhaust stroke is only about 100° long, there is not sufficient opportunity to scavenge the cylinder of all burned gases. The burned gases remaining in the cylinder have a tendency to lower the efficiency of the fresh gases. The exhaust port being located at the bottom of the stroke of the piston instead of at the top prevents the upward moving piston from forcing the burned gases out, which results in a general loss in efficiency. The two stroke cycle engines are divided into two port and three port types.

The crankcase assists in the performance of the cycle of operations, as the gases are drawn into the crankcase before being admitted into the combustion chamber. This causes considerable condensation in the crankcase. Crankcase compression is one of the greatest drawbacks to the two stroke cycle engines. The condensed portion of gasoline remaining in the crankcase decreases the volume of the mixture entering the cylinder.

Construction and Operation

Instead of employing valves as are used in the four stroke cycle engine, the two stroke cycle engine uses ports placed in the sides of the cylinder. These ports are slots in the cylinder wall, which are covered and uncovered by the movement of the piston. The exhaust port connects to the exhaust pipe and the inlet port connects to the by-pass leading to the crankcase.

Consider a charge as being in the combustion chamber of the cylinder ready to fire and a mixture in the crankcase at atmospheric pressure. This mixture was taken into the crankcase during the upward movement of the piston. The piston starts down, driven by the force of the expanding gases (explosion), and as it is driven downward, the piston compresses the mixture in the crankcase. When the piston reaches a point of about 50° before B. D. C. the exhaust port is uncovered which allows the burned gases to pass out of the cylinder. After 10° or 15° more crankshaft travel or about 40° before B. D. C., the inlet by-pass port is uncovered. The compressed mixture in the crankcase will then enter the cylinder through the inlet by-pass. During the upward movement the piston again covers the inlet and exhaust ports, the mixture in the cylinder is compressed and the vacuum formed in the crankcase draws a new charge. When the piston reaches T. D. C. it will again be at the firing point, having completed the cycle of operation. This gives an exhaust stroke of approximately 100° and an inlet stroke of approximately 80°.

The exhaust port is uncovered before the inlet port to rid the cylinder of the burned gases, the excessive pressure and heat. On the piston head is a deflector, which is placed on the inlet side to deflect the incoming fuel charge upward, preventing it from passing out with

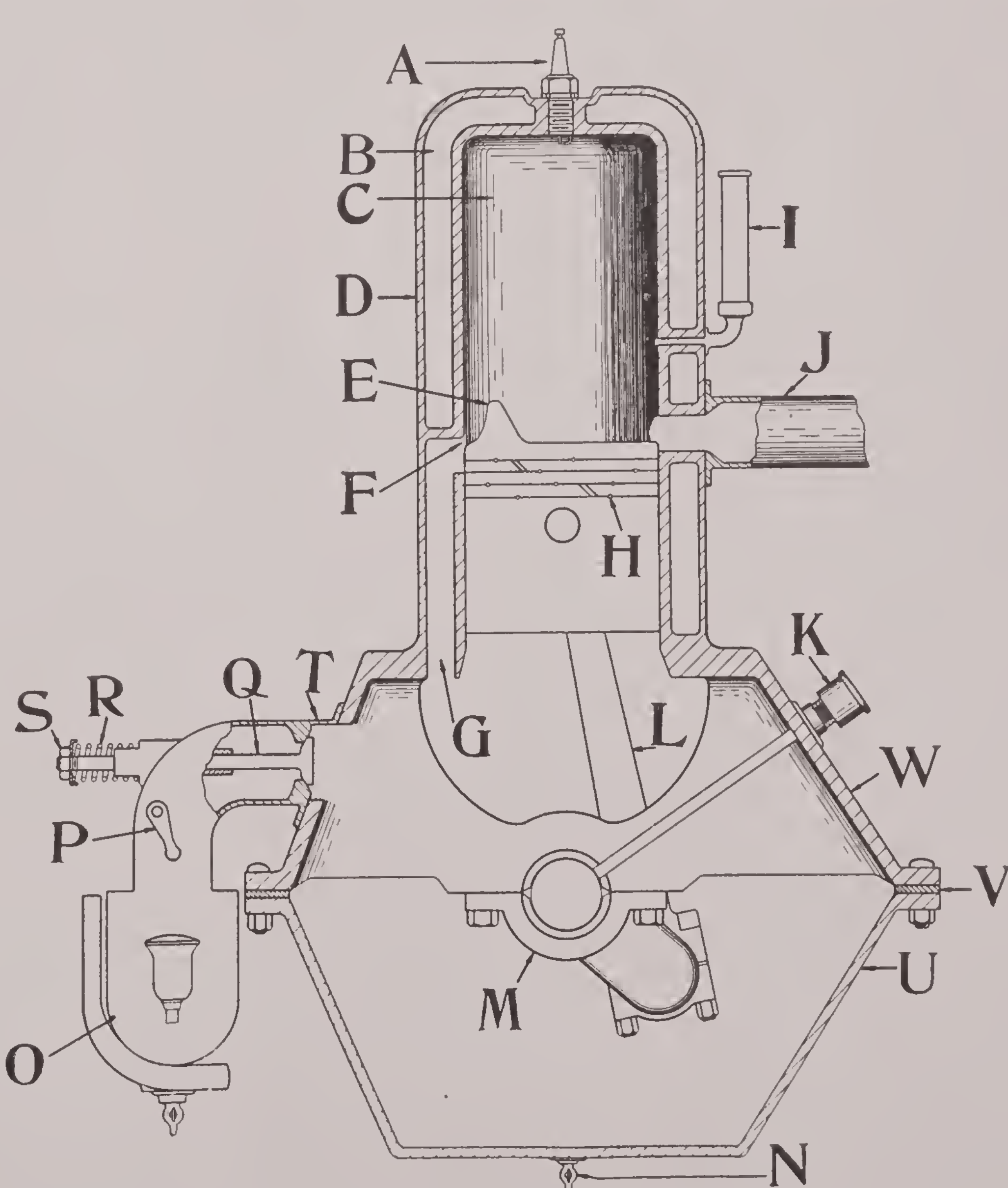


FIG. 82

TWO STROKE CYCLE TWO PORT ENGINE

A. Spark plug.
B. Water jacket.
C. Combustion chamber.
D. Cylinder.
E. Deflector plate.
F. Inlet port.
G. By-pass.
H. Piston ring dowel pin.
I. Oiler.
J. Exhaust connection.
K. Grease cup.
L. Connecting rod.
M. Bearing cap.
N. Drain cock.
O. Carburetor.
P. Throttle valve.
Q. Check valve.
R. Spring.
S. Lock nut.
T. Manifold.
U. Lower half of crankcase.
V. Gasket.
W. Air tight crankcase.

the burned gases. If the inlet port is uncovered at the same time as the exhaust, the pressure in the cylinder being greater than the pressure in the crankcase, will ignite the gases in the crankcase, causing a crankcase explosion. As the exhaust port is uncovered before the inlet port, most of the heat passes out, so that when the fresh gases enter the cylinder they are not ignited.

Either a lean mixture or a rich mixture, which burn slowly, will cause a crankcase explosion, because most of the gas is still burning in the cylinder when the inlet by-pass is uncovered. Since the exhaust port does not close until after the inlet port closes some of the fresh gases entering the cylinder will pass out with the burning gases, which is another disadvantage of the two stroke cycle engine.

The two port engine usually has the fuel admission inlet valve in the crankcase, which is either automatic in its action or mechanically driven. The mechanically driven inlet valve is designed to open as the piston starts upward on the compression stroke, after the inlet by-pass has closed, admitting a fresh charge of fuel to the crankcase and remains open until top dead center or a trifle past, depending upon the speed of the engine.

The three port engine does not employ an inlet valve. In this engine the carburetor is connected to a port which is covered and uncovered by the piston. As the piston goes up on the compression stroke in the cylinder it is forming a vacuum in the crankcase. This vacuum continues until the piston reaches a point about one inch before top dead center. Further movement of the piston uncovers the port to the carburetor and the vacuum formed in the crankcase draws in a supply of gas. This movement of the inrushing mixture drops off again as the vacuum decreases. The gas drawn into the crankcase has a tendency to condense into liquid gasoline, and if the compression in the crankcase is not great enough to force the condensed gases into the cylinder, the mixture will become too lean and also waste the fuel that is left in the crankcase. If too much of this condensed gas remains in the crankcase, the engine cannot be started.

While considering the operation of the two stroke cycle engine, it is necessary to take into consideration the air-tight crankcase, which has no breather tube. As the success of the two stroke cycle engine depends upon the crankcase compression, the bearings must be fitted closely. If the crankcase bearings are worn, the mixture will be blown out through the bearings instead of being compressed. The higher this mixture is compressed in the crankcase, the better it will remain vaporized and the more fuel will reach the combustion chamber. Since it is more essential that the crankcase bearings be air tight, packing glands may be provided on the main bearings.

The main bearings of the two stroke cycle engine are usually lubricated from grease cups, while the cylinders, pistons, and connecting rods are lubricated by oil mixed with the gaso-

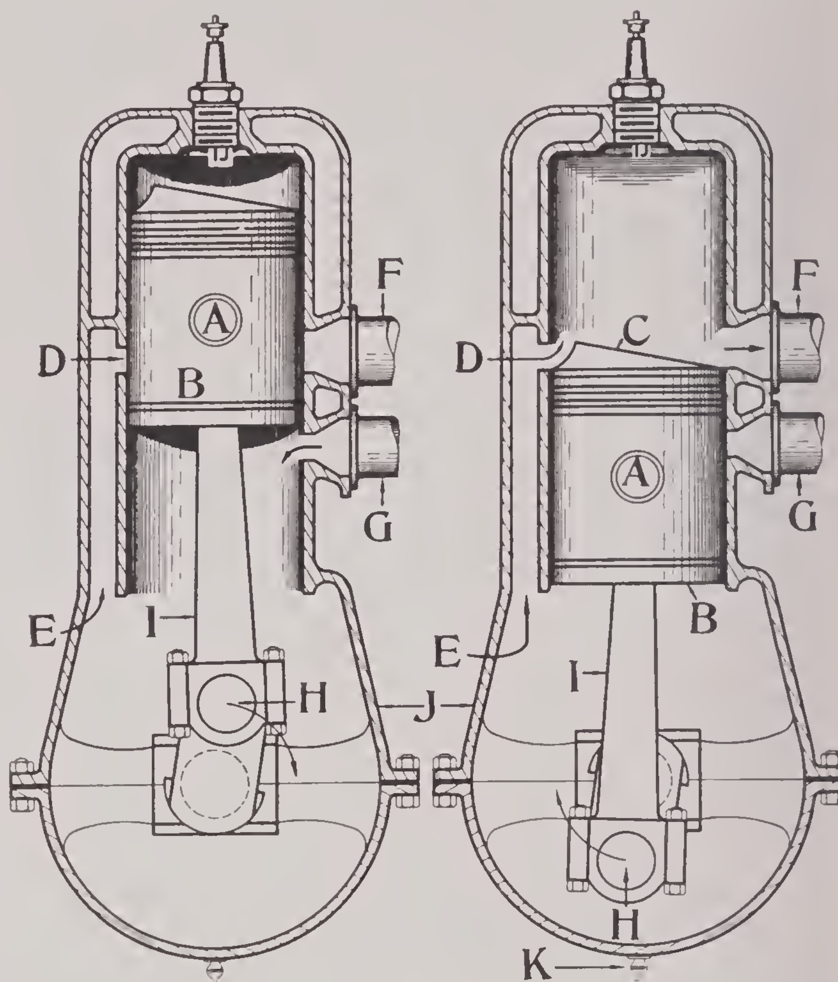


FIG. 83

TWO STROKE CYCLE THREE PORT ENGINE

(Left)

A. Piston pin.
B. Piston.
D. Inlet port.
E. By-pass.
F. Exhaust port.
G. Inlet port from carburetor.
H. Crank pin.
I. Connecting rod.
J. Air tight crankcase.

(Right)

A. Piston pin.
B. Piston.
C. Deflector plate.
D. Inlet port.
E. By-pass.
F. Exhaust port.
G. Inlet port from carburetor.
H. Crank pin.
I. Connecting rod.
J. Air tight crankcase.
K. Drain cock.

Illustration at left shows the piston on top dead center, end of the compression stroke, the bottom of the piston having opened the inlet port (G) to allow the mixture to enter the crankcase. The mixture will be compressed in the crankcase by the downward movement of the piston.

Illustration at right shows the piston on bottom dead center, the burned gases passing out through exhaust port (F) and the compressed mixture passing from the crankcase through by-pass (E) and inlet port (D) into the cylinder.

line. When the lubricating oil is mixed with the gasoline, care must be taken to keep it well mixed, otherwise the oil, being heavier than the gasoline, has a tendency to settle down in the bottom of the tank and may get into the carburetor and stop the engine. A thin or light grade oil should be used for this purpose. Oil cups are also provided in the cylinder to lubricate the cylinder walls.

The speed of the ignition drive differs from that used on a four stroke cycle engine because of the difference in the number of explosions per revolution. A two stroke cycle engine fires twice as often as a four stroke cycle engine, consequently the ignition apparatus must be driven twice as fast.

The two stroke cycle engine is more sensitive to a change in atmospheric conditions than the four stroke cycle engine, hence, the carburetor of the former must be adjusted more accurately. Two stroke cycle engines are not built in as large power units as the four stroke cycle type. Considerable experimenting has been done to eliminate crankcase compression on two stroke cycle engines, as this is one of its greatest drawbacks.

The two stroke cycle engine operates successfully with a mixing valve, which is similar to a carburetor excepting that it has no float chamber to regulate the height of gasoline in the spray nozzle. Also, on the mixing valves the main air valve is adjustable. The mixing valve adjustments are made by means of an adjustable air inlet and a gasoline needle valve. Care must be taken not to have the gasoline turned on for too long a period of time before the engine starts as this has a tendency to flood the crankcase with gasoline. The mixing valve works very successfully on a constant speed engine, and as a two stroke cycle engine usually runs at practically a constant speed it will answer the purpose. The two stroke cycle engine is used mostly as small marine units and as stationary engines for farm use.

Considering the four stroke cycle and two

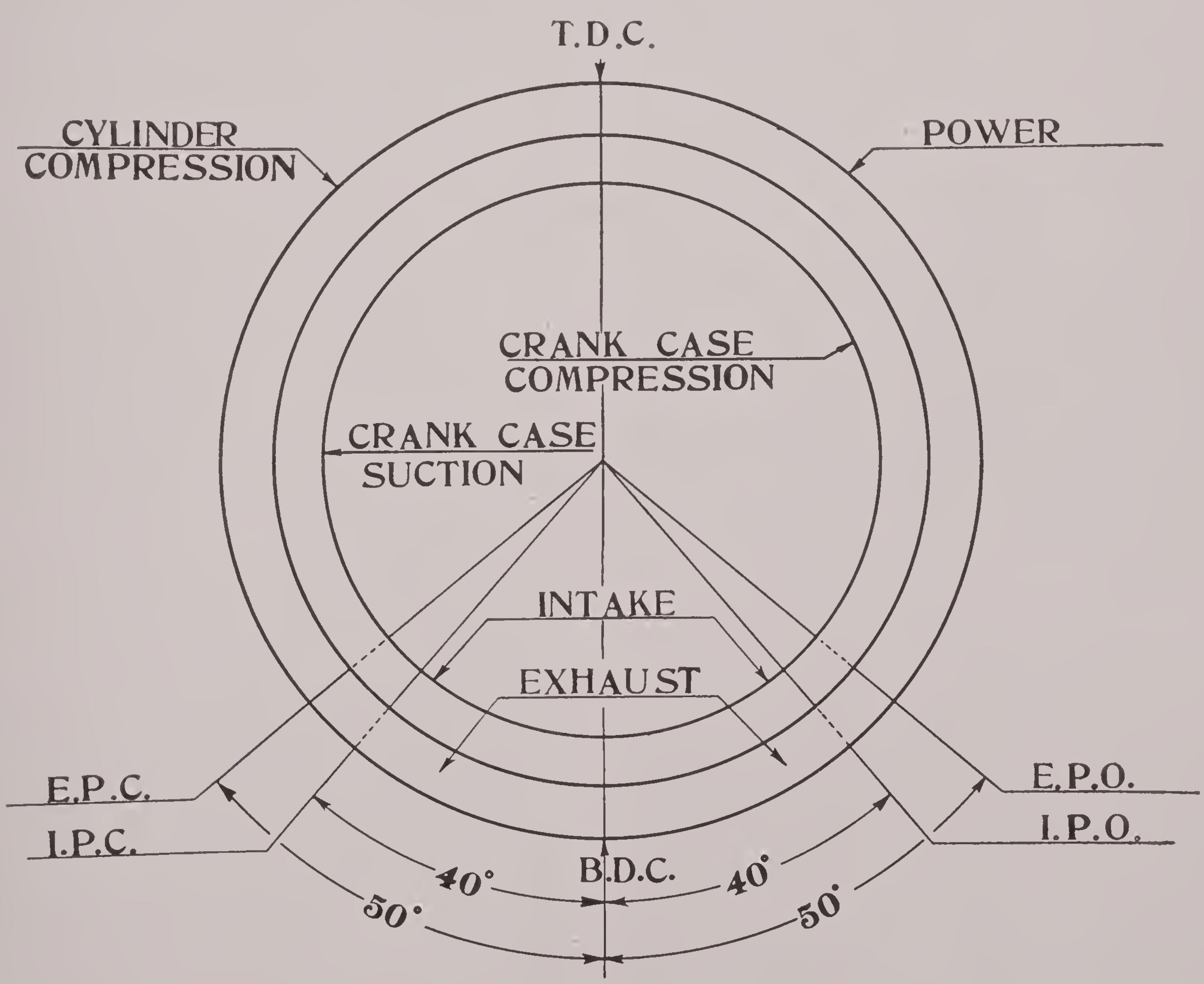


FIG. 84

CYCLE OF OPERATIONS TWO STROKE CYCLE ENGINE stroke cycle engines from a power viewpoint, the two stroke cycle, with its two explosions to one of the four stroke cycle, should give twice as much power, but because of the poor vaporization of the fuel, short inlet stroke and the poor scavenging of the cylinders, it does not develop twice the power. Should these faults be eliminated and the explosions be as powerful as those in the four stroke cycle, the two stroke cycle will develop nearly double the power, if not more, through the elimination of working parts.

STARTING PRECAUTIONS

Before trying to start an engine, after assembling it, always check the compression, ignition and fuel supply.

If there is no compression, then as the piston moves down on intake, it will not form a sufficient vacuum to draw in the necessary amount of fuel. If the valves seat properly it is only necessary to pour a few spoonfuls of oil on the head of the pistons. Then spin the engine over a few times by hand with the ignition off, the pet cocks open, and the throttle valve closed.

The secondary wires should be correctly connected to the spark plugs, according to the direction of rotation of the distributor brush and the firing order of the engine. The spark should occur in each cylinder when the piston is on top dead center compression, with the breaker mechanism in retard.

See that there is gasoline at the top of the spray nozzle. Partly close the choke valve or raise the float needle valve to obtain a rich mixture for starting. The fuel mixture is then taken into the cylinder and compressed and the spark occurring at the right time should cause an explosion. If it does not explode, warm the mixture by either pouring hot water on the inlet manifold, heating the manifold with a blow torch, or by removing the spark plugs and filling them with gasoline; ignite the gasoline and after it has burned out, screw these hot dry spark plugs into the cylinders and crank the engine over, priming it by partly closing the choke valve or by lifting the needle valve.

SUMMARY

INTERNAL COMBUSTION ENGINE

An internal combustion engine is a mechanical device for the changing or transforming of heat energy into mechanical energy.

The two fundamental principles upon which the design and operation of an internal combustion engine depend, are:

When a gas is compressed and its volume reduced, the temperature rises.

When the temperature of a gas is increased, it expands.

Types

Two stroke cycle.

Four stroke cycle.

A cycle is a series of events, beginning at any point, completing each operation always in the same order and returning to the starting point.

A cycle of operations in the internal combustion engine includes the operations necessary to make an engine run; namely, Intake, Compression, Power, and Exhaust strokes.

A two stroke cycle engine completes a cycle of operations during one revolution of the crankshaft, two strokes of the piston, or 360° crankshaft travel, regardless of the number of cylinders.

A four stroke cycle engine completes a cycle of operations during two revolutions of the crankshaft, four strokes of the piston, or 720° crankshaft travel, regardless of the number of cylinders.

The automobile engine operates on the four stroke cycle principle.

The average automobile engine has a thermal efficiency of about 17%.

Operations

The cycle of operations in an automobile engine, beginning at the inlet valve opening is as follows:

The piston moves down with the inlet valve open and the exhaust valve closed, causing a vacuum within the cylinder. The throttle valve in the carburetor is open and there being a higher pressure outside than within, the air rushes in to fill the space formed by the downward movement of the piston. As the air rushes by the spray nozzle, it takes up a supply of gasoline, and due to the high air velocity, mixes it with the air in the form of a gasoline vapor.

At the end of this, the intake stroke, the piston will be down and the cylinder filled with a mixture at approximately atmospheric pressure. At this point, the inlet valve closes. The exhaust valve remains closed and the piston moves up, compressing the mixture. When the piston reaches its highest point of travel, the pressure within has been increased to about 70 pounds per square inch. The mixture has been heated, dried and properly vaporized by this, the compression stroke. The spark occurring at this point ignites the mixture and as it burns, it explodes and expands, driving the piston down, with both valves closed. This is the power stroke.

When the piston approaches the bottom, the mixture has been burned and the exhaust valve opening at this point allows the greater portion of the burned gases, which are under considerable pressure, to pass out. Then the piston moves up with the inlet valve closed and the exhaust valve open, forcing the remainder of the burned gas out of the cylinder. When the piston reaches its highest point of travel, the exhaust valve closes. This ends the exhaust stroke and completes 720° of crankshaft travel. When the piston starts to move down, the inlet valve opens again, and a new mixture will be drawn in, beginning another cycle of operations which the engine performs over and over again.

COMPRESSION

If the compression of an engine is increased, the power developed increases in proportion, until the maximum point of compression is reached.

The maximum point of compression is the amount of compression that an engine will operate under without causing pre-ignition, which varies on different engines.

The average automobile engine has a compression of about seventy pounds per square inch.

S. A. E. HORSE POWER FORMULA

$$H. P. = \frac{D^2 \times N}{2.5}$$

CYLINDERS

Types

T-shape .... T-Head
L-shape .... L-Head
Valve-in-head .... I-Head
Superimposed .... F-Head

Troubles

Scored.
Warped (out of round).
Cracked water jacket.

CARBON DEPOSIT

Cause

Excessive or low grade lubricating oil.
Incorrect mixture, rich, dirty or unvaporized.

Remedy

Kerosene.
Water.
Scraping.
Burning.

PRE-IGNITION

Pre-ignition is a premature explosion, or the explosion occurring too early.

Cause

Advanced Spark—Spark knock.
High Compression—Compression knock.
Carbon Deposit—Carbon knock.
Hot Spots—Hot engine.

PISTONS

Material

Cast Iron. Semi-Steel. Aluminum Alloy.

Design and Fitting

The piston head must be made smaller than the skirt, or fitted with a greater clearance. Reason: It expands more, due to being in direct contact with the source of heat, has less lubrication and less opportunity of cooling. The piston skirt can be fitted tighter because it is farther away from the source of heat, has better lubrication and better opportunity of cooling, because of thinner construction.

Three important points to consider when replacing pistons are: All the pistons in an engine should be of the same weight; all the pistons should be the same height from center of piston pin hole to head of piston; the piston pin holes must be at right angles to the piston wall.

PISTON RINGS

Types

Eccentric. Concentric. One piece. Leak proof.

Material

Cast Iron. The three reasons for using cast iron in piston rings are: Its rate of expansion is low; it retains its elasticity better than other metals when heated; it is a good wear resisting metal.

Clearance

Clearance should be measured between the ends of the ring with a thickness gauge, when the ring is inside the cylinder; allow the same clearance as allowed on the diameter at the head of a cast iron piston of the same size.

Back of the ring allow about 1/32″, or enough to prevent any chance of the ring riding on the bottom of ring groove.

PISTON PINS

Material

Alloy Steel—heat treated—hardened.

Clearance

The fitting of the piston pin in the piston is governed by the type of piston and engine, usually a tight twisting fit with palm of hand being correct.

Precaution

When assembling an engine, always see that the piston pins are properly locked.

CONNECTING RODS

Types

Single {I-Beam
Yoke {Tubular

Bearings

Three reasons why babbitt is used for the crank pin bearing of the connecting rod are: It has a low coefficient of expansion; it is a soft bearing metal (protects the crankshaft), and it is easy to replace and fit.

Precautions to observe when fitting bearings:

Remove all the old babbit.

Press the new bearing into place.

Fasten with screws or dowel pins.

See that the dowel pins are countersunk.

Dress the bearing flush between the rod and cap.

See that the bearing does not ride on the fillets of the crank pin.

Have the scraper sharp.

Do not use long strokes.

Do not use the point of the scraper.

Scrape the high spots only.

Do not fasten the rod onto the crankshaft too tightly.

Each time an impression is taken, clean the bearing.

Examine the crank pin for burrs or rough spots.

Fasten on same crank pin and in the same position each time.

When Assembling Rods in the Engine

Clean and lubricate the bearings, pistons, cylinders, and crank pins.

Lock the piston pin.

Fasten on the same crank pin in the same position as when scraped.

With the correct number of shims between rod and cap, pull the castle nuts as tightly as possible with a socket wrench of the right size. Then lock the nut with a cotter pin.

Alignment

The crank pin and piston pin holes must be parallel.

MAIN BEARINGS

Precaution

When fitting main bearings, scrape in the crankcase bearings first.

To check the alignment of the crankshaft mounting, use a test indicator or surface gauge, and test from face of crankcase, counter bore, cylinder head or any machined surface.

CRANKSHAFT

Alignment

To test the alignment of a crankshaft, use a test indicator or surface gauge while revolving the shaft between lathe centers.

Troubles

If the crank pin bearing of the connecting rods are continuously wearing or working loose, the most probable cause is that the crank pin is out of round.

If the main bearings are continuously working loose, the most probable cause is that the crankshaft is either sprung out of alignment or the main journals are out of round.

VALVES

Types

Poppet.
Rotary.
Sleeve {Sliding.
{Rotary.

Material—Poppet Valve

Alloy steel stem, cast iron head; one piece alloy steel; alloy steel stem and tungsten steel head.

Fitting

When grinding valves, the two most important precautions to observe are:

Do not bear down too hard.

Do not turn the valve continuously in one direction.

When assembling the valves after grinding, observe the following precautions:

Clean the valves and cylinders, remove all the grinding compound.

Place the valves in the same seat in which they were ground.

Place the correct springs on the valves, and see that the springs set squarely on the retainers.

The clearance of the valves in the guides varies on different engines. When fitting a new valve, the stem should have enough clearance in the guide to allow the valve when the stem is properly lubricated, to settle down easily against its seat, under its own weight.

If the exhaust valve stem is too tight, it will stick and hold open, causing misfiring.

The exhaust valve stem fitting too loosely, will not greatly affect the operation of the engine.

The inlet valve stem fitting too tightly, causes the valve to stick and hold open, resulting a steady continuous back-firing in the carburetor.

The inlet valve stem fitting too loosely, causes an irregular back-firing in the carburetor, due to a lean mixture.

VALVE CLEARANCE

Adjust the clearance roughly to about .020″.

Run the engine until it is hot, just before the water boils in the cooling system. Then measuring with a thickness gauge, allow .002″ clearance on the inlet and .004″ clearance on the exhaust. This is the correct measurement after the lock nut is tightened. This measurement is made between the clearance adjusting nut and valve stem when the tappet is on the heel of the cam and the valve seated.

TAPPETS

Types

Roller. Mushroom.

VALVE SPRINGS

The exhaust valve spring requires more tension than the inlet spring, to prevent the exhaust valve from being forced away from its seat by the higher pressure in the manifold, during the time that there is a vacuum in the cylinder.

Where both springs have the same tension, the inlet has an unnecessary amount of tension.

The exhaust valve spring requires enough tension to hold the exhaust valve against its seat during intake stroke. If the spring is too weak, misfiring will result.

The inlet valve spring requires enough tension to cause the valve stem and tappet to follow the contour of the cam to insure the valve closing at the proper time.

CAMSHAFT

The purpose of the camshaft and cams is to operate the valves.

The toe of the cam governs the lift of the valve, the length of the stroke, and the speed of the individual valve opening and closing.

The order in which the cams are set on the camshaft and the type of crankshaft governs the firing order of the engine.

To determine the angles at which the cams are set on the camshaft, divide the angle the crankshaft travels between the explosions, by two.

The camshaft always revolves one-half crankshaft speed in all four stroke cycle engines.

In engines of conventional design, the camshaft timing gear always has twice as many teeth as the crankshaft or master gear.

VALVE OPENINGS AND CLOSINGS

T. D. C. means TOP DEAD CENTER.

B. D. C. means BOTTOM DEAD CENTER.

Valve openings and closings are considered in degrees of crankshaft travel.

F. P. Firing point is T. D. C. at the end of compression stroke.
E. C. Exhaust valve closing.
E. O. Exhaust valve opening.
I. O. Inlet valve opening.
I. C. Inlet valve closing.

The following operations are based on the average engines:

E. C.— 5° past T. D. C.
E. O.—135° past T. D. C.
E. O.—135° past F. P.
E. O.— 45° before B. D. C.
I. C.— 35° past B. D. C.
I. C.—145° before T. D. C.
I. O.— 10° past T. D. C.
I. O.—350° before F. P.

The average length of the different strokes:

Intake	205°
Compression	145°
Power	135°
Exhaust	230°
Lap	5°
One cycle of operation	720°

INLET MANIFOLD

A leak in the inlet manifold will cause an irregular back-firing in the carburetor, due to a lean mixture.

EXHAUST MANIFOLD

If the exhaust manifold is too small it will cause a loss of power, over-heating of the engine and possibly misfiring, due to the back pressure in the manifold.

An explosion in the exhaust manifold or muffler is usually caused by misfiring.

FOUR CYLINDER ENGINE

Four Stroke Cycle

A four cylinder engine fires every 180°. An inlet valve opens every 180° **crankshaft** travel, as also does an exhaust valve. The respective valves open every 90° **camshaft** travel. All inlet cams are set on the camshaft 90° apart; exhaust cams same. There are only two possible firing orders and they are both standard.

Four Cylinder Standard Firing Orders

1-2-4-3
1-3-4-2

In a four cylinder engine with a power stroke of 135°, after the completion of one power stroke, there is 45° crankshaft travel before the next one fires. During every 180° of crankshaft travel, there is an interval of 45° without power. This gives a total of 180° without power during the time required to complete a cycle of operations, or 720° crankshaft travel. When one cylinder misfires, the angle traveled by the crankshaft between explosions is 360°. During this time only one power impulse occurs, which results in 225° travel without power.

SIX CYLINDER ENGINE

A six cylinder engine fires every 120°. An inlet valve opens every 120° **crankshaft** travel, as also does an exhaust valve. The respective valves open every 60° **camshaft** travel. All inlet cams are set on the camshaft 60° apart; exhaust cams same. There are eight possible six cylinder firing orders.

Six Cylinder Standard Firing Orders

1-5-3-6-2-4
1-4-2-6-3-5

In a six cylinder engine with a 135° power stroke, 15° before the end of one power stroke, another begins. Every 120° of crankshaft travel there is an interval of 15° during which there are two cylinders on power. During two revolutions of the crankshaft or the time required to complete one cycle of operations, there are six different intervals of 15° each, or a total of 90° crankshaft travel with two cylinders on power at the same time. If one cylinder misfires there will be an interval of 240° from the time one cylinder fires until another cylinder fires, thus 240°—135° gives 105° without power.

EIGHT CYLINDER V TYPE ENGINE

A standard eight cylinder V-type engine fires every 90°. An inlet valve opens every 90° of **crankshaft** travel, as also does an exhaust valve. The respective valves open every 45° of **camshaft** travel. All inlet cams are set on the camshaft 45° apart; exhaust cams same. Since an eight cylinder V type engine is the same as two four cylinder engines using the same camshaft and crankshaft, each engine block will have a standard four cylinder firing order. There are four possible eight cylinder firing orders.

Eight Cylinder Standard Firing Orders

1R-4L-2R-3L-4R-1L-3R-2L
1R-4L-3R-2L-4R-1L-2R-3L

In an eight cylinder V-type engine with a 135° power stroke, 45° before the end of one power stroke, another begins. Every 90° of crankshaft travel there is an interval of 45° during which there are two cylinders on power. During the time required to complete a cycle of operations, or two revolutions, there are eight intervals of 45° each, or a total of 360°, or one-half the time there are two cylinders on power at the same time.

If one cylinder misfires, from the time that one fires until another fires, is 180°—135° which gives an interval of only 45° without power.

TWELVE CYLINDER V TYPE ENGINE

A standard twelve cylinder V type engine fires every 60°. An inlet valve opens every 60° of **crankshaft** travel, as also does an exhaust valve. The respective valves open every 30° of **camshaft** travel. All inlet cams are set on the camshaft 30° apart; exhaust cams same. There are eight possible twelve cylinder firing orders.

Twelve Cylinder Standard Firing Orders

1R-6L-5R-2L-3R-4L-6R-1L-2R-5L-4R-3L
1R-6L-4R-3L-2R-5L-6R-1L-3R-4L-5R-2L

In a twelve cylinder engine with a 135° power stroke, 60° after the beginning of one power stroke, another begins, 60° later another, etc. Since the third one begins 15° before the first one ends its power stroke, then there are two cylinders on power all the time, and during 15° of the crankshaft travel there are three cylinders on power at the same time. Thus during a cycle of operations in a twelve cylinder engine, there is a total of 720° that two cylinders are on power, and 180° of the 720°, that three cylinders are on power at the same time. When one cylinder misfires, from the time one cylinder fires until another fires is 120°; at the end of 120° crankshaft travel, the first one still has 15° to travel on power, so that there is always continuous power in a twelve cylinder engine even when one cylinder misfires.

COOLING SYSTEMS

Types

Air cooled.

Water cooled {Thermo-syphon. / Circulating pump.}

LUBRICATION

The three most important purposes of lubrication, are:

General lubrication, compression seal and cooling.

OIL PUMPS

The capacity of a gear type pump depends upon:

The speed, the size and fit of the gears, the number and size of the teeth, the grade of oil, and the type of lubricating system.

The capacity of a plunger pump depends upon:

The speed, the stroke, the bore, the size of the inlet and outlet pipes, the grade of oil, and the type of lubricating system.

FUEL SYSTEMS

Types

Gravity—(The tank must have an air vent.)
Vacuum—(The tank must have an air vent.)
Pressure—(The tank must not have an air vent.)

CARBURETION

Definitions

The carburetor is a mechanical device for the mixing of fuel and air into a vapor of different proportions as may be required by the engine.

The purpose of the float and float valve is to regulate the fuel supply in the float chamber and jets, maintaining a constant level just below the top of spray nozzle.

The purpose of the venturi tube is to restrict the air passage, thus increasing the velocity of the air at the spray nozzle.

The purpose of the throttle valve is to control the speed of the engine by regulating the amount of mixture which is taken into the cylinder.

The purpose of the choke valve is to vary the size of the main air inlet, to regulate the mixture while starting. This should be used only while starting or until the engine warms up.

The purpose of the auxiliary air valve is to admit air into the mixing chamber above the spray nozzle when the engine is running at high speed. This prevents the mixture from becoming too rich at high speeds.

The purpose of the stop screw is to keep the throttle valve from closing completely when the throttle valve control lever is in closed position, thus preventing the engine from stopping.

Misfiring at idling speed, an irregular backfiring at normal speed, high speed, or upon acceleration, indicates a lean mixture.

A galloping or loping of the engine, running irregularly but still firing all cylinders, black smoke issuing from the exhaust, is an indication of a rich mixture.

If the mixture is too rich the engine will misfire, but a rich mixture will not cause a backfire.

Blue smoke issuing from the exhaust is an indication of the burning of lubricating oil in the combustion chamber.

Troubles

A leaky carburetor may be caused by a loose connection, flaw or sand hole in the casting, float punctured, or gasoline logged, or stuck down, float valve sprung or seat rough, sediment under the float valve, float lever arms bent (upward), or anything which may prevent the float valve from seating properly when the gasoline reaches the correct level.

A starvation of the carburetor (lack of gasoline) may be caused by anything that prevents the flow of gasoline to the spray nozzle as fast as the engine consumes it. This may be caused by not having an air vent in the gasoline tank (gravity or vacuum), a leak in the gasoline tank or line, loss of pressure (pressure system), insufficient amount of gasoline supplied by the vacuum tank, an obstruction anywhere in the supply line, sediment, screens dirty or rusty, float lever arms bent (down), float stuck (up), gasoline or fuel adjusting valve adjusted too close, sediment or obstruction in the jets or spray nozzle.

TESTING COMPRESSION

To test the compression, remove the spark plug and screw a pressure gauge in the spark plug hole. As the engine is cranked over slowly, this will register the number of pounds pressure per square inch in the cylinder.

To determine the weak from the strong cylinder, where a pressure gauge is not available, open all pet cocks but one, crank the engine over and feel the compression by the resistance of the crank and the rebound of the piston over T. D. C., remembering that tight bearings, tight pistons, or dry cylinder walls offer resistance, but not a rebound or recoil.

ASSEMBLING AND STARTING AN ENGINE

When assembling an engine, always clean and lubricate all bearing surfaces and examine the crankcase surface, the oil pan, the cylinder flange, the cylinder head, the manifold flanges, and every point where one machined surface comes in contact with another and see that there are no nicks, or rough places. Use an oil stone to remove these uneven places on the machined surfaces. If the surfaces are even and a good gasket is used, there is no necessity for using shellac. Place lubricating oil or cup grease on each side of gasket instead. This prevents tearing or destruction of the gasket when the part is removed.

Always use a wrench (a socket wrench if possible) of the correct size when removing or tightening a nut. Never use pliers or a cold chisel.

Always lock a nut where there is a means of locking provided, such as a lock washer, safety wire or cotter pin.

When adjusting a carburetor, always adjust to the operating condition of the engine, that is, make the adjustment when the engine is hot and running under load. Low speed adjustment should be made when the engine is running slowly, under load, and with retarded spark. High speed adjustment should be made when the engine is running at high speed, under load and with an advanced spark.

Three things that are necessary to start an engine that is properly assembled are: Compression, spark occurring at the correct time, and fuel in the engine.

TWO STROKE CYCLE

In a two stroke cycle engine, regardless of the number of cylinders, all cylinders fire during one revolution of the crankshaft, two strokes of the piston or 360° of crankshaft travel.

Every time a piston reaches T. D. C. it is on the firing point.

To determine the number of degrees the crankshaft turns between explosions, divide 360° (the time required to fire all cylinders) by the number of cylinders.

The angle at which the crank throws are set is the same as the angle traveled by the crankshaft between explosions.

DON'TS

Don't race an engine with the clutch disengaged.

Don't run a new car, or an old car that has just been repaired, at high speed until the parts are worn in.

Don't pour cold water in the cooling system when the engine is hot and the water has evaporated; wait until the engine cools.

Don't run the engine without proper means of cooling and lubrication.

Don't tighten the packing nuts on water and oil pumps too tightly; just tight enough to stop the leak is all that is necessary.

Don't use any kind of oil for lubrication except the best; there is no oil just as good as the correct oil.

Don't try to adjust the carburetor every day to suit varying atmospheric conditions. Perhaps it will be correct the next day.

Don't use the choke valve for stopping an engine.

Don't prime an engine by squirting gasoline into the cylinder through a petcock. Partly close the choke valve or raise the needle valve.

Don't use the choke valve any more than is absolutely necessary.

Don't keep spinning an engine. When it will not start, check up the compression, mixture and ignition.

Don't overload an engine. If the engine begins to labor, shift to a lower speed.

Don't take chances. Know that you are right and then go ahead.

Don't depend upon the other fellow. Have confidence in yourself.

Don't tell the other fellow what you can do—show him.

Don't feel discouraged if you make a mistake. If you never make the same mistake again, you are improving.

Don't mind ridicule; every big man is ridiculed sometime in life.

Don't copy. Be original.

Don't watch the clock. Watch your work.

THINK!

QUESTIONS

1—What is an internal combustion engine?
2—Name the types of internal combustion engines.
3—Explain the operation of each type.
4—What is a cycle?
5—What is a cycle of operations of an engine?
6—How many events occur in a complete cycle of operations?
7—How many degrees crankshaft travel are necessary to complete a cycle of operations in a four cylinder, four stroke cycle engine?
8—How many degrees crankshaft travel are necessary to complete a cycle of operations in a six cylinder, two stroke cycle engine?
9 (a)—How many revolutions of the crankshaft are necessary to complete a cycle of operations in an eight cylinder, V type engine, where the crank throws are set 180° apart, and the cylinders 90° apart?
(b)—How many degrees will the camshaft revolve while the above engine is completing a cycle of operations?
10—How many degrees crankshaft travel are necessary to complete a mechanical cycle?
11—On the average engine where does the exhaust valve open and close?
12—Where does the inlet valve open and close?
13—What is the length in degrees of each stroke?
14—Which is the longest and which is the shortest stroke of the cycle?
15—What determines the inlet valve closing point on any engine?
16—Why is the inlet valve allowed to remain open past B. D. C.?
17—What prevents the mixture from being forced out when the piston moves upward before the inlet valve closes?
18—Why is the exhaust valve opened before B. D. C.?
19—What causes the burned gases to pass out when the piston is moving downward with the exhaust valve open?
20—Why is the exhaust valve allowed to remain open past T. D. C.?
21—What is the purpose of the lap between the closing of the exhaust and the opening of the inlet valves?
22—Name the types of cylinder castings.
23—What does the name refer to?
24—What materials are used in cylinder construction?
25—Give the advantages and disadvantages of the different types of cylinders.
26—Name the most common cylinder troubles.
27—How should a scored cylinder be repaired?
28—How would a cylinder be repaired that is out of round?
29—How would a cracked water jacket (a small crack) be repaired?
30—How would a cracked water jacket (a large crack) be repaired?
31—Explain how to lap in a cylinder after reboring.
32—Explain how to fit a new oversize piston after the cylinder has been rebored.
33—Should the rings be removed from the piston when lapping?
34—What precautions should be observed when assembling an engine after the piston and cylinders have been lapped in?
35—What are the two main causes of carbon deposit?
36—What effect will carbon deposit have on the operation of an engine?
37—Why does carbon deposit cause a knock?
38—Name and explain three common methods for removing carbon deposit.
39—Name three probable causes of pre-ignition.
40—Will the spark advanced too far affect the running of the engine? How?
41—How will excessive compression affect the operation of an engine?
42—At what speed will a compression knock be more noticeable?
43—How would a compression knock be remedied?
44—If the compression of an engine is lowered, will there be an increase or decrease in power at normal running speed?
45—If two engines of the same model and size with one running light and the other under load at the same speed, which engine is developing the more power? Which one has the more compression? Why?
46—If one of the engines has forty pounds compression and the other has sixty pounds, which will develop the more power? Why?
47—The same two engines at the same speed, the same load and with equal compression; the water in the cooling system of one has a temperature of 200° F. and the other 120° F. Which engine has the higher efficiency? Why?
48—What are the two fundamental principles that govern the design and operation of an internal combustion engine?

49—What is meant by the H. P. of an engine?

50—What is meant by the piston displacement of an engine?

51—What is meant by the R. P. M. of an engine?

52—What is meant by the piston speed of an engine?

53—What is meant by the M. E. P. of an engine?

54—What is meant by the B. H. P. and I. H. P. of an engine?

55—What is the I. H. P. of a four cylinder, four stroke cycle engine with a 4″ bore and a 5″ stroke, with an M. E. P. of 90 lbs. per sq. in. developing its maximum torque or power at 2,500 R. P. M.?

56—What is the piston speed of the above engine expressed in ft. per min.?

57—What is the total piston displacement of the above engine?

58—Suppose it is desired to determine the H. P. of a six cylinder engine and no data or specifications of the engine are available except that the inside diameter of the cylinder is 3-1/2″. What would be the approximate H. P.?

60—Give three reasons why the skirt of a piston may be fitted tighter, allowing less clearance than at the top.

61—What materials are used in piston construction?

62—On the average water cooled engine, what are the correct clearances to allow on a cast iron piston of three inch diameter, measured on the diameter above the top ring and at the lower skirt? A 3½″ piston? A 4″ piston?

63—How much clearance should be allowed on the head and skirt of an aluminum alloy piston of 3″, 3½″, 4″ diameters respectively?

64—When fitting piston rings, how much clearance should be allowed back of the ring, that is, between the inside diameter of the ring and the outside diameter of the bottom of ring groove, when the outside surface of the ring is flush with the outside surface of the piston?

65—How tight should the rings be fitted into the ring groove on the average piston?

66—What is the correct clearance to allow between the ends or joint of a 4″ diameter ring?

67—What is the proper way to measure the clearance between the ends of a ring?

68—Why is cast iron generally used in piston ring construction?

69—If all the pistons in the engine do not weigh the same, how would this affect the running of the engine?

70—When the pistons in the engine are not all of the same height or distance from the center line of the piston pin hole to the head of the piston, how will this affect the operation of the engine?

71—What is the common method used for fitting piston pins?

72—How tight should the piston pin be fitted on the average engine?

73—What is the purpose of a connecting rod?

74—Why is the crank pin bearing usually made of babbitt?

75—What are the main precautions to observe when fitting bearings?

76—When taking an impression, how tight should the bearing be on the shaft?

77—When fitting the bearings in the engine, what precautions should be observed?

78—When assembling the rods, how many shims should be used? How tight should the bearings be fitted?

79—After the castle nuts are on the connecting rod bolts and are pulled up tight, if the cotter pin hole is not in line, would it be advisable to loosen up on the nut in order to insert cotter pin? Would it be advisable to let the nut remain tight at that point and not insert a cotter pin?

80—How is the alignment of a connecting rod checked? Of a crankshaft?

81—Besides the precautions used in fitting connecting rod bearings, what other precaution must be observed when fitting the main bearings?

82—Is there a thrust bearing on the crankshaft?

83—Is the thrust bearing adjustable?

84—How much end play should be allowed in the crankshaft?

85—How will excessive end play of the crankshaft affect the running of the engine?

86—What method is used to test for a loose connecting rod bearing? Main bearing?

87—If the crank pin bearings of the connecting rods are continuously working loose, what is the most probable cause?

88—If the main bearings of the crankshaft are continuously working loose, what is the most probable cause?

89—Explain how to pour a connecting rod bearing.

90—Explain how to fit a yoke type connecting rod.

91—What precautions should be observed when the crank shaft is to remain out of the engine for some time?

92—What materials are used in valve construction?

93—Name the different types of valves.

94—What precautions should be observed when grinding valves?

95—What precautions should be observed when assembling valves and springs?

96—Which valve requires the stronger spring and why?

97—How strong should an exhaust valve spring be?

98—How strong should an inlet valve spring be?

99—How is the accurracy of a valve stem checked?

100—Under normal conditions, is it advisable to reface a valve?

101—If the exhaust valve stem is fitted too tightly, how will it affect the operation of the engine?

102—If the exhaust valve stem is fitted too loosely, how will it affect the operation of the engine?

103—If the inlet valve stem is fitted too tightly, how will it affect the operation of the engine?

104—If the inlet valve stem is fitted too loosely, how will it affect the running of the engine?

105—How much clearance should be allowed on the exhaust valve measured with a thickness gauge between the clearance adjusting screw and valve stem, when the engine is hot?

106—What precautions should be observed when making this adjustment?

107—How will excessive clearance affect the valve operation?

108—How will excessive clearance affect the engine operation?

109—How will insufficient clearance on the exhaust valve affect the engine operation?

110—How will insufficient clearance on the inlet valve affect the engine operation?

111—Name the different types of tappets with the advantages and disadvantages of each.

112—How tight should the tappets be fitted in their guide?

113—What is the purpose of a camshaft?

114—What is the purpose of the toe on the cam?

115—What part of the engine operation is governed by the toe on the cam?

116—What is governed by the order in which the cams are set on the camshaft?

117—How many degrees apart on the camshaft are the inlet cams set on a four, six, eight and twelve cylinder engine respectively?

118—How many degrees apart on the camshaft are the exhaust cams set on a four, six, eight and twelve cylinder engine respectively?

119—On a four cylinder T-head engine with a firing order of 1-2-4-3, how many degrees apart on the camshaft are No. 1 and No. 2 inlet cams set? How many degrees apart are Nos. 1 and 4 exhaust cams set?

120—On a twelve cylinder V type engine, crank throws set 120°, cylinders set 60°, with a firing order that starts 1R-6L-5R, how many degrees apart will Nos. 1R and 3R cylinders fire? How many degrees apart crankshaft travel will Nos. 1R and 3R inlet valves open? How many degrees apart camshaft travel will Nos. 1R and 3R inlet valves open? How many degrees apart on the camshaft are Nos. 1R and 3R inlet cams set?

121—What determines the distance apart the valves open, camshaft travel?

122—What determines the distance apart that the cams are set on the camshaft?

123—What governs the capacity of a gear oil pump?

124—What governs the capacity of a plunger oil pump?

125—How tight should the packing nut be adjusted on any pump?

126—What is the purpose of this packing?

127—How will a leak in the inlet manifold affect the operation of the engine?

128—How would you test for a leak in the inlet manifold?

129—What three things determine the distance apart the explosions occur?

130—How many degrees apart do the explosions occur in a four, six, eight and twelve cylinder engine respectively?

131—How many possible four cylinder firing orders are there?

132a—Name the standard four cylinder firing orders.

132b—With the cylinder head removed, how would No. 1 piston be placed on T. D. C. at the end of compression? How would the firing order be determined? How would the camshaft be timed?

133—With a firing order of 1-2-4-3, with No. 1 on the firing point, on what strokes would Nos. 2, 3 and 4 be?

134—When the inlet valve starts to open in No. 2, on what stroke will No. 3 be?

135—When the exhaust valve closes in No. 4, on what stroke will No. 1 be?

136—When the exhaust valve starts to open in No. 2, on what stroke will No. 3 be? No. 4?

137—If the camshaft gear has sixty teeth, how many teeth will there be in the crankshaft or master gear?

138—While the engine is completing a cycle of operations, how many degrees will the camshaft revolve?

139—How many degrees does the crankshaft of a four cylinder engine travel without power delivered from the piston, during the time required to complete a cycle of operations and how many cylinders will fire?

140—How many possible six cylinder firing orders?

141—Name the two standard six cylinder firing orders.

142—Explain how to time a six cylinder engine when the flywheel is not marked.

143—Explain how to adjust the valve clearance on a six cylinder engine.

144—With a firing order that starts 1-5, how many degrees apart will Nos. 1 and 6 fire? How many degrees apart on the camshaft will Nos. 6 and 2 exhaust cams be set?

145—With a firing order that starts 1-4, when No. 1 is firing, on what strokes will Nos. 2, 3, 4, 5 and 6 be?

146—When the exhaust valve is opening in No. 2, on what stroke will No. 6 be? No. 5?

147—When the inlet valve is closing in No. 5, on what stroke will No. 6 be? No. 2?

148—When one cylinder misfires, how many degrees does the crankshaft of a six cylinder engine revolve without power?

149—On a six cylinder engine, how many degrees are there with two cylinders on power at the same time, during 720° crankshaft travel?

150—How many possible eight cylinder firing orders?

151—Name the two most used eight cylinder firing orders?

152—How would the firing order of an eight cylinder engine be determined?

153—Explain how to time the camshaft on an eight cylinder engine.

154—With a firing order that starts 1R-4L-2R, how many degrees apart will Nos. 2R and 4R cylinders fire? How many degrees apart will Nos. 1L and 2L inlet valves open, crankshaft travel? Camshaft travel? How many degrees apart on the camshaft will Nos. 2R and 1L exhaust cams be set?

155—With a firing order that starts 1R-4L-3R, when the inlet valve is closing in No. 2R, on what stroke is No. 3R? When the exhaust valve is opening in No. 3L, on what stroke is No. 4R?

156—If one cylinder in an eight cylinder engine misfires, how many degrees does the crankshaft revolve without power?

157—If the secondary cables are removed from the right bank of an eight cylinder engine firing 1R-4L-3R, etc., what will be the firing order of the left bank and how many degrees apart will the explosions occur?

158—How many possible twelve cylinder firing orders?

159—Name the two standard twelve cylinder firing orders.

160—In a twelve cylinder engine, how many revolutions of the crankshaft are required to complete a cycle of operations?

161—How many degrees crankshaft travel are required to fire all cylinders of a twelve cylinder engine?

162—With a firing order that starts 1R-6L-5R, how many degrees will the camshaft travel from the time No. 1R inlet valve opens until it again opens?

163—With the above firing order, how many degrees apart, crankshaft travel, will Nos. 2L and 6R cylinders fire?

164—How many degrees apart camshaft travel will Nos. 1L and 4R inlet valves open? How many degrees apart will Nos. 1L and 4R exhaust cams be set on the camshaft?

165—When No. 5R exhaust valve is just closing, what cylinder will be on the firing point?

166—When the inlet valve just starts to open in No. 1L, to what cylinder should the ignition be timed, with the breaker mechanism in full retard?

167—When the inlet valve is closing in No. 6R, on what stroke will No. 1R be? No. 2R?

168—With a firing order that starts 1R-6L-4R, when the exhaust valve is just opening in No. 3R, on what stroke is No. 4R?

169—What piston is on T. D. C. at the same time as No. 2L?

170—In an eight cylinder engine, when there are two pistons on T. D. C. in one bank, how many will be on B. D. C. in the other bank at the same time? In the same bank?

171—In a six cylinder, when there are two pistons on T. D. C., how many will be on B. D. C. at the same time?

172—What is the standard setting in degrees of the cylinders on eight and twelve cylinder engines?

173—What is the standard setting in degrees of the crank throws on four, six, eight and twelve cylinder crankshafts respectively?

174—In a standard twelve cylinder engine, when there are two pistons on B. D. C. in one bank, how many pistons are on T. D. C. in the other bank?

175—When one cylinder misfires in a twelve cylinder engine, how many degrees does the crankshaft travel without power?

176—What is the test for a misfiring cylinder in an eight cylinder engine? In a twelve cylinder engine?

177—How is it possible to determine if No. 2R is firing?

178—How would No. 2R be placed on T. D. C. compression in a twelve cylinder engine?

179—Explain how to place No. 1R on T. D. C. compression in an eight cylinder engine.

180—Give some of the advantages and disadvantages of a sleeve valve engine?

181—What method is used to determine the firing order of a sleeve valve engine?

182—How would the eccentric shaft be timed in a six cylinder sleeve valve engine?

183—Name the types of fuel systems.

184—Should there be an air vent in the gasoline tank of the gravity fuel system?

185—If this air vent should become stopped up, would the operation of the engine be affected? How?

186—In a pressure system, what are the results if there is a greater pressure than five pounds in the tank and gasoline line?

187—Explain the action of the vacuum fuel system.

188—What is the purpose of the lower chamber of the vacuum tank?

189—What is the purpose of the vacuum or suction valve?

190—If the float should become punctured, what would be the result?

191—If the air valve does not seat properly, what is the result?

192—If the gasoline is coming out of the air vent at the top of tank, what is the most probable cause?

193—Why will a vacuum system starve the carburetor at high engine speeds?

194—Name the different cooling systems.

195—Give some of the advantages and disadvantages of an air cooled engine.

196—Why is it possible to obtain more miles per gallon of fuel from an air cooled engine than from a water cooled engine?

197—What causes the water to circulate in a thermo-syphon cooling system?

198—What governs the temperature required to start a circulation?

199—Explain the different ways of regulating the temperature in a circulating system.

200—Explain how to remove the scale from the cooling system.

201—What causes this scale to form?

202—What is the best prevention of the scale forming?

203—How will this scale in the cooling system affect the operation of an engine?

204—What are the three most important purposes of lubrication?

205—What governs the grade of oil to be used in an engine?

206—How can the correct grade of oil for an engine be determined?

207—What precaution should be observed when buying lubricating oil?

208—What is the correct amount of oil to use in the engine?

209—How can the correct amount of oil be determined?

210—Why is it necessary to drain the old oil and replace with new oil?

211—How often should this be done?

212—What is the advantage of washing the engine with kerosene?

213—What precaution should be observed when washing the engine with kerosene?

214—Why does the average engine demand a heavier oil in summer than in winter?

215—Give a brief explanation of the different lubricating systems.

216—What is the purpose of a carburetor?

217—What is the purpose of the float and float needle valve?

218—What is the purpose of the gasoline adjusting valve?

219—What is the purpose of the choke valve?

220—When should the choke valve be used?

221—What is the purpose of the throttle valve?

222—What is the purpose of the auxiliary air valve?

223—What is the purpose of the stop screw?

224—Where is the auxiliary air valve located?

225—How many valves are used in the average carburetor?

226—What is the purpose of the venturi tube?

227—Is the stop screw adjustable?

228—What is meant by the term "gasoline level"?

229—Name some of the causes of a leaky carburetor.

230—What is meant by the term "starvation of the carburetor"?

231—Why does the engine demand a richer mixture when starting?

232—Why does the mixture grow richer at high speeds?

233—What determines when the mixture is too lean?

234—How will a rich mixture affect the operation of the engine?

235—What does a blue smoke from the exhaust indicate?

236—What will cause a black smoke to issue from the exhaust?

237—What does an irregular backfiring in the carburetor indicate?

238—Will a lean mixture cause a backfire at idling speeds?

239—If the engine backfires in the carburetor when starting, is that an indication of a lean mixture?

240—Why will a leak in the inlet manifold cause a backfire in the carburetor?

241—Why is this more noticeable at low speeds?

242—What will cause a regular continuous backfiring in the carburetor?

243—What is the correct way to obtain the correct mixture for starting?

244—Can a carburetor be adjusted to give the correct mixture under all conditions?

245—Under what conditions should the high speed adjustments be made?

246—Should the low speed adjustment be made with the clutch engaged or disengaged?

247—How will a leaky float affect the carburetor action?

248—If the float valve does not seat properly, will the carburetor action be affected?

249—What will be the result if the engine is stopped by closing the choke valve?

250—Why is the float valve sometimes raised when starting the engine?

251—Explain the operation of a one cylinder, two port, two stroke cycle engine.

252—What is the average length of the power stroke; the exhaust stroke?

253—How is it possible to tell when piston is on T. D. C.?

254—In a four cylinder two cycle engine, how many degrees apart do the cylinders fire?

255—In a six cylinder engine how many degrees apart are the crank throws set?

256—What is the purpose of the deflector plate?

257—If there is unequal compression in the different cylinders of an engine, how is it possible to determine the weak ones?

258—When driving in low at low speed, the engine runs well; when driving in high at high speed, it runs well, but if the engine is throttled down to a hard pull in high, it lopes, vibrates, runs irregularly; what is the trouble?

259—What three things are necessary to start an engine that is properly assembled?

260—If when trying to start an engine only one cylinder fires, what is the cause and remedy?

261—If the engine is wired wrong according to the firing order, how will the engine operation be affected?

262—Name some of the more important precautions to observe when assembling an engine.

263—Is it advisable to try to eliminate backfiring in the carburetor upon acceleration?

264—If when driving at high speeds, the foot should slip off the accelerator, allowing the throttle valve to close suddenly, you notice a misfiring; what is the cause? Is it advisable to try to remedy this?

265—Is it advisable to use the compression of the engine as a brake? What precautions should be observed?

266—When stopping the engine, which is the better, to close the throttle valve first or cut off the ignition? Why?

267—If after cutting off the ignition, the engine still runs, what is the trouble?

LOCATION CHART

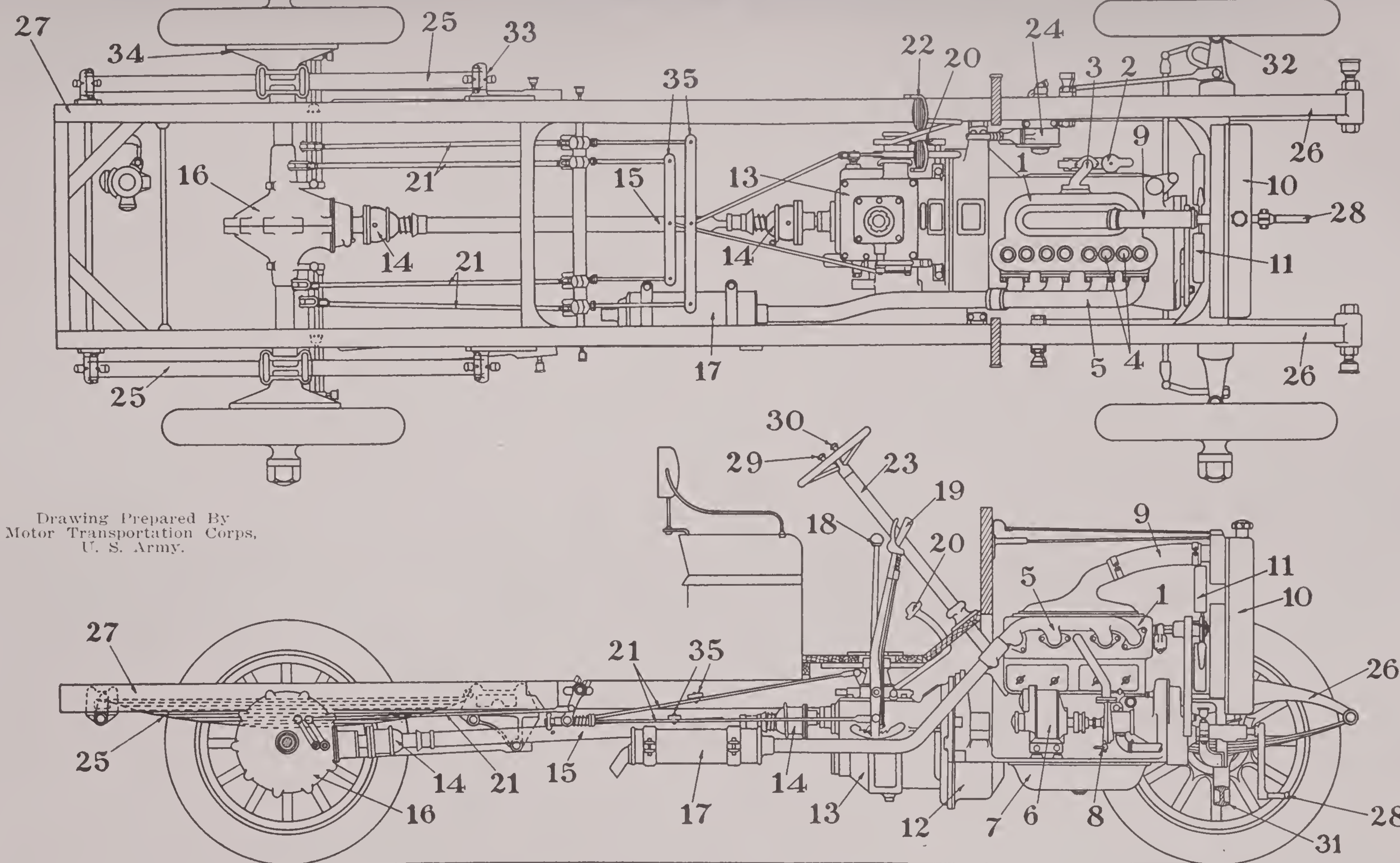


FIG. 85

1. Engine.
2. Carburetor.
3. Inlet manifold.
4. Port plugs.
5. Exhaust manifold.
6. Magneto.
7. Oil pan.
8. Water pump.
9. Rubber hose.
10. Radiator.
11. Fan.
12. Clutch.
13. Transmission.
14. Universal joint.
15. Drive shaft.
16. Rear axle.
17. Muffler.
18. Gear shift lever.
19. Hand brake lever.
20. Brake pedal.
21. Brake rods.
22. Clutch pedal.
23. Steering column.
24. Steering gear.
25. Springs.
26. Frame.
27. Frame.
28. Starting crank.
29. Spark control lever.
30. Gas control lever.
31. Front axle.
32. Steering knuckle.
33. Spring bracket.
34. Brake.
35. Brake equalizers.

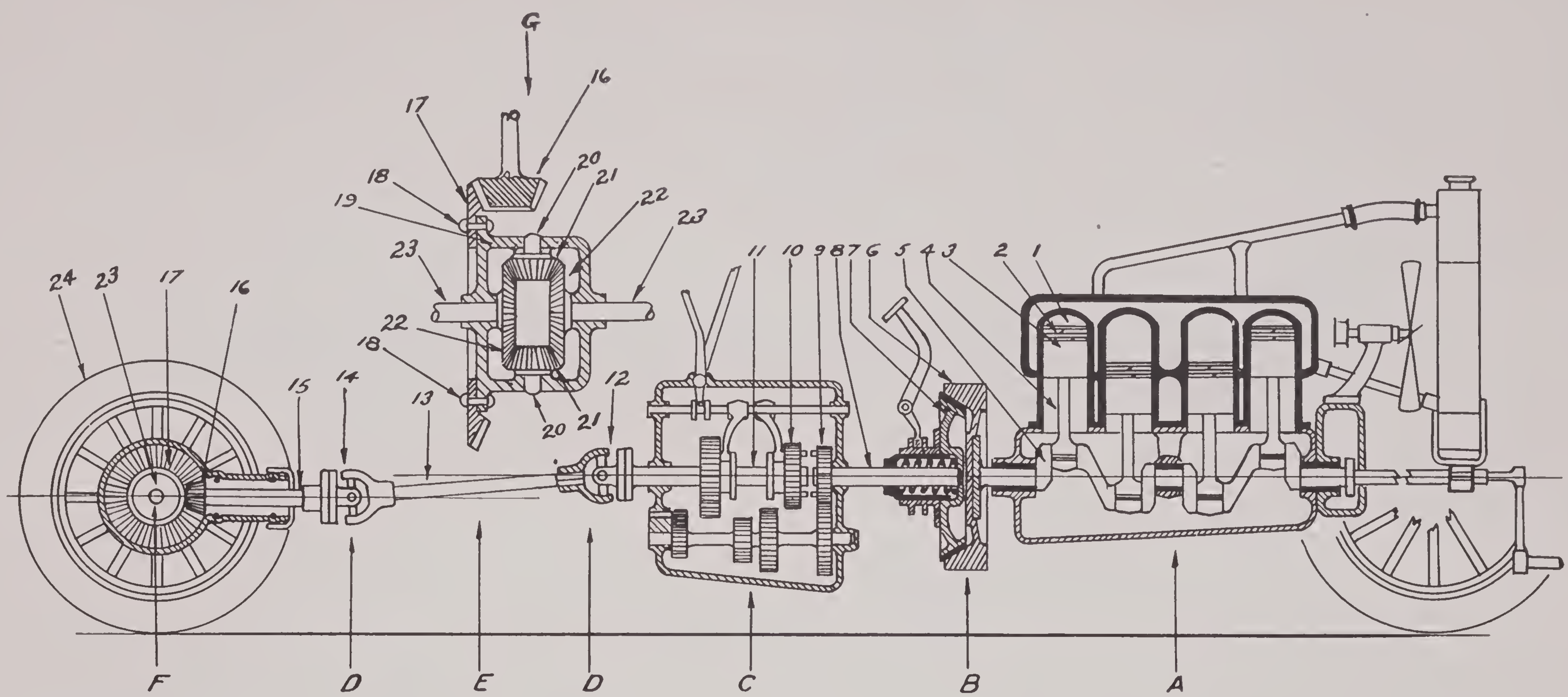


FIG. 86

ILLUSTRATION OF CHASSIS ASSEMBLY

A. Engine.
B. Clutch.
C. Transmission.
D. Universal joint.
E. Drive or propeller shaft.
F. Rear axle.
G. Differential assembly.

This sketch shows the path of power from the combustion chamber to the road wheels. The power is transmitted through the different parts and units in a consecutive order as numbered.

1. Combustion chamber.
2. Piston.
3. Piston pin.
4. Connecting rod.
5. Crankshaft.
6. Flywheel.
7. Clutch cone.
8. Clutch shaft.
9. Clutch gear.
10. Sliding gear.
11. Transmission shaft.
12. Front universal.
13. Drive shaft.
14. Rear universal.
15. Pinion shaft.
16. Pinion gear.
17. Ring gear.
18. Steel rivets.
19. Differential case.
20. Differential spider.
21. Spider gears.
22. Differential side gears.
23. Axle shafts.
24. Rear wheel.

TOOLS

SCREW DRIVERS

The screw driver is a tool, much like a blunt chisel in form, which is inserted in the slotted heads of screws, to turn them for inserting or removing. It is usually made of drill rod or high carbon steel, and the end is hardened and tempered to prevent it from twisting or rolling the edge when in use. It should never be used as a pry for separating parts as it may break the hardened end.

If the screw driver breaks, the end may be restored by first forging it roughly to the proper shape and then grinding it on an emery wheel to the desired form and size. First heat the broken end, keeping it at a bright cherry red while forging, to prevent it from cracking, and using care not to overheat it as that would prevent proper hardening when finished. After forging, dress the end to the desired size on the emery wheel, then harden and temper.

Tempering

To temper the end of the screw driver, first heat it to a cherry red, then dip it 1/4″ deep into clean water, holding it there until the red just leaves the steel. Remove it and polish it with emery cloth. The heat that remains will soften the tip just enough to temper it properly. As the heat works down into the end, the color will change from a pale straw to a dark blue. When it has a light blue color, quench it in the water to prevent it from becoming any softer. If the whole tip is cooled suddenly it becomes glass hard and brittle.

The slot in the screw has straight sides, so the tip of the screw driver should be ground accordingly, to prevent it from upsetting the edges of the screw slot.

If there is only a small break on the end of the screw driver, it may be ground to restore the proper shape. Care should be used in the grinding to keep the end cool, because if it heats up until the end becomes a dark blue, the tempering will be spoiled and it will be necessary to harden and temper it again.

TWIST DRILLS

The twist drill is a tool used to cut round holes. Spiral grooves are cut in the sides of the drill, to allow the cuttings to pass out and also allow the lubricating oil to reach the cutting edges, when used. It is made of tungsten steel or high carbon steel, hardened, tempered and ground. The repair man is never required to harden a drill.

Drills are made in various sizes, the standard drills being in steps of 1/64″. Drills between the standard sizes are designated by numbers or letters.

When grinding drills never hold them to the emery wheel long enough to heat them, as this softens the steel.

In order to have a drill cut true to size, it is necessary to have the angles and the lengths of both of the cutting lips the same, with just enough clearance so that the cutting edge is the only part which touches the metal. Too much clearance will allow the cutting edge to brush off and become dull. If one lip is longer than the other, or at a different angle, the point of the drill will not be in the center, consequently, the drill will cut oversize.

When drilling brass, the cutting lip of the drill should be ground flat, so that the cutting edge scrapes off the metal instead of shearing it. If the edge is not flattened, the drill will either break, or spoil the work when breaking through the under side of the metal.

Do not run the drill too fast, or do not use one which is dull, as the friction heats and draws the temper from the drill.

Always fasten the work rigidly to the drill press table, or if using the electric drill, hold the work rigidly.

When drilling steel, use lard oil or soda water (or old engine oil). For aluminum drilling, use kerosene. Brass and cast iron should be drilled dry.

REAMERS

A reamer is a grooved cutting tool used for finishing to accurate size and smooth surface round holes that have already been drilled or bored to approximate size. It is made with numerous cutting edges around the outside of the body, the edges being carefully ground to give the correct size. It is made of high grade carbon steel, hardened and tempered before the cutting edges are ground. The repair man should never attempt to harden or temper a reamer.

The reamers used in the repair shop are the solid hand reamer and the hand expansion reamer.

The solid hand reamer is not adjustable, but can be obtained in various sizes in steps of 1/64″.

The expansion reamer is slotted and has a screw and conical plug in one end so arranged that turning the screw inward will increase the diameter of the reamer to a size slightly larger than standard. On account of the reamer being quite hard, which is necessary to hold the cutting edges, the amount of expansion obtainable is very limited, the maximum being about 1/64″.

A reamer should always be turned in a clockwise direction only, either when reaming or removing. When turned in this direction, the cutting edge is relieved slightly, to prevent rubbing, and also has a backing of metal which prevents the cutting edge from being brushed off, broken or injured. If turned in the wrong direction, the reamer soon becomes dull.

When reaming steel use a cutting oil, such as lard oil, as a lubricant. Cast iron and brass should be reamed dry.

To insure a good accurately finished hole, leave only a very small amount of metal to be removed by the reamer. A reamer will chatter and cut oversize if too much metal is removed at one operation. Use a double end reamer wrench and be careful to keep the reamer true with the hole, as a slight tilting will cause the hole to be out of line and out of shape.

CHISELS AND DRIFTS

Chisels and drifts are forged of high carbon steel.

Forge the end to the desired shape while cherry red, then grind it to the desired form and sharpen it on the emery wheel.

Proceed with the hardening and tempering. When tempering, quench the chisel in the water when the color is just changing from a dark purple to a blue.

As a result of the variation of the percentage of carbon in the steel, there is a variation in the degree of hardness obtained.

The above tempering rule is correct for the best grades of tool steel.

HAMMERS

There are various kinds of hammers used in repair shop work. The hard steel hammer is used to drive chisels, punches, etc., for riveting and ordinary uses, but for driving on finished surfaces, a hammer made of soft material should be used, such as a wooden mallet, a lead, rawhide or rubber hammer. Never strike a finished surface or parts made of soft materials with steel or hardened hammers; use any of the soft hammers or a block of wood. Monkey wrenches and other tools are not to be used as hammers.

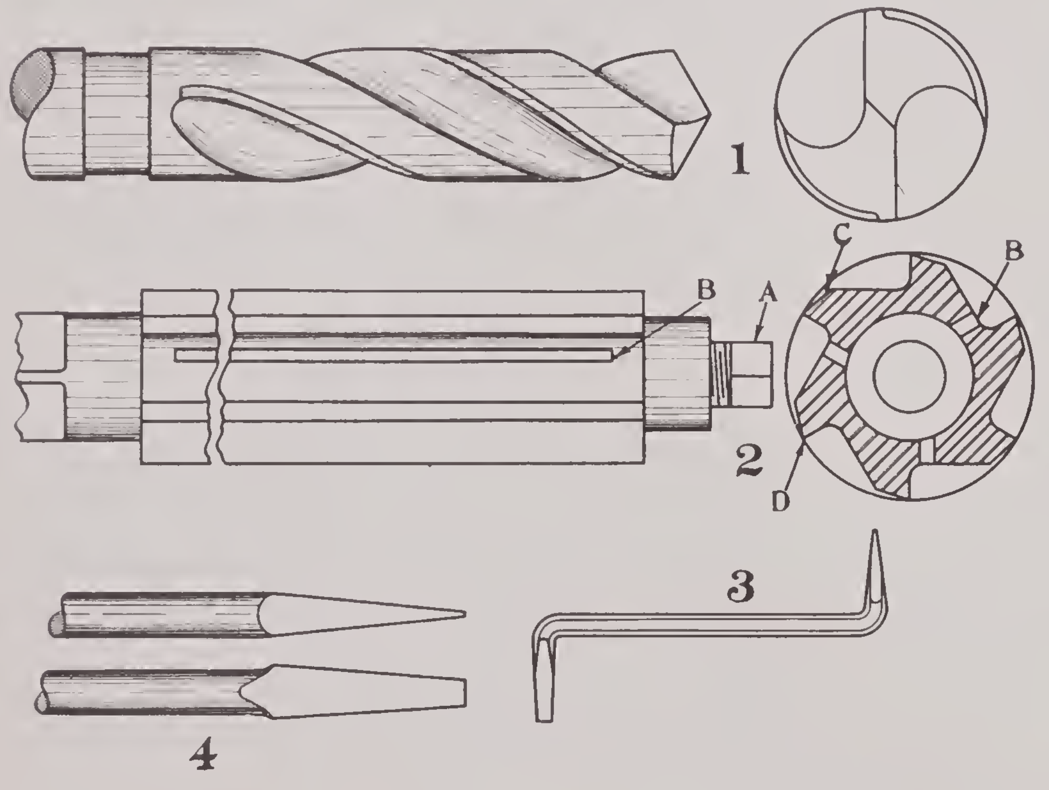


FIG. 87

(1) Twist drill.
(2) Hand expansion reamer.
A. Adjusting screw.
B. Slot.
C. Relieved cutting edge.
D. Cutting edge.
(3) Special screw driver.
(4) Chisel.

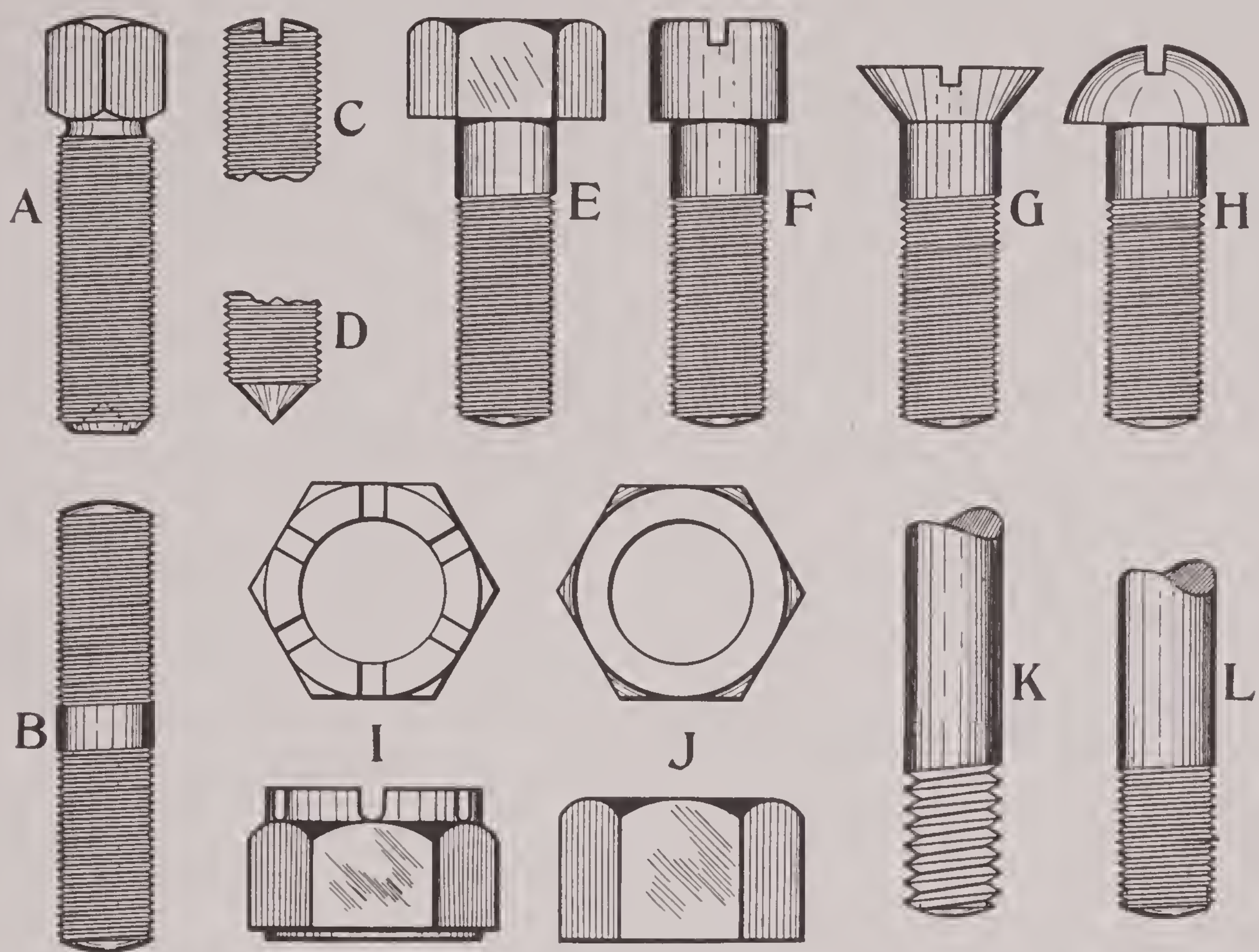


FIG. 88

BOLTS, SCREWS, NUTS AND STUDS

A. Hardened cup-point set screw.
B. Stud.
C. Headless set screw, hardened.
D. V-point set screw, hardened.
E. Cap screw.
F. Fillister head screw.
G. Flat head screw.
H. Round head screw.
I. Castle nut.
J. Plain nut.
K. U. S. Std. thread.
L. S. A. E. thread.

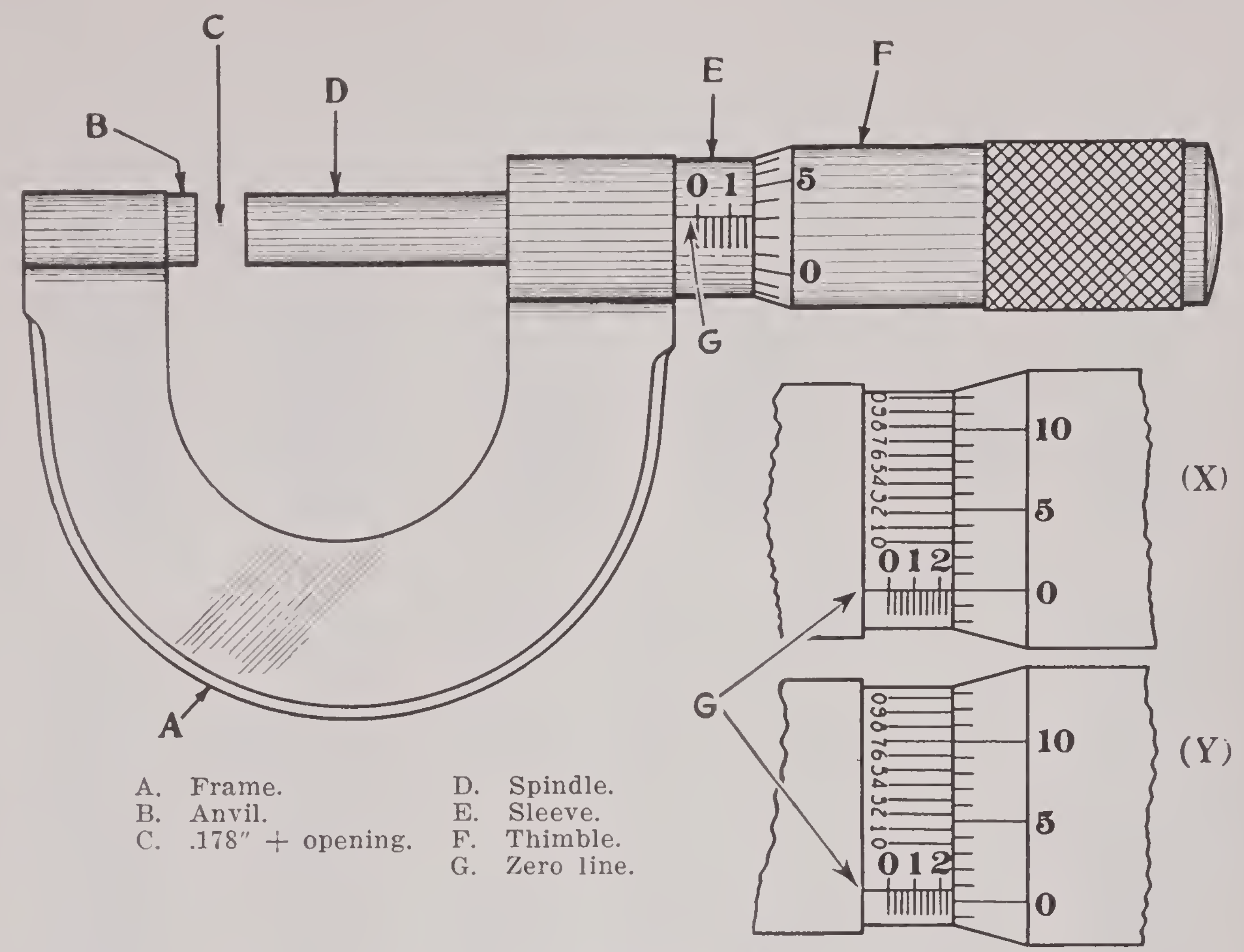
Screws with U. S. Standard thread are commonly used in soft material, such as cast iron, brass, bronze, or aluminum.

S. A. E. Diam.	Thds. per inch.
¼	28
5/16	24
⅜	24
7/16	20
½	20
9/16	18
⅝	18
11/16	16
¾	16
⅞	14
1	14

U. S. Std. Diam.	Thds. per inch.
¼	20
5/16	18
⅜	16
7/16	14
½	13–12
9/16	12
⅝	11
11/16	11
¾	10
⅞	9
1	8

U. S. 60° V threads are used on both these standards. The top and bottom of the thread have a narrow flat surface, which is ⅛ of the pitch.

The threads on the bolts may be re-cut with an adjustable die, and the threads in the nut with the solid tap. These taps and dies may be obtained in either of the two standards, or for "number" bolts. Special taps and dies are made for odd size bolts and nuts. The tap not being adjustable, is of a standard size. Before fitting a nut to a bolt that is tight, run the tap through the nut; then, if it is necessary, run the die over the screw to obtain the proper fit.



A. Frame.
B. Anvil.
C. .178″ + opening.
D. Spindle.
E. Sleeve.
F. Thimble.
G. Zero line.

FIG. 89

MICROMETER

The micrometer is an instrument used to measure in the thousandth part of an inch, and in some instances in one ten thousandth part of an inch. This instrument is made for measuring the thickness and diameter of finished parts, the inside diameter of holes, and other measurements that are required to be extremely accurate.

Micrometer adjustments are also incorporated in various tools. It is a delicate instrument, should not be dropped or used roughly, but handled very carefully and kept free from dirt.

Construction and Operation of the Micrometer

The thimble (F) and the spindle (D) are one piece, with a screw of 40 threads per inch cut on the spindle. The spindle screws into the sleeve (E), which has a split taper nut in the upper end to take the end play out of the thread. The sleeve (E) is threaded at the lower end into the frame (A). By screwing this sleeve in or out the micrometer is readjusted in case of wear, or in case it should be dropped. A small spanner wrench is provided for this purpose, the wrench fitting into a small hole in the lower end of the sleeve.

Outside micrometers generally have a range of one inch, as from 0 to 1″, 1″ to 2″, 2″ to 3″, etc., for which the sleeve is graduated. As the spindle has a 40 pitch thread, it requires 40 turns of the spindle and thimble assembly to move it one inch. For each full turn the thimble moves up or down 1/40″ or 25/1000″ (.025″).

The sleeve is graduated in tenths as indicated by the figures and the distance between any two of the numbered marks represents a tenth of an inch, or 100/1000″ (.100″). The tenths are divided into four parts, each part being 1/40″ or 25/1000″ (.025″). The circumference of the lower end of the thimble is graduated into 25 parts, since for each full turn, it moves up or down 25/1000″ (.025″).

Reading the Micrometer

To read the micrometer, it is necessary to observe the zero line (G) on the sleeve, the lower edge of the thimble and the mark on the thimble that comes in line with the zero line on the sleeve.

Example: If the lower edge of the thimble is on the third line above 2 and the 0 mark on the thimble is in line with the zero line on the sleeve the reading will be .275″. When the 0 mark on the thimble is in line with the zero line on the sleeve, the lower edge of the thimble is just on one of the small cross-lines. In the above setting (X) the lower ledge of the thimble is on the second line above the 2; therefore the reading is .250″.

Example: If the lower edge of the thimble was in line with 8, and the 0 on the thimble in line with the zero line on the sleeve, the reading would be .800″.

Example: Referring to the larger illustration in Fig. 89, the reading is .178″ + because the third mark from the zero on the thimble has just passed the zero line on the sleeve.

Example: Consider that the lower edge of the thimble is between the second and third marks above 5, and the 18 mark on the thimble is in line with the zero line on the sleeve, the reading would be .568″.

Vernier or One Ten Thousandth Reading (.0001″)

The "vernier" graduations are an addition to the regular micrometer, making it possible to measure to one ten-thousandth part of an inch.

On the sleeve at one side of the zero line are eleven long lines, the space between these lines being just 9/10 of the space between the marks on the thimble. When any mark on the thimble is in line with the zero line (G) on the sleeve the two 0 lines on the vernier will be in line with two marks on the thimble. The other vernier marks will not be in line. If the mark on the thimble is not in line with the zero line on the sleeve, only one line of the vernier will be in line with one of the marks on the thimble.

Reading the Vernier Micrometer

The reading for the thousandths of an inch is the same as previously described; then note which line on the vernier lines up with the one of the marks on the thimble.

Example: In illustration (Y), number 7 line on the vernier lines up with a mark on the thimble; the other lines are off; the reading is .2507″, or two thousand five hundred and seven ten thousandths of an inch.

When measuring, place the micrometer over the work and screw down on the thimble until the spindle just touches the work. Do not force the thimble. Then read the setting.

Some micrometers are constructed with a small knurled handle on the outer end of the thimble, which is used for two purposes. It is attached with a ratchet connection, so that the action is positive in one direction, but when turnng it in the other direction and the spindle comes to rest on the piece that is being measured, or on the anvil (B), the ratchet will allow the knurled handle to continue turning. This prevents the operator from turning the spindle too tight against the work, and insures a uniform pressure of the spindle in all readings. The handle is smaller in diameter than the thimble, so that in moving the spindle through longer distances, it can be turned much faster by using the handle.

Testing the Micrometer for Accuracy

Place a piece of paper on the anvil, screw the thimble down until the spindle pinches the paper, then draw the paper away; this is done to remove dirt and to insure the spindle resting on the anvil; then turn the thimble until the spindle just touches the anvil, or if the ratchet is used, screw the thimble down with the ratchet until the ratchet slips, which will be when the spindle touches. The reading should then be 0, or the 0 on the thimble should be in line with the zero line on the sleeve. If the zero line is either side of the 0 mark on the thimble, use the spanner wrench to turn the sleeve until those lines do line up, when the spindle is just touching the anvil.

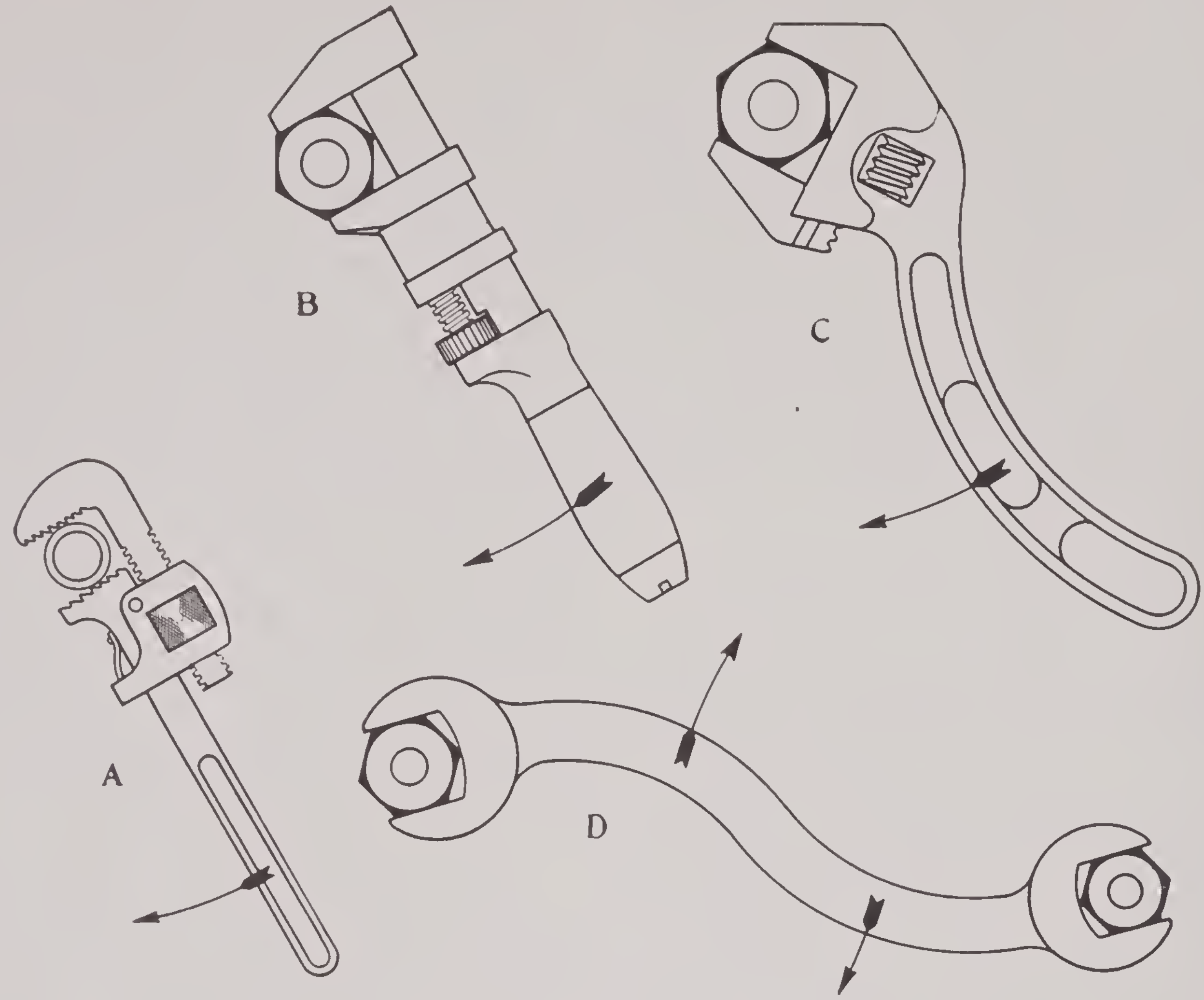


FIG. 90

WRENCHES

A. Pipe wrench (Stillson).
B. Monkey wrench.
C. Adjustable end wrench.
D. Open end wrench.

These tools are generally made of a high grade steel having hardened jaws to prevent the edges turning over and to prevent the jaws from bending. Wrenches are designed in various shapes, some being adjustable.

Illustration (A) shows an adjustable pipe wrench, also called a Stillson wrench. This wrench is used to turn pipes or round pieces, but should never be used on finished or hardened surfaces, as it will mar the surface or dull the wrench. These wrenches may be obtained in various lengths.

Illustration (B) is a Monkey wrench, and is adjustable; the jaws are hardened.

Illustration (C) shows an adjustable end wrench. This wrench is more universal than the monkey wrench, because the opening is at an angle and the jaws are not as heavy.

Illustration (D) represents an open end wrench. These wrenches may be obtained to fit the various size bolts and nuts. The wrenches are numbered, the numbers being standard as to sizes.

The arrows indicate the direction the wrenches should be moved when placed as shown. If it is required to turn the nuts or pipe in the other direction, the wrench should be reversed.

A good rule to remember is to move the wrench in the direction that will press the adjustable jaw inward.

FLAT WRENCHES

Wrench Number	Size Opening	Wrench Number	Size Opening	S.A.E. Bolts Nuts	Diam. of head across Flat	Wrench Number
	Inches		Inches			
21	5/16-11/32	126	7/16-9/16	1/4"	7/16"	126
22	5/16-1/2	127	1/2-9/16	5/16"	1/2"	22-23-25
23	13/32-1/2	128	1/2-5/8			26-127-128
24	13/32-19/32	129	9/16-5/8	3/8"	9/16"	126-127-129-130
25	1/2-19/32	130	9/16-3/4	7/16"	5/8"	128-129-131-132
26	1/2-11/16	131	5/8-3/4	1/2"	3/4"	130-131-133-134
27	19/32-11/16	132	5/8-13/16	9/16"	7/8"	30-31-33-34
28	19/32-25/32	133	3/4-13/16			134-135-137-138
29	11/16-25/32	134	3/4-7/8	5/8"	15/16"	32-33-35-36
30	11/16-7/8	135	13/16-7/8	11/16"	1"	136-137-139-140
31	25/32-7/8	136	13/16-1	3/4"	1 1/16"	34-35-37
32	25/32-31/32	137	7/8-1	7/8"	1 1/4"	36-37-140
33	7/8-31/32	138	7/8-1 1/8			
34	7/8-1 1/16	139	1-1 1/8			
35	31/32-1 1/16	140	1-1 1/4			
36	31/32-1 1/4					
37	1 1/16-1 1/4					

CHASSIS

The chassis includes all the parts of an automobile except the body and its attachments. It consists of the frame, springs, power plant, clutch, transmission system, axles, wheels, steering gear and the control apparatus.

The frame is made of pressed or rolled steel or laminated wood. The steel frame is most commonly used because of its strength and because it can be manufactured speedily. The main side frames are riveted and welded together through cross members which serve to brace it and also support the power plant and transmission system. The wood frame, although little used, is lighter in weight, more flexible and assists in absorbing the shocks encountered in driving. It is expensive to manufacture and difficulty is experienced in obtaining good grade of stock for it.

The springs are interposed between the frame and the axles and act as cushions to take the jars and bumps due to unevenness of the road. They protect the engine and other delicate parts against undue shock and vibration and insure easy riding.

The power plant consists of the engine and all its auxiliaries and includes fuel system, carburetor, ignition apparatus, lubricating and cooling systems, starting and lighting apparatus. It may be mounted upon the side frame and cross members or set in a sub-frame in either of two ways, three-point or four-point suspension.

In the three-point suspension, the front of the engine rests upon the center of the front cross member of the frame while at the rear of the engine there are two projecting arms which rest upon the side members of the frame. In the four-point suspension, there are four projecting arms on the engine which rest upon the side frames.

The power plant, clutch and transmission are frequently combined, forming what is called a "unit power plant." If the transmission is separate, it is mounted upon cross members of the frame, either "amidship" or on the rear axle.

The axles carry the weight of the car as transmitted to them through the springs. The rear axle construction is special on account of its serving two purposes, carrying the weight and also propelling the car. The front axle is solid and the front wheels mounted on pivoted spindles to permit steering the car.

Wheels are of three kinds, wood, wire and disc steel, all being equipped with some form of rubber tire, usually pneumatic type, consisting of strong outside casing with air inflated inner tube, to assist in protecting the car from shock and vibration and insure easier riding. The rear wheels are equipped with brakes, usually two, for slowing down and stopping the car. The two brakes are termed "foot brake" and "hand brake." The foot brake is for general use, and the hand brake for use in case the foot brake fails. It is provided with means for holding the brake when applied, to prevent the car from moving if left standing.

The steering mechanism is mounted upon the side frame and projects up into the driver's compartment. It provides means for steering the car and has levers mounted upon it for controlling the throttle valve and the spark advance and retard on the ignition apparatus.

BEARINGS

The bearings employed in the construction of front wheels, steering devices, clutches, transmissions, differentials, and rear axles may be either plain bronze, babbitt, plain roller, tapered roller, cup and cone, single or double row annular, ball thrust, or plain thrust bearings. The bronze and babbitt bearings may be either the divided or the bushing type.

The bushing type bearing is pressed into the housing, while the divided type has a bearing cap which permits adjustment to compensate for wear. The divided type is necessary in many cases in order to remove the parts, as, for instance, the connecting rod and main bearings of the engine. After bronze or babbitt bearings are fitted into place they should be reamed or scraped to the proper size. The bronze or babbitt bearings, if well lubricated, develop less friction than the average plain bearings, but the friction in these bearings is considerably higher than that developed by the roller or ball bearings.

Roller or ball bearings operate on hardened surfaces, and are polished to as high a finish as is mechanically possible.

The materials used in these bearings are alloy steels, heat treated and hardened to reduce wear, also to make them tough but not brittle. The machining and finishing of these bearings determines the length of service to a great extent. The smoother the surfaces the less the friction, consequently the less wear. Bearings of this type require less lubricant, as the friction and heat developed is very low. The heat developed by friction breaks up and evaporates the oil on the bearings.

Plain Roller Bearing

This bearing is designed for radial load only, taking no end thrust. The plain roller bearing is constructed of an assembly of rollers that roll between two hardened steel sleeves. The roller bearing is constructed either with an inner and outer race assembled with the rollers, or else they roll on the inside of a hardened steel race and on the outside of a hardened shaft. If the material in the shaft is such that it can be heat treated and hardened, it is not necessary to provide an inner race for the rollers. The surface with which the rollers come in contact must be hardened and ground to as high a finish as possible. In case of wear, these bearings are adjustable to a very small extent.

A shim of thin sheet copper or brass may be placed around the outside of the outer race, the race being split to allow it to contract. This will take up some of the clearance, but if it is too great it is best to provide a new outer race. Where end thrust comes on a shaft that is mounted on a plain roller bearing a special end thrust bearing is provided, as this plain roller bearing takes no end thrust. These bearings may be lubricated either by oil or grease, depending entirely on where they are installed.

Tapered Roller Bearing

Tapered roller bearings take both radial and end thrust loads and are adjustable to compensate for wear. Should a bearing of this type wear on any of its bearing surfaces, it is so arranged that the play can be removed by bringing the races closer. The tapered roller bearing is constructed of three principal parts; an outer and an inner race, and a row of tapered rollers.

These parts are made of a high grade alloy steel, heat treated, hardened and ground to a very high finish. The rollers are held in a retainer, which prevents them from coming in contact with one another. The outer and inner race should be a light tapping fit in the housing and on the shaft. When ordering new parts for bearings of this type, always order by the number which is stamped upon either the outer or inner race.

Cup and Cone Bearing

The cup and cone bearings take both radial load and end thrust and are adjustable. The bearing is constructed of three principal parts: the outer cup, the inner cone, and a row of balls which roll between cup and cone.

The cup, cone and balls are made of high grade alloy steel, heat treated and hardened, then ground for accuracy and finish. The outer cup is pressed lightly into the housing, while the inner cone should be a light tapping fit on the shaft. They should never be driven on so tightly that the pressure will spring the races. When a load comes onto a sprung bearing it is taken on a few spots only, consequently it will wear very fast.

There is an adjusting nut provided to set the cup and cone closer together. Either the nut will be resting against the outer cup or against the inner cone, so that as the nut is turned in, it will bring the cone closer to the cup with the row of balls between. This adjustment is to take up whatever play there may be. This type of bearing is used considerably on front wheel spindles although other bearings may be used.

Adjustment of Cup and Cone

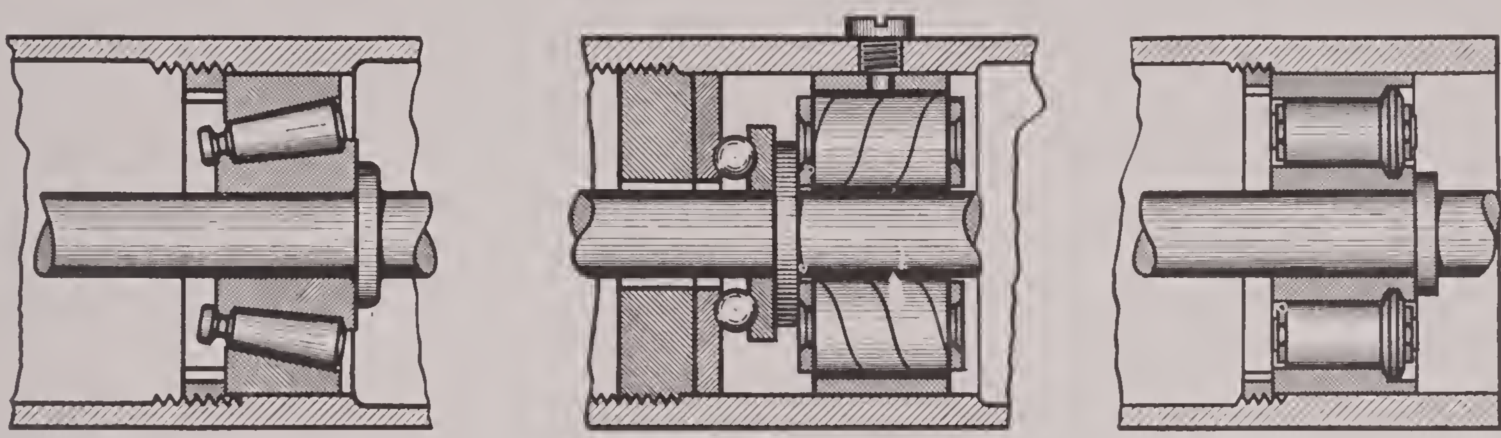
There should be only enough clearance between the balls and the races to prevent them from binding. To adjust this bearing, turn the adjusting nut until the bearing is tight, or until there is no play in the bearng. Then back the nut away sufficiently to relieve all tight spots, but not enough to allow any play. If there is too much play in these bearings, the balls will have a chance to pound the races out of round. With the race out of round, the balls will be flattened, consequently the bearing will be scored or roughened.

When replacing new parts for a cup and cone bearing, either the outer cup or cone may be replaced separately, but if the balls are worn replace the entire set. A heavy load, if taken on one or two balls only, causes the races and balls to wear rapidly.

When disassembling a bearing of any type, care must be taken that neither the race nor the balls become rusted, because the rusting of these surfaces roughens them so that the finish will be marred. To prevent this, when removing the bearings, always cover them with grease or heavy oil, which prevents the air and moisture from coming in contact with the finished surfaces. Also, when bearings are being assembled, be careful not to allow any filings or particles of dirt of any description to come onto the surface of the bearing. The smallest particle of dust may cause the surface of the bearings to become roughened. The life of the bearings depends upon the finish. The better the finish and the material used in their construction, the longer they will wear.

Single Row Annular Bearing

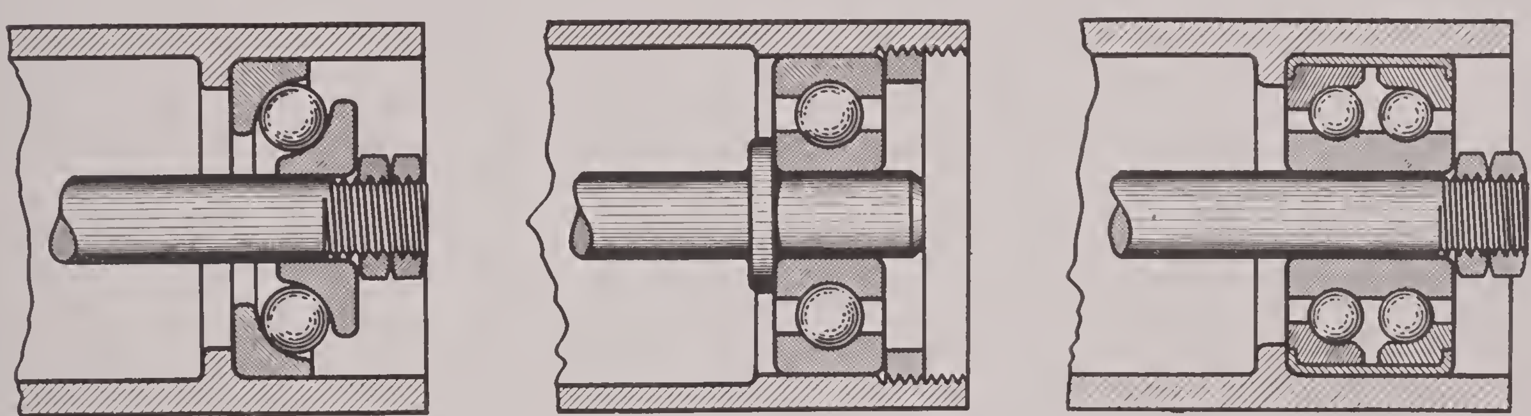
Single row annular type bearings are designed to take radial load only, although the bearing will take about one-third as much end



TAPERED ROLLER

PLAIN ROLLER
BALL THRUST

FLANGED ROLLER



CUP AND CONE

ANNULAR BALL BEARING
SINGLE ROW DOUBLE ROW (RIGID)

FIG. 91

BEARINGS

This figure shows some of the different types of bearings employed in the chassis. In the Tapered Roller bearing the outer race is moved by the adjusting nut. This removes the play between the rollers and the races. Another common mounting is to press the outer race into the housing and against a shoulder with an adjusting nut mounted on the shaft against the inner race.

The Ball Thrust bearing mounted with the Plain Roller bearing is adjustable either by an adjusting nut as shown or by placing thin metallic shims between the race and the shoulder of the mounting. The Plain Thrust bearing with a babbitt or bronze washer between two hardened steel races is mounted in the same manner, except that the races are pinned to the mounting and no adjusting nut is used. The adjustment is made either by placing thin metallic shims back of the races or by replacing the main thrust washer with a thicker one.

The Flanged Roller bearing may be adjusted for end play by tightening the adjusting nut mounted inside the housing against the outer race. The adjusting nut may be mounted on the shaft against the inner race. This bearing is not adjustable for radial wear.

The Cup and Cone bearing is adjusted by tightening the adjusting nut against the cone. The adjusting nut may be mounted inside the housing against outer race.

The Single and Double Row Annular bearings are not adjustable, but the mounting can be adjusted as shown, by an adjusting nut either on the shaft or in the housing. Where no adjusting nut is provided the bearing may be adjusted by placing thin metallic shims between the race and mounting.

thrust as radial load. This is not sufficient for the usual requirements. An extra ball thrust bearing may be provided, or a double row annular bearing may be used, depending entirely upon where the bearing is mounted. Sometimes only a single row annular bearing is used where there is an end thrust, but it causes the bearings to wear excessively. Bearings of this type are not adjustable to compensate for wear.

The single row annular bearing consists of an outer and inner race and a row of balls held by a retainer. The outer and inner races have grooves cut in them and are ground with a larger radius than that of the ball and is expected to take load in radial direction only, so with this construction it is evident that the end thrust throws the bearing out of the true alignment upon which it is designed, causing uneven wear.

When these bearings wear it is necessary to install a complete bearing. They are assembled at the factory and, because of their construction, it is not advisable for the mechanic to repair them. The number or size of the bearing is stamped on the side of the outer or inner race. These bearings are usually measured by the metric system. A bearing may be ordered from any maker, by the number, and the bearing will fit.

These bearings are made in light, medium and heavy series. The inside diameter of the inner race is the same on all the series, but in the larger series, the outer diameter, width of the bearing and the diameter of the balls increases. So if the bearing is ordered by the number, the right size will be obtained. Both the outer and inner race should be only a light tapping fit in the housing and on the shaft. If driven on tightly, it will spring races, causing binding and wear.

Double Row Annular Bearing

Double row annular bearings are constructed in two types; the rigid and the flexible bearing. The flexible double row annular bearing is not used in automobile construction, but is employed usually on line shafts where there is a tendency for the shaft to become out of alignment. The bearings of this type allow greater flexibility. The double row annular bearing when used on the automobile, takes both the end thrust and radial loads. The shoulders extending farther over the sides of the balls make it possible for this bearing to take a greater end thrust than the single row type. This bearing is not adjustable.

Should the bearing become worn it is necessary to replace it with a complete bearing. The bearing should be kept clean and properly lubricated. When ordering new bearings give the series number and the type.

Bearings may be mounted on shafts where there is considerable end thrust due to the separating effect of bevel gears or in the wheels where there are thrust strains caused by skidding. An end thrust bearing must be provided to take this thrust. The cup and cone bearing and the tapered roller bearing take both radial load and end thrust, but where the plain roller or singular row annular ball bearing is used and the end thrust is very great it is necessary to provide a separate thrust bearing.

The thrust bearings used are either the ball or plain thrust type.

Ball Thrust Bearing

The ball thrust bearing consists of a row of hardened steel balls revolving between the surface of two flat hardened steel discs. An end thrust bearing takes no radial load. The steel discs may have either a groove on the surface for the balls to revolve in, or else the balls roll between the flat surfaces and are held in place by a retaining ring.

Bearings of this type are made with holes to fit the various sized shafts. They may also have larger outer diameters and balls. The larger the balls the greater the thrust that can be taken on the bearing without excessive wear.

Thrust Plates or Plain Thrust Bearings

Plain thrust instead of ball thrust bearings are provided in some instances to take the end thrust. The plain thrust bearing consists of two hardened steel plates with a babbitt, bronze, or cast iron plate or spacer between them. The softer metal washer mounted between the hardened steel plates reduces the friction, but not as much as the ball bearing. The thrust plates resist wear very well if they are well lubricated. Plain thrust plates take end thrust only. The plain thrust bearing is adjustable only by replacing the worn parts or by adding or removing thin metallic spacing shims.

FRONT AXLES

Types

Front axles are made in either the tubular or the I-beam section type. The I-beam section is the type more commonly used on automobiles.

Front axles are made of high grade alloy steel, heat treated to increase their strength.

Mounting

The front axle is fastened to the frame through the springs and their mountings. This construction differs from the front axle of a wagon in that the steering knuckles only are pivoted instead of the entire axle. Front axles have the spring seats or the surfaces upon which the springs are mounted, machined and drilled. The drilled holes are for the spring clips and the centering pin on the spring.

The outer end of the axle is made either solid or forked to accommodate the steering knuckle. In the ends of the axle are drilled the holes for the pivot bolt or pin.

Alignment

The pivot bolt holes may be employed to check the alignment of the axle should it become sprung. The alignment may also be checked from the spring seats if they are machined. The two pivot bolt holes are usually parallel and at right angles to the face of spring seat.

When straightening front axles and aligning them by the two pivot bolt holes, use two straight rods three or four feet long of the same diameter as the pivot bolt, placing them in the holes and then measuring the distance between the rods at the top and bottom. They should be parallel.

It is not advisable to heat an axle red hot while straightening, as the high temperature will remove the strength obtained by the heat treatment. There is no danger of breaking an axle while attempting to straighten it cold, but it usually requires a high pressure straightening press to accomplish this. When the lack of equipment makes it necessary to heat the axle to straighten it, it is not advisable to have the temperature any higher than is absolutely necessary.

Caster Effect

When the axle is properly mounted, the pivot bolts and axle are inclined forward toward the bottom usually about 5°. This is termed caster effect, and is obtained either by the machining of the spring seat, the manner in which the spring is mounted, or by driving a wedge between the spring and its seat.

This caster effect is based on the same principle as is used in the front fork of a bicycle, which is bent forward, to take the strain of the road shocks behind the spindle instead of directly in line. This gives a spring effect, which reduces vibration and makes steering easier.

STEERING KNUCKLE

The steering knuckle is usually a drop forging, formed under big drop hammers. It is made of high grade alloy steel, properly heat treated. The steering knuckles are mounted in or on the end of the front axle, and should fit snugly. The steering knuckle is drilled to accommodate the pivot bolt, which in most cases is secured rigidly in the axle. If there is too much play between the steering knuckle and the axle, it causes a knock which is very noticeable when driving over rough pavements.

Fitting

Bushings or bearings are pressed into the steering knuckles and reamed to a snug fit, so that it is just possible to push the pivot bolt through with the palm of the hand without binding. The bushings or bearings sometimes have shoulders or flanges which rest against the outside of the steering knuckle. The shoulders or flanges take the thrust due to steering and carry the weight of the car. In some cases, as on heavy cars or trucks, instead of having the bronze shoulders, ball thrust bearings are employed. This reduces friction and makes steering easier.

When the bearings wear, new ones may be pressed in and a reamer run through the two bushings so as to properly align their holes.

Should the steering knuckle become sprung, it is difficult to straighten it properly, due to the short leverage and to the various angles which are unknown to the repair man. It is advisable to replace with a new steering knuckle.

PIVOT BOLTS OR PINS

The pivot bolt or pin is made of high grade alloy steel, heat treated, hardened and ground to reduce wear. It is hollow, at least to the depth of the bearings, with a hole at right angles leading to the bearings for lubricating them.

A grease cup is usually provided in the upper end of the pivot bolt. Proper lubrication makes steering easier, causes the steering mechanism to be more quiet in operation, and also gives longer life to the pivot bolts and their bearings.

CAMBER

On the steering knuckle is a spindle, upon which the front wheel is mounted. The spindle is set at an angle of from 1° to 5° from a line parallel with the axle (see rear view of axle, Fig. 92, page 126). This causes the front wheels to "set-in," or to be closer together at the bottom, which reduces the distance between the center line of the pivot bolt and the center line of the wheels at the point of contact with the road.

The steering knuckle turns around the pivot bolt when steering. The point of the wheel that is in contact with the road is not

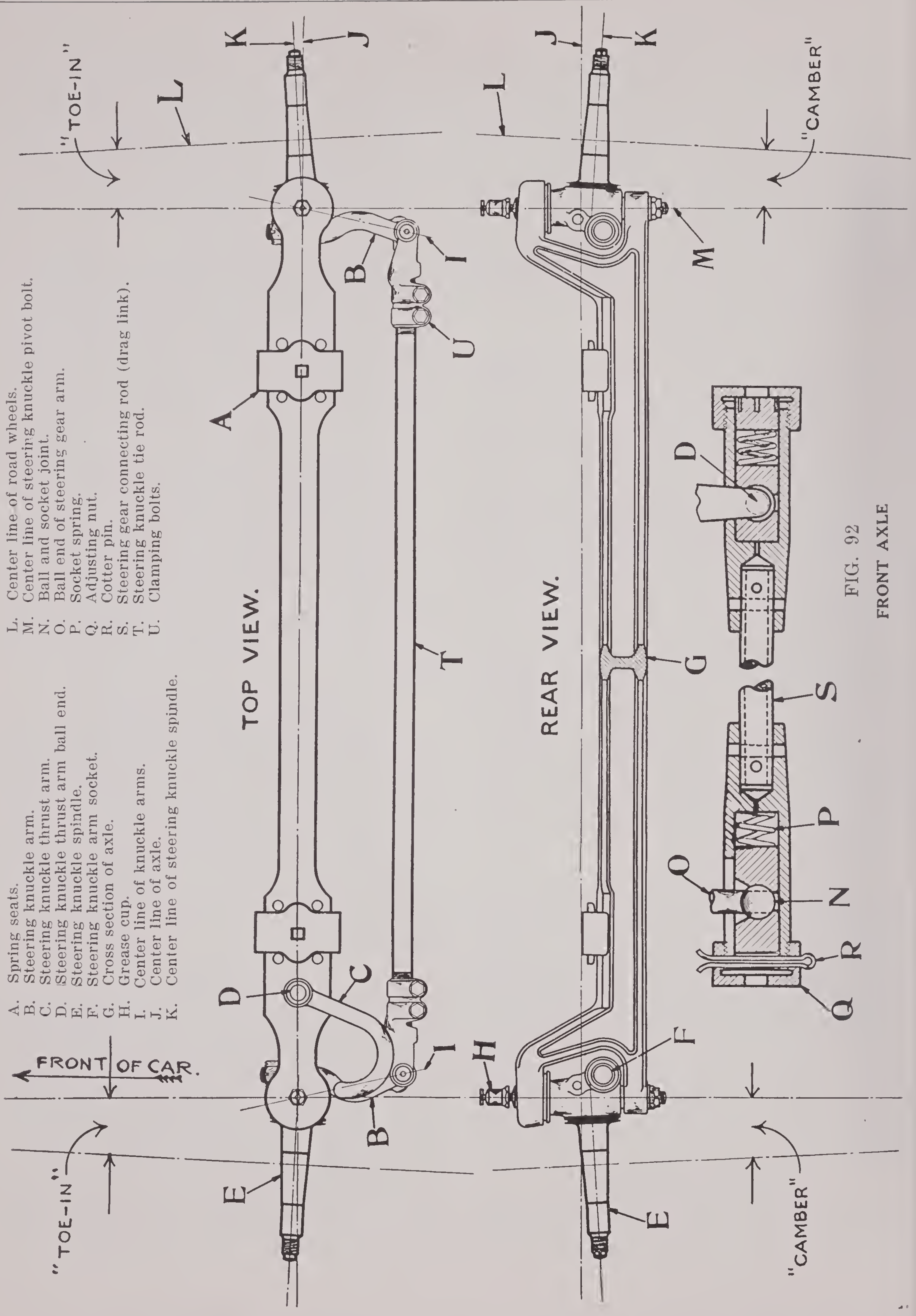


FIG. 92

FRONT AXLE

directly underneath the center of the pivot bolt. Consequently, the wheel must necessarily travel in a circle around the center line of the pivot bolt when steering. When describing this circle, the wheel is dragged over the road, making steering difficult and causing wear of the tires. If the wheels were set at an angle great enough to bring the point of road contact directly underneath the center line of the pivot bolt, the strain of steering would be greatly reduced. This is not practical, as an excessive strain would come on the wheels and bearings. The angle the spindle is set is governed by the width of the bearings and the diameter of the wheel. This angle is termed "camber." It is not adjustable.

STEERING KNUCKLE ARM

The steering knuckle arm is the arm to which the tie rod is fastened. This rod connects the two steering knuckle arms and is adjustable.

When the tie rod is mounted behind the axle, as it is in most cases, for protection, the two knuckle arms are set at an angle greater than 90° from the center line of the spindle. The reason for this construction is that when turning a corner, the inner wheel must swing through a greater angle than the outer wheel, due to the manner in which the axle is mounted. On a wagon, when turning a corner, the axle swings, thus moving the inside wheel backward and the outside wheel forward. This differs on a car, due to the axle being stationary and the spindles being pivoted to its ends, which necessitates swinging one wheel through a greater angle than the other. It is accomplished by placing the steering

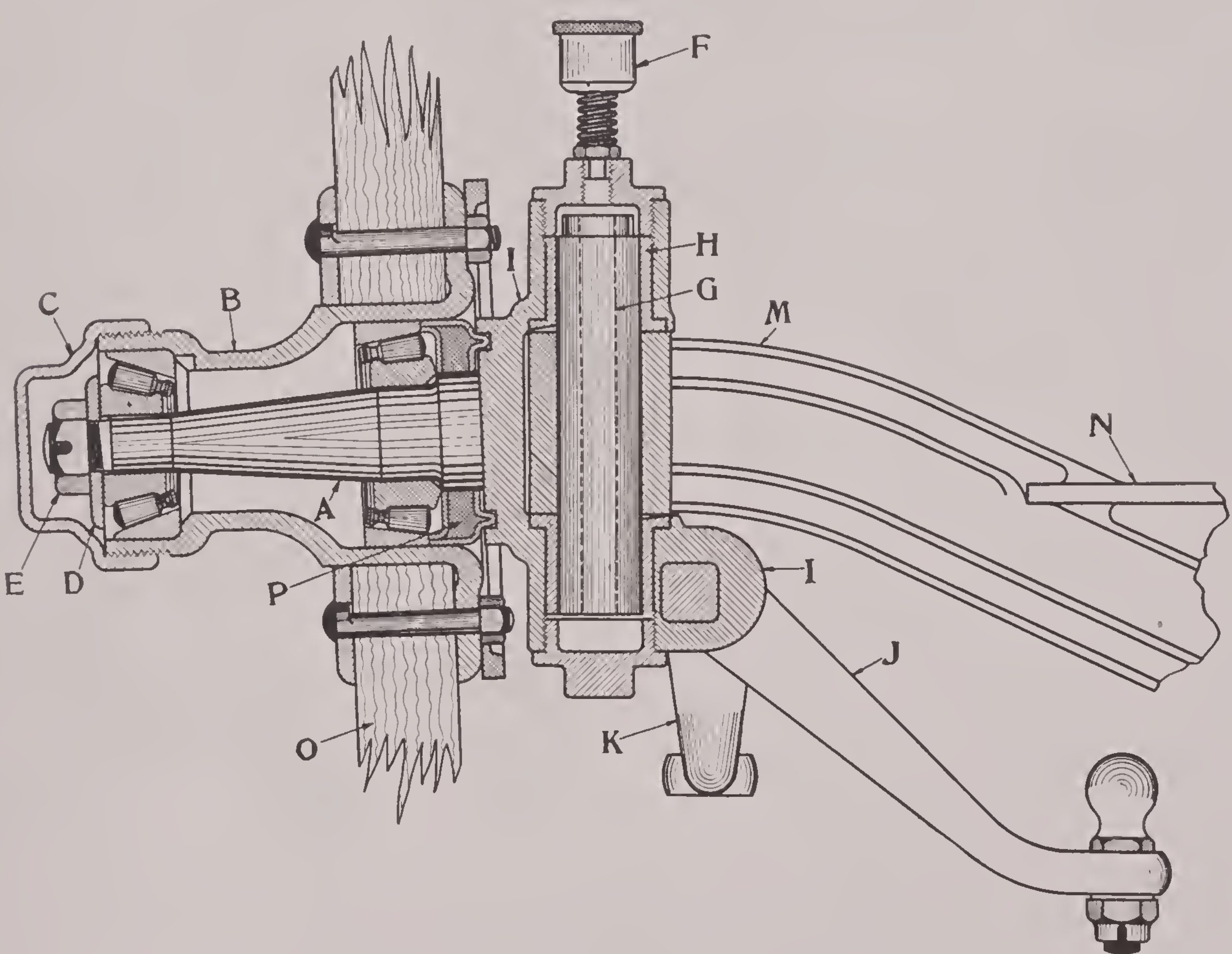


FIG. 93

STEERING KNUCKLE AND FRONT WHEEL MOUNTING

A. Steering knuckle spindle.
B. Front wheel hub.
C. Hub cap.
D. Spindle washer.
E. Spindle nut.
F. Grease cup.
G. Oil hole.
H. Steering knuckle bushing.
I. Steering knuckle.
J. Steering knuckle thrust arm.
K. Steering knuckle arm.
M. Front axle.
N. Spring seat.
O. Spoke.
P. Felt washer.

In this construction the pivot pin is pressed into the axle snugly and locked with a set screw to prevent a movement of the pin in the axle. The steering knuckle has its bearings on the stationary pin. The bronze bearing bushings pressed into the steering knuckle reduce friction and the wearing of the pivot pin.

To remove the pivot pin for replacement of these bushings, unscrew the upper and lower retainer caps and the pivot pin set screw, press the pin out and remove steering knuckle.

knuckle arms at an angle greater than 90° from the spindle, causing one steering arm to swing away from the center line of the pivot bolt and the other to swing toward it.

TOE-IN

The front wheels are closer together at the front than they are at the rear, or are said to "toe-in." This "toe-in" or "gather" of the front wheels is necessary to counteract the action which results from the wheels being cambered. When a car is in motion, the front wheels tend to roll outward, due to the camber, the same as a hoop when rolled along on the floor at an angle will have a tendency to roll in the direction it is leaning. This spreading effect will cause the tires and bearings to wear. To counteract this, the wheels

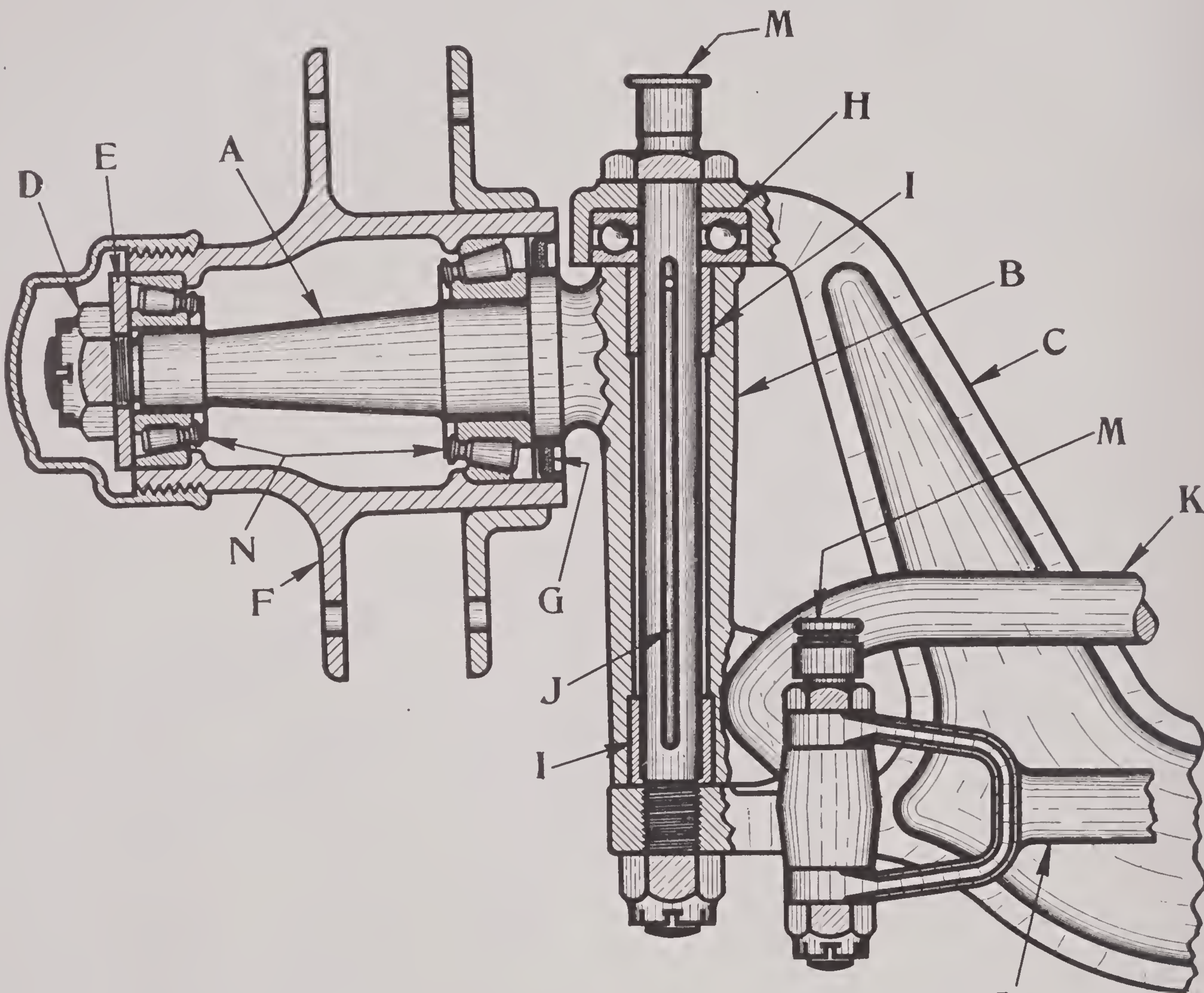


FIG. 94

STEERING KNUCKLE AND FRONT WHEEL MOUNTING

A. Steering knuckle spindle.
B. Steering knuckle.
C. Front axle.
D. Spindle nut.
E. Spindle washer.
F. Front wheel hub flange.
G. Felt washer.
H. Steering knuckle thrust bearing.
I. Steering knuckle bushing.
J. Oil groove.
K. Steering knuckle thrust arm.
L. Steering knuckle tie rod.
M. Grease cup.
N. Wheel bearings.

In this construction the pivot bolt is threaded into the axle and locked by the castle nut on the lower end. A ball thrust bearing is mounted on the upper end of the steering knuckle to reduce the friction when the knuckle turns. Bronze bushing bearings are provided for the pivot bolt. Lubrication is provided by the grease cup (M) through the channel (J).

To remove the steering knuckles, remove the cotter pin and castle nut on the lower end of the pivot bolt, then unscrew the pivot bolt from the axle and drive it out the remainder of the way.

are turned inward. The toe-in varies according to the amount of camber of the front wheels, but the wheels are generally from 1/4″ to 3/8″ closer together at the front than they are at the rear.

The toe-in may be changed by either lengthening or shortening the tie rod, depending upon where it is mounted. To line up the front wheels, raise them clear of the floor by the aid of a jack, then place them as nearly as possible in line with the rear wheels. Spin each wheel in turn, holding a piece of chalk against the tread, marking a line in the center of the tread all the way around. Measure the distance from one center line to the other center line in the front and in the rear of the wheels. The measurements should be taken halfway up on the tires or at the height of the

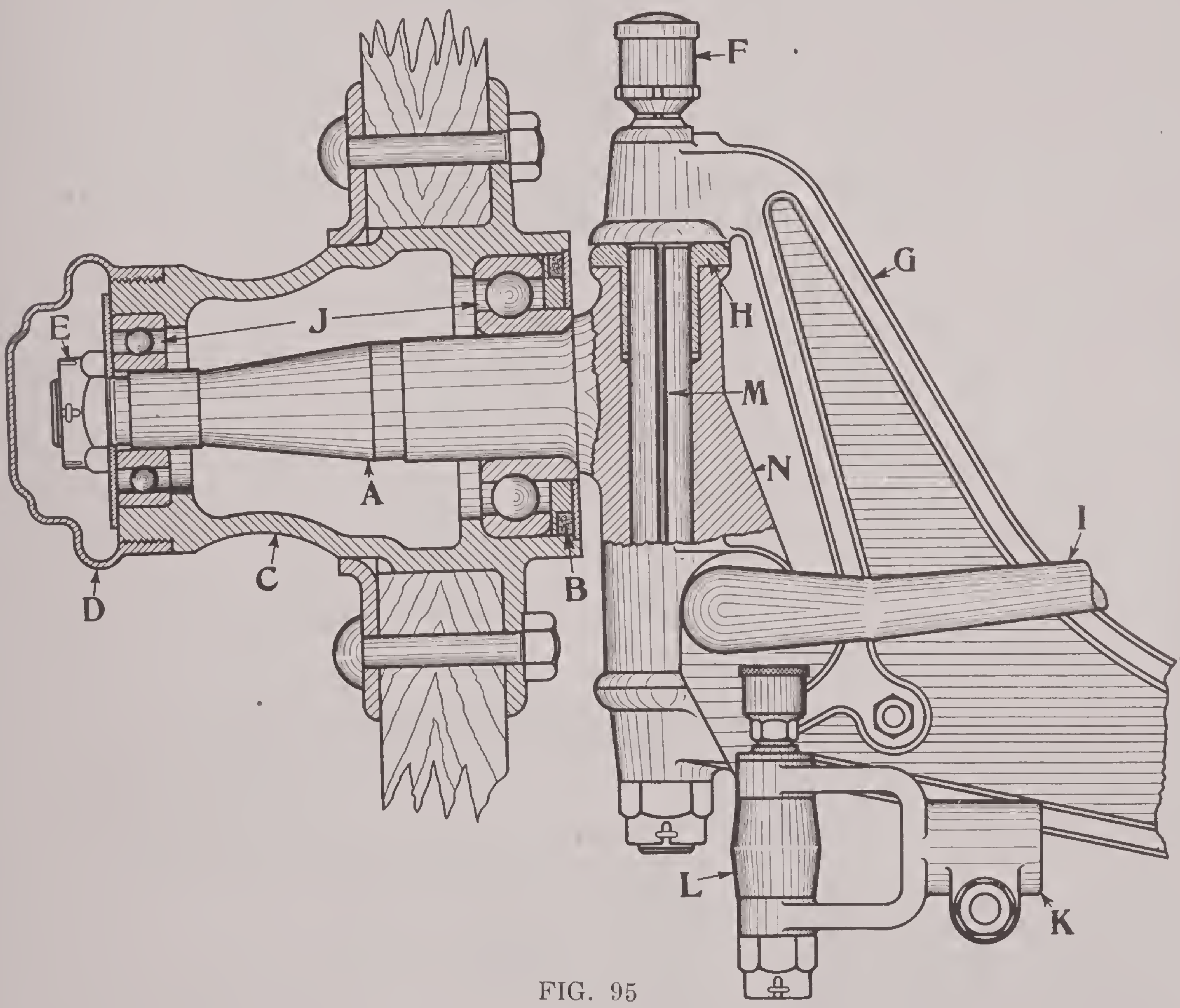


FIG. 95

STEERING KNUCKLE AND FRONT WHEEL MOUNTING

A. Steering knuckle spindle.
B. Felt washer.
C. Front wheel hub.
D. Hub cap.
E. Spindle nut.
F. Grease cup.
G. Front axle.
H. Steering knuckle bushing.
I. Steering knuckle thrust arm.
J. Wheel bearings.
K. Steering knuckle tie-rod end.
L. Steering knuckle arm.
M. Oil groove.
N. Steering knuckle.

In this construction the pivot bolt is made secure in the axle, the steering knuckle having two flanged bronze bearings pressed into it to reduce the friction caused by the radial and end loads. These bronze bearings can be removed, if it should be necessary to replace them.

The bearings are lubricated by the grease cup (F) through the channel (M).

To remove the steering knuckle, remove the cotter pin and the castle nut at the lower end of the pivot bolt, then drive the pivot bolt from the axle.

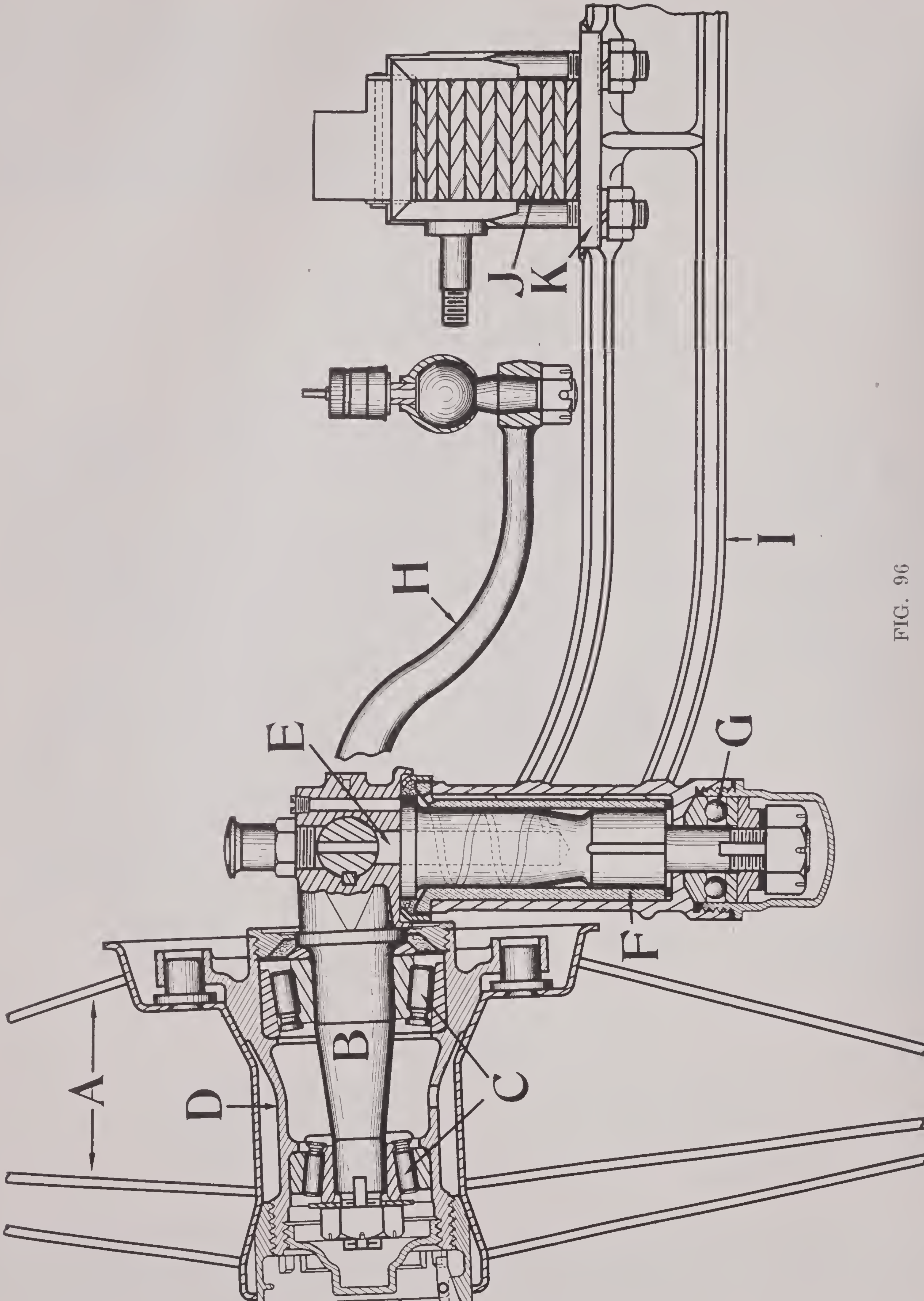


FIG. 96

FIG. 96

STEERING KNUCKLE AND FRONT WHEEL MOUNTING

A. Wire spokes.
B. Steering knuckle spindle.
C. Wheel bearings.
D. Front wheel hub.
E. Oil hole.
F. Steering knuckle bushing.
G. Thrust bearing.
H. Steering knuckle thrust arm.
I. Front axle.
J. Spring leaves.
K. Spring seat.

In this construction the steering knuckle spindle and pivot bolt are all in one piece. Better lubrication is possible by the large oil hole (E), which acts as an oil reservoir. The oil flows through the spiral cut oil groove onto the bushing (F), then through the vertical groove to the lower bearing (G), which takes the load of the car. The oil retaining cap at the bottom prevents loss of oil, making this bearing and mounting practically oil tight and dust proof.

To remove the steering knuckle assembly, remove the oil retaining cap, castle nut, bearing nut and bearing located below bearing (G), then lift the steering knuckle assembly out of the axle. If the bushing (F) is worn, it should be split and removed through the top. Press in a new bushing and ream to fit.

End play of the pivot bolt in the axle may be eliminated by tightening the bearing retaining nut below the bearing (G). The wheel hub is a conventional mounting employing tapered roller bearings and an adjusting nut. The oil retaining cap is threaded inside the hub. The hub cap threaded on outside of the hub holds the wheel flange on. This provides a "quick change" mounting for the wheel.

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wheel hub. The distance in front should be from ¼″ to ⅜″ less than in the rear.

Automobile manufacturers give the correct measurement in their instruction books and it varies on different cars. The tie rod must be locked at each end to prevent it from working loose as a result of vibration.

The tie rod is fastened to the steering arms of the steering knuckle by means of the tie rod end, which is fork shaped, fitting over the steering arm and held in place by the steering knuckle tie rod pin. This pin is hardened and ground, and is locked in place with a castle nut and cotter pin. It is lubricated either by means of an oil or grease cup.

Some axles have the tie rod in front, with the steering arms set outward at an angle less than 90° from the center line of the spindle. The disadvantage of this mounting is that in case of a collision the tie rod is likely to be sprung and the toe-in changed, while if the rod is at the rear of the axle, it is well protected.

To increase the toe-in or gather of the front wheels when the tie rod is at the rear of the axle, lengthen the rod; if the tie rod is in front of the axle the rod must be shortened.

One steering knuckle has the knuckle thrust arm connected to it, either by being forged integral with the steering knuckle or bolted on. The thrust arm is connected to the steering device by means of the steering gear connecting rod (sometimes called drag link). The steering knuckle thrust arm has a ball end, which seats in a socket in the connecting rod.

The ball and socket joint is held together by a nut and a strong coil spring. The purpose of this spring connection is to absorb the small shocks due to the roughness of the road and to prevent these shocks and vibrations from being transmitted to the steering device. The spring pressure in this connecting rod is adjustable.

The ends of the rod are packed with grease, usually held in by a leather boot, which is laced around the ball and socket joint.

FRONT WHEEL MOUNTING

The bearings employed in the front wheels are usually the cup and cone, or the tapered roller type. There are two bearings used in this mounting, one on each end of the spindle, and are mounted opposed, in such a manner that they take the thrust in both directions. These bearings are adjustable to compensate for wear. The inner race or cone of these bearings is a light tapping fit on the spindle, while the outer race should fit the same into the hub.

To adjust the front wheel bearings, lift the wheels clear of the floor so that they are free to revolve. Remove the hub cap and cotter pin. Screw the adjusting nut inward until all play is removed. Turn the castle nut back until the first slot lines up with cotter pin hole. Replace cotter pin and test. If the bearings are free (not binding) and properly adjusted, the weight of the tire valve, when placed in a horizontal position, will cause it to settle to the bottom. If the valve does not settle to the bottom, turn the nut back to the next slot and test again. If the bearings are adjusted too tightly, it causes them to wear quickly. When mounting or adjusting these bearings, see that they are clean, that the adjusting nut is properly locked and that the bearing is well lubricated.

STEERING DEVICES

Types

The steering devices that are employed on present day cars are divided into two distinct classes, irreversible and reversible. Each class is subdivided into several types.

The worm and wheel, the worm and sector, the split nut (or Jay-Cox) and the worm and nut are of the irreversible type. The reversible class has in its group the planetary and the ordinary gear reduction types. Cars equipped with irreversible type steering devices are easier to drive, due to the fact that the vibration and skidding strains of the front wheels, when driving over rough roads or through ruts, are not transmitted back to the steering wheel, as is the case with the planetary and the plain gear reduction types.

In designing steering devices, it is desirable to obtain as much leverage as possible, as this makes steering easier. The increased leverage is obtained by a gear reduction and the heavier

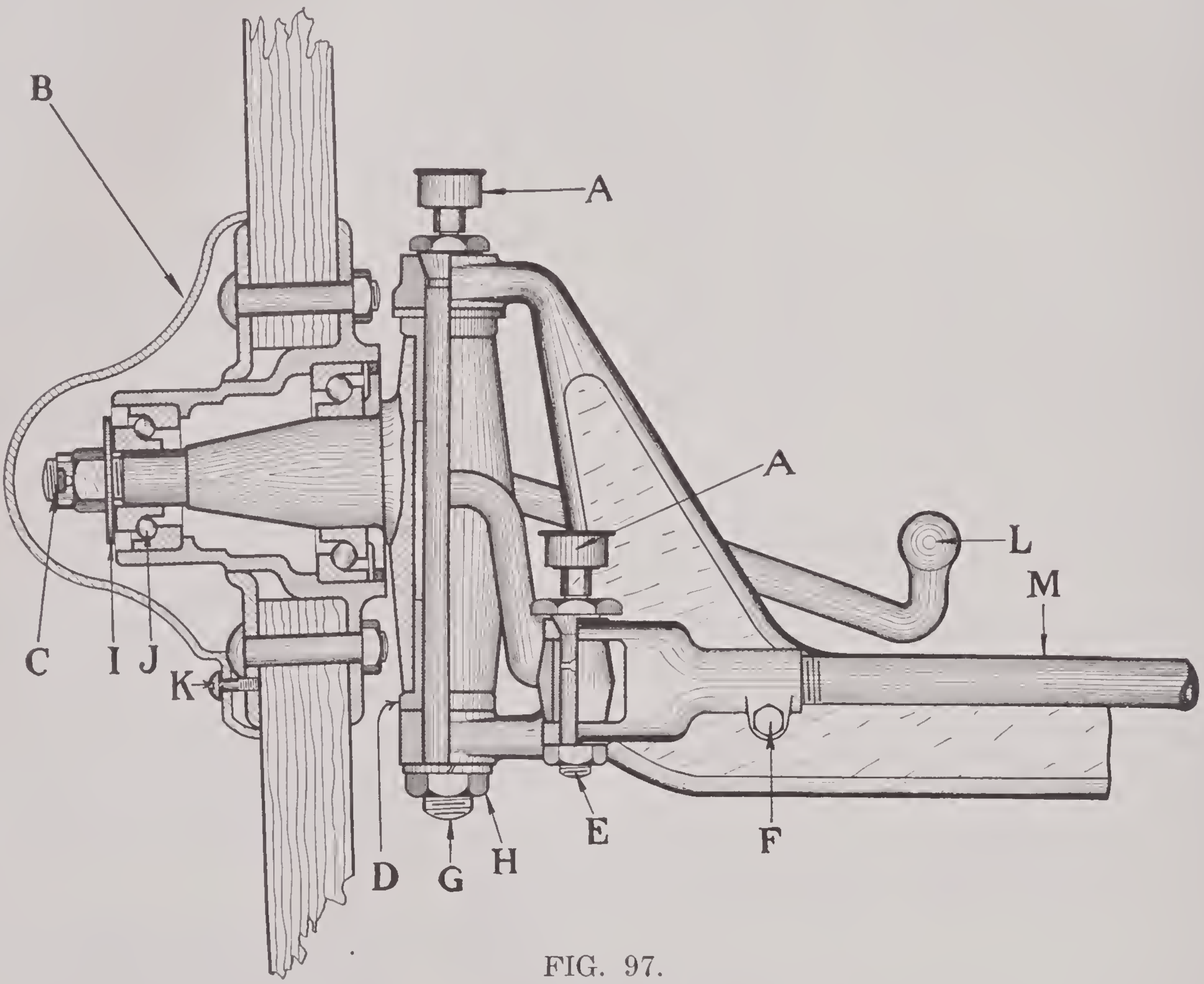

FIG. 97.

STEERING KNUCKLE AND FRONT WHEEL MOUNTING

A. Grease cup.
B. Hub cap.
C. Spindle nut.
D. Pivot bolt bushing.
E. Tie rod pin and nut.
F. Tie rod adjustment lock.
G. Pivot bolt.
H. Pivot bolt nut.
I. Spindle washer.
J. Cup and cone bearing.
K. Hub cap fastening screw.
L. Thrust arm ball end.
M. Tie rod.

On this construction the hub cap is secured to the wheel flange instead of being threaded on to the wheel hub. This acts as an oil retainer and excludes the sand and grit.

To remove worn pivot bolt bushings (D), remove the nut (H), press the bolt out, remove the steering knuckle and press out the bushings—then replace and fit new ones.

To adjust the toe-in of the front wheels, remove nut (E), press out the tie rod pin, loosen the clamping bolt (F), and turn the tie rod end clockwise to decrease, or counter clockwise to increase the gather. With the tie rod pin removed, the bushing may be pressed out of the knuckle arm and a new one pressed in, using an expansion reamer to fit the pin—a light pressing fit with the palm of the hand.

the car, the greater the leverage required. In a steering gear of the reversible type, the strains transmitted back through the steering device, due to vibration caused by road shocks, are greater than with the irreversible type.

Worm and Wheel Steering Device

(See Fig. 98)

The worm and wheel steering device is constructed as follows: A hardened steel worm is

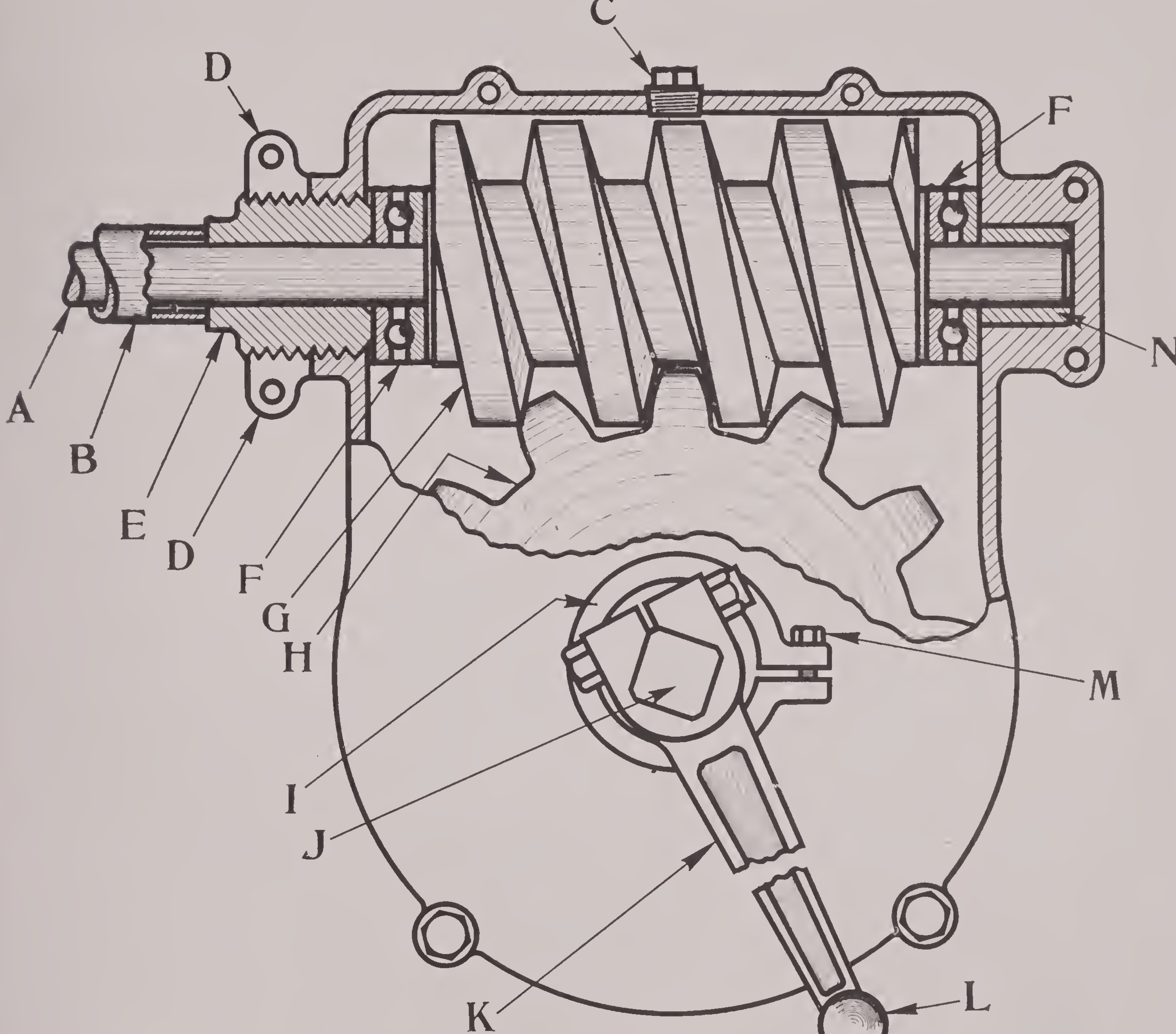

FIG. 98

WORM AND WHEEL STEERING DEVICE

A. Steering wheel shaft.
B. Steering column tube.
C. Grease filler plug.
D. Adjusting nut clamping lug.
E. End play adjusting nut.
F. Thrust bearing.
G. Worm.
H. Steering worm gear.
I. Eccentric bushing clamping hub.
J. Steering arm shaft.
K. Steering gear arm.
L. Ball end.
M. Clamping bolt.
N. Radial bearing bushing.

To remove the end play, loosen the clamping bolts in (D) and turn the adjusting nut (E) in, forcing the upper thrust bearing and worm against the lower bearing and housing. To remove the clearance between the teeth of the worm and worm wheel, loosen the clamping bolt (M) and turn the eccentric bushing around until the thicker part of the bushing is down and the worm wheel is forced upward. This play between the teeth may also be removed by changing the position of the worm gear to bring an unused portion in contact with the worm. This requires some disassembling to bring steering gear arm (K) in proper position. Play between the eccentric bushing and steering arm shaft can only be remedied by replacing and fitting a new bushing.

secured to the steering wheel shaft. The steering wheel, being mounted on the upper end of this shaft, turns the worm, which in turn drives a worm gear. The worm gear is made either of bronze or steel.

On any worm and wheel drive, regardless of its application, there is an end thrust. Consequently, end thrust bearings are provided at each end of the worm. The thrust bearings are generally of the ball thrust type, but they may be thrust plates instead.

To adjust the worm to compensate for wear, an adjusting nut is usually provided, which may be located at either end of the housing, but is usually at the top. By turning this adjusting nut inward, the end play is reduced. The end thrust adjusting nut is locked by means of a clamping lug. The clamping lug, which is part of the steering gear housing, is split for a short distance, thus allowing a clamping bolt to contract the housing around the adjusting nut.

The worm gear has a keyed shaft pressed into it, which is termed the steering gear shaft, and is usually mounted in two bronze bearings. These bearings are, in most cases, eccentric; that is, the hole in them is offset from the center. The eccentric bushing is an adjustment to bring the worm gear closer to the worm.

The steering wheel, to have the right amount of play and to be adjusted properly, should swing from one-half to two inches, rim measurement, before the road wheels respond. More play than this will allow the car to follow the ruts too easily, causing hard steering, while play of less than one-half inch results in unnecessary wear in the different parts of the steering device.

Before adjusting the steering wheel to reduce play, the complete steering mechanism should be examined to determine the location of the play, and what worn parts are causing this play. It may not always be in the steering device proper, but may be caused by any of the connecting parts.

In time, the teeth of the worm gear become worn, and in this case the eccentric bushing may be turned so the gear meshes closer to the worm. Eventually, the limit of adjustment by this method is reached; that is, when the eccentric bushing is moved around one-half revolution, or 180°, the worm gear is moved as close to the worm as possible by this adjustment. It is advisable, under these conditions, to change the mesh and bearing position of the teeth. This is possible because in ordinary steering only the lower half of the threads of the worm are in constant use. The upper half of the threads receives very little wear. The above mentioned adjustment is made by disassembling the device and meshing the worm and worm wheel in a new position.

Play in the radial bearings or bronze bushings of the worm shaft is eliminated by the replacement and refitting of new bearings. The new bearings, after they are pressed in, may be reamed to the correct fit.

The end of the worm gear shaft outside the housing is square. The steering gear arm has a square hole machined in it. One side of the arm is split and provided with a clamping screw which passes through part of the worm gear shaft on which the arm is mounted. There is a small notch cut in the squared end of the shaft to accommodate the bolt or screw. The bolt engages with the notch and prevents the steering gear arm from coming off the shaft.

The worm and worm gear are enclosed in either a cast iron or aluminum housing. The housing may be either a single casting or of the divided type. The divided type is held together by screws or bolts. The housing should be filled with grease or heavy oil, and has an oil filling cup or plug on the upper side for this purpose. It is necessary to keep the steering device well lubricated.

Worm and Sector Steering Device

The worm and sector steering device is usually constructed similar to the worm and worm gear, except that instead of using a complete worm gear, only a section is employed, usually about a ninety degree sector.

The sector may be enclosed entirely in a housing and lubricated the same as the worm and wheel type, or the housing may be of a web construction. The latter construction causes rapid wear, due to the lack of lubrication, as the lubricant will have to be placed on the surface by hand, in which case, it soon loses its proper lubricating quality from contamination by sand and dust. The adjustments are the same as in the worm and wheel type.

Split Nut Type (Jay-Cox) Steering Device

The split nut type steering device has a worm on which is machined both a right and a left hand thread. This worm is hardened and ground to reduce wear. Two half nuts made of bronze, one having a right and the other a left hand thread, are in mesh with the threads on the worm. The outer surface of the nut bears against the inside wall of the housing. When the steering wheel and worm are turned, one nut moves up and the other moves down. Reversing the steering wheel also reverses the direction of the movement of the half nuts.

Fastened on the bottoms of these bronze half nuts are hardened steel plates, upon which the rollers on the rocker arm rest. The rocker arm is mounted on a shaft in the lower end of the housing at right angles to the worm. On the square end of this shaft the steering gear arm is mounted. Turning the steering wheel in one direction, moves the right hand half nut down, pushing the rocker arm with it, while the left hand half nut moves up with the opposite end of the rocker arm. Turning the steering wheel in the opposite direction reverses the movement of the half nuts, the rocker arm and the steering gear arm.

In assembling this steering device the right and left hand nuts must be mounted on their proper sides. If the nuts are transposed in their mounting, it will reverse the action of the steering device. That is, when the steering wheel is turned in one direction, the steering arm is moved in such a way that the car turns in a direction opposite to the movement of the steering wheel.

The only adjustment provided on this steering device is the end play adjusting nut which is usually clamped into the housing with a clamping bolt, similar to the other steering devices. The thrust bearings provided are usually of the ball thrust type.

When assembling this steering device, mount the nuts with the hardened plate ends against the rocker arm rollers.

The housing on this steering device is provided with a grease filling plug and should be kept full of grease at all times.

Worm and Nut Steering Device

The worm and nut steering device is constructed with a right hand thread on the worm. Mounted on the worm is a nut with a connecting link. This link connects with a crank arm on the steering gear shaft, the latter being mounted in the housing at right angles to the worm. The nut moves up and down and

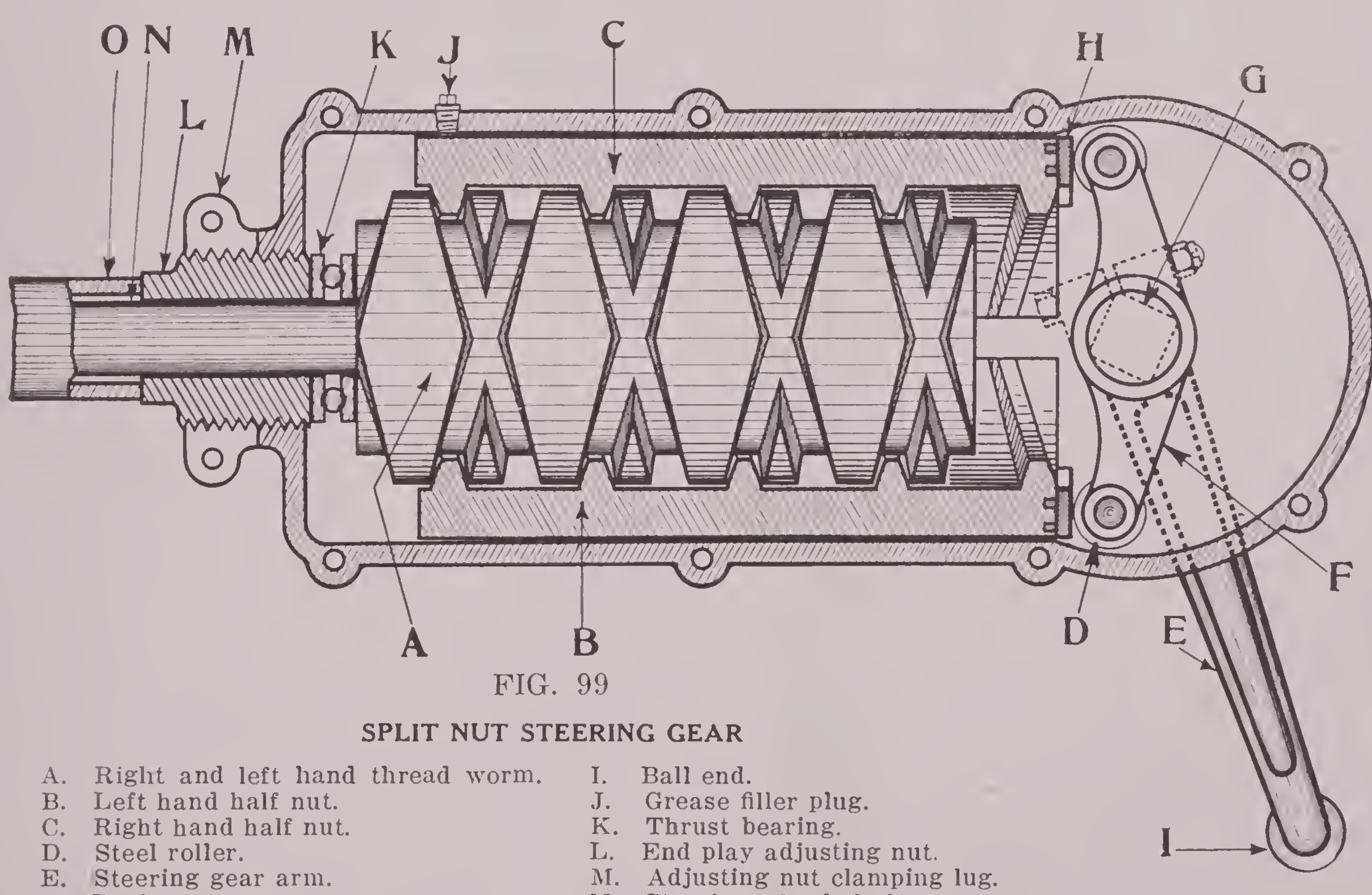

FIG. 99

SPLIT NUT STEERING GEAR

A. Right and left hand thread worm.
B. Left hand half nut.
C. Right hand half nut.
D. Steel roller.
E. Steering gear arm.
F. Rocker arm.
G. Steering gear shaft.
H. Hardened steel plate.
I. Ball end.
J. Grease filler plug.
K. Thrust bearing.
L. End play adjusting nut.
M. Adjusting nut clamping lug.
N. Steering wheel shaft.
O. Steering column tube.

The adjustment on this type of steering device is the end play adjusting nut (L). This nut adjusts the end play in the worm and its connections. To remove the lost motion caused by the end play in the worm, loosen the screw in the clamping lug (M), move the nut inward until the bearings are tight, back the nut away a fraction of a turn so as to give the thrust bearing a little clearance, tighten the bolt in the clamping lug and lock it. The ball thrust bearing may wear, as may also the threads on the half nuts, the surfaces of the half nuts that rub on the wall of the housing, the hard steel rollers, roller pins and the steering arm shaft and bearings. The housing should be packed with light cup grease for lubrication.

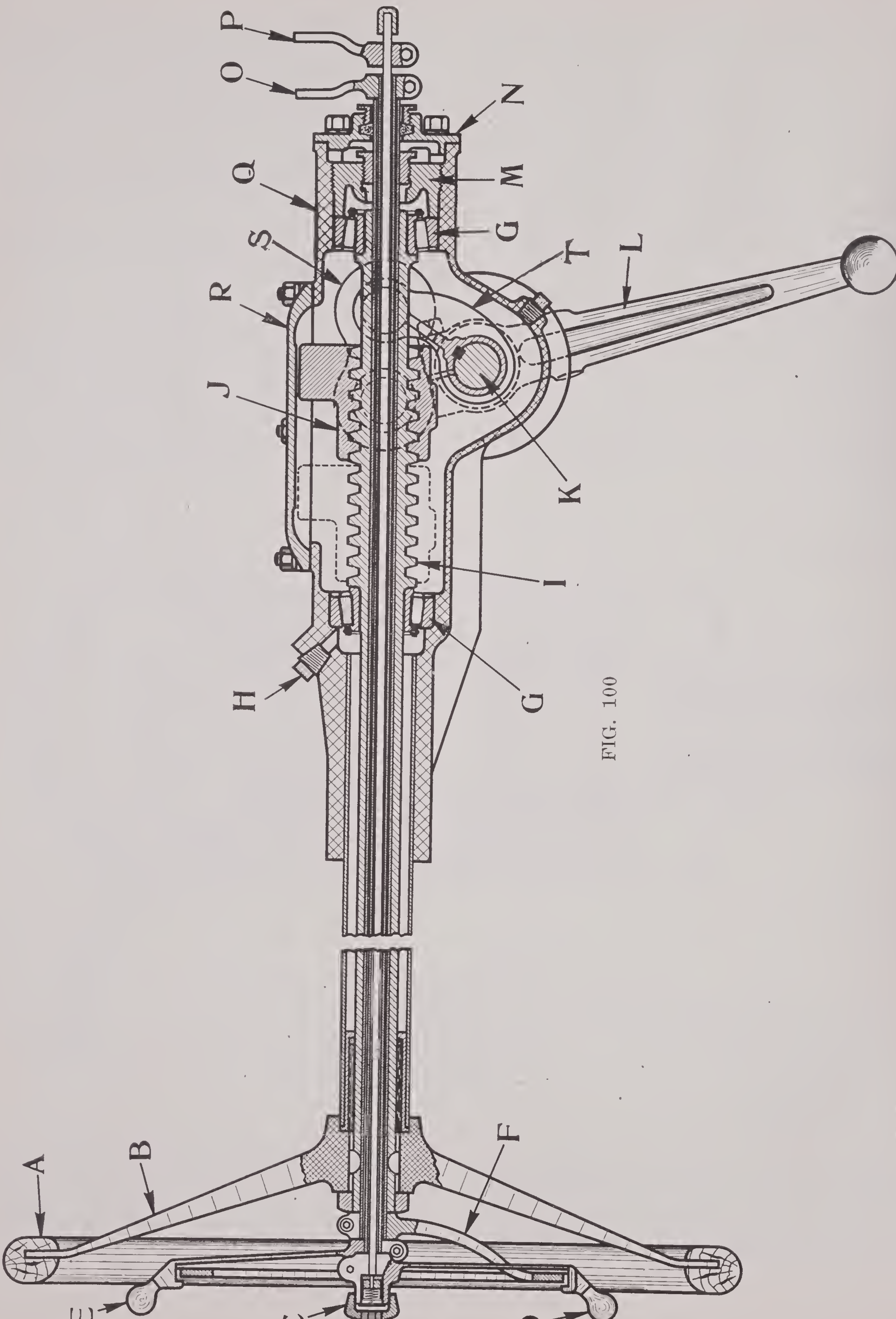

FIG. 100

FIG. 100

WORM AND NUT STEERING DEVICE

A. Steering wheel rim.
B. Steering wheel spider.
C. Horn button.
D. Spark hand lever.
E. Throttle hand lever.
F. Spark and throttle sector arm.
G. Shaft bearings.
H. Grease filler plug.
I. Worm.
J. Worm nut.
K. Steering gear shaft.
L. Steering gear arm.
M. End play adjusting nut.
N. Cover.
O. Throttle tube lever.
P. Spark tube lever.
Q. Steering gear case.
R. Steering gear case cover.
S. Connecting link.
T. Crank arm.

This sketch shows a conventional mounting of the control rods or tubes through the center of the steering column. The standard number of tubes for a steering device in which the controls extend through the center is five—two stationary and three movable.

The outer tube is called the steering column tube, and is fastened rigidly to the stationary case or housing (Q). The next is the steering wheel tube (or shaft). At the top of this tube the steering wheel spider (B) and rim (A) are fastened on with keys and a nut. Mounted just below the wheel spider and within the outer or stationary tube is a plain roller bearing which takes the radial load of the steering wheel and shaft.

On the lower end of the steering wheel tube is a screw thread or worm (I) provided with bearings (G). This worm or screw thread (I) actuates the nut (J), which in turn operates the steering arm (L) through the connecting link (S) and crank arm (T). When the steering arm is moved back and forth, there is an end thrust on the nut, worm and steering tube. This thrust is taken by the tapered roller bearings (G), which also take the radial load. In some devices of this type, a plain bronze bushing takes the radial load and two ball thrust bearings take the thrust load with the adjusting nut at the top as in the worm and wheel device. The third tube from the outside is called the spark and throttle sector tube. This tube is held stationary with the housing at the lower end by an adjuster, which is threaded into the cap (N) with a packing between the tube and case to prevent oil leakage. At the top of this stationary tube the spark and throttle sector (F) is mounted.

At the top of the fourth tube from the outside, the throttle hand lever (E) is mounted. Moving this hand lever moves the throttle tube lever (O), which is connected to the throttle valve of the carburetor. This fourth tube is called the throttle hand lever tube.

The inner tube is called the spark lever tube. At the top of this tube the spark lever (D) is fastened. Moving this hand lever moves the spark tube lever (P), which in turn operates the spark advance lever of the breaker mechanism. The horn wire, which connects the horn button (C) with the horn, passes through the center of this tube.

To remove play of the worm and wheel tube in the housing, remove lever (O) and lever (P), also packing nut and cap (N). Screw the adjusting nut (M) forward, forcing the outer race of the tapered roller bearing forward and downward. This adjusts for both radial and thrust play.

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through the connecting link and crank, moves the steering gear shaft and steering gear arm backward and forward.

This steering device is provided with an adjusting nut to take up the end play. The housing should be packed with grease to reduce the amount of friction and wear.

Worm, Screw and Nut Type

There is also a worm, screw and nut steering device, which has a worm with a left hand thread on the outside and a right hand thread on the inside. A screw with a right hand thread is mounted within the worm. The screw projecting outward fits into one end of a rocker arm fastened on a shaft that is mounted at right angles to the worm. A nut with a left hand thread is mounted on the outside of the worm. The nut is connected to the other end of the rocker arm. When the steering wheel is turned the worm will turn, and this moves the screw inward and the nut outward, thus causing the rocker arm shaft and steering gear arm to move. This device is provided with an end thrust bearing and an end play adjusting nut. No other adjustments are provided.

Planetary Steering Device

The two main points of difference between a planetary type and others are: first, the drive is by planetary action through spur gears instead of through a worm. The other is that the movement of the steering gear arm is parallel with the axle, crosswise of the car, instead of back and forth, parallel with the frame.

The Ford steering device is of the planetary type. It consists of five gears; one is a large internal stationary gear on which the teeth are cut on the inner instead of the outer face. This internal gear, which has thirty-six teeth, forms a part of the steering gear case or housing.

There is a three-pronged spider fastened to the top of the steering gear post, which continues through the steering gear housing and has the steering gear ball arm fastened to it at the bottom. On this spider are mounted three gears having twelve teeth each, which are called the planet gears. The steering wheel is keyed to the steering wheel shaft on which is cut a small gear with twelve teeth, called the sun gear. On the interior of the steering gear post is a bronze bushing in which the end of the steering wheel shaft rides.

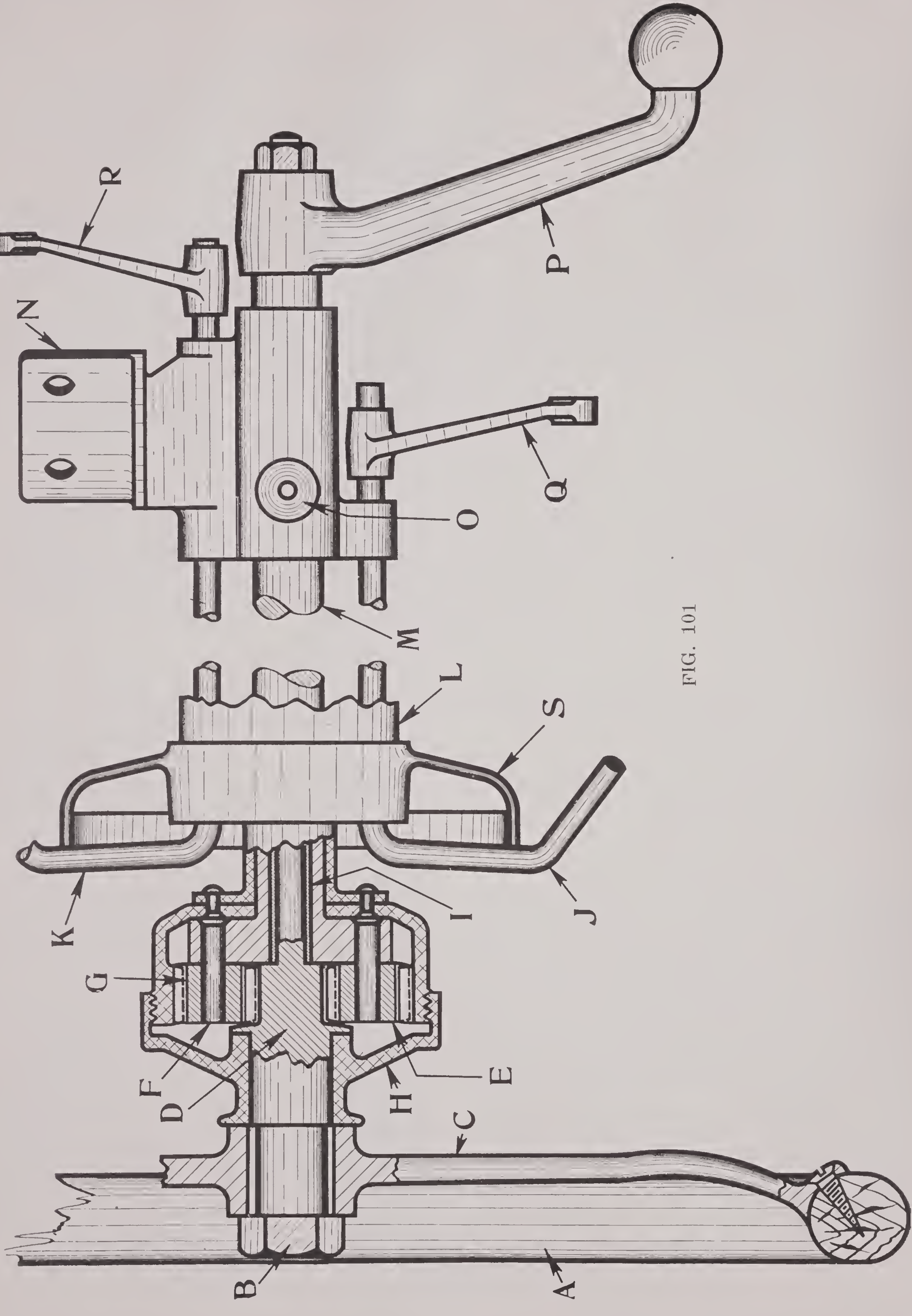


FIG. 101

FIG. 101

FORD PLANETARY STEERING DEVICE

A. Steering wheel rim.
B. Wheel nut.
C. Steering wheel spider.
D. Sun gear.
E. Planet gear.
F. Spider pin.
G. Internal stationary gear.
H. Cover.
I. Bearing bushing.
J. Gas control lever.
K. Spark control lever.
L. Steering column tube.
M. Steering shaft.
N. Supporting bracket.
O. Grease cup.
P. Steering gear arm.
Q. Gas control lever arm.
R. Spark control lever arm.
S. Quadrant.

This sketch shows a partial cross-sectional view of the planetary steering device (Ford). There is no adjustment provided on this device to compensate for wear. Worn gears or pins should be replaced with new parts.

If the bearing (I) wears, it can be split with a chisel and removed. Then press in a new bushing. Play at the lower end, where the steering shaft passes through the bracket, can be remedied by pressing in a thin bushing. It may be necessary to ream the bracket out slightly in order to press a bushing in. Wear at this point is greatly reduced by lubrication supplied through the grease cup (O).

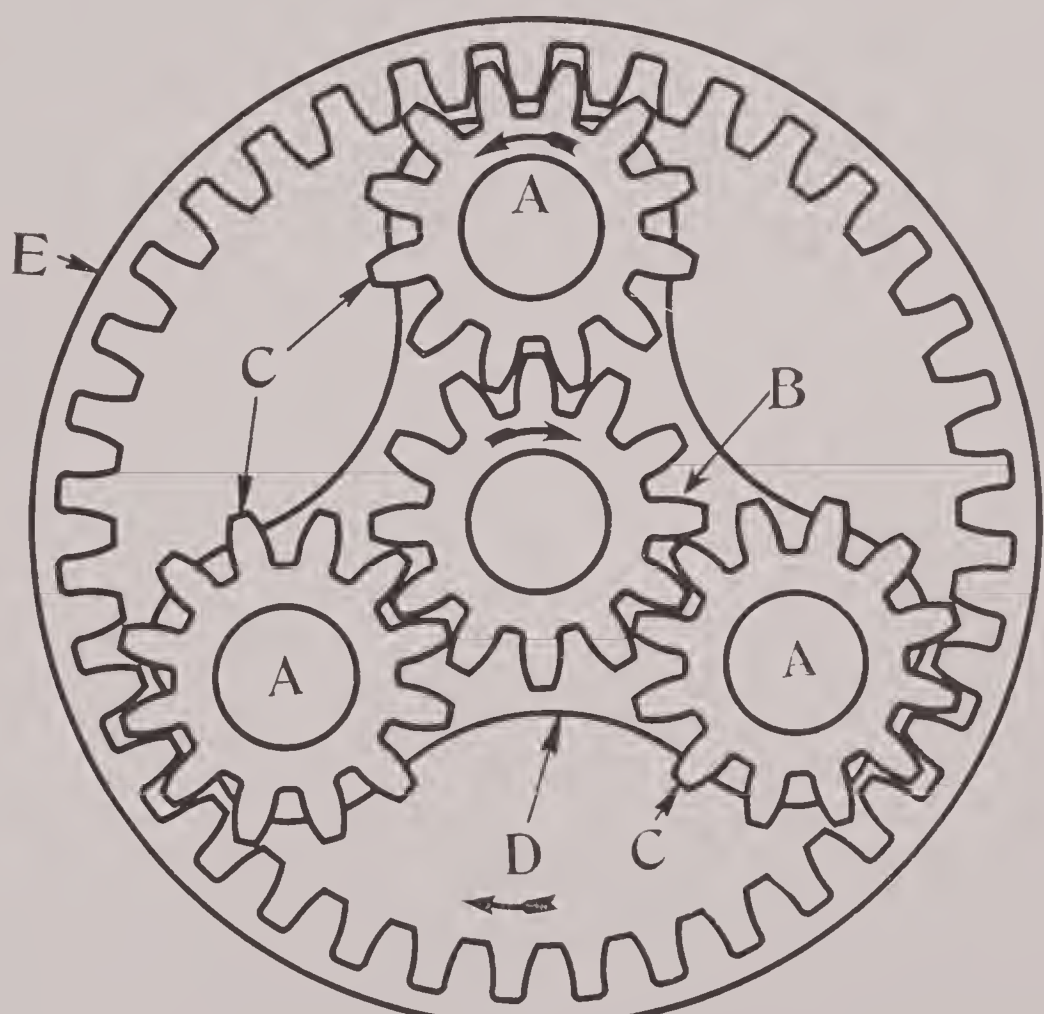


FIG. 102

PLANETARY GEAR ASSEMBLY

A. Spider pins.
B. Sun gear.
C. Planet gears.
D. Spider.
E. Internal stationary gear.

This sketch shows an end view of the gear assembly employed in the planetary steering device (Fig. 101). The steering wheel is fastened to the shaft on which the sun gear (B) is cut.

When the steering wheel and the sun gear (B) are turned, the planet gears (C) revolve on their axes and at the same time travel around on the internal stationary gear. This drives the spider and the steering gear ball arm in the same direction in which the steering wheel and sun gear are turned.

There is no connection between the steering wheel shaft and the steering gear post and spider except through the gears.

When the steering wheel is turned, the center gear of twelve teeth turns with it. This gear is in mesh with the three planet gears and causes them to revolve on their own axes. The three planet gears are meshed with the large stationary internal gear of thirty-six teeth; by holding the thirty-six tooth gear stationary and turning the center twelve tooth sun gear, the three twelve tooth planet gears in revolving on their own axes will travel forward, using the interior of this large gear as a track.

The spider turns in the same direction as the steering wheel. The planetary action of the gears and spider causes the steering wheel to travel a greater distance or faster than the spider and steering gear ball arm.

When the steering wheel makes one complete revolution on its own axis, the planet gears do not make a complete revolution on their axes, but travel forward on the outer gear nine teeth instead of twelve, the difference being caused by the forward travel of the spider. If the spider was held stationary and the thirty-six tooth gear was free to revolve, in one revolution of the steering wheel the planet gears would revolve twelve teeth or one complete revolution on their axes.

The difference in the distances traveled by the steering wheel, planet gears and spider is due to the fact that the planet gears are traveling forward on the outside of the center gear, using the thirty-six tooth gear as a track. In one revolution of the center gear which is connected to the steering wheel, the spider moves forward one-quarter of a revolution. In order to make the spider travel a complete revolution, the steering wheel must necessarily make four revolutions.

This device is not adjustable. To take up any lost motion or play in the steering device, it is necessary either to put in new planet gear pins on which the planet gears revolve, or put in new gears. There is no end thrust in this device to necessitate the use of a thrust bearing. The bearing at the end of the steering wheel shaft, which is made of bronze, can be replaced.

The housing in which these gears are mounted should be packed with grease.

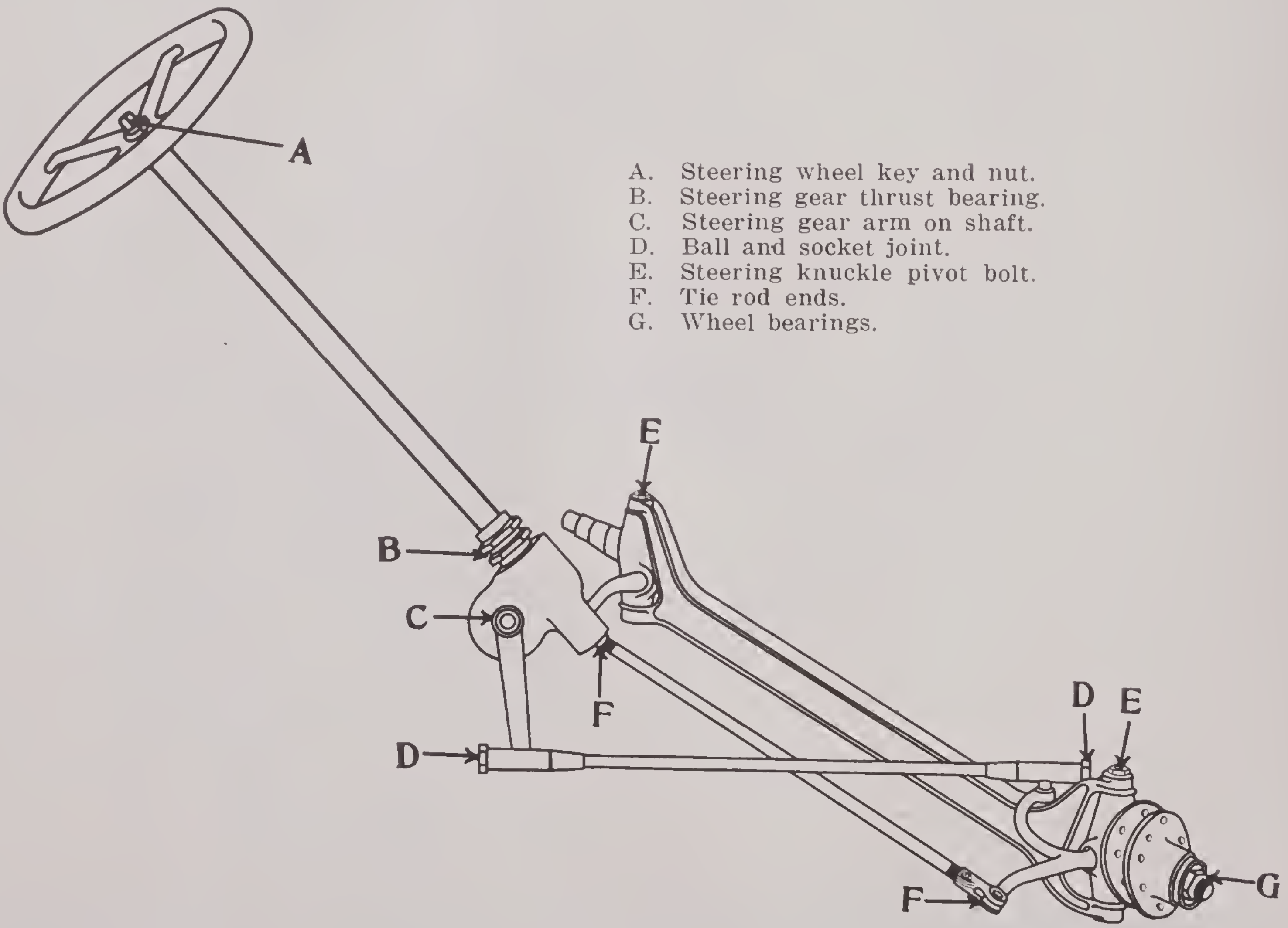


FIG. 103

POINTS FOR ADJUSTING LOST MOTION IN THE STEERING ASSEMBLY

GAS AND SPARK CONTROL LEVERS

The gas and spark control levers are mounted on a sector at the top of steering column, either just above or below the wheel spider. The portions of these levers that are parallel to the steering column may be either shafts or tubes, and may be mounted in brackets on the outside of the steering column or pass through the center of the steering column. One lever operates the spark advance and retard mechanism, and the other operates the throttle valve on the carburetor. Both the spark lever and the gas lever may move downward to advance the spark and open the throttle valve or both move upward. Sometimes both are on the same side, either moving downward or upward.

A foot operated lever is also used to control the movement of the throttle valve. It is called the foot accelerator. The connections between these levers are so arranged that moving the gas control lever at the steering wheel also moves the foot accelerator, but moving the foot accelerator does not move the gas control lever at the steering wheel. To open the throttle valve with the foot accelerator, press it downward or forward.

To distinguish the gas lever from the spark control lever when they are not marked, proceed in the following manner: Knowing that the movement of the foot accelerator forward or downward opens the throttle valve, then move the gas control lever at the steering wheel in the direction that moves the foot accelerator upward. Continue to move the gas control lever in that direction until the foot accelerator is all the way up. This is the closed position of the throttle valve, and in all cases the spark lever is in the same relative position for a fully retarded spark. Moving the spark lever will not move the foot accelerator.

The spark lever and gas lever always move in the same relative direction for advancing the spark and opening the throttle valve. This is mentioned because when carburetors are changed, care should be taken to see that moving the gas control lever in the same direction as formerly, opens the throttle valve. This mounting and action should never be reversed. If it does not work the same as formerly, put in an extra bell crank.

CLUTCHES

In the study of the internal combustion engine it was shown that the operation depended upon power developed within itself, and that it had to be started by some external means. It is one of the fundamental points in the gas engine that the power developed bears a very important relation to the speed of the engine. It must attain a certain amount of speed and momentum in order to overcome the effect of any load when it is applied; also in using the automobile, there are many times when it is desired to stop the car without necessarily stopping the engine.

It is the purpose of the clutch to meet these conditions, and it is placed between the engine and the transmission system to permit the connecting and disconnecting of those two units at the will of the operator. In accomplishing this, it is very necessary that the engine should be engaged with as smooth and gradual an action as possible, to avoid too sudden an application of a heavy load, which might stop the engine, also to prevent undue strain on all parts of the car, and jerky or uncomfortable riding. Thus one of the important requisities of the clutch is flexibility.

To obtain this flexibility, provision must be made to allow the clutch to slip. That is, the flywheel or driving member will turn faster than the driven member until the car is under motion, after which the clutch should cease to slip.

Clutches are made in several types, as follows:

Cone:
Disc: { Lubricated / Dry }
Plate.
} Single Spring. / Multiple Spring.

CONSTRUCTION

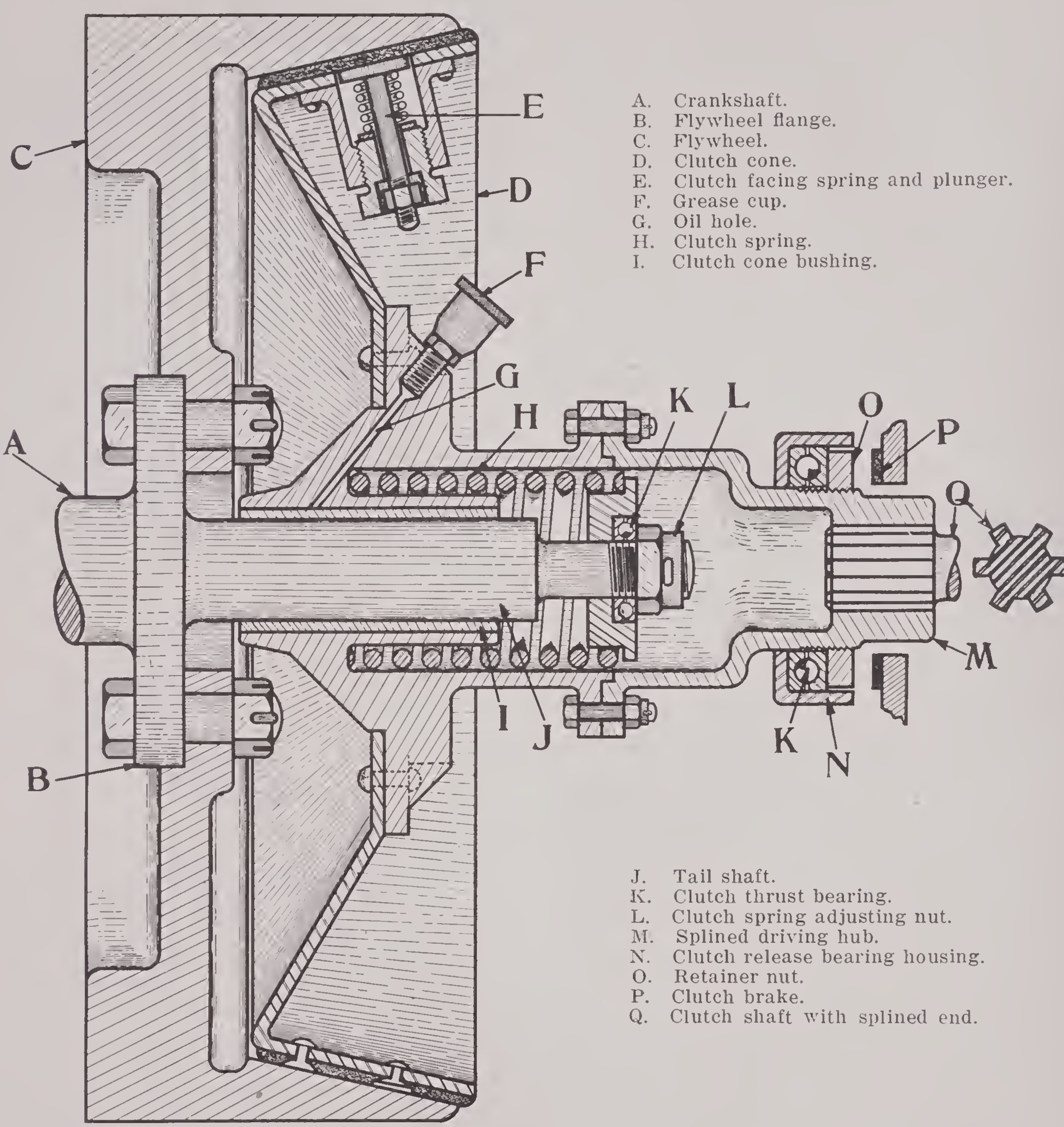
Cone Clutch

Single Spring (Fig. 104):

The flywheel is fastened rigidly to the crankshaft and acts as the driving member. The inside of the flywheel is machined smooth and at an angle. On an extension of the crankshaft, which is called the tail shaft, the driven member is usually mounted. The driven member is termed the cone, and the outside surface is machined at the same angle as the inner surface of the flywheel.

A leather facing is fastened on the cone with copper rivets. Mounted in the face of the cone and resting against the inside of the leather facing are usually a number of small springs called insert or clutch facing springs. The purpose of these springs is to raise the leather facing in several spots and prevent the full surface of the facing from coming in contact with the flywheel when engaging the clutch, thus eliminating grabbing.

A bronze bushing is pressed into the cone, which carries the radial load of the driven member when the clutch is disengaged. The clutch spring (a heavy coil spring)is mounted



A. Crankshaft.
B. Flywheel flange.
C. Flywheel.
D. Clutch cone.
E. Clutch facing spring and plunger.
F. Grease cup.
G. Oil hole.
H. Clutch spring.
I. Clutch cone bushing.
J. Tail shaft.
K. Clutch thrust bearing.
L. Clutch spring adjusting nut.
M. Splined driving hub.
N. Clutch release bearing housing.
O. Retainer nut.
P. Clutch brake.
Q. Clutch shaft with splined end.

FIG. 104

CONE CLUTCH—SINGLE SPRING

To disassemble, remove the transmission from the clutch, remove the bolts that hold the driving hub (M) on the clutch, then remove the cotter pin and nut (L). This will allow the spring and the cone to be removed.

When refacing the cone, tighten the insert spring plunger nut which holds the spring and plunger compressed. After the facing is riveted on, loosen this nut and allow the spring and plunger to force the facing away from the cone when the clutch is disengaged. The larger nut acts both as a guide for the plunger and as the spring adjuster.

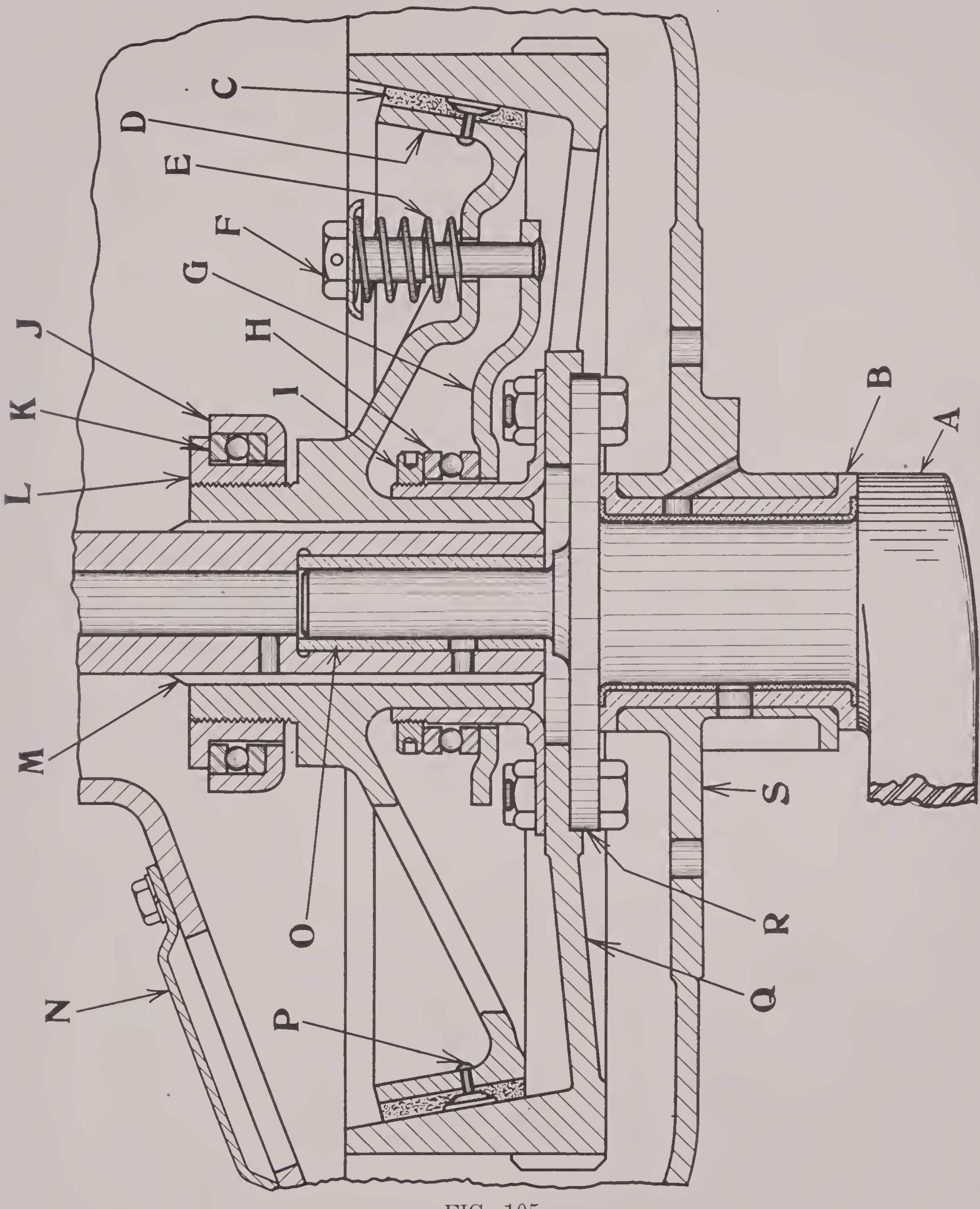


FIG. 105

CONE CLUTCH—MULTIPLE SPRING

A. Crankshaft.
B. Crankshaft bearing.
C. Clutch facing—leather.
D. Clutch cone.
E. Clutch spring.
F. Clutch spring nut.
G. Clutch spring spider.
H. Thrust bearing.
I. Clutch thrust bearing retainer.
J. Clutch release bearing housing.
K. Clutch release thrust bearing.
L. Clutch release sleeve.
M. Splined clutch shaft.
N. Inspection plate.
O. Tail shaft bearing bushing.
P. Clutch facing rivets (copper).
Q. Flywheel.
R. Flywheel flange.
S. Crankcase.

around the tail shaft and is usually held in position by an adjusting nut with a ball thrust bearing mounted against the spring to take the thrust strain when engaging or disengaging the clutch.

Multiple Spring (Fig. 105):

The construction of the multiple spring cone clutch is the same as a single spring, with the exception of the mounting of the clutch spring. A separate spider is mounted on the tail shaft, which is held in position by a retaining nut with a ball thrust bearing to take the thrust strain.

The radial load of the spider is taken by the cone member. The clutch springs are mounted upon the spider pins or studs outside the cone. The springs are held in place by either adjusting nuts or retainers.

These clutch springs are farther away from the center of the shaft, permitting the use of several light springs instead of one heavy spring as on the single spring type. By having the spring as close to the clutching surface as possible, the multiple spring clutch is easier to disengage than the single spring type. The clutch springs, being mounted on the outside, are more accessible and easier to adjust.

The clutch shaft extends through the cone member, and is fitted with a bushed bearing in which the tail shaft runs.

Disc Clutches

The disc clutch consists of two sets of annular discs, one set of driving discs and one set of driven discs. They are placed together in alternate order each driven disc being located between two driving discs. The driving discs are provided with keys or slots on their outer circumference which fit in to slots or keys on the inside of a drum-shaped housing secured to the flywheel or fit over studs secured to the flywheel. The driven discs are fitted with lugs or keyslots on their inner circumference, or fit over studs, either of which places them in connection with a drum on, or secure them directly to, the driven shaft. Generally there is one more driving disc than there are driven discs making the two outside discs of the same kind. The drum carrying the driven discs has a flange at one end which forms a stop for the discs, and the other end is a spider or pressure plate against which the clutch spring exerts its pressure.

The number of discs required is dependent upon several things. The power to be delivered by the engine determines the amount of frictional area and the clutch spring pressure required, and yet the amount of work done by the operator in disengaging the clutch must be taken into consideration in proportioning the various units.

An extension on the driven drum or shaft is supported in the driving member by a bronze bushed bearing or a ball bearing to take the radial load. Disc clutches are made in two types **lubricated** and **dry.**

Lubricated Disc Clutches

In the lubricated clutch the discs are generally made of saw steel about 1/16″ thick. Saw steel is selected because of its being hardened and of more uniform thickness than ordinary sheet steel. In some clutches one set of discs is of bronze, and in others sheet copper is used. Clearance between the discs when disengaged varies from 1/64″ to 1/100″.

One set of discs is sometimes provided with cork inserts. The cork is quite compressible, and it is customary to make the cork plugs of such a size that when free they project about 1/16″ above the surface of the metal plate. When the discs are forced together the contact is between metal and cork only and owing to the compressibility of the cork the engagement will be very smooth. When the full pressure of the spring is applied, the surfaces of the cork are compressed flush with the plate surface. The cork usually covers from 25% to 50% of the area of the discs.

The clutch spring arrangements for engaging the discs in this type clutch are both single and multiple, similar to those used on the cone type clutch. The distinct advantage of the disc clutch is that the amount of frictional surface can be made much greater than on the cone clutch, and the frictional force per unit of surface will be much smaller.

The bath of oil in which the lubricated disc clutch runs, serves two purposes; first to lubricate the face of the discs when disengaged, and second to assist in making a smooth application of power. When the clutch is thrown in, the film of oil is gradually squeezed out permitting a very easy and gradual engagement. The cork inserts provide greater friction in engaging the clutch and also have the advantage of protecting the discs from scoring in the absence of proper amount of lubricant.

The clutch is enclosed in an oil tight housing and may be lubricated directly from the engine or separately. When lubricated separately, manufacturers recommend a mixture of machine oil or gas engine oil and kerosene. The thinner the lubricant the better the clutch will hold, while the more viscous the lubricant the more gradually it will pick up the load. The kerosene should never be used when the clutch is lubricated from the engine.

The weak point of the lubricated disc clutch is its tendency to drag if the oil in the housing is not suitable for the purpose, or if too much is introduced.

Dry Disc Clutch

In the dry disc clutch one set of discs is either faced with asbestos fabric on both sides or else provided with cork inserts. Both of these materials when used with steel have a much greater frictional contact than steel or bronze on steel.

The asbestos facing is a fabric composed very largely of asbestos fibre and containing some brass wire and cotton to give it the necessary strength. The asbestos is used on account of its good frictional qualities and its resistance to heat. It is usually secured to the metal discs by means of rivets, and is used on both sides of alternate discs only. The rivets must be countersunk to be sure of no metal contacts as that would destroy the frictional qualities.

Plate Clutch

The plate clutch consists of three discs or plates only and is used without lubricant. The plates are of cast iron and bronze or cast iron and steel. Since there are only two friction surfaces, it is necessary to use rather large plates and multiply the pressure of the clutch spring by using levers or toggle mechanism, as illustrated in Fig 111.

CLUTCH BRAKE

In engaging the transmission gears for starting the car or changing the speed, it is necessary that both the shaft driven by the clutch and the sliding or change gears of the transmission be either stationary or running at approximately the same speed in order that they may engage quietly and without damage.

It is the purpose of the clutch brake to stop the revolving driven member or decrease its speed so that the gears may be properly engaged. It is a stationary member, mounted so that when the clutch is disengaged, the driven member, which is revolving from the momentum received from the flywheel, will come

(Continued on Page 149)

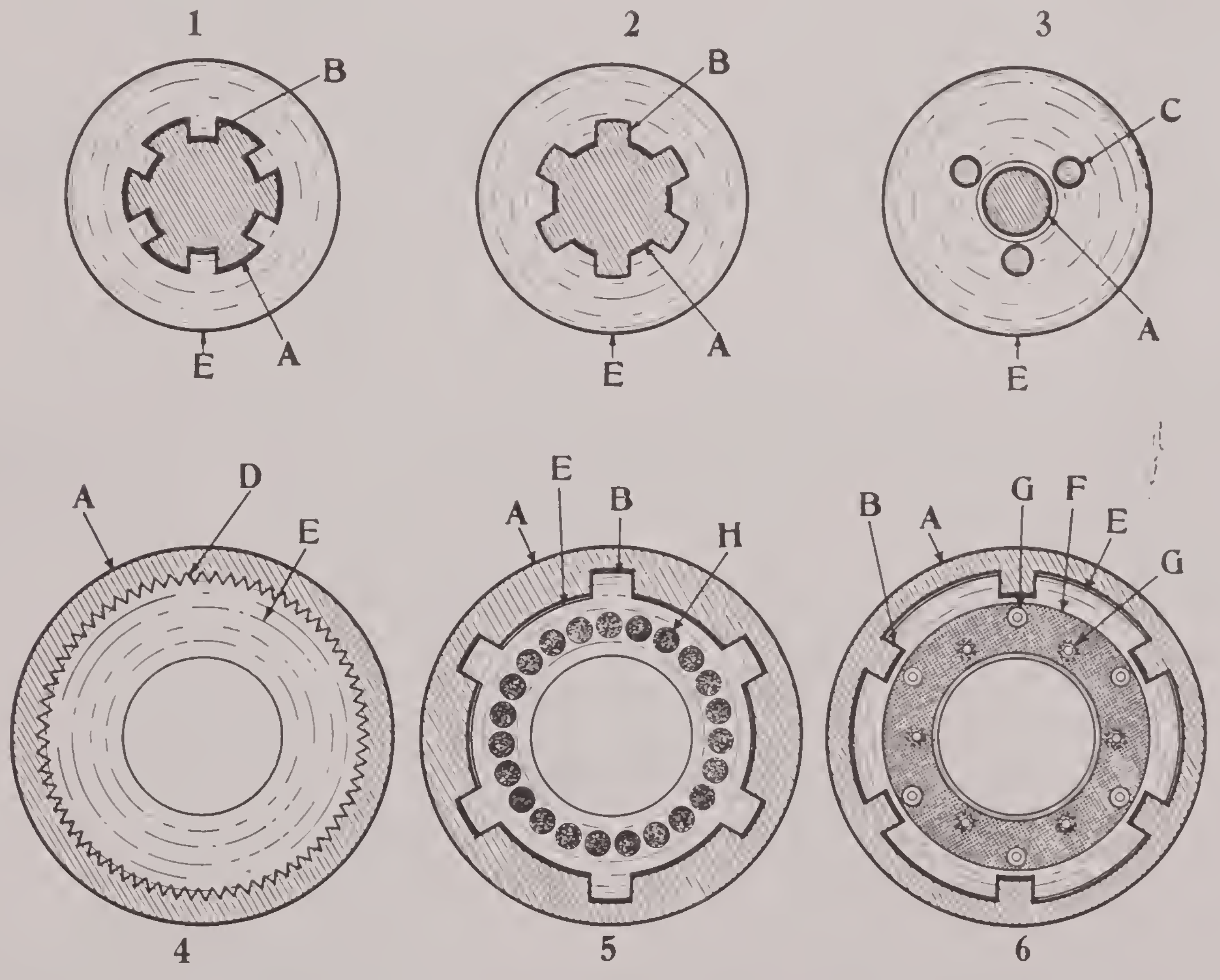


FIG. 106

CLUTCH DISCS

(1) A. Clutch driven drum.
B. Driving groove.
E. Driven disc.
(2) A. Clutch driven drum.
B. Driving key.
E. Driven disc.
(3) A. Clutch driven drum.
C. Clutch driven disc stud.
E. Driven disc.
(4) A. Clutch driving drum.
D. Clutch driving teeth.
E. Driving disc.
(5) A. Clutch driving drum.
B. Driving groove.
E. Driving disc.
H. Cork insert.
(6) A. Clutch driving drum.
B. Driving key.
E. Driving disc.
F. Asbestos facing.
G. Copper rivets.

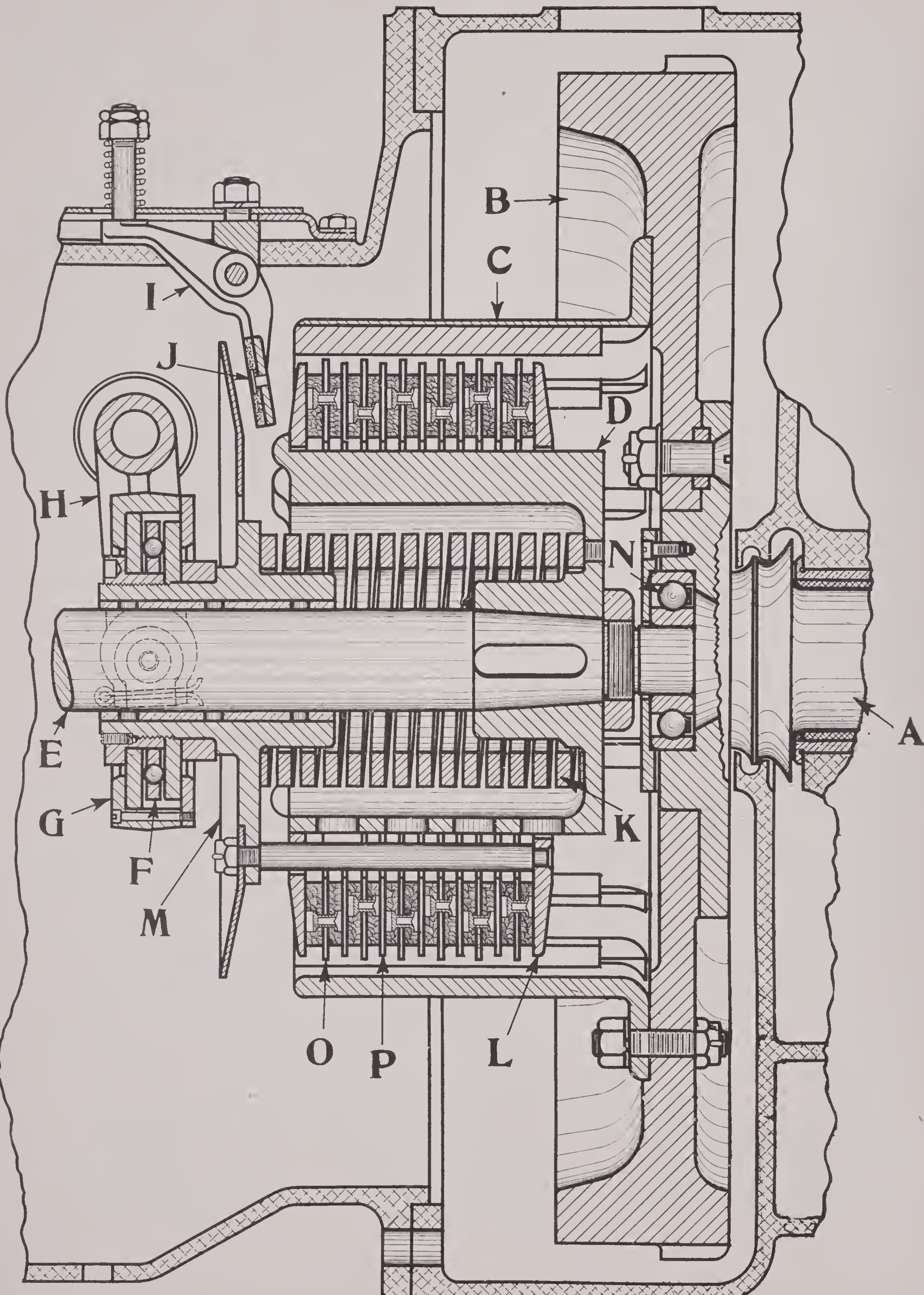


FIG. 107

FIG. 107

DRY DISC CLUTCH—SINGLE SPRING

A. Crankshaft.
B. Flywheel.
C. Driving drum.
D. Driven drum.
E. Clutch shaft.
F. Ball thrust bearing.
G. Clutch release collar.
H. Clutch release fork.
I. Clutch brake lever.
J. Clutch brake facing.
K. Clutch spring.
L. Pressure plate.
M. Clutch release hub plate.
N. Clutch shaft bearing.
O. Driving discs.
P. Driven discs.

In this clutch the release fork (H) moves forward and with it (M) and (L), thereby disengaging the discs from the power. To move the clutch pedal and release fork forward, necessitates a double lever and connecting link action. As the release fork (H) is moved forward, the hub plate (M) engages with the flexible clutch brake, reducing the speed of the transmission countershaft and allowing the gears to slide into mesh more easily.

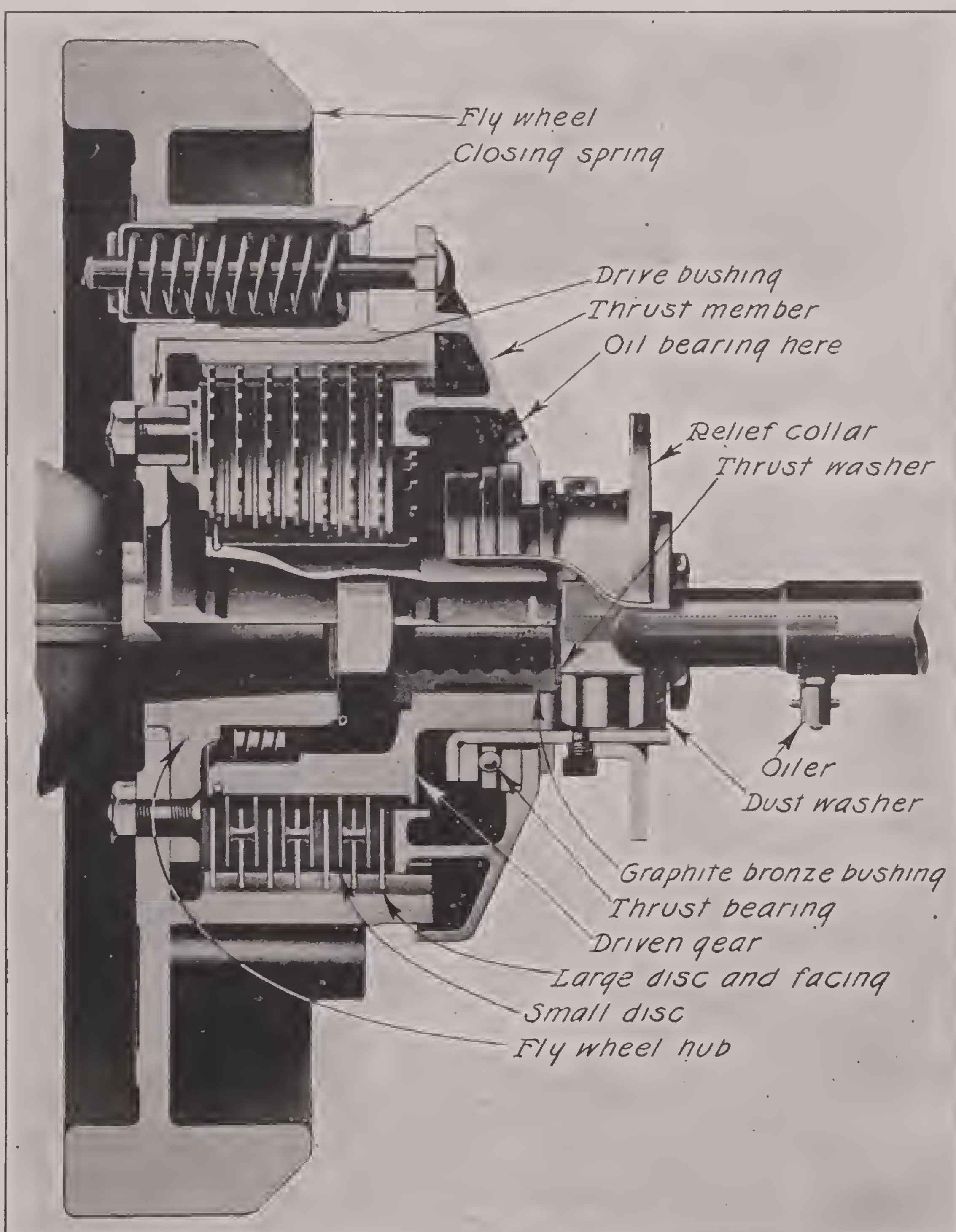
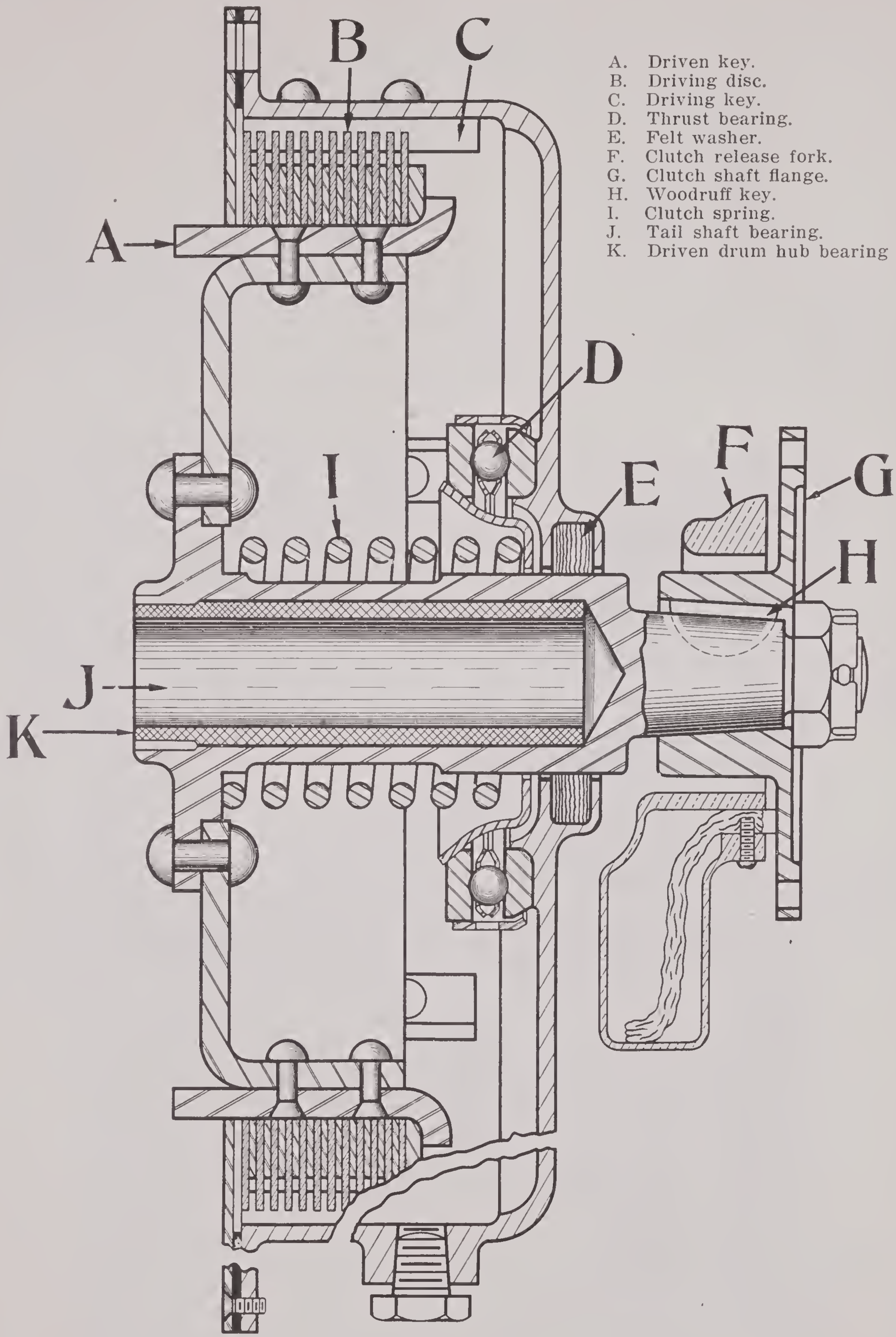


FIG. 108

DRY DISC CLUTCH, MULTIPLE SPRING



A. Driven key.
B. Driving disc.
C. Driving key.
D. Thrust bearing.
E. Felt washer.
F. Clutch release fork.
G. Clutch shaft flange.
H. Woodruff key.
I. Clutch spring.
J. Tail shaft bearing.
K. Driven drum hub bearing bushing.

FIG. 109

LUBRICATED DISC CLUTCH—SINGLE SPRING

OPERATION

As the clutch pedal is pressed forward, the fork (F) moves the flange (G) and shaft back, and with it (A), thereby disengaging the discs. As the clutch pedal comes back, the spring (I) will press the discs together again.

in contact with the brake, thus retarding its motion. The conditions existing when starting the car give the best demonstration of the necessity for the brake. The gear driven by the clutch shaft may possibly be revolving 200 R. P. M. when the clutch is disengaged, while the transmission gears are not in motion at all.

CLUTCH OPERATION

Cone type clutch—To disengage the clutch, a clutch release fork or shifting yoke is provided, which is mounted around the driven member and operated by the clutch pedal. Pushing the clutch pedal forward forces the driven clutch member backward, since the clutch pedal fulcrum is above the release fork. The clutch normally stands engaged. With few exceptions there is no provision made to lock or hold the clutch disengaged when the driver removes his foot from the clutch pedal. The clutch spring will engage the clutch when the pedal is released.

When engaging the clutch, the clutch spring is allowed to force the driving and driven members in contact with each other.

Suppose the transmission gears are in neutral; pressing the clutch pedal forward moves the driven member back out of contact with the driving member.

After the transmission gears are engaged, the clutch must be engaged to transmit the power from the engine to the rear wheels. When the clutch is disengaged, the small insert springs force the clutch facing away from the cone, so that as the clutch pedal is allowed to move back slowly, only a small surface of the clutch engages with the flywheel. The clutch facing at the points where the insert springs are mounted is the first to come in contact with the flywheel. The friction between the two members causes the driven member and the rear wheels to start revolving slowly.

As soon as the car is in motion, the clutch pedal should be allowed to move all the way back, which allows the full pressure of the clutch spring to overcome the pressure of the

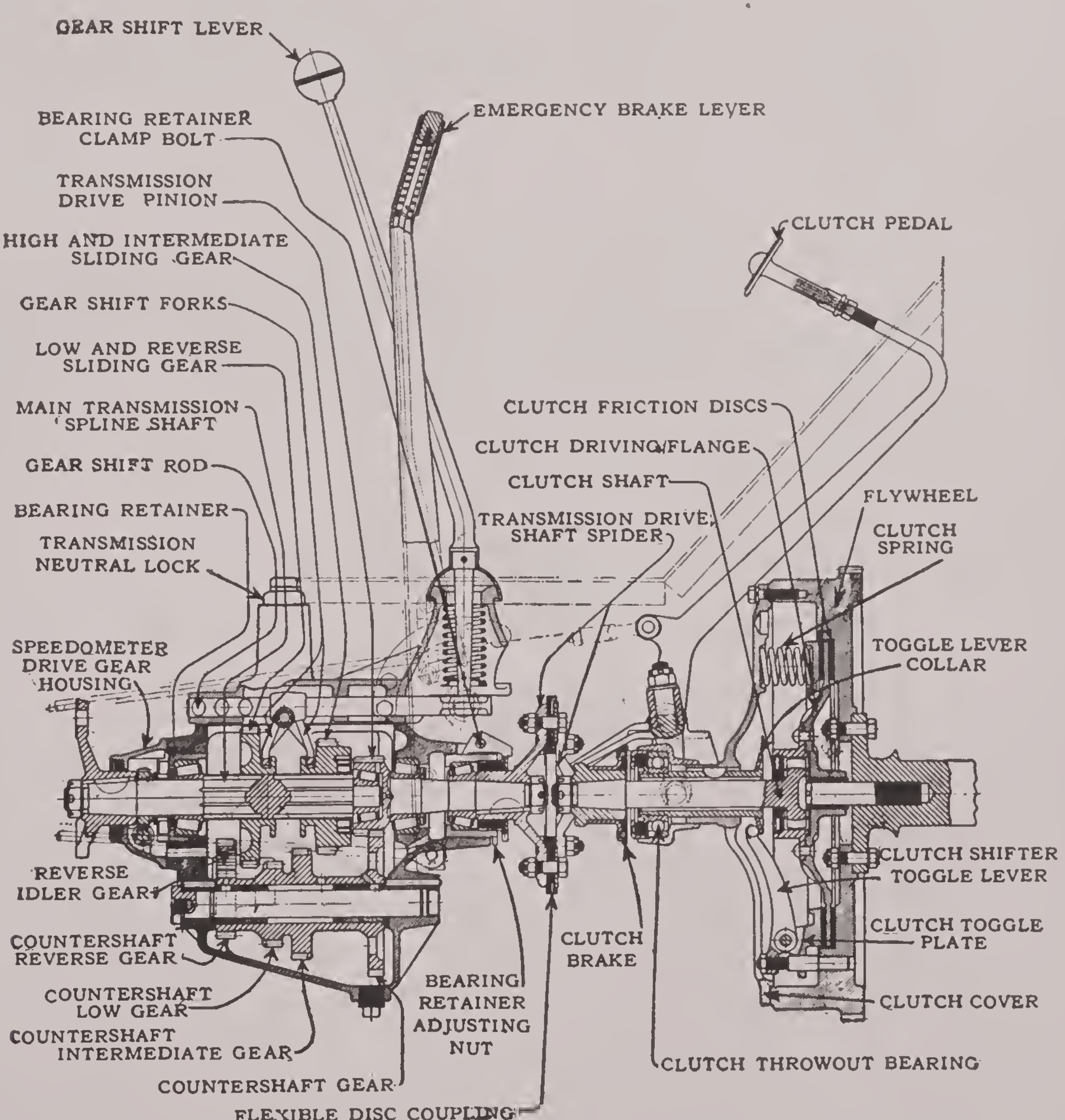


FIG. 110

DRY PLATE CLUTCH AND TRANSMISSION

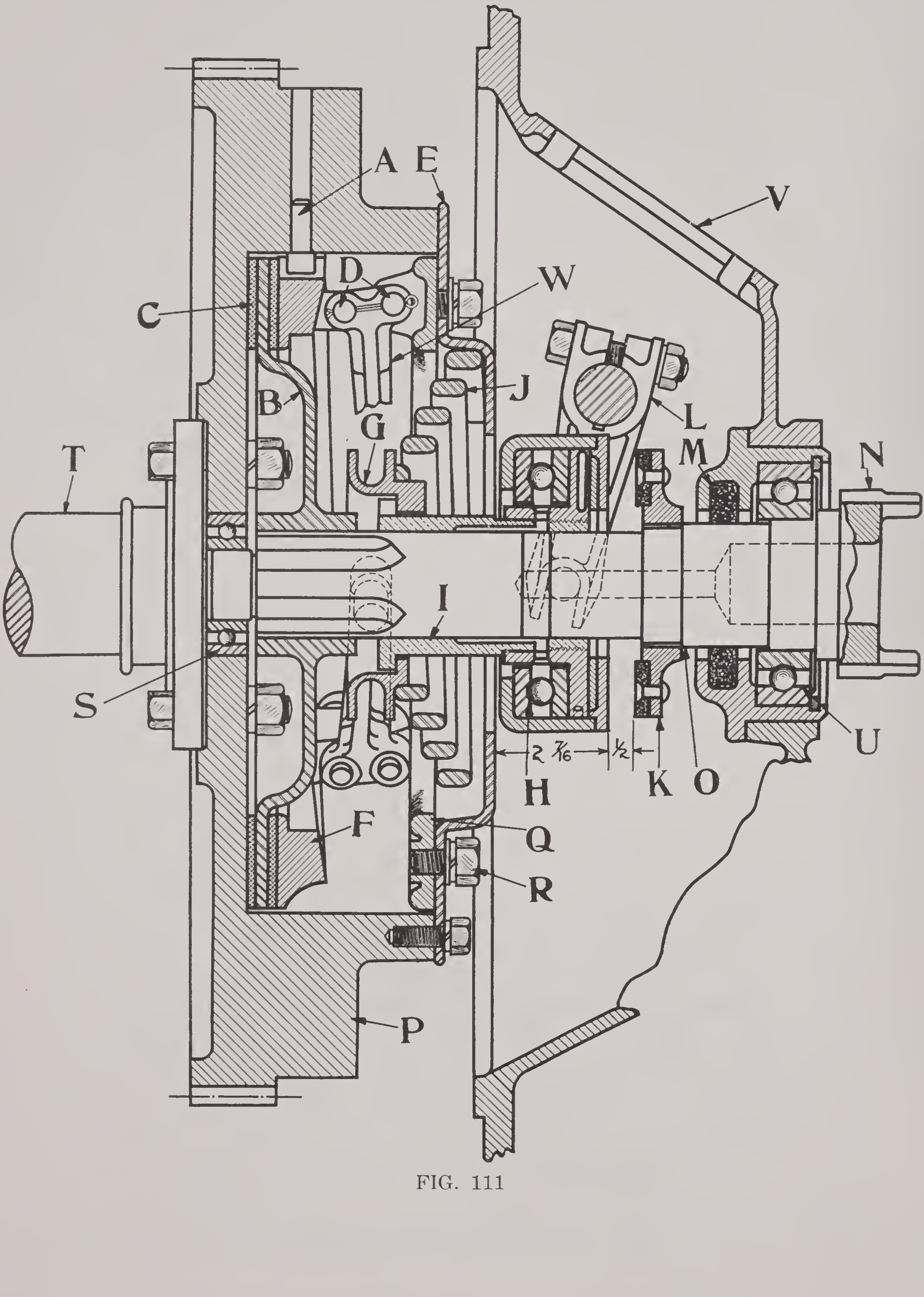


FIG. 111

FIG. 111

BORG & BECK DRY PLATE CLUTCH SINGLE SPRING

A. Clutch drive pin.
B. Clutch driven plate.
C. Clutch Raybestos disc.
D. Clutch bell crank pins.
E. Clutch cover.
F. Clutch thrust ring, or driving plate.
G. Clutch thrust collar.
H. Clutch release bearing.
I. Clutch release sleeve.
J. Clutch spring.
K. Clutch brake.
L. Clutch release fork.
M. Felt washer.
N. Clutch gear.
O. Clutch shaft.
P. Flywheel.
Q. Clutch adjusting ring.
R. Clutch adjusting screws (or slot bolts).
S. Clutch shaft ball bearing.
T. Crankshaft.
U. Clutch shaft bearing.
V. Inspection plate opening.
W. Clutch bell crank, or pressure levers.

To adjust the clutch; first disengage it, remove the inspection plate (V) and loosen the slot bolts (R). In the position shown, one slot bolt can be loosened. Then by turning the flywheel one-half a revolution, the other slot bolt (R) will be on top and can be loosened. The next step is to move the slot bolts (R) clockwise about one-half an inch.

Engage the clutch, and if the distance between the clutch cover and the face of the clutch release bearing retainer face is less than $2\frac{7}{16}''$, again disengage the clutch and tap the slot bolts back counter clockwise until this space is $2\frac{7}{16}''$. This adjustment also adjusts the foot pedal, and when the clutch slips it is usually due to the clutch pedal striking against the under side of the floor board.

When adjusting the clutch, see that at least ½″ clearance is left between the pedal and foot board for clearance. If the pedal hangs on the under side of the foot board, use the clutch adjustment only for obtaining the necessary clearance, as the single clutch adjustment automatically adjusts the pedal. When the clutch is adjusted, the clutch pedal automatically moves forward, allowing the necessary clearance.

The above adjustment can be followed when adjusting a new clutch, but does not always hold true on a clutch after it becomes worn. On the average car equipped with a Borg & Beck clutch, when the clutch slips, first examine the clutch pedal to see if it strikes the floor board when the foot is removed. If so, adjust the pedal to prevent this, without changing the clutch adjustment. If the pedal is clear of the floor board when the clutch is engaged, slippage may be caused by excessive oil on the facings or asbestos discs; but the more common cause is worn facings. To remedy this, remove the inspection plate, loosen the two slot bolts, and tap the bolts clockwise about ¼ to ½ an inch. Then tighten the slot bolts. Do not adjust the clutch too tight. If the distance between the clutch release bearing surface and the clutch brake is less than ½″, the clutch may drag due to only a partial disengagement. This may sometimes be remedied by adjusting the clutch brake. The clutch pedal should move about one-half its full forward travel before the clutch brake is applied.

If the clutch has been adjusted until the adjusting screws rest against the end of the cover slot, screw them out of their mounting holes and into the repeat holes exposed near the first end of the slot. This doubles the range of adjustment. When it is impossible to get further adjustment through the adjusting screws, new friction rings will have to be installed. To do this, the clutch must be taken apart. First, disengage the clutch and place a block of wood between the clutch release bearing housing and the cover (E). This holds the spring compressed. Remove the clutch cover by taking out the cover screws which hold the cover onto the flywheel. Place a punch mark on the flywheel and the cover plate in order that they can be correctly assembled. Then remove the transmission and clutch shaft (O), spring (J), cover (E) and units attached (H), (I), (G), (D), and (W).

Pull out the clutch thrust ring (F), then from the outside of the flywheel remove two of the drive pins (A) with a punch. This allows the removal of the clutch driven disc (B) and the inner and outer asbestos discs (C). After replacing new Raybestos discs, assemble in the reverse order from which it was disassembled. Before assembling the clutch, examine the bearing (S) for wear, clean this bearing out well and pack with cup grease.

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small insert springs and forces the entire surface of the facing against the cone.

After the clutch is fully engaged, there should be no slippage. Slippage in this case means that the flywheel turns faster than the driven member. The amount of spring pressure required for any clutch should be sufficient to hold the driven and driving members together tightly enough to prevent slippage when the clutch is engaged. If the clutch is not allowed to slip when it is being engaged, however, there would be an excessive strain placed on all the parts in the driving mechanism.

The flexibility of the cone clutch depends upon the spring inserts and clutch facing, which takes care of the friction and slippage necessary for a smooth engagement.

Disc Clutch—The action of the disc clutch involves the same principles as explained above. In the dry type, the friction facing gives flexibility and takes care of the friction from the slippage when engaging, the same as the leather facing on the cone type.

In the lubricated type, the oil between the driven and driving members prevents metal from coming in contact with metal, thereby reducing the friction. As the clutch is engaged slowly, the power is applied from one disc to the other through the oil, instead of through a facing, as in the cone and dry disc types.

The oil creates a drag with a certain amount of slippage, depending entirely upon how close the discs are together.

The driven end of the clutch shaft which connects the clutch and the transmission is usually squared or splined. (A shaft that is splined has numerous keys on the outside of it, the metal between the keys being removed, instead of cutting the keyways in the shafts and inserting the keys, thus making a solid and strong construction). The purpose of this splined shaft is to allow for end movement of the driven member of the clutch and at the same time drive it.

Troubles and Repairs

Clutch troubles may be classified under the following headings:

Slipping.
Grabbing.
Spinning.
Dragging.
Stuttering.

Cone Type

If the clutch slips after it is engaged the facing will soon become worn from the excessive friction and high temperature.

The cause of a **slipping** clutch may be:

(1) Clutch spring tension weak.
(2) Burned or worn clutch facing.
(3) Warped cone.
(4) Clutch facing oily or greasy.
(5) Clutch shaft out of line.
(6) Clutch release mechanism out of adjustment.

Remedies for slipping clutch:

(1) To remedy weak tension of clutch spring, tighten the clutch spring adjusting nut. If no adjusting nut is provided, either the spring will have to be replaced or shims or washers inserted behind the spring. As a temporary remedy, wooden wedges may be driven in under the clutch facing. These should be removed as soon as possible for the facing will wear excessively at the high points.

(2) To remedy a burned or worn clutch facing it will be necessary to replace the facing.

(3) A warped cone must be removed and replaced by new one.

(4) Oily and greasy clutch facing may be remedied by washing the surface with kerosene oil. A temporary remedy is to apply "Fuller's Earth" or some form of talc to dry and absorb the oil. This should only be used in an emergency for if allowed to remain, it will cause the facing to become dry and then crack.

(5) The breaking of a ball in the thrust bearing or tail shaft bearing may cause the clutch shaft to get out of a line. The remedy for this is replacement of bearing.

(6) If anything interferes with the full movement of the clutch release yoke, clutch pedal or any of the parts of the clutch release mechanism, it may prevent the clutch from fully engaging. Check up on all these parts and see that they are free to move the required amount.

The cause of a **grabbing** clutch may be:

(1) Too sudden engagement.
(2) Clutch facing rivets projecting.
(3) Clutch facing dry and hard.
(4) Clutch facing spring improperly adjusted.
(5) Excessive tension on clutch spring.

Remedies for grabbing clutch:

(1) Too sudden engagement is caused by the operator letting clutch in too quickly. Use care release clutch pedal slowly and gradually.

(2) If the clutch facing is badly worn the rivet heads may project above the surface of the facing and cause the clutch to grab when engaging. The rivets must be countersunk deeper and hammered down. The metal to metal contact first causes the grabbing then after the clutch is engaged may cause it to slip.

(3) When the clutch facing becomes dry, hard and glazed it is not flexible, and causes the clutch to grab. To remedy this, clean the glazed surface with emery cloth and apply as much Neatsfoot oil as the leather will absorb. This softens the leather and makes it flexible, restoring the life and texture of the material.

(4) If the clutch facing springs are not adjusted to force the facing away from the cone, the clutch will grab. The remedy is adjusting the springs. This trouble may be particularly noticeable after a new facing has been put on if the adjustment of these springs has been neglected.

(5) Excessive tension on the clutch spring may make it impossible to obtain a smooth gradual engagement of the clutch. Remedy for this is to weaken the spring tension.

A spinning clutch is one in which the driven member of the clutch continues to revolve for some time after the clutch is disengaged. This makes it very difficult to shift the transmission gears. A spinning clutch is due to the clutch brake being worn or out of adjustment. To remedy this, adjust or reface the clutch brake

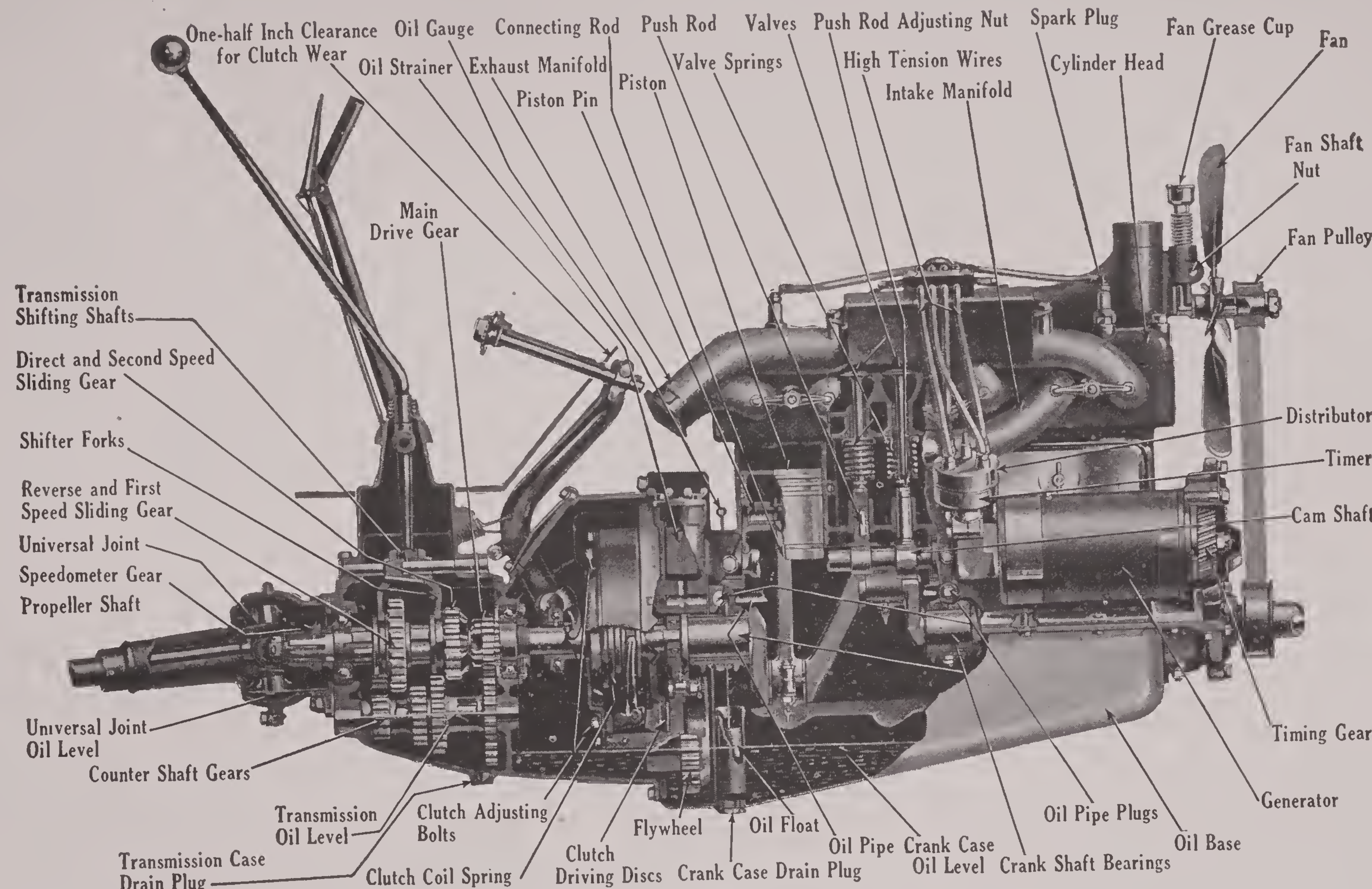

FIG. 112·

ENGINE, CLUTCH AND TRANSMISSION ASSEMBLY

In this construction the oil that lubricates the engine also lubricates the clutch, transmission and the universal joint.

with fiber or asbestos so that the driven member of the clutch makes contact with the brake when the clutch pedal moves about one-half its travel forward.

A dragging or sticking clutch is one in which the driven member continues to revolve even after the clutch pedal is pressed forward as far as it can move. The clutch will not be properly disengaged even though the driven member is not in contact with the driving member. This may be caused by the bushing that is pressed into the cone or driven member fitting too tightly on the tail shaft. This is noticeable quite often on new cars, and will usually take care of itself after a certain length of time. If not, it can be remedied by removing the cone member and reaming the bushing to a running fit with an expansion reamer.

It may be caused by improper lubrication of the tail shaft, or if the tail shaft should become bent or sprung out of alignment, it will cause the cone to stick and drag on this shaft.

A stuttering clutch is one in which the clutch chatters and vibrates excessively. It may be caused by the flywheel being out of alignment, or the bushing that is pressed into the cone becoming worn, which will cause the cone to have play on the tail shaft. This can be remedied by replacing with a new bushing. Lack of lubrication or lost motion at the clutch release sleeve or clutch release fork also causes a stuttering clutch. This is remedied by lubrication and adjustment.

Lubricated Disc Type

This type of clutch has no exposed rivets, worn or dry facings, etc., and thus the majority of the common troubles are prevented. If the oil is too heavy, it may prevent the discs from making proper contact, causing clutch to slip. Remedy for this is to remove the oil, clean clutch with kerosene and refill with grade of oil as recommended by car manufacturer or if clutch is contained in a separate housing lubricant may be thinned by adding a small amount of kerosene. If clutch is lubricated from the engine oil supply, such change or thinning of oil is not possible; but grade of oil used in engine will seldom be heavy enough to give this trouble. NEVER add kerosene or a lighter oil to the clutch lubricant if it is supplied from the engine oil reservoir. The secret of efficient lubricated clutch operation is to use the correct oil recommended by the manufacturer of the automobile upon which the clutch is installed.

Dry Disc Type

Troubles of this type of clutch are practically the same as cone clutch troubles.

Dragging clutch may be caused by the driven member fitting too tightly on the tail shaft.

Spinning clutch may be caused by a faulty clutch brake, although this is a trouble seldom found in a disc clutch.

Grabbing clutch may be caused by exposed rivets, sudden engagement, worn facings or glazed and hardened facings.

Slipping clutch may be caused by oil on the surface of the facing. Remove the oil by cleaning with kerosene. Insufficient spring tension can be remedied by tightening the adjusting nut.

Stuttering clutch is caused by play of the driven member on the tail shaft, or by the discs becoming loose in their mounting. This can be remedied by replacing with new parts.

The correct sized facings for a disc clutch or cone clutch may be obtained from the manufacturers. Always make sure that the rivet heads are below the surface of the facing.

TRANSMISSIONS

It is the purpose of the transmission to provide means for varying the ratio between the speed of the engine and the speed of the car. Knowing that the engine develops more power at the higher speeds, it is necessary to have some means of connecting the engine at this high speed when the load conditions are heavy, such as starting the car or climbing a hill. It also provides means for reversing the direction of motion of the car. .

Transmissions are made in three types; **progressive, selective** and **planetary.**

The progressive and selective types are made with three or four speeds forward and one reverse.

Bearings

The bearings used in the progressive and selective type transmissions may be either the plain roller bearing, the tapered roller bearing, or the annular ball bearing of either the single or double row construction. Some transmissions are equipped with plain bronze or babbitt bearings.

Progressive Type

In the progressive type of transmission as shown in Fig. 113, the clutch shaft fits in a bearing mounted in the transmission housing. On the end of the clutch shaft, inside the transmission housing, is fastened the clutch gear, and meshing with this gear is another gear usually of larger diameter, called the countershaft drive gear, since it is mounted on a countershaft placed at one side of or below the clutch shaft. These two gears are called the constant mesh gears, being engaged at all times and providing a positive continuous drive for the countershaft. The countershaft runs in bearings mounted in the transmission housing and has three other gears rigidly mounted upon it, either keyed or shrunk on, or machined integral with the shaft. They are called the intermediate or second speed gear, the low speed gear and reverse gear.

The main shaft or transmission shaft runs in a bronze, roller, or circular ball bearing in the end of the clutch shaft and another in the opposite end of the transmission housing. On this shaft which is squared or splined, are two sliding gears, fastened together. They are moved back and forth on the shaft by a shifting fork, operated from outside the housing by a shifting lever. These gears engage with the countershaft gears to obtain different speeds.

When the larger sliding gear on the transmission shaft engages with the small low speed gear on the countershaft, there are two reductions, the first through the constant mesh gears and the second through the low speed gears.

To slide these gears into mesh, it is necessary to disengage the power connection between the engine and the transmission. This is accomplished by disengaging the clutch. As both sliding members are connected together, it is necessary to have only one shifting collar, one shifting fork and one shifting bar. Re-

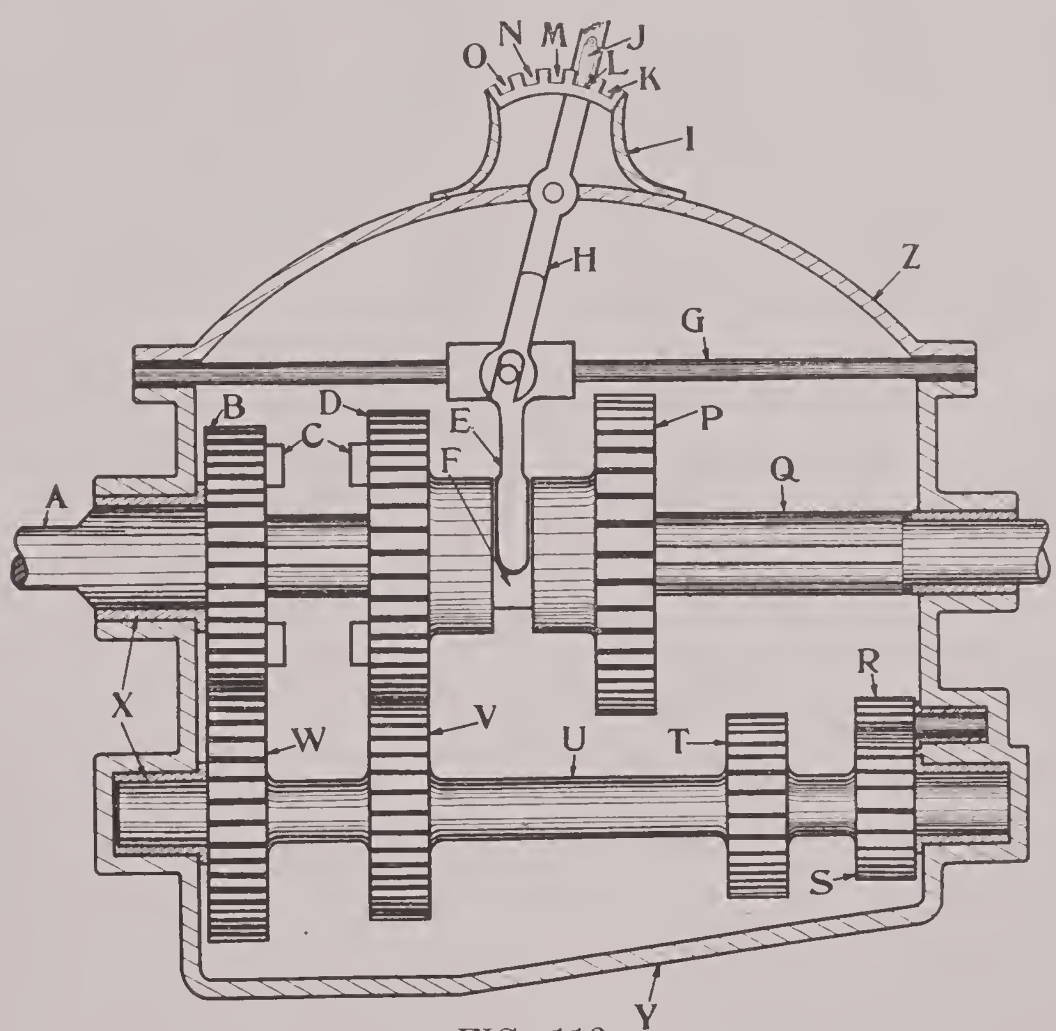

FIG. 113

PROGRESSIVE TYPE TRANSMISSION, 3-SPEED FORWARD, 1 REVERSE

A. Clutchshaft.
B. Clutch gear.
C. Third speed driving dogs.
D. Second and third speed sliding gear.
E. Shifting fork.
F. Shifting collar.
G. Gear shift bar.
H. Gear shift lever.
I. Quadrant.
J. Pawl.
K. Third speed notch.
L. Second speed notch.
M. Neutral notch.
N. First speed notch.
O. Reverse notch.
P. Low and reverse sliding gear.
Q. Transmission shaft.
R. Reverse idler gear.
S. Reverse countershaft gear.
T. Low speed countershaft gear.
U. Countershaft.
V. Second speed countershaft gear.
W. Countershaft drive gear.
X. Bearing bushings.
Y. Transmission case.

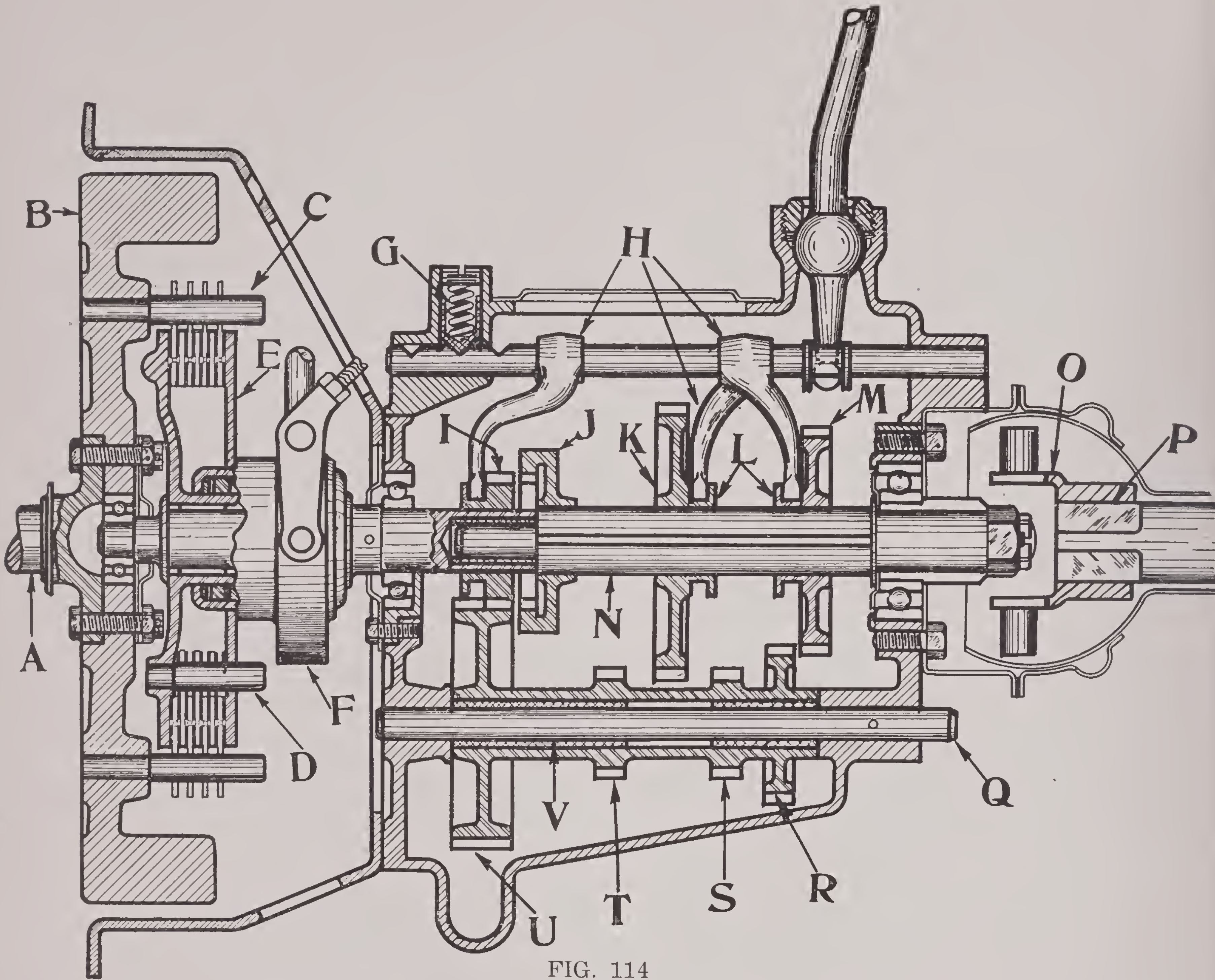

FIG. 114

SINGLE SPRING, DRY DISC CLUTCH AND SELECTIVE TRANSMISSION, THREE SPEED FORWARD, ONE REVERSE

A. Crankshaft.
B. Flywheel.
C. Driving studs.
D. Driven studs.
E. Pressure plate.
F. Clutch release fork.
G. Gear lock.
H. Shifting forks.
I. High speed sliding gear.
J. High speed internal gear.
K. Low and reverse sliding gear.
L. Shifting collars.
M. Second speed sliding gear.
N. Main shaft or transmission shaft.
O. Universal joint.
P. Slip joint.
Q. Countershaft.
R. Countershaft second speed gear.
S. Countershaft low speed gear.
T. Countershaft reverse gear.
U. Countershaft drive gear.
V. Countershaft bearings.

In this construction the transmission gears are not mounted conventionally, which results in the gear shift not being standard. That is, by moving the shifting lever forward, low and high are obtained—instead of reverse and second, as in the standard transmission. With this mounting of the gears, when the high speed sliding gear (I) is meshed with the high speed internal gear (J), the countershaft is disconnected. When driving in high speed, the power is transmitted from sliding gear (I), through (J) to shaft (N). The countershaft remains stationary. When the sliding gear (I) is moved out of mesh with (J), it engages with the countershaft drive gear (U), transmitting the power through the countershaft for the other speeds.

This construction employs three sliding gears instead of two (the usual number for a three speed forward transmission). One sliding gear (I) moves back and forth on the square clutch shaft. The other two (K) and (M) move back and forth on the splined shaft (N). The gears (I) and (M) are controlled by the same shifting bar.

verse is obtained by sliding the large sliding gear into mesh with the reverse idler. The reverse gear on the countershaft is usually smaller than the low speed gear, which allows the countershaft gear to slide in line, but not in mesh with it. By interposing an idler gear between the main transmission shaft and the countershaft, it reverses the direction of rotation of the transmission shaft.

To shift from reverse to neutral, it is necessary to pass the large sliding gear through the low speed gear, causing a grating noise, which is a disadvantage of this type of transmission.

To start the car, disengage the clutch and move the gear shift lever until the low speed sliding gear meshes with the low speed counter shaft gear, then allow the clutch to gradually engage.

To shift the gears into second speed, disengage the clutch again, slide the second speed gears into mesh and then engage the clutch. The second speed sliding gear engages with the second speed countershaft gear, which is larger than the low speed countershaft gear, giving a higher speed but still a reduction to the drive.

To obtain third speed, there are dogs machined on one end of the sliding gear to engage with the dogs machined on the end of the clutch gear. This gives a direct drive through the main drive shaft without taking any driving strains through the countershaft.

Sometimes, when shifting gears, the teeth on the gears, are in such a position that they cannot slide into mesh; that is, the teeth in one gear will line up with the teeth in the other. This makes it impossible to slide the gears into mesh, until the clutch is engaged the least bit to turn the countershaft over to a new position so that the teeth can mesh properly. The teeth on these grears are generally rounded or chamfered to make shifting easier.

The gears are made of alloy steel, heat treated and hardened to reduce wear and make them tough. If the teeth are brittle, the ends will break when sliding them into mesh. This is one of the most common transmission troubles.

The bearing mountings on either end have felt washers to prevent the grease from leaking through. The transmission is partly filled with an oil, called 600-W (steam cylinder oil), or light cup grease. This heavy oil has a tendency to cling to the surfaces of the teeth better than other oils. Some oil, although just as heavy as 600-W, will not have the same tendency to cling to the gears. The correct amount of oil to put into the transmission housing is just enough for the gears to run in, never up to the center of the shaft. If the teeth of the gears are running in the oil, they will carry the oil upward, lubricating all bearings and the upper gears.

This transmission has only one sliding member and one shifting bar; therefore, the gear shift lever that is used to shift the gears will have only a backward and forward motion. The end of the transmission in which the constant meshed gears are placed, and the shifting lever connection determines whether the reverse position of the shifting lever is forward or backward. First speed will be adjacent to the reverse position, with neutral, second and third following in order.

The progressive transmission may be made in the four speed type, in which case there is one extra forward speed. If this transmission is used in a truck, the fourth speed will be engine speed, the others being reduced, thus employing a higher engine speed to get the truck under motion and to pull a heavy load. If the four speed progressive type transmission is used on a touring car or a racing car model, the fourth speed will be an increase over the engine speed, the third speed being a direct drive.

Selective Type

The construction of the selective type transmission does not differ greatly from the progressive, except that the sliding member is divided into two parts. The sliding gear with which low and reverse speeds are obtained is separate from the second and third speed sliding gear. Each sliding member has a separate shifting fork and shifting bar to which a single shifting lever connects. This changes the gear shift considerably from that which is employed on the progressive type. On the selective type gear shift the lever is shifted over to either side and then forward or backward. On one side, depending entirely upon how the gear shift bars are arranged, are low and reverse. On the other side are second and high. Reverse and second are either both backward or both forward, and first and high are opposite to these respectively.

The gear shift lever which is operated by the driver may operate in a gear shift gate, made in the form of an H which is called an "H" plate. When the "H" plate is used, the lower end of the shifting lever below the fulcrum moves in the same direction as the upper end, when sliding it sideways. To shift from one side to the other causes the shifting lever to slide along on the shaft, but for the forward and backward movement of the gear shift lever, the lower and upper ends move in opposite directions. *(Continued on Page 161)*

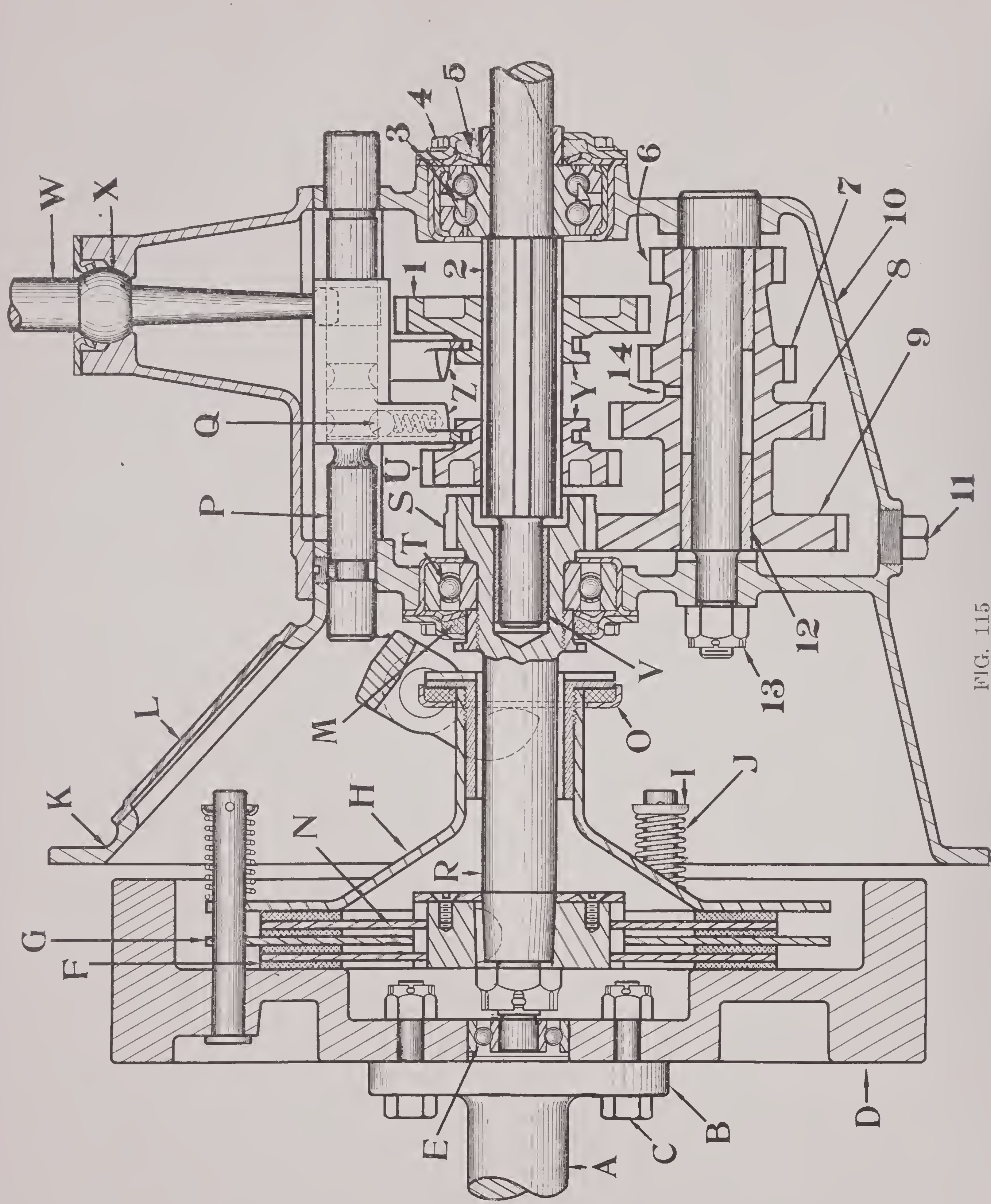

FIG. 115

FIG. 115

MULTIPLE SPRING, DRY DISC CLUTCH, SELECTIVE TRANSMISSION, 3-SPEED FORWARD AND ONE REVERSE

A. Crankshaft.
B. Flywheel flange.
C. Flywheel bolt.
D. Flywheel.
E. Clutch shaft bearing.
F. Driven disc facing.
G. Driving disc.
H. Clutch pressure plate.
I. Clutch spring retainer.
J. Clutch spring.
K. Clutch housing.
L. Inspection plate.
M. Felt washer.
N. Driven disc.
O. Clutch release collar, thrust bearing and adjusting nut.
P. Gear shifting bar.
Q. Gear lock.
R. Clutch shaft.
S. Clutch gear.
T. Clutch shaft bearing.
U. Second and high speed sliding gear.
V. Transmission shaft pilot bushing.
W. Gear shift lever.
X. Ball and socket bearing.
Y. Shifting collars.
Z. Shifting forks.
1. Low and reverse sliding gear.
2. Transmission shaft.
3. Transmission shaft rear bearing.
4. Bearing lock.
5. Felt washer.
6. Countershaft reverse gear.
7. Countershaft low-speed gear.
8. Countershaft second-speed gear.
9. Countershaft drive gear.
10. Transmission housing.
11. Drain plug.
12. Countershaft bearing bushing.
13. Countershaft nut.
14. Oil hole.

Disassembling the Clutch and Transmission

Remove the inspection plate (L) from the clutch housing, the spring retainers (I), the bolts holding the clutch housing on to the crankcase, and slide the housing away from the flywheel.

To disassemble the transmission, remove the bolts holding the shifting lever mounting on the transmission housing. Lift this assembly up, then remove the headless set screws that hold the shifting rods in the case. The shifting rods can now be removed. Remove the bolts holding the bearing retainers in the case, also remove the retainers and bearings, pull the transmission shaft out of the sliding gears and transmission case, remove the clutch gear, lift the sliding gears out of the case, then remove the cotter pin and castle nut from the countershaft, and also remove the countershaft. Now lift the countershaft gears from the housing.

The bronze bearings in the countershaft gears can be replaced with new ones and then reamed to fit the countershaft. These bearings are lubricated by the oil that passes through the oil hole (14). 600-W oil is the proper lubricant to use. Do not have the oil level above the countershaft, as the gears on the countershaft will carry the oil on to the other gears and bearings.

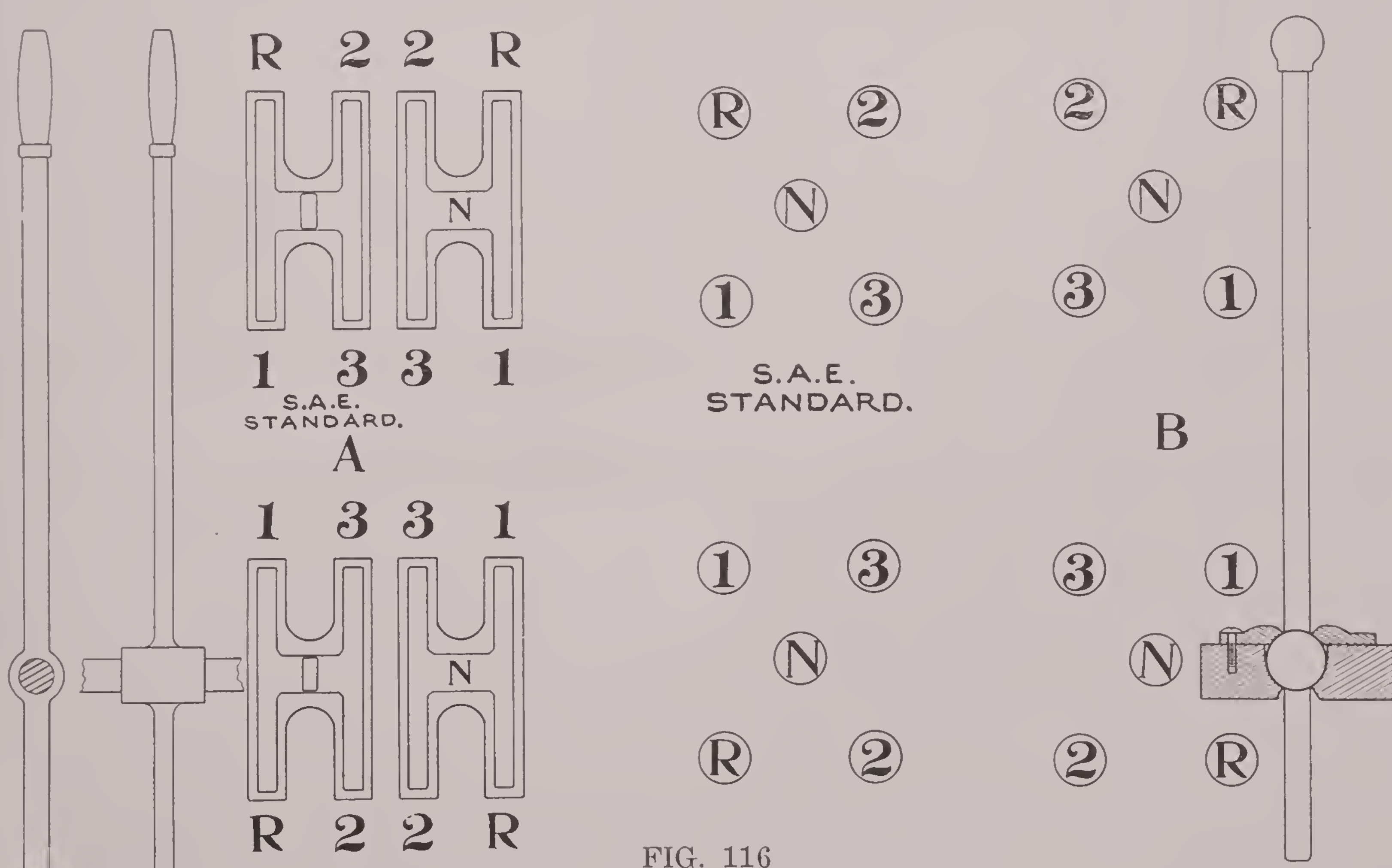

FIG. 116

POSSIBLE GEAR SHIFTS AND LEVERS

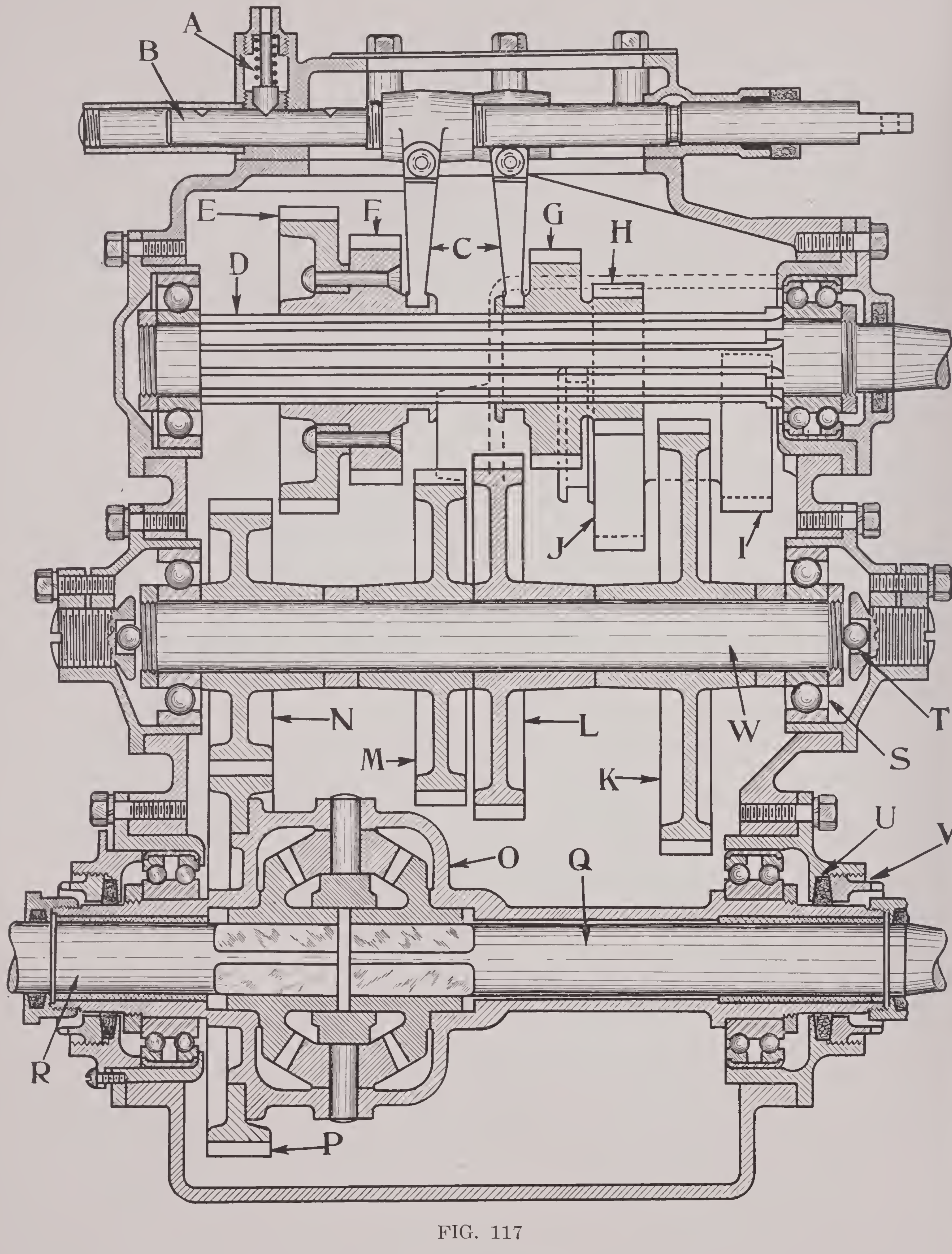

FIG. 117

FIG. 117

TRANSMISSION ASSEMBLY EMPLOYED WITH FOUR WHEEL DRIVE

A. Gear lock.
B. Shifting bars.
C. Shifting forks.
D. Transmission shaft.
E. High speed sliding gear.
F. Third speed sliding gear.
G. Second speed sliding gear.
H. Low speed sliding gear.
I. Reverse speed sliding gear.
J. Reverse speed sliding gear.
K. Countershaft low and reverse gears.
L. Countershaft second speed gear.
M. Countershaft third speed gear.
N. Countershaft high speed gear.
O. Differential case.
P. Differential drive gear.
Q. Front wheel driving shaft.
R. Rear wheel driving shaft.
S. Radial bearing.
T. Thrust bearing.
U. Felt oil retaining washer.
V. Retainer collar.
W. Countershaft.

In the types of trucks in which the power is applied to all four wheels, a special form of gear set is necessary, in which the main drive will be directed to a cross shaft, which in turn will distribute power to both front and rear axles. In the illustration on opposite page, a standard American design four speed gear set for four wheel drive is shown.

The engine power is delivered to the shaft (D). This main shaft carries two sets of sliding gear members. Engaging (H) and (K) gives low speed; (G) and (L), second speed; (F) and (M), third speed and (E) and (N), high speed. Reverse speed is obtained by meshing (J) with (G) and (I) with (K).

It will be observed that there is no direct drive on high or fourth speed, in the sense of having no gears transmitting power, as is the case in most passenger car transmissions.

The drive on the three lowest forward gears is through four gears; that on the main shaft turning the corresponding member on the countershaft in the reverse direction to engine rotation.

The high speed gear (N) imparts its power to the large spur gear (P) carried by the differential casing (O). This results in the driving shafts (R) and (Q) turning in the same direction as the crankshaft. On high speed, only three gears are used for power transmission. On reverse speed the power is transmitted through six gears.

The bearing mounting on the main drive shaft from the engine is clearly shown, as are also the method of using single row annular bearings (S) on the countershaft with special thrust members (T) and the double row mounting of the differential case (O).

It will be observed that stuffing boxes are provided on the outside of the lower shaft bearing housings. This is necessary because this shaft is mounted lower than the other two and is covered by lubricating oil, which would be apt to leak through the closure members if no means were provided for its positive retention. Note that all bearings are mounted in removable housing members instead of seating directly in the transmission case casting.

The shifting bars, which are located in the transmission housing, have recesses cut in them in which the gear shift lever engages. These bars are arranged so that when in the neutral position, the lever cannot be shifted backward and forward. On the majority of modern transmissions, a ball and socket shifting lever is employed. On this type, when the shifting lever at the top is moved sideways, the bottom moves in the opposite direction. This type of lever also necessitates a device to prevent the sliding of both shifting bars at the same time. This is known as the inter-locking device.

INTERLOCKING DEVICE AND GEAR LOCK ASSEMBLY

The purpose of the interlocking device is to prevent the shifting of two sets of gears into mesh at the same time. It consists of either a dog or ball mounted in the transmission case between the shifting bars. Besides the interlocking device mentioned above, the shifting bars are provided with "V" shaped notches, in which a small dog engages, the dog being held in place by a spring. This dog prevents the gears from sliding back and forth, for when the gears are properly meshed for any speed, or in neutral, one of the notches lines up with the dog; but when attempting to shift the gears, this notch and spring tension are not noticeable to the driver, due to the leverage of the gear shift lever. This is termed the gear lock.

The notches and dogs will wear in time, allowing the gears to come out of mesh. To remedy this, file the notches deeper and grind the dog to the proper shape. Sometimes the shifting forks and lever become sprung or out of alignment, which prevents the sliding gear from meshing properly and the locking notch in the shifting bar from lining up with the dog. This can be checked by placing the shifting lever in position and removing the adjusting nut, spring and dog of the gear lock. The trouble may be caused by a lack of spring tension which can be increased by tightening the adjusting nut.

The gear lock sometimes becomes worn, allowing the dog to turn over in the notch and perhaps locking the shifting bars so they cannot be shifted. When this occurs, file the notch in the shifting bar deeper and ream the hole larger. Tap new threads in the hole and re-

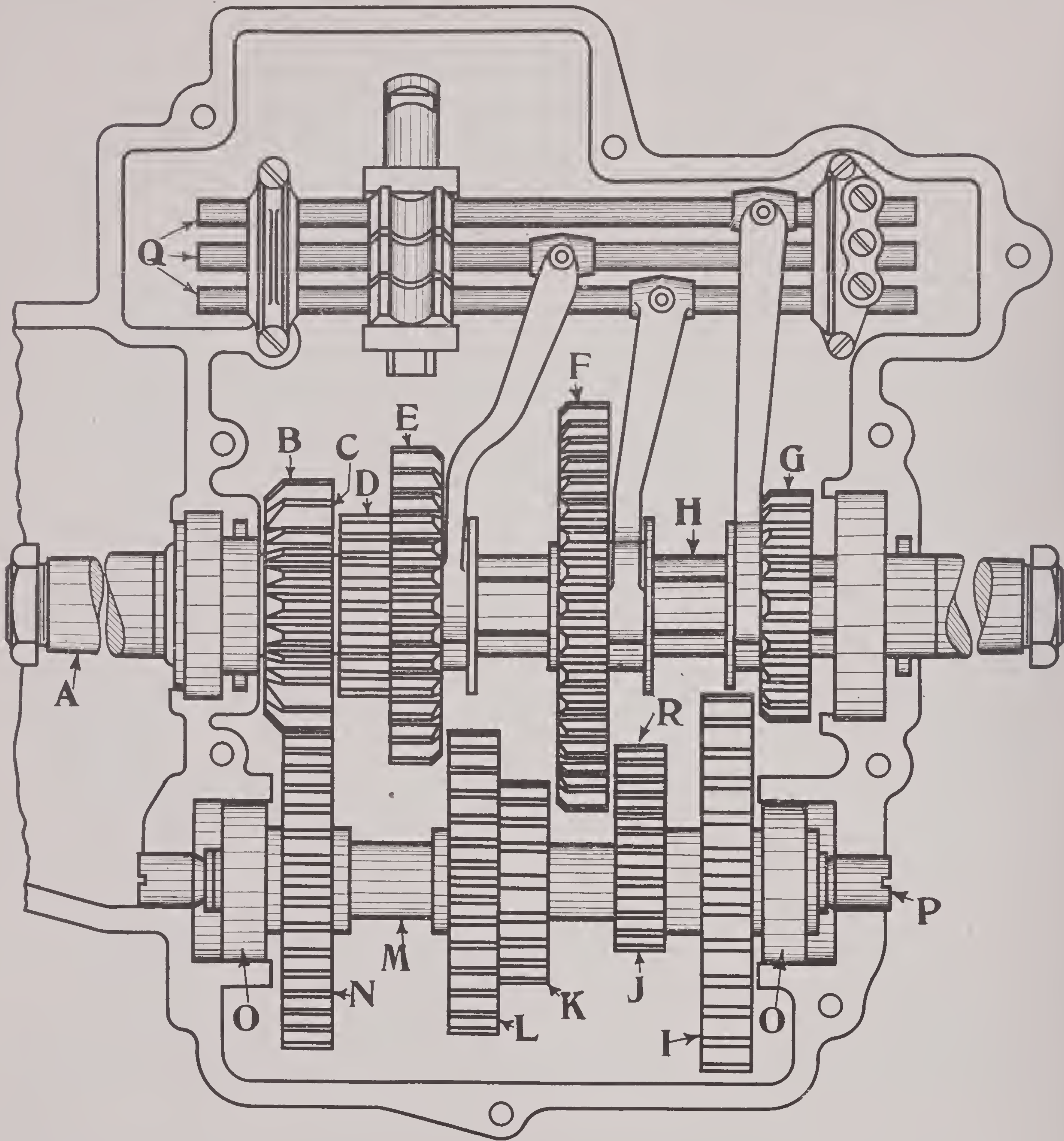

FIG. 118

SELECTIVE TRANSMISSION—FOUR SPEED FORWARD

A. Clutch shaft.
B. Clutch gear.
C. Third speed clutch gear (internal).
D. Third speed sliding gear.
E. Second speed sliding gear.
F. First and reverse sliding gear.
G. Fourth speed sliding gear.
H. Transmission shaft.
I. Fourth speed countershaft gear.
J. Reverse countershaft gear.
K. First speed countershaft gear
L. Second speed countershaft gear.
M. Countershaft.
N. Countershaft drive gear.
O. Countershaft bearing.
P. End play adjusting nut.
Q. Shifting bars.
R. Reverse idler gear.

In this construction, (D) meshed with (C) gives the third speed drive direct from clutch shaft (A) to transmission shaft (H). The sliding gear (E) meshed with (L) gives the second speed drive through the countershaft. Low speed is obtained by meshing the sliding gear (F) with (K). Reverse speed is obtained by meshing (F) with the reverse idler (R), which is always in mesh with the countershaft gear (J). Engaging the sliding gear (G) with the countershaft gear (I) gives the fourth speed drive, which steps up the speed of the mainshaft, driving it at greater than engine speed. The radial load of the shafts is taken by annular bearings. The alignment and end play adjustment of the countershaft is made through the plug (P).

place with a new oversize dog, spring and nut. The interlocking device wears very little, but should it become worn, it may be repaired by filing the notches deeper with a rat tail file and replacing with oversize balls.

On the propeller shaft end of the transmission, the shaft is either splined or squared to accommodate a universal joint which connects the propeller shaft and transmission shaft.

Planetary Type Transmission

The Ford transmission is a typical planetary type transmission. It has a low and high speed forward and one speed reverse. The flywheel and tail shaft are bolted to the end of the crankshaft. The flywheel has three pins pressed into it, which are spaced 120° apart. The triple gears are mounted and revolve on these pins. These gears are fastened together, either made solid or riveted, and have a bronze bushing pressed on the inside for a bearing. The gears mounted nearest the flywheel have twenty-seven teeth, those in the middle have thirty-three teeth, and the others have twenty-four teeth. These gears revolve as a single unit on their axes, which are the pins that are pressed into the flywheel.

There are three drums in this clutch and transmission. The drum nearest the flywheel is the reverse drum. This drum has a hub on the end of it on which is cut a gear containing thirty teeth which is in constant mesh with the twenty-four tooth gears of the triple gear set. On the interior of this reverse drum hub is a bronze bushing to accommodate the hub of the drum next to it, which is the low speed drum. The hub of the low speed drum revolves inside the hub of the reverse drum. The low speed drum has an extension that continues through the reverse drum, on which is cut another gear containing twenty-one teeth, and this gear is in constant mesh with the thirty-three tooth gears of the triple gear set. In the interior of this low speed drum there is another bronze bush-

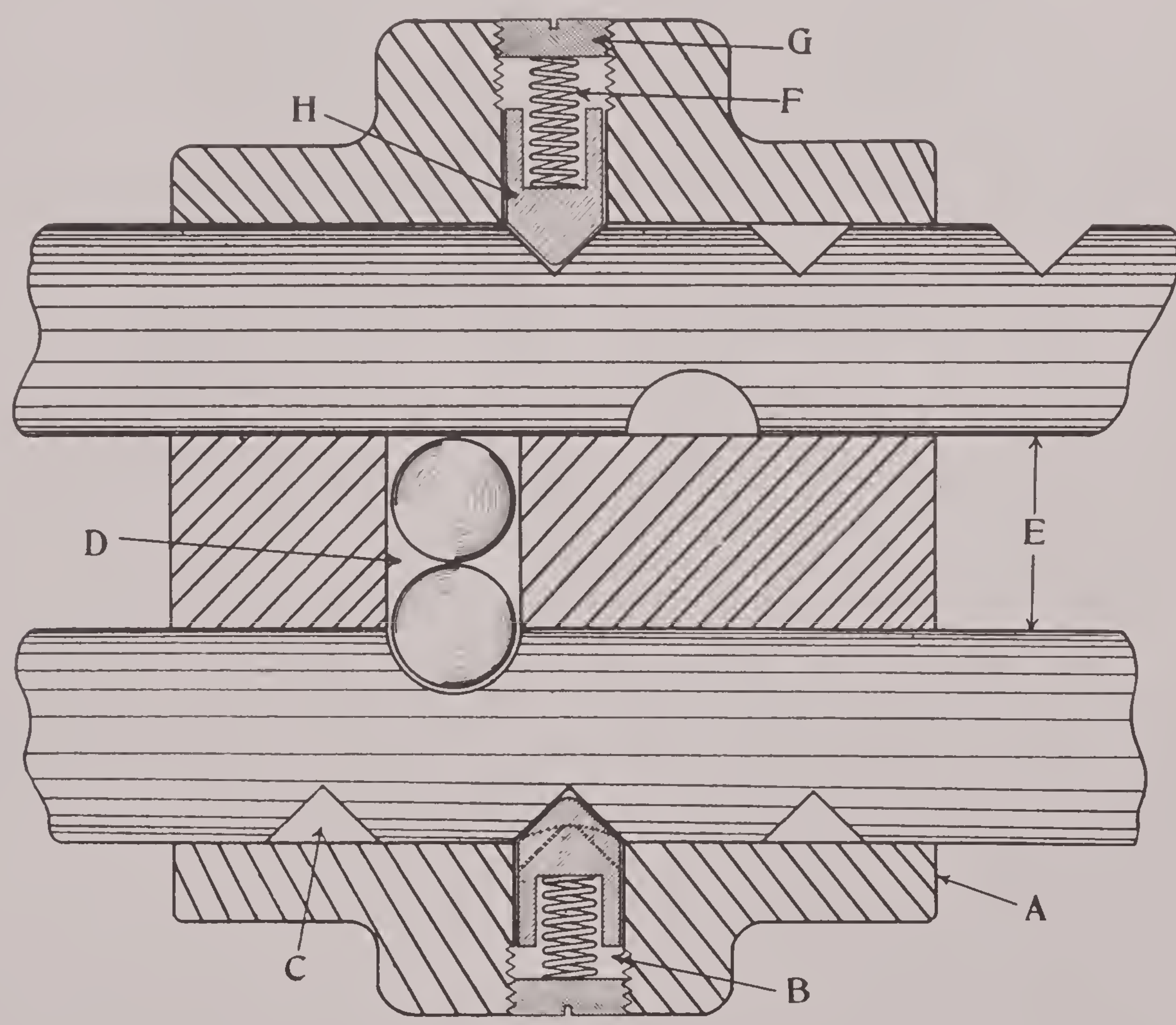

FIG. 119

GEAR LOCK AND INTERLOCKING DEVICE ASSEMBLY

A. Transmission case.
B. Gear lock.
C. Shifting bar locking notch.
D. Interlocking device.
E. Shifting bars.
F. Gear lock spring.
G. Gear lock spring nut.
H. Gear lock dog.

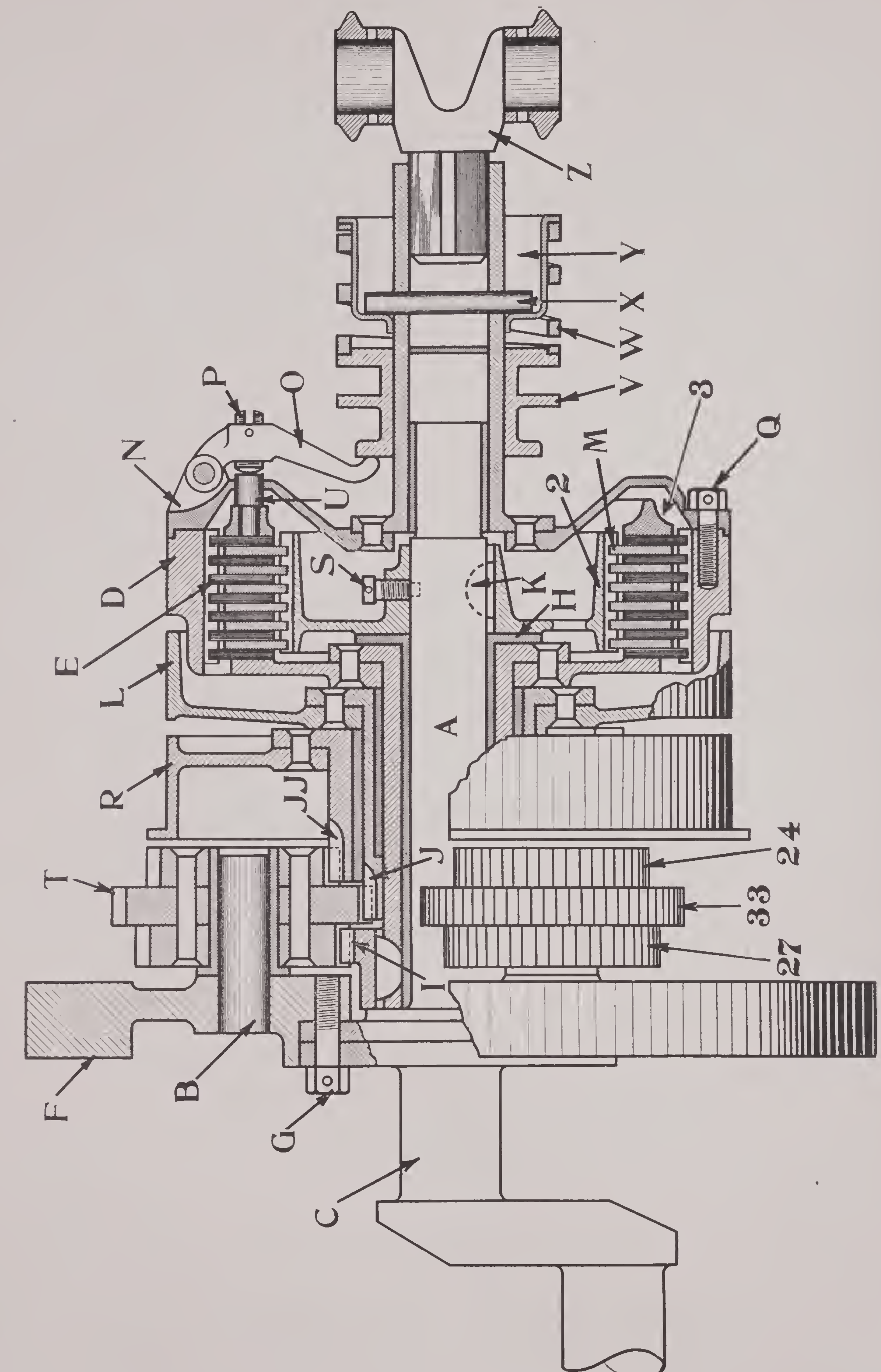

FIG. 120

FIG. 120

FORD PLANETARY TRANSMISSION

A. Transmission gear shaft or tail shaft.
B. Triple gear shaft.
C. Crankshaft.
D. Brake drum.
E. Driven disc.
F. Flywheel.
G. Flywheel bolt.
H. Driven gear sleeve bushing (end thrust bearing).
I. Driven gear (27 teeth).
J. Slow speed gear (21 teeth).
JJ. Reverse gear (30 teeth).
K. Woodruff key.
L. Slow speed drum.
M. Driving disc.
N. Driving plate.
O. Clutch finger.
P. Clutch finger adjusting screw.
Q. Driving plate screw.
R. Reverse drum.
S. Clutch disc drum set screw.
T. Triple gear.
U. Push ring pin.
V. Clutch shift.
W. Clutch spring.
X. Clutch spring thrust ring pin.
Y. Clutch spring support.
Z. Universal joint.
2. Clutch disc drum.
3. Clutch push ring.
24. 24 tooth gear.
27. 27 tooth gear.
33. 33 tooth gear.

DISASSEMBLING THE FORD TRANSMISSION AND CLUTCH

Remove the universal joint, then remove the driving plate (N) by removing the screws (Q). The set screw (S) should next be removed, after which the clutch disc drum (2) should be drawn off endwise.

Next remove the Woodruff key (K) from the transmission shaft. The transmission can now be removed from the shaft by turning it as it is being withdrawn.

To separate the drums, the driven 27-tooth gear (I) should be pressed off the brake drum hub and the keys should be removed.

Repairs

The triple gear shafts (B) can be pressed out of the flywheel. The bronze bearings in the triple gear sets are also removable, should it be necessary to replace them when worn. The bronze bearings in the low-speed, reverse and brake drums are also removable by being pressed out of the drum hubs.

It is behind the bearing flange (H) that the spacing shims are placed to remove the end play from the clutch. The bronze bearing in the driving plate hub that bears on the transmission shaft can be replaced. The new bearings, after being pressed into place, must be reamed a snug fit to fit their respective shafts. An expansion reamer should be used when reaming these bearings.

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ing in which the hub of the third drum revolves. This is the brake drum hub, on the end of which is keyed a separate gear with twenty-seven teeth which engages with the twenty-seven tooth gears of the triple gear set. The brake drum has six internal splines on which the high speed driven discs are mounted. On the end of this drum is a plate that is bolted on with six cap screws. This plate has a hub, in the rear end of which is a square hole to accommodate one end of the universal joint.

The clutch disc drum is mounted on the end of the tail shaft and revolves as a unit with it. This drum is made rigid with the tail shaft by means of a woodruff key and a set screw. The woodruff key is to prevent the drum from turning on the tail shaft, and the set screw is to prevent end play. The drum is mounted in such a position that it comes on the interior of the brake drum. The clutch disc drum has six keyways cut in the outer circumference to accommodate the driving discs, which are the small ones.

The larger discs, which are the driven discs, slip freely over the clutch disc drum. They engage with the six splines on the interior of the brake drum. The driving plate is provided with three fingers spaced 120° apart, which bear on the clutch push ring that is placed against the discs. When the fingers on the driving plate are pushed forward by the clutch spring, the discs are forced together, giving a direct drive.

For the low and reverse speeds, the drive is obtained through the triple gears, through the hub of the brake drum and the driving plate, to the universal joint and propeller shaft.

For high speed the drive is through the tail shaft which is bolted to the crankshaft, the clutch disc drum, driving and driven discs, brake drum and driving plate, to the universal joint and propeller shaft.

The three drums which are the reverse, low speed and brake respectively, have contracting bands around them. These contracting bands are provided with linings which are riveted on in a manner similar to ordinary brake linings. There are three foot pedals for this transmission and clutch. The one at the driver's left is the low and high speed clutch pedal. the center one is the reverse pedal, and the one on the right is the brake pedal. The low and reverse speeds are obtained by pushing forward on their respective foot pedals. By pushing forward on the foot pedals, the bands are contracted around the drums, thus holding them stationary.

Operation

Low: Pushing forward on the low speed pedal holds the low speed drum stationary. Holding this low speed drum stationary also holds the twenty-one tooth gear on the hub of the low speed drum stationary, as it is rigid with the drum. When the flywheel revolves, it carries the triple gears around with it. This causes the thirty-three tooth gear to roll around the outside of the twenty-one tooth gear, which at this time is stationary. In one revolution of the flywheel, the thirty-three tooth gear will not make one complete revolution on its own axis, (which is the pin pressed into the flywheel), but makes only 21/33 of a revolution. The three triple gears also turn 21/33 of a revolution, as all three of them revolve as a unit. As the forward gear of this triple gear set has twenty-seven teeth and is in mesh with the twenty-seven tooth gear which is rigid with the hub of the brake or driving drum, it imparts motion to this drum. The triple gear

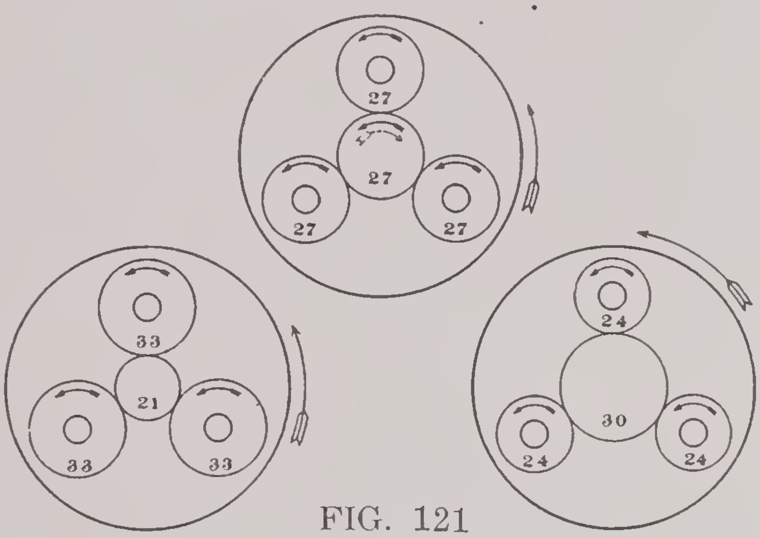


FIG. 121

(Solid arrow on 27 tooth sun gear shows direction of rotation, direct drive, forward. Dotted arrow, direction of rotation in reverse gear.)

sets roll around on the twenty-seven tooth gear, but turn less than one revolution while the flywheel is turning one complete revolution, therefore, it drags the twenty-seven tooth gear on the forward end of the brake drum ahead with it, just as much as the triple gears are losing on their axes during each revolution of the flywheel, which is 12/33 of a revolution. If the driving drum is dragged ahead 12/33 of a revolution during each revolution of the flywheel, it will require as many revolutions of the flywheel to make one revolution of the brake drum as 12 is contained in 33, which is 2¾. It requires 2¾ turns of the flywheel to drag or drive the brake drum ahead one complete revolution.

Reverse: To obtain the reverse speed, it is necessary to push forward on the center foot pedal, which causes the reverse drum to be held stationary. When this drum is held stationary, the thirty-tooth gear is also held stationary. With the flywheel revolving and the twenty-four tooth gear in mesh with the thirty-tooth gear, the triple gears turn 1¼ revolution on their own axes while the flywheel turns one revolution. This is due to the fact that while the flywheel is revolving, the twenty-four tooth gear is rolling around on the outside of the thirty tooth gear. In one revolution of the flywheel, the twenty-four tooth gear travels through thirty teeth or turns 1¼ revolutions; hence, the complete set of triple gears turns 1¼ revolutions. 1¼ revolutions of the twenty-seven tooth gear of the triple gears causes the driven gear (which is rigid with the brake drum) to be driven in the opposite or the reverse direction ¼ of a revolution while the flywheel revolves once. Therefore, in reverse it requires as many revolutions of the flywheel to turn the brake drum one revolution as 6 is contained in 24, or 4 revolutions of the flywheel to one revolution of the brake drum.

Adjustments

The adjustments for the reverse and low speeds are made on the bands, while the adjustments for high speed are made by means of the three fingers which press against the push ring. The pressure of the spring against all three fingers should be the same. The small screws in the fingers are the adjusters. When the low speed band is contracted, the clutch shifting collar is moved backward. There are two adjustments in this connection. One is the connecting link at the lower end of the pedal. This adjustment is to change the position of the low speed or clutch pedal. The other is the screw which rides on the hand brake lever cam, which serves to disengage the clutch when the brake lever is pulled halfway or all the way back.

There are three positions of the emergency brake lever. When this brake lever is in its extreme forward position and the foot pedal is all the way back, it allows the clutch spring to engage the discs for high speed. With the hand brake lever half way back the low speed may be engaged but not high speed, due to the fact that on pulling the brake lever backward, it moves the cam back, thus disengaging the clutch. If the hand lever is drawn all the way back, the high speed clutch is held in neutral, and at the same time the emergency brake is engaged. The low speed band can still be contracted, but the engine will be stalled, because the emergency brake is engaged and the high speed clutch disengaged. The radial and thrust bearings employed in this transmission are constructed of bronze and are not adjustable.

Repairs

When excessive wear is evidenced by lost motion, the transmission should be disassembled and the worn bushings pressed out. The new bushings, after they are pressed in, should be reamed to an easy rolling fit, always remembering that a certain amount of clearance must be allowed for a film of oil. These bearings are provided with spiral oil grooves, so that the revolving of the drums causes the oil to be distributed to the bearing surfaces.

The bushing on the interior of the brake drum hub has a shoulder on the outside which revolves with the brake drum. This shoulder is the end thrust bearing. When the shoulder wears, it allows the brake drum hub to slip back and forth on the tail shaft between the flywheel and the clutch drum. To remedy this (if the bushing is not worn more than one-third), cut the oil grooves deeper and place shims between the shoulder and brake drum. If the shoulder is worn more than one-third, replace it with a new bushing. This replacement is to overcome end play.

Care must be taken that the bands and linings are in good condition. If the rivets are exposed or the linings worn, it may result in scoring and roughening the surface of the drums. After the drums are scored, it is impossible to prevent excessive wear of the linings.

The brake band contracting around the exterior of the brake drum stops the car, because the driving plate which is bolted to the brake drum connects with the universal joint and propeller shaft, which in turn forms the connection with the rear axle and wheels.

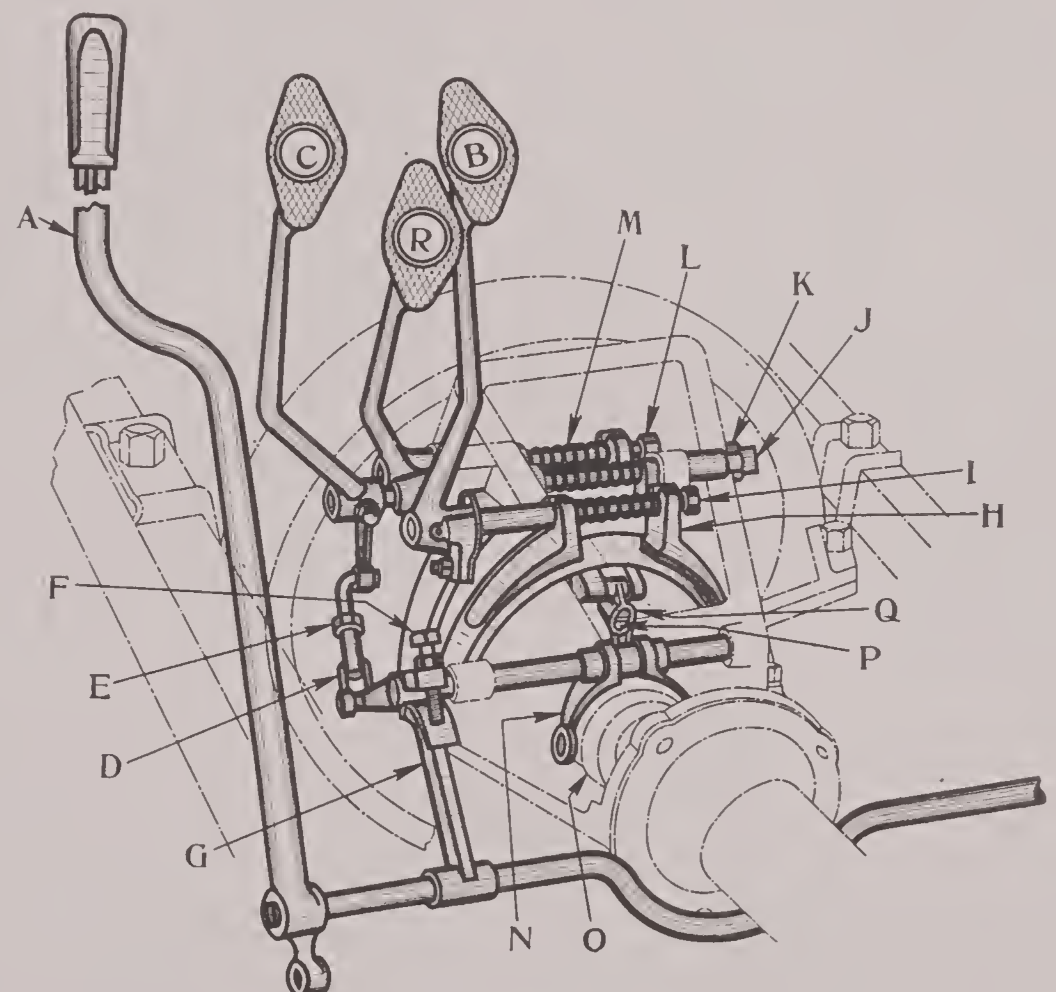


FIG. 122

CONTROLS OF THE FORD PLANETARY TRANSMISSION

A. Hand brake lever.
B. Brake foot pedal.
C. Clutch and low speed foot pedal.
D. Low speed connection clevis.
E. Clevis lock nut.
F. Clutch lever cam screw.
G. Clutch release cam.
H. Brake band.
I. Brake adjusting nut.
J. Low speed adjusting screw.
K. Lowspeed adjusting screw lock nut.
L. Reverse adjusting nut.
M. Transmission band springs.
N. Clutch release fork.
O. Clutch spring.
P. Clutch finger adjusting screw.
Q. Clutch finger.
R. Reverse foot pedal.

The low speed adjustment of the drum is made by loosening the lock nut (K) and adjusting the band with the adjusting screw (J). The reverse adjustment is the nut (L). The brake adjustment is the nut (I). The clevis (D) with the lock nut (E) is the adjustment for the position of the low speed pedal. The clutch adjustment for neutral, when the hand lever is in neutral notch, is the screw (F) and lock nut. The adjustments for the clutch, if it slips while driving in high, are the three adjusting screws (P) in the fingers.

UNIVERSAL AND SLIP JOINTS

The purpose of the universal joint is to connect two revolving shafts or rods whose axes are at different angles, and permit a change in the angle of the axes while they are turning. The universal joint, as applied to the automobile, connects the propeller shaft with the transmission and in some cases with the rear axle.

The rear axle bounds up and down in a line which is not a true radius from the point at which the universal joint connects to the transmission. This necessitates a construction which will allow for end movement of the propeller shaft in the universal joint. To compensate for the variable distance between the transmission and rear axle caused by this up and down movement of the axle, the universal joint hub and the propeller shaft connection are usually square or splined, which allows the propeller shaft to slip back and forth in the joint. This is called a slip joint.

The universal joint is constructed by using two two-pronged forks straddling a center block or spider in such a manner that the axes of the fork trunnions are at right angles to each other, thus permitting flexing in four directions.

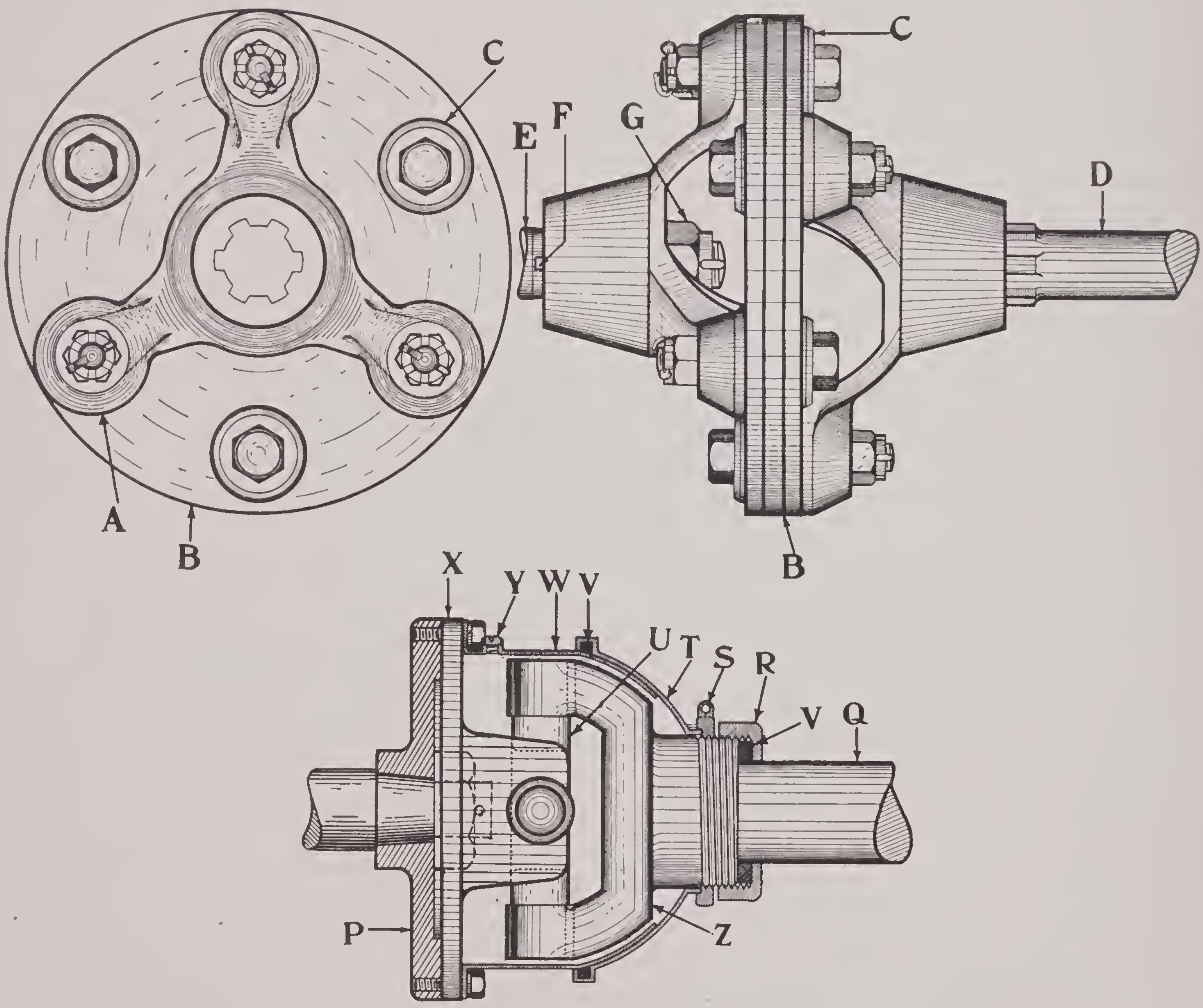


FIG. 123

FLEXIBLE COUPLING AND UNIVERSAL JOINT

No. 1

A. Spider.
B. Fabric.
C. Washers.
D. Propeller shaft.
E. Transmission shaft.
F. Key.
G. Castle nut.

No. 2

P. Transmission shaft, universal joint flange.
Q. Propeller shaft.
R. Universal joint casing nut.
S. Adjusting nut.
T. Outer casing.
U. Universal joint centre cross (or spider).
V. Packing.
W. Inner casing.
X. Universal joint flange yoke.
Y. Filling hole.
Z. Universal joint slip yoke.

Due to the peculiar action of the universal joint when turning, the driven shaft that is connected to the universal joint does not revolve at the same uniform speed but slows down and speeds up every half revolution. To overcome this, two joints are usually used.

The universal joint is generally constructed of heat treated alloy steel and is usually enclosed in a housing which prevents the dirt and grit from working into the bearings. The housing should be packed with grease for lubrication. In some cases a leather boot is provided to enclose the universal joint and to hold the grease.

FLEXIBLE COUPLINGS

The flexible coupling or joint is used for the same purpose as the universal joint, but where the angle between the transmission shaft and the propeller shaft is not so great. The flexible coupling will not move to as great an angle as the universal joint. It is usually constructed of three principal parts, which are; two, three-pronged spiders fastened to either a steel disc or a fabric disc of some tough material made especially for this purpose. The prongs of the spiders are placed 60° apart, which allows the prong of each spider to come directly between two prongs of the other spider.

The advantage of the flexible coupling over the universal joint is that it has less parts to wear, no bearings to replace, no lubrication needed and gives greater accessibility.

PROPELLER SHAFTS

The propeller shaft is employed in transmitting the power from the transmission shaft and universal joint to the pinion shaft and rear axle. The entire driving strain is transmitted through this propeller shaft, which necessitates a strong construction in which heat treated alloy steel is usually employed. The ends of the propeller shafts are generally squared or splined to allow the shaft to move back and forth in the universal joint as the axle bounds up and down.

TORQUE MEMBERS

The propeller shaft may be enclosed in a housing which is known as the torque tube. The purpose of this tube is to take the twisting strain that would come on the springs when the car is started, the clutch suddenly engaged, or a sudden acceleration of the engine. When the power is applied, the axle housing has a tendency to revolve in the opposite direction to the movement of the wheels. By fastening this torque tube to the axle housing and to a cross member at the universal joint, this torque strain is overcome but it still allows for the up and down movement of the rear axle. In some cases a torque arm is used instead of a tube. The torque arm fastens to the rear axle housing and is hinged to a cross shaft close to the universal joint. When neither torque arms nor torque tube are provided, the torque strain is taken by the rear springs in which one extra heavy leaf is assembled. This is known as the Hotchkiss drive.

THE DIFFERENTIAL ASSEMBLY

The purpose of the differential is to allow one rear wheel to turn independent of, or faster than the other, which is necessary when making a turn. By studying the action of the rear wheels when the car is turning a corner, it is noted that the outside wheel travels a greater distance and at a greater speed than the inside wheel. In order to obtain maximum efficiency, it is necessary to drive both wheels, therefore, a differential has to be used in the rear axle assembly to provide for the higher speed of the outside wheel and still provide a drive on both wheels.

The differential assembly is enclosed in the differential case to which the ring gear is riveted or bolted. The beveled drive pinion, which is keyed to the pinion shaft or propeller shaft, meshes with the beveled ring gear. The drive pinion is driven by the pinion shaft which is coupled to the propeller shaft either by a universal joint, or flexible coupling.

Assembled in the differential case are the differential spider, the spider gears and the side gears. This spider may have either two, three or four prongs, on which are mounted the differential pinions or spider gears. The spider is held rigidly between the two halves of the differential case and always revolves in the same direction and at the same speed as the ring gear. In mesh with the differential pinion gears are two side gears (beveled), which are sometimes called the compensating gears. The side gears are mounted on the inner ends of the two halves of the rear axle shaft. The path of power from the propeller shaft to the axle shafts is through the driving pinion and ring gear to the spider, and from the spider gears through the side or compensating gears to the axle shafts.

When driving straight ahead with the wheels turning at the same speeds, the spider gears do not turn on their axes but act as a lock between the two side gears. When making a turn, the inside wheel and side gear offer more resistance than the outside wheel and side gear; hence, the inner side gear slows down or turns slower than the ring gear. The spider revolving faster than the inner side gear, causes the spider gears to revolve on the spider, which drives the outer side gear faster than the spider and ring gear. The spider assembled in the differential case drags the spider gears ahead, and by revolving it around on the surface of the side gear that is turning slower, the other side of the spider gears are moved ahead faster than the spider and ring gear, thereby driving the outer side gear at a faster speed.

For example, consider an ordinary automobile wheel. The point of the wheel that is in contact with the road is moving ahead at a slower speed than the very top of the wheel, due to the fact that the point of the wheel that is in contact with the road is like the fulcrum of a lever. Consider this wheel as a gear with another gear in mesh with it at the top. The point of the wheel that is in contact with the road corresponds to the point on the spider gear which is in mesh with the side gear that is either standing still, or moving at a slower speed; consequently, the gear that would be in mesh with the outside of that gear would travel faster. In like manner the side gear that is connected to the wheel shaft on the outside will, while making a turn, travel faster, due to being driven ahead by the action of the differential spider and pinion.

It is necessary, if quietness of operation is desired, that the ring gear, which is fastened to this differential case, should run exactly true. The loads that come on these beveled gears are uneven and it is difficult to keep them absolutely quiet. If a gear does not run exactly true, that is, if it is tight at one point and loose at another, it will cause the gears to "howl." When riveting the ring gear on the differential case, the surfaces of both should be finished smooth and be free from dirt to insure a good contact. The rivets should be drawn up while still red hot. The advantage of having the rivets red hot is that when the steel is hot it is expanded. This causes the rivets to contract as they cool, resulting in a tighter fit.

The axle shafts are fastened into the side gears in various manners. Some are fastened

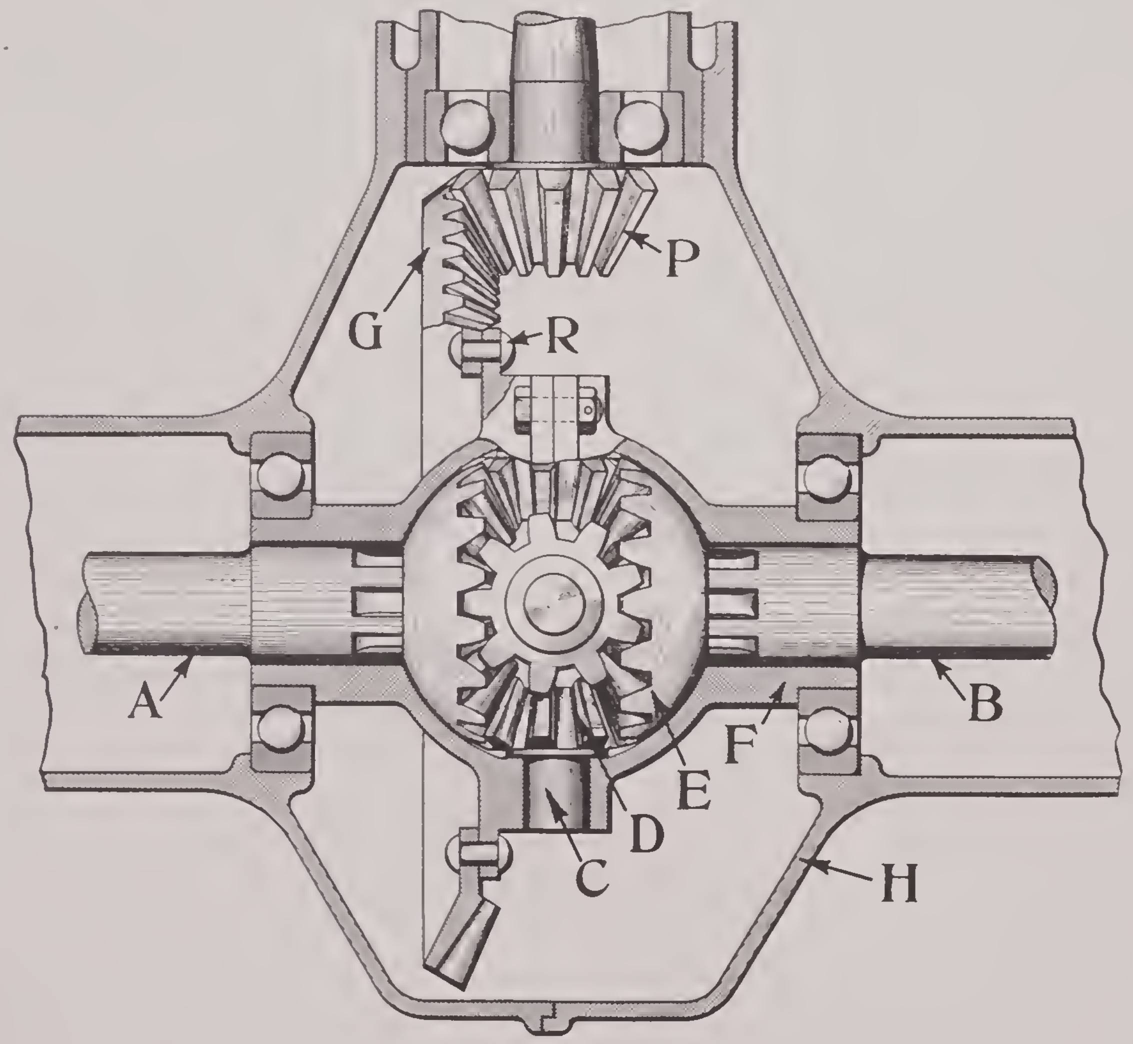


FIG. 124

DIFFERENTIAL ASSEMBLY AND MOUNTING

A. Left axle shaft.
B. Right axle shaft.
C. Differential pinion shaft.
D. Differential pinion or spider gear.
E. Side gear (or compensating gear).
F. Differential case.
G. Axle drive bevel gear (or ring gear).
H. Axle housing.
P. Axle drive bevel pinion (or pinion gear).
R. Rivet.

with a woodruff key and a horse shoe washer. The washer resting on the interior of the side gear, prevents the axle shaft from coming out. To remove the axle shaft from this essembly, it is necessary to separate the differential assembly and push the axle shaft inward, removing the horse shoe washer and then the woodruff key, which will allow the removal of the shaft.

If the hole in the side gear is tapered another method of fastening is used. A fastening nut on the interior pulls the tapered axle shaft tightly into the side gear and the drive is through a woodruff key. In some axles the hole in the gear is either square or splined, in which case the axle shaft is not fastened in the side gear, but slides freely into the gear, being held in place by a retaining nut at the end of the axle.

The type of axle housing usually determines the method of fastening the axle shafts in the gears.

In many axles, the rear wheel hub is held to the axle shaft by a nut and the driving strain is taken by a key. The wheel is fastened to a tapered portion of the axle shaft. The axle shaft being tapered, allows the wheel to be held more tightly without depending entirely upon the key. The wheel should be pulled up as tightly as possible on the tapered portion of the shaft and the nut then locked with a cotter pin. On other types the axle shaft is not fastened rigidly in the wheel, the drive being obtained through a flange that is secured to the axle shaft. This type of fastening is used when the wheel is mounted on bearings on the exterior of the axle housing, and held on by a nut, in which case the axle shaft is used only to drive the wheel, and does not carry any of the weight of the car.

REAR AXLES

A dead axle has the road wheels mounted on a stationary member, these wheels being driven by chains. There is no provision in the axle itself for driving the wheels.

A live axle is a general name for types of axles with revolving driving shafts mounted within the housing.

Live axles are divided as follows: plain live, semi-floating, three-quarter floating and full floating.

The type of axle is determined by the mounting of the bearings.

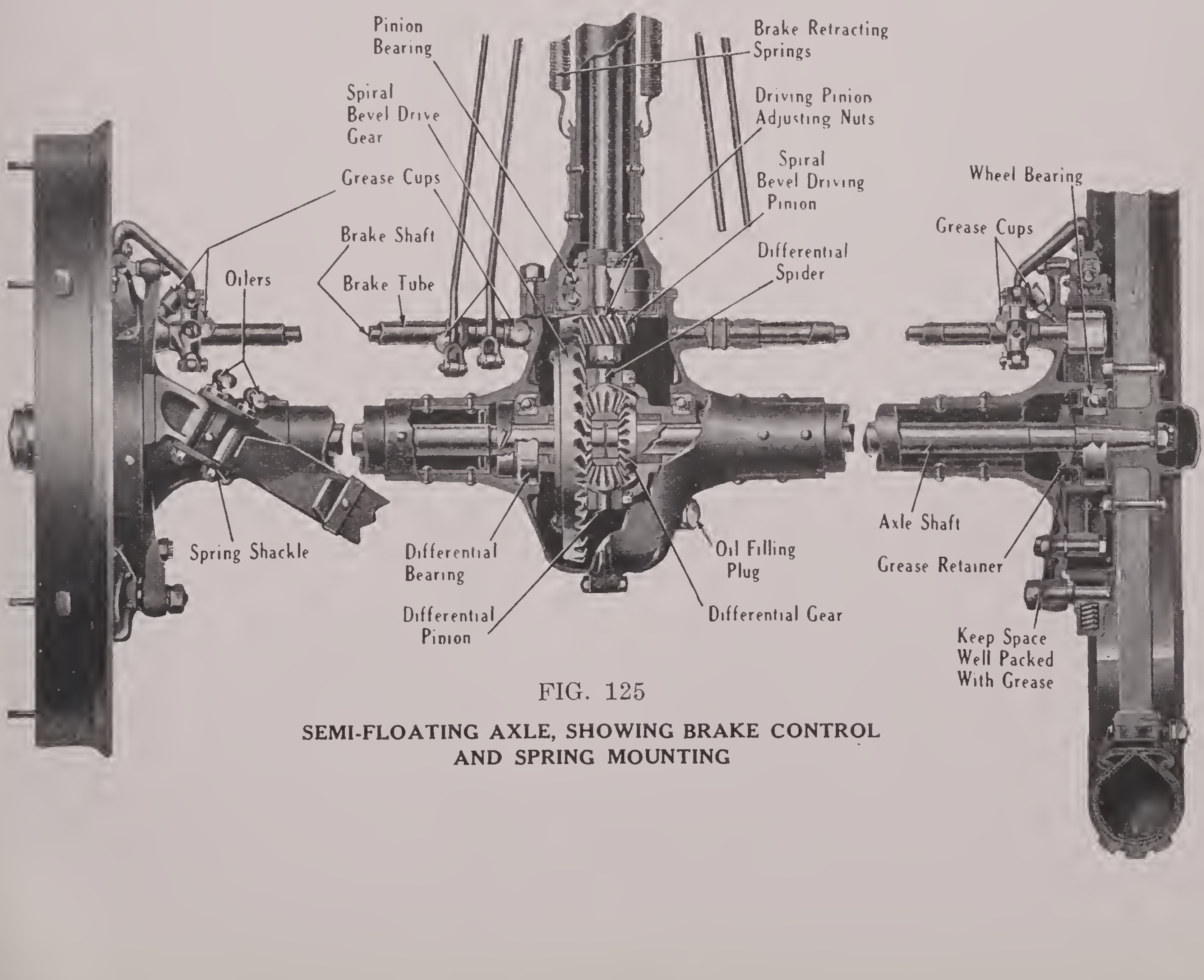
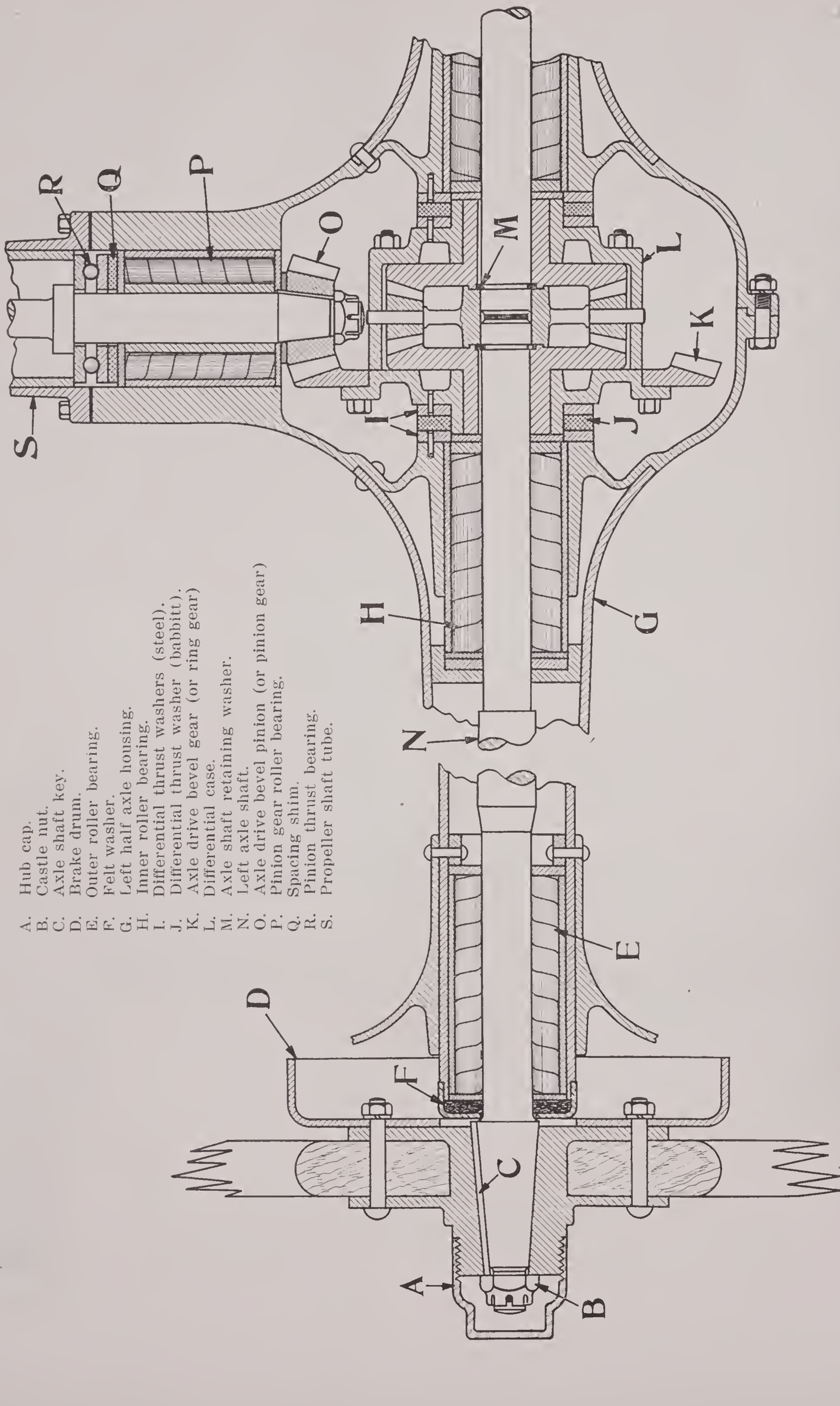


FIG. 125

SEMI-FLOATING AXLE, SHOWING BRAKE CONTROL AND SPRING MOUNTING



A. Hub cap.
B. Castle nut.
C. Axle shaft key.
D. Brake drum.
E. Outer roller bearing.
F. Felt washer.
G. Left half axle housing.
H. Inner roller bearing.
I. Differential thrust washers (steel).
J. Differential thrust washer (babbitt).
K. Axle drive bevel gear (or ring gear)
L. Differential case.
M. Axle shaft retaining washer.
N. Left axle shaft.
O. Axle drive bevel pinion (or pinion gear)
P. Pinion gear roller bearing.
Q. Spacing shim.
R. Pinion thrust bearing.
S. Propeller shaft tube.

FIG. 126
PLAIN LIVE AXLE

FIG. 126

PLAIN LIVE AXLE

In the plain live axle the axle shafts are held into the side gears by a key and washer. The key prevents the gears from turning on the axle shaft, and the washer prevents end movement of the axle shafts in the gears.

On the outer end of the axle shaft, the wheel hub is keyed to the tapered portion of the shaft and held in place by a nut (B). To remove the end play in the drive shaft and pinion gear (O), place in an additional spacing shim (Q) or replace with a thicker one. To remove the end play in the differential case (L), use a thicker thrust washer (J). The purpose of the felt washer (F) is to prevent the oil in the axle housing and differential from working out on the brakes, which would cause a loss of oil as well as slipping brakes.

To remove the axle shafts, jack up the car, disconnect the spring mounting, brake controls, universal joint, etc. Remove the axle, wheels, and drive shaft tube assembly from underneath the car. Remove hub cap (A) and nut (B), and with a wheel puller remove the wheel; take out the cap screws, remove the propeller shaft tube, and with it the drive shaft pinion gear (O) and bearings (P), (Q) and (R). Also remove bolts and separate the two parts of the axle housing. Remove the differential case bolts and force the two halves of the differential case apart. By moving the axle shaft inward far enough to remove the split washer (M), the axle shaft can be removed.

Plain Live Type

(Fig. 126)

On a plain live axle, the inner and outer bearings are mounted on the axle shafts. The axle shafts fasten rigidly to the road wheels and differential side gears, and take all the strains, which are radial or weight, torque or driving and thrust or skidding. If an axle shaft breaks, the wheels will come off, necessitating the use of a truck or support of some kind being placed under the axle in order to tow the car to a garage.

Semi-Floating Type

(Fig. 129)

On the semi-floating type axle, the outer bearings are mounted on the axle shaft the same as in the plain live, but the inner bearings are mounted on the differential housing or case instead of on the axle shafts. This relieves the axle shafts of the differential housing strain,

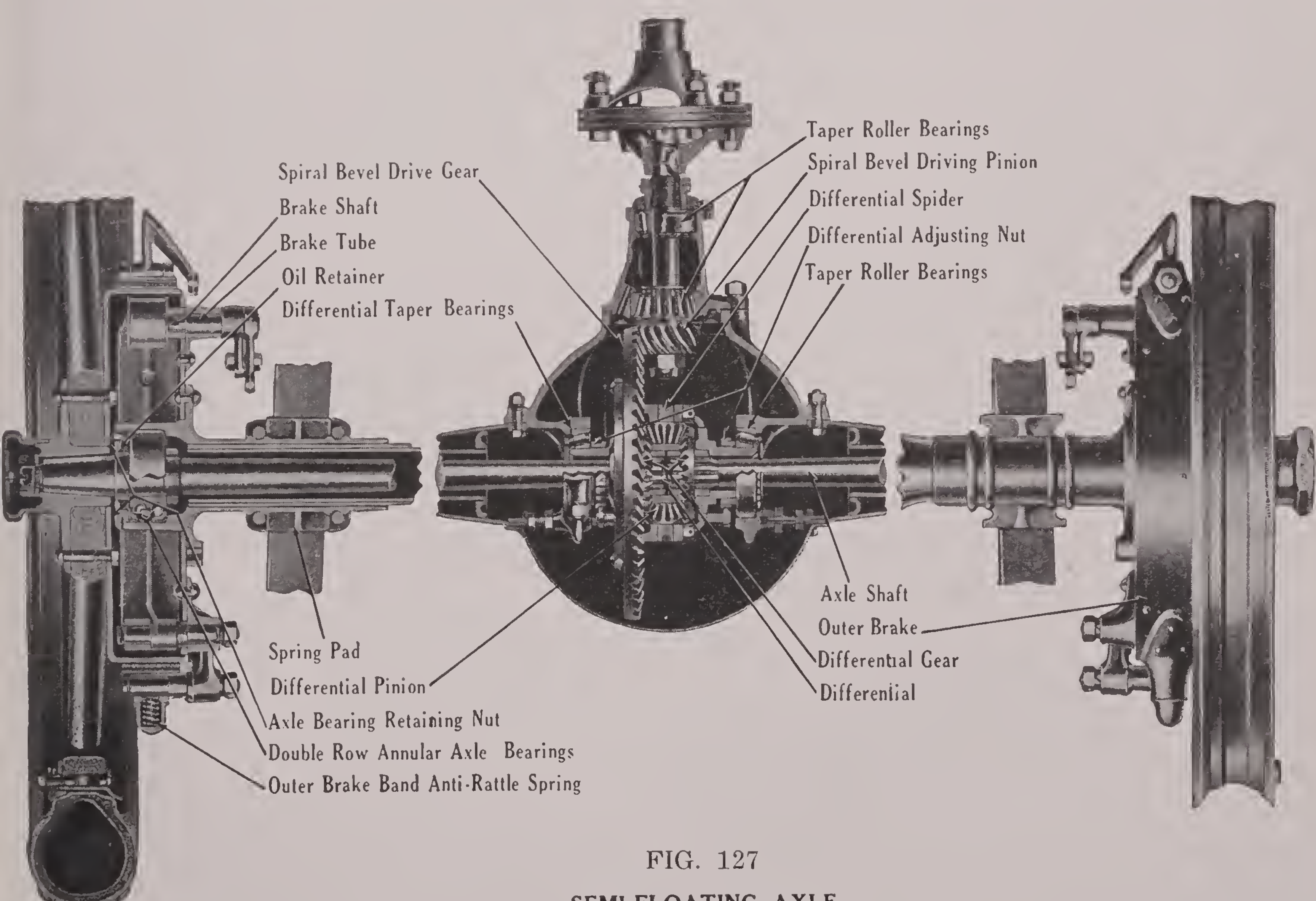


FIG. 127

SEMI-FLOATING AXLE

but the axle shafts still carry load, torque and thrust strains. On some axles of this type, the axle shafts are fastened into the differential side gears and the wheel is keyed on the shaft the same as in the plain live. In others the axle shafts are not fastened into the differential side gears, but are merely engaged, employing the use of a spline or square construction. On most semi-floating axles, the outer bearings are mounted on the tapered part of the shaft or against a shoulder on the shaft with a retaining and adjusting nut screwed inside the axle housing. This outer bearing takes the weight of the car and the skidding strains of the wheels, and with its mounting holds the axle shafts in place.

Three-Quarter Floating Type
(Fig. 130).

In the three-quarter floating axle, the inner bearings are mounted on the differential housing the same as in the semi-floating type. The bearings at the outer ends are mounted on the axle housing inside the wheel hub and are held on by a nut. The axle shafts take the torque and part of the thrust strains, and the wheels depend upon the axle shafts for alignment. The axle housing carries the radial load and part of the thrust strains. On some three-quarter floating axles, the shafts are fastened into the differential side gears, and the wheel is keyed on the axle shaft the same as in the semi-floating type.

Full Floating Type
(Fig. 138)

On the full floating type, the inner bearings are mounted on the differential housing the same as in the semi and three-quarter floating types. The outer bearings are mounted the same as in the three-quarter floating, except that each wheel has two bearings which are held on the axle housing by a retaining nut. The wheels do not depend on the shafts for alignment, and may be driven by a flange or jaw clutch which is fastened to the outer end of the axle shaft. The axle shafts carry only the torque strain. The axle housing carries the radial and thrust load.

TYPES OF AXLE DRIVES

The various types of live axles can be driven by a bevel gear, spiral bevel gear, worm gear, double reduction gear, or single chain. The dead type axle may be driven by double chains or internal gears. *(Continued on Page 180)*

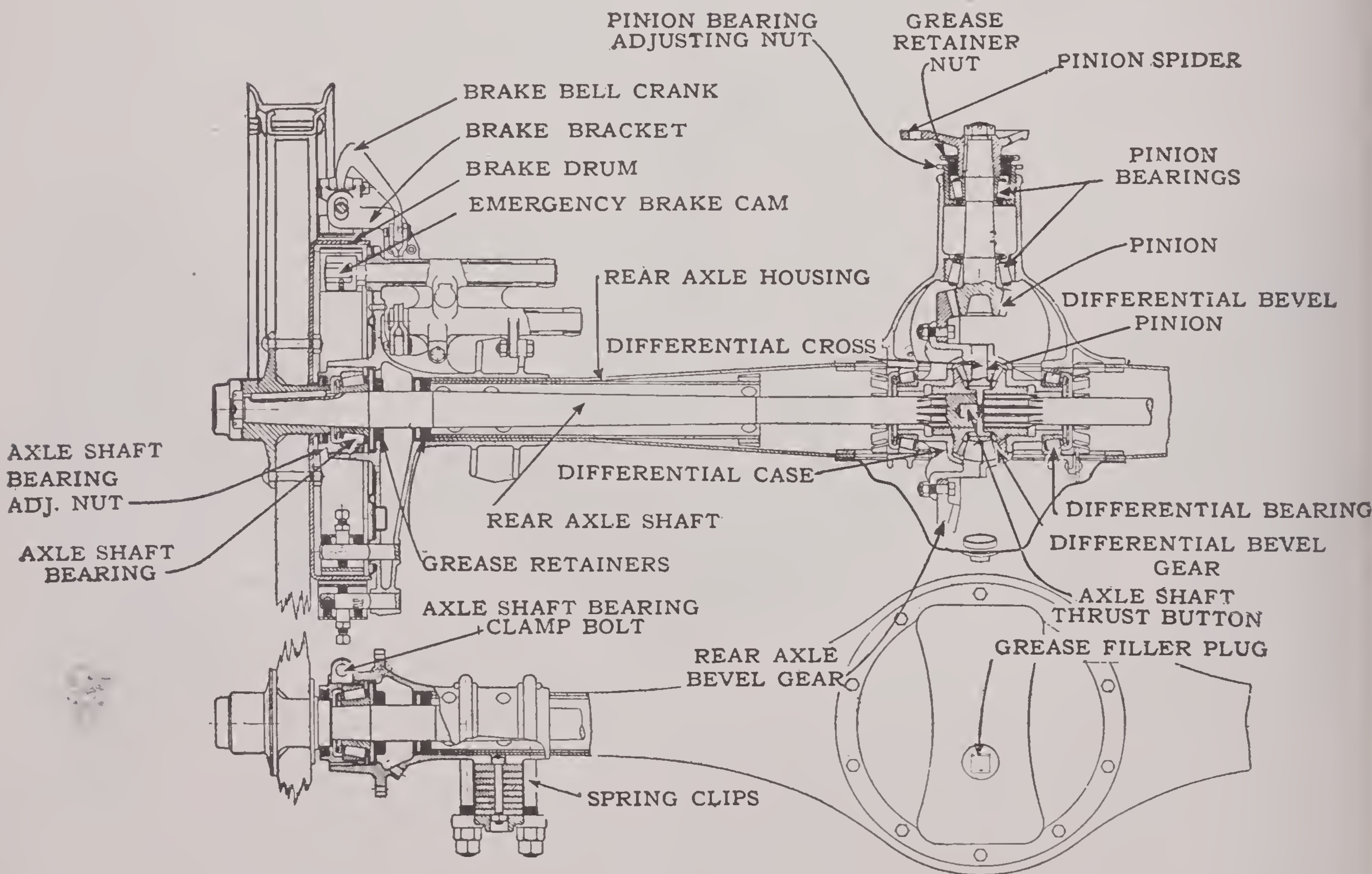


FIG. 128

SEMI-FLOATING AXLE

A. Axle shaft.
B. Axle shaft bearing.
C. Adjusting nut and bearing retainer.
D. Differential case.
E. Drive pinion shaft bearings.
F. Differential bearing.
G. Differential bearing adjuster.
H. Bevel gear housing.
I. Grease cup.
J. Brake drum.
K. Axle shaft key.
L. Axle shaft nut.
M. Rear axle spring seat.
N. Hub cap.
O. Pinion shaft rear bearing adjuster.
P. Pinion shaft rear bearing adjuster lock.
R. Pinion shaft bearing adjusters.
S. Inner bearing adjuster.
W. Wheel spoke.

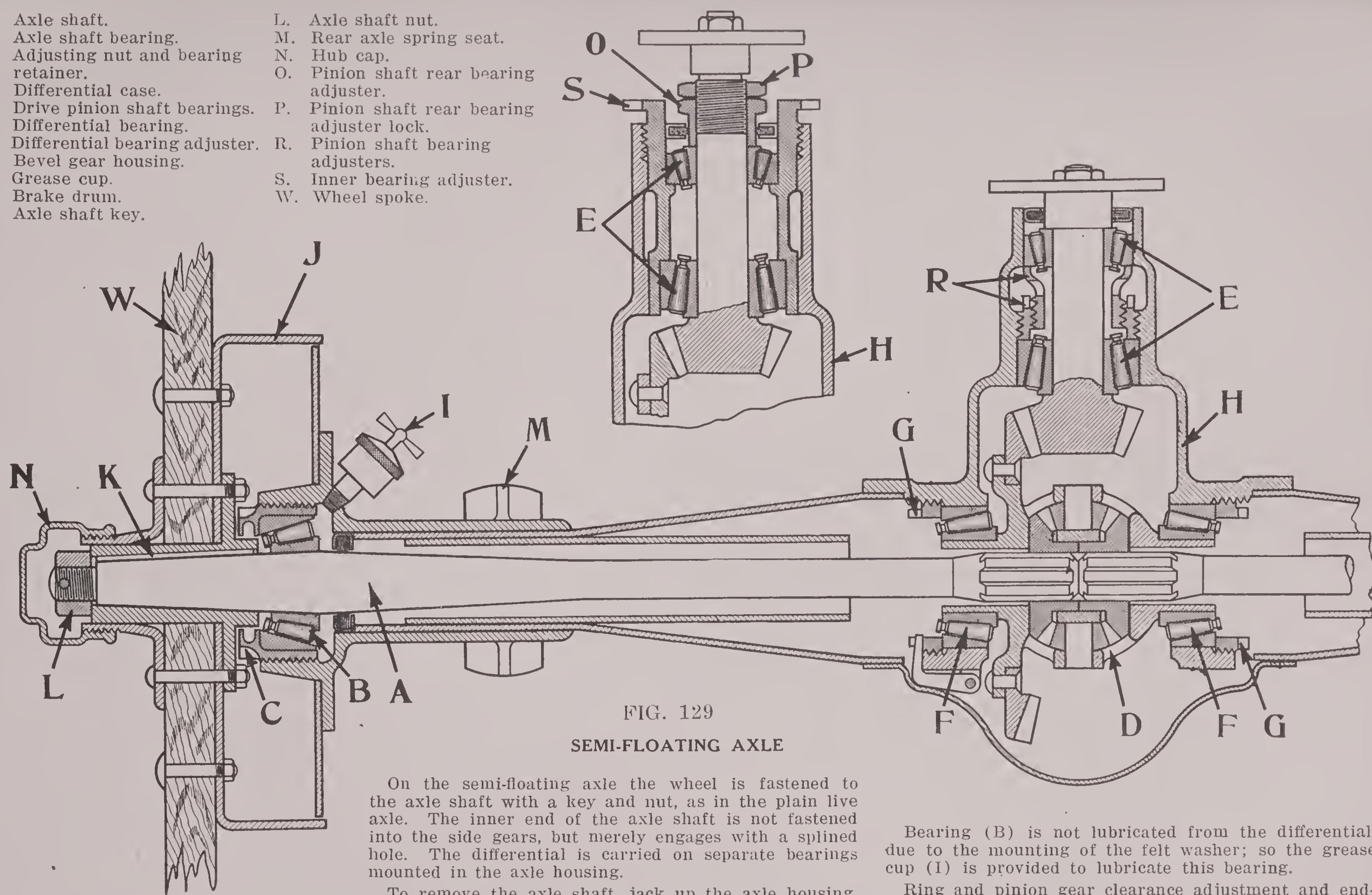


FIG. 129

SEMI-FLOATING AXLE

On the semi-floating axle the wheel is fastened to the axle shaft with a key and nut, as in the plain live axle. The inner end of the axle shaft is not fastened into the side gears, but merely engages with a splined hole. The differential is carried on separate bearings mounted in the axle housing.

To remove the axle shaft, jack up the axle housing, remove hub cap (N) and nut (L), pull the wheel off and remove the bearing retainer nut (C). The axle shaft may then be removed and with it the bearing (B). This bearing, besides taking the weight of the car and the skidding strains of the wheels, holds the axle shaft in place.

Bearing (B) is not lubricated from the differential, due to the mounting of the felt washer; so the grease cup (I) is provided to lubricate this bearing.

Ring and pinion gear clearance adjustment and end-play adjustment of the differential case are made by the adjusters (G). End play and alignment adjustments of the pinion shaft are made through the adjusting sleeves (R).

In the insert, alignment is obtained through the sleeves (S), while (O) is the end play adjusting nut.

A. Axle shaft.
B. Outer bearing.
C. Axle shaft nut.
D. Differential case.
E. Axle shaft key.
F. Differential bearings.
G. Differential bearing adjuster.
H. Differential thrust bearings.
I. Drive pinion shaft bearings.
J. Axle drive bevel pinion adjuster.
K. Hub cap.

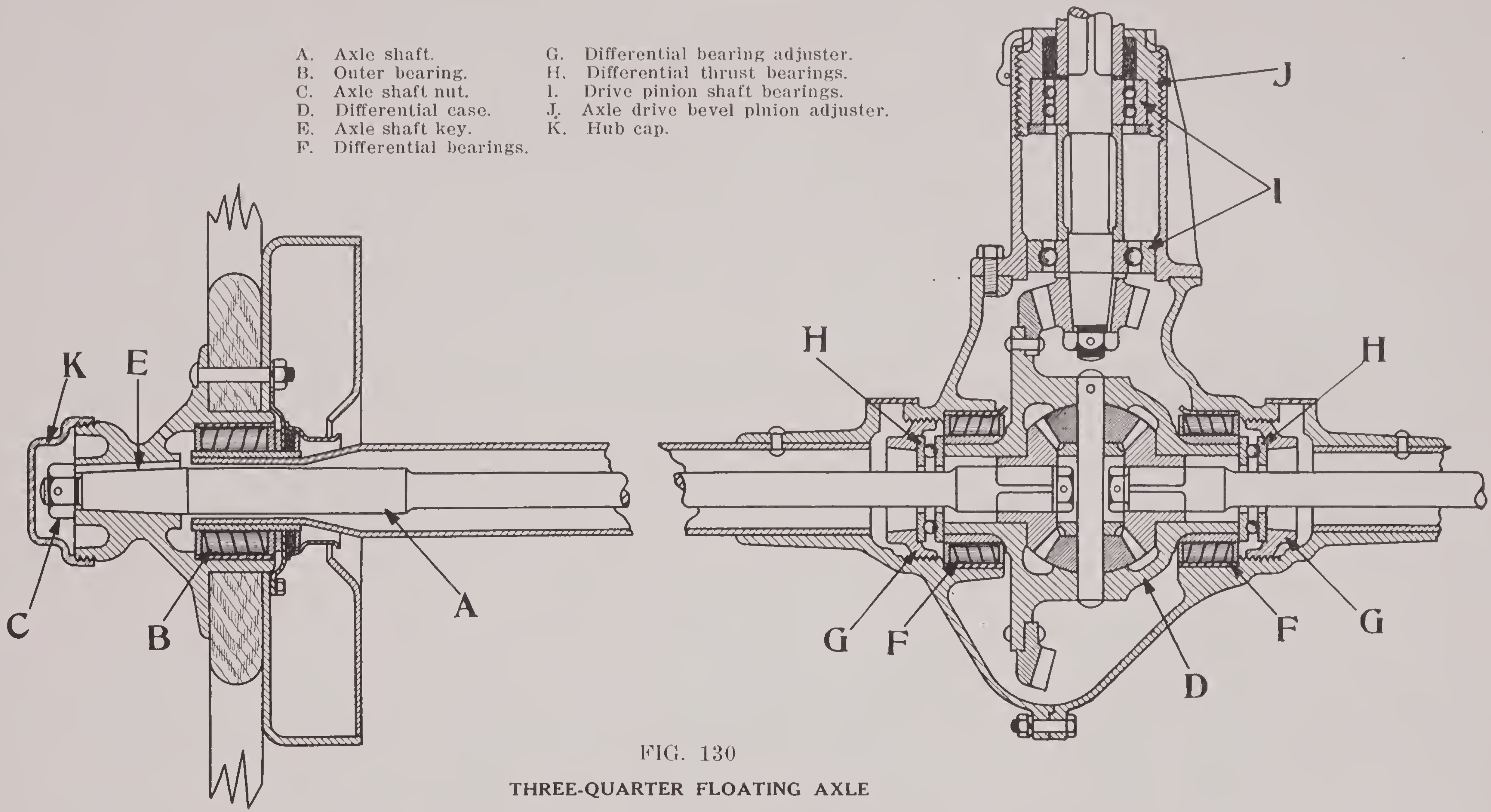


FIG. 130

THREE-QUARTER FLOATING AXLE

This three-quarter floating axle employs an axle shaft that is tapered on the outer end and squared on the inner end. The wheel is fastened on to the axle shaft with a key (E) and nut (C). The differential side gears are fastened on to the axle shaft and held in place by a nut.

To remove the axle shaft, first remove the axle assembly from underneath the car. Next, remove hub cap (K) and nut (C) and pull the wheel off. Then remove the pinion shaft housing and axle housing bolts and force the two parts of axle housing apart. Also remove the differential case bolts, pry the two halves of the differential case apart and remove the axle shaft lock nuts, after which the axle shaft can be removed.

The alignment or end play adjustment of the differential case and ring gear is made through adjusting nuts (G). The pinion shaft alignment is made through the adjusting sleeve (J), while the end play adjustment is made through the small nut threaded into the sleeve against the double row annular bearing. The outer bearing at the wheel end is lubricated by the oil from the differential.

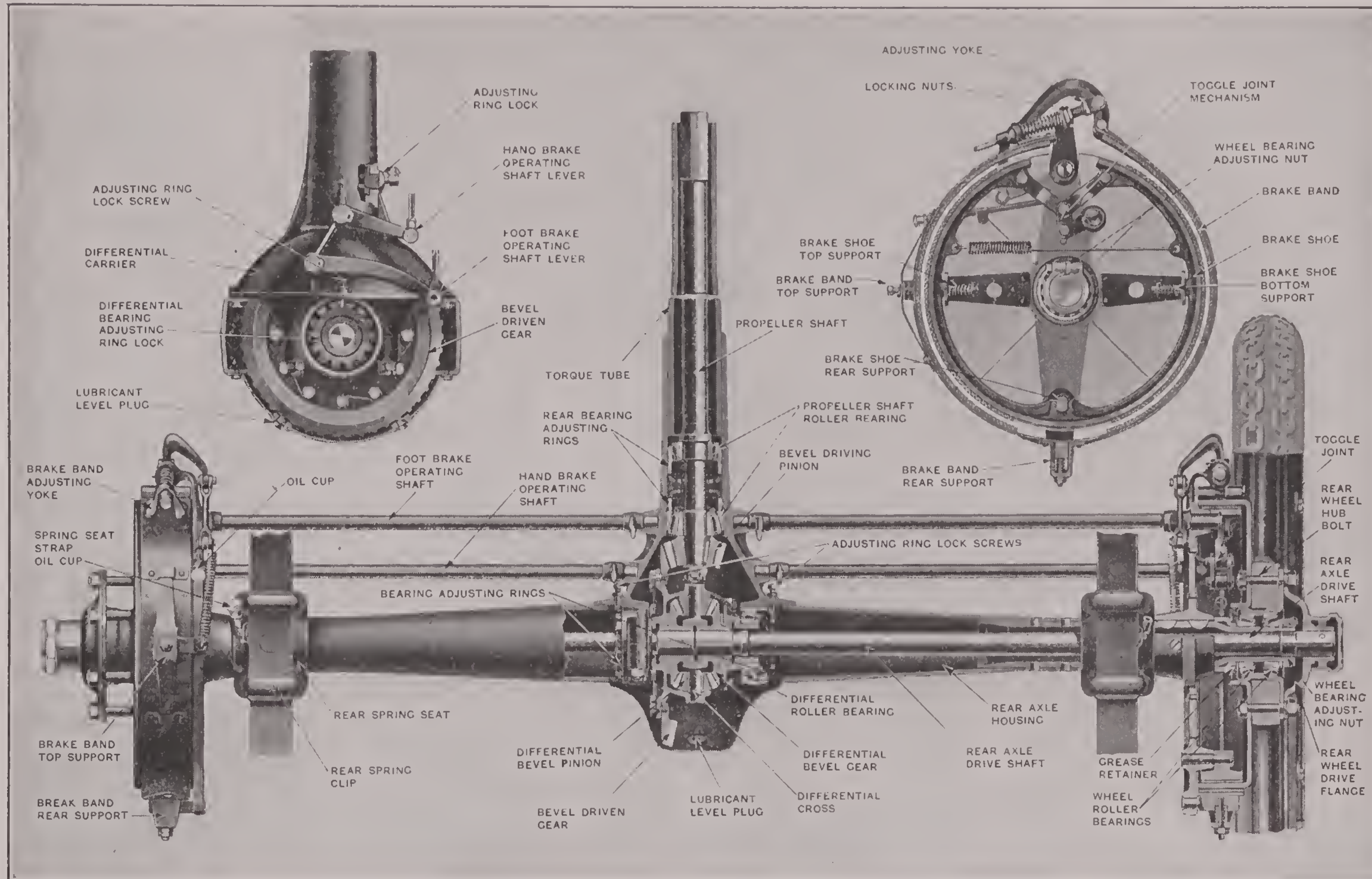


FIG. 131

A FULL FLOATING AXLE EMPLOYING A DRIVING FLANGE TO TRANSMIT THE POWER FROM THE AXLE SHAFT TO THE WHEEL HUB

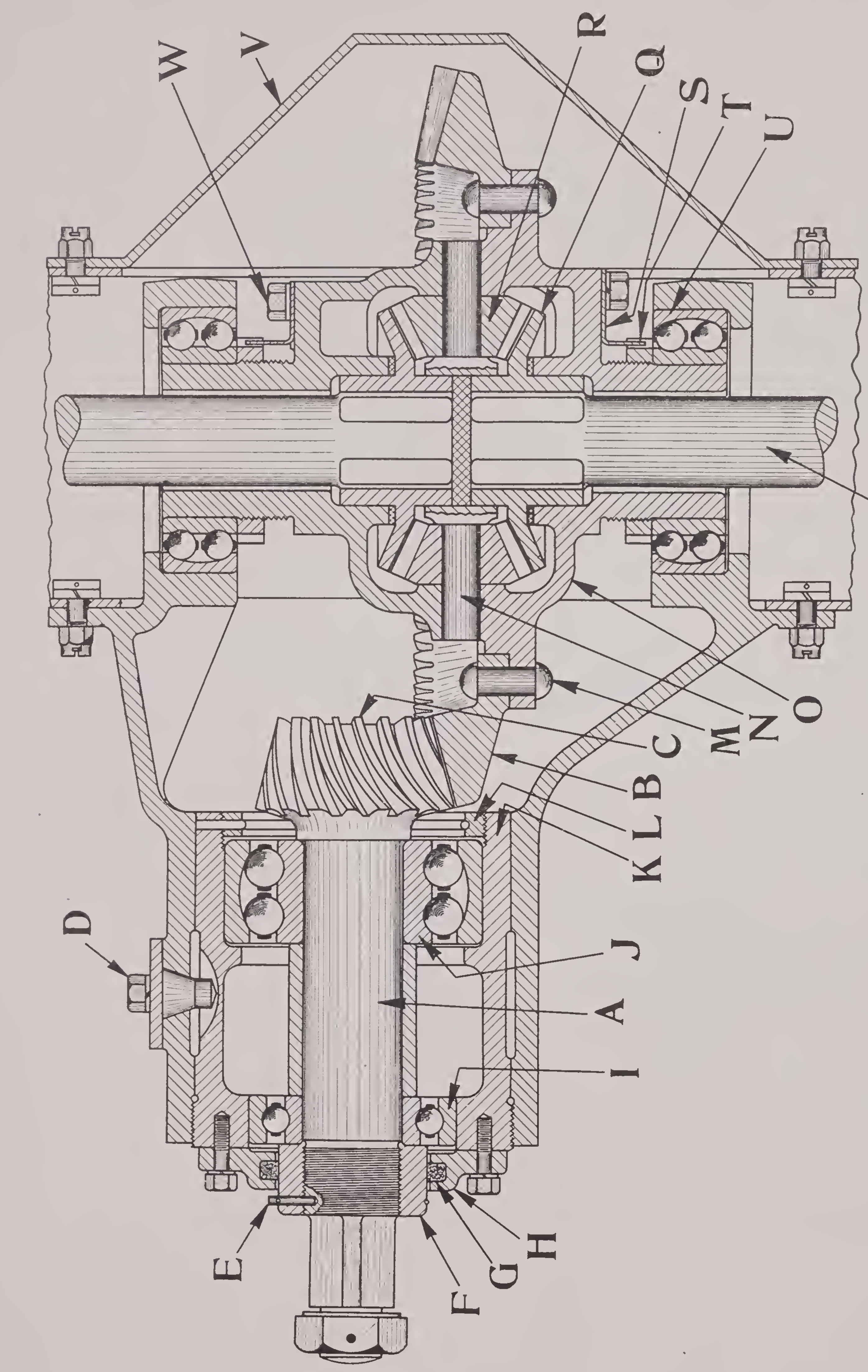


FIG. 132

SPIRAL BEVEL GEAR DRIVE REAR AXLE

FIG. 132

SPIRAL BEVEL GEAR DRIVE REAR AXLE

A. Axle drive pinion shaft.
B. Axle drive bevel gear.
C. Axle drive bevel pinion.
D. Drive pinion adjusting sleeve lock.
E. Front bearing adjuster lock.
F. Front bearing adjuster.
G. Felt washer.
H. Retainer.
I. Drive pinion front bearing.
J. Drive pinion rear bearing.
K. Drive pinion adjusting sleeve.
L. Rear bearing adjuster.
M. Steel rivet.
N. Differential spider gear pin.
O. Differential case.
P. Axle shaft.
Q. Differential side gear.
R. Differential spider gear.
S. Differential adjuster lock.
T. Differential adjuster.
U. Differential bearing.
V. Bevel gear housing cover.
W. Lock retaining screw.

The correct alignment of the pinion shaft is obtained by moving the adjusting sleeve (K), which is locked by the set screw (D). End play is taken up by tightening the adjuster (L). To remove the outer bearing (I), remove retainer plate (H), adjuster lock (E) and adjuster (F).

The rear bearing (J) can be removed by unscrewing the lock screw (D), then the adjusting sleeve (K); after these are removed, pull the pinion gear off its shaft and remove end play adjuster (L). The felt washer (G) acts as an oil retainer, preventing a loss of oil around the pinion shaft. The differential end play adjustment is made through the adjusters (T).

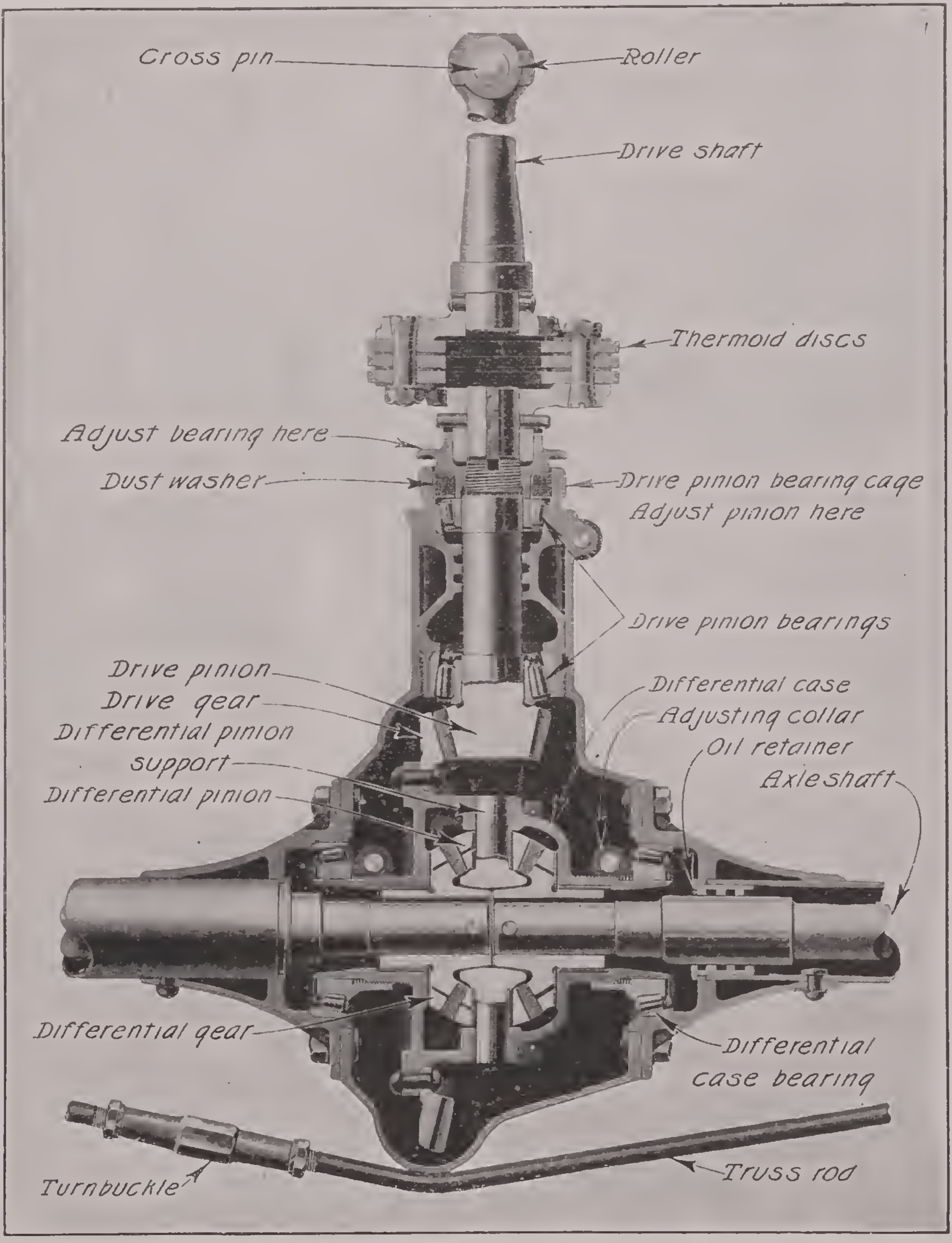


FIG. 133

DIFFERENTIAL ASSEMBLY

TYPES OF AXLE HOUSINGS

Rear axle housings are usually divided into two general types: one piece, or bell type, and two or three piece, or divided type.

There are two types of bevel gears used, the ordinary bevel gear with straight line teeth and the spiral tooth gear whose teeth curve around the gear cone in the shape of a spiral. The latter is more commonly used for passenger cars, the chief advantage being their noiseless operation at all speeds.

Other advantages of the spiral bevel gear are; smaller number of teeth can be used permitting higher gear ratios; the form of the tooth is such that the point of contact is always at the pitch line, or the point where there is no slipping between the teeth that are touching, which makes a stronger tooth with practically no wear and insures the quiet running; also more teeth in contact at one time giving added strength.

REAR AXLE ADJUSTMENTS

The clearance allowed between the teeth on new drive pinion and ring gears is about twelve-thousandths of an inch. When one new gear and one old gear are employed, as on a repair job, about eight-thousandths should be allowed. When both gears are old and "worn in" and are only being adjusted, a clearance of six-thousandths of an inch is usually sufficient. The above clearances may be obtained by the use of paper or a lead wire. When adjusting old gears take a tough piece of paper that measures three-thousandths of an inch. This paper, after passing between the gears, should show a good impression without being cut. A soft lead wire, when run through the gears and compressed, should measure the desired clearance. That is, the thickness of the wire or paper gives the clearance at the pitch line between the two gears.

See that the gears do not bind at any point,

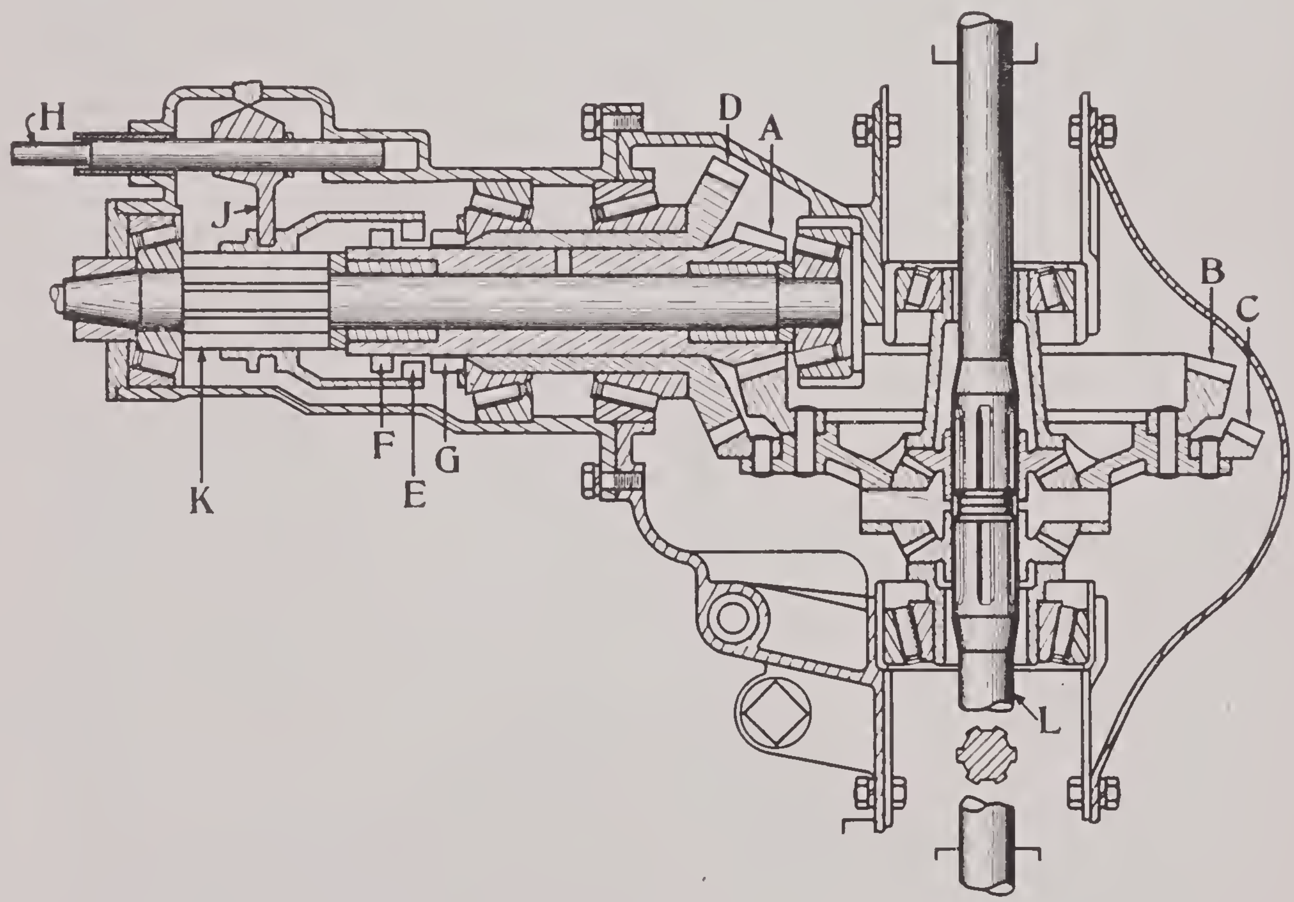


FIG. 134

TWO SPEED REAR AXLE

A. Low speed axle drive pinion.
B. Low speed axle drive bevel gear.
C. High speed axle drive bevel gear.
D. High speed axle drive pinion.
E. Shifting jaw clutch.
F. Low speed pinion gear drive.
G. High speed pinion gear drive.
H. Shifting bar.
J. Shifting fork.
K. Splined shaft.
L. Axle shaft.

Greater reduction is obtained by sliding the shifting bar (H) forward, which engages the teeth on the jaw clutch (E) with the teeth on the low speed pinion gear driving sleeve (F). The power is transmitted from the pinion gear (A) to the ring gear (B), through the differential assembly to the axle shafts.

If the shifting bar is moved back, the teeth on the jaw clutch (E) engage the teeth on the high speed pinion gear drive (G), transmitting the power from the pinion gear (D) to the ring gear (C).

but have a free rolling contact all the way around. If too much clearance is allowed between the gears, when driving along or coasting, there is noted a clattering noise. Upon sudden acceleration, or when the car is getting under motion, this is usually not noticeable. Gears that have not enough clearance, or that are meshed too tightly, howl and groan, this being very noticeable on sudden acceleration or when pulling a heavy load.

When adjusting these gears, it is necessary that the back surface of the two gears line up properly. If one gear projects beyond the other only a few thousandths of an inch, the gears will be noisy, regardless of the amount of clearance. This adjustment is the alignment adjustment of the pinion and should be made first. After these gears are lined up properly, then the clearance can be adjusted by either the adjusting nuts which are provided for moving the ring gear to the right or the left, or by the space which is provided for

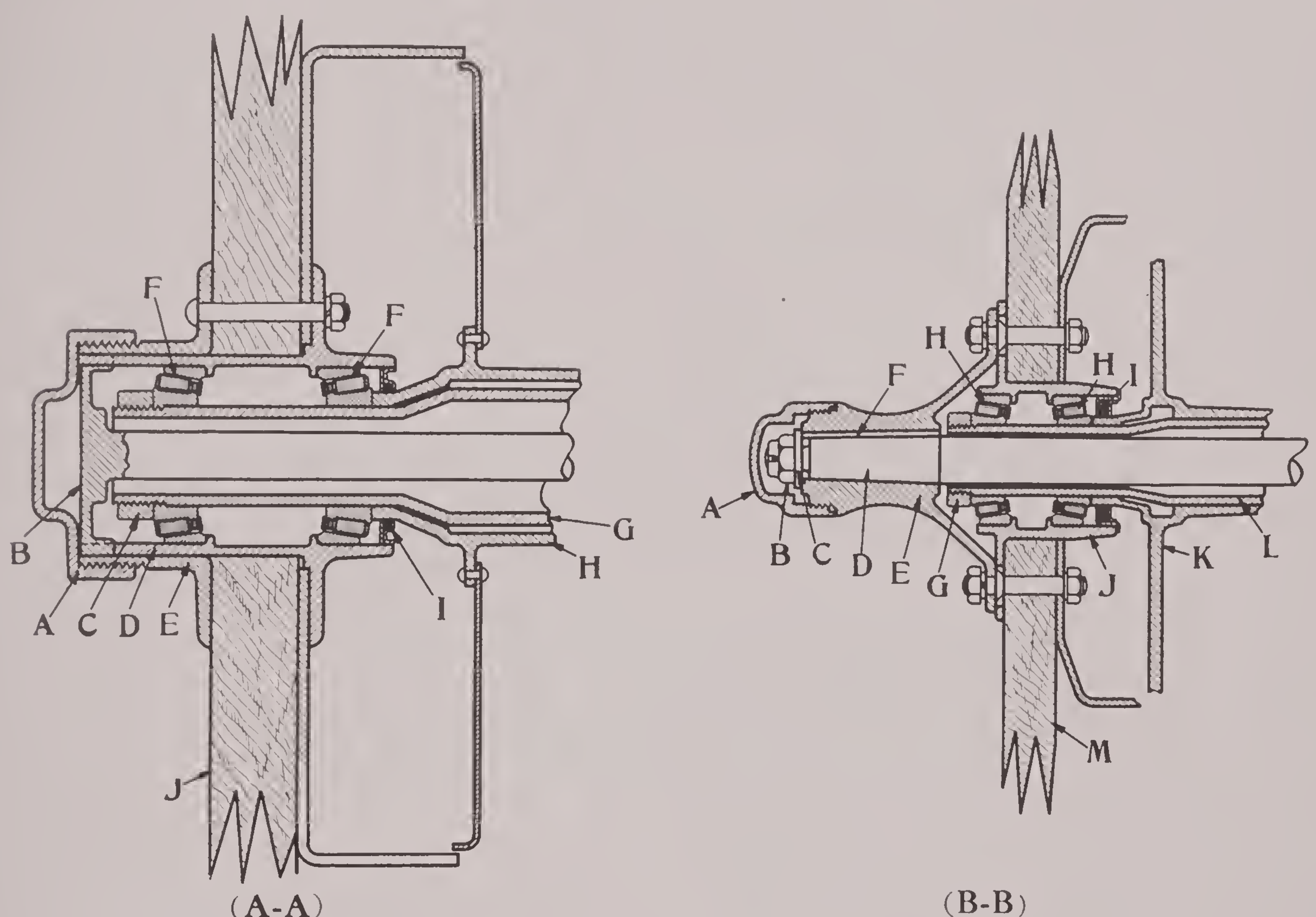


FIG. 135

FULL FLOATING AXLE WHEEL MOUNTINGS

(A-A)

A. Hub cap.
B. Jaw driving clutch.
C. Wheel bearing adjusting nut and retainer.
D. Wheel hub.
E. Wheel hub flange.
F. Bearings.
G. Axle tube.
H. Axle housing.
I. Felt washers.
J. Spokes.

ILLUSTRATION A-A

To remove the axle shaft from the housing, first remove the hub cap (A) by unscrewing it, after which the axle shaft can be pulled out. The nut (C) is used to adjust the wheel bearings as well as hold the wheel on the axle housing.

(B-B)

A. Hub cap.
B. Retainer.
C. Washer.
D. Tapered axle shaft.
E. Wheel driving flange.
F. Key.
G. Wheel bearing adjusting nut and retainer.
H. Bearings.
I. Felt washer.
J. Wheel hub.
K. Axle housing.
L. Axle tube.
M. Spokes.

ILLUSTRATION B-B

To remove the axle shaft, take off the flange nuts, after which the hub and axle shaft can be drawn out of the housing.

placing shims behind the thrust bearing on each side of the differential housing. After obtaining the correct clearance, the adjuster for end play should be locked on each side of the differential case. The differential assembly should have about two-thousandths of an inch end play, and at the same time the ring gear and the pinion gear should have the proper clearance. The drive pinion is moved toward or away from the beveled ring gear either by an adjusting nut or sleeve which holds the bearings or by the aid of the spacing shims.

The bearings employed in rear axles may be tapered roller, plain roller with end thrust bearings provided of either the plain or ball type, or the single or double annular ball bearings. If an adjusting nut is provided to move these bearings back and forth, a lock is also provided to hold the adjusting nut in place, preventing it from shaking loose by vibration. On the outer end of the axle housing a felt washer is provided. The purpose of this felt washer is to prevent the oil or grease from working out of the axle housing into the brakes. If oil gets into the brakes, they will not hold. Remove the felt washer, soak in glycerine and then replace. The glycerine does not mix with the oil, but prevents the oil from penetrating through the washer.

The oil or grease that is used in the rear axle is 600-W oil or light cup grease. Fill the axle housing one-third full. This is suffi-

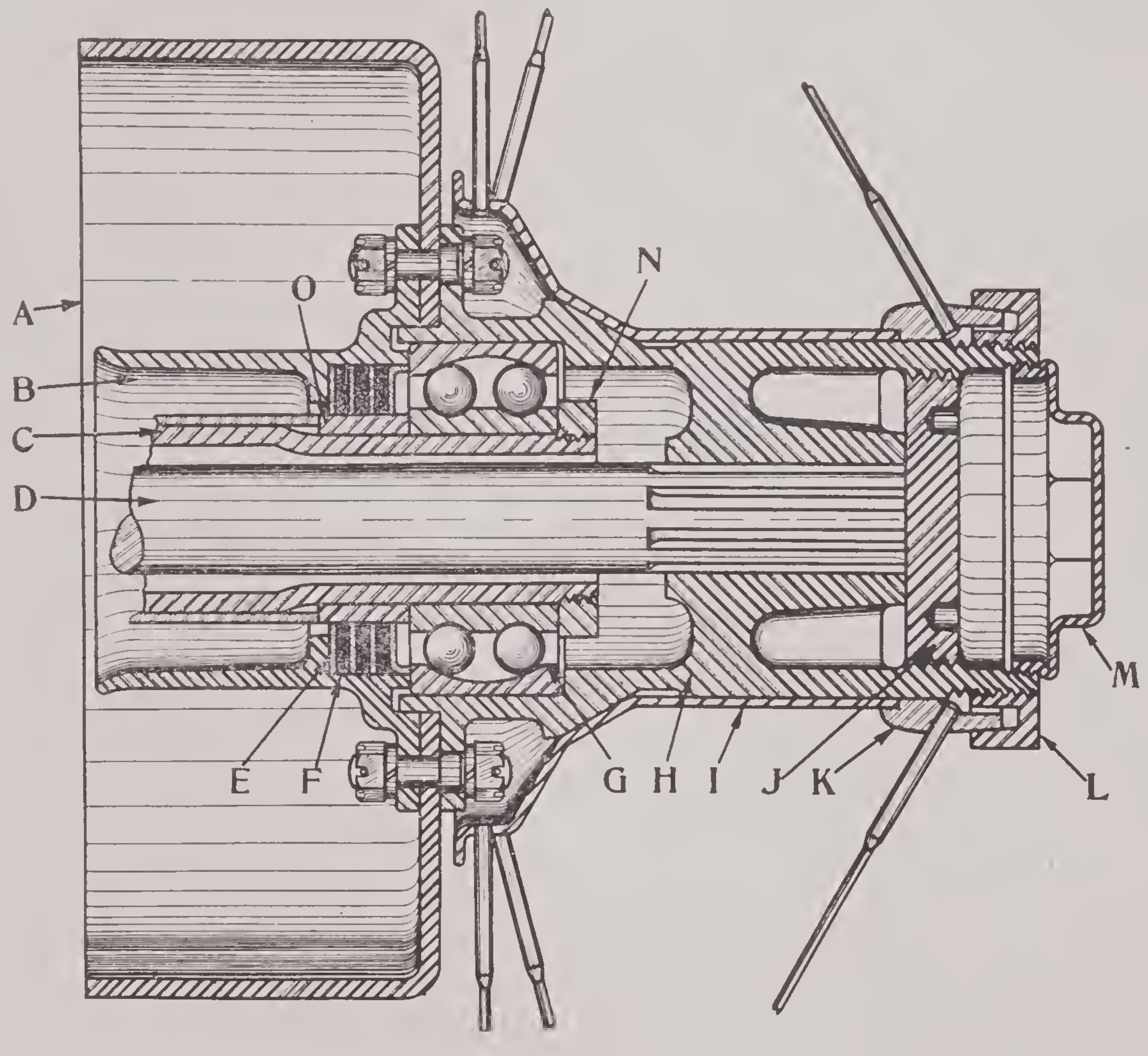


FIG. 136

THREE-QUARTER FLOATING AXLE, WITH SPECIAL WHEEL MOUNTING

A. Brake drum.
B. Brake drum hub.
C. Rear axle housing.
D. Rear axle shaft.
E. Thrust washers (steel).
F. Thrust washers (felt).
G. Wheel bearing.
H. Wheel driving hub.
I. Wheel driven hub.
J. Axle shaft retaining nut.
K. Spoke hub and retainer.
L. Wheel hub retainer nut.
M. Hub cap.
N. Wheel bearing retainer nut.
O. Spacing sleeve.

In this construction the wheel bearing is mounted on the axle housing and is held on by the nut (N).

The main wheel driving hub (H) transmits the power from the splined axle shaft through driving pins (not shown) to the driven hub (I), which is held in place by the retainer nut (L).

·ient for the oil to be carried around by the ;ears, lubricating all the gears and bearings. f the oil level is too high, there is a tendency or the oil to be forced out past the felt washers ıt the end of the housing, where it will work nto the brakes.

The axle shafts are made of high grade, heat reated alloy steel, and are usually finished ›nly on the outer and inner ends.

WORM DRIVE REAR AXLE

The worm drive is used mostly on trucks and allows a greater ratio between speed of engine and speed of rear axles, resulting in more power. The worm drive is one of the most efficient drives, due to the lesser amount of friction on the bearing surface. The worm drive rear axle is generally of the full floating type, there being one main adjustment, which is the end play adjustment of the worm. The worm is usually made of low carbon steel, case hardened, while the worm wheel is made of high grade bronze. The worm wheel is bolted or riveted onto the differential housing,

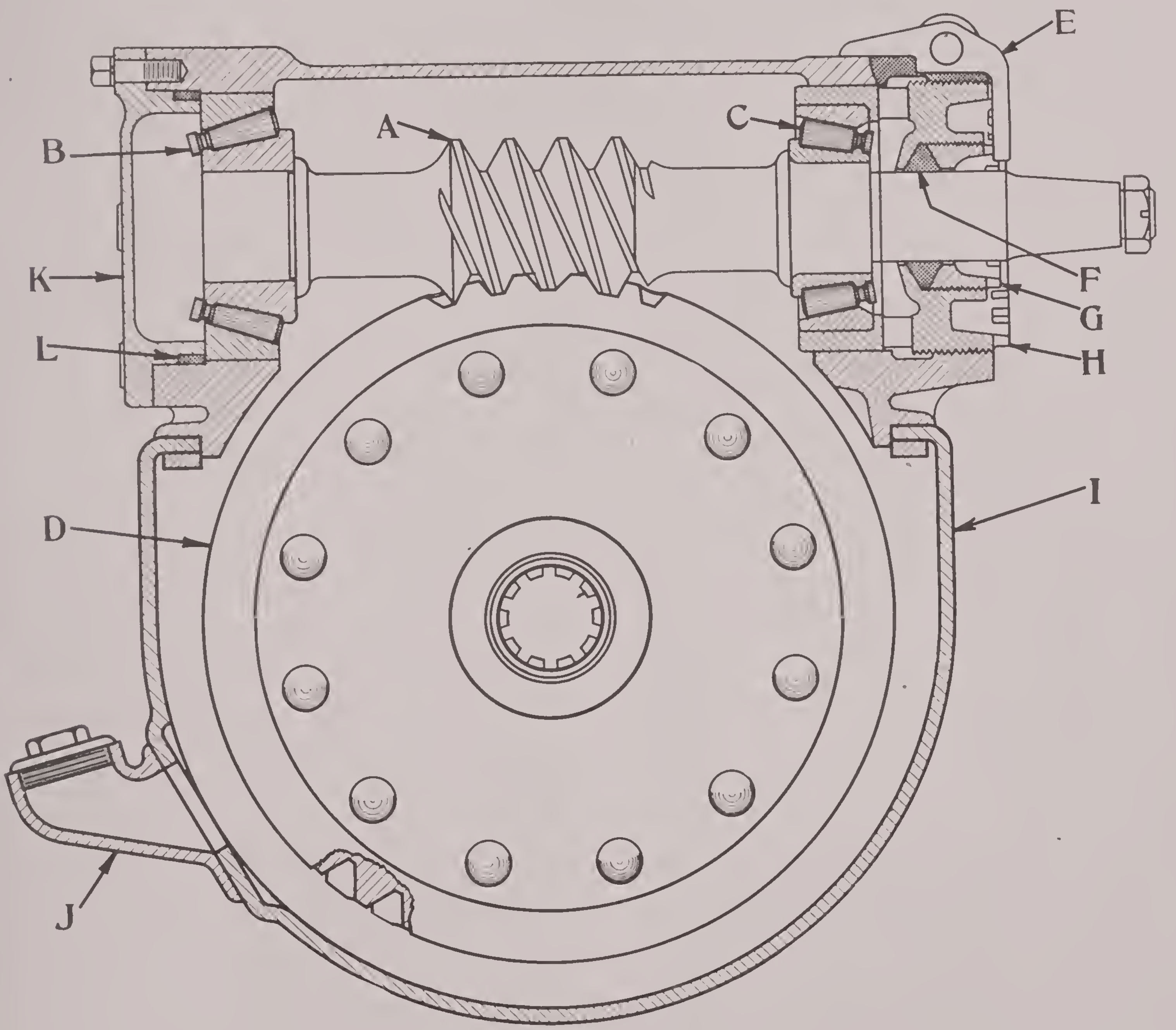
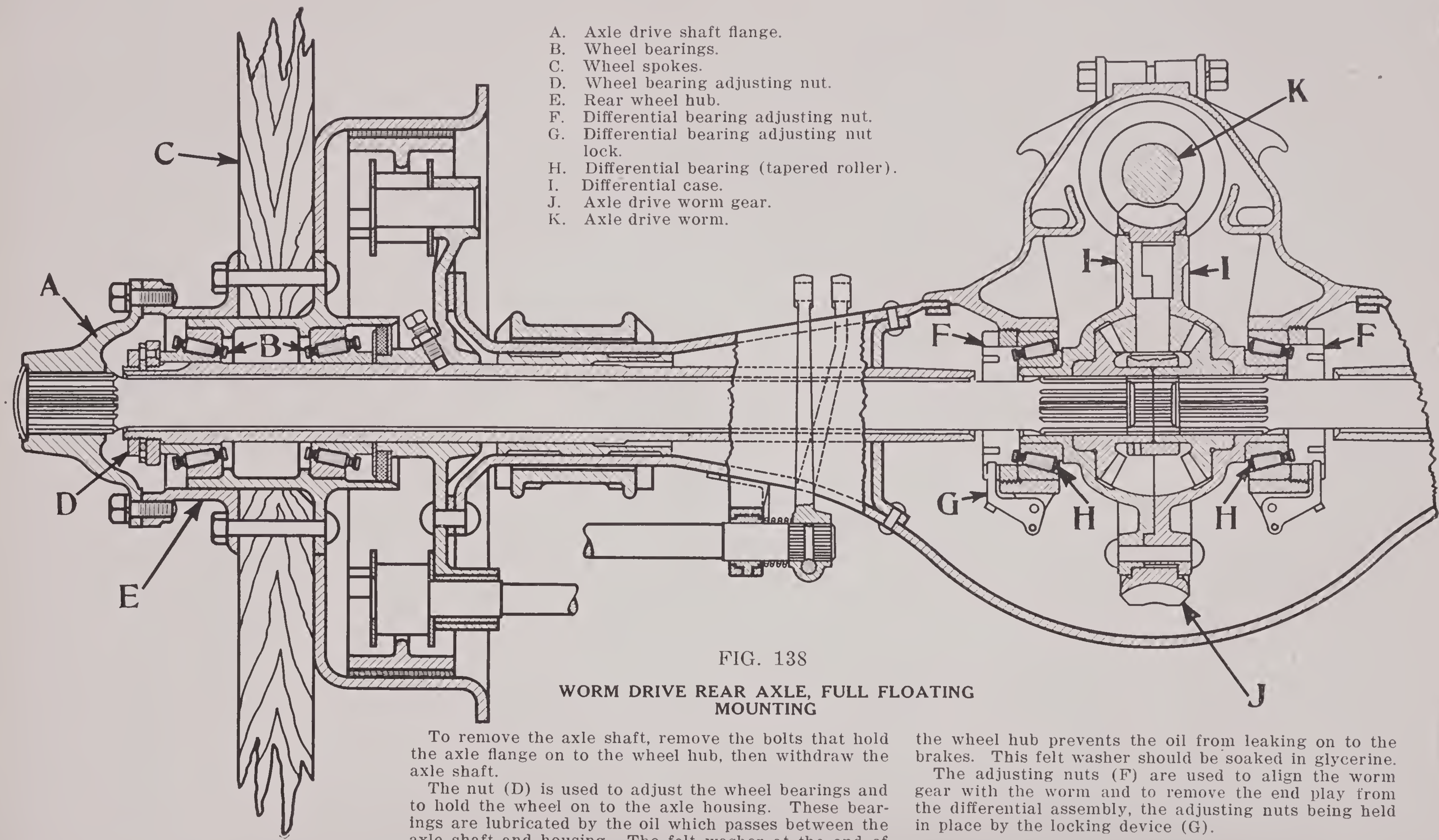


FIG. 137

WORM DRIVE

A. Axle drive worm.
B. Rear bearing.
C. Front bearing.
D. Axle drive worm gear.
E. Adjuster lock.
F. Felt washer.
G. Felt washer adjuster.
H. Worm front bearing adjuster.
I. Rear axle housing.
J. Grease filler and level tube.
K. Rear cover.
L. Felt washer.

The adjustment on this type of drive is the adjuster (H), which removes the end play from the worm. To keep this nut properly adjusted, the lock (E) is provided. The inner adjuster (G) is provided to adjust the felt washer (F) which prevents the leakage of grease at this point. The washer should be soaked in glycerine.



A. Axle drive shaft flange.
B. Wheel bearings.
C. Wheel spokes.
D. Wheel bearing adjusting nut.
E. Rear wheel hub.
F. Differential bearing adjusting nut.
G. Differential bearing adjusting nut lock.
H. Differential bearing (tapered roller).
I. Differential case.
J. Axle drive worm gear.
K. Axle drive worm.

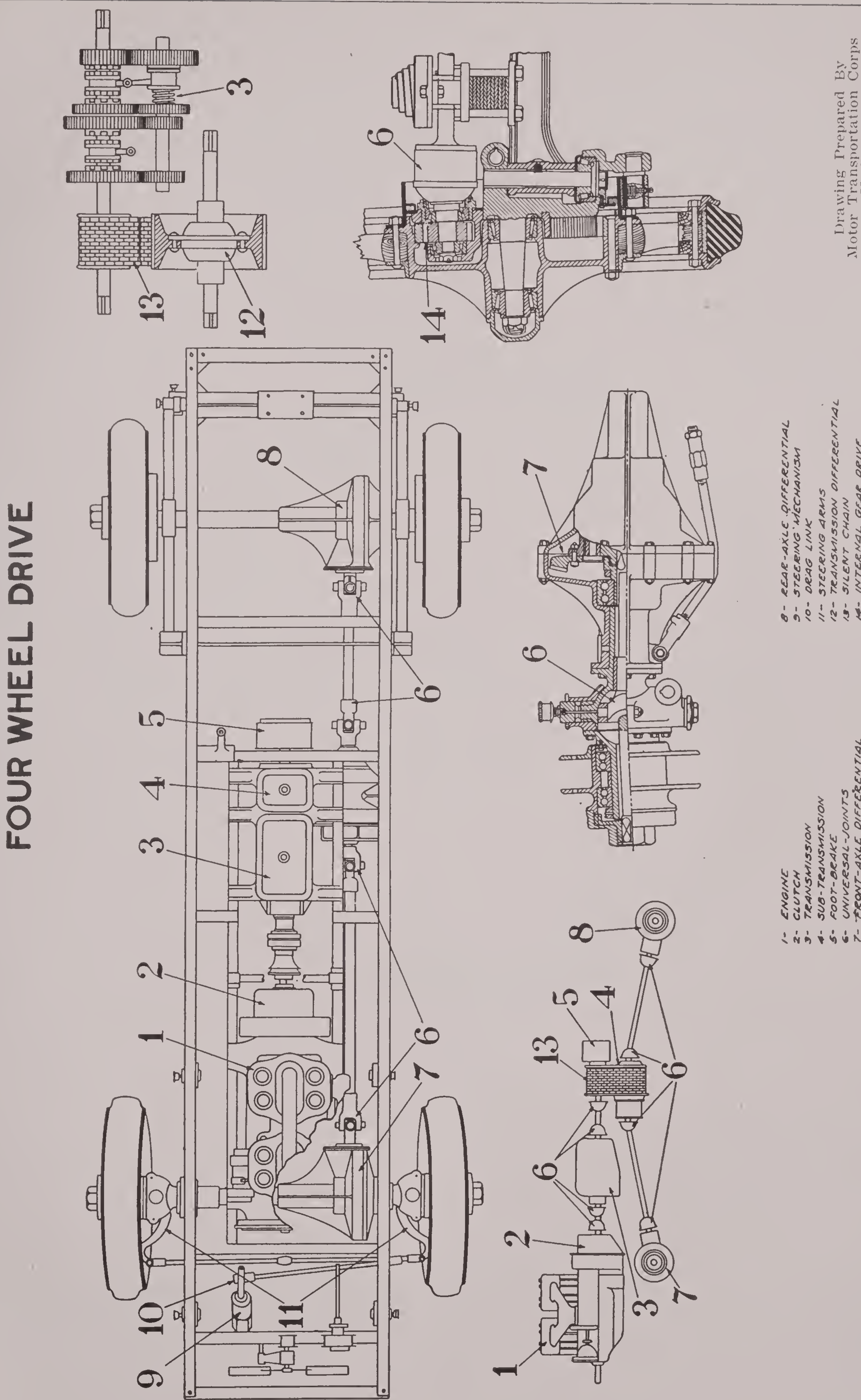
FIG. 138

WORM DRIVE REAR AXLE, FULL FLOATING MOUNTING

To remove the axle shaft, remove the bolts that hold the axle flange on to the wheel hub, then withdraw the axle shaft.

The nut (D) is used to adjust the wheel bearings and to hold the wheel on to the axle housing. These bearings are lubricated by the oil which passes between the axle shaft and housing. The felt washer at the end of the wheel hub prevents the oil from leaking on to the brakes. This felt washer should be soaked in glycerine.

The adjusting nuts (F) are used to align the worm gear with the worm and to remove the end play from the differential assembly, the adjusting nuts being held in place by the locking device (G).



Drawing Prepared By Motor Transportation Corps U. S. Army

FIG. 139

which is mounted on a set of bearings that are adjustable and that take both radial load and end thrust.

The gear ratio of the worm and wheel drive is calculated by dividing the number of teeth on the worm wheel by the number of threads on the worm. The worm drive axle is lubricated by running the worm wheel in oil which supplies oil to the worm and bearings. Felt washers at the outer end keep the oil from working out.

BRAKES

The purpose of the brakes is to slow down or stop the car after the clutch is disengaged. The brakes may operate either directly on drums mounted on the rear wheels or on a drum fastened on the transmission shaft. There are usually two sets of brakes and in most cars they are both mounted on the rear wheels. One is known as the foot brake, and is controlled by the foot pedal, the other as the hand brake, and is controlled by the hand

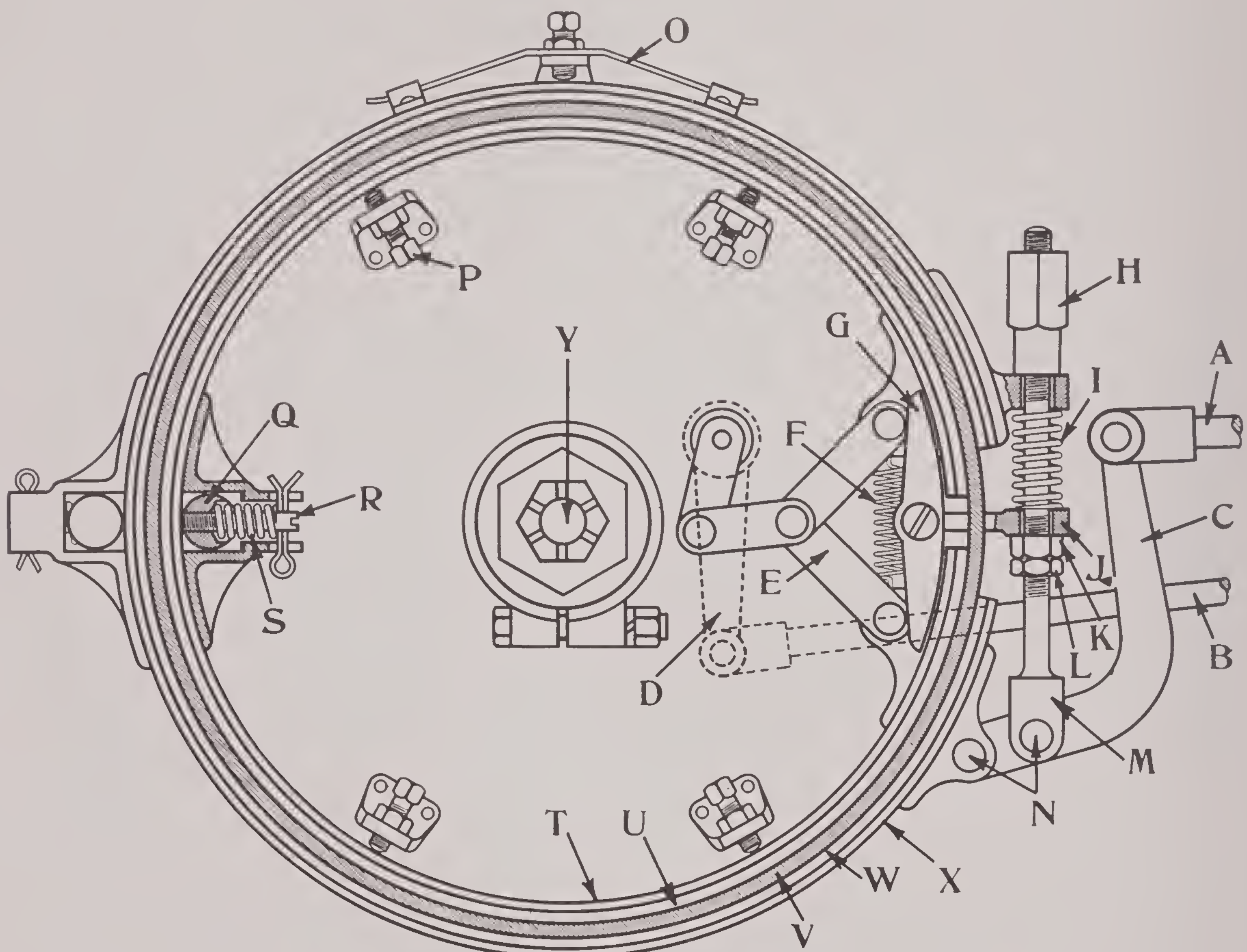


FIG. 140

BRAKES

A. Brake rod yoke.
B. Hand brake rod.
C. Outer brake band lever.
D. Inner brake shaft lever.
E. Inner brake toggle.
F. Inner brake toggle spring.
G. Inner brake stop.
H. Outer brake band adjusting nut.
I. Outer brake band expanding spring.
J. Outer brake band spring rest.
K. Centering nut.
L. Lock nut.
M. Clevis.
N. Pins.
O. Outer brake band support.
P. Inner brake band rest.
Q. Inner brake band support.
R. Adjusting screw.
S. Spring.
T. Inner brake band.
U. Inner brake band lining.
V. Brake drum.
W. Outer brake band lining.
X. Outer brake band.

When adjusting brakes, always adjust the brake bands as close to the drum as possible without binding or dragging, adjusting the clearance at the back first. Remove the cotter pin and turn the adjusting screw (R) forward into the stationary shaft (Q) to decrease the clearance. The clearance adjustment for the outer band is the same. After adjusting the clearance at the back, adjust the clearance on the upper and lower half of each brake band. Screws (P) control the clearance of the inner brake band, adjusting nut (H) regulates the upper half of the outer brake band, while the lower half is adjustable through nuts (K).

brake lever mounted alongside the gear shift lever. The foot brakes are, as a rule, mounted on the exterior of the brake drum fastened onto the rear wheel, and are of the contracting type. The hand brake operates on the interior of the brake drum and is of the expanding type.

On some cars one brake is mounted on the rear wheels and the other on the transmission. The transmission brake may be either the foot brake or hand brake. Mounting the brake on the transmission shaft eliminates long brake rods and tubes and results in less noise and a cleaner chassis assembly.

Sometimes the hand brake band is made of cast iron with no facing or lining, the lining being omitted for the reason that these brakes are not used as much as the foot brakes, although the majority have an asbestos facing. Due to the manner in which the hand brake is mounted, the rods that actuate it pass through the interior of a tube. This has a tendency to cause them to rust, due to their not being used often enough. A good plan to follow is to pull up on the hand brake every time the car is stopped, which is a good precaution against accidents and helps to prevent rust from gathering in this tube.

The outer brake band has a lining made of asbestos and other materials. The lining is made fairly hard but still pliable, and resists wear and heat. It is held on the brake band with copper rivets. When riveting this lining onto the bands, the heads of the rivets should not be exposed, as they will cut the brake drum. If this happens, it is impossible to keep the brake linings on the bands for any length of time, due to the rough surface cutting and tearing them.

The foot brake should not engage until the foot pedal is pushed halfway forward. The brakes are adjusted either by lengthening or shortening the brake rods or by changing the setting of the adjusting screw directly at the band.

The hand brake should not take hold until the hand brake lever has been pulled back at least half of its full travel, thus preventing the brake from dragging when the lever is forward.

Using Engine as Brake

When traveling through hilly country or in case the foot and hand brakes fail, the engine may be used as a brake. This also relieves regular brakes and prevents them from overheating or burning.

To use the engine as a brake, shift the gears to either second or low speed and shut off the ignition. The car will then be driving the engine, and the engine working against the compression will tend to resist and retard the movement of the car.

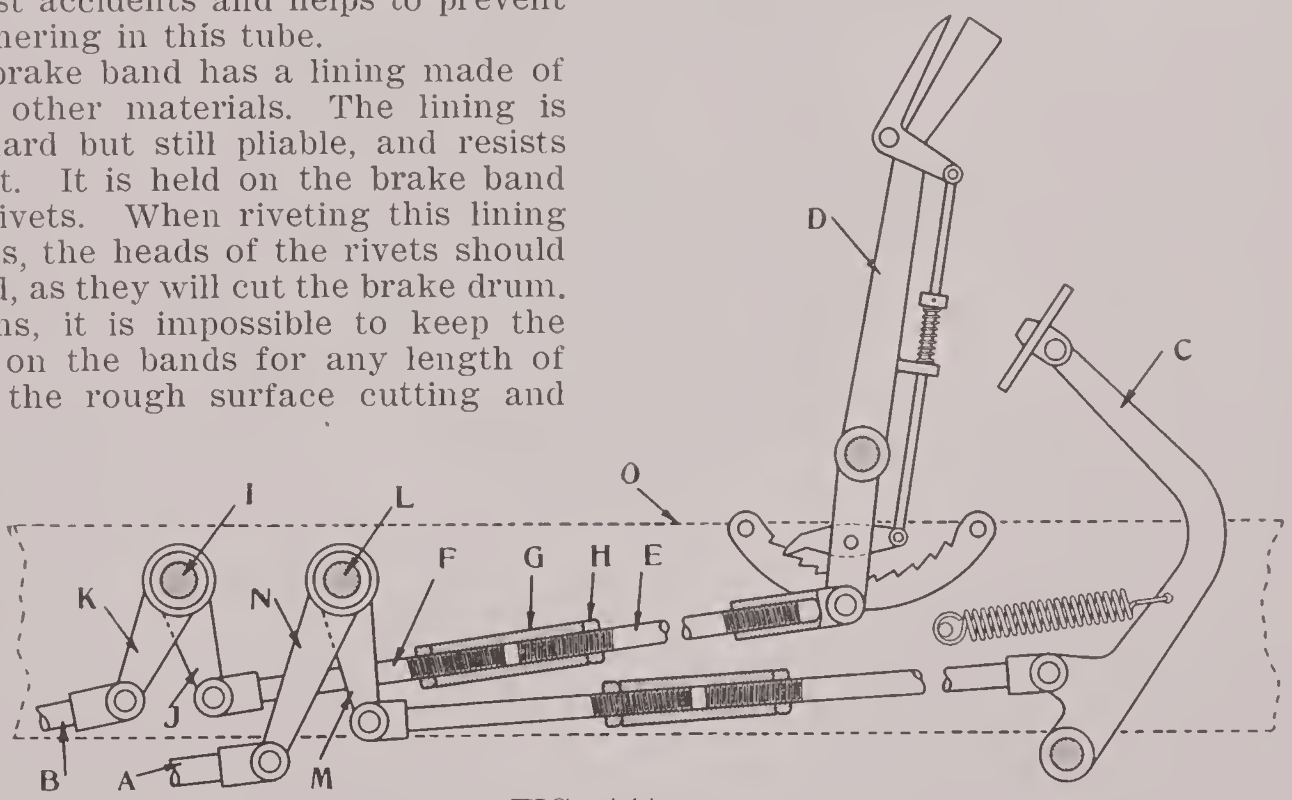


FIG. 141

FOOT AND HAND BRAKE CONTROLS

A. Brake rod yoke.
B. Brake rod yoke.
C. Foot pedal.
D. Hand lever.
E. Brake rod.
F. Brake rod.
G. Right and left threaded turnbuckle.
H. Lock nut.
I. Intermediate shaft.
J. Intermediate shaft lever.
K. Intermediate shaft lever.
L. Intermediate shaft.
M. Intermediate shaft lever.
N. Intermediate shaft lever.
O. Frame.

This illustration shows the foot and hand brake connections and adjustments. The turnbuckle (G) is used to adjust the length of the brake rod, and the lock nut (H) prevents it from coming loose.

The rod (E) has a right and left hand thread and can be used to change the position of the hand lever.

Troubles and Remedies

Dragging brakes may be caused by improper adjustment, insufficient pressure of the retractor or brake band springs, brake members out of alignment or worn wheel bearings. Check the alignment of the bands and brake drum. If the drum is out of round, or the drum and brake band are not concentric the brake will drag at one point. A centering adjustment is provided for this purpose. If the wheel mounting is loose, the brake will also drag.

The brakes and controls must be so adjusted that the right and left brakes are applied at the same time with equal pressure, that is, equalized. If the brake is applied only on one wheel, the car is more likely to skid and an excessive strain is thrown on the final drive.

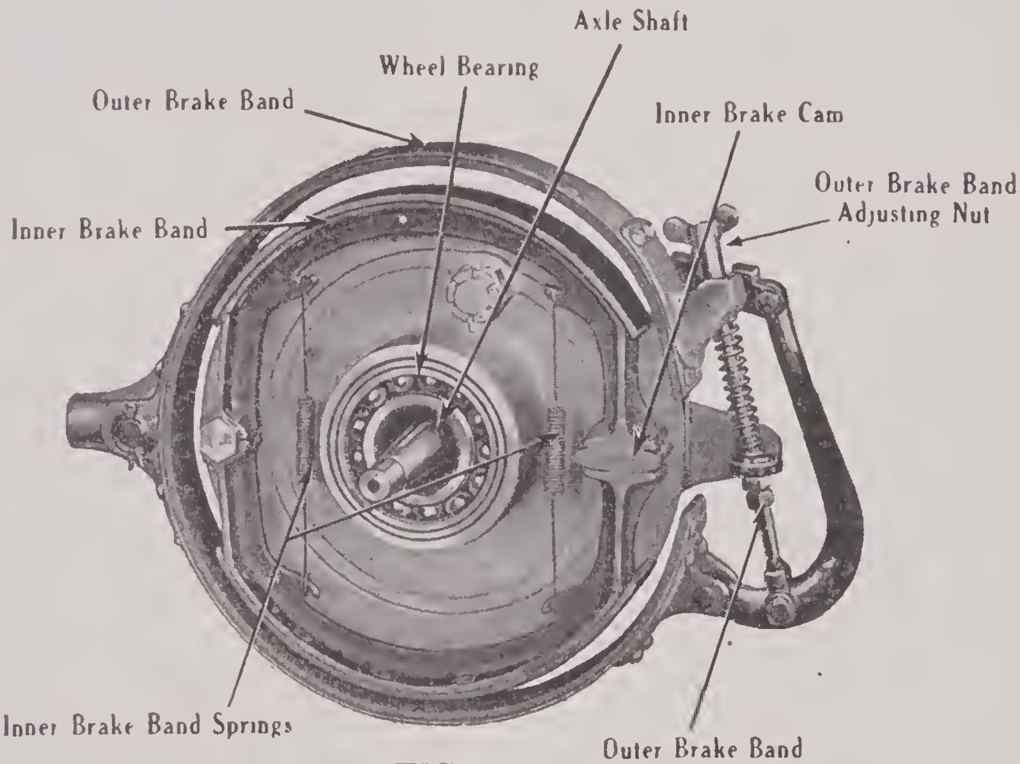


FIG. 142

BRAKES

Slipping brakes may be caused by an oil soaked lining, worn lining or improper adjustment. The controls should be adjusted so that the brake is applied when the control pedal or lever moves one-half of its travel, and should stop the brake drum before they have moved their full travel. To remove oil from the lining, clean with kerosene. Fuller's earth may be used to absorb the oil.

Sticking brakes may be caused by lack of lubricant on the brake mechanism, toggle, tube, shaft, lever, pins, clevis, etc. The rust and dirt should be removed from these operating parts and lubrication applied freely. Excessive wear of these parts will sometimes allow the brake to lock by moving past the center line. This can be remedied by replacing with new pins, clevis, etc., or by pressing in a new bushing where needed.

Chattering brakes may be caused by the above mentioned parts becoming worn, lack of tension in the releasing springs, or the spring clips not properly adjusted.

Squeaking brakes are usually caused by the lining becoming worn, dirty or glazed. To remedy this, clean the lining with a stiff brush and kerosene, or replace with new lining.

Do not apply the brakes too severely. Control the speed of the car with the throttle as much as possible.

SPRINGS

The springs that are used on the present day cars are of the built up leaf type. The leaf spring has proven more successful than the coil springs, and there is less liability of breakage. These springs are divided into several different types; namely, one-quarter elliptic, semi-elliptic, three-quarter elliptic, full elliptic, cantilever, and platform.

In time the springs will squeak, due to the surfaces between the leaves becoming dry from lack of lubrication. To remedy this without removing the springs from the axles and frame, separate the spring leaves and squirt kerosene between them, which will loosen the rust. Then operate the car for about a day. Separate the leaves again and apply a mixture of graphite and oil between the leaves. Oil used alone will gradually dry out and be ineffective, while the graphite has a

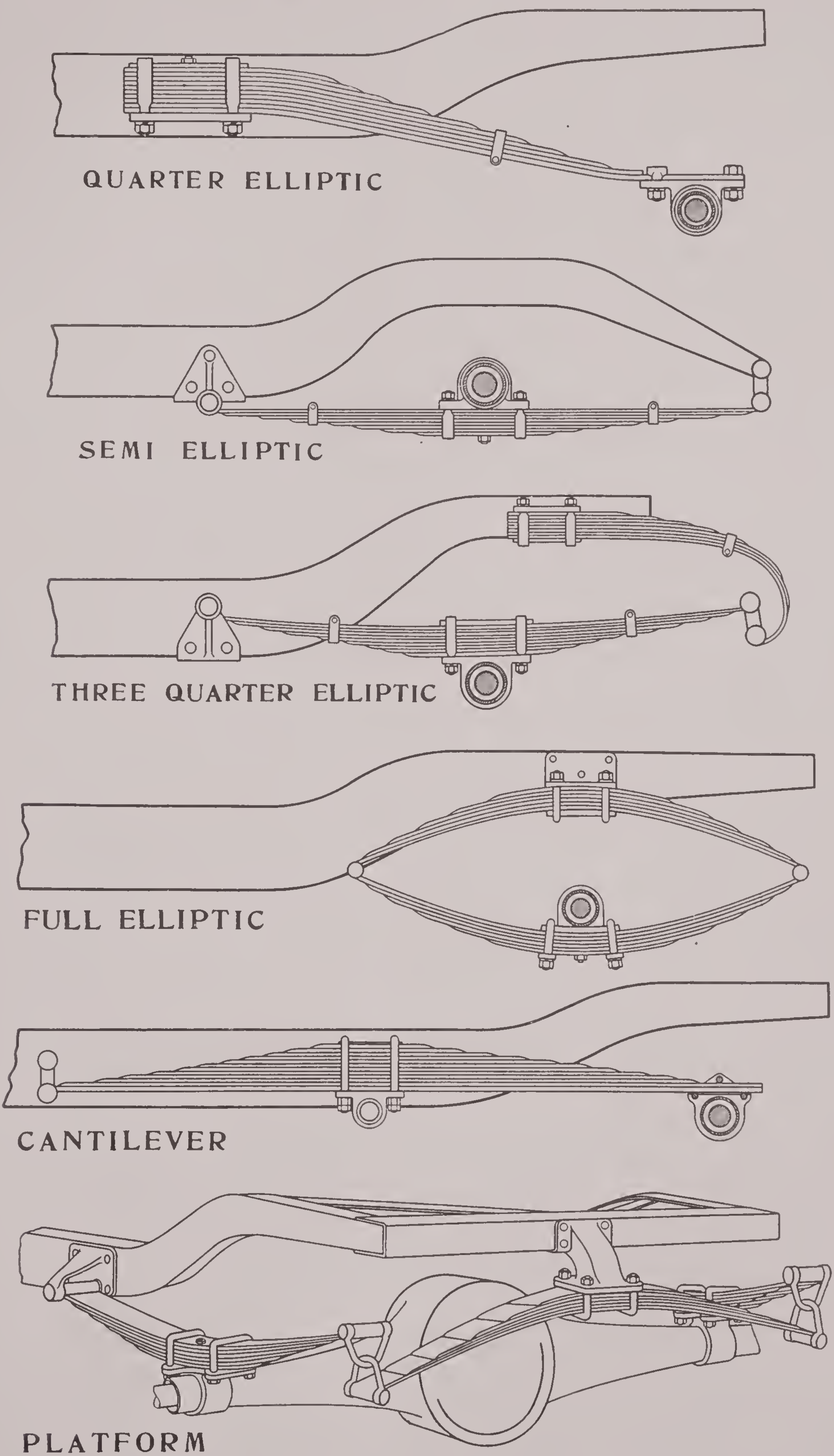


FIG. 143
SPRINGS

tendency to fill the porous surface of the rough steel and stay between the surfaces. The best way to remedy a squeaking spring, caused by rust between the leaves, is to remove the springs from underneath the car, separate the leaves entirely by disassembling the spring and remove the rust with a wire brush, or emery cloth, and kerosene. When assembling them, apply graphite and oil between the leaves. The springs will wear very fast if not lubricated properly.

The ends of the springs have bronze bushings pressed into them to receive the shackle bolt. The shackle bolt is hardened and ground and has a hole drilled in it to admit the lubricant from the grease or oil cup directly onto the bushing. When fitting these bushings and shackle bolts, they should be reamed to a snug fit, so that the bolt can just be pushed in with the palm of the hand without any play.

MUFFLER

The purpose of the muffler is to deaden the noise of the explosion as the exhaust gases escape. Mufflers are of many designs, some having greater tendency than others to hold back the exhaust and cause a back pressure in the exhaust pipe and cylinder. This back pressure being effective on the head of the piston, has a tendency to slow down the engine. Some mufflers are more efficient than others. Carbon from the burned gases accumulates in the muffler, decreasing the area of the openings and causing back pressure.

One common trouble with mufflers is that of internal explosions, which are caused by un-

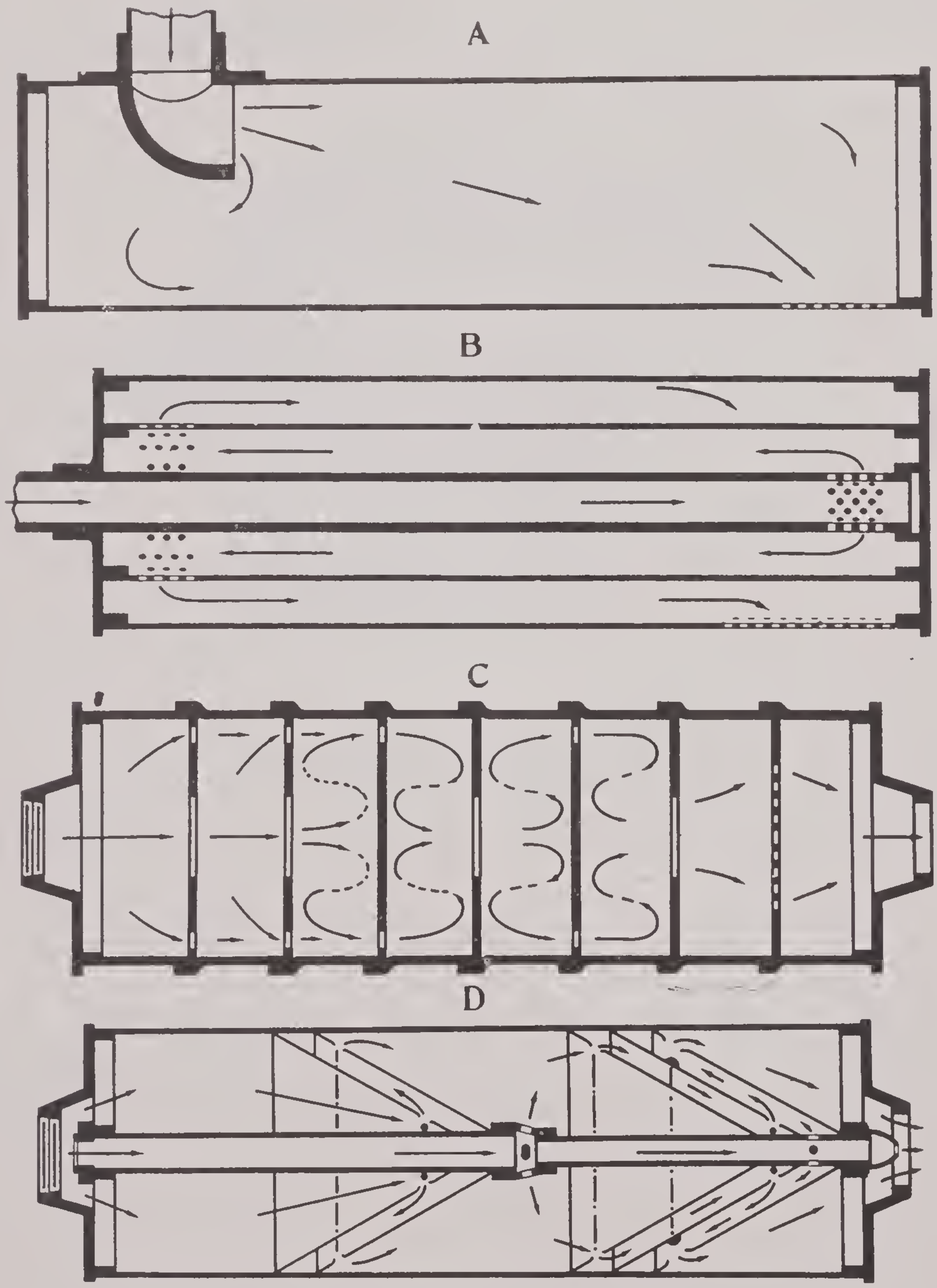


FIG. 144

MUFFLERS

burned gases passing out of the cylinder and gathering in the muffler, where they are ignited by the hot gases passing through. This may be caused by cutting off the ignition and then turning it on again while the engine is still running. Cutting off the ignition when the engine is in operation causes the charge of fuel, which is not burned, to be forced out through the exhaust port into the muffler. When the ignition is turned on again, this gas ignites, often resulting in bursting the muffler.

Mufflers can easily be disassembled by removing the stay bolts and taking the sections apart. Scrape the carbon out, clear the passages and then reassemble.

A cut-out may be provided in the exhaust pipe between the muffler and the engine. It is noticeable that when the cut-out is opened, the engine usually increases its speed due to the reduction of the back pressure in the exhaust pipe. The cut-out is made in various types, but all operate upon the same principle, the function being to provide an opening in the exhaust pipe for the purpose of allowing the exhaust gases to escape with less resistance. The cut-out is usually controlled by a foot lever close to the clutch pedal, which can be left open or closed at the will of the operator.

CARE OF TIRES

Proper care of the tires is necessary to be assured of uninterrupted service and also to keep down expense.

There are certain common sense rules which apply to the proper maintenance of the three main parts of a tire, the casing or body, tread, and tube.

Care of Casing

The casing or body gives strength to the tire as long as the cords or the fabric remain unbroken.

The most common cause of a broken casing is under-inflation. Keep the tires inflated to about eighteen pounds for each inch of tire width on fabric tires, and about fifteen pounds on cord tires.

An average that can be used for fabric tires is as follows:

30 x 3	.55	pounds
30 x 3½	.60	"
32 x 3½	.65	"
32 x 4	.70	"
34 x 4	.75	"
36 x 4½	.80	"
36 x 5	.90	"

For cord tires allow about five pounds less.

Keeping the air in the tires at these pressures results in a good compromise between easy riding and maximum mileage.

When an under-inflated tire is used, the excessive flexing or bending of sides of the casing heats it up and destroys adhesion of the fabric or cord layers. These layers will weaken, then separate and finally break around the inner ply, weakening the side walls and if not immediately repaired, will usually result in a blowout, which sometimes cannot be repaired. If the injury is discovered before anything more than the inner plies are broken, a reliner may be cemented into the casing. If this is not possible, a boot can be placed on the inside to reinforce the side walls at the weak point.

This trouble can be prevented by maintaining the proper air pressure. Test the pressure with a reliable gauge at least once or twice a week.

When driving regularly or when touring, test the pressure every morning. In case of tire trouble on the road, do not drive the car with the tire flat, even for a hundred yards, for the casing will be mashed between the steel rim and the road, and the tube will be cut so that it is practically impossible to properly repair either.

"Fabric breaks" in the casing, caused by under-inflation, may not extend around the tire parallel with the rim, but across diagonally from one rim to the other. An injury of this kind is called a bruise, and it results from sudden shocks when tires strike stones, curbs or holes in the road, when travelling fast. To prevent "fabric breaks," and keep the tires properly inflated, drive slowly over rough roads.

For making roadside repairs of "fabric breaks," use a cord patch or rim cut patch applied with one coat of cement inside, so that it can be removed and a vulcanized repair made later. Another method is to place a boot inside the casing, allowing the edge of the boot to clamp between the tire and rim when mounting.

The tough tread or rubber covering of the casing gives the tire its wearing quality. Though the tread rubber is tough, it may occasionally be cut by some sharp object, such as a stone or a piece of glass. These small cuts should be repaired as soon as possible. If they are neglected, dirt, sand and water will work through them, rotting the casing, and finally cause a blowout. Clean these places and repair with tire putty or by vulcanizing them.

An unusual jolt or strain, caused by bumping a curb, striking a rise or hole in the road or scraping along curbs, may result in misalignment or wobbling of the wheels, or both. Then rapid tread wear results, because the wheel no longer runs true with the one opposite, but instead, travels over the road with a diagonal grinding motion. To check the proper alignment of the front wheels, check the toe-in or gather.

To prevent scraping off the tread, always apply the brakes gradually. When the brakes are applied suddenly, they may lock and the tires be dragged over the pavement or roadway for several feet.

The brake bands on both wheels should be adjusted equally, otherwise all the work of stopping the car is done by the wheel with the tighter brake, causing the tire on this wheel to be subjected to abnormal wear.

Engaging the clutch too suddenly is another cause of worn treads, causing the tires to spin before obtaining a grip on the road surface.

When the rubber on the side walls of a tire is scraped off by ruts or curbs, the cord or fabric underneath will soon rot if exposed to the dirt and moisture. Repair small side wall cuts while still new by vulcanizing or with tire putty.

Apply chains loosely, because if applied too tightly, the cross chains strike the tire always at the same spot and will soon cut into the tread.

If chains are applied on one wheel only, it will cause the other to spin and its tire to wear excessively.

Do not reverse the chains by putting the worn side next to the tires, as the edges of the chains, sharpened by use, will cut into the tread. Remove chains as soon as possible after the emergency for which they were applied is passed.

Always protect tires as much as possible from excessive heat and light, both of which tend to harden the tread and make it wear more rapidly.

Spare casings should be carried in tire covers.

Do not let the tires stand in oil on the garage floor, as oil and grease cause the tread to rot, stretch and pull loose. Use gasoline to remove the oil and grease.

Driving on car tracks is not advisable, due to the fact that only a portion of the tread of the tire runs on the rail and supports the load. A groove is worn around the tread where the edge of the track comes in contact with the tire, and the casing underneath is weakened. The car rails are frequently splintered by continued hard use and these splinters or the rough edges of the rails may easily cause bad cuts or punctures.

Keep the spare tubes protected. They will become unfit for service by jostling around in their cardboard container, or by being loose in the tool box. The tube may become cut by sharp objects in the tool box, or may rot as a result of contact with oil and grease. Fold the tubes, dust with soapstone or French Talc, then wrap them in a cloth or place in a tube bag to prevent depreciation.

When applying a tire, see that there is no dirt or rust on the rim. Examine the inside of the casing for fabric breaks, nails, dirt, or other foreign matter which may injure the tube.

Dust the inner surface of the casing with mica, soapstone, or French Talc to reduce friction between the tube and casing. Do not use too much of these powders, as they will cake in one spot and chafe the tube.

Inflate the tube slightly and place it straight in the casing, making sure that the flap, if used, is not old and covered with rust. See that the tube does not slip under the bead so that it will be pinched between the bead and rim. When using tire irons, be sure that they are smooth.

Valve leaks can be largely prevented by screwing the valve caps on tightly after inflating or testing the tubes. The cap keeps out dirt and assists in holding the air in, should the plunger leak.

CARE OF CAR IN STORAGE

Wash and polish the body and cover it with a tarpaulin to prevent the dust, oil and light from marring the finish.

Drain the water from the cooling system.

Remove the spark plugs and pour two or three tablespoonfuls of clean cylinder oil into each cylinder.

Clean the plugs, dip the ends in oil and replace in the cylinders, after which crank the engine for twenty or thirty seconds with the ignition off. As the starter spins the engine, the oil is distributed over the cylinders, valves, etc., preventing rust.

Exposed and unpainted metal parts of engine, body, and chassis should be well greased with vaseline to prevent corrosion and rusting. This can be removed with gasoline before putting the car back in service.

Tires that are out of service for any length of time should be removed from the rims. The inner tubes should be put in the casings, partially inflated, and the tires stored in a moderately heated room away from the light, or the tires may be left on the rims, partially inflated and the car jacked up so that no weight is allowed to rest on them.

SUMMARY

BEARINGS

Types:

Babbitt bearing.
Bronze bearing.
Plain roller bearing.
Tapered roller bearing.
Flanged roller bearing.
Cup and cone bearing.
Single Row annular bearing.
Double Row annular bearing (rigid).
Ball thrust bearing.
Plain thrust bearing.

Strains

The babbit or bronze bearing, governed by its mounting, will carry both thrust and radial load.

The plain roller bearing is designed to carry radial load only and is slightly adjustable.

The tapered roller bearing is designed to carry both thrust and radial loads and is adjustable.

The flanged roller bearing is designed to carry both thrust and radial load and is slightly adjustable.

The cup and cone bearing is designed to carry both thrust and radial loads and is adjustable.

The single row annular bearing is designed to carry radial load, but governed by it's mounting, may carry radial only or radial and some thrust. It is not adjustable.

The double row annular bearing is designed to carry both thrust and radial loads, governed by its mounting—not adjustable.

The ball thrust bearing is designed to carry thrust load only and is adjustable.

The plain thrust bearing is designed to carry thrust load only and is adjustable.

Thus (not considering the bronze and babbit), there are seven bearings that will carry some thrust load.

Six of these bearings will carry some radial load, the ball and plain thrust bearings being exceptions. Five of them will carry some thrust and radial load, the plain roller, ball and plain thrust bearings being exceptions in this case.

Three of these bearings will carry both thrust and radial load.

FRONT AXLES

Types:

Tubular.
I-Beam.

The purpose of the **caster effect** in the front axle mounting is to reduce vibration and steering strains, and produce a "trailing" action that will cause the car to follow the road more easily.

The purpose of the **steering knuckle** is to provide a movable mounting for the front wheel, that will permit its turning to control direction in which the car travels.

The steering knuckle is controlled by the knuckle arm, acting through the knuckle thrust arm, which is controlled by the thrust rod or connecting rod from the steering device.

The purpose of the **pivot bolt** or pin is to provide a swivel mounting for the steering knuckle in the axle yoke, to permit turning of the spindle for steering.

The purpose of the **camber** of the front wheels is to reduce the distance from the point of wheel contact on the road to the center line of the pivot bolt, bringing the arc of wheel travel, when steering, nearer the axis of the bolt. This reduces steering strain, since the strain that has to be overcome by the driver, acting through the steering device, is the friction of the tires on the road multiplied by the distance traveled by the wheel around the axis of the pivot bolt. Camber also reduces wear on tires.

The amount of **camber** is governed by the wheel mounting and diameter of the wheel.
The camber is not adjustable. The approximate camber for large cars will be from 1° to 2°, on medium size cars 3°, and on small cars from 4° to 5°.

The purpose of **"toe in"** or **"gather"** is to counteract the tendency of the front wheels to roll outward or pull apart in front, due to the camber.

The toe in or gather is adjustable. When the tie rod is located behind the axle, to increase the gather, lengthen the tie rod; to decrease it, shorten the tie rod.

When the tie rod is located in front of the axle, to increase the gather, shorten the tie rod; to decrease it, lengthen the tie rod.

The amount of gather is governed by the amount of camber. On the average large car, allow 1/4″ gather, on the medium size cars, allow 5/16″, and on the smaller cars, allow 3/8″.

Thus:

Camber	Gather
1° - 2°	$\frac{1}{4}$ inch
3°	$\frac{5}{16}$ inch
4° - 5°	$\frac{3}{8}$ inch

The purpose of the tie rod is to connect the steering knuckle arms and adjust the gather.

To check the alignment of the knuckle arms on the average car, two lines drawn, one through the center of each knuckle arm, should cross approximately in the center of the rear axle.

Thus, the angle at which the knuckle arm is set is governed by the wheel base of the car, and the angle of the knuckle arms governs the difference in travel of the two spindles around their axes, which in turn governs the distance required to make a complete turn, or the turning radius.

To prevent play developing between the steering arm of the steering device and the front wheels, it is necessary to adjust and lubricate the following: the ball and socket joints of the thrust rod, the tie rod and knuckle arm connections, the pivot bolt, the steering knuckle, and the front wheel mountings on the spindle.

If these different points are not properly adjusted, the wheels will have a tendency to wobble. Sometimes the wheels wobble even though these different points are properly adjusted. This is caused by the wheels becoming sprung or warped. This can be remedied by straightening the wheels under a press or by replacement.

STEERING DEVICES

Types:

Reversible — Planetary.
Reduction Gear.
Irreversible—Worm and Wheel.
Worm and Sector.
Split Nut or Jay-Cox.
Worm and Nut.
Worm Screw and Nut.

Adjustments:

Planetary—No adjustment.
Reduction Gear—No adjustment.
Worm and Wheel—Three adjustments.
Worm and Sector—Two adjustments.
Worm and Nut—One adjustment.
Jay-Cox or Split Nut—One adjustment.
Worm Screw and Nut—One adjustment.

CLUTCHES

Types:

Cone:
Disc: { Lubricated / Dry } } Single Spring. / Multiple Spring.
Plate.

The purpose of the **clutch spring** is to hold the driving and driven members together when the clutch is engaged.

The purpose of the **clutch brake** is to stop the revolving driven member after the clutch is disengaged, thus allowing easier shifting of the transmission gears.

The purpose of the **facing springs and plungers** is to force the facing away from the cone when the clutch is disengaged. This helps to make a smooth and gradual engagement of the clutch.

There is no function of the springs and plungers after the clutch is engaged.

Clutch Troubles:

Slipping.
Grabbing.
Spinning.
Dragging.
Stuttering.

Cone and Dry Disc Type

Slipping: Spring tension weak; worn clutch facing; warped cone; oily or greasy facing; clutch shaft out of line; release mechanism out of adjustment.

Remedy: Increase spring pressure; renew facing; replace cone; clean facing with kerosene, temporarily apply Fuller's Earth or talc; replace bearings; check up operating mechanism.

Grabbing: Too sudden engagement; rivets exposed; facing dry and hard; facing springs improperly adjusted; excessive spring tension. Remedy: Engage more gradually; countersink rivets; renew facing or clean and roughen with emery cloth and apply Neat's foot oil; adjust facing springs; relieve spring tension.

Spinning: Examine the condition of the clutch brake.

Dragging: Lubricate the tail shaft.

Check up clutch operating mechanism to see that it permits full release of clutch.

Stuttering: Replace the radial bearing, or adjust the clutch release fork.

Lubricated Disc

Dragging: Caused by heavy or gummed oil. Remedy: If the clutch is lubricated individually, add about one-third the amount of kerosene to the clutch oil or use a lighter oil. If the clutch is lubricated from the engine, drain the oil, clean the clutch with kerosene and replace with the correct grade of oil recommended for the engine. Never add kerosene.

TRANSMISSIONS

Types:

Progressive.
Selective.
Planetary.

There are eight gears in the standard three speed forward and one reverse selective or progressive transmission.

The progressive transmission has a lock on the shifting lever that locks it in the different positions. This prevents the sliding gears from working into or out of mesh.

In the progressive transmission the two sliding gears are integral and the gears are so spaced in the transmission that it is impossible to have both sliding gears in mesh at the same time.

The selective transmission is equipped with a gear lock and sometimes an interlocking device. The purpose of the interlocking device is to prevent the shifting of two sets of gears into mesh at the same time. The purpose of the gear lock is to lock the shifting bars and sliding gears, thus preventing the gears working out of or into mesh due to vibration.

To determine the engine end of a transmission, place the shifting lever in low, second or reverse, and turn either one of the projecting shafts, which will result in driving the other. The shaft that revolves the faster will be the clutch shaft or engine end.

When checking the alignment of gears and shafts, always check from the transmission drive or clutch gear.

In a selective or progressive transmission with three speed forward and one reverse, when driving in low, there are six gears in mesh and the power is transmitted through four. When driving in second, there are six gears in mesh and the power is transmitted through four. In reverse, there are five gears in mesh and the power is transmitted through five. When driving in high, there are four gears in mesh, and power is transmitted through the high speed dogs or the internal clutch gear.

To determine the gear shift arrangement of any three speed forward and one reverse selective transmission, place the shifting lever in different positions until reverse is obtained. Always on the same side, but on the opposite end, will be low, and diagonally across from low is second, on the same end as reverse. On the same side as second, but on the opposite end, is high.

On the Ford planetary transmission, there are always twelve gears in mesh. When the gears become worn, the transmission is very noisy, due to the numerous gears not being in proper mesh.

When driving in low or reverse, the power is transmitted through the triple gears, which revolve on their axes. There is no power transmitted through the tail shaft.

When driving in high, the power is transmitted directly through the tail shaft and clutch discs. There is no power transmitted through the triple gears.

When assembling the clutch discs, always begin and end with a large or driven disc. That is, place a large disc in the brake or driving drum first, then a small one, then a large one, and so on alternately, ending with a large disc, after which place the push ring against the last large disc.

When assembling the triple gears, use care to see that the gears are properly meshed. The teeth on the three triple units are in line at three points and are usually marked at one of the points on the twenty-seven tooth gear. Mesh the marked point of the twenty-seven tooth triple gear with the twenty-seven tooth driving gear, and exactly nine teeth each side of that point, mesh the two remaining sets of triple gears according to marks. This places the three sets of triple gears at equal distances of 120°.

When starting in low or reverse, allow the revolving drums to slow down gradually as the band is compressed around the drum. This friction lined band acts as a clutch to provide flexibility for starting by allowing a certain amount of slippage. If these bands are applied too suddenly, the car will jerk when starting, the same as when the clutch is engaged too quickly on any car. Grabbing may be caused by the rivets being exposed, the facing being hard or adjusted too tightly, or the drums being rough.

Slipping may be caused by the facings being worn, or the bands being adjusted too loosely. The brake and reverse bands should be adjusted so that the foot pedal can move one-third forward before the band comes in contact with the drum. This is to prevent dragging and wearing of the facing and drum when the pedal is all the way back. When the foot pedal is pressed two-thirds the way forward, the band should be contracted enough to stop the drum from revolving. This same adjustment will hold true on the low speed band and drum, except that the band should be adjusted to contract and stop the revolving of the drum about three-fourths the way forward. To adjust the brake and reverse bands, the transmission cover plate will have to be removed. The low speed band can be adjusted from the outside.

Due to the construction of the transmission, two units will revolve, unless both engine and rear wheels are stationary. If the engine is running and the rear wheels are stationary, the stationary twenty-seven tooth driven gear will drive the triple gears on their axis, and this will drive the low and reverse drums around idle inside the bands. If either the low or reverse drum is held stationary, the twenty-seven tooth driven gear will revolve and drive the rear wheels. If the engine is not running and the rear wheels revolve, the twenty-seven tooth drive gear will drive the drums through the triple gears.

The purpose of the clutch lever screw that rides on the clutch lever cam is to adjust the neutral position of the clutch. That is, if this screw becomes worn, when the hand lever is pulled half way back, the clutch shifting collar will not be moved back enough to disengage the clutch. To remedy this, turn the screw inward at the cam until neutral is obtained.

If this screw is turned down too much, when the hand lever is moved all the way forward the cam screw may still ride on the cam and prevent the full engagement of the clutch, which will cause slippage. To remedy this, loosen the screw at the cam.

If the clutch slips, increase the spring pressure with the clutch spring adjusting screws in the clutch fingers. The purpose of the connecting link is to adjust the clutch pedal so that it corresponds with the hand lever movement. That is, when the hand lever is all the way forward, the clutch pedal should move all the way back. When the hand lever is half way back, the clutch pedal should not move forward to the extent that the band will hold the drum stationary. If this occurs, it will be difficult to obtain neutral.

If the controls are properly adjusted and the clutch still drags or neutral cannot be obtained, the most probable cause is that the oil is too heavy or is gummed. To remedy this, clean the clutch with kerosene and replace with the correct oil for the engine. After using kerosene, remove the oil pan and all traces of kerosene.

Planetary Transmission and Clutch Adjustments

There are three points of adjustment on the transmission—the three transmission bands. There is one replacement on the transmission—shims or a new bushing between the brake or driving drum and the disc or clutch drum. This is to overcome end play. There are five points of adjustment on the clutch—the three clutch fingers or the spring adjustment screws, which are all for the same adjustment, the clutch lever adjusting screw at the cam and the connecting link. There are eight points of adjustment on the transmission and clutch.

UNIVERSAL JOINTS

The purpose of the **universal joint** is to transmit a revolving motion through shafts set at an angle with each other.

The purpose of the **flexible joint** is to transmit a revolving motion through shafts set at an angle with each other, and to cushion the shocks and reduce vibration. The construction of the flexible joint will permit of only a limited angle between the two shafts.

The purpose of the **slip joint** is to compensate for the variation in distance between the rear axle and the transmission, caused by the movement of the springs when driving.

TORSION STRAINS

The purpose of the torque tube or rod is to brace the axle mounting against the tendency to revolve around its own axis when power is applied, thus preventing the torque strain from being thrown on the springs.

When no torque tube or rods are used, the torque is taken by the springs and mountings and it is called a Hotchkiss drive.

DIFFERENTIAL

The purpose of the differential is to transmit the power from the drive or pinion shaft to the axle shafts and to both rear wheels equally, depending upon the resistance offered, and at the same time to permit the wheels revolving independently when the car is turning a corner.

Differential Action

When driving straight ahead with both tires of the same size and inflated to the same pressure, each wheel will offer the same resistance, and for every revolution of the ring gear, each wheel will make a full revolution.

When making a turn, the inside wheel offers the more resistance to the spider gears, which will cause the outside wheel to travel faster. If one wheel is held stationary, the other wheel will be driven twice as fast as the ring gear. If the ring gear is held stationary and one wheel is moved forward, the other wheel will be driven backward at the same speed.

REAR AXLES

Types of live axles:
- Plain live axle.
- Semi-floating axle.
- Three-quarter floating axle.
- Full floating axle.

Types of axle housings:
- Divided housing.
- Bell type housing.

Types of final drives:
- Bevel gear.
- Worm gear.
- Chain drive.
- Internal gear.

Types of final drive gears:
- Straight tooth bevel.
- Spiral tooth bevel.
- Worm.

Clearance between the teeth of the ring and pinion gear:

Both gears new, allow .012″ clearance.

Both gears old, allow .006″ clearance.

One old and one new gear, allow .008″ clearance.

Too much clearance will cause clattering of the gears.

Insufficient clearance will cause growling gears.

There should not be more than .002″ end play in differential mounting.

The ring gear should always be mounted on the left side of the pinion gear. If it is mounted on the right side, there are three speeds reverse and one forward.

SPRINGS

One-quarter elliptic.
Semi-elliptic.
Three-quarter elliptic.
Full elliptic.
Cantilever.
Platform.

BRAKES

Inner, (hand operated), expanding.
Outer, (foot operated), contracting.

Brake Troubles:

Dragging, Slipping, Sticking, Chattering, Squeaking.

PRECAUTIONS AND DON'TS

Don't use pliers as a substitute for a wrench.

Don't use a cold chisel for removing a nut.

Don't "choke" a hammer, by grasping it too far up on the handle.

Don't bear down on a file or hacksaw on the back stroke.

Don't wipe the filings off the work with your hand.

Don't allow a drill to become hot when sharpening.

Don't use a monkey wrench for a hammer.

Never draw a monkey wrench away from the jaws, but towards them.

Keep your tools orderly arranged.

Don't use a tap or die without oil—except on brass and copper.

Don't grind one lip more than the other when sharpening a drill.

Don't turn a drill or reamer backwards.

Always run an expansion reamer all the way through the hole.

Always see that bearings are perfectly clean before mounting.

Don't fit bearings so tightly that they will bind.

Don't fit bearings so loosely that they will pound.

Don't drive a bearing into its mounting.

Always remove the sharp edge of a bushing before pressing it into the hole.

Always remove the sharp edges of the hole before pressing the bushing into it.

Keep the front wheels adjusted. Examine the thrust rod and the tie rod connections occasionally.

Don't turn the steering wheel unneccessarily when the car is stationary.

Don't assemble a Jay-Cox steering gear with the half nuts transposed.

Don't engage the clutch too quickly.

Keep your foot off the clutch pedal when driving.

Don't slip the clutch unnecessarily.

Don't run a lubricated type clutch without the proper lubrication.

See that the facing rivets are properly countersunk on the cone and dry disc clutch, as well as on transmission and brake bands.

Don't try to shift the gears in or out of mesh without first disengaging the clutch.

Don't speed up the car too much before shifting into high.

Don't overload the engine by trying to make a hard pull in high. Shift to a lower speed.

Always know the position of reverse before shifting into the different speeds.

On a selective transmission, when shifting from a low to a higher speed, accelerate the car, disengage the clutch, allow the clutch brake to slow down the counter shaft for an instant, shift the gears into mesh and engage the clutch.

When shifting from a higher to lower speed, disengage the clutch and shift the gears into mesh, then again engage the clutch.

Never shift into reverse without allowing the car to come to a stop.

Don't press on the low or reverse pedal of a Ford car too quickly. Force the pedal forward slowly until a movement is started, then hold it all the way down.

Always see that the pinion shaft and differential adjustments are properly locked.

Don't drive with the tires under-inflated.

Keep the shackle bolts lubricated and the shackles tight.

Don't apply the brakes too severely.

Never drive a car without testing the brakes.

Don't use one brake continuously.

When coasting down a hill, alternate or use the compression of the engine.

See that the brakes are equalized, especially if the road is slippery.

Don't take chances unnecessarily.

DRIVING

Complete control of the car while driving is necessary at all times to prevent accidents.

To have this complete control requires confidence in yourself and the car. This can only be obtained by knowing the car and its mechanical appliances thoroughly.

The various parts of the car, such as the engine, clutch, brake, etc., must be in perfect working order and sensitive in action for perfect control.

The driver should be positive that there is sufficient oil in the engine, transmission and rear axle, also sufficient water in the radiator. In cold weather, a non-freezing compound should be mixed with the water in the radiator. See that there is sufficient gasoline in the tank. The tires should be inflated to the proper pressure.

The gear shift should be thoroughly understood so that the driver will not shift the gears into the reverse speed with the car still moving forward, as this will break the teeth of the transmission gears.

If the gear shift is not known, it can be determined by the following method: Allow the engine to run slowly, disengage the clutch, move the gear shift lever into one position after the other, each time engaging the clutch, until the reverse speed is found. Low will be on the same side, but on the opposite end, second speed will be on the same end as reverse, but on the opposite side, while third speed will be on the same side as second, but on the opposite end. This rule applies to the three speed selective transmissions of modern automobiles and trucks. After the driver understands the gear shift, it is necessary to learn to control the clutch correctly. It must be prevented from grabbing suddenly, thereby spinning the tires on the road, breaking the propeller or axle shaft, or stripping the teeth of the transmission or differential gears. Again, if the clutch is allowed to slip too much when racing the engine, the clutching surfaces will be badly worn and require repairs.

The purpose of the clutch is to disengage the engine from the transmission while shifting the gears into the different speeds and neutral. It also permits the power to be engaged gradually after the gears are in mesh.

To start the car, allow the engine to run at a moderately low speed, then disengage the clutch and shift the gears into low, after which gradually engage the clutch, feeding gas a little at the same time to prevent the load from stalling the engine. This will cause the car to gain momentum. When the clutch is fully engaged, the speed of the engine should then be increased, as it will eliminate unnecessary slippage when shifting the gears from low to second speed.

To change from low to second gear: As the clutch is disengaged, allow the engine to slow down again, shifting the gears from low to second and engaging the clutch gradually without speeding the engine but feeding gas a little at the same time. When the clutch is fully engaged, the engine should be speeded up.

Before changing the gears from second to high, it is again necessary to slow down the engine as the clutch is disengaged. After the gears are changed, engage the clutch. When the clutch is fully engaged, the car may be driven at the various speeds by controlling the speed of the engine. If the car will not pick up in speed after being slowed down, shift the gears to the lower speeds in preference to speeding the engine and allowing the clutch to slip. Never start the car in the intermediate or high speeds from a dead stop, as this causes too much slippage of the clutch. This is one of the reasons for equipping the car with the low speed gearing. Do not shift the gears into the lower speeds while the car is moving at a speed not requiring the use of the low speed gears. This can be accomplished only by increasing the speed of the engine to prevent the clattering of the gears.

After the driver has mastered the operation of the car, it is necessary to become familiar with the rules and regulations of traffic, as drivers must govern themselves accordingly. With this knowledge, one may know what to expect of other drivers, though allowance must always be made for reckless drivers who do not follow or respect these rules.

In driving the car, allow sufficient distance between your car and the one ahead, or at the side. Do not drive too close to the curb or the side of the road, because if it should be necessary to stop suddenly, there should be space enough to maneuver the car without bumping other cars. When passing another car, always pass upon the left side, and only after a warning signal has been sounded. In turning into a side street, or when stopping the car, the driver should indicate this by a signal of the hand.

The driver should always endeavor to protect the car and its accessories while driving. He should strive not to drive in the car tracks, or rub the tires on the side of the curb while stopping, as this will wear and tear the plies of fabric, thereby subjecting the tires to unnecessary damage.

Accelerating the car too suddenly when not necessary, driving with the spark too far in advance or retard, or operating the car with the mixture too rich or too lean, causes a loss of fuel and power.

The driver should study the car and its capabilities with respect to efficiency and economy, as this will give greater mileage and will save fuel, oil and tires. Any repairs necessary should be taken care of at once, and properly done by mechanics thoroughly familiar with the construction of the car. Neglect will cause unnecessary wear and greater expense.

QUESTIONS

1. Name the different types of bearings used in the chassis and final drive.
2. How tightly should a bearing be fitted on a shaft and in a housing?
3. Is it advisable to replace one new ball in a ball bearing?
4. Is it advisable to carry thrust strains on a single row annular ball bearing?
5. How tightly should a cup and cone or tapered roller bearing be adjusted?
6. How many bearings are designed to carry some thrust load?
7. How many bearings are designed to carry some radial load?
8. How many bearings are designed to carry both thrust and radial load?
9. How many bearings are designed to carry both thrust and radial load and are adjustable?
10. Name the types of front axles.
11. What material is used in axle construction?
12. By what two points and how is the alignment of the front axle checked?
13. What is the purpose of the caster construction of front wheels and how is it obtained? Is it adjustable?
14. What is the purpose of camber?
15. What governs the amount of camber?
16. What is the purpose of the toe-in or gather of the front wheels?
17. How is the gather measured?
18. How should the gather be adjusted?
19. About how much camber will a medium sized car have and how much gather should be allowed?
20. How is the alignment of the steering arms proven?
21. When making a turn to the left, which wheel swings through the greater angle? Which wheel travels the greater distance?
22. Why can a quicker turn be made with a car having a short wheel base than with a long wheel base?
23. What will cause a front wheel to wobble?
24. How can this be remedied?
25. Name the different types of steering devices.
26. How many adjustments on a worm and wheel steering device?
27. What is the purpose of the eccentric bushing?
28. What two precautions should be observed when assembling a Jay-Cox or split nut steering device?
29. What is the cause if, after assembling a Jay-Cox or split nut steering gear, the steering wheel is turned to the right and the car moves to the left?
30. How is this trouble remedied?
31. What is a planetary gear set?
32. Explain the action of the planetary steering device.
33. When the steering wheel of a Ford steering gear is turned one-half revolution, how many degrees will the steering arm revolve?
34. How many adjustments are there on a Ford planetary steering device?
35. What is the purpose of a clutch?
36. What are the different types of clutches?
37. How many types of cone clutches are there?
38. What advantages has the multiple spring over the single spring cone clutch?
39. How much tension is required on any clutch spring?
40. What is the purpose of the facing spring plungers?
41. Is there any function performed by the spring plungers on a cone clutch, when the clutch is fully engaged? Disengaged?
42. What advantages has the lubricated type disc clutch over the dry type?
43. What is the main objection to a lubricated type clutch?
44. Name the five common clutch troubles.
45. What are the two most probable causes of a slipping cone clutch?
46. What is a temporary remedy for a slipping cone clutch caused by an oil-soaked facing?
47. How is a grabbing cone clutch in which the facing has just been replaced remedied?
48. What is the most probable cause of a dragging cone clutch?
49. How is a dragging lubricated type clutch remedied when the clutch is lubricated from the engine?
50. What is the most probable cause of a stuttering clutch?
51. What is the purpose of the clutch brake?
52. Name the types of transmissions.
53. What is the principal difference in construction between the progressive and selective transmissions?
54. What is the standard number of gears for a three speed forward and one reverse progressive or selective transmission?
55. When driving in low speed how many gears are in mesh?

56. When coasting down hill with the gear shift lever in second speed and the clutch disengaged, how many gears in the transmission are revolving?

57. When the car is standing with the engine running, the clutch engaged and the gear shift lever in neutral, how many gears are revolving?

58. What prevents the shifting of two sets of gears into mesh at the same time on a car with the ball and socket gear shift lever?

59. What holds the gears in mesh on a car with an "H" plate gear shift?

60. What prevents the shifting of two sets of gears into mesh at the same time on a progressive transmission?

61. How is the engine end of a transmission determined?

62. Suppose that the second speed gears will not stay in mesh in a selective transmission, how can this be remedied?

63. When driving a Ford car in low gear, is there any pulling strain on the tail shaft?

64. Will the triple gears be rotating on their axes?

65. When driving in low gear and the flywheel makes one revolution, what part of a revolution does the drive shaft make?

66. How many revolutions of the flywheel are necessary to complete one revolution of the drive shaft when driving in low gear?

67. When driving in high gear, is there any pulling strain on the triple gears?

68. Will the triple gears be rotating on their axes when driving in high?

69. Looking at the rear of the transmission, in which direction do the triple gears rotate on their axes when driving in low? In reverse?

70. How many points of adjustment are there on the Ford planetary transmission?

71. How many points of adjustment are there on a Ford clutch?

72. How is the tension of the Ford clutch spring increased?

73. If the hand lever of a Ford car is pulled half way back and the clutch is not disengaged, how is this trouble remedied?

74. How is end play in a Ford planetary transmission overcome?

75. What are the purposes of the universal joint, flexible joint and slip joint?

76. What is the purpose of a differential?

77. Which rear wheel offers the more resistance to the spider gears when making a turn, the inside or outside?

78. If the left wheel is held stationary and the right wheel turned forward four revolutions, how many revolutions will the ring gear make and which way will the spider gears rotate on the spider?

79. Suppose the right wheel is held stationary while the ring gear is turning forward two revolutions. How many revolutions will the left wheel make and in which direction will the spider gears rotate on the spider?

80. When making a turn to the left, in which direction do the spider gears rotate?

81. If, after assembling an axle, there are three speeds reverse and one forward, what is the trouble?

82. Name the types of rear axles and explain the mounting of the bearings and the strains carried by the axle shafts.

83. How many types of axle housings are there?

84. What is the advantage of a spiral cut bevel gear over a straight tooth bevel gear?

85. What is the most probable cause of a slipping brake?

86. How is a chattering brake remedied?

87. What will cause a brake to stick?

88. How are squeaking springs remedied?

89. What will be the result if the brakes are not adjusted evenly?

90. Would it be advisable to remedy a noisy brake by applying lubricating oil on the facing?

91. What is the trouble if the brakes are adjusted properly when the wheels are off the ground and the brakes drag when the wheels are on the ground?

ELEMENTS OF ELECTRICITY AND IGNITION

MAGNETISM

Magnetism is the property that enables a magnet to attract iron and steel. The word magnetism is derived from "Magnesia," the name of a province in Asia Minor, where it is thought magnetism was first discovered. Here the ancient Greeks found a peculiar iron ore which possessed the property of magnetism. This ore is called magnetite, sometimes lodestone. Lodestone means "leading stone" and the ore was so named because use was made of it to guide ships at sea. An elongated piece of lodestone freely suspended comes to rest so that a certain point is toward the north and another point is toward the south. Lodestone is a natural magnet.

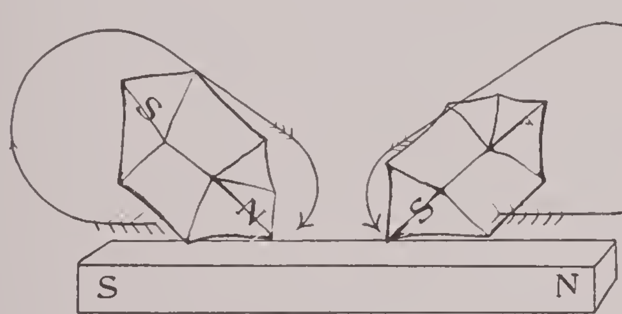


FIG. 201

Artificial Magnet

A piece of iron or steel when stroked with a piece of lodestone becomes magnetized. See Fig. 201. Magnetized bars of iron or steel are called artificial magnets. Magnets made by magnetizing hardened steel are called permanent magnets because hardened steel remains magnetized indefinitely. Only thin bars of hardened steel can be magnetized with lodestone; the larger bars are magnetized with strong electro-magnets, which will be described later.

Magnetic Materials

There are only a few materials which a magnet will attract, or which can be magnetized. Such materials are called magnetic materials. Only iron and steel are magnetic to a degree of practical importance and are usually thought of as the magnetic materials. Nickel and cobalt are slightly magnetic. Bismuth is repelled by a magnet instead of attracted. It is said to be diamagnetic.

Non-Magnetic Materials

Materials which cannot be magnetized and which are not attracted by a magnet, are called non-magnetic materials. Examples:—Copper, bronze, aluminum, glass, rubber, etc.

Poles

The points of strongest attraction on a magnet are called the poles. (See Fig. 202.) The pole that always seeks the north, when the magnet is suspended free to turn, is called the north pole and the pole that seeks the south is called the south pole. Every magnet has at least one north pole and one south pole.

FIG. 202

Either pole of a magnet attracts unmagnetized iron or steel with the same force. That is, the north pole of a magnet will lift as much as its south pole, or vice versa.

The strength of a magnet's attraction is inversely proportional to the square of the distance from its poles. That is to say, a magnet will attract a piece of iron 1/4″ from its poles with four times the force that it will attract the same piece of iron 1/2″ from its poles.

Law of Attraction and Repulsion

Like poles repel, unlike poles attract. Repulsion is illustrated in Fig. 204 and attraction in Fig. 205.

Magnetic Lines of Force

The exact nature of magnetism is not known. Magnetism is thought to flow along lines, called magnetic lines of force, which extend from pole to pole of a magnet. The space surrounding a magnet through which the lines of force are said to flow is called the "magnetic field." The extent of this field is indefinite. However, the field becomes so weak as the distance from the magnet increases, that it soon becomes scarcely perceptible.

The lines of force in a magnetic field can best be shown with iron filings. Place a piece of glass (or a cardboard) over a magnet and then sprinkle iron filings on it. As the iron filings drop upon the glass, they become aligned along the magnetic lines of force so

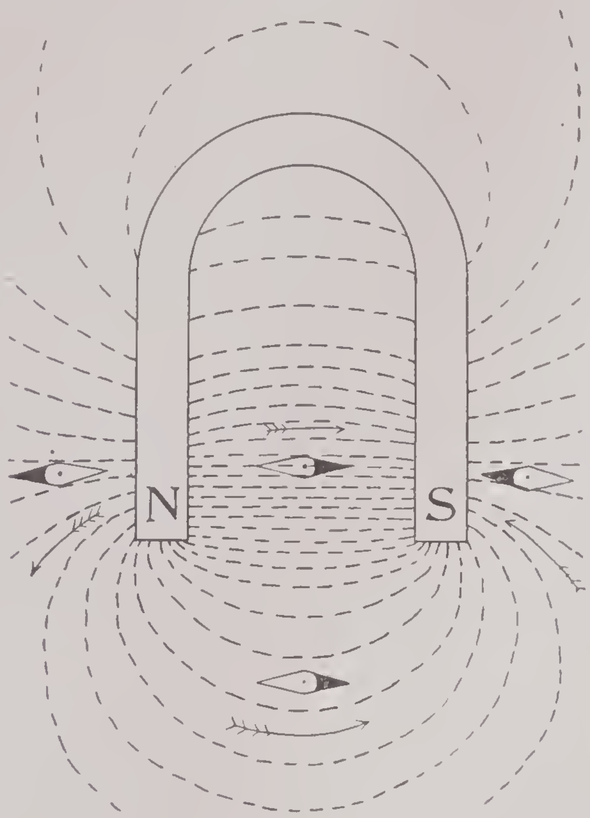


FIG. 203

that the lines are plainly shown. By shifting the glass to various positions with relation to the magnet, the lines of force forming different parts of the field can be shown.

A compass needle, when placed in a magnetic field, always points from the north pole of the magnet and to the south pole. For this reason, magnetic lines of force are said to flow out of the north pole, and through the magnetic field to the south pole. The total number of

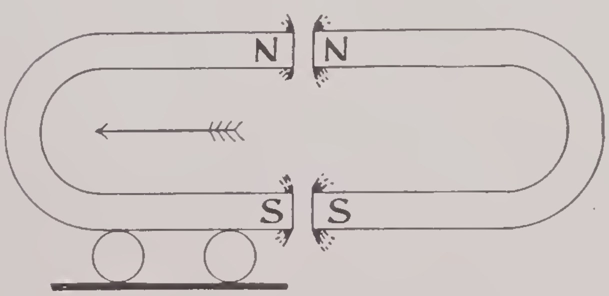


FIG. 204

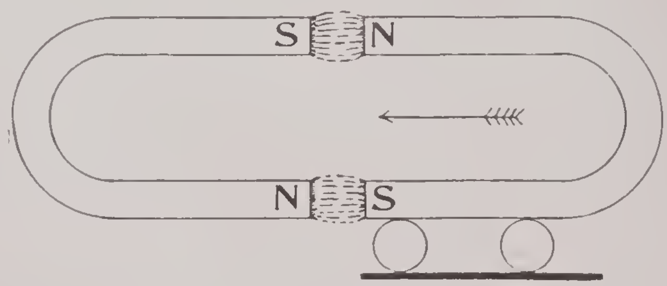


FIG. 205

these magnetic lines makes up what is called the magnetic flux. Fig. 203 shows the conception of a magnetic field set up by a horseshoe magnet.

The stronger the magnetic field the more magnetic lines of force are set up and the closer they are crowded together. Since the magnetic lines of force are crowded closely together in a strong field, a strong field is properly called a dense field. The magnetic field is densest around the poles of the magnet.

When a magnet is broken, each of the pieces becomes a magnet. If the pieces are arranged in the order shown in Fig. 206, the magnetic lines of force flow in at the end of the piece that was the south pole of the magnet and from piece to piece toward the end of the piece that was the north pole of the magnet. From this it is assumed that magnetic lines of force not only flow from the north pole to the south pole outside the magnet, but from the south pole through the magnet to the north pole, and so flow through complete circuits.

Characteristics of Magnetic Lines of Force

1. Continuous—flow out of the north pole of the magnet, from the north pole to the south pole outside the magnet, back into the magnet at the south pole, and from south to north within the magnet.
2. Lines of force repel each other or spread apart.
3. Lines of force tend to contract or shorten their path.
4. Lines of force tend to crowd into and flow through magnetic materials. (See Fig. 207.)
5. Lines of force flow through all materials; that is, they cannot be insulated.

Magnetic Compass

The earth is a large natural magnet having a south magnetic pole near its north geographical pole and a north magnetic pole near its south geographical pole. (See Fig. 208.) The compass needle is a small bar magnet mounted on a pivot so that it is free to turn. It is marked so that its north pole can be easily distinguished. Its north pole is attracted by the earth's south magnetic pole and drawn toward the north geographical pole, and its south pole is attracted by the earth's north magnetic pole and drawn toward the south geographical pole. This causes the compass needle to align itself with the earth's magnetic lines of force, and therefore point north and south.

Molecular Theory of Magnets

The molecular theory of magnets assumes that magnetic materials are composed of molecules which are each a tiny magnet having a north pole and a south pole. In the unmagnetized state these molecules lie with their unlike poles adjacent so that the magnetic circuits are complete within the bar. In the magnetized state these molecules are aligned so that the magnetic lines of force must pass out of the bar at some point, flow through the space surrounding the bar, and back into the bar at another point to complete their magnetic circuit. Magnetizing a bar, then, is taken as aligning its molecules.

Figs. 209 and 210 respectively show the theoretical state of unmagnetized and magnetized bars. Fig. 209 shows the molecules lying with unlike poles adjacent, completing the magnetic circuits within the bar. Fig. 210 shows a magnet that is magnetized to the theoretical saturation point. In practice this degree of magnetization is never reached.

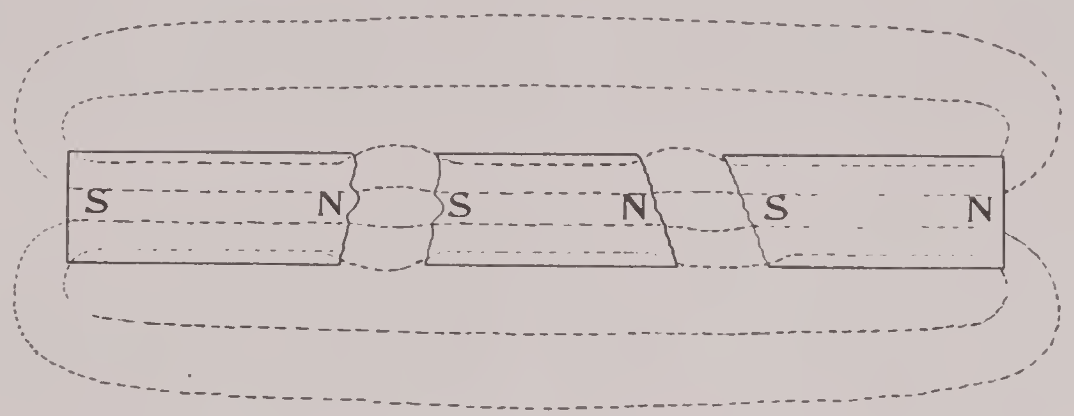


FIG. 206

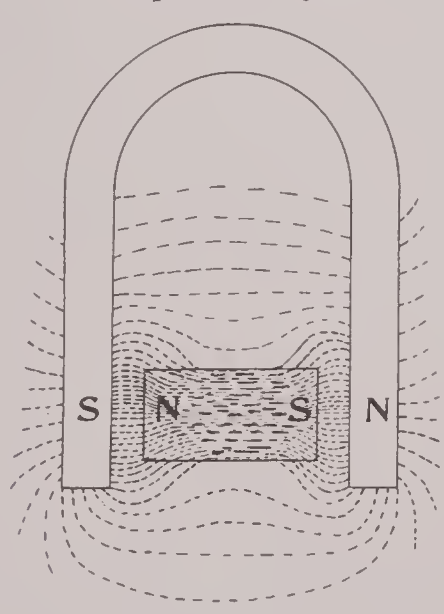


FIG. 207

Magnetic Induction

A bar of iron or steel becomes magnetized when placed in a magnetic field. It is said to be magnetized by magnetic induction. The stronger the magnetic field the stronger the bar becomes magnetized. The bar becomes so magnetized that its poles are unlike the poles of the magnet to which they are adjacent. (See Fig. 207.) The attraction between the unlike poles of the bar and the magnet, draws or tends to draw, the bar and magnet together. The attraction between the unlike poles is often described as caused by the magnetic lines of force tending to contract or shorten their length and so pull one pole to the other.

Permeability and Retentivity

Soft iron is much easier to magnetize than is hard steel, but soft iron remains magnetized only so long as it is under the influence of a magnetizing force. Hard steel is more difficult to magnetize, but when it is magnetized, it remains magnetized indefinitely. Soft iron is said to have high permeability, but, since it demagnetizes when removed from the magnetizing force, it is said to have very low retentivity. Hard steel, on the other hand, is said to have low permeability but high retentivity.

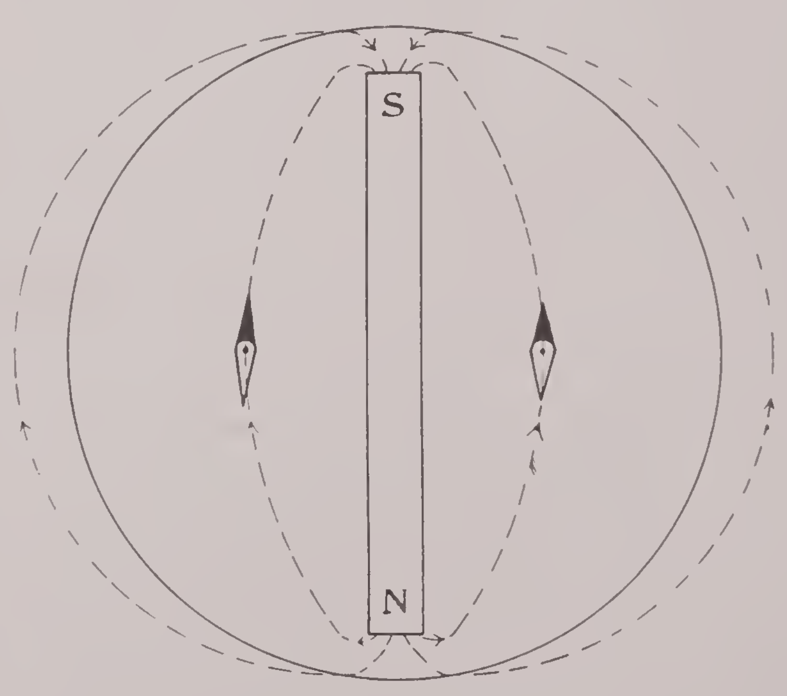


FIG. 208

Permeability expresses the relative ability of magnetic materials to be permeated by magnetic lines of force. It expresses the relative ease with which a magnetic material becomes magnetized. The value of permeability is obtained by comparing the number of lines of force in a certain area in the material, with the number of lines of force in the same area in air, under the same conditions.

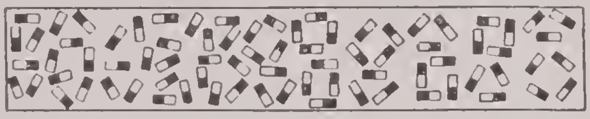


FIG. 209

Retentivity is the ability of a magnetic material to "retain magnetism," or remain magnetized. Soft iron and annealed steel have high permeability but practically no retentivity. Cast iron and hard steel have low permeability, but high retentivity. Hard steel has very high retentivity, hence is used for the manufacture of permanent magnets.

The molecular theory of magnets offers a simple explanation for the high permeability and low retentivity of soft iron, and the low permeability and high retentivity of hard steel. The explanation assumes that the molecules of soft iron can twist with ease within the bar, but the molecules of hard steel can twist only with difficulty. The molecules of soft iron can readily twist into alignment when the soft iron bar is placed in the field and so is readily magnetized. But, since the molecules twist with ease, they twist

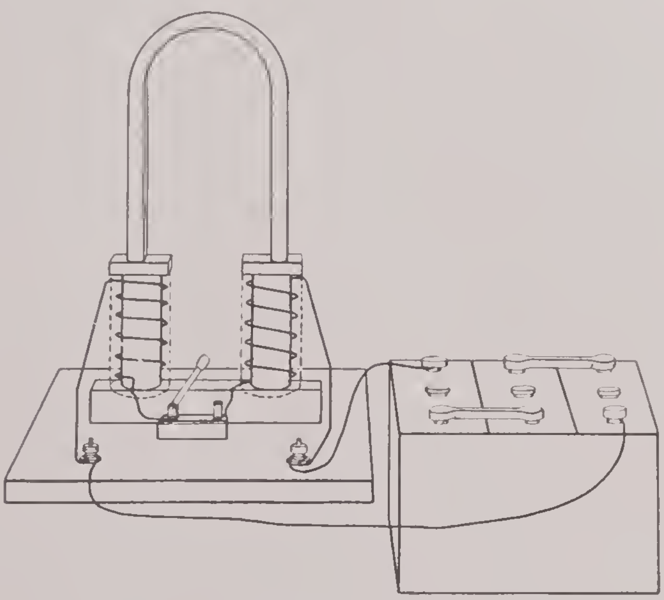


FIG. 211

out of alignment as soon as the soft iron is removed from the influence of the magnetic force. The molecules of hard steel cannot twist so easily, consequently a stronger field is required to align them, and when once aligned they cannot twist out of alignment so easily.

There is a magnetic phenomenon which strongly supports the molecular explanation for permeability and retentivity. When hard steel is rapidly magnetized and demagnetized it becomes heated. Rapidly magnetizing and demagnetizing soft iron does not pro-

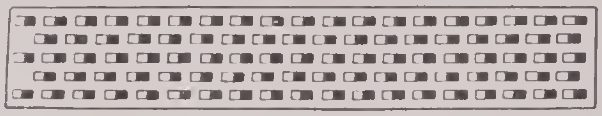


FIG. 210

duce so much heat. If magnetizing is aligning the molecules and the molecules of soft iron twist with ease, it is evident that rapidly magnetizing and demagnetizing soft iron will not produce as much heat as rapidly magnetizing and demagnetizing hard steel.

Reluctance

Reluctance is the opposition offered to the flow of magnetic lines of force. Materials that have high permeability have low reluctance and materials that have low permeability have high reluctance. Non-magnetic materials have about the same reluctance as air.

Recharging Magnets

Magnets that have become weak can be remagnetized on a magnet charger. The magnet charger is a strong electro-magnet. Fig. 211 shows an electro-magnet that is used for recharging magnets. When a magnet is placed on a charger, unlike poles of the charger and the magnet must be placed together. If like poles of the magnet and the charger are placed together, the polarity of the magnet will be

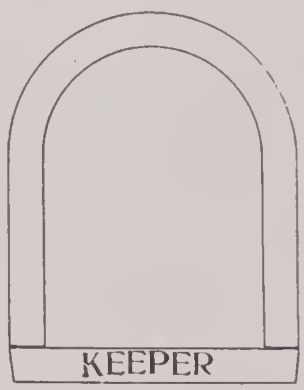


FIG. 212

reversed. Once the polarity of a magnet is reversed it is seldom possible to remagnetize it as strongly as it would be if the polarity had not been reversed. The attraction between the charger and the magnet cannot be taken as evidence that unlike poles are together, since the charger being so much stronger than the magnet, reverses the polarity of the magnet easily. If the magnet is suspended high enough so that the charger will not reverse its (magnet's) polarity, then a slight repulsion can be perceived if like poles are adjacent.

Care and Assembling of Magnets

Jars and sharp knocks cause magnets to demagnetize. If magnets are permitted to stand without keepers across their poles they demagnetize. A keeper is a bar of soft iron that can be placed across the poles of the magnet to form a path of low reluctance for the lines of force from one pole to the other. (See Fig. 212.) If magnets are placed together so that unlike poles are adjacent, one magnet acts as a keeper for the other. When unlike poles are placed together one magnet attracts the other. If magnets are assembled on a magneto, like poles must be placed together. If unlike poles of the magnets are placed together, one magnet so neutralizes the other that a strong field can not be set up. When like poles are placed together one magnet repels the other.

ELEMENTARY ELECTRICITY

Electricity is an agent of energy used to produce ignition sparks for the engine, to light the lamps, to crank the engine when starting, and to accomplish various other operations which are more or less necessary for the comfort and safety of automobile passengers and drivers. The exact nature of electricity is unknown, and no attempt will be made here to definitely explain what it may be. However, the action of electricity under certain conditions is definitely known, and the uses to which it is put are many.

The word "electricity" is derived from "elektron," the Greek word for amber. The ancient Greeks discovered that amber, after being rubbed to polish it, would then attract small bodies, such as chaff, lint, etc. Why the polishing of amber caused it to attract small bodies, the Greeks made no attempt to explain, but attributed it to a mystical property possessed by amber. Later it was discovered that other materials after being rubbed together would then attract chaff, lint, bits of paper, etc., just as amber. These attractions were then named electric attractions (meaning attractions like that of amber) to distinguish them from magnetic attractions.

After hard-rubber has been rubbed with cat's fur, both the hard rubber and the cat's fur attract small bodies. The hard rubber and the cat's fur also attract each other, but the hard rubber will repel another piece of hard rubber that has been rubbed with cat's fur, and the cat's fur will repel other cat's fur that has been rubbed on hard rubber. The change in condition of the hard rubber and cat's fur brought about by rubbing one on the other, is described by saying they are charged with unlike electric charges by the friction of one rubbing on the other; and the cause for the attraction and repulsion is explained by the statement, UNLIKE CHARGES ATTRACT, LIKE CHARGES REPEL. There are various other materials such as flint-glass and silk, cat's fur and sealing wax, flannel and ebonite that, when rubbed together, behave much in the same manner as the hard rubber and the cat's fur.

When highly electrified bodies carrying unlike charges are brought near to each other, there is usually a spark between the bodies and a crackling sound produced. After the spark and crackling sound the bodies are found to be discharged. The spark thus produced is called an electric spark, and is a result of electricity passing from one body to the other. The discharging of the bodies is brought about by one charge being unlike the other and so one neutralizes the other. Bodies which can be discharged by sparking through greater distances are said to be charged to higher potentials.

Electric charges produced by friction of one material rubbing on another are called frictional electricity, or static charges. They are called static charges because they seem to be held at rest on the bodies. Static electricity is of little importance since the amount of electricity moving from one body to another when a discharge takes place, is too small to be of a practical use. However static electricity is one source of trouble which has only recently come to light. The flow of gasoline, either through a hose or through a metal retainer, such as a funnel, generates static charges which produce electric sparks when the air is very dry, as in a heated garage in winter. However, the spark cannot be produced if there is metal-to-metal contact at all points. Therefore it is well to see that the filling can or hose has metal contact with the funnel and that the funnel has metal contact with the gasoline tank.

Since the nature of electricity is not definitely known we can merely speculate as to what it is. Electricity acts as if it were a weightless, invisible, non-compressible fluid permeating all space—saturating everything. The fact that electricity is not a fluid is definitely known; but, since the laws governing the flow of fluids through a pipe are much the same as the laws governing the flow of electricity through a circuit, it is to our advantage, for the purpose of explanation, to think of it as acting like the imaginary special kind of fluid described above.

CONDUCTORS AND INSULATORS

There is no material which cannot be charged with electricity, but electricity moves through some materials with greater ease than through others. Materials which will conduct an electric current are called conductors. There is no material that does not offer some resistance to the flow of electricity, and so there is no perfect conductor. Some materials are much better conductors than others. All metals are good conductors. Some materials offer such high resistance to the movement of electricity that it is practically impossible to pass electric currents through them. These materials which offer very high resistance to the movement of electricity are called insulators. Some materials are much better insulators than others, but there are no materials through which electricity cannot be moved to some extent and for this reason we have no perfect insulator.

The following is a list of materials classed as good conductors, fair conductors, partial conductors, and insulators. Silver, the best conductor, is placed first. The better insulators are placed last.

Good Conductors:

Silver
Copper
Aluminum
Zinc
Brass
Platinum
Iron
Lead
Mercury

Fair Conductors:

Carbon
Acid solutions (electrolytes)
Living vegetable substances
Moist earth

Partial Conductors:

Water
Animal bodies
Linen and cotton
Dry wood
Marble

Non-Conductors (Insulators):

Slate	Resin
Oils	Rubber
Porcelain	Shellac
Dry leather	Mica
Dry paper	Paraffin
Wool	Glass
Silk	Air

POSITIVE AND NEGATIVE CHARGES

The unlike electric charges have been named "Positive" and "Negative." The positive charge is taken as one of higher electrical pressure. A positive charge may be thought of as an excess of electricity; that is, more than the normal amount of electricity being present. We may think of electricity forming a positive charge in much the same manner as air compressed in a tank. Electricity forming a positive charge, like air compressed in a tank, tends to escape from the body in which it is confined. The negative charge is taken as one of lower electrical pressure. We may think of a negative charge as being a partial "electrical vacuum;" that is, a condition in which less than the normal amount of electricity is present. Bodies in this condition tend to draw electricity toward them. Bodies carrying unlike charges are bodies charged to unequal electrical pressures.

ELECTROMOTIVE FORCE

When bodies charged to unequal electrical pressures are connected by some material through which electricity will flow, electricity moves or flows through the conductor from the body of higher electrical pressure to the body of lower electrical pressure, until the pressure becomes the same on both bodies. Electricity moving through the conductor is an electric current. The force that moves electricity from one point to another is called Electromotive Force, or "electric moving force." It is usually abbreviated E. M. F. Electromotive Force is the attraction of unlike charges.

ELECTRIC CIRCUIT

The electric circuit is a path that an electric current follows. To form an electric circuit the path must be complete and made of materials which are conductors. The conductors are usually covered with some insulating material to prevent them from touching, should two of them come together.

To have an electric current, it is necessary to have a complete circuit and an electromotive force. The electromotive force is usually supplied by either generators, or batteries. A generator, or battery, forces the electricity from one point to another. Forcing electricity from one point to another creates points of unequal electrical pressure, and so produces the electromotive force.

Fig. 214 illustrates a simple electric circuit. The electromotive force is supplied in this circuit by a generator. The lamps are connected to the generator by copper wires, which are represented by heavy lines. The generator, when running, forces electricity through the lamps.

The hydraulic circuit in Fig. 213 is analogous to the electric circuit in Fig. 214. The centrifugal pump, pipes, and pipe coil correspond respectively to the generator, wires, and lamps. The pipes and pump are assumed to be filled with water. When the pump is driven, it draws the water out of the lower pipe and crowds it into the upper pipe. This results in a difference in pressure being produced which the water is pumped through the circuit. This meter corresponds to the ammeter (A) in the electric circuit.

Strength of Current

The rate water flows through the hydraulic circuit depends upon the force produced by the pump and the resistance offered to the flow of the water through the pipes. This resistance depends upon the length of the pipes and their size. Likewise in the electric circuit the rate the electricity flows through the electric circuit depends upon the electrical pressure produced by the generator, and the resistance offered by the wires and the lamps to the flow of electricity.

Figs. 215 and 216 show two simple electric circuits, each made up of a generator, a long

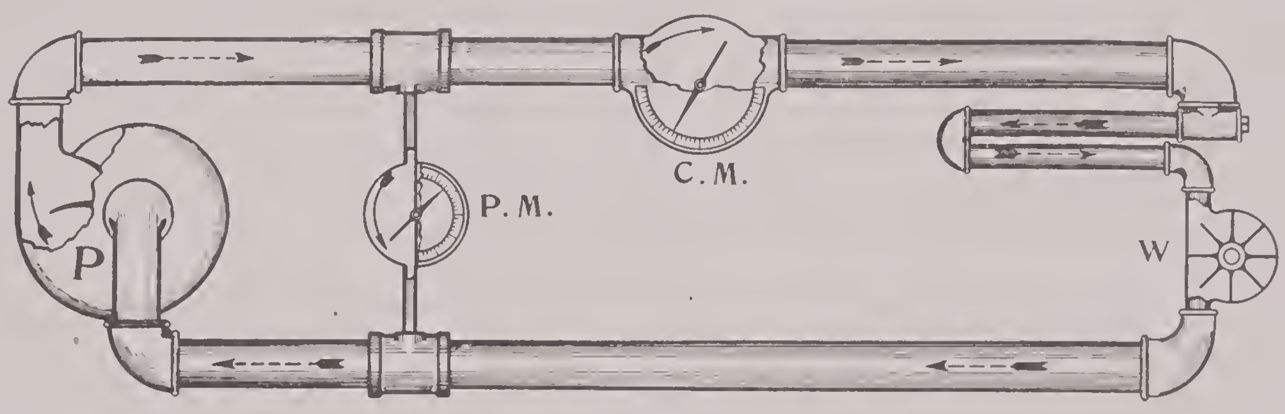


FIG. 213

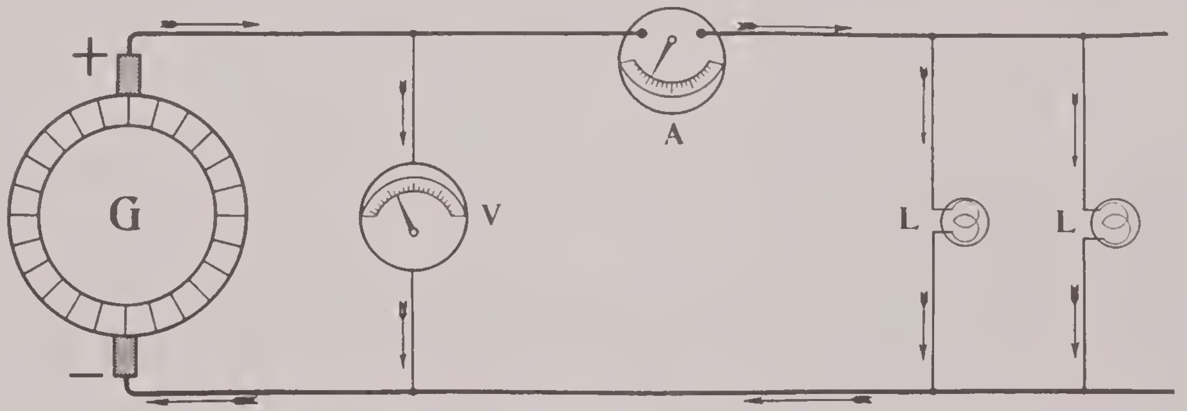


FIG. 214

between the pipes. This difference in pressure in the hydraulic circuit corresponds to the difference in electrical pressure produced in the electric circuit by the generator. The higher pressure in the upper pipe causes the water to flow through the pipe coil from the upper pipe to the lower pipe. The water flowing through the hydraulic circuit corresponds to the electricity flowing through the electric circuit. The meter (P. M.) connected between the pipes measures the difference between the pressures in the two pipes. This meter corresponds to the voltmeter (V) in the electric circuit, Fig. 214. The meter (C. M.) in the upper pipe of the hydraulic circuit measures the rate at

wire connected to one terminal of the generator and to one terminal of an ammeter, the other terminal of ammeter connecting to the other terminal of the generator. A voltmeter in each figure is connected across the terminals of the generator. The voltmeter measures the electromotive force produced by the generator, and the ammeter measures the rate that the electricity is forced through the circuit.

In Fig. 215 the wire is a No. 10 copper wire, 500 ft. long. When the generator is driven fast enough for a voltmeter to read "5," the ammeter will then read "10." If the generator is driven fast enough to make the voltmeter read "10," the ammeter will then read "20." Thus it is, when the resistance of the circuit is kept the same, and the E. M. F. is doubled, the strength of the current will be doubled.

In Fig. 216 the wire is a No. 10 copper wire, 250 ft. long. The wire in the circuit in Fig. 216 is half as long as the wire in the circuit in Fig. 215, hence the resistance of the circuit in Fig. 216 is about half the resistance of the circuit in Fig. 215. When the generator in the circuit in Fig. 216 is driven fast enough for the voltmeter to read "5," the ammeter then reads "20." Thus it is, when the resistance of the circuit is reduced one-half and E. M. F. kept the same, the strength of the current is doubled. The facts brought out by the consideration of the two figures are stated in a law called "Ohm's Law." Ohm's law is as follows:

OHM'S LAW

The strength of the current is directly proportional to the E. M. F. and inversely proportional to the resistance.

Ohm's law, though simple, is very important and must be remembered.

Before attempting to measure electromotive

OHM

The ohm is the unit of resistance. A No. 10 copper wire, one thousand feet long, has a resistance of approximately one ohm. The resistance of a conductor can be calculated by the joint use of a voltmeter and an ammeter.

The volt, ampere and ohm have been selected of such values that one volt causes a current of one ampere to flow through a resistance of one ohm.

By Ohm's law,

Volts divided by Ohms equal Amperes.
Volts divided by Amperes equal Ohms.
or Amperes multiplied by Ohms equal Volts.

Where,

E represents volts, or electromotive force.
I represents amperes, or strength of current.
R represents ohms, or resistance.

Then,

$$\frac{E}{R} = I \qquad \frac{E}{I} = R \qquad IR = E$$

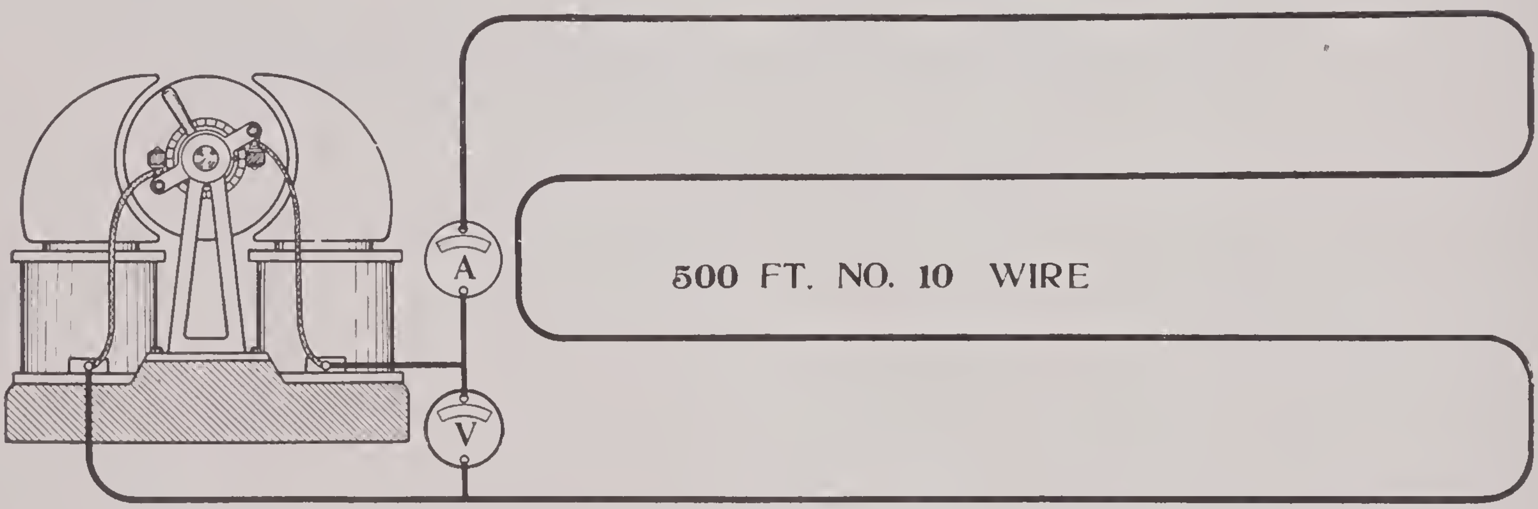


FIG. 215

force, strength of current, or resistance, it is necessary to become familiar with the units used.

VOLT

The unit of electromotive force is the volt and wherever used it should bring to mind the thought of "electrical moving force" or pressure. The instrument used to measure it is called a voltmeter. An ordinary dry-cell gives an E. M. F. of about one and one-half volts. A lead plate storage cell gives an E. M. F. of about two volts.

AMPERE

The unit for measuring the strength of an electric current is the ampere, and the instrument used to measure it is called an ammeter.

With the above formulas the resistance can be calculated when the volts and amperes are known, by dividing the number of volts by the number of amperes. If the volts and ohms are known, the amperes can be found by dividing the number of volts by the number of ohms. If the amperes and ohms are known, the volts can be found by multiplying the number of amperes by the number of ohms. These formulas are of great value in estimating the result without having to make actual test.

TYPES OF CIRCUITS

There are two principal ways of connecting electrical appliances; namely, Series and Parallel.

Series Circuit

Electrical appliances are said to be connected in series when they form one continuous path and the current which flows through one must flow through the others. (See Fig. 217.) The total resistance of appliances connected in series is equal to the sum of their separate resistances. The total resistance of the lamps in Fig. 217 is six ohms.

Voltage Drop—IR Drop

When appliances are connected in series, the strength of the current in any one is the same as that in any one of the others, but the voltage acting on each appliance is proportional to the resistance of the appliance.

The drop or the difference in electrical pressure as a circuit is followed around from the positive terminal to the negative terminal of the source of E. M. F., or vice versa, is called "Voltage Drop," or "IR" drop. The voltage drop across any part of an electric circuit is equal to its resistance in ohms, multiplied by the number of amperes passing through it. If the resistance, and the strength of the current are not known, a voltmeter must be used to determine the voltage drop.

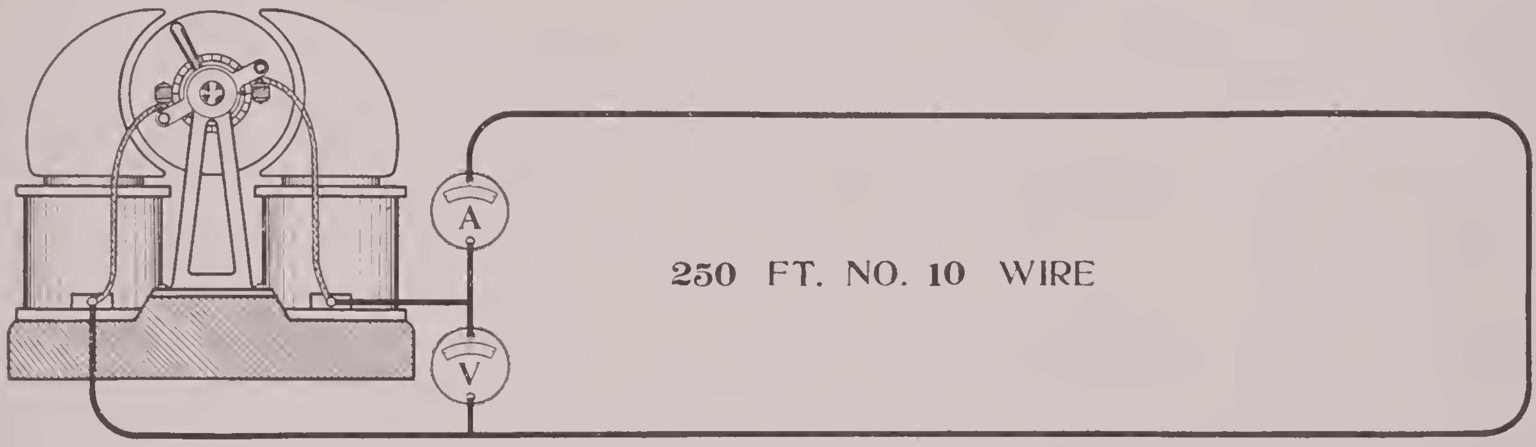


FIG. 216

Parallel or Multiple Circuit

Electrical appliances are connected in parallel when each forms a separate path for the current to take from one point to another. When appliances are connected in parallel, the voltage acting on one is equal to the voltage acting on any other one. The strength of the current passing through each of the appliances connected in parallel is inversely proportional to its resistance. The joint resistance of appliances in parallel is always less than the resistance of any one of the appliances. If the appliances have equal resistances, their joint resistance can be found by dividing the resistance of one by the number connected in parallel. If the appliances have unequal resistances their joint resistance may be found by taking the reciprocal of the sum of their reciprocals. (The reciprocal of a number is 1 divided by the number. Example—The reciprocal of 2 is 1/2. The reciprocal of 4 is 1/4. The reciprocal of a fraction is equal to the fraction inverted; thus, the reciprocal of 1/2 is 2/1, of 2/3 is 3/2, etc.)

Fig. 218 illustrates three lamps connected in parallel and in circuit with a six-volt battery. With this connection, each lamp forms a separate path for the current to take from the positive wire to the negative wire. The full voltage of the battery acts on each lamp. The strength of the current through each lamp is three amperes. [6, (No. of volts) ÷ 2, (No. of ohms) = 3, (No. of amperes).] Since the current flows through each lamp at the rate of three amperes, the battery must force the current from the negative wire to the positive wire at the rate of nine amperes. The joint resistance of these three lamps in parallel is two-thirds of an ohm. [2, (ohms resistance in one lamp) ÷ 3, (number of lamps in parallel) = 2/3 (No. of ohms joint resistance).]

Consider now the lamps in Fig. 218 as having one ohm, two ohms, and three ohms resistance respectively. Six amperes then flows through the first lamp, three amperes through the second, and two amperes through the third. The battery now forces the current through the circuit at the rate of eleven amperes. Since eleven amperes flow under six volts pressure, the joint resistance of the circuits must be six-elevenths ohms. [6, (No. of volts) ÷ 11, (No. of amperes) = 6/11, (No. of ohms).] The joint resistance of the lamps may be found in this manner, or by taking the reciprocal of the sum of their reciprocals. The following is an example, to illustrate how to take the reciprocal of the sum of the reciprocals of numbers.

1/1 (reciprocal of "1") + 1/2 (reciprocal of "2") + 1/3 (reciprocal of "3") =6/6 + 3/6 + 2/6 = 11/6 (the sum of their reciprocals).

1 ÷ 11/6 (reciprocal of the sum of their reciprocals) = 1x6/11 = 6/11, No. of ohms joint resistance.

There is usually little difficulty in calculating the joint resistance of appliances in series, since the combined resistance increases as the number of appliances in series increases. On the other hand, calculating the joint resistance of appliances in parallel is usually found confusing at first. The difficulty arises chiefly from the fact that the meaning of the term, joint resistance, is not understood. Joint resistance is the resistance of that part of the circuit which the appliances jointly form. Since more paths are provided for the current to take, the joint resistance of appliances in parallel always decreases as the number in parallel increases.

ELECTRICAL POWER—WATT

The watt is a unit of electrical power. Work is being done at the rate of one watt when one ampere flows under an E. M. F. of one volt. Watts are equal to the volts multiplied by the amperes.

Where,

P represents watts, or power

Then,

$$EI = P \qquad \frac{P}{E} = I \qquad \frac{P}{I} = E$$

An electrical horse-power equals 746 watts.

A kilowatt is one thousand watts.

A watt-hour is one watt acting for one hour. Watt-hours are equal to the watts multiplied by the hours. A kilowatt-hour is one thousand watt-hours.

RESISTANCE

Resistance, as an electrical term, is the opposition offered by a material to the flow of electricity. The resistance of a conductor depends upon (a), length, (b), cross-sectional area, (c), material used for conductor, and (d), temperature.

The resistance of a conductor is directly proportional to its length and inversely proportional to its cross-sectional area. The longer the conductor the higher its resistance; the larger the conductor the lower its resistance. If the length of the conductor is doubled its resistance is doubled; if the length is reduced one-half its resistance is reduced one-half. If the cross-sectional area of the conductor is doubled the resistance is reduced one-half; if the cross-sectional area of the conductor is reduced to one-half its resistance is doubled.

The resistance of a conductor depends largely upon the kind of material used. Silver is the best conductor, hence has the lowest resistance. Copper is a very good conductor but has slightly higher resistance than silver. The following is a table giving the relative resistance of the more common metals, as compared to the resistance of copper.

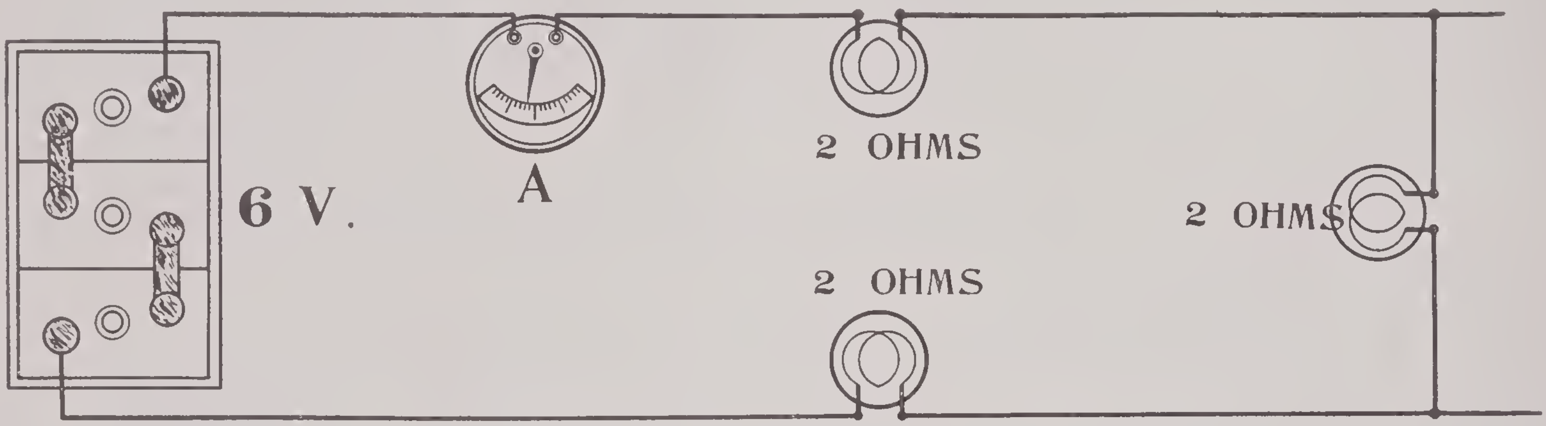


FIG. 217

Conductor	Ohms Per Circular Mil Foot	Relative Resistance as Compared to Copper
Silver, pure annealed	9.7	0.925
Copper, annealed	10.5	1.000
Copper, hard-drawn	10.8	1.022
Aluminum (97.5 per cent pure)	17.7	1.672
Zinc (very pure)	38.	3.608
Iron wire	65.2	6.173
Nickel	85.	7.726
Steel wire	90.	8.621
Brass		4.515
Phosphor-bronze		5.319
German Silver	128.29	17.300

The resistance of all pure metals increases with an increase in temperature. Copper increases about twenty-two hundredths of one per cent (.0022) in resistance for each degree Fahrenheit increase in temperature. The resistance of certain alloys does not increase with an increase in temperature. For example, Manganin, an alloy of 84 parts copper, 12 parts nickel, and 4 parts manganese, all by weight, has a negligible temperature change for practical purposes. Other alloys having similar properties are produced. The resistance of most alloys increases with an increase in their temperatures, but to a less degree than do the resistance of pure metals.

Brown & Sharpe Wire Gauge

Wire gauges are arbitrary standards for the measurement of the sizes of wire. The Brown & Sharpe gauge, which is the same as the American Wire Gauge, is the standard in the United States for the measurement of copper wires. Wire sizes are referred to as gauge numbers, and usually the smaller the number, the larger the wire. Every third number from any given number of the Brown & Sharpe gauge gives a wire size with either approximately half the area or twice the area. To illustrate—a No. 10 wire is approximately twice the area of a No. 13 wire, and approximately half the area of a No. 7 wire.

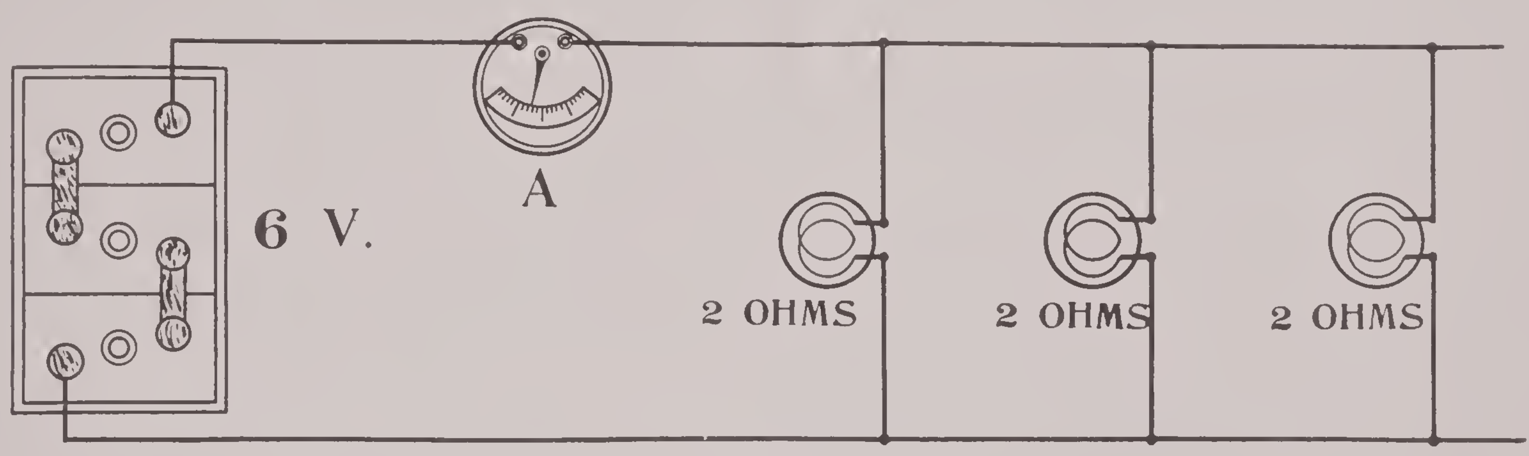


FIG. 218

CIRCULAR MIL

The size of a wire is proportional to its cross-sectional area. Computing the area of a circle by the common square units involves fractions that are more or less complex. Hence, a unit called the Circular Mil is used for measuring the cross-sectional area of wire. A circular mill is the area of a circle one thousandth (.001″) of an inch in diameter. The area of circles vary as the squares of their diameters. That is, the area of a circle of a diameter of .002″ (two mils) is four times the area of a circle of a diameter of .001″ (one mil). It follows that since a circle of a diameter of .001″ is one circular mil and a circle of a diameter of .002″ has four times the area of the circle .001″ in diameter, the area of the circle .002″ in diameter is 4 circular mils. The cross-sectional area of any conductor in circular mils is equal to the diameter of the conductor in mils, squared.

CIRCULAR MIL FOOT

A circular mil foot is the unit conductor. A wire having a sectional area of one circular mil, and a length of one foot is a circular mil foot. The resistance of a circular mil foot of ordinary commercial grade copper wire at a temperature of 75° F. is about 10.8 ohms. The resistance of a copper wire can be found by multiplying the length in feet by 10.8 and dividing by the diameter of the wire in mils squared. By formula, resistance in ohms can be found as follows:.

$$R = \frac{\text{Length in feet x Ohms per Cir. M. Ft.}}{\text{Sectional area in Cir. Mils.}}$$

The resistance of copper wire varies with the degree of purity of the copper used and so the resistance for various lengths of wire as given in the wire table can be taken only as approximate, unless the degree of purity is expressed. The resistances given in the following wire table are for wires of standard grade and at a temperature of 68 degrees F. Unless a high degree of accuracy is necessary, the resistances as given in the table can be taken for copper wire of the various sizes and lengths.

STANDARD COPPER WIRE TABLE

Weights, lengths and resistances of wire at 68° F.

A.W.G.	Dia.	Area	Length		Safe Carrying Capacity	
B.&S.	Inches	Circular Mils	Feet Per Lb.	Feet Per Ohm	Rubber Insulation	Insulat'ns Other Than Rubber
000	.4096	167,800	1.968	16,180	175	275
1	.2893	83,690	3.947	8,070	100	150
4	.2043	41,740	7.914	4,025	70	90
7	.1443	20,820	15.87	2,007	43	56
10	.1019	10,380	31.82	1,001	25	30
14	.06408	4,107	80.44	396	15	20
18	.04030	1,624	203.4	156.6	3	5
20	.03196	1,022	323.4	98.5		
22	.02535	642.4	514.2	61.95		
32	.007950	63.21	5,227	6.095		
36	.0050	25.0	13,210	2.411		
38	.003965	15.72	21,010	1.516		
40	.003145	9.888	33,410	.9534		

SIMPLE ELECTRIC CELLS

If two unlike materials are immersed in some chemical solution that attacks one of the metals only, or one more than the other, they will become charged to unequal electrical pressures. The difference in electrical pressures on the metals depends upon the kind of metals, and upon the strength and kind of solution.

Two metals, such as copper and zinc, immersed in a solution of sulphuric acid form a simple electric cell. When the zinc and copper are placed in the acid, a chemical action immediately begins. The sulphur and oxygen elements of the acid attack the zinc, forming zinc sulphate, and liberate (or set free) the hydrogen element as shown by bubbles rising to the top of the liquid and also forming on the surface of the copper. As this chemical change takes place, the copper plate becomes charged to a pressure of about one volt above that of the zinc.

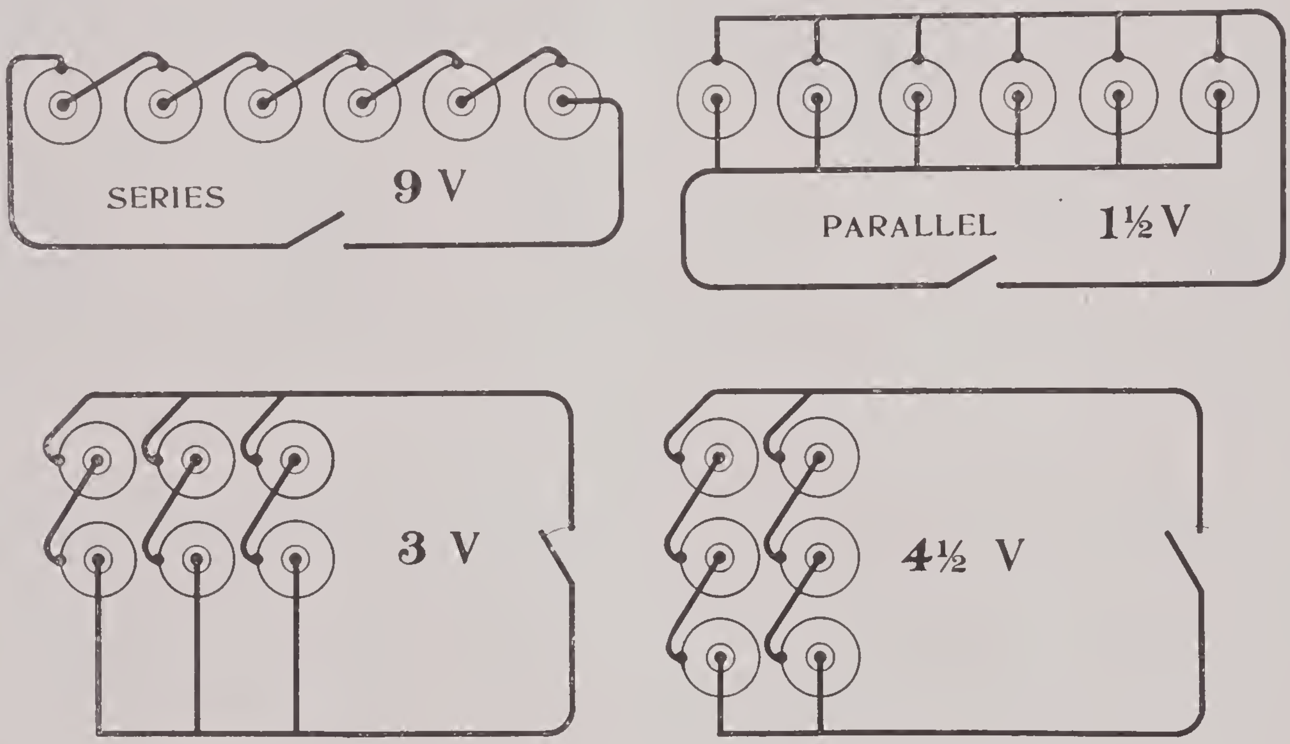
If a wire connects the top of the copper plate to the top of the zinc plate, an electric current will pass through the wire from the copper to the zinc. As long as the current flows from the copper plate to the zinc plate, the chemical action continues between the acid and the zinc. If the wire is disconnected, and the copper and zinc are pure, the chemical action practically stops.

The rate at which the chemical action takes place between the zinc and acid has a direct relation to the rate electricity flows through the wire from the copper plate to the zinc plate.

There is, however, a limit to the rate at which the chemical action will take place and so there is a limit to the rate at which the cell will force the current through the wire. The rate the cell will force the current through the wire is the ampere capacity of the cell. The capacity of the cell depends upon the size of the plates and the volume and strength of the solution. The larger the plates, and the more solution, the higher the ampere capacity of the cell. The voltage of the cell does not depend upon the size of the plates, but upon the kind of metals used in the plates and the solution.

Discharge

The chemical action in the cell which forces the electricity through a circuit will continue until the zinc has been entirely eaten away or the acid has been exhausted. When the zinc has been entirely eaten away the cell is discharged and will no longer force current through a circuit. Just as the maximum rate at which the cell will force current through a circuit depends upon the size of the plates, so does the life of the cell depend upon the amount of zinc, or the size of the zinc plate. The thicker and heavier the zinc plate the longer the life of the cell. A pound of zinc for the zinc plate will give about 370 ampere-hours; that is, a pound of zinc will be sufficient for the plate of a cell that will keep one ampere flowing for 370 hours.



SERIES---PARALLEL CONNECTIONS.

FIG. 219

Polarization

The hydrogen gas which collects around the copper plate while the cell is discharging, is likely to cling to it and in time almost completely cover the part immersed in the solution. Hydrogen gas offers a high resistance to the flow of current and so insulates the copper plate from the solution, thus retarding the chemical action, and adding to the conditions which make up an internal resistance in the cell. When this condition is reached, the cell is said to be polarized. If polarization is not counteracted in some way the cell is of no practical use.

Local Action

All commercial zinc contains particles of carbon, iron and various other metallic impurities, which cause a chemical action to take place between the acid and the zinc when the copper plate is not connected to the zinc. The zinc together with some metallic impurity, such as a particle of carbon, and the solution form a simple cell. The chemical action between the acid and the zinc, charges the carbon to a higher pressure than the zinc, but since the carbon and zinc are in contact, electricity passes from the carbon back to the zinc, so that the unlike charges cannot build up high enough to stop the chemical action. As a result, the zinc is continuously being eaten away and the cell discharges without forcing the current through a circuit where it can be made to do work. This is called local action. It can be prevented by using chemically pure zinc, or by amalgamating the zinc. This is accomplished by wetting it with the acid, and then rubbing its surface with mercury.

Dry Cell

A dry cell is an electric cell, the action of which is much like that just described. The dry cell is not truly a "dry" cell, but is so called since there is no liquid to spill. However if a dry cell is completely dried out, it is useless. The principal parts of a dry-cell are as follows:

A zinc cylinder or can is used for the negative plate. Inside of this zinc cylinder several layers of thick blotting paper are placed which are saturated with a solution of sal-ammoniac and zinc chloride. Inside of this is placed a carbon rod, which acts as the positive plate. A mixture of sawdust, charcoal, carbon granules and manganese peroxide is packed between the carbon rod and the blotting paper. The blotting paper extends only within about an inch of the top of the zinc, and the carbon rod is long enough to extend out above the top of the mixture. Over the top of the mixture is placed heavy corrugated paper or fine sand. Over this is poured a melted pitch sealing compound which cools and seals the blotting paper, mixture, and carbon rod in the zinc can. Terminals are provided for connections to the zinc and to the carbon. The chemical action, which takes place on the zinc, causes the carbon rod to become charged to electrical pressure of about one and one-half volts higher than that of the zinc. As a cell discharges, there is a tendency towards polarization. The manganese peroxide is added so that oxygen from it will combine with the hydrogen as it forms, and reduce polarization. The corrugated paper, or fine sand at the top of the cell, provides an expansion chamber which permits the contents of the cell to expand with an increase in temperature without

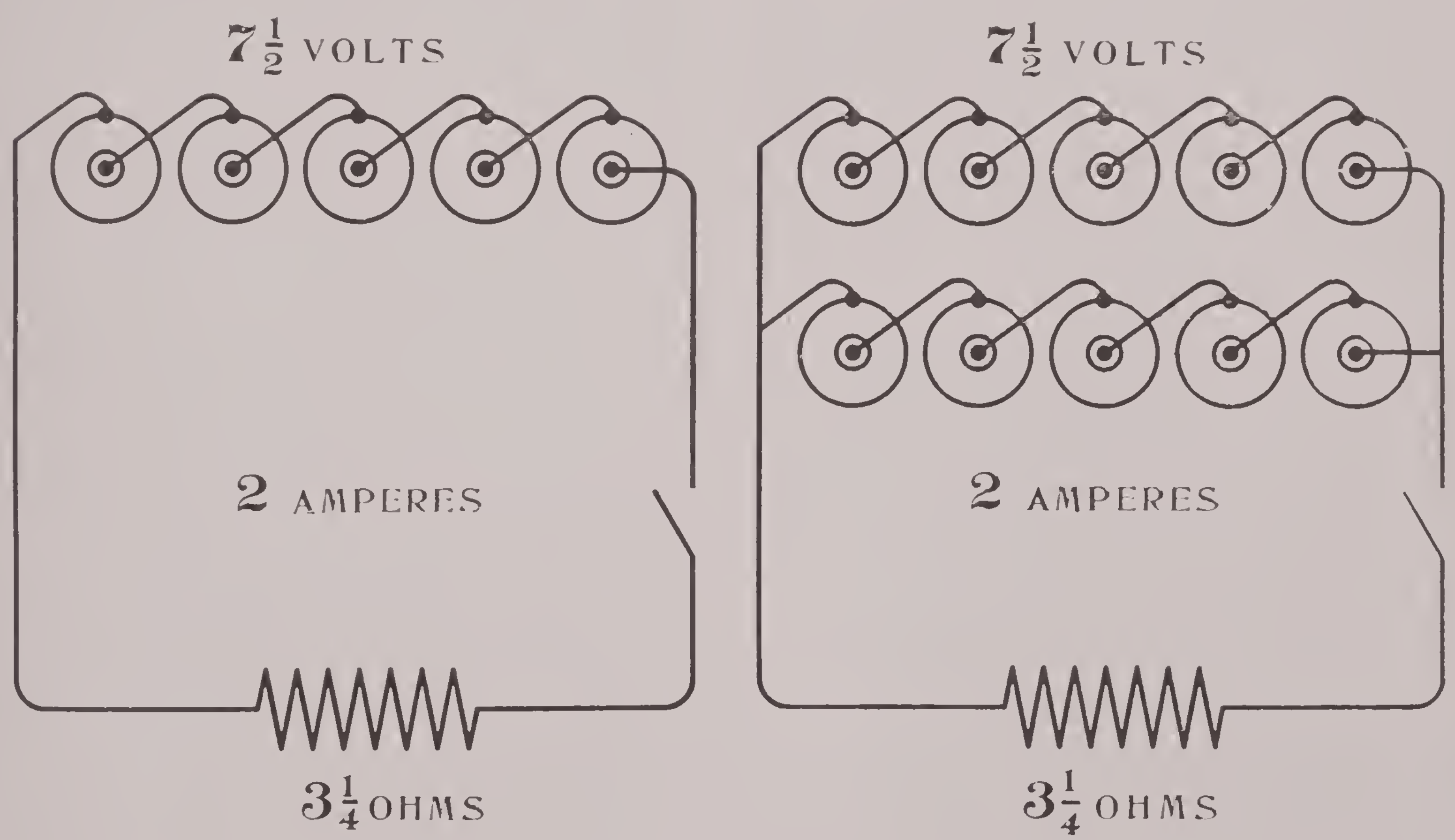


FIG. 220

cracking the pitch seal. A cardboard case acts as a protection and insulation for the zinc.

Voltage of Dry Cell

The electromotive force produced by a dry-cell when new is about one and one-half volts. This is called its terminal voltage. The terminal voltage drops when the cell is placed on discharge. For average working conditions of the cell it is about one volt. The drop in terminal voltage is due largely to partial polarization, which takes place as soon as the cell is placed on discharge.

Ampere Capacity

The short-circuit ampere capacity of a good new dry cell varies from 20 to 30 amperes. The short-circuit should be made by connecting the cell to an ammeter having not more than one-hundredth of an ohm resistance.

Ampere Hour Capacity

The ampere-hour capacity of dry-cells ranges from five to twenty-five ampere hours, depending upon the quality of materials used, age of cell and manner in which it is discharged. If a dry-cell is discharged intermittently, and at low rate, its ampere-hour capacity is much higher than when discharged either continuously or at higher rates.

Electric Battery

The E. M. F. of a cell or the capacity of a cell is seldom high enough for the cell to be used alone. For this reason several cells are usually connected together to produce a higher E. M. F. than one cell, or give a higher capacity than that of one cell. Two or more cells connected in series, parallel, or series-parallel form a **battery.**

Cells in Series

Cells are connected in series when the positive terminal of each connects to the negative terminal of the next, as is shown in the upper left Fig. 219. When cells are connected in series, their combined voltage is equal to the sum of their separate voltages. The current capacity of cells in series is equal to the current capacity of one cell, since all the current must pass through each cell and the internal resistances of the cells must be added together.

Cells in Parallel

Cells are connected in parallel when the positive teminals of all the cells connect to one wire and the negative terminals connect to another wire. Cells are connected in parallel to prolong their life. The total voltage of cells in parallel is equal to that of one cell and their total current capacity is equal to the sum of their separate current capacities. The upper right illustration of Fig. 219 shows cells connected in parallel.

Cells in Series-Parallel

Cells are connected in series-parallel to form a battery having a combined voltage and a combined current capacity higher than that of one cell. The illustrations in the lower left and the lower right of Fig. 219 show cells connected in series-parallel. The total voltage of cells in a series-parallel connection is equal to the voltage of a single series of cells. The current capacity of cells in a series-parallel connection is equal to the sum of the current capacities of the series groups.

The scheme of connection used for a certain purpose depends upon the nature of the apparatus to be operated and upon the demands for energy. Every electrical appliance is designed to operate under a given electrical pressure and will not operate satisfactorily under any other pressure. The pressure required to operate an appliance is predetermined by the manufacturers.

Application of a dry battery is illustrated in Fig. 220. The illustration at the left shows a series connection of five dry cells, with a coil of wire having 3¼ ohms resistance connected across the terminals of the battery. Under these conditions the flow of current is at a rate of 2 amperes. The cells which form the battery are all discharging at a rate of 2 amperes, as they are in series and the total current flows through each of them.

The illustration at the right shows a battery of 10 cells connected in series-parallel. The battery consists of two groups of cells in series, having five cells in each series. The same coil is connected across the terminals of this battery as was used in the illustration at the left. In this case, the voltage is just the same as if a single series of five cells were used, but the ability of the battery to deliver current is twice as great. The pressure being only 7½ volts and the resistance of the external circuit being constant, the flow of current is the same as in the illustration at left; that is, 2 amperes. In this case the current is taken from two series of cells instead of one, and requires that each group of series cells must deliver only one-half of the total current, which is one ampere.

The advantages obtained by employing the series-parallel connection of cells are: The ability of the battery to deliver current is multiplied by the number of series groups of cells which are connected in parallel, and the cells are discharged at a lower rate which results in the life of the cells being prolonged.

An example of the increase in the life of cells by employing a number of series groups in parallel can be obtained by comparing the batteries shown in Fig. 220. If the rate of discharge in the illustration at left is 2 amperes and the life of the cells is 5 hours, the life of the cells in the series-parallel connection at right is approximately 15 hours, thus by the latter arrangement the first cost of the cells is only double, whereas their life is 3 times greater.

STORAGE BATTERIES

A storage battery is a device for storing chemical energy. The storage battery does not store electricity, as is commonly supposed, but instead, it converts the electrical energy in the electric current forced through it, into chemical energy, and stores the chemical energy. The chemical energy stored in a battery is capable of forcing current back through the circuit.

The storage batteries used for starting and lighting purposes on the automobile are all of the lead plate type. The plates for these batteries are pasted; that is, the active materials are pasted into framework called grids. The grids are cast of an alloy of lead and antimony. The materials that become the active materials are lead oxides when pasted into the grids. After the lead oxides which have been pasted into the grids have dried, the plates are placed in forming tanks where the lead oxide, which is to become the active material for the positive plates is changed to peroxide of lead, and the lead oxide that is to become the active material for the negative plates is changed to pure spongy lead. The positive plates are brown and the negative plates are gray.

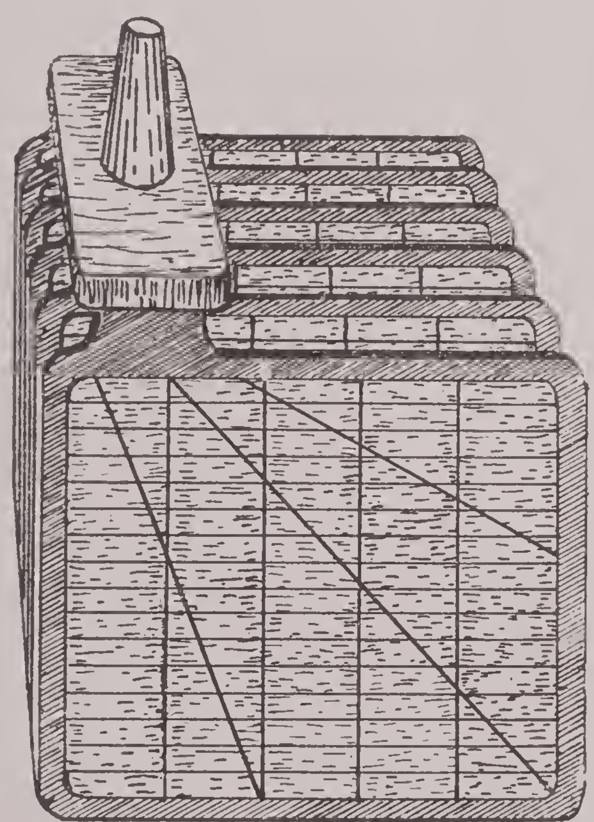


FIG. 221

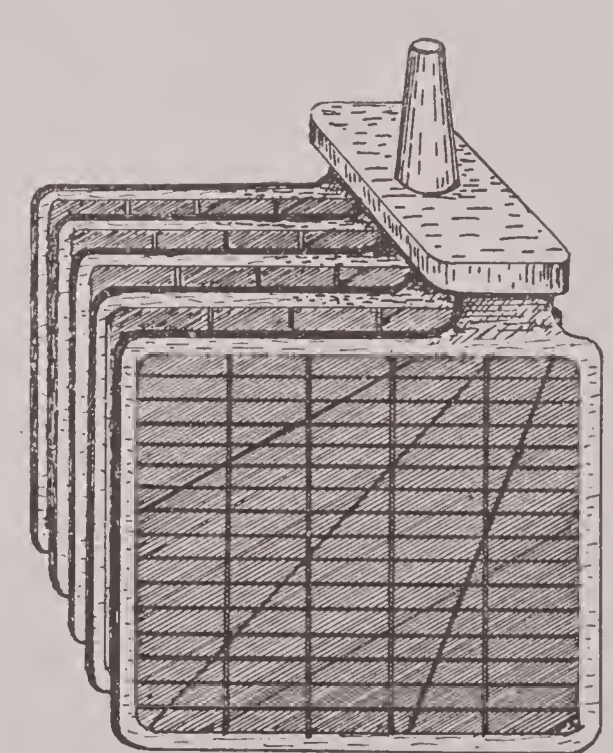


FIG. 222

Electrolyte

The solution in which the plates are immersed is called the electrolyte. The electrolyte is a solution of sulphuric acid (H_2SO_4). The specific gravity of the electrolyte for a fully charged storage cell should be from 1.275 to 1.300 in temperate latitudes, and from 1.200 to 1.230 in tropical latitudes.

Jars

The jars are usually made of rubber, though those in batteries used with farm lighting plants or other places where they will not be subject to shocks and vibrations, are made of glass. In the bottoms of the rubber jars are high ribs that support the plates. These ribs hold the plates high enough above the bottom of the jars so that the sediment which forms in the bottom due to the plates shedding does not short circuit the cell.

Separators

Separators are insulators placed between the plates to prevent positive and negative plates from touching, which would result in short circuiting the cell internally. They are usually made of wood, though sometimes rubber is used. The wood is treated chemically to remove any substance which would cause trouble when added to a cell. The separators are grooved on the side placed next to the positive plates, because positive plates shed more than negative plates.

Positive Group

Two or more positive plates secured to a strap form a positive group. (See Fig. 222.) A lead post is burned to the strap. This post forms the positive terminal of the cell in which this group is used.

Negative Group

Two or more negative plates, secured to a strap form a negative group. (See Fig. 221.) The post burned to the strap of this group forms the negative terminal for the cell in which this group is used.

Element

A positive group and a negative group, assembled with separators between the plates form an element. There is always one more plate in a negative group than in a positive group of an element, because the positive plates are more active.

Cell

An element sealed in a jar with electrolyte forms a cell. An opening is provided in the cover plate, so that distilled water may be added as the water evaporates from the solution. If water is not added at regular intervals the electrolyte will get below the top of the plates, and the capacity of the cell will be reduced. The small vents in the caps are to permit the gas that forms in the cell to escape. These small vents must be kept open. The vent caps must be kept on the openings in the covers of the cells to keep dirt out. Dirt must be kept out of the cells, as some materials cause the cells to self-discharge in a short time, while others cause chemical actions to take place that damage the plates and separators. The voltage of a lead-plate storage cell is from 2 to 2.2 volts when charged, and about 1.8 volts when a cell is considered discharged.

Battery

Two or more cells connected in series, parallel or parallel-series, form a battery. The voltage of a storage battery depends upon the number of cells in series, and the condition of the cells. The voltage is approximately two times the number of cells in series.

The ampere hour capacity of a storage battery depends upon the size and number of plates in each cell, the volume and strength of the electrolyte, and the condition of the cells.

The cells of a storage battery to be used on an automobile are arranged in a substantial wooden box, thoroughly coated with acid-proof paint, and provided with suitable handles for carrying the battery, and also for anchoring it in position in the car. The cells of the battery are connected together by heavy lead connectors, which are burned to the posts on the strap of each group.

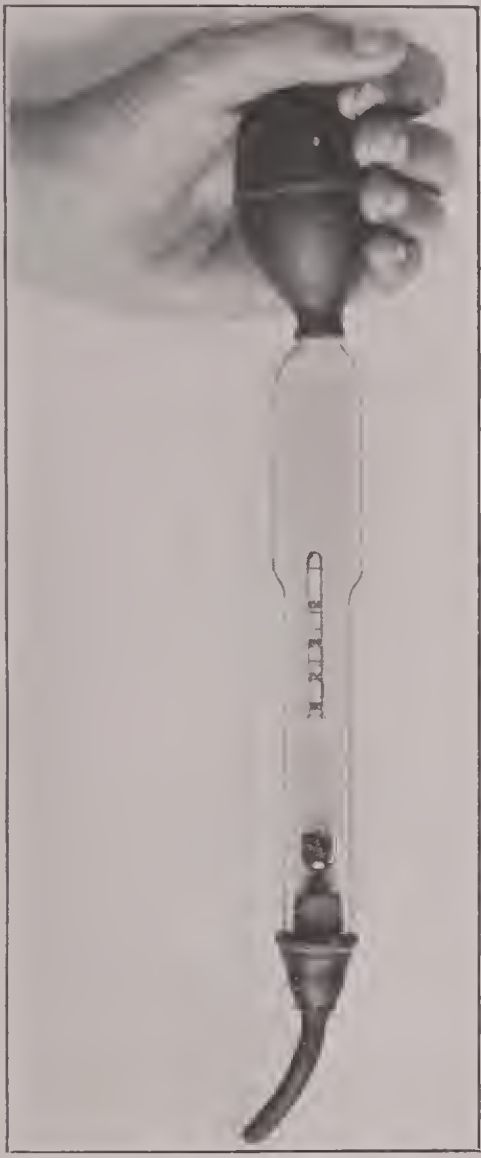
Specific Gravity

Specific Gravity is the ratio between the weight of a substance and the weight of an equal volume of water. The Specific Gravity of a substance may be found by dividing the weight of a volume of the substance by the weight of an equal volume of water. The specific gravity of battery acid (chemically pure sulphuric acid) is 1.835. That is to say, a gallon of sulphuric acid weighs 1.835 times as much as a gallon of water. The electrolyte is part water, therefore, its specific gravity is not as high as that of the pure acid. Since the specific gravity varies with the percentage of acid, it can be used as an accurate measure for the strength of the electrolyte. The specific gravity of the electrolyte is usually measured with an instrument called a hydrometer.

Hydrometer

The hydrometer shown in Fig. 223 is a small closed glass tube with a small quantity of shot sealed in one end, which serves to keep the tube in an upright position when it is placed in the liquid, and provided with a suitable scale marked on the glass tube, or on a piece of paper on the inside of the tube. The depth to which the hydrometer sinks in the liquid, as indicated on the scale of the instrument where the surface of the liquid is in contact with the tube, is a measure of the specific gravity of the liquid. For convenience in using a hydrometer, it is usually placed within a larger glass tube provided with a rubber bulb at one end, and a suitable nozzle or a short piece of hose at the other. This combination is known as a hydrometer syringe.

To use the hydrometer the bulb is squeezed, the nozzle placed in the liquid and then the bulb released. As the bulb is released, the liquid is drawn into the glass tube and floats the hydrometer. The specific gravity can then be read at the surface of the electrolyte when the hydrometer floats free of the sides of the syringe, and the syringe is held in a vertical position. After the reading is taken, the bulb is compressed to expel the liquid from the syringe.



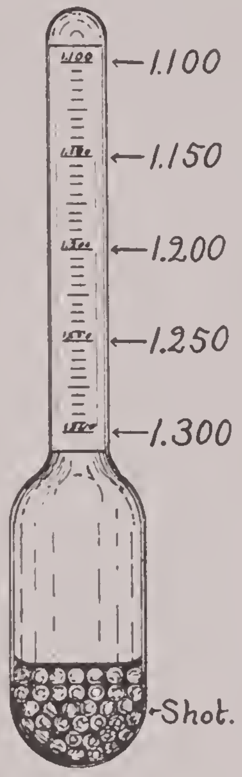


FIG. 223

Temperature Correction for Hydrometer

The scale on the battery hydrometer is graduated and set to register correctly only when the temperature of the electrolyte is 70 degrees Fahrenheit. As the temperature of the electrolyte increases it becomes less dense, so that the hydrometer will sink deeper into it. Therefore, if the temperature of the electrolyte is above 70 degrees the hydrometer will register low. A temperature correction may be made by adding one point to the hydrometer reading for each three degrees above 70 degrees F. As the temperature of the electrolyte becomes lower, its density increases until a temperature is reached that is slightly above the freezing temperature of the electrolyte. Therefore, if the temperature of the electrolyte is below 70 degrees, the hydrometer will register high. The temperature correction may be made by substracting one point from the hydrometer reading for each three degrees below 70 degrees Fahrenheit. The variation in temperature of the electrolyte makes only a slight variation in the hydrometer reading, and so where only the approximate specific gravity is wanted, the temperature correction can be neglected.

Ampere Hour Capacity of the Storage Battery

The capacity of the storage battery is given in ampere-hours, which is the number of hours times the rate in amperes that the battery is discharged.

The S. A. E. standards require that batteries for combined lighting and starting service shall have two ratings. The first indicates the lighting ability and shall be the capacity in ampere hours of the battery when discharged continuously at a 5-amp. rate to a final voltage of 1.8 per cell, the temperature of the battery at the beginning of the discharge being 80 deg. Fahr.

The second rating shall indicate starting ability and shall be the rate in amperes at which the battery will discharge continuously for 20 minutes to a final voltage of not less than 1.65 per cell, the temperature of the battery at the beginning of the discharge being 80 degrees Fahr.

For example, a battery discharging for 16 hours at a 5 ampere rate has an 80 hour ampere-hour capacity. The ampere-hour capacity decreases slightly as the temperature of the battery is lowered.

Action of Storage Cell on Discharge

When a storage cell is fully charged, the active material in the positive plate is lead peroxide (PbO_2) and the active material in the negative plate is pure spongy lead (Pb). The electrolyte is a solution of sulphuric acid, (H_2SO_4). (See Fig. 224.) When the plates are immersed in the electrolyte, a chemical action takes place between the active materials of the plates and the acid of the electrolyte. This chemical action forces the electricity from the plate having the pure spongy lead for the active material, to the plate having lead peroxide for the active material and so charges the lead peroxide plate to a higher pressure than the lead plate. An explanation of the chemical action is given in the following.

Each molecule of the acid is composed of two atoms of hydrogen, one atom of sulphur, and four atoms of oxygen (H_2SO_4). When the acid is mixed with water, according to a theory in chemistry, the acid dissociates; that is, each molecule breaks into two ions—a hydrogen ion, composed of the two atoms of hydrogen (H_2), and a sulphion composed of an atom of sulphur and four atoms of oxygen (SO_4). The hydrogen ions carry positive charges and the sulphions carry negative charges. So long as the plates are not immersed in the solution, the solution remains neutral since there are the same number of ions with positive charges as ions with negative charges.

Each molecule of lead peroxide, the active material of the positive plates, is composed of one atom of lead and two atoms of oxygen (PbO_2). The pure spongy lead (Pb), the active material of the negative plates, is an element itself and not a chemical combination of elements.

When the plates are immersed in the electrolyte, the affinity of the sulphions for the lead causes them to combine with atoms of lead from both plates. For each sulphion that combines with an atom of lead from the plates, a molecule of lead sulphate ($PbSO_4$) is formed and two atoms of hydrogen are liberated from the acid. For each atom of lead in the positive plate that combines with a sulphion, two atoms of oxygen are liberated from the lead peroxide. Since the sulphions combine with atoms of lead from both plates the hydrogen is liberated twice as fast as the oxygen. The hydrogen and oxygen combine—two atoms of hydrogen to one of the oxygen (H_2O)—forming water.

The atoms of lead from the plates carry positive charges with them as they combine with the sulphions. These positive charges are neutralized by the negative charges which the sulphions carry. As the atoms of lead from the negative plate combine with the sulphions, the negative plate is charged with a negative pressure. As each atom of lead of the positive plate combines with a sulphion, two atoms of oxygen combine with four atoms of hydrogen. Therefore as a positive charge is subtracted from the positive plate by an atom of lead combining with a sulphion, two negative charges are subtracted by the two atoms of oxygen which combine with the hydrogen; and since four atoms of hydrogen combine with the two atoms of oxygen, two of the positive charges which the hydrogen atoms carry are not neutralized, hence are added to the positive plate.

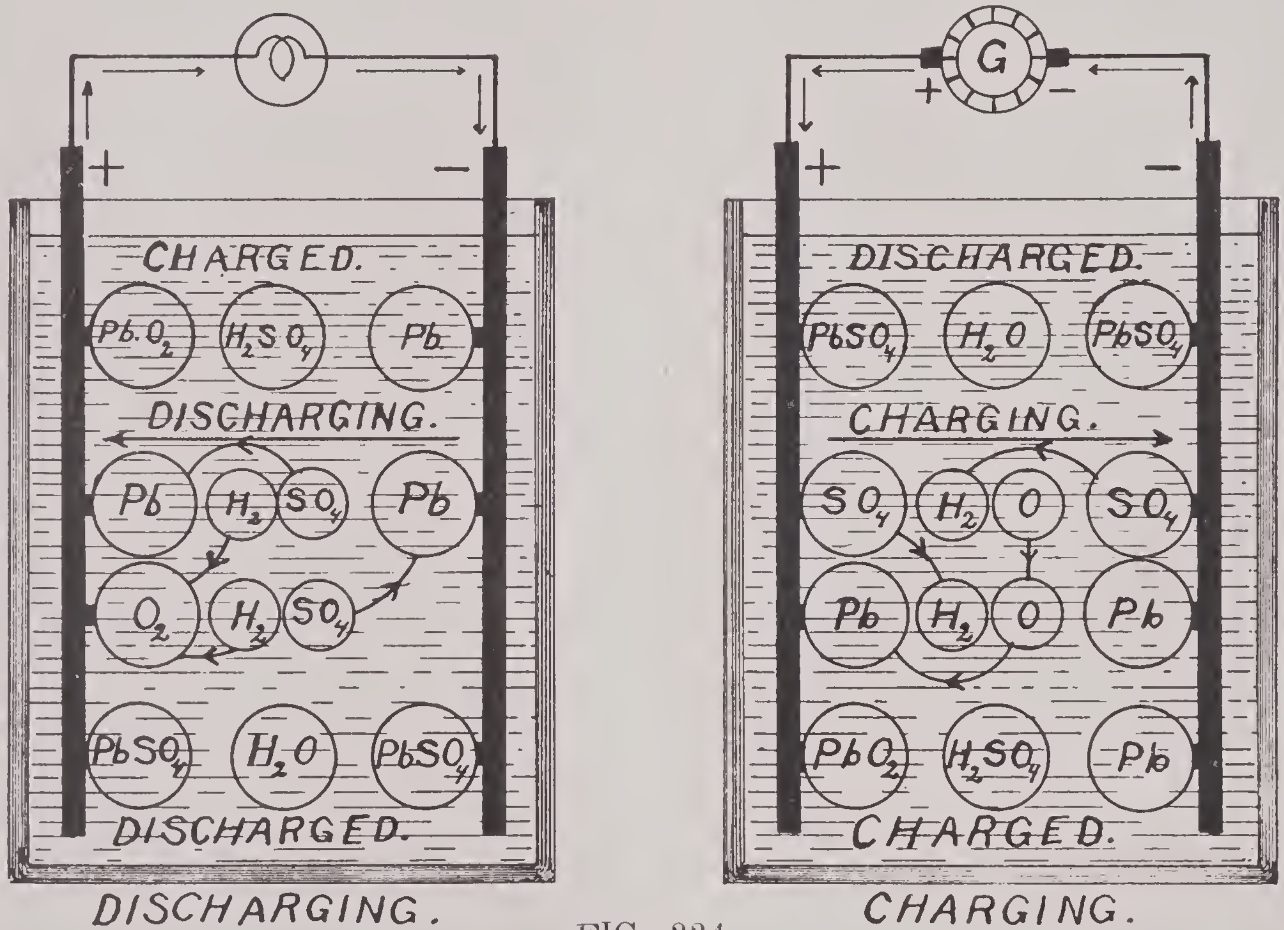


FIG. 224

When the charge on the positive plate reaches a pressure about 2.2 volts higher than that on the negative plate, the chemical action practically stops. The negative charge left on the negative plate so attracts the positive charges which the atoms of oxygen carry, that the atoms of lead are prevented from combining with the sulphions. The positive charge on the positive plate so attracts the negative charges which the atoms of oxygen carry, that the oxygen is bound to the plate and the hydrogen ions are repelled. The oxygen then cannot combine with the hydrogen and the lead that is held in combination with the oxygen cannot combine with the sulphions, hence the chemical action at the positive plate is stopped. If a wire connects the positive plate to the negative plate, an electric current will flow through the wire from the positive plate to the negative. As the current flows, the charges become weaker (the difference in electrical pressure on the two plates becomes less) and the chemical action takes place at a rate that is proportional to the strength of the current.

The chemical action between the acid and the active materials of the plates reduces the electrolyte to a weak solution of acid and the active materials to lead sulphate. When the discharge has been continued till the difference in the electrical pressures on the plates has dropped to about 1.8 volts, the discharge rate being about one-tenth the ampere-hour capacity of the cell, the cell is considered to have reached the safe limit of discharge. To recharge the cell it is necessary to force an electric current back through the cell in the reverse direction. This is done by connecting the cell to a generator with the positive terminal of the cell connected to the positive terminal of the generator and the negative terminal of the cell connected to the negative terminal of the generator.

Action of Storage Cell on Charge

When a storage cell is in a discharged state, the active material on both plates is lead sulphate ($PbSO_4$), and the electrolyte is mostly water, being only a very weak solution of sulphuric acid. If now the cell is connected to a generator, positive plate to the positive terminal of the generator and the negative plate to the negative terminal of the generator, the generator can be made to force current back through the cell, in at the positive plate through the electrolyte from the positive plate to the negative plate, and out of the negative plate. As the current is forced through a cell in this direction, the chemical action which takes place on discharge is reversed; the sulphions are driven out of the plates; the water in the electrolyte is broken up into hydrogen and oxygen; the hydrogen ions are caused to unite with the sulphions coming from the plates and form molecules of acid, and the oxygen is caused to travel to the positive plate and unite with the lead forming

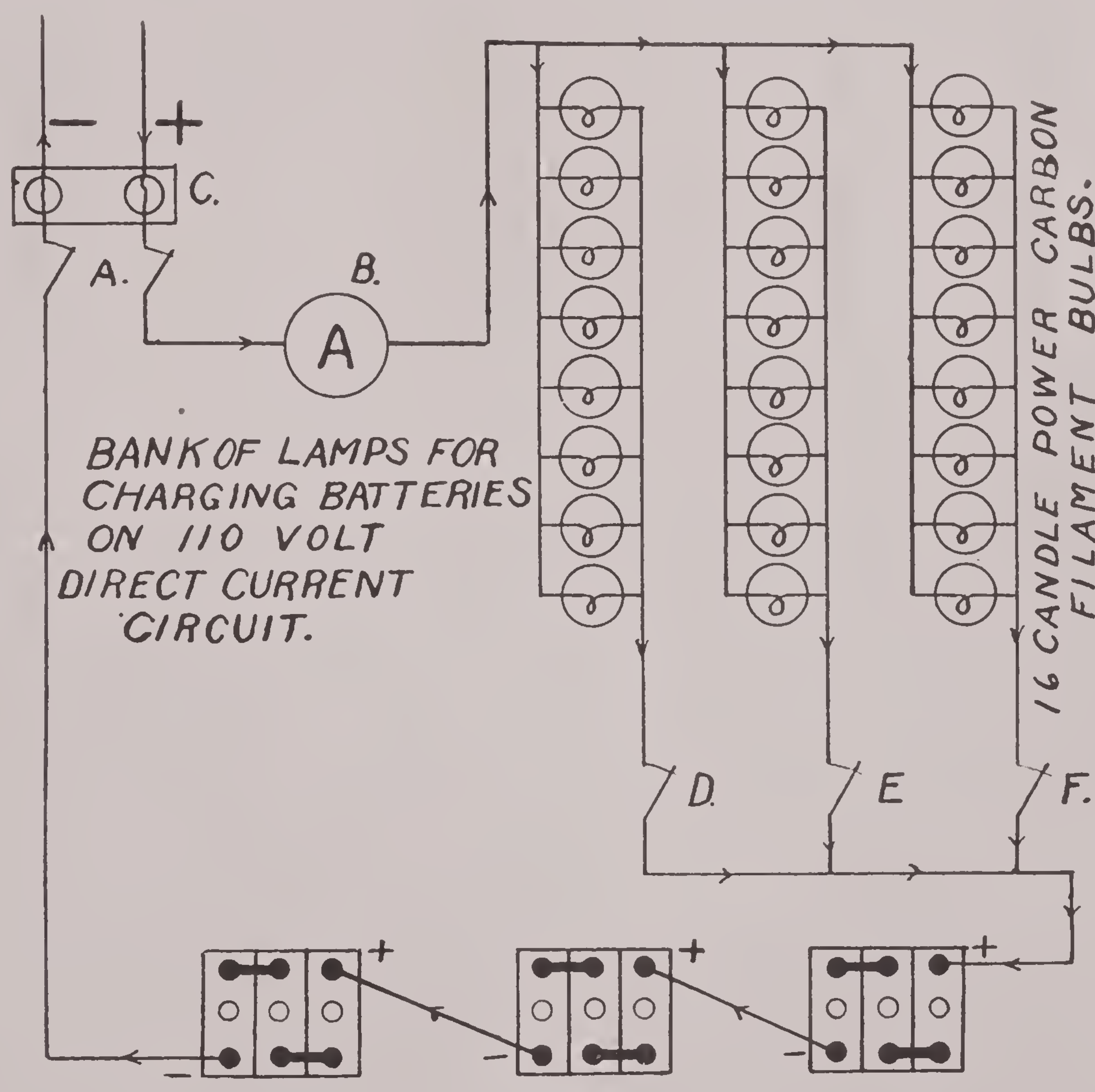


FIG. 225

lead peroxide. Continuing this action will in time, reduce the negative plate to a pure spongy lead, the positive plate to lead peroxide, and form enough acid in the solution to increase the strength of electrolyte to what it should be when cell is fully charged. When this condition is reached the cell is in a charged state, and is again capable of forcing current through a circuit for a given time.

During the latter part of the charge of a storage cell, water is broken up into hydrogen and oxygen faster than the sulphions are driven out of the plates, resulting in more hydrogen being liberated than there are sulphions to unite with it and more oxygen being liberated than there is lead in the positive plate to combine with it. The excessive hydrogen and oxygen escape from the cell in the form of gas. As the hydrogen and oxygen escape from the cell, the electrolyte is caused to bubble, or "gas." Reducing the rate electricity is forced through the cell during the last half of the charge, prevents excessive gassing. Gassing of the electrolyte, so long as the current is not being forced through the cell at too high rate, is an indication that the cell is nearly charged.

Storage cells should not be charged at too high rate. If the charge rate is too high, the cells will become heated and damaged and the electrolyte will be caused to gas excessively, or "boil." The charge rates for storage batteries are usually specified by the manufacturer, and sometimes marked on the name plate. If the charge rate is not stamped on the name plate, the starting rate may be taken as one tenth the ampere-hour capacity of the battery. These rates are for the first half of the charge, and should be reduced to one-half this rate during the last half of the charge.

To Determine Polarity

The polarity of a battery, or of the charging wires can be determined by any one of several methods. Two methods of accomplishing this are given in the following.

Insert the two ends of the conductors in a glass of water which contains a small amount of acid or common salt. (See Fig. 226.) The passage of current through the water separates it into its constituent parts, hydrogen and oxygen. The hydrogen follows the current to the negative wire forming bubbles about it. The oxygen goes against the current forming bubbles about the positive wire. Since the volume of hydrogen is twice the volume of oxygen, the greater number of bubbles will rise from the negative wire.

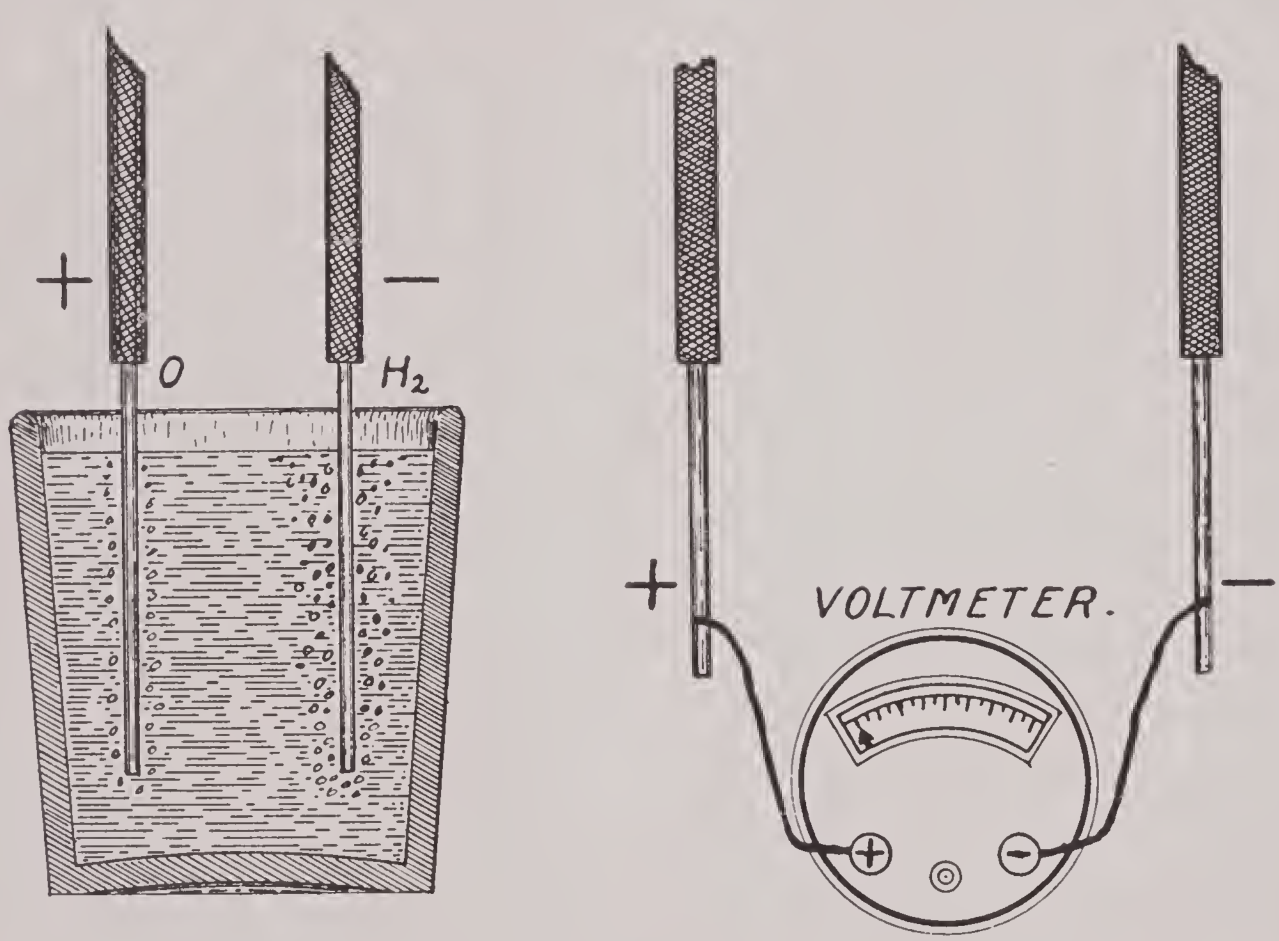


FIG. 226

The right hand illustration shows the voltmeter method. The voltmeter must have proper capacity to measure the voltage of the lines across which it is to be connected. The positive terminal of the voltmeter is marked. Touch the wires lightly to the terminals to see if the needle moves across the scale in the correct direction. If it does, the positive terminal of the voltmeter is then connected to the positive line.

Battery Charging

To charge a battery, connect its positive terminal to the positive terminal of the charger, and its negative terminal to the negative terminal of the charger. (A scheme for connecting a bank of lamps to be used as a charging resistance where 110 volts direct current is available is shown in Fig. 225). Adjust the charging resistance, or if a motor-generator is used, adjust the voltage, so that the current is sent through the battery at the proper charging rate.

Continue the charge at this rate until the specific gravity of the electrolyte comes up to between 1.225 and 1.250, then reduce the charging rate one-half. Continue the charge at this rate until there is no noticeable rise in the specific gravity of the electrolyte for a period of four or five hours, and the back E. M. F. is 2.5 volts per cell. The specific gravity of the electrolyte should then be from 1.275 to 1.300. (See Fig. 227.) If at any time during the charge, the temperature of the battery goes above 105 degrees Fahrenheit, the charging rate must be reduced or the battery taken off of charge and allowed to cool. If the electrolyte gases excessively during the first part of the charge, the charging rate is too high and must be reduced.

When storage batteries are allowed to stand for sometime in a discharged condition, or the electrolyte is permitted to get below the top of the plates, the sulphate on the plates so hardens that the charging current will not drive the sulphions out of the plates at the normal rate. If then, the battery is placed on charge at the full charging rate, the electrolyte will gas excessively and the battery will heat. Batteries in this condition (sulphated) must be put on a long slow charge.

If, at the end of the charge of a battery, the specific gravity of the electrolyte is above 1.300, there is too much acid in the electrolyte and some of the electrolyte should be drawn from the cells and replaced with distilled water. This condition is very likely the result of an attempt to charge the battery by adding acid. NEVER ATTEMPT TO CHARGE A STORAGE BATTERY BY ADDING ACID TO THE ELECTROLYTE. A battery will operate when its specific gravity is above 1.300, but then the electrolyte is so strong with acid

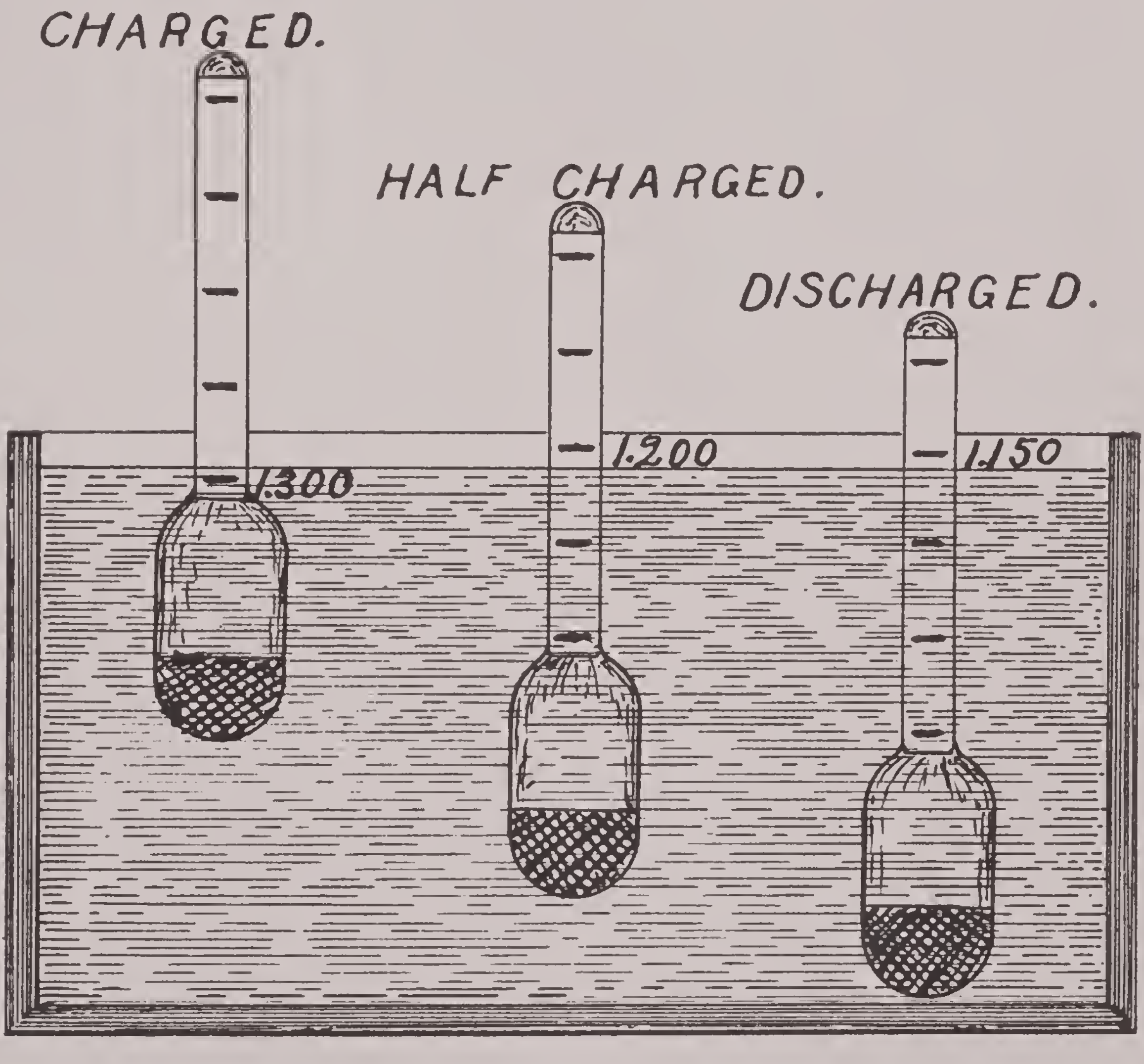


FIG. 227

that the grids will become corroded and the separators burned. If the grids corrode, the active material is likely to be cracked off, reducing the capacity of the battery. If the separators become burned, or charred by the acid, they will crumble and the plates will break through them, short-circuiting the cells internally.

If at the end of the charge the specific gravity is below 1.275 the electrolyte is weak. This may be due to cracked jars which permit the electrolyte to leak out, or to filling the cells too full when adding distilled water, and so causing them to overflow when charging begins. If the bottom of the battery box is rotted, one or more of the jars are likely to be cracked. If the terminals of the battery are corroded, and the top of the box is rotted, the cells are likely overflowing, or the cover-plates are not properly sealed in the jars. If there are cracked jars in a battery, or the cover-plates are not properly sealed in the jars, the services of a battery-repairman are required. After new jars have been placed in a battery, or the cover-plates properly sealed in the jars, the battery-repairman should make the necessary adjustment of the electrolyte.

The specific gravity not coming up to 1.275, when the battery is charged, may be the result of sulphated plates. When the plates become sulphated, it is seldom possible to drive all of the sulphate out of the plates by one charge, and as a result there will not be enough acid formed during a charge to bring the specific gravity of the electrolyte up to 1.275. But after the battery has been discharged and charged a few times with proper care, all of the sulphate will, in time, be loosened so that it will be driven out of the plates during charge. In old batteries, the specific gravity of electrolyte is not so likely to come up as high on charge as that in new batteries, since the plates shed with use and the active material is lost.

The charging of a battery should not be continued very long after it reaches a fully charged condition. Charging a battery after it has reached a fully charged condition, loosens the active materials causing them to fall to the bottom of the jars, and oftentimes heats the battery, damaging it and shortening its life. Overcharging storage batteries causes considerable damage.

Adding Water

Distilled water should be added to the cells about twice a month to keep the electrolyte above the tops of the plates. It is not necessary to add acid, as the acid does not leave the cell on either charge or discharge, and does not evaporate. Water evaporates from the cells and is also lost when the gassing takes place while the battery is charging.

If the specific gravity of the electrolyte is to be measured, do so before the water is added; or, if water has just been added to the cells, charge the battery a while to mix the water with the electrolyte, before measuring the specific gravity. If the weather is cold, temperature below freezing, the battery should always be charged for a while after the water is added. The water is lighter than the electrolyte and will remain on top unless mixed with the electrolyte. The gassing of the electrolyte mixes it with the water. If the water remains on top it is likely to freeze and burst the jars.

Corroded Terminals

If the battery terminals corrode, the substance formed by the corrosion should be loosened and removed. This can be done by moistening it with a solution of bicarbonate of soda, washing soda and water, or a rag wet with ammonia. Then brush the terminals with a wire brush. Corroded terminals may be cleaned by scraping with a knife, but when scraped, care must be taken not to scrape off the lead. (Scraping is not recommended.) After the terminals are cleaned, they should be covered with vaseline. The top of the battery should be cleaned with a rag moistened with ammonia and then covered with vaseline. Do not let the cleaning solution get into the cells as it will neutralize the acid within the cells in the same manner that it does the acid on the top and terminals.

Freezing Temperatures

The freezing temperatures for the electrolyte are as follows:

Specific Gravity.		Freezing Temperatures.	
	Above Zero.		
1.000 (Water)	Plus	32	Degrees
1.050	”	26	”
1.100	”	18	”
1.150	”	15	”
	Below Zero.		
1.200	Minus	22	”
1.250	”	60	”
1.275	”	90	”
1.300	”	97	”

A battery when not in use should not stand at freezing temperatures, even though it is charged, as the acid settles to the bottom, leaving a weak solution at the top that will freeze at higher temperatures than given above.

Batteries used in tropical climates must operate at higher temperatures than those used in the temperate climates and for this reason the electrolyte is not as strong.

Storing Batteries

Storage batteries, when not in use, should be stored in a cool dry place. The temperature should be about 70 degrees Fahrenheit. A freshening charge should be given the battery every month or six weeks. A storage battery can be left for as long as six months without damage to battery, but at the end of this time it is necessary to give the battery a long slow charge before putting it into service. The battery will not be as active as before it was allowed to stand until it is charged and discharged several times.

ELECTROMAGNETISM

An electric current always produces a magnetic field; that is to say, electricity in motion sets up magnetic lines of force in the space immediately surrounding the conductor in which it is flowing. The lines of force flow in circular paths around the conductor. The direction of the flow of the magnetic lines of force bears the same relation to the direction of the flow of current, as the direction of rotation of a corkscrew bears to its backward and forward movement. Looking at the end of the wire, if the conductor is carrying current away from the observer, the magnetic lines of force flow around it in the same direction as the corkscrew must be turned to turn it into a cork. If the conductor is carrying current toward the observer, the lines of force flow around it in the same direction as the corkscrew must be turned to turn it out of the cork.

When the direction of the flow of the current in a conductor is known the direction of the flow of the lines of force around the conductor may be determined by the following right hand rule. Grasp the conductor with the right hand so the thumb points in the direction of the flow of current, and the fingers will then bend in the direction of the flow of the lines of force.

Magnetic Field About a Straight Conductor

Fig. 228 gives a conception of the magnetic field set up about a straight conductor carrying current from right to left. This figure is merely illustrative and the idea that the magnetic field only extends out for a short distance from the conductor must not be formed. The magnetic field extends to an indefinite distance from the conductor, though the strength of the field becomes weaker and weaker as the distance from the conductor increases. The change in density of the field is inversely proportional to the distance from the conductor. In practice, the field becomes so weak only a short distance from the conductor that it is usually assumed there is no field except near the conductor. If a compass needle is placed beneath the conductor in Fig. 228, it will point toward the observer. If the compass is placed above the conductor, it will point away from the observer. This shows that the magnetic lines of force flow toward the observer beneath the conductor and away from the observer above the conductor. The flow of the magnetic lines of force around the conductor is always at right angles to the flow of the electric current. They do not flow along the conductor but flow around it.

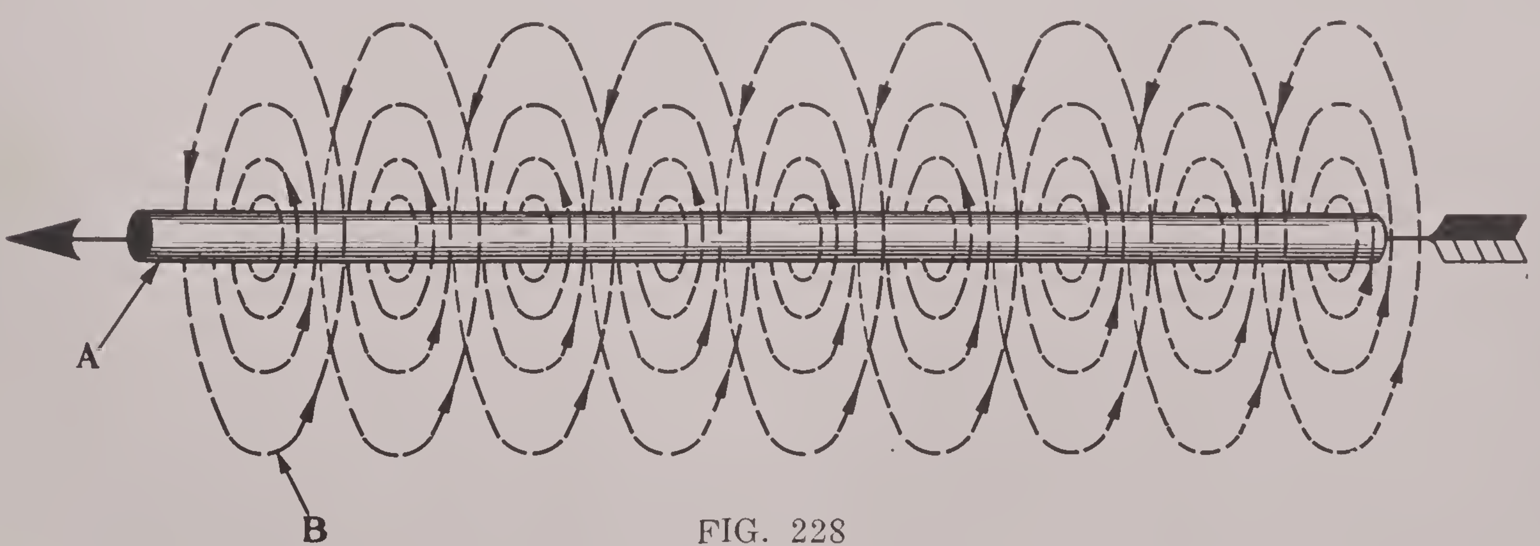


FIG. 228

Strength of Field Depends Upon Strength of Current

The strength of the magnetic field set up about the conductor is directly proportional to the strength of the current. Any variation in the strength of the current causes a corresponding variation in the strength of the magnetic field about it. If the strength of the current is increased the strength of the field will be increased; or if the strength of the current is decreased the strength of the field will be decreased. If the current is interrupted the field collapses, the instant the flow of electricity stops. The strength of the field does not dedepend upon the size of the conductor or the material of which it is made.

Parallel Conductors Carrying Current in Same Direction

Fig. 229, illustration (C) shows a section of three parallel conductors carrying current in the same direction and the manner in which the magnetic lines of force flow around all of the conductors instead of around each one separately. The magnetic lines of force flowing around all three conductors tend to pull the conductors together. Parallel conductors carrying current in the same direction attract one another.

Parallel Conductors Carrying Current in Opposite Directions

Fig. 229, illustration (D) shows a section

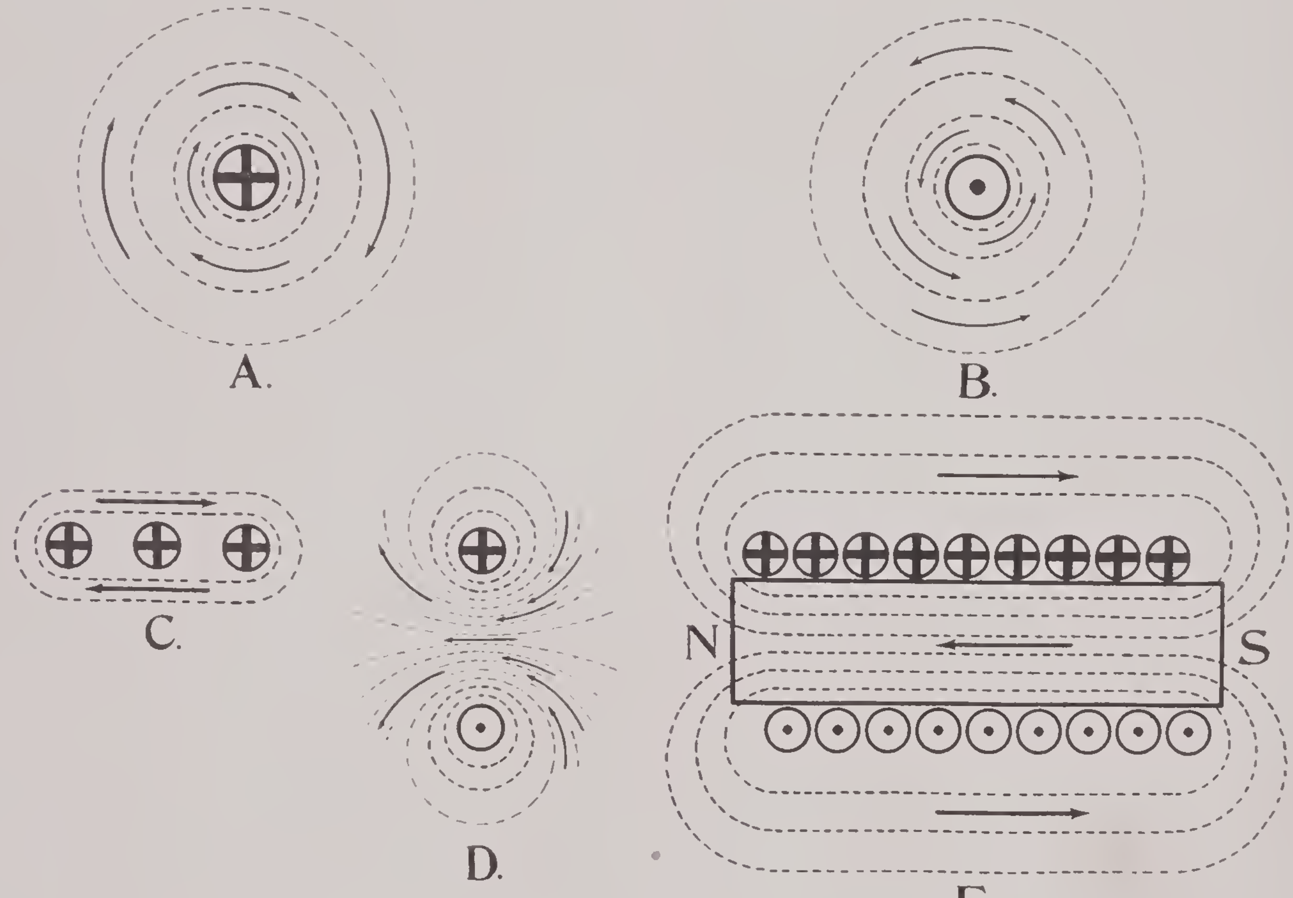


FIG. 229

Direction of Field Depends Upon Direction of Current

Fig. 229, illustration (A) shows a cross-section of a conductor carrying current away from observer and the magnetic lines of force flowing around the conductor in a clockwise direction. Illustration (B) shows the cross-section of a conductor carrying current towards observer and the magnetic lines of force flowing around the conductor in a counter clockwise direction. These figures are illustrative and show that a change in the direction of the flow of current causes a change in the direction of the magnetic lines of force which flow around the conductor.

through two parallel conductors carrying current in opposite directions and the manner in which the magnetic lines of force crowd in between the conductors. The cross in the center of one conductor indicates that the current is flowing away from observer. The magnetic lines of force flow around this conductor in a clockwise direction. The dot in the center of the other conductor indicates the current is flowing toward observer. The magnetic lines of force flow around this conductor in a counter clockwise direction. The magnetic lines of force crowd in between the conductors and as one line repels another, a force is set up that tends to push the conductors apart. Parallel conductors carrying current in opposite directions repel one another.

Magnetic Field Set Up by Current in a Coil

When an electric current is passed through a coil of wire, magnetic lines of force are set up which flow through the coil, out at one end, around the coil and back into the coil at the other end. A coil of wire carrying current is much the same as a bar magnet. It has a north pole and a south pole. If the coil is suspended free to turn while it is carrying current, it will come to rest with one end towards the north and the other end towards the south. If the coil is brought near magnetic material while it is carrying current, it draws, or tends to draw, the magnetic material into it. Fig. 229, illustration (E) shows a section through a coil and the direction in which the magnetic lines of force are set up. The polarity of a coil carrying current may be determined by the following right hand rule. Grasp the coil with the right hand so the fingers bend in the direction the current flows around coil, and the thumb will then point to the north pole.

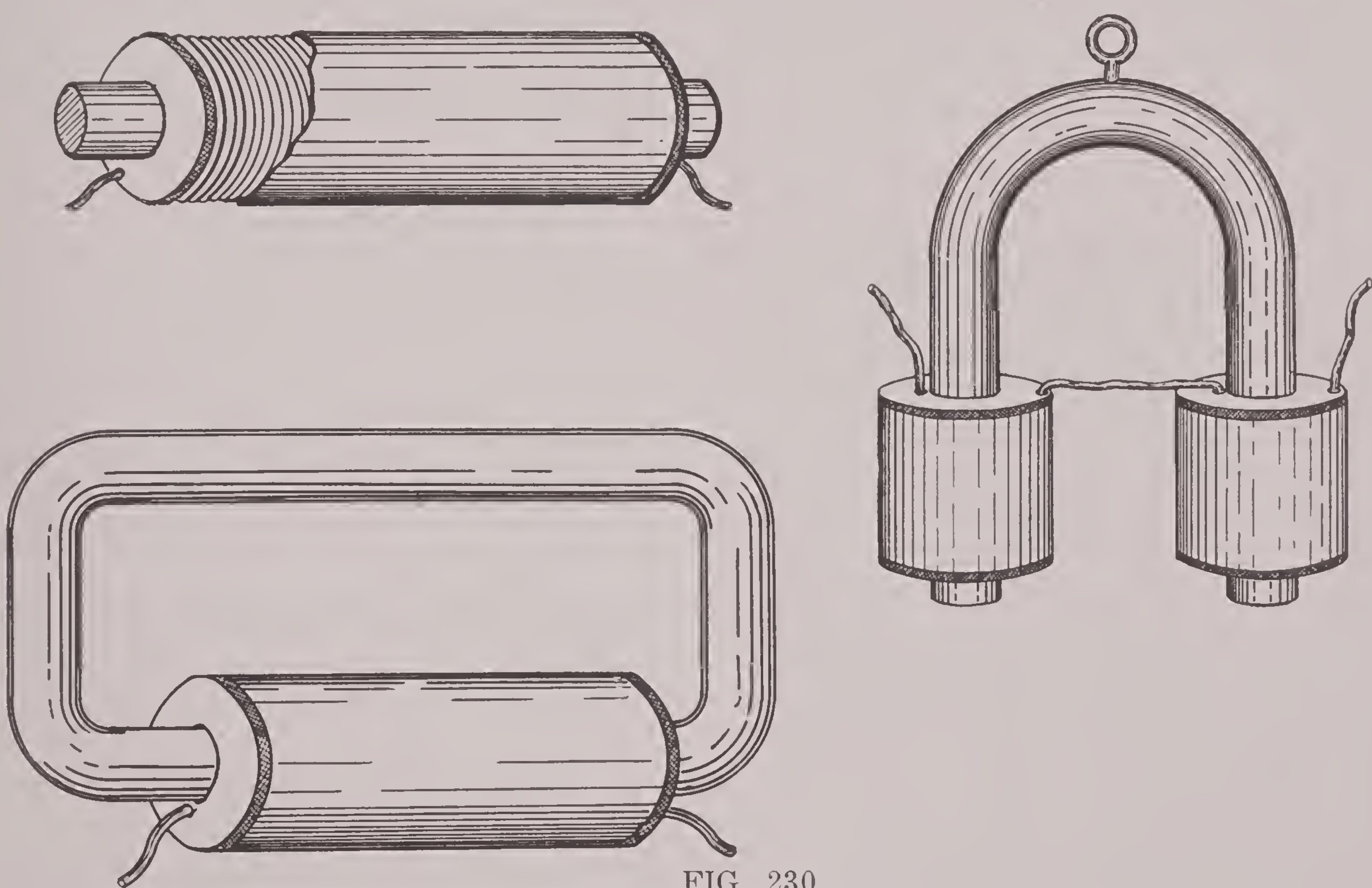


FIG. 230

Helix Solenoid

A coil that will carry an electric current is called a helix. If the length of the coil is greater than its diameter it is usually called a solenoid. The strength of the magnetic field set up by a helix depends upon the number of turns, the number of amperes and shape of helix. The number of amperes multiplied by the number of turns equals the number of ampere-turns in a helix.

Ampere-Turns

One ampere passing through one turn is one ampere-turn. One ampere passing through two turns will be two ampere-turns; two amperes passing through one turn will be two ampere-turns. One ampere passing through two turns sets up as strong magnetic field as two amperes passing through one turn. Since the magnetic field is proportional to the ampere-turns, they may be taken as a measure of the magnetic strength of a helix.

Advantage of Many Turns

Consider two coils which will be referred to as coil "A" and coil "B." Both are wound of the same sized wire, and are the same diameter. Coil "A" has 500 turns and coil "B" has 1,000 turns. Twice as much wire must be used for coil "B" as for coil "A" and so its resistance is twice as great. If coil "A" has one ohm resistance, coil "B" then has two ohms. Coil "A" when connected to the terminals of a six-volt battery will carry six amperes, [6, (number of volts) ÷ 1, (number of ohms) = 6, (number of amperes)] and so has three thousand ampere-turns [6, (number of amperes) × 500, (number of turns) = 3000, (number of ampere-turns)]. The power used by "A" is equal to 6, (the number of volts), multiplied by 6, (the number of amperes), equals 36, (the number of watts). Coil "B" when connected to the same battery carries three amperes [6, (number of volts) ÷ 2, (number of ohms) = 3, (number of amperes)] and has three thousand ampere-turns [3, (number of amperes) × 1000, (number of turns) = 3000, (number of ampere-turns)]. The power used by "B" is equal to 6, (the number of volts) multiplied by 3, (the number of amperes) equals 18, (the number of watts). Coil "B" has the same number of ampere-turns as coil "A," consequently it sets up practically as strong a field, but the power required for coil "B" is only half the power required for coil "A." The advantage then of more turns in a coil is that practically the same strength of magnetic field can be produced with less power consumption.

From the comparison of these two coils it can be seen that, were it not for the coil heating, the short circuiting of turns would not change its ampere turns, since the resistance decreases in proportion to the number of turns short circuited, causing the current to increase, thereby keeping the ampere-turns approximately constant.

The strength of the magnetic field set up by a helix depends to a great extent upon its length. The longer the helix the farther the lines of force must flow to complete their circuit and so the higher the reluctance of the circuit. If the helix is wound compactly, a stronger field will be set up for a given number of ampere turns than will be set up if the helix is longer than its diameter.

Electromagnet

When an insulated conductor is wound around a soft iron core an electromagnet is formed. When current is sent through the coil, the magnetic lines of force which it sets up flow through the core and magnetize it. By using the core, from several hundred to several thousand times as many magnetic lines of force are set up as would be possible without the core. Fig. 230, upper left, shows a straight core type electromagnet. In this type, the magnetic lines of force must flow in one direction through the air from one pole to the other to complete their circuit, hence the reluctance is high. This type core is used for induction coils. The illustration at right shows a "U" or horseshoe core. The ends of this core are not so far apart, hence the reluctance is not so high. This type core is used for magnet chargers and lifting magnets. The illustration at bottom shows a closed core. This type core is not used for lifting magnets, as the magnetic circuit is closed and there are practically no poles. This type core is used to some extent in induction coils. It gives a

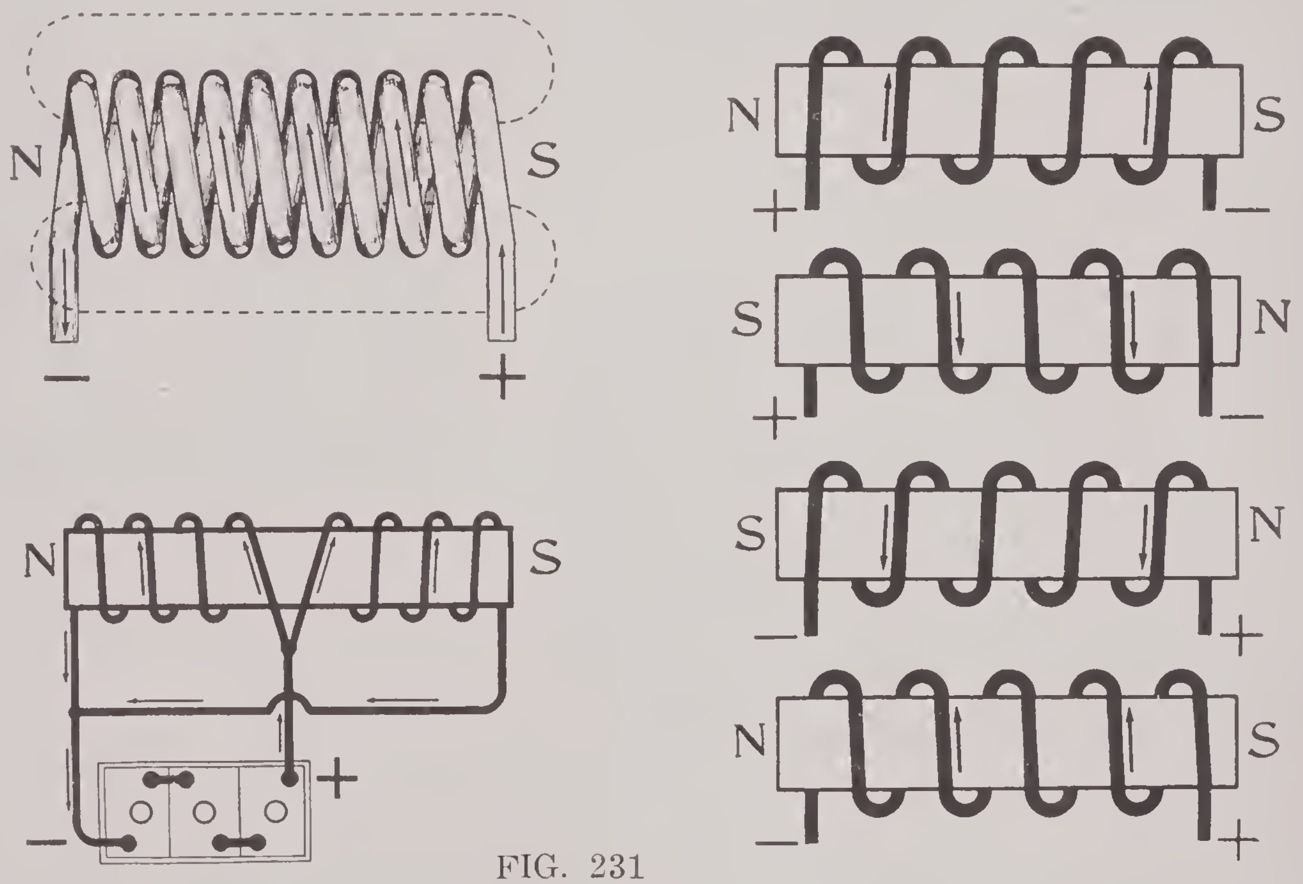


FIG. 231

magnetic circuit of low reluctance, hence, more magnetic lines of force are set up for a given number of ampere-turns.

Polarity of Electromagnet

The polarity of an electromagnet depends upon the direction the current flows around the core. (See illustrations in Fig. 231.) The right hand rule by which the polarity of a coil is determined can be used to determine the polarity of an electromagnet. Some electromagnets have two windings on the core as shown at the lower left in Fig. 231. As long as the current is passed around the core in the same direction in both windings, both windings assist in magnetizing the core. If the current is passed around the core in one winding in the opposite direction to the flow of the current in the other winding, one then tends to neutralize the other. If there are the same number of ampere-turns in both windings, the core will not be magnetized. If there are more ampere-turns in one winding than in the other, the polarity of the core depends upon the direction the current flows in the winding having the greater number of ampere-turns. The current in the other winding then merely tends to weaken the magnetic strength of the core.

Strength of Electromagnet

The strength of the electromagnet depends upon the number of ampere-turns in the coils, and the size and shape of the core and the material of which it is made.

ELECTROMAGNETIC INDUCTION

When a conductor cuts magnetic lines of force, an E. M. F. is induced in it that is proportional to the rate at which the lines of force are cut. The conductor can be moved and the field held stationary; the field moved and the conductor held stationary; or both conductor and field moved—but in any case the movement of one with relation to the other must be such that the conductor cuts the lines of force. If the relative movement of the conductor is parallel to the lines of force, no E. M. F. is induced in the conductor.

Strength of Induced E. M. F.

When a conductor cuts one hundred million lines of force per second during its movement with respect to the magnetic field, an E. M. F. of one volt is induced in the conductor. If the conductor cuts lines of force at the rate of two hundred million per second, the induced E. M. F. is two volts; and if the conductor cuts six hundred million lines of force per second, the induced E. M. F. is six volts. If the conductor that cuts the magnetic lines of force is part of a circuit, a current is produced equal in strength to the induced E. M. F. divided by the total resistance of the circuit.

Direction of Induced E. M. F.

The direction of the induced E. M. F. depends upon the direction of magnetic lines of force flow, and the direction the conductor moves across the field. One of the best rules for remembering the relation between the direction of the flow of the magnetic lines of force, the direction that the conductor moves across the magnetic field, and the direction of the induced E. M. F., is known as Fleming's Right Hand Rule. The rule is as follows: Place the thumb, first finger and middle finger of the right hand all at right angles to each other; turn the hand into such a position that the thumb points in the direction of the movement of the conductors and the first finger in the direction the magnetic lines of force flow, then the middle finger will point in the direction of the induced E. M. F.

Illustrations in Fig. 232 show the relation between the flow of the lines of force, the direction a conductor moves across the field and the direction of the induced E. M. F. In the upper left illustration the north pole of the horseshoe magnet is at the bottom, and the south pole at the top. The general direction of the flow of the lines of force then is upward. A cross-section of a conductor which is being moved between the poles is shown. The direction of the movement of the conductor is from right to left. The cross in the center of the conductor indicates that the induced E. M. F. would be forcing the current away from observer. The dotted circle around the conductor represents the magnetic lines of force that would be set up by the induced current in the conductor. Because of lines of force set up by the induced current, the lines of force between the poles of the magnet are crowded ahead of the conductor and compressed on the side moving against them. These lines of force being compressed on this side of the conductor and flowing upward, may be thought of as tending to set up a magnetic whirl around the conductor in a clockwise direction which, if set up, will cause current to flow through the conductor away from the observer.

Illustration at lower right shows another relation between the direction of the flow of the magnetic lines of force, the direction of the movement of the conductor and the direction of the induced E. M. F. when the conductor is moving out from between the poles. Moving in this direction, the induced E. M. F. causes the current to flow through the conductor towards the observer. The magnetic lines of force set up by the magnet are compressed on the opposite side of the conductor to that shown in upper left, hence they tend to set up a magnetic whirl about the conductor in a counter-clockwise direction, which, if set up, will cause current to flow toward the observer.

If the current is increasing in strength, more magnetic lines of force are expanding from the centre of the conductor much like "ring waves" expand from a point where a stone is dropped in a body of water. As these magnetic lines of force expand from the centre of the conductor, they are cut by the conductor, inducing an E. M. F. in it. The direction of the flow of the magnetic lines of force set up by the current, and the direction the conductor cuts them as they expand is always such that the induced E. M. F. opposes the increase in the strength of the current.

If the strength of the current is decreased, the magnetic field also decreases; that is, lines of force collapse toward the centre of the conductor. As the lines collapse, they are cut by the conductor, and so induce an E. M. F. in it.

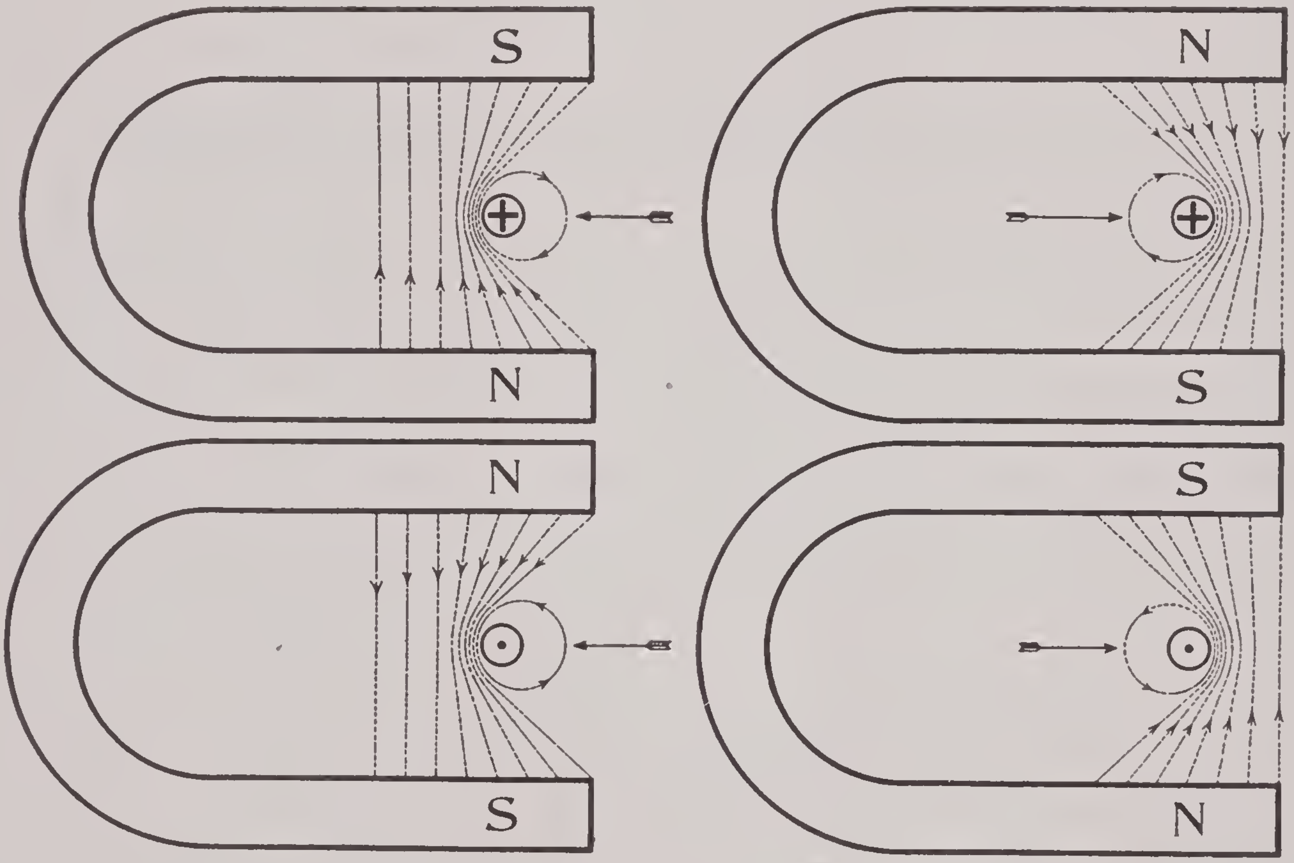


FIG. 232

Self-Induction

Whenever the strength of the current flowing through a circuit is caused to change, an E. M. F. which opposes the change is induced. If the strength of the current is increased, while the increase is taking place, an E. M. F. is induced which is against the flow of current. If the strength of the current is decreased, while the current is decreasing, an E. M. F. is induced which tends to keep the current flowing in the same direction and at the same strength. These E. M. F's. are induced in the circuit by the movement with relation to conductor of the magnetic lines of force set up by the current.

The direction of the lines of force set up by the current and the direction they are cut by the conductor when they collapse, is always such as to induce an E. M. F. that tends to keep the current flowing in the same direction and at the same strength.

The inducing of an E. M. F. in a circuit by changing the strength of the current flowing through it, is called self-induction.

Self-induction of an electric circuit is analagous to the property of matter called inertia. When an electric circuit is closed, the strength of the current does not reach its full strength (volts divided by ohms) the instant the circuit is closed, but gradually "builds up" to full strength. When a circuit is opened the flow of electricity does not stop the instant the break occurs, but instead, a spark, or arc is usually produced at the point where the circuit is broken and the flow of electricity is quickly but not instantly stopped. Stopping a flow of electricity through a circuit by opening a switch is much like holding a number of planks in the path of a moving car to bring it to a standstill. The self-induced E. M. F. drives the electricity through the thin air-gap, between the switch blade and jaw, when the switch is first opening, just as the momentum of the car will cause it to crash through a number of the planks before being brought to a standstill.

The self-induction of long straight conductors is very low since the lines of force which are set up by the current, cut the conductor once when they expand, and once when they collapse. The self induction of coils is comparatively high, varying as the square of the number of turns. The self-induction of a coil may be made very high by winding it on a soft iron core. If the coil is wound on a soft iron core more lines of force are set up by the current, hence there are more to be cut by the turns of the coil as they expand; and, when the current is interrupted there are more lines to be cut by the turns of the coil as they collapse. Since a coil of many turns (high self-induction) causes the current to lag so much that it will not reach full strength in a short space of time, only coils of comparatively few turns are used in circuits which are rapidly opened and closed.

Mutual Induction

Fig. 233 shows two circuits, one of which is called the primary circuit and the other the secondary circuit. The primary circuit includes a dry cell, a switch and a long conductor forming a loop. The secondary circuit is made up of a long conductor and a millivoltmeter. One side of the primary circuit lies parallel with one side of the secondary circuit.

When the switch in the primary circuit is closed, the E. M. F. of the cell causes current to flow through the circuit, and as the current builds-up, magnetic lines of force expand from the centre of the conductor and flow around it. As the lines of force expand from the part of the primary wire that lies parallel to the secondary, they are cut by the secondary and induce an E. M. F. in it, causing current to flow through the meter, deflecting the needle. The direction of the induced current in the secondary, as the lines expand, is opposite to that in the primary.

When the switch in the primary circuit is

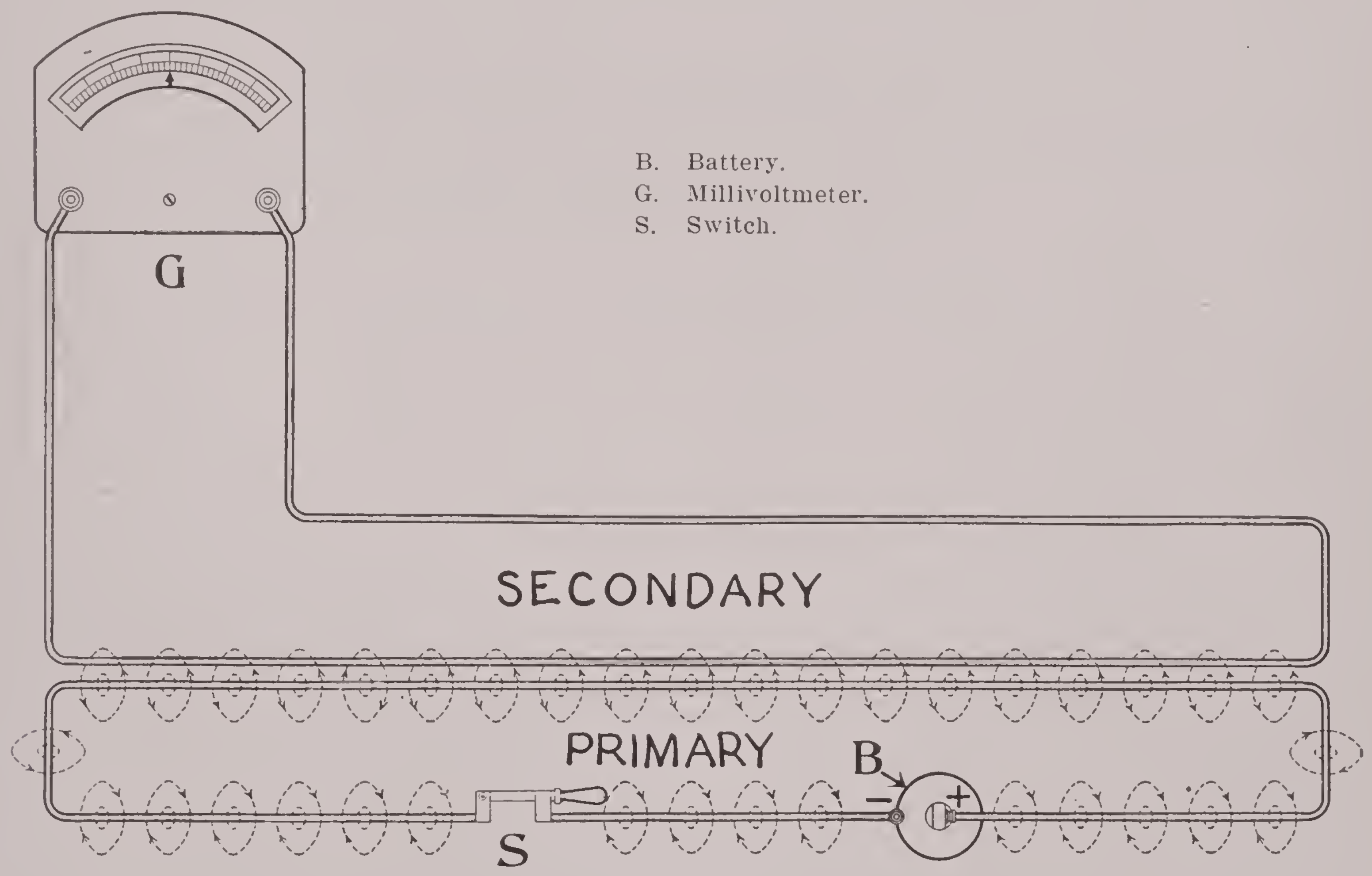


FIG. 233

opened, the lines of force collapse to the center of the primary wire, and as they collapse they are again cut by the wire of the secondary circuit inducing E. M. F. in it. The current which flows through the secondary as a result of the induced E. M. F. during the collapse of the lines of force, is in the same direction as that in the primary.

The inducing of E. M. F. in a secondary circuit by varying the strength of the current in a primary circuit is called mutual induction. Mutual induction is caused by expanding or collapsing lines of force and so takes place while the current in one of the circuits is increasing or decreasing.

A good example of an application of mutual induction is the high tension induction coil. The induction coil, sometimes called a transformer, consists of: (1) Core—usually a bundle of soft iron wire; (2) Primary—a winding of a few hundred turns of about No. 18 or No. 20 wire wound over the core, but insulated from it; (3) Secondary—a winding of several thousand turns of fine wire, about No. 36 or No. 38, which is wound over the primary but well insulated from it. The induction coil is used to produce a current of high voltage from one of low voltage. As required for ignition, the high voltage must be sufficient to cause a spark to jump an air gap and the low voltage varies from 6 to 30 volts.

The primary winding of the induction coil is connected in series with the battery or generator, and some device such as a breaker or vibrator which opens and closes the circuit. For the present consideration a switch may be used for closing and opening the circuit. The secondary is connected in series with a small air gap which in practice, is usually the gap of a spark plug. (See Fig. 234.) The figure is illustrative and is not intended to show the number of turns in either the primary or secondary. The primary is shown in heavy lines and the secondary is shown in lighter lines. The relative position of core, primary, and secondary and the method of connecting the ends of both primary and secondary to terminals are plainly shown. In actual construction the turns of the primary and secondary are wound as closely as the insulation will permit.

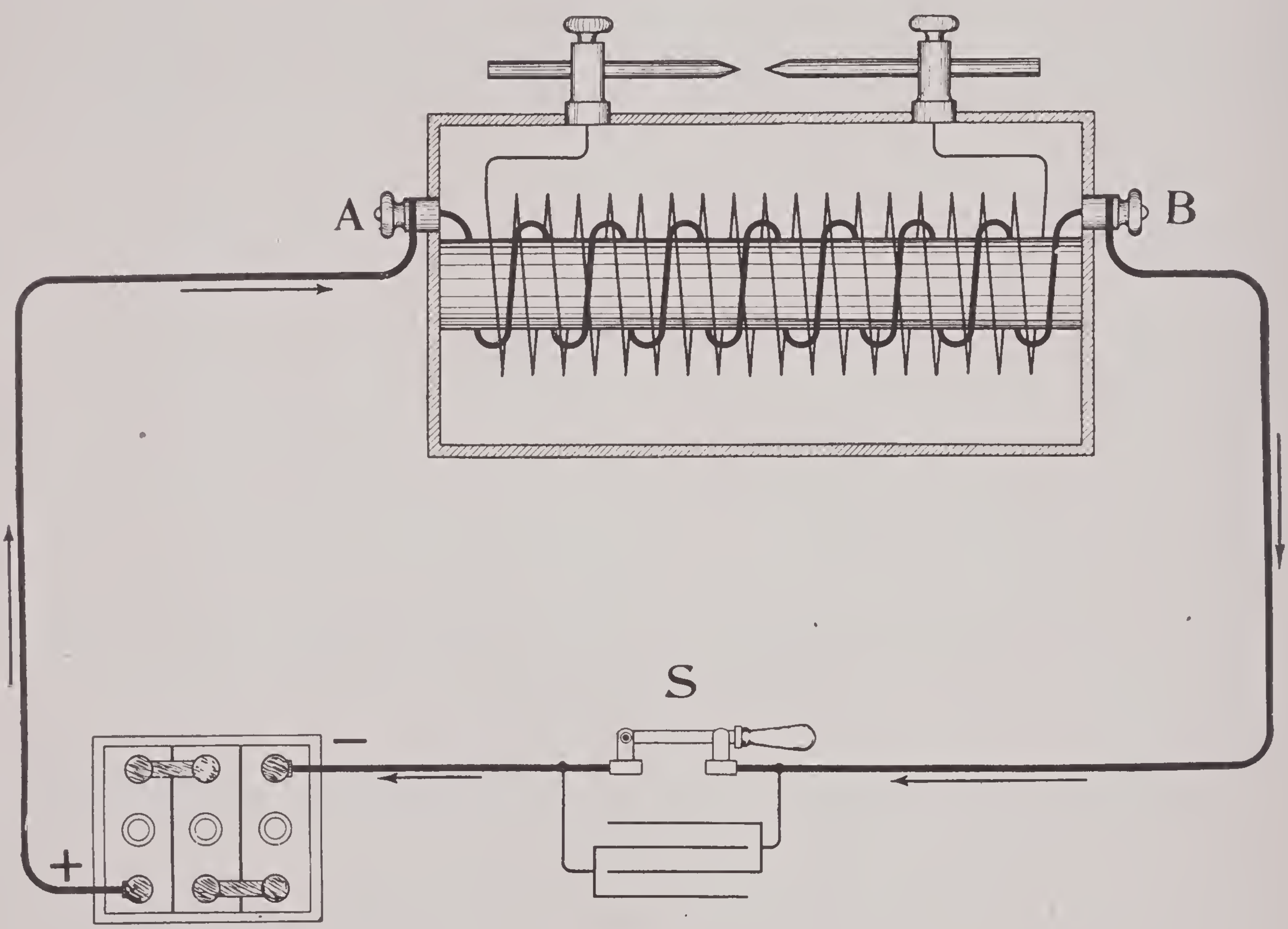


FIG. 234

Operation of Induction Coil

When the switch is closed, the battery causes current to flow through the primary circuit, which as it flows through the primary winding of the coil, magnetizes the core. As the core becomes magnetized, lines of force expand from the primary and are cut by the coils inducing an E. M. F. in each turn of the secondary winding. The lines expand at a rate that, disregarding the losses due to resistance of wires, reluctance of core, etc., induces in the secondary an E. M. F. which is as many times the E. M. F. of the battery as the number of turns in the secondary are times the number of turns in the primary. If there are 100 times as many turns in the secondary as in the primary, the E. M. F. induced in the secondary is about 100 times the E. M. F. of the battery.

When the switch is opened, the current in the primary is interrupted, causing the lines of force to collapse. The flow of electricity is stopped in 1/20 to 1/100 the time required for the E. M. F. of the battery to build it up. Since the lines collapse 20 to 100 times as quickly as they expand, the E. M. F. induced in the secondary when the primary circuit is broken is from 20 to 100 times as strong as the E. M. F. induced when the primary circuit is closed. If there are 100 times as many turns in the secondary as in the primary, the E. M. F. induced in the secondary when the primary is broken may be from 2,000 to 10,000 times the E. M. F. of the battery. The secondary voltage of ignition coils is very high, from 12,000 to 30,000 volts and even higher. This high E. M. F. induced in the secondary winding by the collapse of the magnetic lines of force is strong enough to drive electricity across the air gap that is in the secondary circuit. As the electricity is forced across the gap a spark is produced.

The strength of the current in the secondary cannot be other than weak, since the watts in the secondary can never equal or be more than the watts in the primary. It is for this reason that the secondary terminals of an induction coil can be held in the hands without danger of severe shock or burn.

The self-induced E. M. F. produced in the primary by the collapse of the lines of force tends to keep the primary current flowing, resulting in the current being forced across the gap between the switch contacts as they separate. This prevents a quick collapse of the lines of force and causes a spark which burns the switch contacts. To reduce this sparking to minimum and at the same time effect a quick interruption of the current, a condenser is connected parallel to the switch.

Condenser

If a metal plate is connected to the positive terminal of a battery and a similiar one is connected to the negative terminal of the battery, the former will receive a positive charge and the latter will receive a negative charge. So long as the plates are some distance apart the charges are small. If the plates are brought near together, but not touching each other, there will be an attraction between the two unlike charges on the plates. The nearer the two plates are, the greater this attraction will be and the greater the charge on each plate will be, because the charge on one plate will draw a stronger charge on the other. The binding effect of one charge on the other makes it possible for the E. M. F. of the battery to draw a quantity of electricity from one plate and force it on the other.

Two such metal plates insulated from each other form a simple condenser. The capacity of a condenser is determined by the quantity of electricity that can be stored on the positive plate under a pressure of one volt. If enough electricity under a pressure of one volt can be stored on the positive plate to give an average current of one ampere for one second when discharged the condenser has a capacity of one farad. A condenser to have a capacity of one farad must be very large, so instead of using the farad as the common unit of capacity the microfarad is used. The microfarad is one millionth of a farad.

If air is used to insulate the plates, one from the other, it is difficult to keep the plates from touching, and it has been found that other materials will insulate the plates better and at the same time give the condenser a higher capacity. Paraffin paper and mica are both very good materials for placing between the plates and both can be made in comparatively thin sheets so the plates can be placed very close together and yet be well insulated from each other. If the condenser is made of tinfoil for the plates and paraffin paper for the insulation between the plates, the condenser can be rolled into a small roll so that it is very compact. If mica is used it is not necessary to make the plates so large since stronger charges will store on plates separated by mica than when separated by paraffin paper of the same thickness.

It is hardly practical to construct two plates large enough to have the proper capacity for a condenser to be used in parallel to the switch. Instead, the condenser is made up of a number of plates. Alternate plates are joined together forming two groups of plates arranged similar to the positive and negative groups of the storage battery. Each group is connected to one of the terminals.

The capacity of the condenser depends upon the size and number of plates and the thickness and kind of material used to insulate them from each other. The area of the plates can be increased either by using larger plates or more plates. The greater the area of the plates the higher the capacity of the condenser. The closer the plates are together, that is, the thinner the insulating material between them, the higher the capacity. Some insulating materials permit a stronger charge to be stored on the plates under a given pressure than others, so are better for this use.

There is no circuit through a condenser because the plates connected to one terminal are entirely separated by insulating material from the plates connected to the other terminal. If there is a circuit through a condenser, the condenser is either shorted or punctured and is worthless. A condenser can be charged by connecting it to a battery or a generator. If the charge stored in the condenser is to be of noticeable strength, the voltage of the battery or the generator should be something over a hundred volts. If the test points of a 110 volt D. C. test lamp are placed on the terminals of an ignition condenser it will be charged with strong enough charge to give a spark when discharged through a slight air gap.

The action of a condenser around the switch is, in many ways, like that of a surge chamber around a valve in a hydraulic circuit similar to that shown in Fig. 235. The chamber above the valve is divided by a diaphragm made from a heavy sheet of rubber. With the pump running and the valve open, the water which fills the pipes, pump and surge chamber, is caused to circulate through the circuit formed by the pipes and the pump. If the valve is quickly closed, the force of the water in motion (momentum) causes it to surge against the gate of the valve. By having the surge chamber connected around the valve, the force of the water on the valve is reduced considerably. Some of the water surges into the part of the surge chamber on the left and an equal volume passes out of the part of the chamber on the right, pushing the rubber diaphragm to the position shown by the dotted line, thus permitting the water to continue flowing for an instant after the valve closes. As soon as the flow of the water is stopped, there is no longer any force to hold the diaphragm in this position and the action of the rubber, tending to flatten out, then crowds water back out of the chamber on the left, around through the circuit, producing a momentary current in the reverse direction.

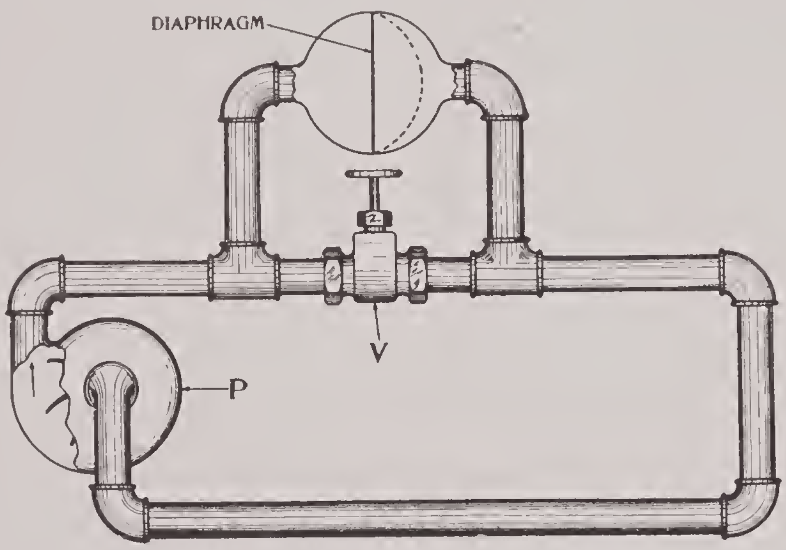


FIG. 235

In the condenser, as long as the switch is closed, the condenser is shorted and so is not charged. At the instant the switch opens, an air gap is formed in the primary circuit which resists the flow of electricity, causing it to crowd in on one set of plates of the condenser and charge them with a positive charge, and to be drawn from the other set of plates, leaving them with a negative charge. As the condenser is being thus charged, the current is permitted to continue flowing through the battery and the primary winding of the coil for an instant after the switch contacts begin to separate. This delays the collapse of the lines of force until the switch has opened far enough so that the gap between the contacts will withstand the self-induced E. M. F. of the primary. As the condenser is charged, its back E. M. F. increases until it becomes equal to the E. M. F. of the battery plus the self-induced E. M. F. of the primary and so quickly stops the flow of electricity. As soon as the flow is stopped, the lines of force which it set up have collapsed and there is no self-induced E. M. F. to keep condenser charged, hence it discharges back through the primary.

The momentary current back through the primary in the reverse direction, produced by this discharge, forces the lines of force set up by the residual magnetism of the core to collapse.

The functions of the condenser are to reduce sparking at the points where the primary circuit is broken and to intensify the E. M. F. in the secondary by causing a quicker and more nearly complete collapse of the lines of force across the secondary. Without a condenser connected in parallel with the device used to open the primary circuit, the coil will seldom produce strong enough E. M. F. to break down the resistance of the air gap in the secondary circuit.

IGNITION

Electrical ignition systems for gas engines are divided into two classes; namely, low tension ignition systems which are used on some tractor and stationary engines, and high tension ignition systems which are used on the automobile, aviation, truck and most tractor engines.

Low Tension or "Make and Break" Ignition System

Fig. 236 shows a typical low tension system as applied to a one-cylinder four-stroke cycle engine. In order that the parts of the ignition system may be emphasized, only a few of the principal parts of the engine are shown.

The igniter is a mechanically operated switch which opens and closes the circuit within the combustion chamber of the engine, so that the spark which occurs when the contacts (C) separate will ignite the mixture compressed in the cylinder. (D) is a rod that passes through the cylinder wall but is insulated from the plug by mica washers. The outer end of this rod is the igniter terminal and the inner end is one of the igniter contacts. A second rod or shaft passes through the cylinder but is made to rotate, and on the inner end of this shaft is fastened an arm that carries the other igniter contact. On the outer end of the shaft is another arm by which the shaft is rotated far enough to bring the contact on the inner arm against the contact on the inner end of rod (D). The contacts are opened and closed by the push-rod (J) which is actuated in one direction by the cam (K) on the camshaft and in the other direction by the spring (L).

The coil has one winding on a soft iron core. There are only two terminals (A) and (B) on the coil, and it is usually about the size of a dry-cell. The battery is usually five dry-cells connected in series, or ten dry cells connected in series-parallel. One terminal of the battery is grounded to the frame of the engine at some point as shown, and the other terminal connects through the switch to terminal (A) of the coil.

Operation of Low Tension Ignition System

The ignition switch is first closed. The engine is then cranked. As the piston comes up on compression stroke the cam on the camshaft forces the push-rod (J) up, closing the igniter contacts. When the contacts come together, the E. M. F. of the battery causes current to flow through the circuit. As the current flows through the coil, the core is magnetized and a large number of magnetic lines of force are set up, which expand around the coil. As the piston continues to move up, the cam turns farther so that by the time the compression stroke has been completed, the lobe of the cam slips from beneath the push-rod (J) and the spring (L) throws the push-rod back, causing igniter contacts to be thrown apart as nut (F) strikes the igniter arm.

When the igniter contacts separate, the circuit is broken and the self-induction of the coil causes a strong spark to occur between the contacts (C). This spark ignites the gases compressed in the combustion chamber of the cylinder causing them to explode (rapidly expand), and drive the piston down, giving a power stroke to the engine.

The cam is driven at half crankshaft speed so that when the piston again comes up on compression stroke the same series of events will be repeated. The spark is always produced when the igniter contacts separate, and not when they close.

Low tension ignition systems are simple and have a high degree of reliability. On the other hand, they are noisy, not flexible enough to give a wide range of speed, and the igniter contacts soon become burned and pitted, requiring frequent cleaning and smoothing.

High Tension or "Jump Spark" Ignition

There are two distinct circuits in a jump spark system—primary and secondary. (See Fig. 237.) The primary circuit includes a source of E. M. F., ignition switch, primary of coil, breaker, and a condenser. The secondary circuit includes the secondary of the coil and spark plug. The wire used to connect the secondary to the spark plug is well insulated to prevent the secondary current from leaping from the wire to some metal part of the engine before it jumps the gap in the spark plug.

Since the voltage in the secondary is very high, ranging from 12,000 to 30,000 volts, wire especially insulated to withstand that voltage is called secondary or high tension cable. Because of the high voltage in the secondary, the jump spark system is often called a high tension system.

The source of E. M. F. which produces the current in the primary may be a battery, generator, or magneto. If the system is used with a battery, or with the generator used to charge a battery, it is called a battery ignition system. If a magneto is used to produce the current in the primary, the system is called a magneto ignition system.

The induction coil is the same as that described under "Induction Coil." The coil transforms the low tension current which a battery produces into a high tension current of sufficient pressure to drive it across the gap in the spark plug.

The breaker is a mechanically operated switch used to open and close the primary circuit. The mechanism by which it is operated is timed to the crankshaft so that the spark is produced at the proper time. Because the breaker times the spark, it is often called a timer; however, this device must not be confused with the device called a timer which is used on Ford ignition systems. The breaker is also called "interrupter."

A condenser is connected in parallel with the

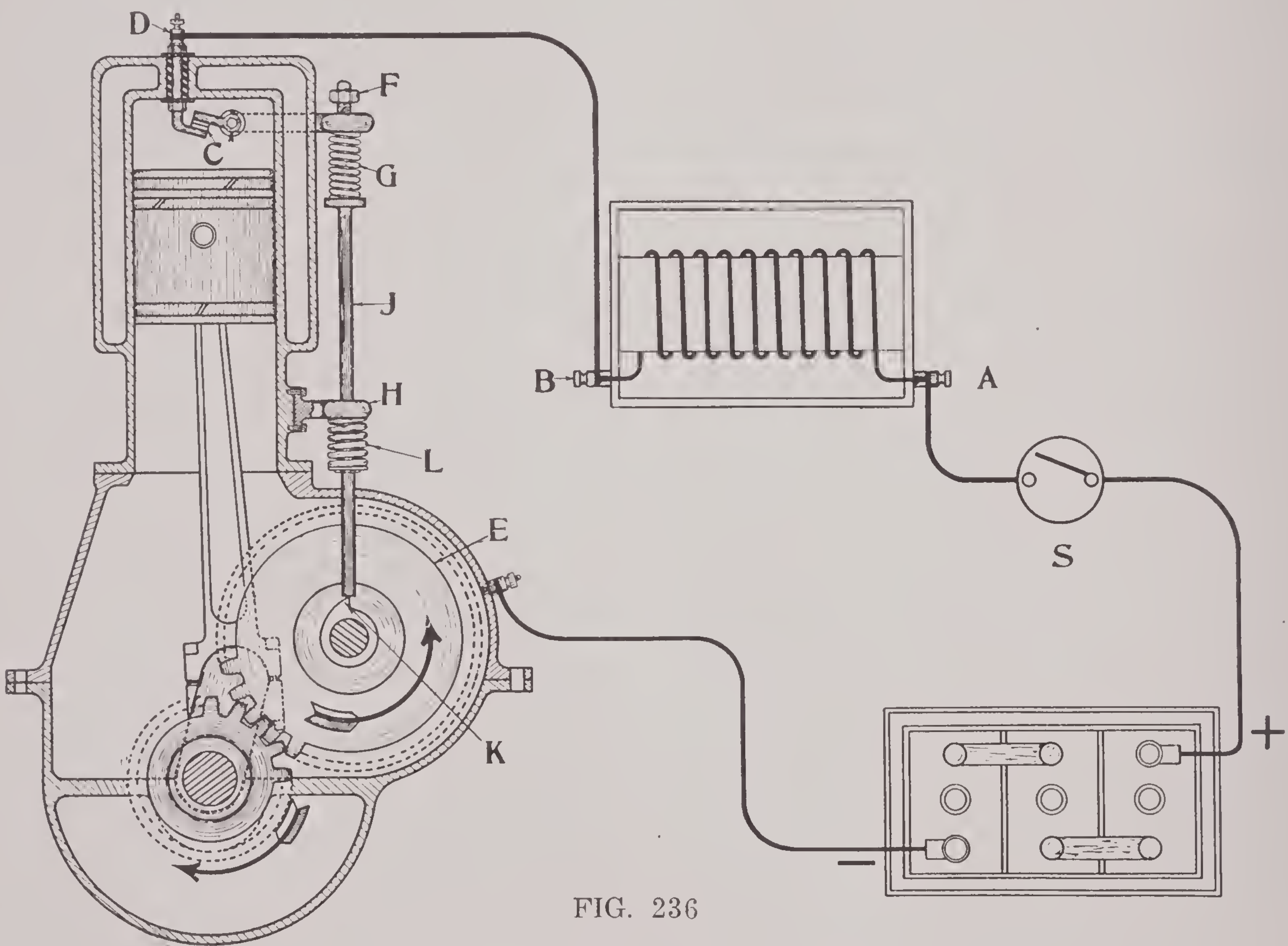


FIG. 236

MAKE AND BREAK IGNITION SYSTEM

A. and B. Terminals of the low tension coil.
C. Igniter points or contacts.
D. Igniter terminal. The rod of which the terminal is a part is insulated from the cylinder by mica washers and carries one of the igniter contacts.
E. Camshaft gear.
F. Nut at top of rod (J). This nut strikes the igniter arm when (J) is thrown back by spring (L), causing igniter contacts to separate.
G. Coil spring on (J) placed between the igniter arm and shoulder on (J). (G) prevents excessive strain being thrown on the igniter mechanism when cam (K) forces (J) past the point where igniter contacts come together.
H. Guide for (J).
J. Push rod.
K. Cam. This cam is mounted on a shaft with gear (E). Gear (E) has twice as many teeth as the gear on the crankshaft so turns at half crankshaft speed. The gears are so meshed that lobe (K) turns from beneath (J) when piston reaches the point where the spark should occur.
L. Return spring for (J). When lobe of cam turns from beneath (J), spring (L) forces (J) down.

breaker to prevent sparking at breaker points. The condenser is sometimes in the coil and sometimes in the breaker housing. In either case, it is always connected in parallel with the breaker.

Action of the Jump Spark System

(See Fig. 237)

When the ignition switch is closed, the E. M. F. of the battery causes current to flow through the primary of coil while the breaker points are together. The current as it flows through in the primary magnetizes core, setting up a magnetic field about the secondary. When the breaker points separate, the current in the primary is interrupted causing the field to collapse. The strong E. M. F. induced in the secondary as the lines collapse, drives the current across the gap in the plug, producing the spark.

The secondary circuit, traced from the secondary of coil, is from secondary terminal through high tension cable to spark plug, across the gap in plug to the shell, from shell to cylinder, through walls of cylinder and crankcase to the wire connecting ground terminal of secondary to crankcase, and through the wire back to the secondary.

The gears through which the crankshaft

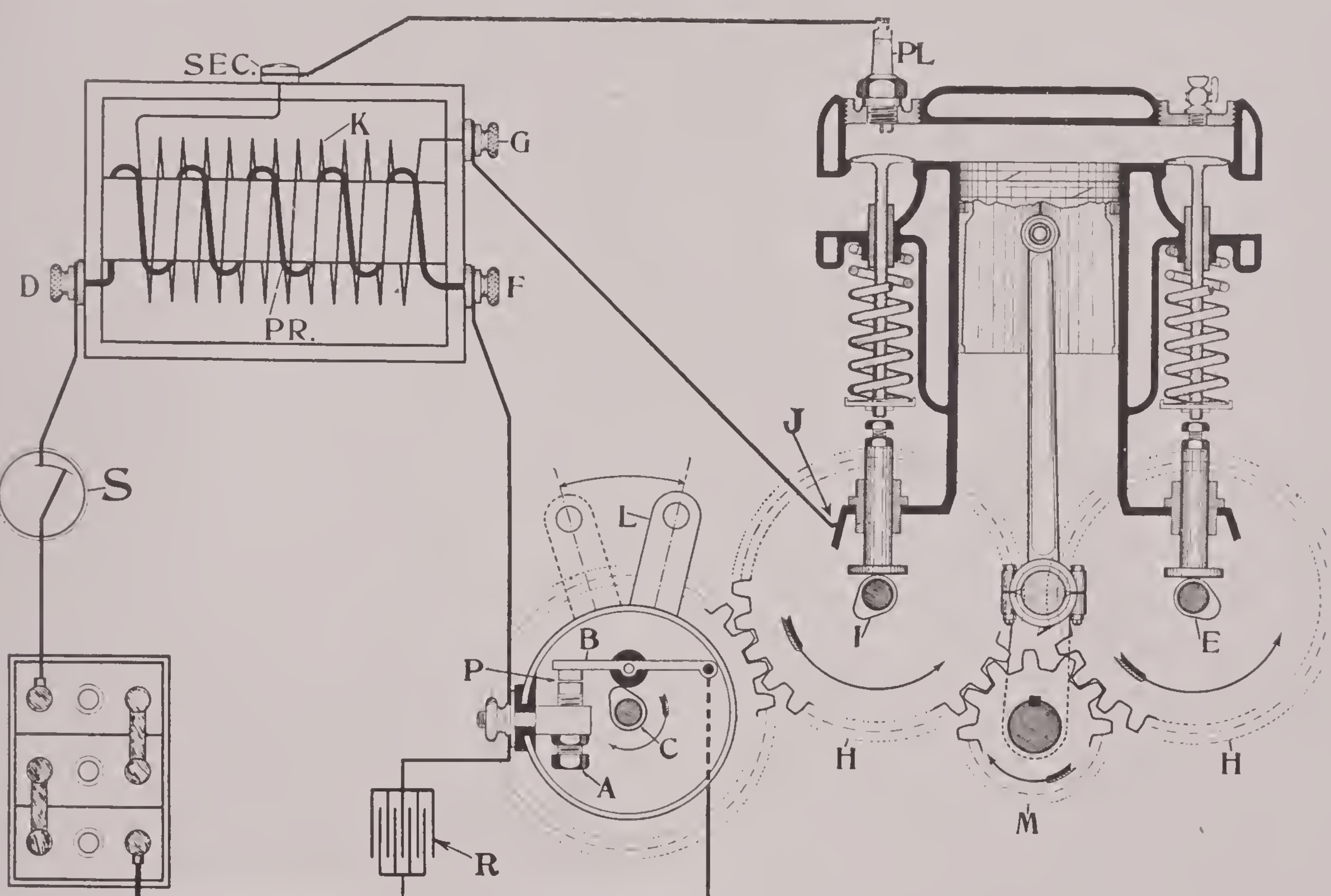


FIG. 237

JUMP SPARK SYSTEM FOR ONE CYLINDER ENGINE

A. Small screw carrying one of the breaker points. It is provided with a locknut to lock it in adjustment.

B. Breaker arm. The end of the arm carrying the breaker point is forced up when lobe of cam (C) turns beneath the fiber roller which the arm carries.

C. Breaker cam which is driven at half crankshaft speed. The gears through which it is driven by the crankshaft are so meshed that lobe turns beneath the roller on breaker arm, separating the breaker points B, just as piston passes top dead center between compression and power strokes.

D. and F. Primary terminals of coil.

E. Exhaust cam.

G. Secondary ground terminal on coil.

H. and M. Valve timing gears.

I. Inlet cam.

J. Secondary ground connection on engine.

K. Secondary of coil.

L. Spark advance and retard lever. If this lever is thrown to the left as shown by dotted lines in the illustration, the breaker housing is moved around the axis of the cam. This pulls the breaker arm around to a point where the cam separates the breaker points earlier in the rotation of cam and so causes spark to occur earlier.

P. Breaker points or contacts—usually made of tungsten, sometimes platinum.

PR. Primary of coil.

PL. Spark plug.

R. Condenser.

S. Ignition switch.

SEC. Secondary terminal of coil which connects to the spark plug.

drives the breaker cam are so meshed that the cam separates the breaker points when piston just passes top dead center at the end of the compression stroke. If the spark lever is moved to the position shown in dotted lines, the breaker arm is moved against the rotation of the cam and so causes the breaker to interrupt the current a little before piston reaches top dead center. This gives an advanced spark which is necessary at higher engine speeds. The retarded spark, as is produced with spark lever in the position shown in solid lines, is necessary when starting to prevent engine from kicking back.

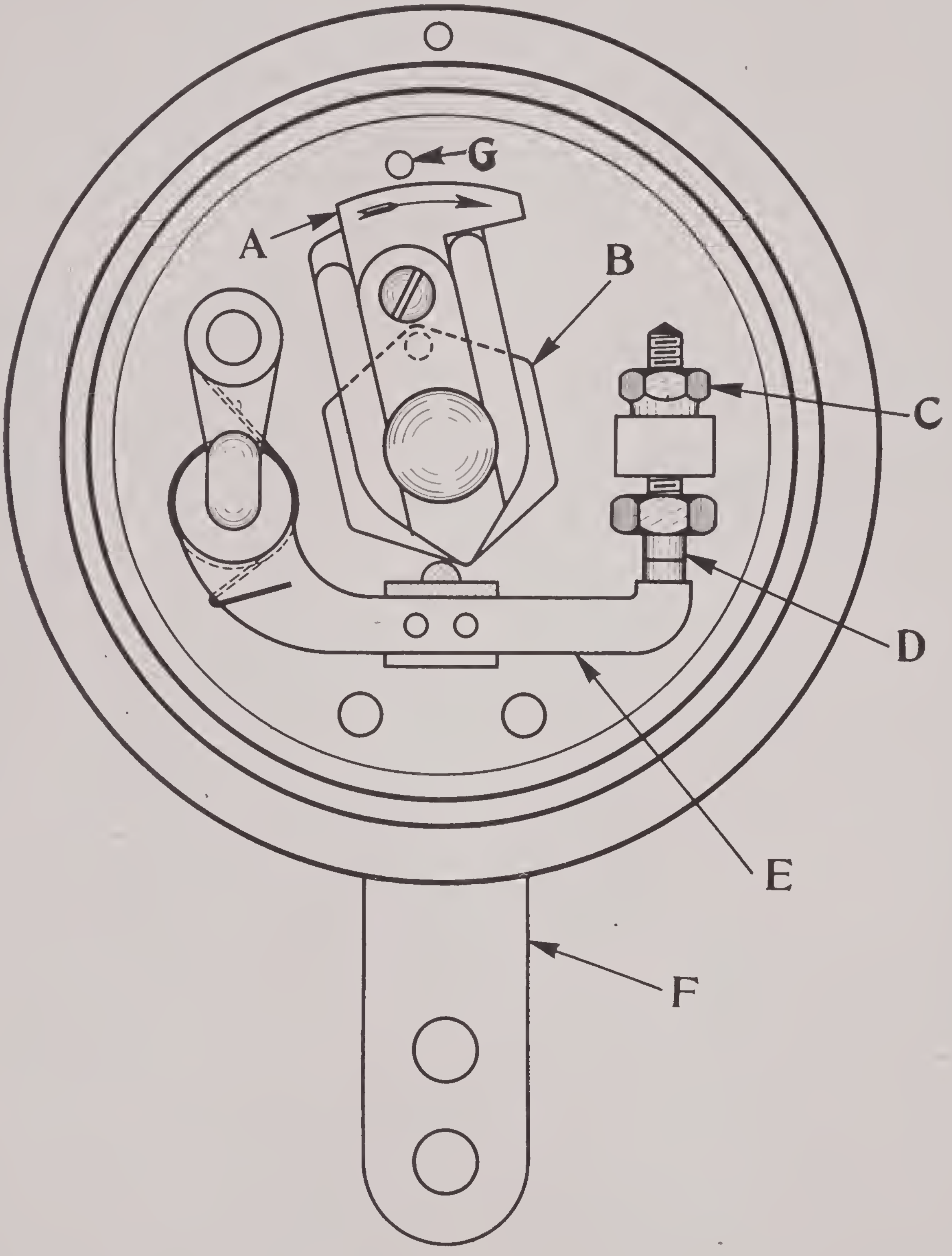


FIG. 238

SIX CYLINDER DISTRIBUTOR-BREAKER, CLOSED CIRCUIT TYPE—REMY

A. Distributor brush. Instead of contacts as in Fig. 239, pins are molded in distributor head. These pins project through the head and are so placed that the end of brush swings past without touching them, the gap between pin and brush being about .015".

B. Cam. The cam is locked on tapered shaft with a locknut which is concealed in the figure by the distributor brush.

C. Locknut for locking breaker point adjustment.
D. Breaker points.
E. Breaker arm.
F. Spark advance and retard lever.
G. Distributor pin.

Jump spark systems are silent, reliable, and are capable of a wide range of spark advance and retard. They are used on all aircraft, automobile, and truck internal combustion engines, and on most tractor engines and on a large number of stationary engines.

Jump Spark System for Multiple Cylinder Engine

(See Fig. 240)

The jump spark system for multiple cylinder engines differs in general from the one cylinder system in that the breaker cam usually has as many lobes as there are cylinders in the engine and a distributor is added to distribute the secondary current to the different spark plugs. The illustration in Fig. 238, and the illustration in Fig. 246, show typical six cylinder breakers. The cam is driven at half crankshaft speed as in the one cylinder system. The gears through which the cam is driven are so meshed that a

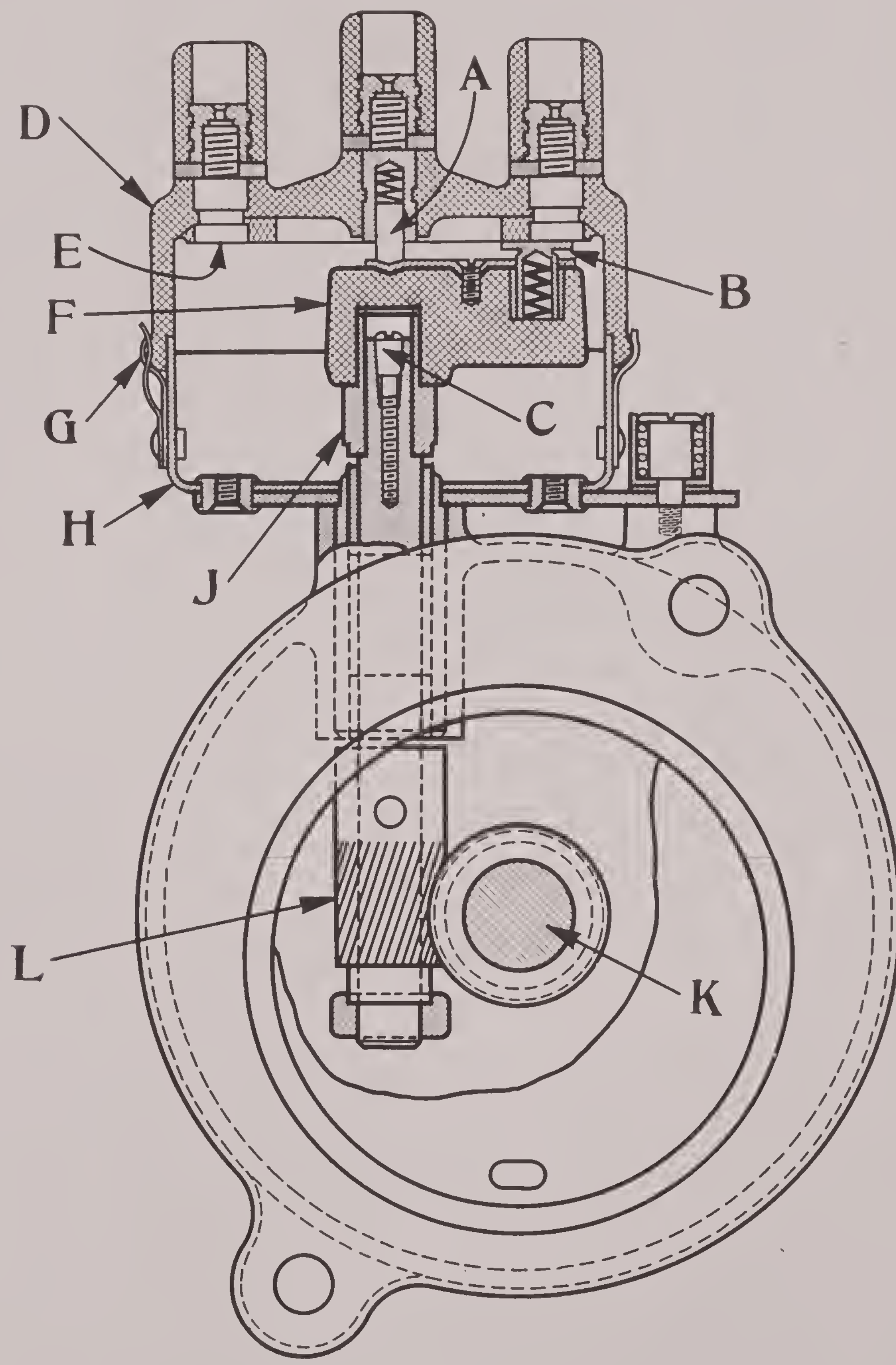


FIG. 239

SECTION THROUGH A DELCO DISTRIBUTOR

A. Small carbon or metal brush.
B. Contact button.
C. Screw which locks cam (J) on shaft.
D. Distributor head.
E. Distributor contact.
F. Distributor brush, also called segment brush or rotor.
G. Clip securing distributor head.
H. Breaker housing.
J. Breaker cam.
L. Spiral gear at bottom of breaker shaft which meshes with gear on shaft (K).

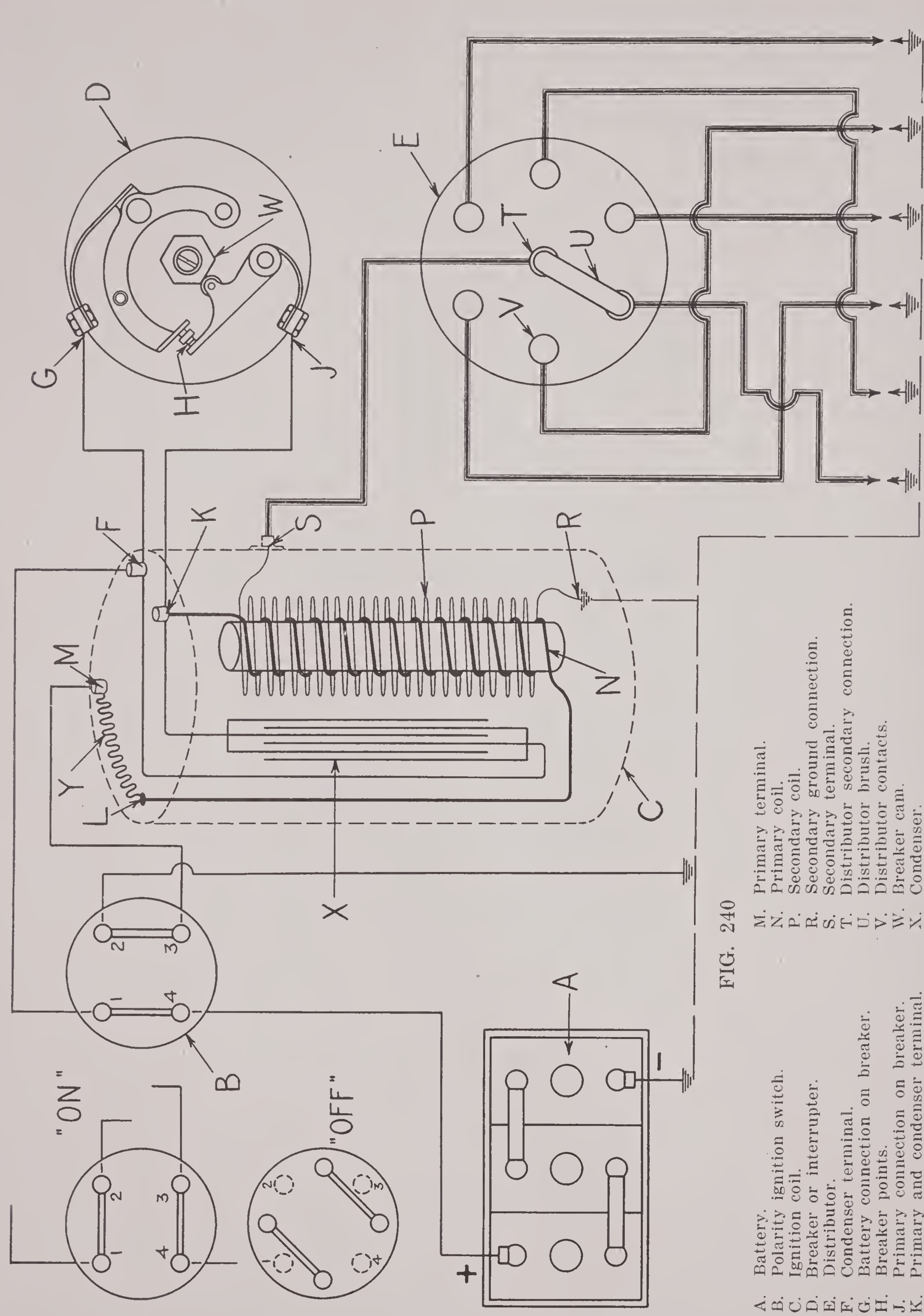


FIG. 240

A. Battery.
B. Polarity ignition switch.
C. Ignition coil.
D. Breaker or interrupter.
E. Distributor.
F. Condenser terminal.
G. Battery connection on breaker.
H. Breaker points.
J. Primary connection on breaker.
K. Primary and condenser terminal.
L. Primary and ignition resistance connection.
M. Primary terminal.
N. Primary coil.
P. Secondary coil.
R. Secondary ground connection.
S. Secondary terminal.
T. Distributor secondary connection.
U. Distributor brush.
V. Distributor contacts.
W. Breaker cam.
X. Condenser.
Y. Ignition resistance.
1-2-3-4 Polarity switch terminals.

lobe of the cam, (spark lever in retard) separates the points as a piston passes top dead center at the end of the compression stroke.

Distributor

The illustration in Fig. 239 shows a section through a distributor. The distributor brush (F) fits on the end of the cam so that it must turn with the cam. As many distributor contacts (E) as there are lobes on the cam are molded in the bakelite head. The arrangement of the distributor contacts is shown in Fig. 240. An extra, or odd contact, is carried in the center. The secondary of coil connects to this central contact and the spark plugs to the other contacts. With the distributor head and brush in position the small carbon brush (A) (Fig. 239) forming the center contact, rests on the small metal strip at the top of the brush. As the brush revolves with the shaft, the small metal contact button (B) slides over the distributor contacts molded in the head, connecting one after the other to the center contact, thus switching one of the plugs at a time in the circuit with secondary of coil. The brush so fits on the end of the cam that contact button (B) is on a distributor contact when breaker points separate. The distributor head (D) consists of a bakelite body in which distributor pins, or contacts (E), are molded. These pins are equally spaced about the inside of the distributor cap and are connected through secondary cables to the spark plugs.

The spark plugs are connected to the distributor contacts, or pins, according to the direction the distributor brush revolves and the firing order of the engine. For example (see Fig. 240), suppose the piston in number one cylinder of a six-cylinder engine is on top dead center at the end of compression stroke and the firing order of the engine is 1-5-3-6-2-4. Wire the contact on which the brush rests, to the plug in number one cylinder. Wire the next contact in the direction the brush revolves, to the plug in number 5 cylinder, the next, number 3 cylinder, the next, number 6 cylinder, the next, number 2 cylinder, and the last to the plug in number 4 cylinder.

Polarity Ignition Switch

Switch (A) Fig. 240 is so constructed that each time it is thrown to "ON" position, the current is passed through breaker points in opposite direction. This provision is made on some systems to prevent the breaker points from polarizing. When the current passes through the breaker points in one direction only, in time, an irregular pit forms in one and an irregular cone on the other. This is the result of the current carrying bits of metal from one point across and depositing it on the other, which is called polarization. Reversing the current through the points prevents polarization. A switch so constructed to reverse the current is called a polarity switch. A polarity ignition switch can almost always be connected properly if diagonally opposite terminals are connected to the breaker and coil, and the other terminals to battery and ground.

Spark Coil Connections
(See Fig. 240)

This coil is of the type designed to be mounted on a metal bracket which bolts to the crankcase or to the frame of the car. One end of the secondary connects to a metal contact in the base of the coil box. This contact must rest on some piece of metal which is grounded or no ground connection will be made to complete the secondary circuit. If the coil is mounted on a wooden dash, the contact in the base must be grounded with a wire. Terminal (M) is connected to the battery; terminal (F) to the battery and one side of the breaker; terminal (K) to the other side of the breaker, making the condenser in parallel with the breaker points.

Some spark coils have one end of secondary connected to a terminal to which one end of the primary connects. Coils of this type are used on systems grounding one terminal of battery. The ground return for the secondary current is then obtained through battery and switch.

Tests for Coil Terminals

The terminals of a coil constructed as shown in Fig. 240 can be determined with a test lamp. If the test points are placed on the condenser terminals (F) and (K), the lamp will not light and no spark will occur when the points are lifted. The condenser will be charged, however, and a spark will be produced if it is discharged by touching a short wire to these two terminals.

To distinguish between the primary terminal (M) and the primary and condenser terminal (K), charge the condenser and note the intensity of the spark produced when the condenser is discharged by connecting terminals (F) and (M). Charge the condenser again and note the spark produced when discharged by connecting terminals (F) and (K). The weaker spark will occur when connecting terminals (F) and (M) since the condenser must then discharge through the primary coil and ignition resistance.

The terminals to which the secondary connects can easily be determined with a test lamp. The lamp will not light while test points are on secondary terminals but a spark will be produced at a test point when lifted from the terminal.

The primary terminals can be determined

with a test buzzer. A test buzzer sounds a little lower when the points are on the terminals of the primary than when the points are held together.

Open Circuit and Closed Circuit Type Breakers

Open circuit type breakers are so constructed that a spring separates the points and a cam forces them together. The cam is usually so constructed that breaker is open a little longer than closed. In the Atwater-Kent open circuit type breaker the mechanism is so constructed that it is not possible to stop the breaker cam so that the points are together. The points remain closed just as long at high speeds as at low speeds, so the spark at all speeds of engine is practically the same.

In the closed circuit type breaker the spring forces the points together and the cam separates them. (See Figs. 238 and 246.) The cam is usually so constructed that breaker remains closed a little longer than open. This is done to give more time for current to build up in primary of coil at high speeds. Since with this construction the breaker remains closed longer at low speeds than at high speeds, a ballast resistance is necessary for the primary circuit as shown at (C) Fig. 240. This resistance is called the ignition resistance unit.

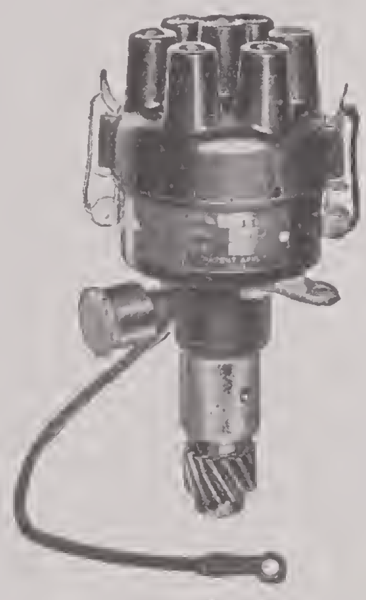


FIG. 241
REMY IGNITION-DISTRIBUTOR

Ignition Resistance

(See Fig. 240)

At high speeds the breaker remains closed for a very short space of time, consequently the coil must be of low resistance, if the E. M. F. of the battery builds up current strong enough to magnetize the core, while the breaker remains closed. If the coil has low enough resistance for the E. M. F. of the battery to magnetize the core at high speeds, the resistance will be so low, that at low speeds, when breaker remains closed longer, the current will reach a strength which will heat the coil. To prevent this, the ignition resistance unit is connected in series with the primary.

The ignition resistance is a small coil, usually of iron wire, wound on a porcelain spool. The wire is of such size that it will safely carry the current that will magnetize the core, but when the current becomes excessive, as at lower speeds, the wire becomes heated. As the temperature rises the resistance of the wire increases rapidly. This increase in resistance prevents the current from reaching a strength that will heat the spark coil and cause sparking at the breaker points.

The closed circuit type ignition systems can sometimes be operated without the ignition resistance, but in doing so the coil is likely to heat and sparking to occur at the breaker points. The resistance unit offers further protection to the system, as it will burn out before the current reaches a strength that would burn out the coil.

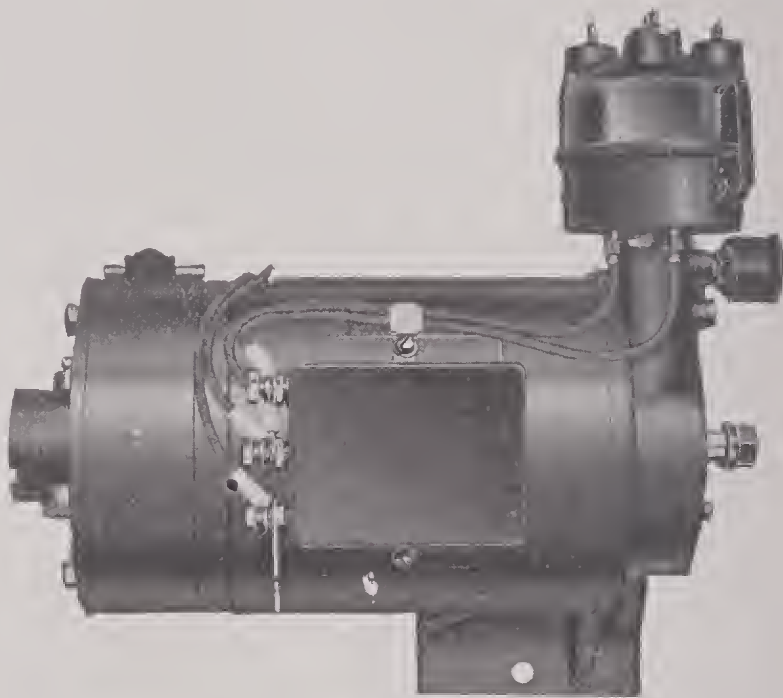


FIG. 242
GENERATOR MOUNTING FOR IGNITION-DISTRIBUTOR

When the open circuit type breaker is used, it is not necessary to use the ignition resistance, since the breaker remains closed just as long at high speeds as at low speeds. The primary of some coils is wound of such wire that the primary acts both as the ignition resistance and the primary. No resistance unit is used with coils of this type.

Breaker Point Adjustment

The breaker point adjustment for breakers used in battery ignition systems varies with the type and make of breaker. Some adjust for points to separate only .006″ and some adjust for points to separate as much as .030″.

A small wrench, carrying two thickness gauges, is usually provided by the manufacturers to make the breaker point and spark plug adjustment. One gauge should just slip between points when fully separated, if properly adjusted. The other gauge should just slip between electrodes of spark plug. Without the gauge provided for the particular systems on which adjustments are being made, adjust according to manufacturers' instructions. The majority of breakers adjust for points to separate between .012″ and .020″.

Spark Plug Gap

The width of gap in the spark plug varies with the type of ignition system and type engine on which they are used. The gap in spark plugs used in battery ignition systems should be, on an average, from .025″ to .030″

Spark Advance and Retard

When starting an engine, the spark should not occur till the piston has reached top dead center at the end of the compression stroke. If the spark occurs before the piston reaches top dead center, the piston is likely to be driven back down before having passed top dead center, thus causing the engine to kick back. After the engine is started and is running, the spark must be advanced, since it takes a little time for the charge of vaporized fuel compressed in the combustion chamber to burn and so expand or explode. If, while engine is running, the spark does not occur a little before the piston passes top dead center, the explosion will not occur till the piston has moved part way down on the power stroke, in which case there is a loss in power and the engine is abnormally heated. To prevent this the spark should be advanced. The charge then begins to burn while the piston is at top of cylinder and the explosion takes place before piston has moved down but very little on power stroke.

If the spark is advanced too far, the explosion takes place before the piston has time to pass top dead center. In this event, when the engine is running, the momentum of the flywheel will usually drive the piston past top dead center, but a peculiar knock, called a "spark knock," is produced.

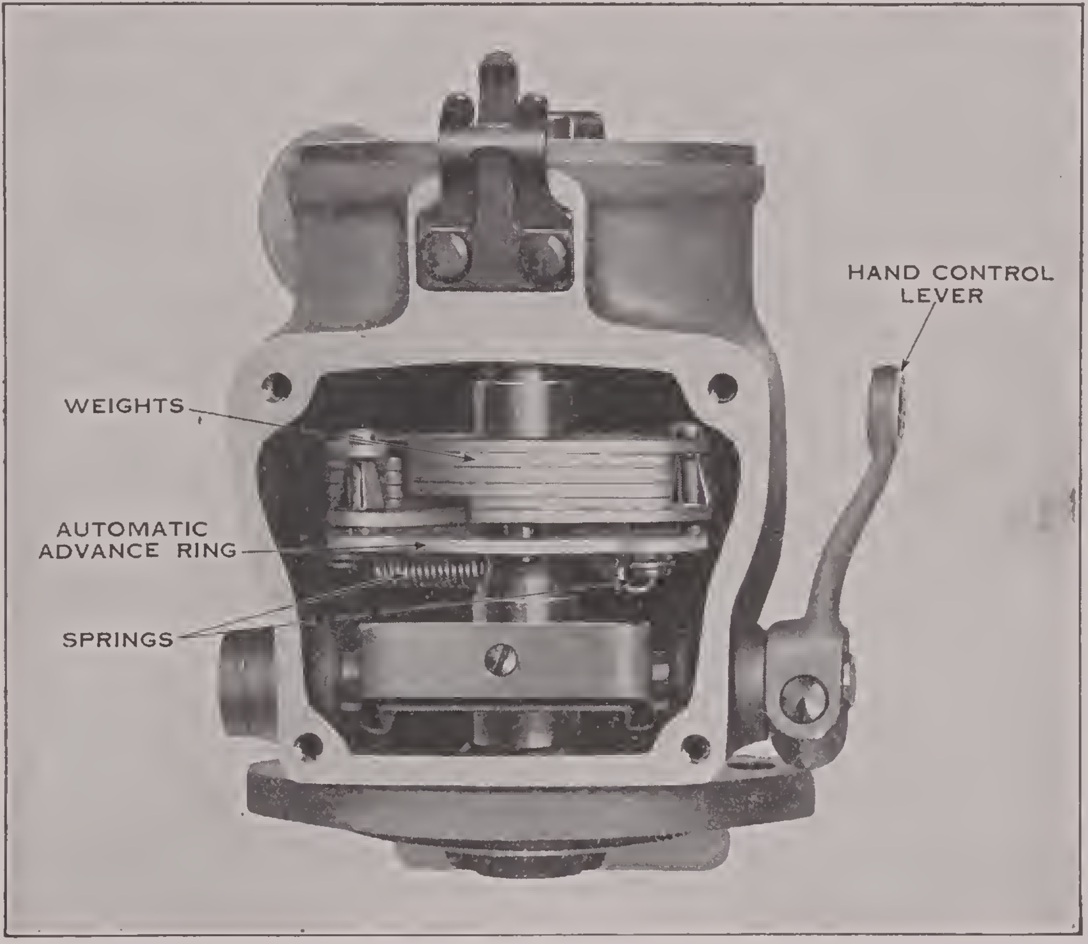


FIG. 243

DELCO AUTOMATIC SPARK CONTROL—ESSEX

In the more common types, the breaker housing is so constructed that the breaker mechanism can be rotated part way around the shaft carrying the cam. Then, to advance the spark, the breaker mechanism is turned against the direction the cam is driven, and to retard the spark the breaker mechanism is turned in the direction the cam is driven.

Other breaker mechanisms are so constructed that the cam is thrown forward to advance the spark and thrown backwards to retard the spark. Some of the Delco breakers, are constructed in this manner. The housing of this type breaker is bolted rigidly to the crankcase. The shaft carrying the timing gear is hollow and has a spiral slot machined in it. The shaft on which the cam is mounted has a straight slot machined in it at the bottom and fits into the hollow shaft that carries the gear. A small pin carried by a collar fitting around the hollow drive shaft, passes through the spiral slot in the hollow shaft and the straight slot in the other shaft. A shifting yoke connected to the spark advance and retard lever by a fork, controls the position of the collar. When the collar is moved upward, or downward by the shifting yoke, the pin passing along the spiral slot in the hollow shaft and the straight slot in the other shaft, either throws the cam forward or backward. If the cam is thrown forward, the spark is advanced. If the cam is thrown backward, the spark is retarded.

The automatic spark advance and retard is controlled by a governor mechanism. As the speed increases, the spark is automatically advanced, and as speed decreases, the spark is automatically retarded.

The automatic spark advance and retard takes care of the spark advance and retard so far as the variation in the speed of the engine necessitates it, but because an engine does not require the spark to be advanced as far when pulling, as when running idle, most of the mechanisms are constructed with a manual control as well as an automatic. The harder the engine is pulling the more fuel each cylinder draws in on the intake stroke and therefore the higher the compression. The higher the compression the more quickly a mixture of vaporized gasoline and air burns, hence, it is not necessary to introduce the spark into the charge so early. The average engine will have a spark knock under heavy load if the spark lever is advanced to the point at which engine runs well at the same speed under little load. The range of advance obtained by the automatic advance is independent of the hand advance. The actual advance is equal to their sum, expressed in degrees.

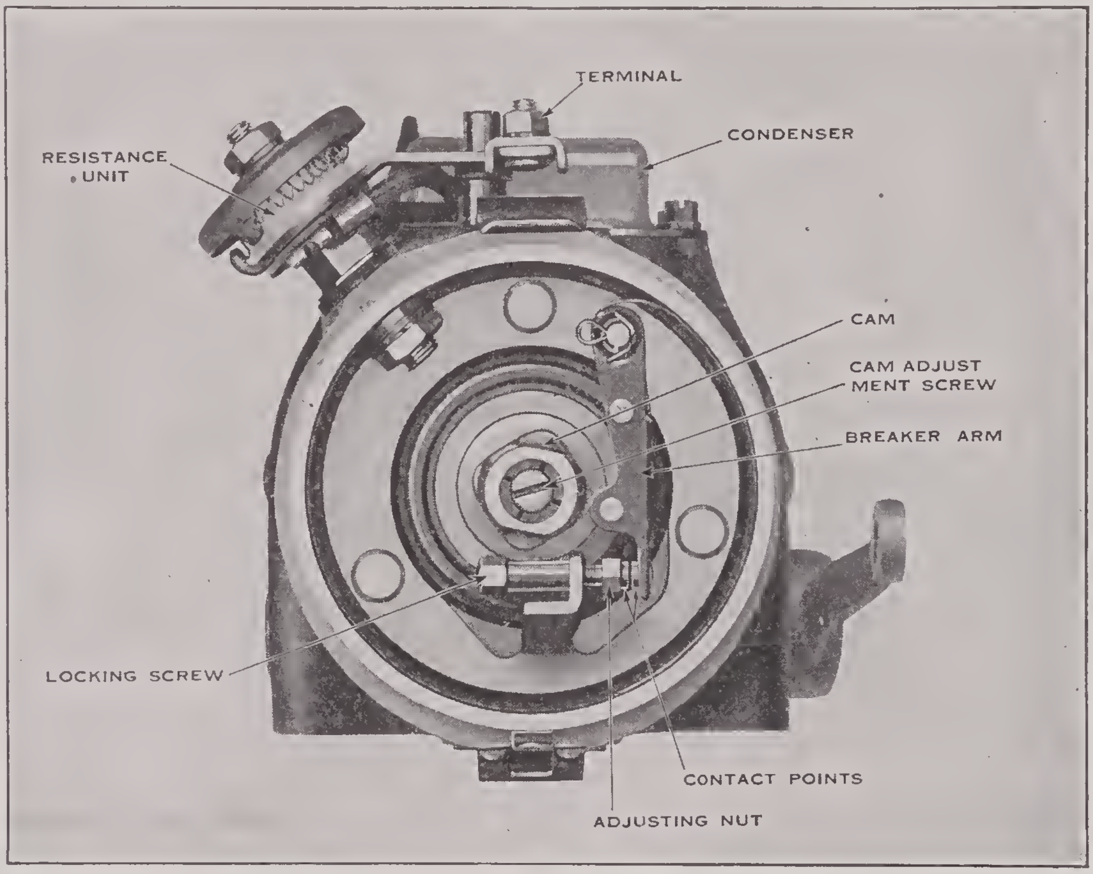


FIG. 244

DELCO DISTRIBUTOR-BREAKER—ESSEX

The illustration in Fig. 239 shows a section through one of the later types of Delco ignition-distributors. The distributor brush (rotor) makes a wiping contact on the distributor segments which are molded in the distributor head flush with the surface of the bakelite. The cam is locked on the shaft by a tapered screw that is threaded into the top of the shaft. To change the timing with this type of breaker it is not necessary to draw the timing gears out of mesh as the cam can be loosened on the shaft by loosening the tapered screw.

Fig. 238 shows a Remy distributor-breaker and distributor brush. The cam is locked on the tapered shaft by a lock nut (not shown in illustration). To loosen the cam, remove lock nut and pull cam from the tapered shaft with a cam puller. The distributor brush does not rub against the pins (G) in the distributor head, but there should be a gap of about .015 of an inch between the brush and the pin.

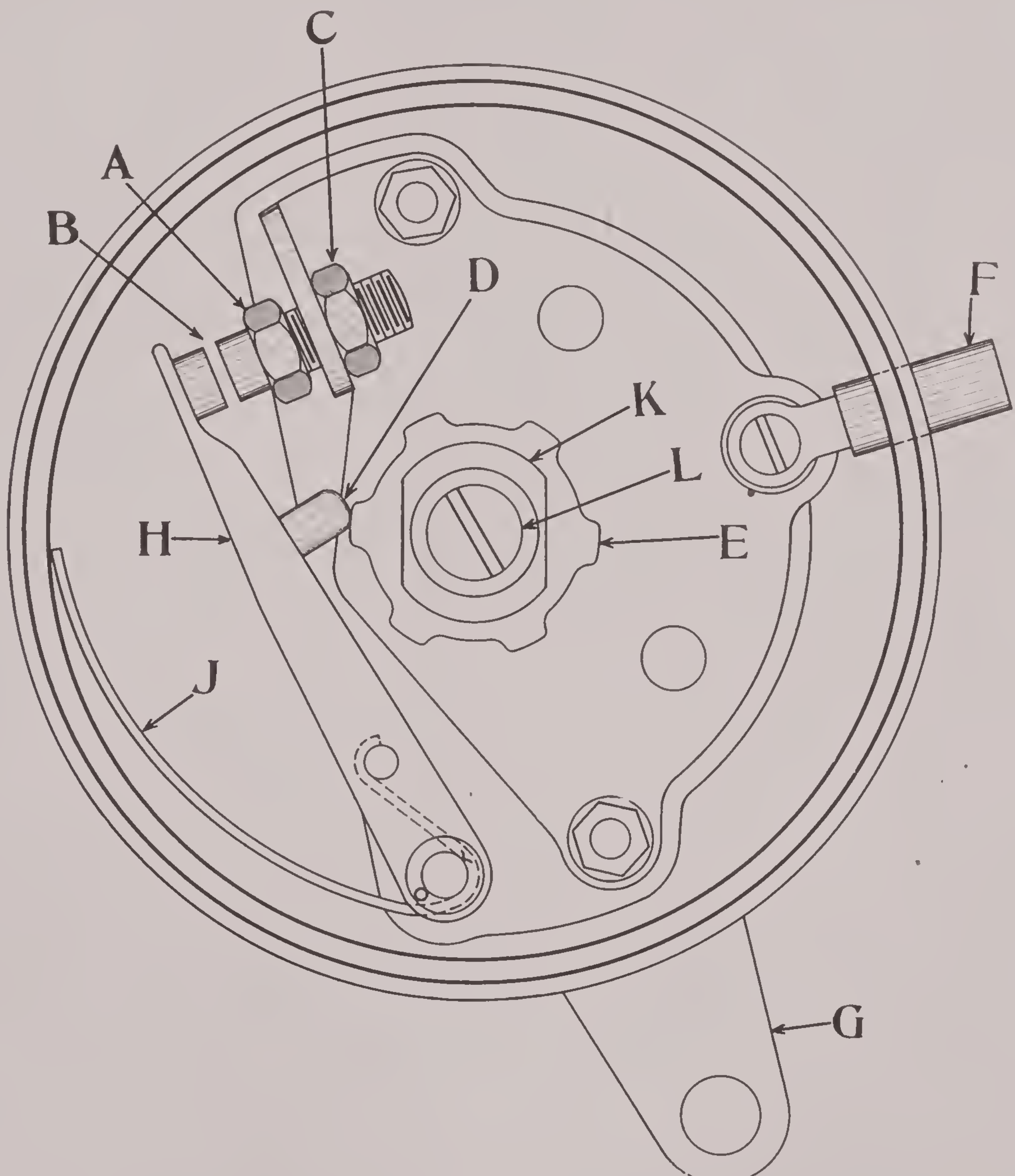


FIG. 245

SIX CYLINDER CLOSED CIRCUIT TYPE BREAKER
DELCO

A. Breaker point adjusting nut. Adjustment for opening of points is made here. The adjustment on this type is so contacts separate .018" to .020".
B. Breaker points or contacts, usually made of tungsten.
C. Locknut for (A).
D. Fiber block carried on breaker arm. The lobes of cam strike this block and so separate points.
E. Lobe of cam.
F. Wire from coil which connects to plate carrying breaker point. A sheet of fiber beneath the plate insulates it from the breaker housing.
G. Spark advance and retard lever.
H. Breaker arm, grounded through spring (J) which rests against breaker housing and through the pin on which it is mounted.
J. Breaker spring which forces points together when lobe of cam is not under (D).
K. Top part of cam on which distributor brush fits. One side is cut away a bit more than other so brush will fit on cam in one way only.
L. Tapered screw which locks cam on shaft. See (C) in Fig. 239. The cam can be loosened on the shaft for timing ignition by loosening this screw.

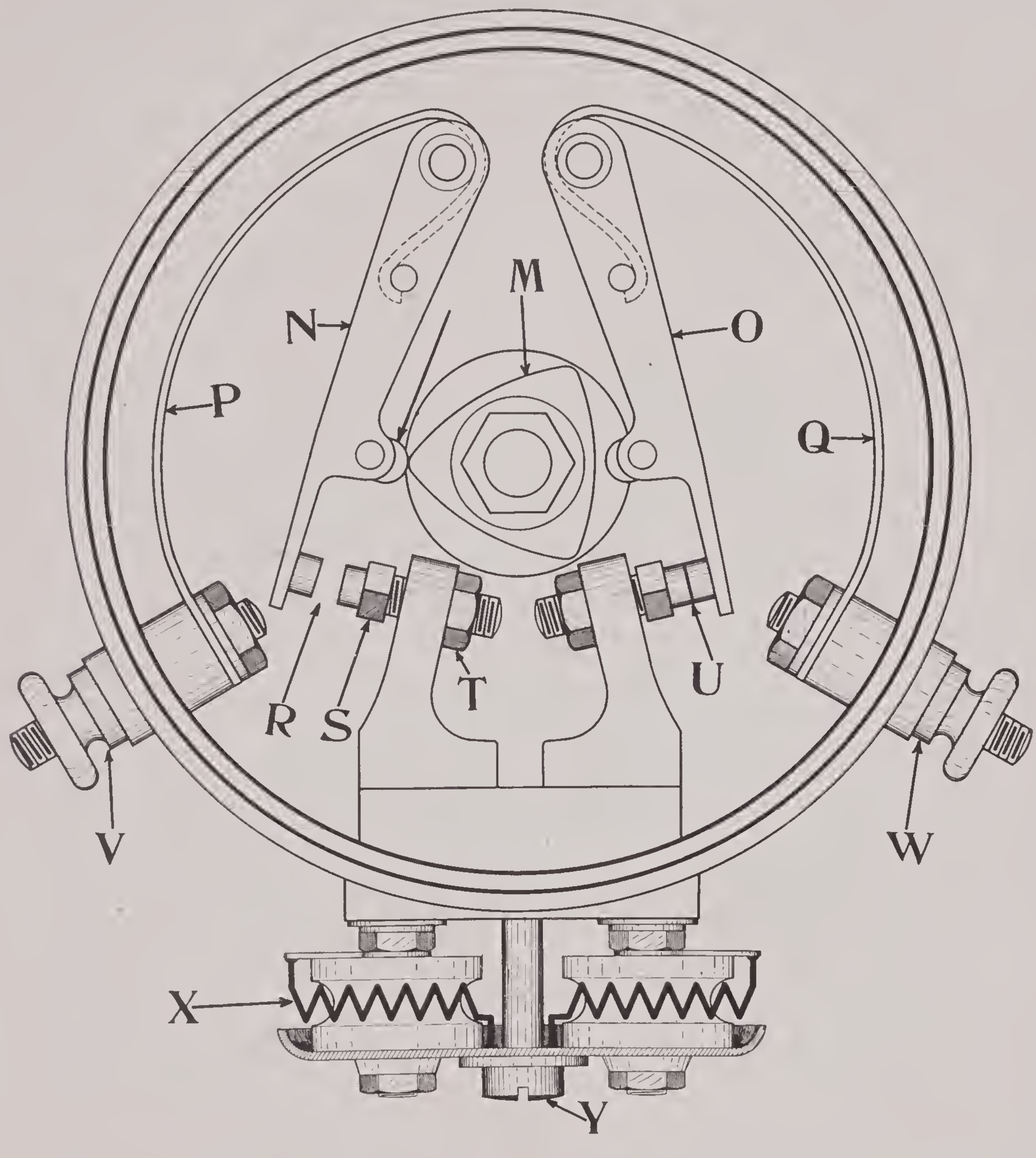


FIG. 246

BREAKER MECHANISM USED ON THE PACKARD TWIN SIX

There are two breakers operated by one cam. Cam is driven at crankshaft speed. There are two 6 cylinder distributors, and two coils. One coil, breaker, and distributor fire one bank of cylinders and the other coil, breaker, and distributor fire the other bank.

M. Cam.

N. and O. Breaker arms—not grounded as in Fig. 246.

P. and Q. Breaker springs.

R. Gap between points when separated.

S. Breaker point adjustment.

T. Locknut.

U. Breaker points or contacts.

V. and W. Terminals to which wires from coils connect.

X. Ignition resistance.

Y. Screw which grounds one end of each resistance coil.

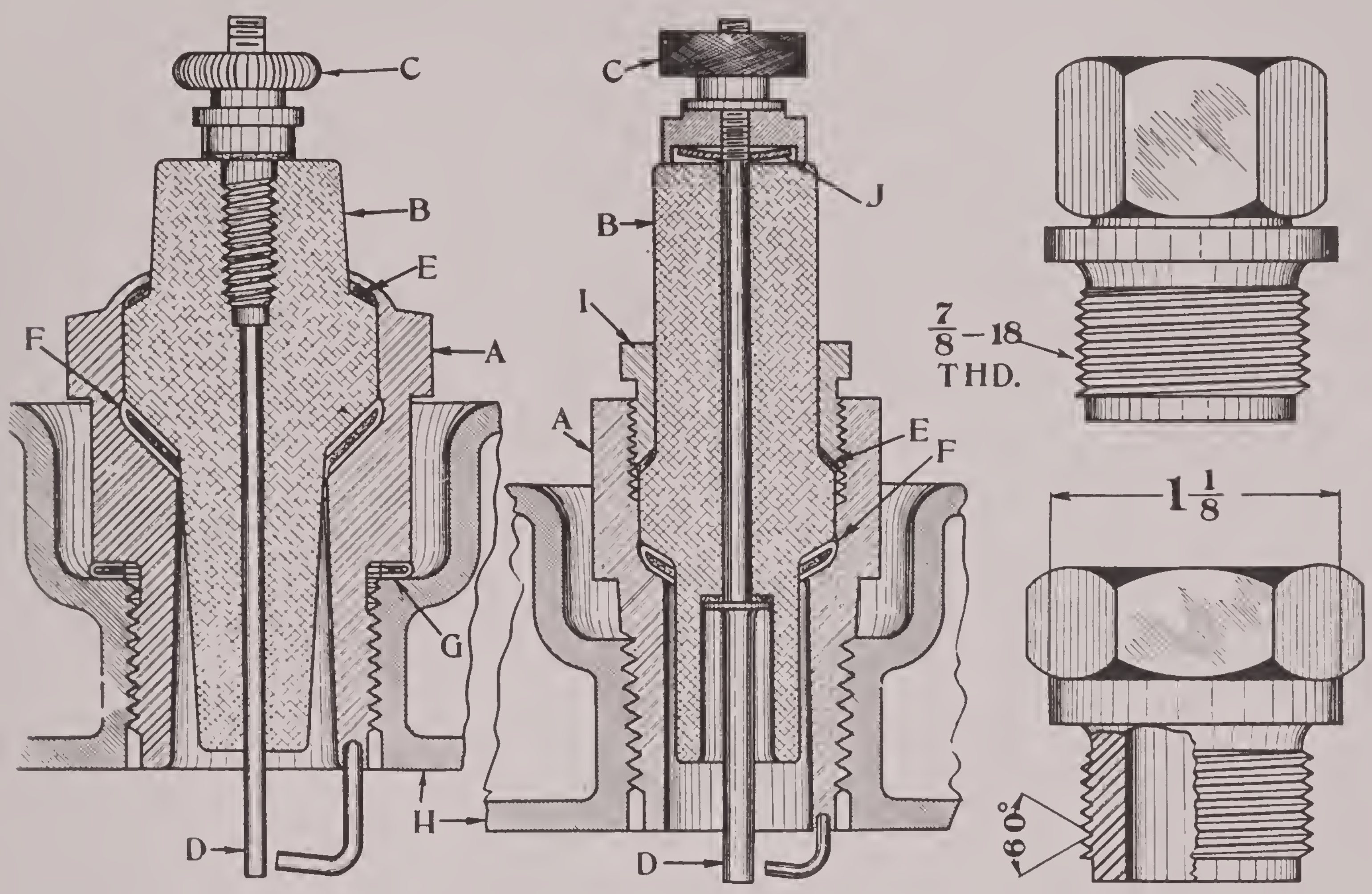


FIG. 247

SECTIONAL VIEWS OF TYPICAL SPARK PLUGS

In center illustration, (C) is the terminal on the upper end of the small rod (D) which passes through the porcelain core (B). Porcelain is used here because it is a very good insulator and at the same time withstands heat. Rod (D) must be well insulated from the other parts of the plug. Mica washers instead of porcelain are sometimes used to insulate this rod. (A) is the shell of the plug, or the part that screws into the cylinder. (I) is a bushing that holds the core (B) in the shell. (E) and (F) are gaskets of copper covered asbestos, placed between the core and the shell and between the core and bushing. These gaskets are a seal between the core and the shell and at the same time allow for the unequal expansion between the porcelain and the metal shell, so that as the porcelain heats, it will not crack. The gap between electrode (D) and the smaller electrode in the plug base (A) is the gap through which the high secondary voltage of the coil drives the electricity to produce the spark. This gap is inside the combustion chamber when the plug is screwed into the cylinder.

The illustration at the left shows a sectional view of the one-piece or inseparable type spark plug. The porcelain (B) is held into the plug base (A) by means of crimping, or rolling the top edge of base (A) over a shoulder of the porcelain insulator. Copper-asbestos gaskets (E) and (F) serve the same purpose in this plug, as in the separable type previously described.

Spark Plug Bases

There are three distinct types of spark plug bases in common use: the S. A. E. standard base, the half-inch pipe size base and the metric base.

Two of the S. A. E. standard bases are shown at the right. The S. A. E. standard base is ⅞ inch in diameter across the threads and has 18 threads to the inch. The threaded portion of the base is straight and has a shoulder above the threads which turns down against a copper-asbestos gasket as shown at (G) in left-hand illustration.

Both of the S. A. E. standard bases shown in right hand illustrations are identical below the shoulder. The only practical differences in the two bases are above the shoulder. One of the bases is ⅞ inch across the flats of the hex, and the other is 1⅛ inch across the flats of the hex.

The half inch pipe size spark plug base is ¾ inch across the threads. The threaded portion is tapered in the same manner that the threaded portion of ½ inch iron pipe is tapered. There are 14 threads to the inch.

The metric plug differs from the S. A. E. standard in that it is .705 inch across the threads. It has 18 threads to the inch.

Spark plugs should always be turned into the cylinder firmly, with a wrench, to prevent air leaks around the threads.

Caution

Never turn a cold tapered spark plug into a hot cylinder as tightly as it will go, but turn it down by hand and allow it to become heated, then tighten with wrench. If the cold plug is turned in tightly, when it heats it expands and is liable to seize, making removal very difficult. Use oil and graphite on threads of spark plugs.

MAGNETOS

Early forms of ignition systems depended upon dry cells as a source of E. M. F. but, since the dry cells would polarize or become discharged, causing ignition trouble, better ignition systems were demanded. To provide a more reliable source of E. M. F. than that offered by dry cells, magnetos were added to the equipment of the automobile. From time to time various supplementary parts were added, or combined with the magneto until the present, highly efficient high tension magneto—which is virtually a complete system in itself—was developed. Since the addition to the automobile of the storage battery and a generator to keep it charged, the tendency is strongly toward battery ignition systems. However, many magnetos are used on automobiles and they are very extensively used on trucks, tractors and aircraft engines.

The fundamental principle of the magneto can be obtained from Fig. 248. The rings and brushes form slipping connections to the ends of the loop, so that the loop can be revolved in the field, and still have a connection to the lamp (K). As the loop revolves past the position shown, it is cutting the magnetic lines of force and an E. M. F. is induced in it, which causes current to flow through the loop and the lamp in the direction indicated by the arrows. When the loop has revolved a quarter turn from the position in the illustration, the sides of the loop are then moving parallel to the lines of force and no E. M. F. is induced in the loop, so no current flows.

When the loop has revolved a little further, it begins cutting the lines of force again, but the sides of the loop have changed places and this time the induced E. M. F. acts to cause a current to flow through loop in the opposite direction. When the loop has moved another quarter turn, the sides of loop are again moving parallel to lines of force and no E. M. F. is induced in the loop. The next quarter turn brings the loop back to the position shown in figure.

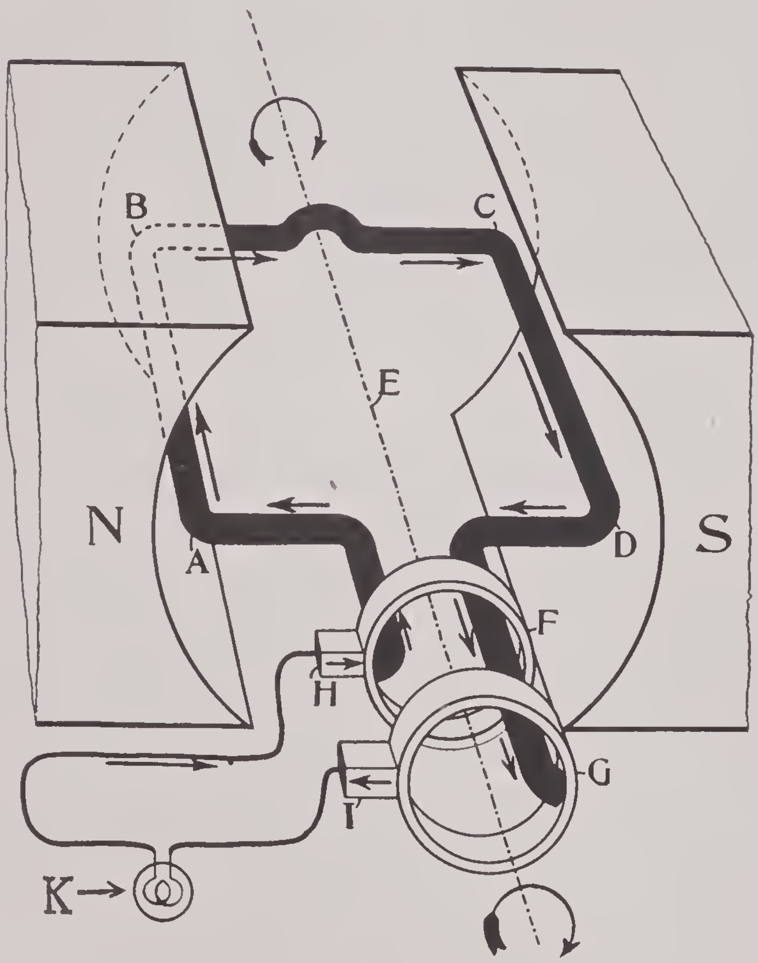


FIG. 248

As the loop revolves an E. M. F. is induced in it that builds up to maximum while the sides are moving directly across the lines of force and drops to zero while sides move parallel to the lines of force. Each half turn the E. M. F. reverses.

In the construction of the magneto, instead of using a loop, a coil of wire is wound around a soft iron core. The core is much the same

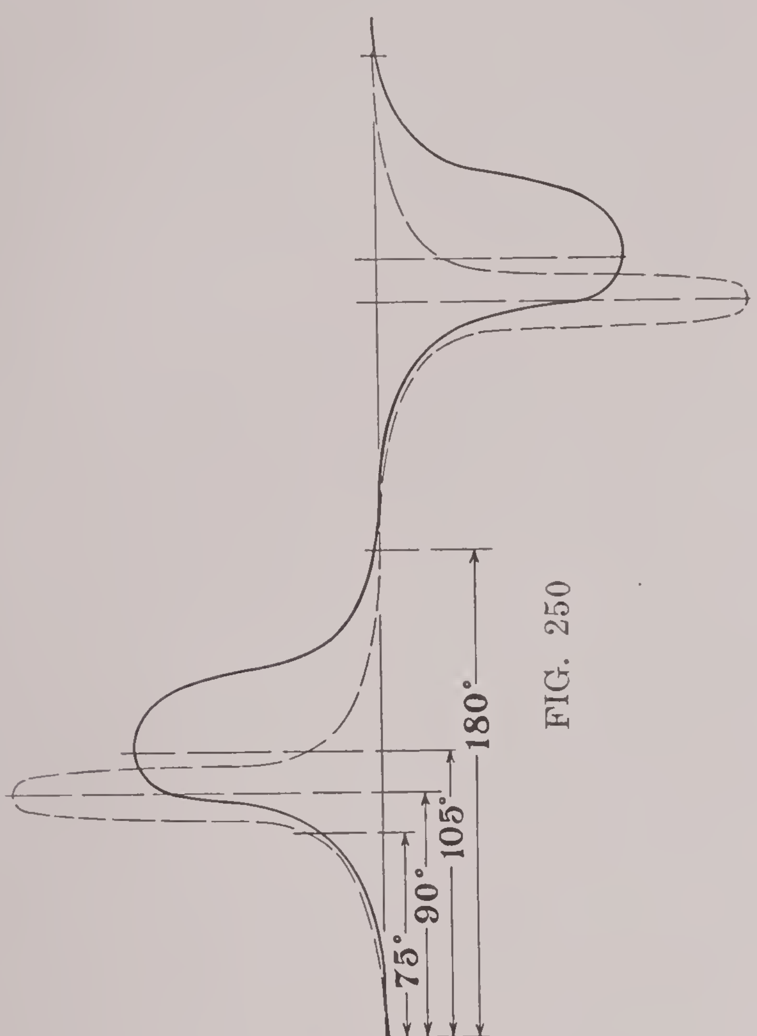
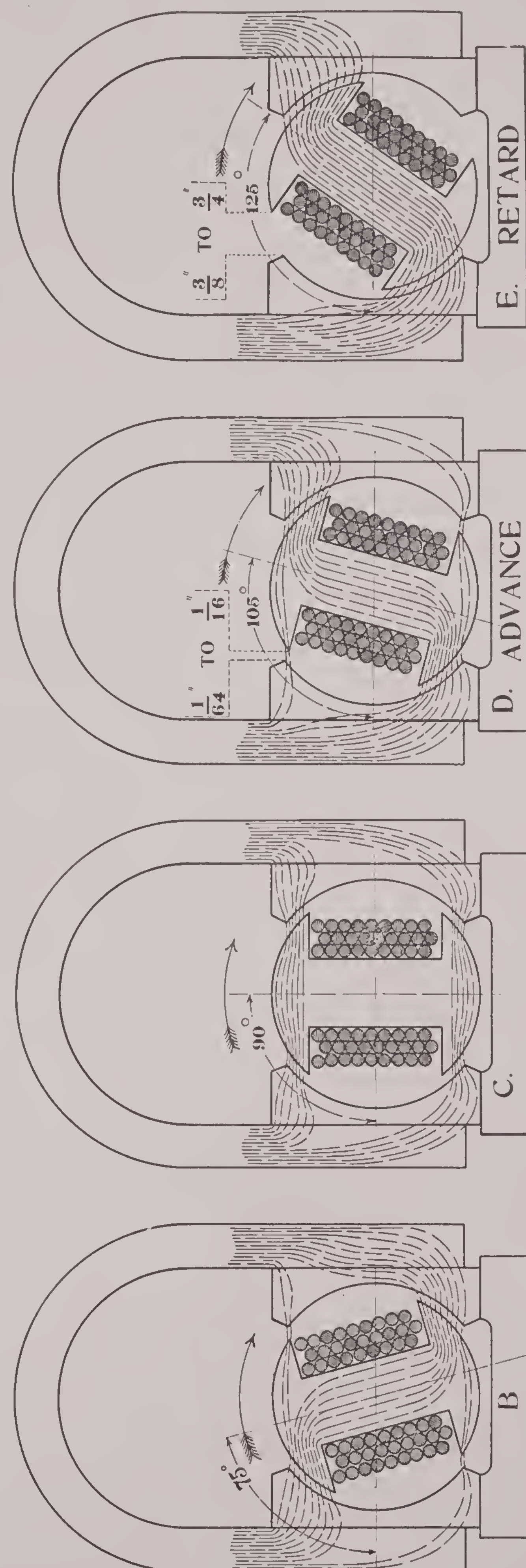


FIG. 250



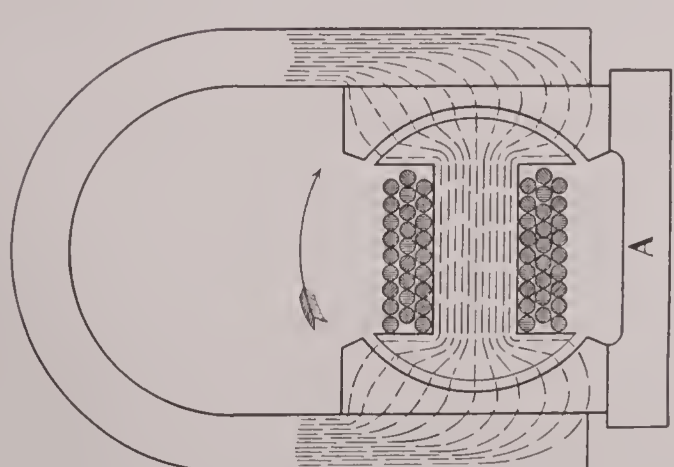


FIG. 249

shape as a shuttle. In Fig. 252 is shown a section through an armature of a low tension magneto. One end of the coil is grounded to the iron core, and other end connects to the lead screw which is insulated from the shaft through which it passes. To the ends of the core are fastened bronze plates in which the shafts are secured. These end plates are made of non-magnetic material so that the magnetic lines of force will not be shunted around the core. The core, coil, end plates and shafts assembled form the part of the magneto called the armature. The armature is mounted in bearings at either end of magneto and revolves between the poles of the magnets.

Fig. 249, illustration (A) shows a cross-section of a low tension revolving armature type magneto. The pieces secured to the poles of the magneto are called the "pole shoes." The pole shoes reduce the air gap between the poles of the magnets and the armature core. With the armature core in the position shown at (A) the magnetic lines of force set up by the magnets flow from the north pole through pole shoes and core to the south pole. The magneto base is of non-magnetic material, bronze or aluminum, so that lines of force will not flow through it, around the core.

As the core is revolved, the sides of the coil cut the magnetic lines of force set up by the magnets and an E. M. F. is induced in the coil. Because of the shape of the core and the pole shoes, the E. M. F. in the coil does not build up as gradually as in the loop revolving in the magnetic field shown in Fig. 248, but builds up in quick strong impulses, lasting for only about a twelfth of a turn. The illustrations (A), (B), (C), (D) and (E) in Fig. 249 show the path of the magnetic lines of force with the core in various positions.

As the core turns from the position (A) to the position (B), the magnetic lines of force twist with the core, taking the path of low reluctance through the part of the core on which the coil is wound, from one pole to the other. So long as the lines twist with the core they are not cut by the sides of the coil and no E. M. F. is induced in coil. When the core is turned past position (B), the magnetic lines of force begin whipping up on the right side and down on the left side, so that when the core reaches position (C) the lines are flowing through the cheeks of the core and not through the coil. As the core turns past position (C) and to position (D) the magnetic lines of force continue to whip up on the right side and down on the left side until the lines again flow through the part of the core on which the coil is wound, as shown at (D). Hence while the core turns from position (B) to position (D) the sides of the coil are cutting the lines, and E. M. F. is induced in it. Since the lines whip across the sides of the coil while core is turning only about a twelfth of a revolution they cut the lines at a high rate inducing an E. M. F. of several volts when armature is turned 100 revolutions per minute, or more.

After the core reaches position (D) practically no lines are cut by the sides of the coil until the core turns about five-twelfths of a revolution further. This brings the core to a position that is just one-half revolution from position (B). As the core passes this position the lines again begin to whip across the sides of the coil and again an E. M. F. is induced in the coil, but this time the E. M. F. acts in the opposite direction.

The comparative strength of the E. M. F. induced in the armature for different positions of the core is shown in Fig. 250. The dotted line shows the two E. M. F. waves (impulses) which are produced per turn of the armature and that the wave on one-half turn is in the opposite direction to the one following it; consequently, the current that flows is an alternating current. The curve shown in full lines represents the comparative strength of current delivered by a magneto. The current, because of self-induction, lags behind the E. M. F. and so does not reach full strength until the tip of core has broken away from pole shoe from about 1/64″ to 1/16″.

Connection is made to the ends of the armature coil through the lead screw and the ground. A small brush or spring is carried in the breaker cap of magneto which, when cap is in position, rubs against the end of the lead screw. A terminal is provided on the cap for connection to the brush. On some magnetos a collector ring to which one end of armature coil connects is placed on the end of the armature instead of using a lead screw. A terminal is then provided on the brush holder which holds a small carbon brush on the ring. To make a better ground connection to the revolving core than that made through bearings, a small carbon brush which rubs against the end of armature is usually carried in one of the end plates.

LOW TENSION MAGNETO

Revolving Armature Type

The E. M. F. generated by low tension magnetos is seldom more than 30 volts, hence the current which it produces is low tension. There is only one winding in the low tension armature. This winding is usually about No. 18 insulated copper wire.

When the low tension magneto is used on low tension systems, it is usually the oscillating type. That is, instead of the armature making complete revolutions, it oscillates through a small angle. Heavy coil springs are arranged to bring the core to the position shown at "C" in Fig. 249. The igniter contacts on the engine which connect directly to armature, stand normally closed. As the push rod which operates the igniter is moved out by the cam, it rocks the armature core back to position shown at (B) in Fig. 249. When the spark should occur, the push rod trips and the heavy springs throw the core back to vertical position. The core does not come to rest when it reaches a vertical position but swings beyond the vertical position to about the position shown at (E), making a few oscillations which quickly die out.

The springs during this operation throw the armature through the part of a revolution in which the magnetic lines of force cut the sides of the armature coil, and so past the point at which the E. M. F. is induced. The igniter contacts are held together, shorting the armature coil until the tip of the armature core breaks away from the tip of the pole shoe so that a comparatively strong current will build up through the armature coil as a result of the E. M. F. induced in it. Just as the tip of the armature core breaks away from the tip of the pole shoe (the point when current in coil is maximum) the igniter contacts are thrown apart breaking the circuit within the combustion chamber. The self-induction of the armature forces current across the gap between contacts as they separate, producing a heavy spark which ignites the charge in the cylinder.

This type magneto is generally used on single cylinder stationary engines.

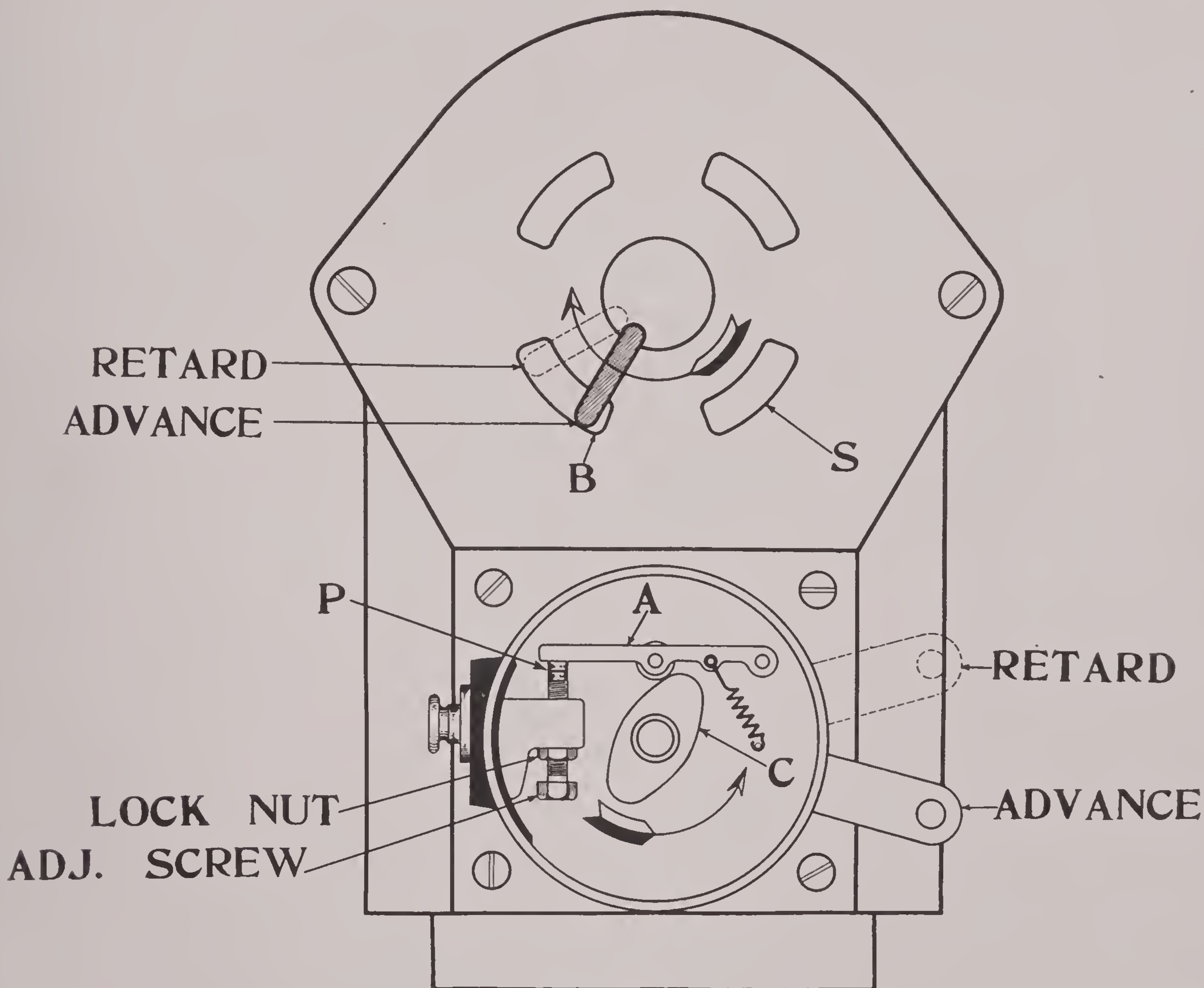


FIG. 251

If the low tension magneto is used in a high tension ignition system, an induction coil and breaker must be used. A breaker is usually carried on the magneto and is timed to the armature. The breaker cam is so keyed on the armature shaft that the contact points separate in full advance just as the tip of the armature core breaks away from the pole shoe—from 1/64″ to 1/16″ varying with different magnetos—and in full retard when tip of core is from 3/8″ to 3/4″ from pole shoe. Fig. 249,. illustration (D) shows position of core when points separate in full advance with armature turning clockwise and illustration (E) shows position of core when points separate in full retard. The timing of the breaker to the armature is necessary in order that points separate while the current is flowing through the coil. The current is about maximum when points separate in full advance, hence the advanced spark is more intense than the retarded spark.

If the magneto is for a multiple cylinder engine it is equipped with a distributor. The distributor brush is carried on a large gear that is driven by a smaller gear on the armature. The distributor brush is always driven at one-half crankshaft speed for the four stroke cycle engine.

The relative speeds of the armature and the crankshaft depend on the number of cylinders in the engine on which the magneto is used. If it is a four cylinder engine, the armature is driven at crankshaft speed. The large distributor gear will then have twice as many teeth as the small gear on the armature. If it is a six cylinder engine, the armature will be driven at one and a half times crankshaft speed and the large distributor gear will have three times as many teeth as the gear on the armature. If it is an eight cylinder engine, the armature will be driven at twice crankshaft speed, and the large distributor gear will have four times as many teeth as the small gear on the armature.

Distributor gears must be so meshed that the distributor brush will always be on a distributor segment when the breaker points separate. The following is an easy way to time the distributor gears:

Place the breaker mechanism halfway between full advance and full retard position and then turn the armature forward till the breaker points just begin to separate. Stop the armature and hold it in this position. Draw the distributor gears out of mesh and rotate the large gear to the position at which the distributor brush will be in the center of a segment with the distributor head in position, then re-mesh the gears. The gears should then be so meshed that, when the breaker points separate half way between full advance and retard, the distributor brush will be in the middle of a segment.

Fig. 251 shows the breaker and distributor end of a low tension magneto. The heavy lines show the position of the distributor brush when breaker points separate in full advance. The dotted lines show the position of the brush when the breaker points separate in full retard. It should be noted that distributor brush turns in opposite direction to the armature.

The breaker mechanism as shown, is carried in the breaker housing. The cam (C) is carried on the shaft. The fixed breaker point is insulated from the housing by fibre washers, which are shown in black. This point is carried on a small bolt that screws through the insulated support. The locknut on the bolt locks the bolt in position when properly adjusted. The other breaker point is carried on the breaker arm (A) which is grounded. A small spring draws the breaker arm down and closes the breaker when the lobe of the cam carried on the shaft turns from beneath the fibre roller on the arm. The breaker housing is so attached to the end-plate of the magneto that it can revolve part way around the shaft as an axis. A small lever is attached to the housing with which the housing is moved to advance and retard the spark. To advance the spark, the housing should be moved in the direction opposite to that in which the shaft turns. To retard the spark, the housing should be moved in the same direction as the shaft turns.

The end plate of the magneto and breaker housing are made of either bronze or aluminum (non-magnetic materials) to prevent the magnetic lines of force from flowing around the armature core from one pole of the magnet to the other. The large distributor gear is made of bronze for the same reason.

Clockwise and Counter-Clockwise Magnetos

If the breaker and distributor of a magneto are properly timed for the magneto to run in clockwise direction they will not be properly timed if the magneto is turned in a counter-clockwise direction. That is to say, if the breaker points separate in full advance, just as the tip of the core breaks away from the pole shoe and the distributor brush has just come on to a distributor segment with the armature turning clockwise, the breaker points will not separate in full advance when tip of core breaks away from pole shoe, and distributor brush will not have just come on to a distributor segment, if the armature is turning counter-clockwise. For this reason, it is necessary to specify the direction that the magneto is timed to be driven. If, when looking at the driven end of a magneto, the armature turns in the direction the hands of a clock move, the magneto is called a clockwise magneto. If, when looking at the driven end, the armature turns in a direction opposite to that of the hands of a clock, the magneto is called a counter-clockwise or anti-clockwise, magneto. When determining whether a magneto is clockwise or counter-clockwise, always consider it from the driven end.

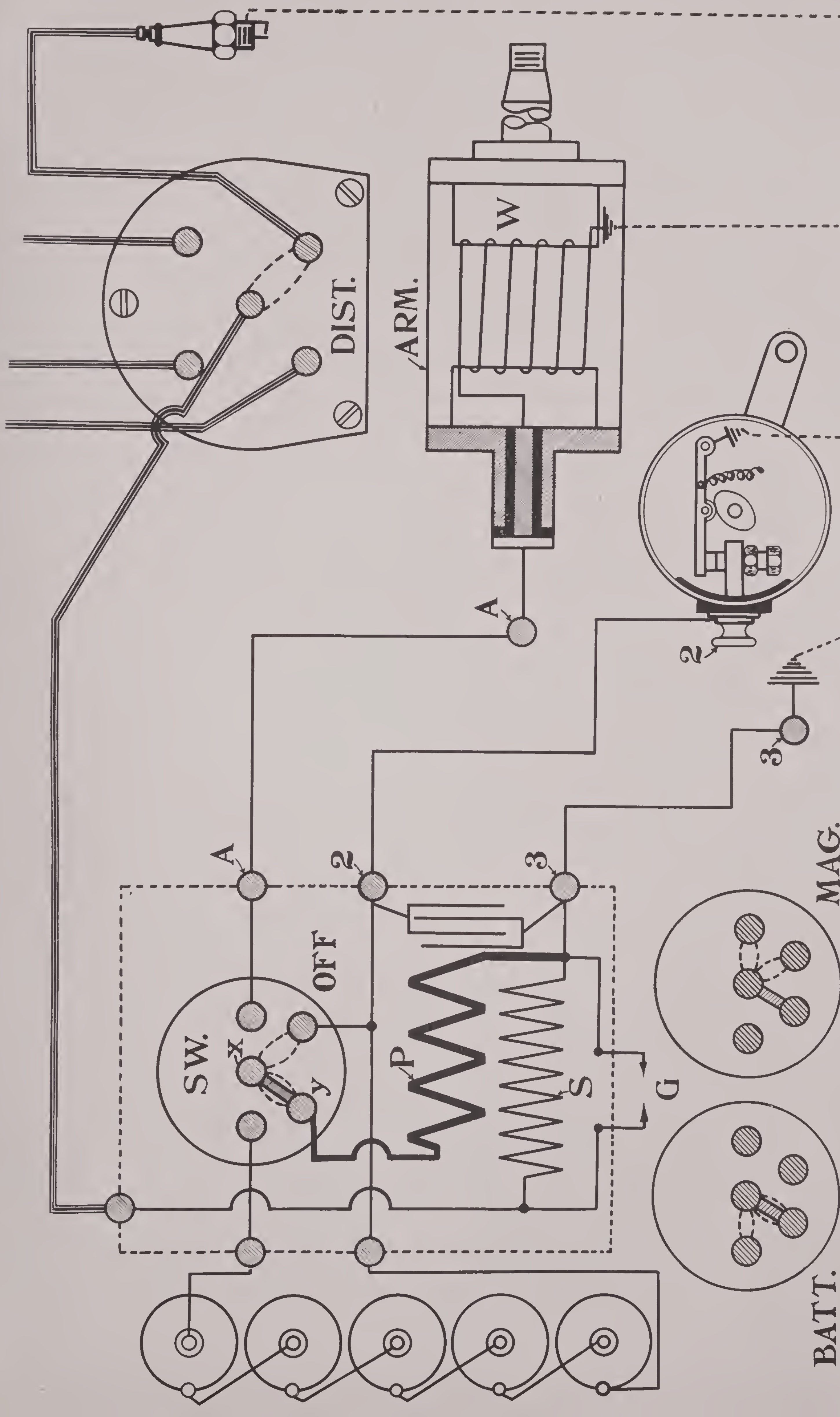


FIG. 252
LOW TENSION DUAL MAGNETO SYSTEM

To Determine Direction of Rotation

The direction a magneto should be driven can be determined in the following manner. Turn the armature slowly in a clockwise direction till the tip of the armature core is just breaking away from the pole shoe. If the breaker points are then just separating with breaker mechanism in full advance, the magneto is clockwise. If the breaker points do not separate in full advance as the tip of the core is just breaking away from the pole shoe, the magneto is probably counter-clockwise. Turn the magneto armature counter-clockwise till the tip of the armature core just breaks away from the pole shoe. If the breaker points are separating in full advance with the core in this position, the magneto should be driven counter-clockwise. If the breaker points do not separate in full advance as the tip of the core breaks away from the pole shoe with the armature turning in either direction, it is probable that the wrong cam has been placed on the shaft, or the cam has slipped because of key being left out, or breaker housing is not on the magneto in proper position.

LOW TENSION DUAL MAGNETO

The low tension dual magneto is called dual because the switch and coil with which it is used are so constructed that either a battery or magneto may be switched into the primary circuit and used as a source of E. M. F. The breaker and distributor are used when running on either magneto or battery.

Fig. 252 is a wiring diagram for a low tension dual magneto ignition system. The switch is usually carried on the coil. The switch arm has three positions — "OFF," "BATT." and "MAG." The connection between (x) and (y) on the switch is permanent.

Operation on Battery

With the switch in battery position, the battery, coil, breaker and distributor make up a battery ignition system. The armature of the magneto does not come into use. The battery is usually five dry-cells in series. The secondary of the coil connects with a high tension cable to the middle terminal on the distributor head.

The distributor switches the secondary of coil in circuit with each plug according to firing order of engine, hence distributes the secondary current to the plugs.

Operation on Magneto

When the switch is thrown to the magneto position, the battery is disconnected and the magneto armature is switched in series with the primary of the coil, and the breaker in parallel with the primary winding. The breaker is so timed to the armature that the points are always closed as the E. M. F. builds up in the armature. The breaker being in parallel with the primary, shorts the armature when the points are together. Since the resistance of the complete armature circuit is very low when the breaker is closed, a comparatively strong current is built up in the armature coil as its sides cut the lines of force set up by the magnets.

At the instant the current in the armature reaches about its maximum strength, the breaker points separate. When the breaker points separate, the circuit is then through the primary coil only and all the current which flows through the armature must flow through the coil. The high self-induction of the armature tends to drive the current through the primary winding at the same rate that it was flowing through the breaker. This results in the building up of current through the primary at a very high rate, which so quickly magnetizes the core that strong enough E. M. F. is induced in the secondary to produce the spark at the plug. The coil operates by the building up of the field when running on magneto, instead of by the collapse of the field, but the spark occurs when breaker points separate, and when a partial collapse of the lines of force is produced in the armature.

Connecting the breaker in parallel with the primary reduces the sparking at the breaker points. If both armature and primary of coil are connected in series with breaker, the sparking at the points is excessive.

The condenser may be in either the coil or the magneto. In either case, it is connected in parallel with the breaker.

Some low tension magnetos carry a condenser and coil beneath the arch of the magnets. The coil is connected in the same manner with relation to the magneto, as the coil in the low tension dual system, when the switch is in "MAG" position. That is, the breaker points are connected in parallel with the primary of the coil, and a condenser in parallel to breaker points. Since the coil is mounted within the magneto, the connections are made inside and are very well protected. The breaker cap carries a terminal which makes connection to the armature when cap is in position. Connection is made from this terminal to one terminal of the ignition switch. The other terminal of the ignition switch is grounded. When the switch is in "OFF" position, it shorts the breaker points. With the breaker shorted, the current in the armature is not switched to the primary of the coil when they separate, therefore any E. M. F. induced in the secondary is not strong enough to drive the current through the gap in the plug to pro-

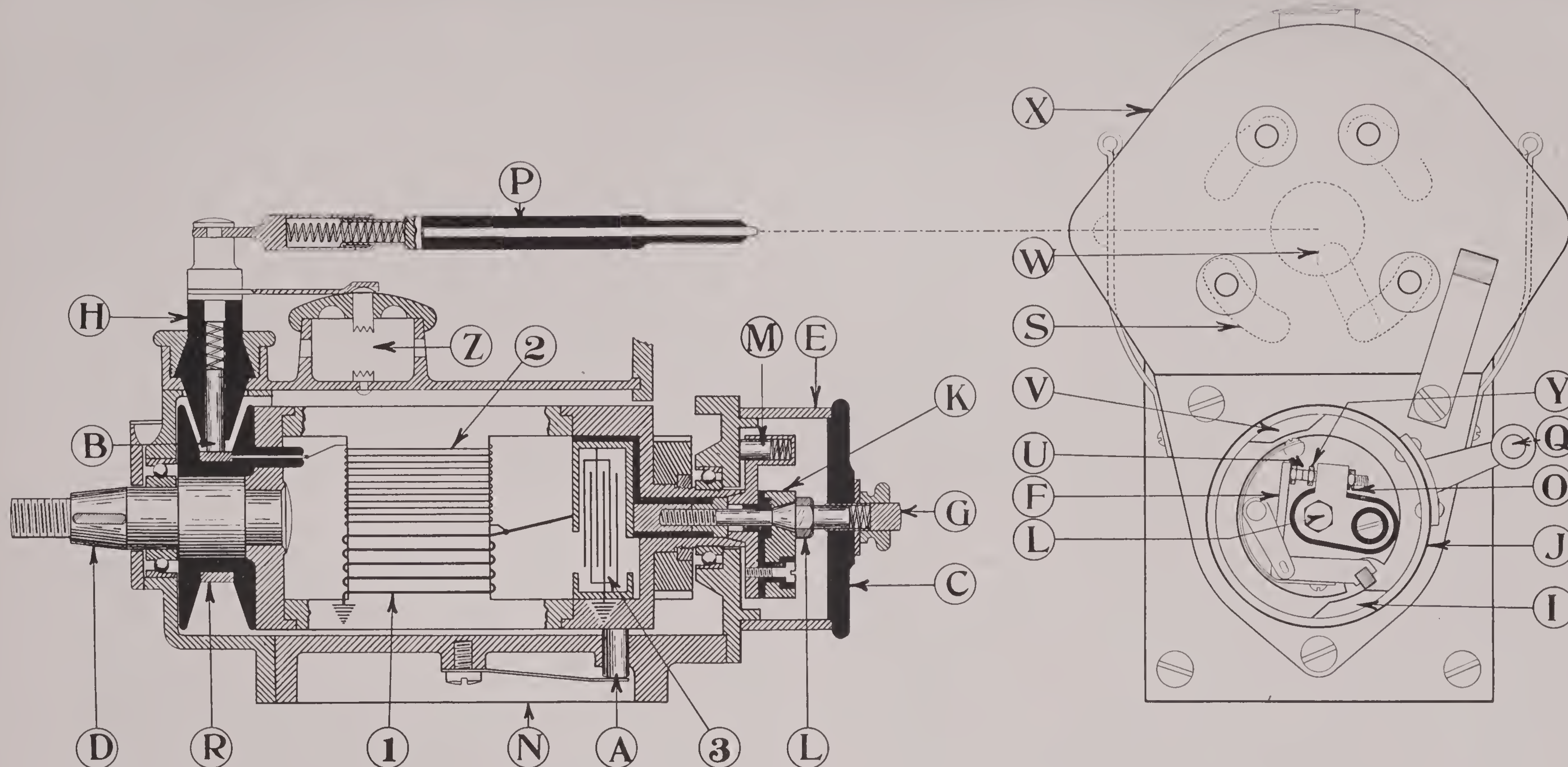


FIG. 253

HIGH TENSION MAGNETO—REVOLVING ARMATURE TYPE

A. Base grounding brush.
B. Carbon brush in brush holder forming secondary terminal. (Collector brush.)
C. Breaker cap.
D. Drive shaft.
E. Breaker housing.
F. Breaker arm.
G. Armature terminal.
H. Collector brush holder.
I. Cam.
J. Breaker housing.
K. Block carrying fixed breaker point.
L. Lead screw.
M. Disc grounding brush.
N. Base.
O. Locknut to lock breaker point adjustment.
P. Pencil.
Q. Spark advance and retard lever.
R. Collector ring.
S. Distributor segment.
U. Breaker points.
V. Cam.
W. Distributor brush.
X. Distributor head.
Y. Breaker point adjusting nut.
Z. Safety gap.
1. Primary.
2. Secondary.
3. Condenser.

duce a spark. When the switch is in "ON" position the short on the breaker is broken, and the magneto operates the same as a low tension dual with the switch in "MAG" position.

An example of the magneto just described is found in the Kingston. This magneto from outside appearances is much the same as a straight high-tension magneto. Instead of making connections to the armature through the lead screw, a small brass ring is mounted on a Bakelite spool at the driven end of armature, and to this ring, one end of the armature winding connects. A small carbon brush which rides on the ring is carried by the brush holder on the side of the end plate of magneto. From this brush holder a wire runs to one end of the primary of coil, one terminal of condenser, and to the insulated breaker contact. There is no center terminal on the distributor head, since connection is made from the secondary coil to the distributor, by an insulated shaft that passes through the center of the distributor gear.

HIGH TENSION MAGNETO

Fig. 253 shows a breaker and distributor end of a high tension magneto of the revolving armature type, and also a longitudinal section through the armature.

There are two windings on the armature core, primary and secondary. The primary (1) is a winding of about No. 20 insulated copper wire of only a few hundred turns. One end of this winding grounds to the core and the other end connects to the lead screw (L). In the illustration the primary is shown as being wound over just one end of the core, but in practice the primary is wound from one end of the core to the other and usually consists of about four layers. It is shown in this manner in order that the circuits can be traced with greater ease. The secondary (2) consists of several thousand turns of fine wire usually enamel insulated and wound directly over the primary. One end of the secondary connects to the end of the primary that connects to the lead screw and the other end of the secondary connects to the collector ring (R) which is carried in the bakelite spool at the driven end of the armature. In some magnetos the collector is at the breaker end of the armature directly under the distributor head. There are high flanges on both sides of the ring to prevent the secondary current from jumping from the ring to the ring housing. A condenser (3) is carried in the wide end plate of the armature. The breaker mechanism is mounted on a disc that revolves with the armature. The cams (I) and (V) are carried in the breaker housing. With this construction the primary circuit is completed in the armature and the low tension current does not flow through any slipping contacts.

A small carbon brush (B) which rides on the collector ring (R) is carried in a fibre or hard rubber brush holder (H) that screws into the ring housing. From the terminal at the top of the brush holder, connection is made with a device called a pencil (P) to the distributor (X). The pencil passes through the center of the distributor gear. The pencil is well insulated at the point where it passes through the gear to prevent the secondary current from jumping from the pencil to the gear. An induction coil is not necessary for the operation of the high tension magneto, since the strong E. M. F. which produces the spark at the plug is produced in the armature.

Operation of the High Tension Magneto

The operation of a high tension magneto is in many respects the same as that of a high tension induction coil. It differs fundamentally in that the E. M. F. causing current to flow through primary is generated by causing the turns of primary to cut lines of force set up by permanent magnets.

The armature of the revolving armature type high tension magneto is revolved between the poles of the magnets in the same manner as in the armature of the low tension magneto. The armature core is of soft iron and of the same shape as that in the low tension magneto. As the armature is revolved in the field, the magnetic lines of force set up by the magnets are cut by the sides of the coils, and so induce an E. M. F. in the coils. There are many thousand turns in the secondary but it is not practical to revolve the armature at a speed that would generate in the secondary an E. M. F. strong enough to produce a spark in the gap of the spark plug, hence the primary, condenser and breaker are necessary.

The breaker, as on the low tension magneto, is so timed to the armature that the points are together, shorting the primary as the E. M. F. is induced in it by its sides cutting the lines of force set up by the magnets. The resistance being low, a comparatively heavy current is generated in the primary, which magnetizes the core much stronger than it is magnetized by the magnets. Just as the tip of the core is breaking away from the pole shoe (the time when the current is about maximum in the primary) the breaker points separate, interrupting the current. This causes the lines of force set up by the current to quickly collapse across the secondary at a rate that induces in it an E. M. F. strong enough to drive the current across the gap in the plug, producing a spark.

When running with an advanced spark, the breaker points separate before the sides of the coils have cut all the lines of force set up by the magnets. Consequently, because of the generator action of the secondary revolving in the field set up by the magnets, there is still an E. M. F. in the secondary after the lines set up by the current in the primary have collapsed. This E. M. F., called "follow-up" voltage, increases the flow of electricity through the gap in the plug for an instant after the spark is established, thus producing a very intense flame. This peculiar "follow-up" voltage produced in the secondary of a magneto armature, even though it is of very short duration, enables the magneto to give a more intense spark than that which is produced by battery ignition.

is fastened to the top of the pole shoes, is connected between the secondary terminal on the brush holder and the ground. The gap is usually set at approximately 5/16″. This gap is provided to prevent the voltage from rising high enough in the secondary to puncture the insulation on the secondary coils. The width of the safety gap is such that its resistance is greater than that of the spark plug and yet small enough to protect the secondary coil from an excessive voltage that would damage it. Sparking at the safety-gap is an indication of too wide a gap in the spark plug, or a wire disconnected from either the distributor or from a spark plug.

INDUCTOR TYPE MAGNETO

In the revolving armature type magneto, the armature coils are revolved to cause them to cut the lines of force. In the inductor type

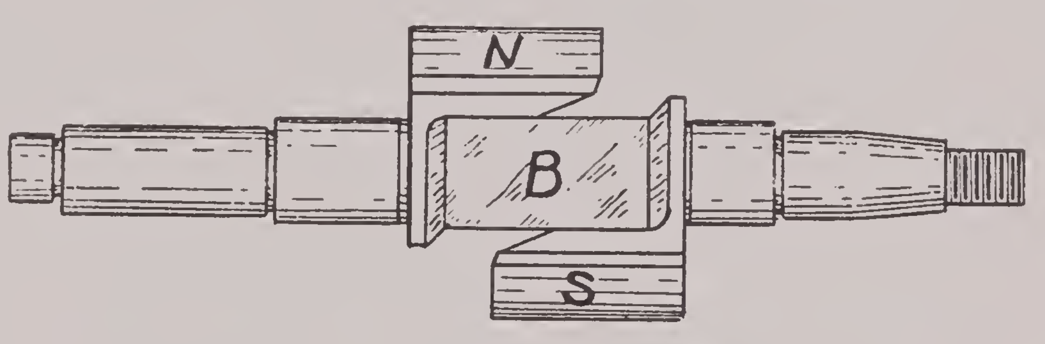


FIG. 254

ROTOR FOR 2, 4 AND 6 CYL. DIXIE MAGNETOS

N and S. Rotating poles. B. Bronze block to which poles are riveted.

The condenser carried in the armature is connected in parallel with the breaker points to prevent sparking between them as they separate. The breaker cap carries a small spring that presses against the lead screw when the cap is in position. Connection is made from this spring to the terminal on the cap. This terminal connects with a wire to the ignition switch. With the switch in "OFF" position it grounds the lead screw, shorting the breaker points. With the switch in "ON" position it is open and so breaks the ground connection on the lead screw. The small carbon brush (A) carried in the base of the magneto, rubs against the wide end-plate of the armature, forming a better connection between the base of the magneto and the revolving core than could be made through the bearings. This gives a better ground connection to the primary. Sometimes this brush is carried in the disc which carries the breaker as shown at (M) and as the disc revolves with the armature the brush rubs against the end-plate that carries the bearing.

The safety gap (Z) on the cover plate which

magneto the armature coils are stationary and the magnetic lines of force are switched through the coils in first one direction and then another. As the lines of force are switched through the coil in one direction and then in the opposite direction they are cut by the sides of the coils and so induce E. M. F. in them. Since the coils do not revolve no lead screw or collector ring is used.

DIXIE MAGNETO

Fig. 255 illustrates the magnetic path as formed in the "Dixie" magneto, and the position of the armature coils with relation to the magnets. Rotating poles (N and S) are carried on the drive shaft (Fig. 254) and are coupled together by a bronze block (B) to which they are riveted. Bronze being nonmagnetic, the magnetic lines of force follow the armature core from one pole to the other instead of flowing directly from one pole to the other through the block to which they are riveted.

The rotating poles form a "magnetic switch" which, as they are turned, switch the magnetic lines of force through the armature coils first in one direction and then in the opposite direction. As the lines of force are switched back and forth through the coil they are cut by the coil and so induce E. M. F. in it. The maximum voltage is generated in the primary as the rotating poles are passing between the ends of the armature core. The current in the primary of the armature reaches about maximum strength when the rotating pole has broken away from the tip of the core .020″. The Dixie magneto is a high tension magneto and so has both primary and secondary armature windings.

Since the armature coils do not revolve, the breaker is mounted in the housing as in the low tension magneto of the revolving armature type. The cam is carried on the shaft, and there is no lead screw. One end of the primary winding is grounded to the core, the other end connects to one terminal of the condenser, and to the stationary breaker point. The other terminal of the condenser grounds to the core, and the breaker point on the breaker arm grounds to the breaker housing.

One end of the secondary is grounded and the other end connects to a contact on the side of the armature. This contact on the side of the armature rests against a small carbon brush that is carried in a cup at the end of an insulated rod passing through the distributor gear shaft. This insulated rod connects to the metal distributor brush that is carried on the distributor gear.

The two magnets fit on either side of the rotor shaft instead of straddling the rotor as magnets of the revolving armature type straddle the armature.

The breaker cam is keyed on the rotor shaft so that the breaker points separate as the rotating poles break away from tips of the armature core .020″. The breaker housing is carried on a sleeve on which the armature is carried. When the breaker housing is moved forward to retard the spark, the armature is moved forward an equal distance, hence the breaker contacts always separate when tip of pole breaks away from tip of core .020″. The advantage of this arrangement is that the breaker points separate at the point when the current is maximum in the primary so that maximum number of lines of force collapse across the secondary. The magneto gives a spark of equal intensity in both retard and advance.

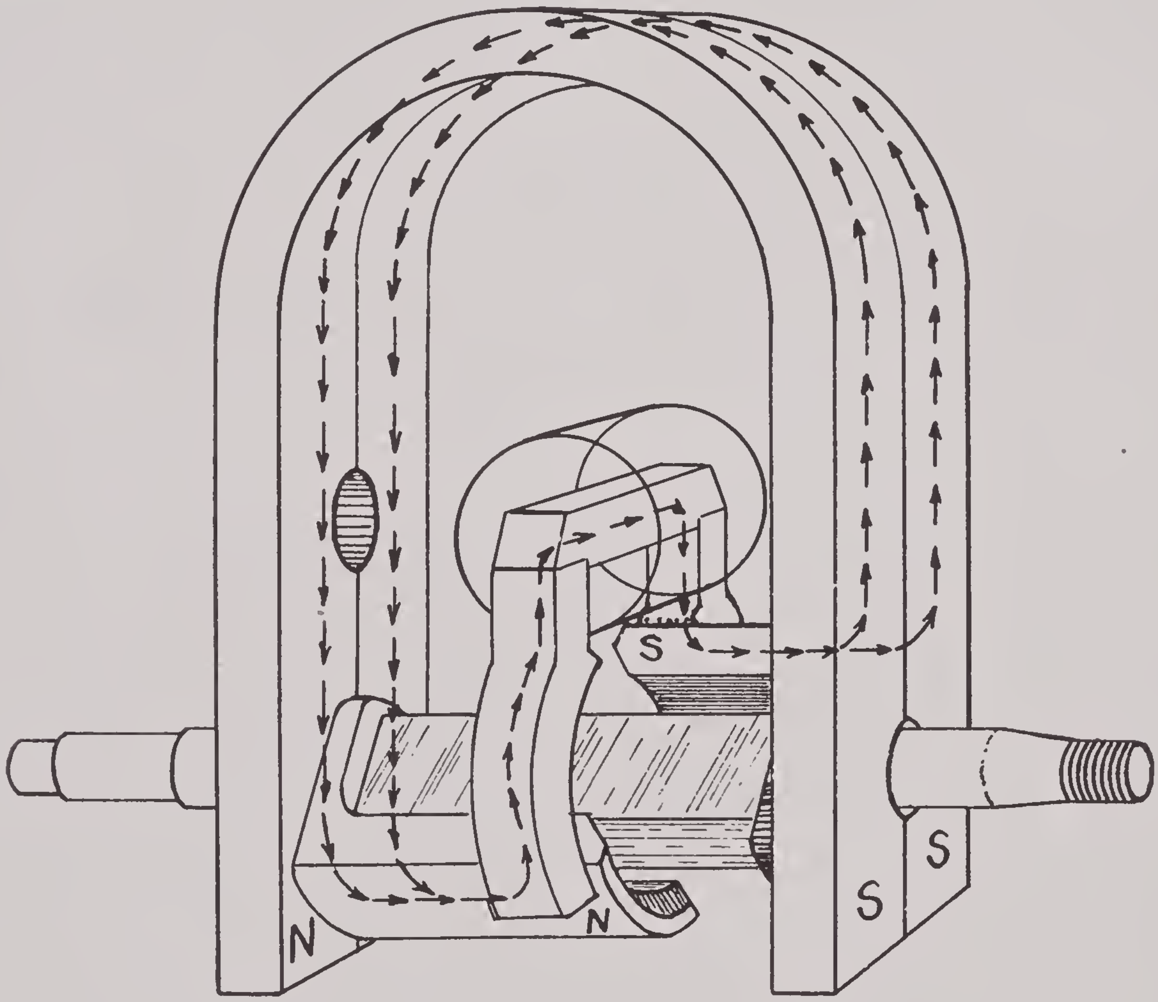


FIG. 255

The terminal on the breaker cap which connects to the ignition switch, makes connection with the stationary breaker point. When the ignition switch is thrown to "OFF" position, it grounds this terminal, thus shorting the breaker points.

The four and six cylinder Dixie magnetos give two sparks per turn of the rotor just as the shuttle type armature magneto, and so there are two lobes on the cam. The rotor for the eight and twelve cylinder magnetos has four rotating poles instead of two, and so four sparks are produced per turn of the rotor. The breaker cam on these magnetos has four lobes.

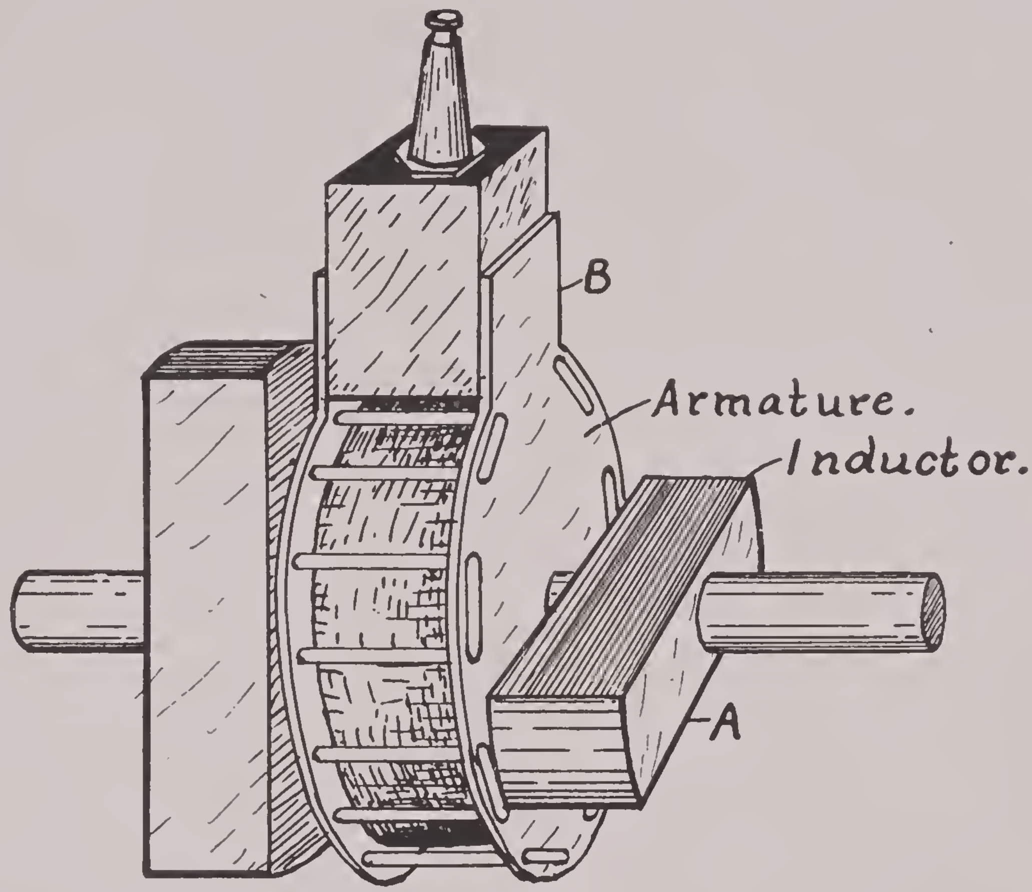


FIG. 256

K-W MAGNETO

Fig. 257 shows the magnetic circuit of the "K-W" magneto. The armature coils are concentric with the rotor shaft and are situated between the rotating poles or inductors. (See Fig. 256.) The opening of the coil is large enough for the rotor to turn with the coil held stationary. Since this magneto is made in both low tension and high tension types, there may be one winding or two windings in the armature.

Turning the rotor causes the magnetic lines of force to be switched through the armature coils first in one direction and then in the other. As the lines of force are switched back and forth through the coil they are cut by the sides of the coils and so induce an E. M. F. in them. Four impulses of current are produced per revolution of the rotor. If the magneto is for a four or six cylinder engine there are only two lobes on the breaker cam, and only two of the four impulses of current produced per turn of the rotor are used. If the magneto is used for eight or twelve cylinders, a four lobe cam is used for the breaker, and all four impulses of current are used. Since the armature coils do not revolve, the breaker contacts are carried in the breaker housing, and the cam is carried on the shaft. The breaker points separate in full advance just as an inductor breaks away from the pole shoe.

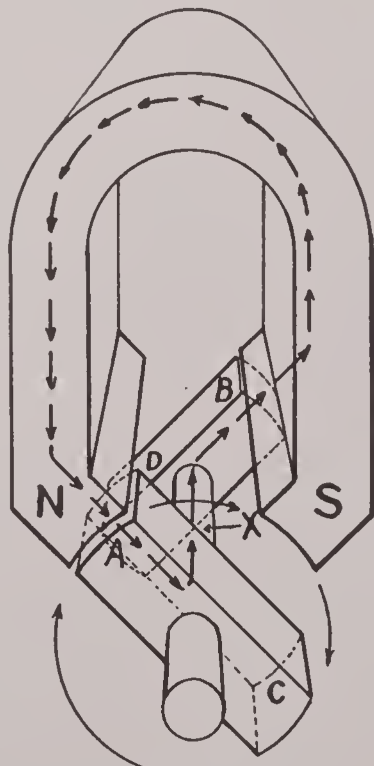


FIG. 257

TEAGLE MAGNETO

Figs. 258 and 259 show the magnetic circuit of the Teagle magneto. This magneto is a departure from the conventional type. Bar magnets are used instead of horse-shoe magnets and a soft iron base is used instead of a bronze or aluminum base.

By comparing the two diagrams, it can be seen how turning the rotor (B) causes the lines of force to be cut by the armature coil, and so induce an E. M. F. in it. The magneto is a high tension magneto, hence there are both primary and secondary windings on the armature. The breaker points separate in advance when rotor breaks away from leg of core on which the armature coils are wound.

The duplex coil is much the same as a substantially constructed buzzer (see Fig. 306). A condenser is connected around the vibrator contacts of the duplex coil.

When the ignition switch is thrown to the battery position, the battery, duplex coil and armature terminal are thrown in series. If the magneto breaker points are opened the circuit is completed from the armature terminal through the primary winding of the armature to the ground, and through the ground back to the grounded terminal of the battery. As soon as this connection is made, the E. M. F. of the battery causes current to flow through the circuit. As the current flows through the circuit, it magnetizes the core of the duplex coil and magnetizes the armature

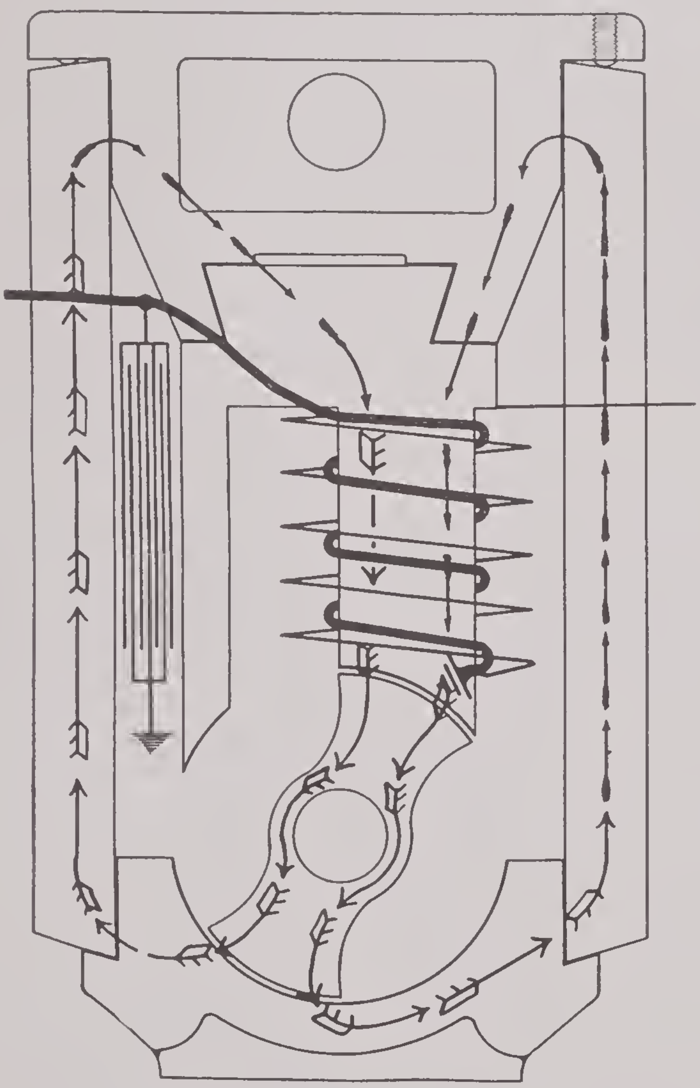


FIG. 258

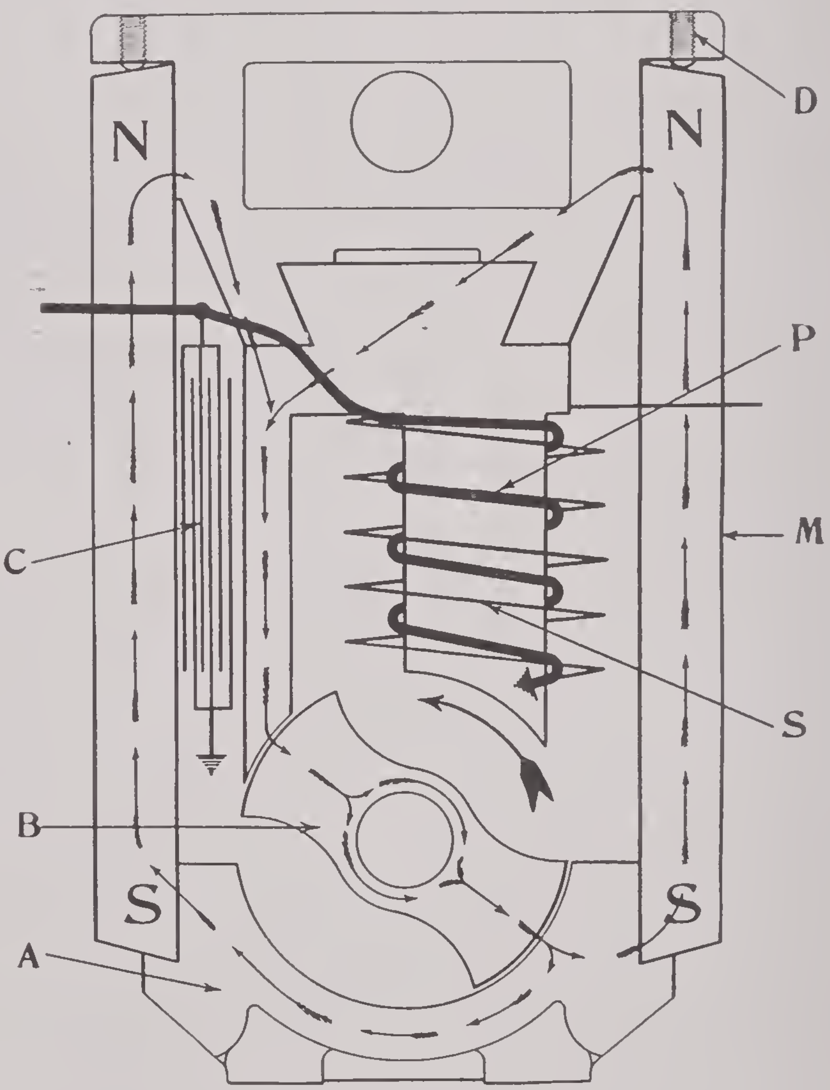


FIG. 259

HIGH TENSION DUPLEX MAGNETO
(Vibrator Type)

Fig. 260 is wiring diagram for a high tension duplex magneto. In addition to the magneto, which is the same as a straight high tension magneto, either revolving armature or inductor type, a duplex coil is switched in series with a battery and the armature terminal on magneto (terminal on breaker cap) when switch is in "BAT" or "START" position.

core. When the current reaches about 1½ amperes, the core of the duplex coil is magnetized strong enough to draw the contacts apart. When the contacts separate, the current through the circuit is interrupted. The interruption of the current through the primary causes the lines of force to collapse and cut the secondary, and so induces in the secondary a strong E. M. F. that drives the current across the gap in the plug producing a spark. As soon as the current is interrupted, the core of the duplex coil demagnetizes, and the vibrator spring throws the contacts together again. When the contacts come together the E. M. F. of the battery again causes current to build up through the primary circuit, repeating the operation. As long as the breaker points of the magneto are open, a shower of sparks is produced at the plug. If the magneto is turned so that the breaker points are together, the current which the E. M. F. of the battery causes to flow, is shorted around the primary of armature, hence no sparks are produced at the plug.

When the switch is thrown to "MAG" position, the connection between the duplex coil and the armature is broken, and the magneto runs as a straight high tension magneto. When the switch is thrown to the "OFF" position, the armature terminal is grounded, shorting the breaker points.

The advantage of the duplex over the straight high tension magneto is, a shower of sparks can be produced as long as breaker points are open, without turning the magneto. This makes starting easier. It is often possible to start on the spark, in which case it is unnecessary to crank the engine. This, however, is only possible when a charge of gas is left compressed in one of the cylinders and the breaker points are separated.

Fig. 261 is a combined internal and external wiring diagram of the single spark duplex system.

HIGH TENSION DUAL MAGNETO

Figs. 262 and 264 show high tension dual magneto ignition systems. Fig. 262 is the Eisemann magneto, and Fig. 264 is the Bosch. Fig. 266 shows the breaker mechanism for the Bosch high tension dual. There is a revolving breaker mechanism for the magneto, which is much the same as the breaker mechanism for the straight high tension magneto revolving armature type, and mounted in the lower part of the breaker housing is another breaker mechanism which is called the battery breaker. It is controlled by a cam carried just back of the magneto breaker mechanism. With the exception of the double breaker mechanism and the absence of a pencil, the high tension dual magneto is of practically the same construction as the straight high tension magneto.

An induction coil is carried in the coil-box with the ignition switch. This coil is a high tension induction coil, having a core, a primary and a secondary winding. A condenser is within the coil box. This coil is used in connection with a battery and the battery breaker mechanism on the magneto, when the ignition switch is in battery position. The secondary of the coil is then connected to the middle terminal on the distributor head. The lead screw is grounded by the switch so that the magneto breaker points are shorted. With the switch in this position ("Batt." position) the battery, induction coil, battery breaker on magneto, magneto distributor and spark plugs, form an ignition system, which is used for starting. The condenser carried with the coil is then in parallel with the battery breaker points. When the switch is thrown in the magneto position, the connections between the battery and the coil and between the distributor and the coil are broken. The secondary of the magneto is switched in series with the distributor and the ground on lead screw is broken. The magneto then runs as a straight

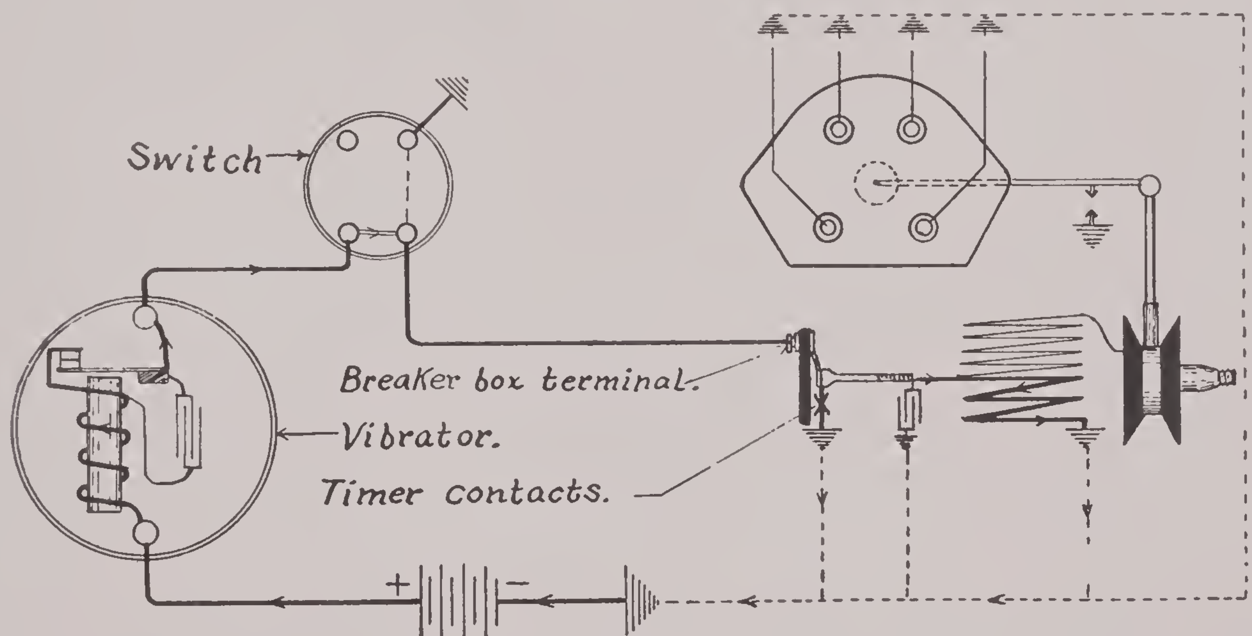


FIG. 260

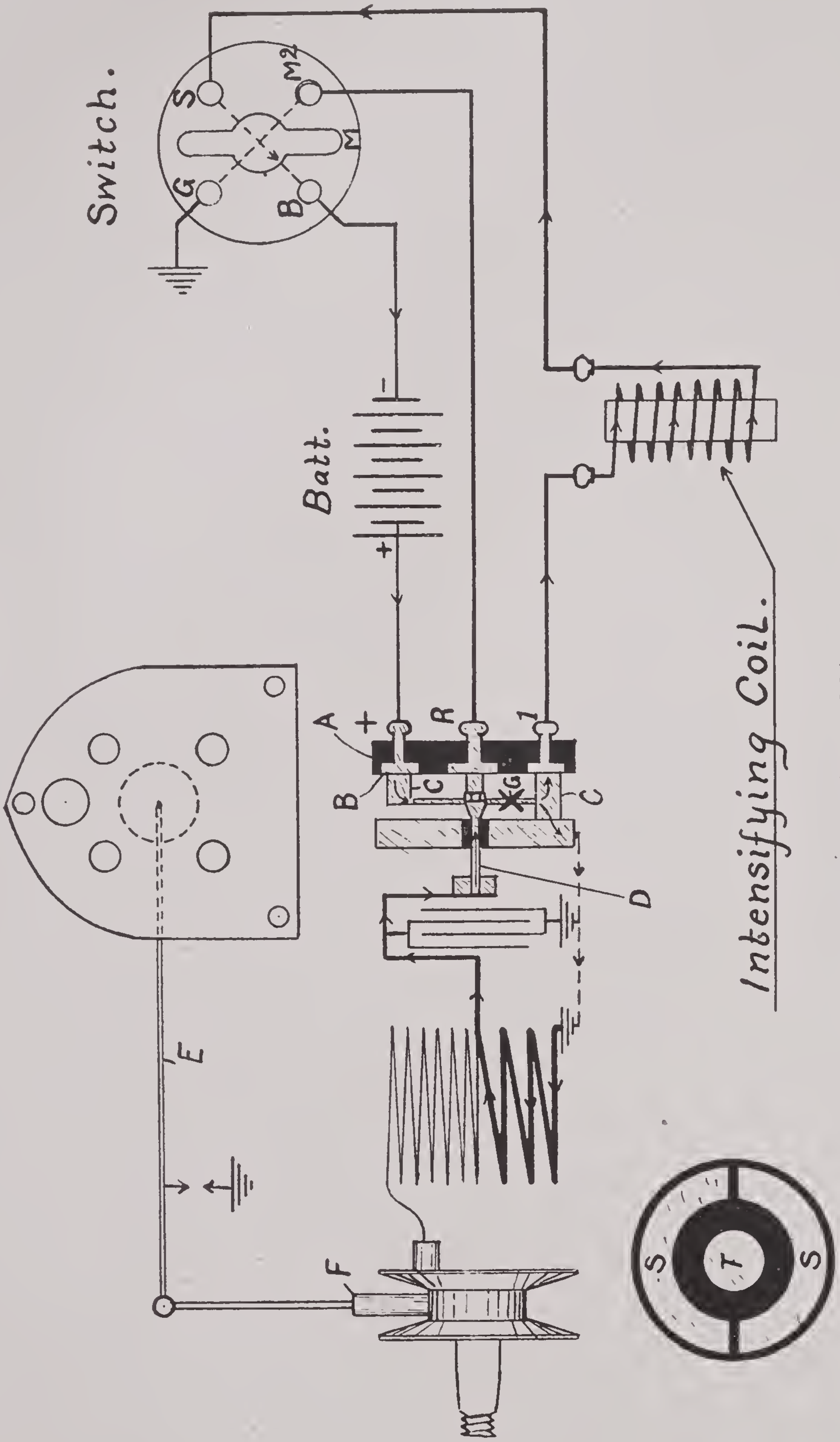


FIG. 261

HIGH TENSION DUPLEX MAGNETO—SINGLE SPARK

A. Breaker cap.
B. Segment in cap. See S in lower left illustration.
C. Carbon brush.
D. Lead screw.
E. Pencil.
F. Collector brush.
G. Breaker points.
R. Armature terminal. See T in lower left illustration.
1 & + terminals on breaker cap which connect to the two brass segments in breaker cap.

high tension magneto. When the switch is thrown to "OFF position, the lead screw is grounded, shorting the breaker points.

Fig. 263 shows the switch terminals and switch connections with switch in the various positions for the Eisemann. Fig. 265 shows the switch terminals and switch connections for the Bosch.

of the magnets are placed together. Fig. 267, illustration (A) shows the arrangement of magnets on the flywheel.

The soft iron pieces placed over the poles of the magnets form the pole pieces. The poles of the magnets are held out from the rim of the flywheel by non-magnetic spools, and the screws by which the poles are secured

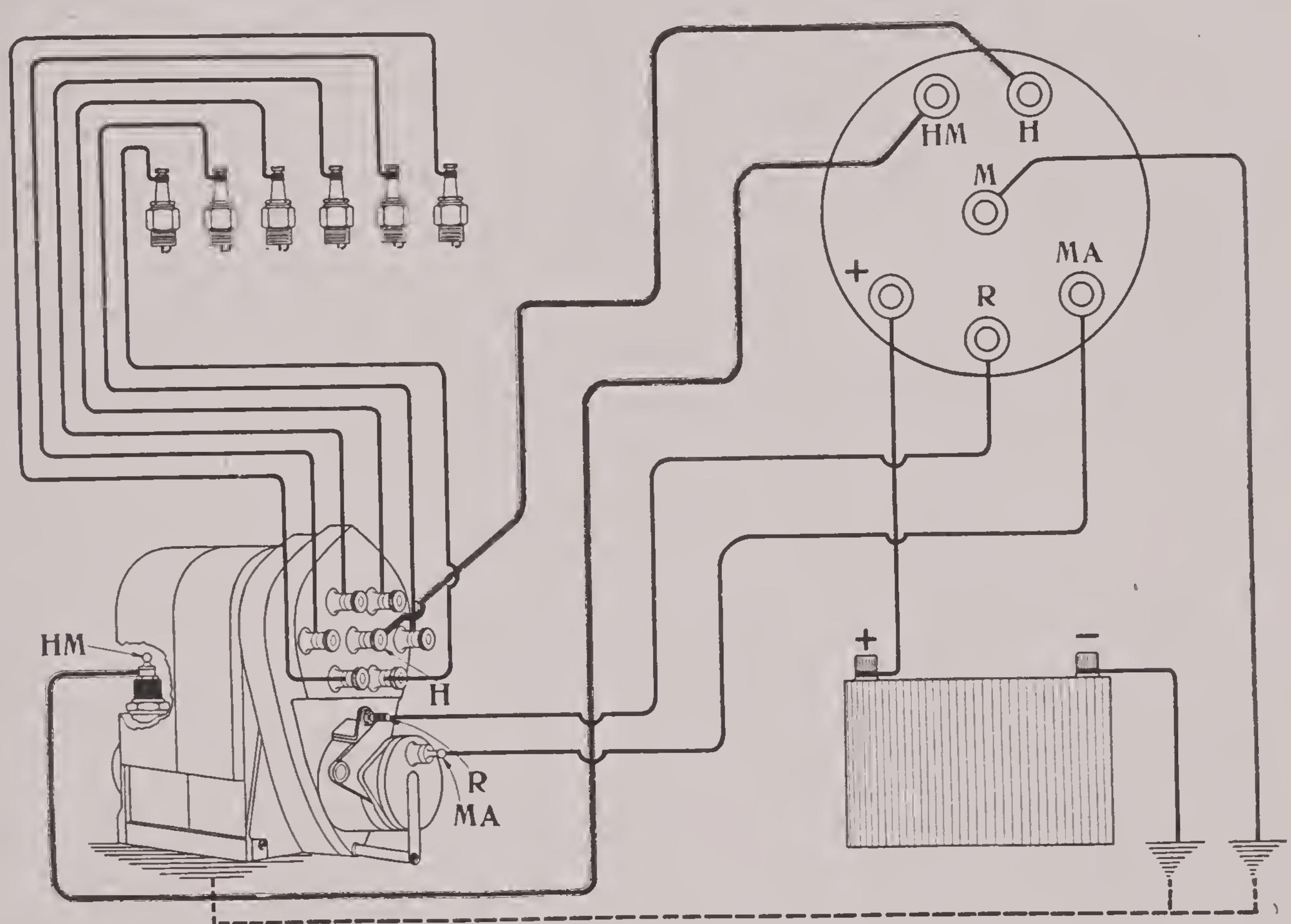


FIG. 262

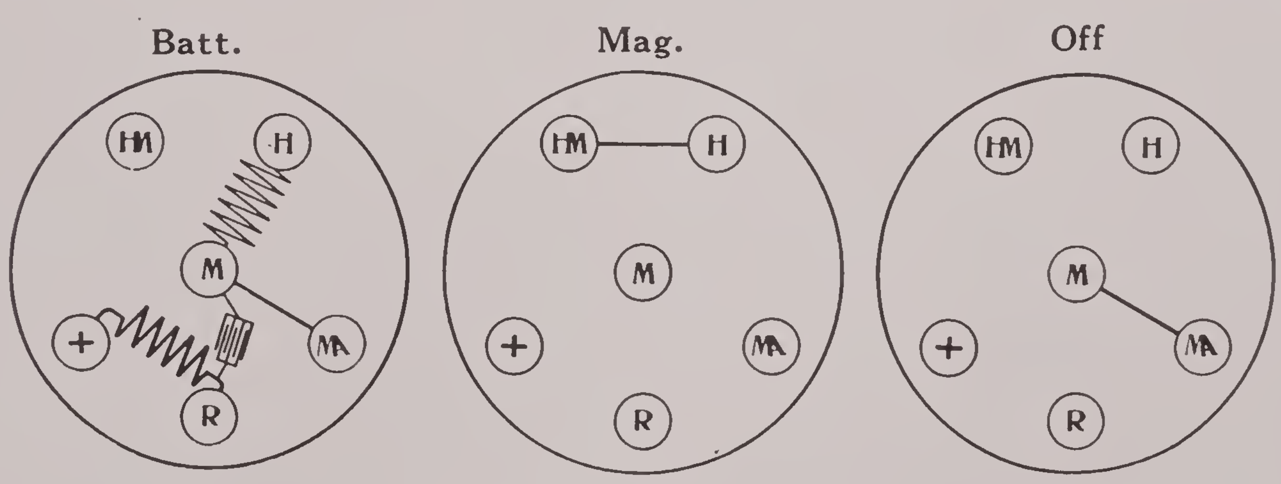


FIG. 263

FORD MAGNETO

The Ford magneto is quite unlike other types. Instead of using two or three horseshoe magnets, the Ford magneto has sixteen magnets arranged in a radial manner with their poles pointing outward and all bolted to the front of the flywheel of the engine. Like poles

to the wheel are bronze. The screws which extend through the flywheel are riveted on the back side. The non-magnetic bolts and supports are provided to prevent the magnetic lines of force from flowing from one pole through the flywheel to the other pole. The shape of the flywheel permits the loop of the magnets to be bolted directly to it. The bolts which pass through the loop of the magnets are prevented from working loose by a small wire which is passed through the hole in the head of each bolt.

Mounted directly in front of the magnets is the armature which is bolted to the crankcase. The armature frame is of cast iron and carries 16 coils about its circumference, so spaced as to correspond with poles of the magnets.

Fig. 268 illustrates the arrangement of the coils, and the manner in which they are connected together. One end of the armature winding is grounded to the frame as shown at (F), the other end is carried on a small fibre block (D) to the top of the armature.

The magneto terminal post is mounted on the upper half of the flywheel housing, and is so mounted that when the flywheel housing is in place, the lower end of terminal post rests on

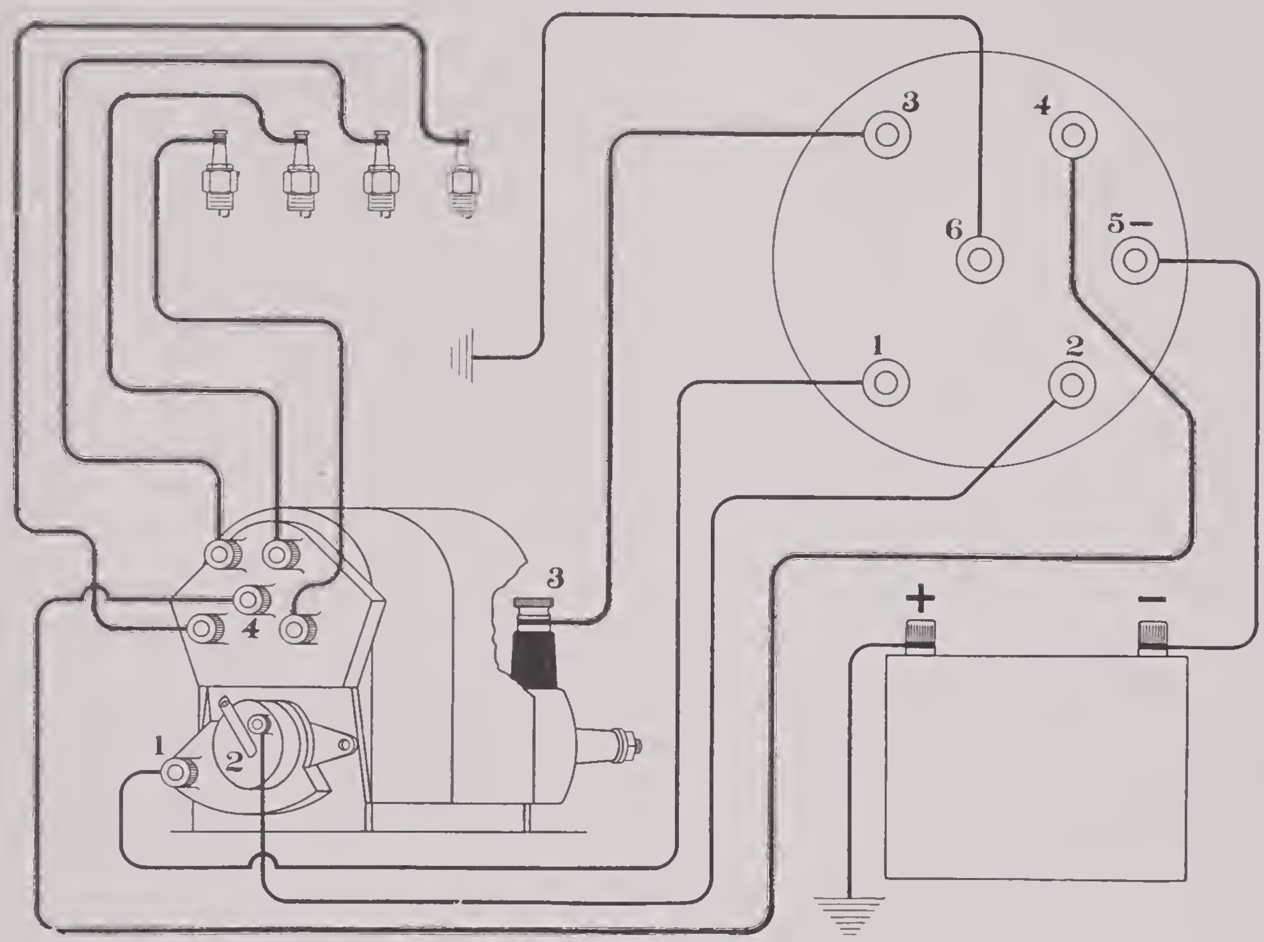


FIG. 264

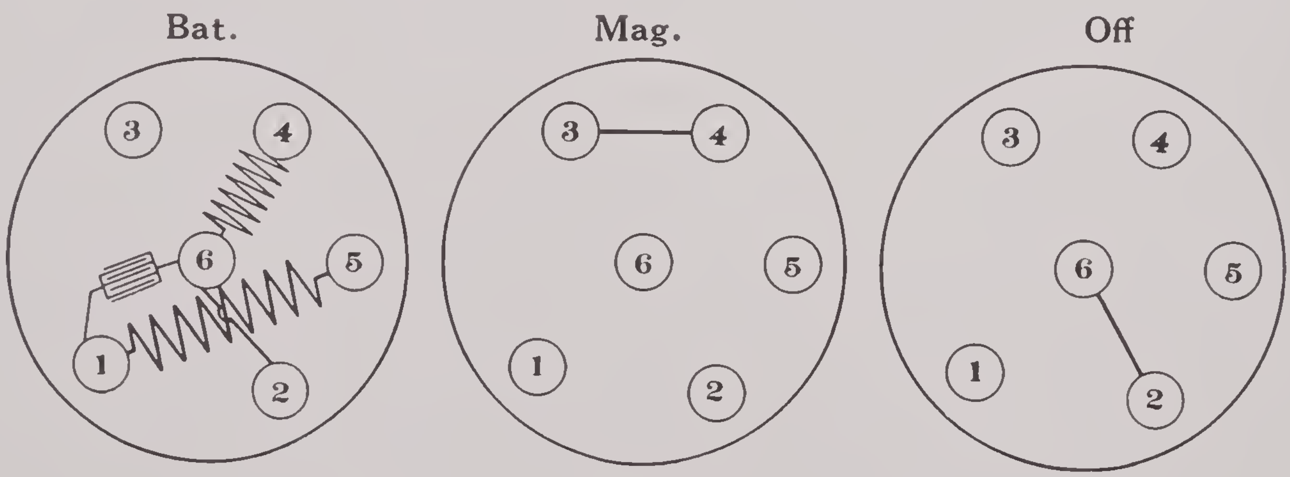


FIG. 265

By means of metal shims between the armature and the crankcase, adjustment is made on the armature so that the coil cores are just 1/32″ in front of the poles of the magnets. The armature coils are wound of copper ribbon. Eight of these coils are wound in one direction, and the other eight in the opposite direction.

the end of the winding that is carried on the fibre block at the top of the armature frame. This post is the only terminal on the magneto, the other end of armature being grounded.

As the magnets revolve with the flywheel, the magnetic lines of force are cut by the sides of the coils and an E. M. F. is induced in them.

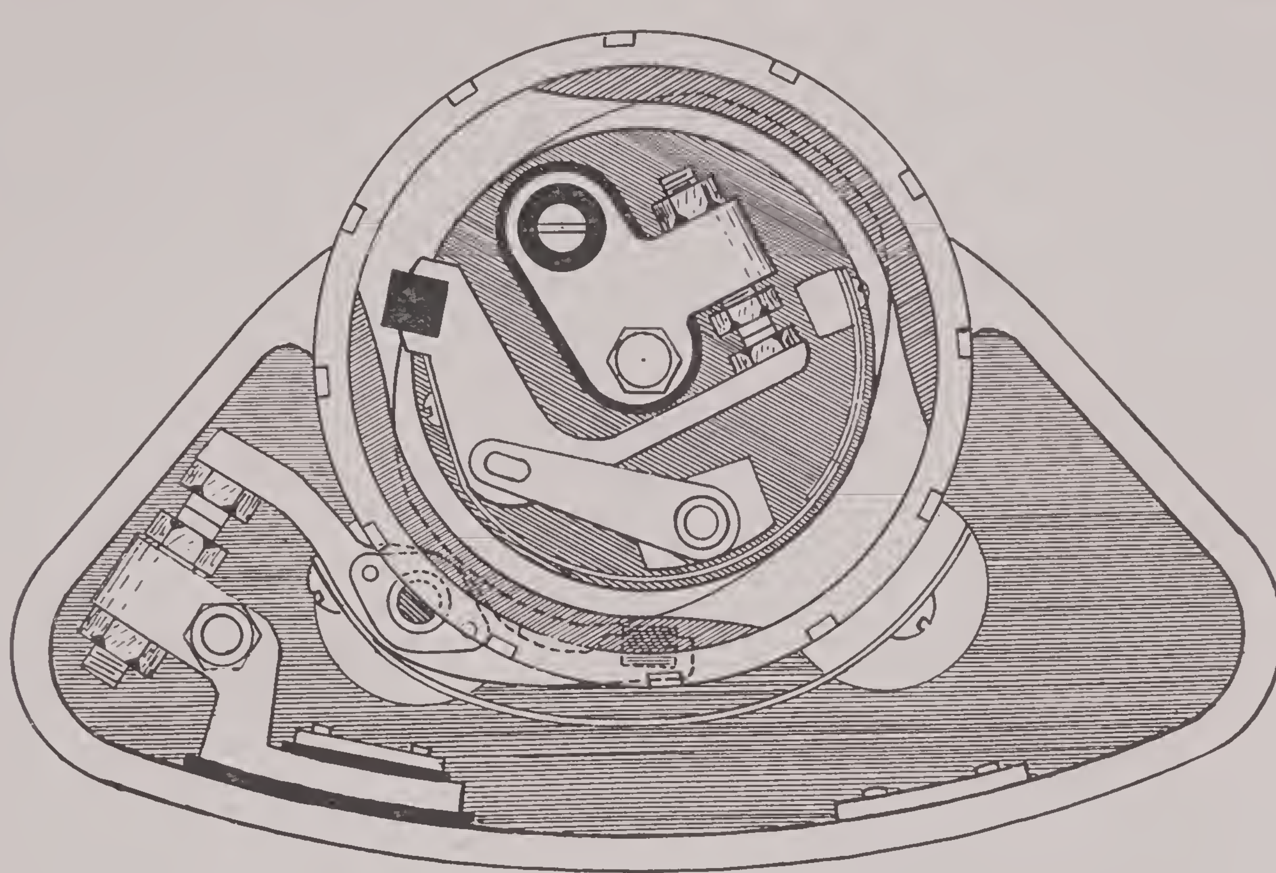


FIG. 266

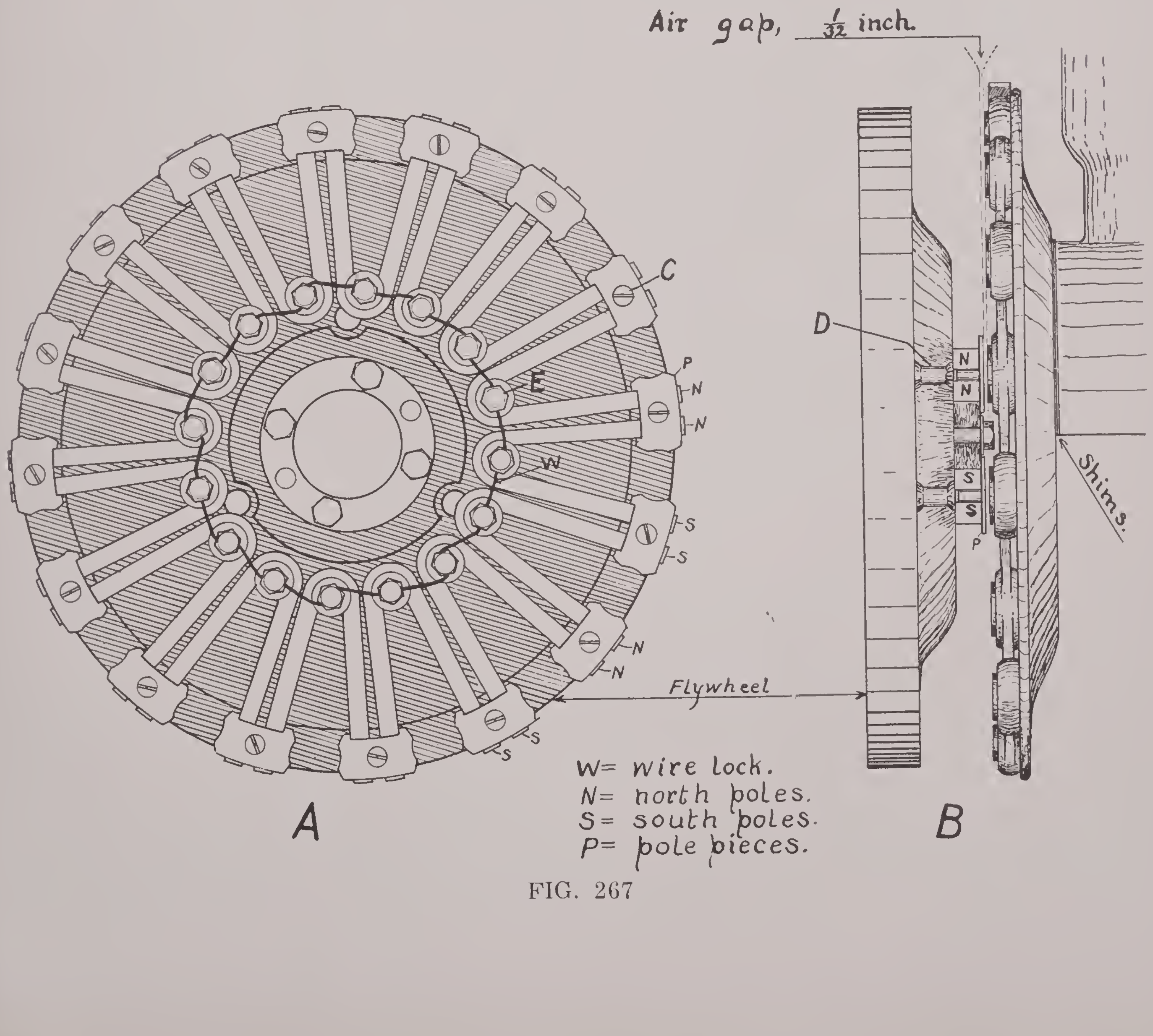


FIG. 267

The E. M. F. is induced in the coils while the poles of the magnets are moving from one coil core to the next, but when the poles are just passing the coil cores, the E. M. F. in the coils drops to zero, then starts to build up in the opposite direction, since the lines of force change from cutting one side of the coils to cutting the opposite side. This causes the E. M. F. to reverse 16 times during a revolution of the flywheel, and the current which flows as a result of this E. M. F. is an alternating current. The magneto is a low tension magneto.

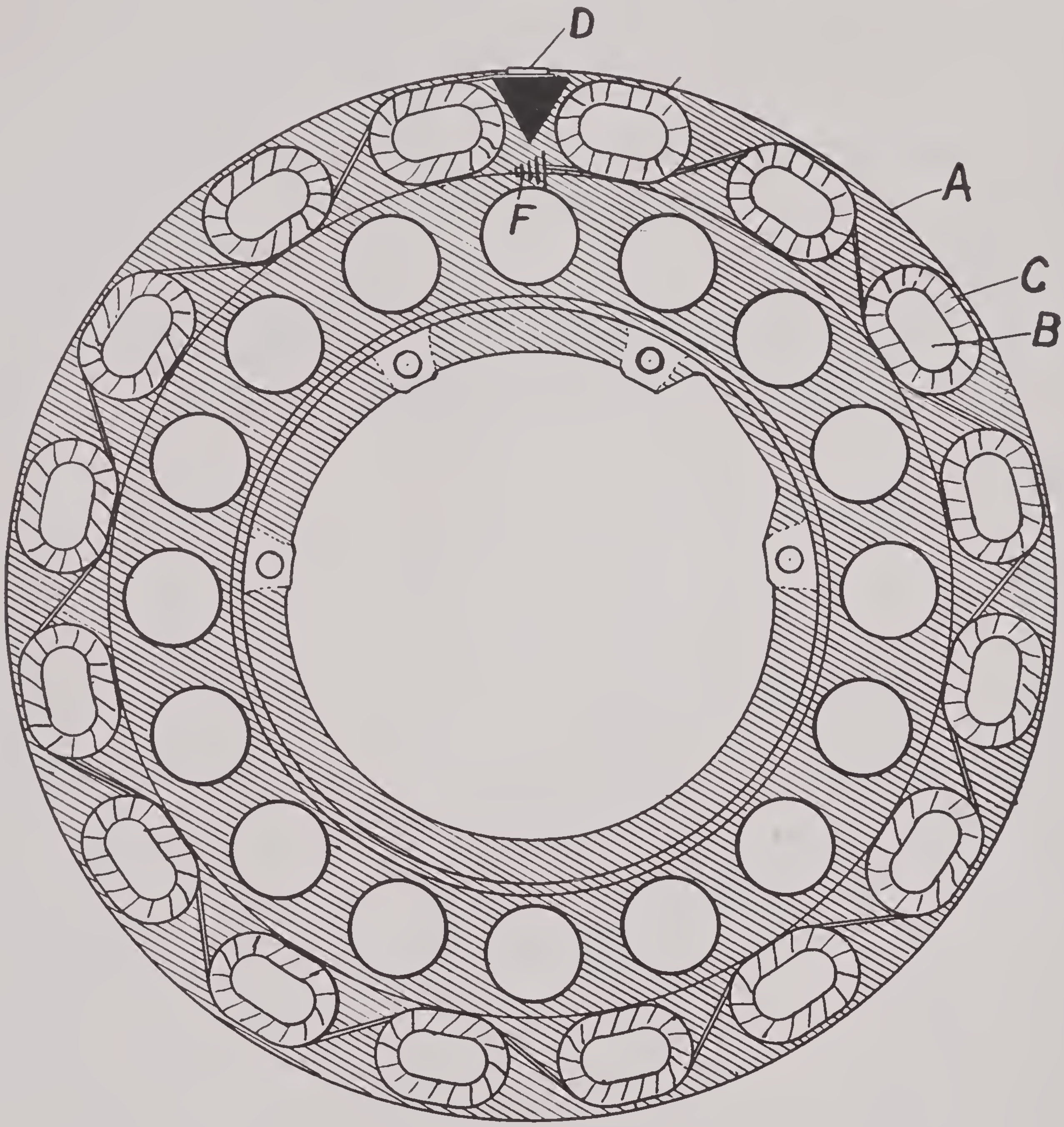


FIG. 268

A. Frame.
B. Coil core.
C. Coil.
D. Armature terminal.
F. Armature ground.

FORD IGNITION SYSTEM

The complete Ford ignition system is shown by wiring diagram in Fig. 271. Instead of using a single coil and a distributor, a coil for each cylinder is used. The conventional type breaker is not used since, if it is timed to magneto, the spark could not be advanced or retarded. Instead, each coil is provided with a vibrator to interrupt the current in primary, and a device called a timer or commutator is used to switch each of the coils into circuit with battery or magneto at the proper time.

Fig. 269 shows diagrammatically the construction of the Ford coil. The core (J) of the coil is a bundle of soft iron wires. The primary (C) is wound in two layers over the core. One end of the primary connects to metal contact (B) on the bottom of the wooden coil box. The other end of primary connects through the vibrator to the upper contact (G) on the side of coil box. The secondary connects to the two contacts (G) and (M) on the side of coil box. The condenser is separated from the coil by a glass plate. It is connected in parallel to the vibrator contacts.

The vibrator spring is a flat steel spring secured at one end to support (D). The other end, which is suspended over the end of core, carries a tungsten contact which is held against the other tungsten contact at (E). As the core is magnetized it attracts the vibrator spring, drawing the contacts apart, thereby breaking the primary circuit. When the core is demagnetized the spring again closes the contacts.

There are two adjustments on the vibrator. The adjustment at lock-nut (L) is for the distance the vibrator contacts separate. This adjustment should be made so that the vibrator contacts are .030″ apart when the vibrator spring is held down against the core. The other adjustment, made with the small screw (P), is for the tension of the vibrator spring. The tension of the spring should be so adjusted that the coil draws about 1½ amperes.

Fig. 273 shows a test arrangement for testing a Ford coil to determine if the vibrator spring has the proper tension. If the coil draws more than 1½ amperes the tension of spring is too strong. The tension of spring can be relieved by turning back on small screw (P) so as to slightly separate the ends of the horseshoe shaped support for the vibrator spring. If the coil draws less than 1½ amperes the spring is too weak. Adjustment can be made by turning down on the small screw permitting the ends of the horseshoe shaped support to spring together and so throw the vibrator contacts together with more force. If the support will not spring together enough to give the proper amount of tension to the vibrator spring, the support should be bent together. To obtain access to this small adjusting screw (P), it is necessary to remove the small screw directly above it with which the spring is secured to the support.

On some of the new coils this type support is not used for the vibrator spring. Instead of making adjustment here by the small adjusting screw it is necessary to bend the support

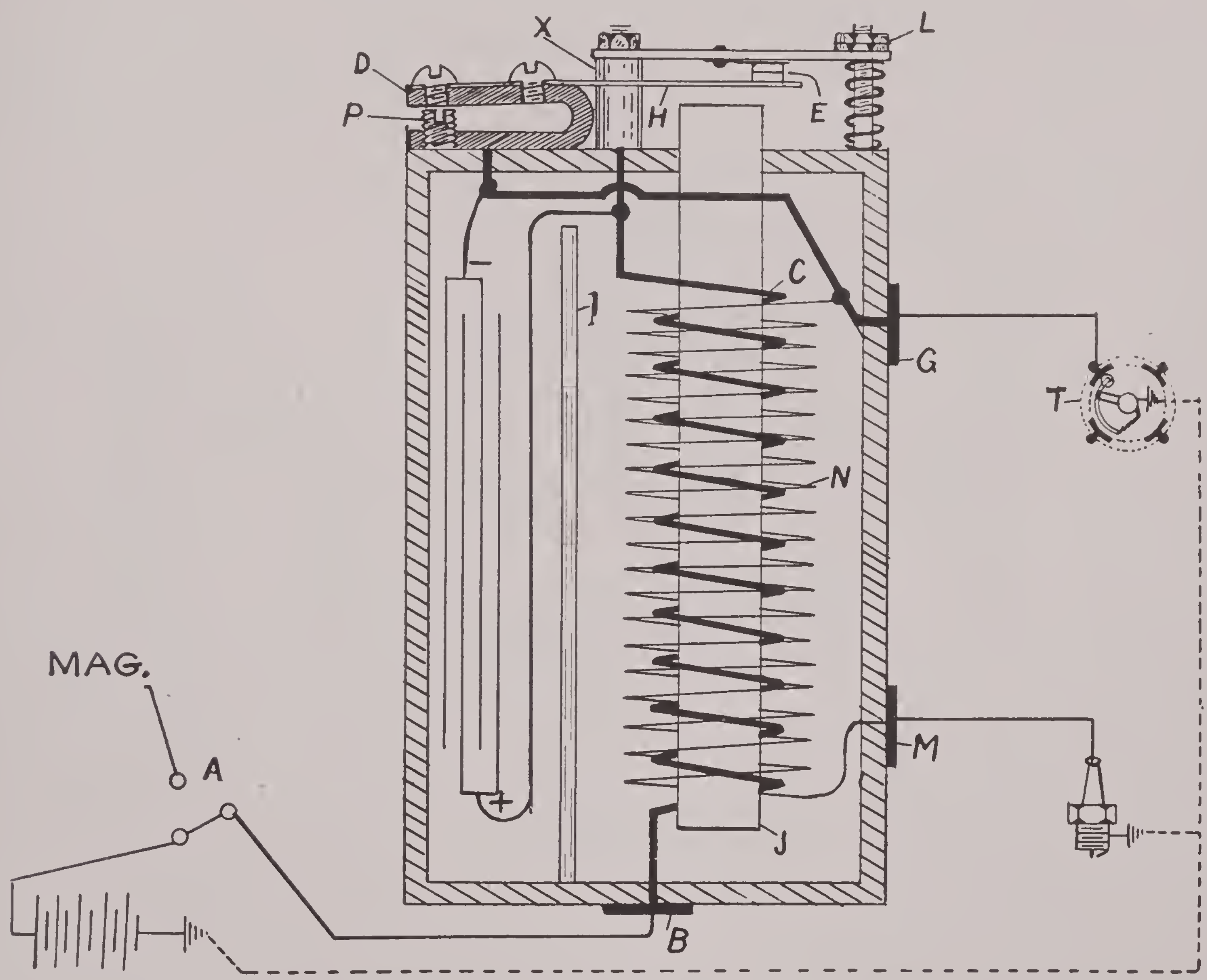


FIG. 269

slightly to increase or decrease the tension of the spring.

The fundamental construction of the timer is shown in Fig. 271. There are four steel segments equally spaced around the inside of the timer housing and well insulated from the metal shell. Terminals are provided for connection to each of these segments. A small steel roller which is carried on an arm that is pinned on the front end of the camshaft, revolves within the timer housing. In some of the timers a brush is used instead of a roller. This brush, or roller, grounds through the camshaft. The timer housing fits on over the end of the camshaft, just in front of the gear housing, and is held in position by a metal clip. The mounting of the housing permits it to be swung around camshaft either in the direction in which the roller revolves, or in the direction opposite to that in which the roller revolves.

A small lever is riveted to the metal shell of the timer which connects with small rods to the spark lever on steering column. By moving the spark lever down the timer housing is swung around the shaft in the direction opposite to that in which the roller revolves. This advances the spark. Moving the spark lever up moves the timer housing around the shaft in the direction in which the roller revolves. This retards the spark.

The four spark coils are assembled in a coil box which carries the terminals. Within the coil box are small brass springs, so spaced that the springs press against the contact terminals on the coils when the coils are assembled in the box. The springs connect to the terminals on coil box. The upper row of four terminals on coil box connect to timer segments. The lower row of four terminals connect directly to the spark plugs. The lower right hand terminal, looking from front of car, connects to the magneto. The lower left hand terminal connects to a battery whenever a battery is used as an auxilliary source of E. M. F. for ignition.

Operation of Ford Ignition System

When the switch is thrown to "MAG" position, magneto, coils, and timer are thrown in series. When the timer roller rolls on a timer segment, a circuit is completed from the magneto terminal through one of the coils and the timer to the ground, and through the ground back to the magneto armature. The E. M. F. generated in the armature of the magneto causes current to flow through the circuit. The vibrator on coil interrupts the current through the primary as soon as it magnetizes the core, and so causes the lines of force to collapse across the secondary, inducing in the secondary the strong E. M. F. that drives the current across the gap in the plug to produce the spark. Since the current through the primary is interrupted by a vibra-

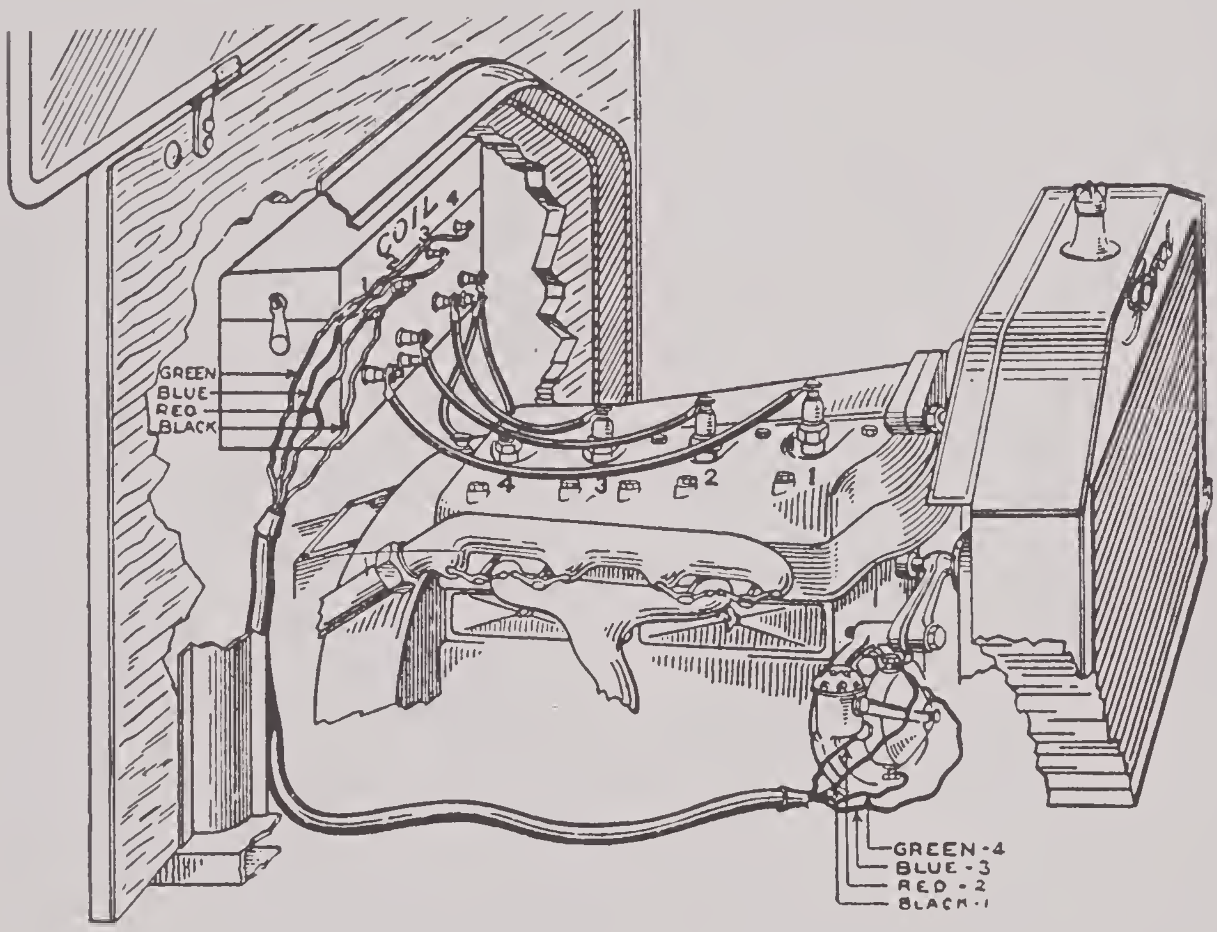


FIG. 270

tor, a shower of sparks is produced at the plug connected to the coil in operation, so long as timer roller is on the segment. As soon as roller rolls off the segment, the coil is switched out of the circuit. When the roller rolls on another segment, another of the coils is switched in circuit with magneto and so is thrown into action. The timer controls the time of operation of the coils.

The Ford engine is a four cylinder engine, and of the four stroke cycle type therefore a cylinder fires every half revolution of the crankshaft. Since the camshaft is driven at half crankshaft speed, the timer roller makes one-fourth of a revolution while the crankshaft makes a half revolution. Every one-fourth revolution of the roller, the timer switches the current through another coil causing another cylinder to fire. Connection is made from the timer segments to the four upper terminals of coil box, so that the coils are switched into operation in the following orders: 1-2-4-3, this being the firing order of the Ford engine.

Fig. 270 shows the correct relationship of the different parts of the standard Ford ignition system.

Fig. 329 shows the relationship of the circuits of the standard Ford ignition system to the circuits of the starting and lighting system on the later models of Ford cars.

IGNITION TIMING

Turn the engine forward till the piston in No. 1 cylinder moves up to top dead center at the end of compression stroke. Place breaker mechanism in full retard. Loosen the breaker cam by drawing drive gears out of mesh—or, if possible, loosen cam on shaft — and turn it in the direction it is driven until the distributor brush will be under No. 1 segment in distributor head when breaker points are just beginning to separate. Mesh the drive gears with the cam in this position or lock the cam on the shaft in this position. Replace distrib-

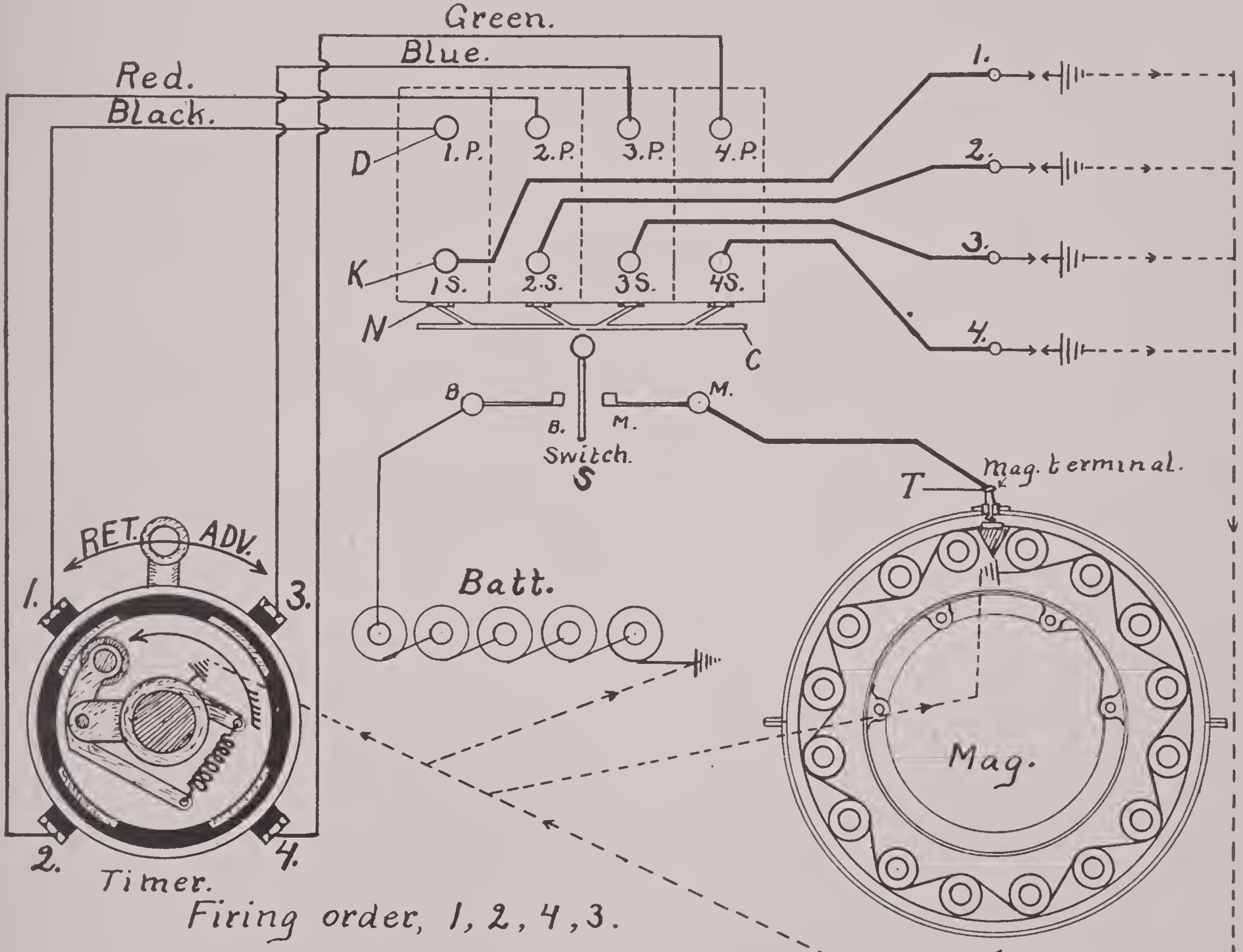


FIG. 271

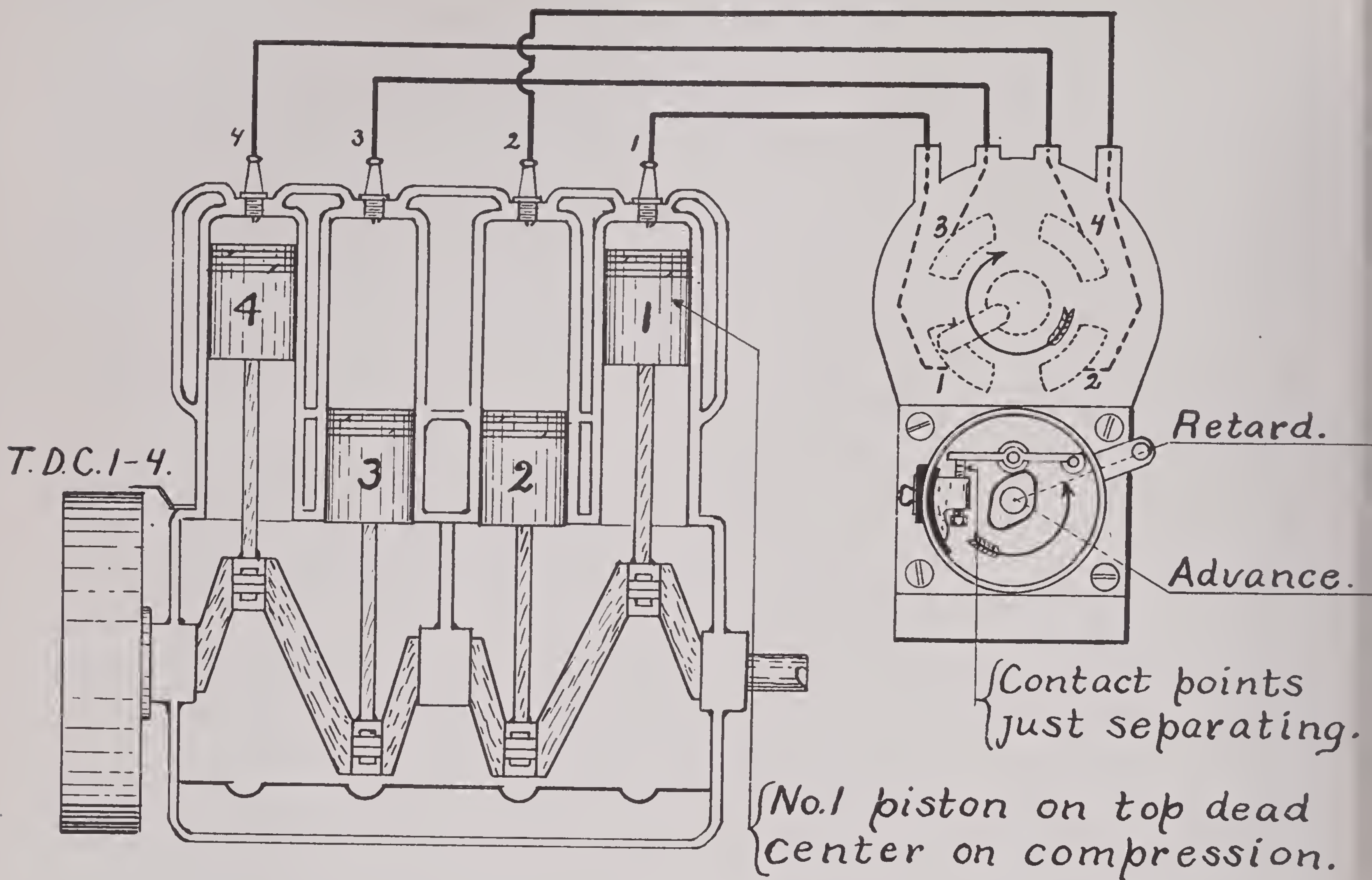


FIG. 272

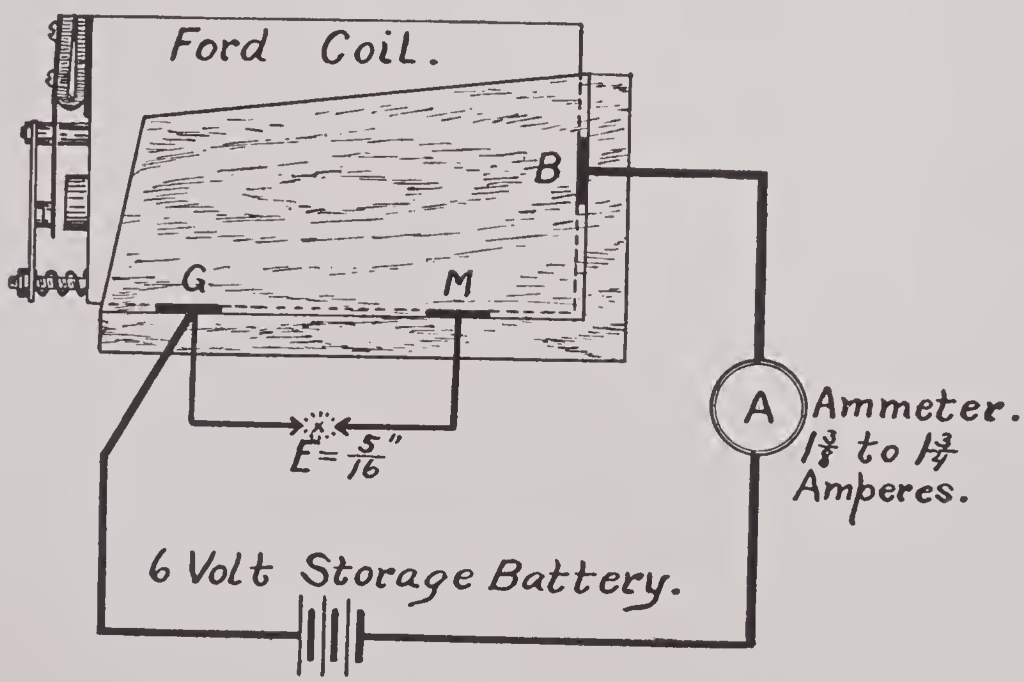


FIG. 273

utor brush and distributor head. Wire the segment under which the brush rests to the plug in No. 1 cylinder. Wire the other distributor segments to the plugs in the other cylinders according to the firing order of the engine and the direction the distributor brush revolves.

Timing With Magneto Ignition

Turn the engine forward till the piston in No. 1 cylinder comes up to top dead center at the end of the compression stroke. Place the breaker mechanism of the magneto in full retard position by turning the breaker housing as far as it will go in the direction the armature turns. Turn the magneto slowly in the direction it is driven until the distributor brush comes under No. 1 segment of the distributor head and the breaker points are just beginning to separate. Couple the magneto to the engine with armature in this position and then secure the magneto to its supporting bracket. Wire the segment under which the distributor brush rests to the plug in No. 1 cylinder. Wire the other segments to the plugs in the other cylinders according to the firing order of the engine, and the direction the distributor brush revolves. Fig. 272 illustrates the method of timing the magneto and the method of wiring the distributor to an engine having a firing order of 1-3-4-2.

The timing of Ford ignition is very simple so long as the wires to the timer segments are connected in the proper order. So long as the valves are in proper time the ignition is likely to be in time, since the timer roller is carried on the camshaft. There are only two positions in which the timer roller can be fastened on the camshaft. The proper position can be determined in the following manner: Turn the engine until the piston of No. 1 cylinder comes up to top dead center at the end of compression stroke. Pin the timer arm on camshaft so the roller is on upper left hand segment of timer when observed from front of engine. If the ignition spark is too early as indicated by inability to retard the spark far enough to prevent the spark knock when engine is pulling at low speeds, the small rod which connects to the lever on timer housing should be lengthened. If the ignition spark is late this rod should be shortened. With the spark lever in full retard the timer roller should not roll on timer segment until piston comes up to top dead center.

SUMMARY

MAGNETISM

Magnetism is that property occasionally possessed by some materials (more especially iron and steel) whereby they naturally attract or repel one another according to determinate laws.

Lodestone is a peculiar iron ore which possesses the property of magnetism. A piece of lodestone is a natural magnet.

Poles

The poles of a magnet are the portions from which the lines of force seem to radiate. A magnet has at least one north and one south pole, and may have more than two, but there will always be an equal number of north and south poles.

The north pole of a magnet is the pole that points in the direction of the north pole of the earth, and the south pole is the pole of the magnet that points to the south when the magnet is suspended so that it is free to turn.

Magnetic Substances

The common magnetic substances are iron and steel, although nickel and cobalt are magnetic to a slight extent.

Bismuth is diamagnetic; that is, it is repelled by either pole of a magnet.

Non-Magnetic Substances

Non-magnetic substances are substances which are not capable of being magnetized. Some of the common metals which are non-magnetic are: Copper, brass, bronze, aluminum, gold, silver, lead, tin, zinc, etc. Such materials as wood, glass, paper, rubber, porcelain, etc., are also non-magnetic.

Magnetism will pass through all known substances; that is, it cannot be insulated.

Law of Attraction and Repulsion

Like poles repel one another. Unlike poles attract one another. Either pole of a magnet attracts magnetic materials which are not magnetized with equal force. Magnetic attraction is inversely proportional to the square of the distance (D^2) which separates the magnet from the material attracted.

Residual Magnetism

Residual magnetism is the magnetism retained by a substance after the magnetizing force is withdrawn.

ELECTRICITY

Three common ways of generating electrical charges are: By friction, chemical action and induction.

Conductors

A conductor is any material that will conduct an electric current.

Insulators

Any material that offers extremely high resistance to the flow of current is called an insulator. Examples: Porcelain, glass, rubber, mica, bakelite, silk, varnish, oil, paraffin, etc.

Positive and Negative Charges

Positive and negative are relative terms and pertain to the difference in electrical pressures. The charge of higher pressure is called the positive charge and the charge of lower pressure is called the negative charge.

Electromotive Force (E. M. F.)

Electromotive force is the force that causes electricity to flow through a circuit. It is sometimes referred to as the "push" in the circuit. The terms voltage, pressure, electromotive force and potential are synonymous. The unit of electrical pressure is called the volt.

Electric Circuit

A continuous path for an electric current is termed an electric circuit. A circuit may be made up of a number of parts—conductors of various materials and various appliances.

Electric Current

An electric current is electricity in motion. Current strength is the rate or intensity of flow and is analogous to the flow of water in a pipe. The unit of current strength or rate of flow is the ampere. A current will flow only when there is a complete circuit and a difference in electrical pressure at two points in the circuit.

Resistance

Resistance is the opposition offered by a material to the flow of electricity through it.

Electrical Units

Volt—Unit of electrical pressure.
Ampere—Unit of current strength.
Ohm—Unit of resistance.
Watt—Unit of power.
Kilowatt—One thousand watts.
Watt Hour—One watt acting for one hour.
Kilowatt Hour—One thousand watt hours.
Ampere Hour—One ampere flowing for one hour.
Farad—Unit of capacity.
Micro-farad—One-millionth of a farad.

Ohm's Law

The current which flows in a circuit is directly proportional to the electrical pressure (E. M. F.) and inversely proportional to the resistance.

The formulas for the relationship of pressure, current and resistance in an electric circuit are as follows:

$$I=\frac{E}{R} \qquad R=\frac{E}{I} \qquad E=IR.$$

Voltage divided by resistance equals current.
Voltage divided by current equals resistance.
Current multiplied by resistance equals voltage.

Series Circuit

Appliances or conductors so connected that they form one continuous path are connected in series. The resistance of a series circuit is equal to the sum of the separate resistances which make up the circuit.

The current in one part of a series circuit is equal to the current in any other part of it.

The pressure which acts upon any part of a series circuit is directly proportional to the resistance of that part of the circuit. That is, the pressure which acts upon any part of a series circuit is in the same proportion to the total pressure acting, that the resistance of that part of the circuit is to the total resistance of the circuit.

Parallel Circuit

When two or more circuits are so connected that they form separate paths for the current to take, they are said to be in parallel. Any one of the several paths in parallel may be called a "shunt" of the others. The same voltage that acts upon one of several circuits in parallel acts upon each of the others.

The current in any one of several circuits in parallel is equal to the pressure acting upon the circuits divided by its resistance. The total current strength in the circuit is equal to the sum of the current strengths in the parallel paths.

The joint resistance of parallel circuits is equal to the pressure acting upon the circuits divided by the total current in them. Also, the joint resistance of parallel circuits is equal to the reciprocal of the sum of the reciprocals of the resistance of the circuits. (The reciprocal of a number is equal to one divided by the number. The reciprocal of a fraction is equal to the fraction inverted).

The joint resistance of parallel circuits which have equal resistances is equal to the resistance of one of the circuits, divided by the number of circuits. That is,

$$\text{Joint Resistance} = \frac{R}{N}$$

R equals the resistance of one circuit.
N equals the number of circuits.

Voltage Drop

Voltage drop is the loss in pressure due to overcoming the resistance of a conductor. The amount of voltage lost in a circuit is equal to the current flowing through it multiplied by the resistance of the circuit; that is, $E = IR$.

Power

Electrical power is measured in watts. A watt is equal to one ampere flowing under a pressure of one volt. The number of watts expended in a circuit equals the pressure in volts acting on the circuit, multiplied by the number of amperes of current flowing through it. Seven hundred and forty-six watts are equivalent to a mechanical horse-power.

One kilowatt equals approximately one and one-third horse-power.

Resistance of Conductors

The resistance of a conductor depends upon:
(A) The length of the conductor;
(B) The cross-sectional area (size) of the conductor;
(C) The material of which it is made;
(D) The temperature of the conductor.

The resistance of a conductor is directly proportional to its length and inversely proportional to its cross-sectional area (size).

The resistance changes with a change in temperature. For nearly all metals, the resistance increases with an increase in temperature, and vice versa.

The resistance of copper changes .0022 of an ohm, for each ohm, with a change of temperature of one degree.

The resistance in ohms of a copper conductor may be calculated approximately by the following formula:

$$R = \frac{\text{Length (in feet)} \times 10.8}{\text{Circular Mils.}}$$

Dry Cells

The size of a standard dry cell is 2½″ x 6″. The pressure of a dry cell averages 1½ volts, when new. The amount of a current a standard dry cell will deliver, when short circuited, ranges from 15 to 30 amperes, or an average of approximately 20 amperes.

When dry cells are connected in series their total pressure is equal to the sum of their separate pressures. The total resistance of a series connection of dry cells is equal to the sum of the separate resistances of the cells.

The current that a series of cells will deliver is no greater than the current of a single cell, with the exception of the effect of the external resistance upon their output.

A parallel connection of dry cells produces no greater pressure than one cell. The ampere capacity of cells in parallel is equal to the sum of the capacities of the cells in parallel.

The ability of a parallel connection of cells to deliver current depends upon the number of cells so connected.

A combination of the series and parallel connections of cells is called a series-parallel connection.

A battery is any correct connection of two or more cells of any kind.

STORAGE BATTERY

A storage battery is an accumulator of energy. It does not store electric current, as is commonly believed, but accumulates chemical energy when an electric current is forced through it in the proper direction. The chemical energy stored in a storage battery is expended as it discharges.

The voltage of a fully charged storage cell averages about 2.2 volts. The voltage of a discharged cell ranges from 1.7 to 1.9 volts.

The ampere-hour capacity of a storage battery depends upon the number of the plates and the volume and strength of electrolyte.

An ampere-hour is equal to one ampere of current flowing for one hour of time.

The ampere-hour capacity of a cell is equal to the product of the amperes and the hours when discharged from fully charged condition at a rate of 5 amperes until the voltage of each cell falls to 1.8 volts.

There are usually two charging rates for a storage battery, "starting" and "finishing." The starting rate is about one-tenth of the ampere-hour capacity, and is used until specific gravity of electrolyte is 1.225 to 1.250, then reduced one-half, which is the finishing rate.

The specific gravity of the electrolyte of fully charged storage cells averages 1.285. The specific gravity of a discharged cell is approximately 1.150.

The specific gravity of the electrolyte is measured with an instrument called a "hydrometer."

The hydrometer reads correctly at 70 degrees F. For temperatures other than 70 degrees F., corrections must be made, to determine the correct specific gravity. For each three degrees change of temperature there is one point change in the hydrometer reading. For temperatures above 70 degrees F., the corrections should be added, and for temperatures below 70 degrees, the corrections should be subtracted.

The freezing point of a fully charged battery, of the lead plate type, is —90 to —100 degrees F.

The freezing point when discharged is about +10 degrees F.

The battery should not be allowed to stand in a discharged condition. Keep the plates and separators covered at all times with distilled water. Do not add acid or electrolyte to a cell.

ELECTROMAGNETISM

When an electric current flows through a conductor, a magnetic whirl is set up about it. This whirl is in a clockwise direction about the conductor, when the current is flowing away from the observer and counter-clockwise if the current is flowing toward observer.

A solenoid is a coil of wire without a core. A solenoid equipped with a core of magnetic material is called an electromagnet.

The polarity of an electromagnet or solenoid depends entirely upon the direction the current circulates through the conductor or around the core.

The polarity of an electromagnet can be determined as follows: Grasp the coil in the right hand, in such a manner that the fingers point in the direction in which the electric current flows; the thumb then points to the north pole of the electromagnet.

An ampere-turn is a turn of wire conducting one ampere of current. The ampere-turns of a coil are equal to the number of turns in the coil, multiplied by the number of amperes of current flowing in it. The strength of an electromagnet depends upon the number of ampere-turns and the size, shape and material of the core.

The number of ampere-turns a coil is capable of producing depends upon the size of the wire and the voltage under which the current is forced through it. To wind more or less turns of a given size of wire into a coil does not change the magnetizing power of the coil, but it varies the current because the resistance is varied and the current is inversely proportional to the resistance of the coil.

The heating effect is reduced by winding more turns into the coil, but its magnetizing power remains about constant. A coil of many turns is more economical than one of a few turns, but is much slower in its action.

ELECTROMAGNETIC INDUCTION

When a conductor is moved across a magnetic field so that it cuts across the lines of force, an electromotive force is induced in it.

The strength of the induced E. M. F. depends upon the rate at which the lines of force are cut. To produce one volt, a conductor must cut 100,000,000 lines of force per second.

An E. M. F. can be induced by moving either the conductor or magnetic field, or by moving both. The direction in which an induced E. M. F. acts depends upon the relative directions of the lines of force and the direction the conductor is moving.

Fleming's rule to determine the direction that an induced E. M. F. acts is as follows:

Place the thumb, first and second fingers of the right hand at right angles to each other. Place the hand in such a position that the first finger points in the direction the lines of force are flowing (N. to S.), the thumb pointing the direction that the conductor is moved, and the middle finger then points in the direction in which the induced E. M. F. acts.

Self-induction in a circuit is the induction which results from a variation in current in the same circuit. The self-induction in a coil is proportional to the square of the number of turns. The self-induced E. M. F. in the primary winding of the average ignition coil sometimes is as high as 200 volts.

Mutual induction is the induction in one circuit, caused by a variation of current in an adjacent circuit. The operation of an induction coil depends upon mutual induction.

BATTERY IGNITION

The necessary parts of a battery ignition system are: An induction coil, usually an ignition resistance unit, a breaker or interrupter, a condenser, a distributor (if for more than a single cylinder engine), spark plugs, a switch, a battery and the necessary wiring.

The Ignition Coil

The ignition coil consists of a soft iron core, with primary and secondary windings. The primary is a coil of about No. 18 B. & S. copper wire (insulated) wound over the core and usually consists of a few hundred turns. Over the primary winding, but well insulated from it, is the secondary winding, consisting of many thousand turns of very fine copper wire, silk or enamel insulated. The battery current flows in the primary. The current induced in the secondary flows through the spark plugs.

The Breaker (Interrupter)

The breaker is a device that closes and opens the primary circuit in time with the engine. The spark is produced at the opening of the breaker. The breaker is sometimes called a timer.

The Distributor

The distributor is employed where a single coil furnishes the ignition current for more than one cylinder. The distributor is really a rotating switch. The distributor switches the plugs in circuit with the secondary of the coil according to the firing order of the engine, hence properly distributes the secondary current to the different spark plugs.

The Condenser

The condenser has two functions in the ignition system, that of absorbing the self-induced current from the primary winding, thus protecting the breaker points from being rapidly burned away, and of effecting a more nearly complete demagnetization of the core of the coil. The three common troubles which may develop in connection with the condenser are: Shorted condenser, open condenser, and loss of capacity. The best way to determine when a condenser is functioning properly is to observe the arcing at the breaker points and the intensity of the spark at the spark plug.

The Ignition Resistance Unit

The ignition resistance unit is connected in series with the primary circuit. It consists, in most cases, of a small coil of iron wire. Its resistance is low when cold, but increases rapidly as its temperature rises. It protects the primary winding from being overheated at low engine speed or when the ignition switch is closed and the engine not in operation. If the design of any electrical system calls for the use of a resistance unit, it should never be operated without one.

The Polarity Ignition Switch

The polarity switch as used with the battery ignition system, is to reverse the primary current through the breaker each time the switch is closed. It causes the contacts to burn more evenly, as the metal that is carried from one point to the other during a period of operation will be carried back during the next period of operation.

Breaker Point Adjustment

The breaker points should be dressed with a file or oilstone so that they strike squarely together. The air gap between the breaker points of ignition systems range from .006″ to .030″, with an average of .012″ to .020″.

Spark Plugs

The air gap in spark plugs varies from .025″ to .030″ for average systems. On some of the magneto systems it is advised to make the gap much smaller to assist in starting. Keep the spark plugs clean and have the gaps of all the plugs of an engine equal.

MAGNETOS

A magneto is a device used to convert mechanical energy into electrical energy. The magnetic field of a magneto is furnished by permanent magnets. The armature of a magneto is the portion of the magneto in which the E. M. F. is induced. The armature may be of either the revolving or stationary type. Magnetos used for ignition purposes are usually equipped with a breaker mechanism and distributor, although the latter is not necessary when used on single cylinder engines.

Types of Magnetos

Magnetos are divided into three different types:

(A) The revolving armature type.
(B) The inductor type.
(C) The revolving field type (Ford).

Magneto Classifications

Magnetos are divided into five different classes, viz:

(A) Straight low tension, ("Make and break"), (not used on automobiles).
(B) Low tension dual.
(C) Straight high tension.
(D) High tension dual.
(E) High tension duplex, (single spark and vibrating spark).

The magnetos in the above classifications may be of either the revolving armature type or inductor type.

The magnetos in which the induced E. M. F. reaches the peak of the wave twice in one revolution are driven at the following speeds:

The armature of the magneto for four cylinder engines is driven at crankshaft speed.

The armature of the magneto for six cylinder engines is driven at one and one half crankshaft speed.

The armature of the magneto for eight cylinder engines is driven at twice crankshaft speed.

SPARK ADVANCE

Most ignition systems are designed in such a manner that the time of the spark in relation to piston position may be varied so as to occur earlier or later.

To cause the spark to occur earlier in relation to the position of the piston, is advancing the spark. To cause the spark to occur later in relation to piston travel, is retarding the spark. The necessity of advancing the spark is caused by the lapse of time between the production of the spark and the occurrence of the explosion. The lapse of time is practically constant, hence at high engine speed the spark must be produced before the piston reaches top dead center in order to have the explosion occur before the piston has moved down on the power stroke.

Automatic Spark Advance

The spark is automatically advanced on some systems by the use of a specially constructed mechanism, operating upon the principle of the centrifugal governor. As the speed of engine increases, the breaker cam is automatically moved ahead of the shaft that drives it.

Where both manual and automatic advance is used, the range of advance is equal to the sum of the number of degrees obtained by each of them when used separately.

IGNITION TIMING

Ignition timing is so setting the breaker mechanism that the ignition spark will occur, each time a piston of the engine moves up to the firing point.

The firing point of the average engine is a few degrees past top dead center at the end of the compression stroke, with a fully retarded spark. There are exceptions to this rule, as some engines are timed to fire in full retard at top dead center, while still others are timed to fire a few degrees before top dead center.

When timing ignition, No. 1 piston should be set at top dead center at the end of the compression stroke.

The breaker mechanism should be set in full retard and the breaker cam turned in its direction of rotation until the points are just separating. Lock the cam in this position. Wire the distributor terminal to which the distributor brush points, to No. 1 spark plug. Wire the remaining spark plugs to the other distributor terminals according to distributor brush rotation and the firing order of the engine.

QUESTIONS

1. What is lodestone?
2. Define magnetic materials; non-magnetic materials.
3. What materials are used when magnetic properties are necessary?
4. What are the poles of a magnet? Is one pole stronger than the other?
5. Can a magnet have two north poles and no south pole?
6. What is the north pole of a magnet?
7. Name five characteristics of magnetic lines of force.
8. Describe the magnetic compass needle. What causes the compass needle to point north?
9. What is the theoretical difference between a magnetized bar of iron or steel and an unmagnetized bar?
10. Define each of the following terms: (a) permeability, (b) retentivity, (c) reluctance, (d) residual magnetism.
11. What is a keeper? How can magnets be assembled so one magnet is a keeper for the other?
12. How should a compound magnet be assembled? If unlike poles are placed together what is the result?
13. Give three ways of producing an electric charge.
14. Define conductor; insulator.
15. Explain what is meant by the terms "positive charge" and "negative charge."
16. Define E. M. F.
17. What is meant by the term, "electric circuit."
18. What is an electric current? What is necessary to produce an electric current?
19. Upon what does the strength of an electric current depend?
20. Define volt, ampere and ohm.
21. What is Ohm's Law?
22. Describe a series connection of electrical appliances.
23. What is voltage drop?
24. Describe a parallel connection of appliances. To what is the joint resistance of appliances in parallel equal?
25. What is a watt?
26. Define the term "resistance."
27. Upon what does the resistance of a conductor depend?
28. What is a circular mil foot?
29. What are the parts of a simple cell?
30. When is a cell said to be discharged?
31. What is the voltage of a standard dry cell? The short-circuit ampere capacity?
32. What is an electric battery?
33. For what reason are cells connected in series? What is the total ampere capacity of cells in series?
34. For what reason are cells connected in parallel? What is the total voltage of cells in parallel?
35. How is the total voltage of cells in series-parallel found? The total ampere capacity?
36. Does a storage battery store electricity?
37. Of what are the positive plates of a storage battery made? Of what are the negative plates made?
38. Define the term "electrolyte."
39. What are separators? What is their purpose in a storage cell?
40. What is a positive group? A negative group?
41. Define element.
42. Define specific gravity.
43. What is a hydrometer? In connection with storage batteries what use is made of a hydrometer?
44. When the temperature of electrolyte is above 70 F., is the temperature correction for the hydrometer added or subtracted?
45. How is the ampere-hour capacity of a storage battery determined?
46. Upon what does the voltage of a storage battery depend? The ampere-hour capacity?
47. Is anything taken from a storage cell when it discharges?
48. What causes storage cells to gas when charging?
49. Why is it necessary to add water to storage cells?
50. What is meant by the term corroded battery terminals? What should be done when the terminals become corroded?
51. Why should a battery be charged for a while after water has been added, before measuring the specific gravity of the electrolyte?
52. In winter why should a storage battery be charged for a period after the water has been added to the cells?
53. Draw a diagram to show how a storage battery may be charged from a 110 volt D. C. lighting circuit. Use a bank of lamps for a charging resistance.
54. Upon what does the strength of the magnetic field set up about an electric conductor depend?
55. Upon what does the direction of the

flow of the lines of force about the current depend?

56. What is a solenoid?

57. Upon what does the strength of the magnetic field set up by current in a solenoid depend?

58. Upon what do the ampere-turns of a coil depend?

59. How is an electromagnet made?

60. Upon what does the polarity of an electromagnet depend?

61. Upon what does the strength of an electromagnet depend?

62. When a conductor is moved across a magnetic field, upon what does the induced E. M. F. depend?

63. Upon what does the direction of the induced E. M. F. depend?

64. What is self-induction? How does self-induction affect a circuit?

65. Upon what does the self-induction of a circuit depend?

66. What is mutual induction?

67. What is an induction coil?

68. What are the necessary parts of an induction coil?

69. Why is the core of an induction coil made of soft iron wires instead of solid steel?

70. Upon what three things does the strength of the induced E. M. F. in secondary depend?

71. Which winding, primary or secondary, is first wound over the core?

72. Which winding has the most turns?

73. Is a connection between the primary and the secondary necessary?

74. Does the battery current flow through the secondary?

75. When the circuit through the primary of the coil is closed, is there an E. M. F. induced in the primary winding? In the secondary?

76. Is there an E. M. F. induced in the primary when the primary circuit is broken?

77. What is the purpose of a condenser in the ignition system?

78. Upon what three things does the capacity of a condenser depend?

79. In what relation to the breaker is the condenser connected?

80. How is a condenser made?

81. What is shorted condenser? Open condenser? Punctured condenser?

82. Explain how a condenser can be tested.

83. Does the condenser discharge through the breaker points when they close, through the primary or through the secondary?

84. How can the secondary winding of the coil be tested?

85. What is an ignition resistance unit? What is its purpose?

86. Explain the difference between open circuit type breakers and closed circuit type breakers.

87. What is a distributor?

88. What is a polarity ignition switch?

89. Why is it necessary to advance and retard the spark?

90. What is an automatic spark advance and retard? Under what conditions is a manual control of the spark better than the automatic control?

91. Define the terms "breaker" and "interrupter."

92. What is the difference in construction between primary cable and secondary cable?

93. What is the purpose of the induction coil in the ignition system?

94. What is a spark plug? What is the difference between an inseparable plug and the separable plugs?

95. What is the difference between the taper threaded plug and the plug having the S. A. E. standard base?

96. What is a magneto?

97. Why is the base of a magneto made of bronze or aluminum?

98. What is the armature of a magneto?

99. When the breaker points are in full advance what should the approximate position of the distributor brush be?

100. What is clockwise magneto? Counter clockwise or anti-clockwise magneto?

101. How can a clockwise magneto be distinguished from a counter clockwise magneto?

102. What is used to recharge magnets?

103. What must one be careful about when recharging magnets?

104. How should magnets be placed on a magneto?

105. Does a magneto produce alternating or direct current?

106. Explain what is meant by internal timing?

107. Explain how to check up the internal timing of a magneto.

108. Is an induction coil necessary with a low tension magneto?

109. Describe the low tension dual magneto ignition system.

110. Describe the high tension magneto. How does it differ from the low tension magneto? How can one be distinguished from the other?

111. How many windings are there on the armature core of a high tension magneto?

112. Are the primary and secondary windings connected together?

113. One end of the primary winding of a straight high tension magneto is grounded; to what is the other connected?

114. Where is the condenser located and to

what is each of its terminals connected when used with the high tension magneto?

115. For what is the pencil used?

116. What is the collector brush?

117. How is the ignition cut off when using a high tension magneto?

118. What is the purpose of a safety gap?

119. Explain how the condenser of a high tension revolving armature type magneto can be tested.

120. Do all magnetos have pencils?

121. How can the engine be started if the pencil from the magneto had been lost?

122. What is the position of the armature core with relation to the pole pieces when the breaker points separate in full advance?

123. With the breaker points separated, should test buzzer sound when one test point is on one breaker point and the other test point on the other breaker point?

124. Why is it easier to start an engine with battery ignition than with a high tension magneto?

125. State the difference between the high tension dual magneto and the straight high tension magneto.

126. Do all high tension dual magnetos have a condenser in the magneto?

127. What causes sparking at the safety gap of a magneto?

128. In what way does a high tension duplex magneto differ from the high tension dual magneto?

129. How does the inductor type magneto differ from the revolving armature type?

130. How can an inductor type magneto be distinguished from a revolving armature type?

131. When the distributor brush of a six cylinder revolving armature type magneto has made one revolution, how many has the armature made?

132. Why cannot steel screws be used to secure the poles of the magnets to the flywheel on Ford magneto?

133. How are the coils of armature of a Ford magneto connected? If one volt is generated in each coil, how many volts in the entire armature?

134. What should the air gap between the pole pieces of the magnets be? How is their gap adjusted?

135. Explain how to test the armature for—(a) open coils, (b) shorted coils, (c) grounded coils.

136. Why are four induction coils necessary in the Ford ignition system?

137. How many adjustments on the Ford vibrator and how made?

138. What is the purpose of the vibrators?

139. What is the purpose of the timer?

140. How is the spark advanced and retarded?

141. Describe fully how to time the ignition of a four cylinder engine when a magneto is used.

142. Describe fully how to time the ignition of an engine having a battery ignition system.

GENERATORS AND MOTORS

A dynamo is a machine for converting mechanical energy into electrical energy, or electrical energy into mechanical energy. The dynamo, when used to transform mechanical energy into electrical energy, is called a generator; and when used to transform electrical energy into mechanical energy is called a motor. The dynamo consists fundamentally of two parts; namely, field—the frame, field poles, and field coils which form an electromagnet—and the armature which revolves between the field poles.

toward the observer. Since the E. M. F. induced in one side is in the opposite direction to that in the other side, they act jointly to produce a flow of electricity around the loop as indicated by the arrows. There is no induced E. M. F. in the ends of the loop, since they cut no lines of force.

The strength of the induced E. M. F. in either side of the loop at any instant, depends upon the number of magnetic lines of force cut by the conductor per second. The number of lines cut depends upon the length of the side

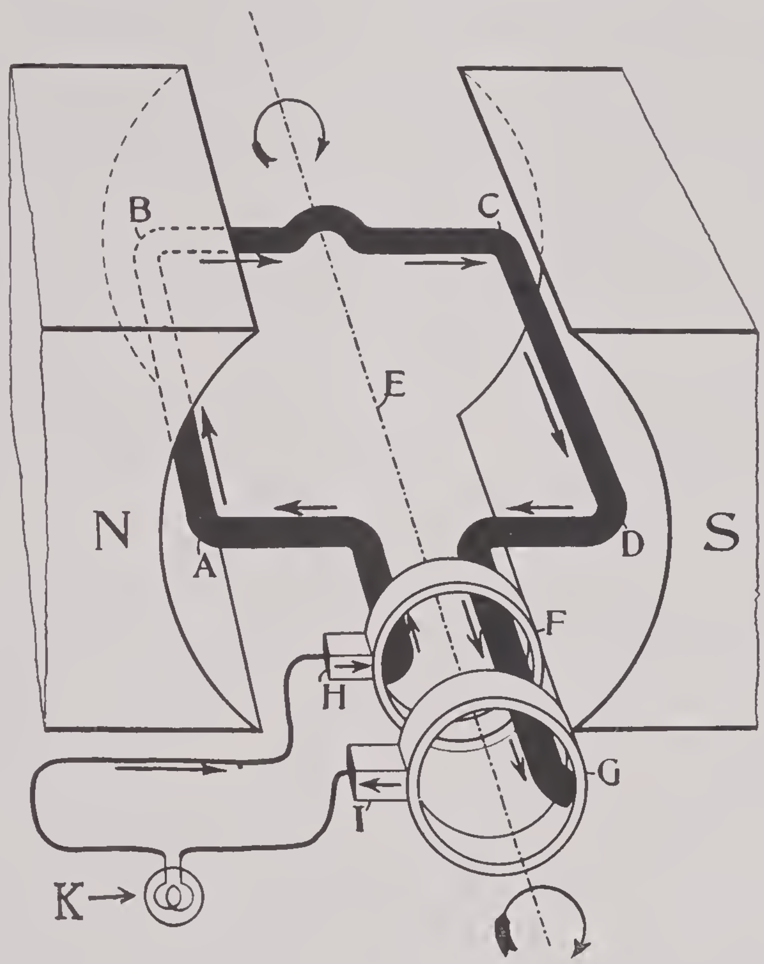


FIG. 274

The Simple Alternator. (Single Loop Armature)

If a single loop of wire is revolved in the magnetic field, as shown in Fig. 274, an E. M. F. will be induced in the sides of the loop. If the ends of the loop are connected to metal rings (F) and (G) upon which the brushes (H) and (I) ride, the induced E. M. F. will produce current in a circuit such as is formed when a lamp (K) is connected to the brushes. The direction of the induced E. M. F. in the sides of the loop may be determined by Fleming's Right Hand Rule.

The motion of one side of the loop with respect to the magnetic field is just the reverse of the motion of the other side. As a result of this difference in motion the E. M. F. induced in the side (AB) is from the observer, while the E. M. F. induced in the other side (CD) is

in the magnetic field, the strength of the magnetic field, and the number of revolutions per second. If the strength of the magnetic field is uniform—that is, the same in every part of the field—and remains constant in value and the loop revolves about its axis at constant speed, the induced E. M. F. in either side of the loop will change in value, due only to a change in direction of motion of the two sides with respect to the magnetic field. When the loop is in a horizontal position, as shown, the direction of the field also being horizontal, the two sides of the loop are moving in a path, for an instant, perpendicular to the direction of the magnetic field, and the rapidity with which the sides cut the lines of force is greatest, hence the induced E. M. F. of the loop is at a maximum.

The value of the induced E. M. F. for any other positions of the loop depends upon the angle at which the sides are moving with relation to the direction of the magnetic field. When the loop reaches a vertical position, the sides, for an instant, are moving parallel to the lines of force and so there is no E. M. F. induced in the loop. The direction of the induced E. M. F. reverses as the sides of the loop change places each half revolution, hence the current which flows in the circuit is an alternating current.

Simple Direct Current Generator

The E. M. F. induced in the loop of wire described in the previous section may be made to produce a direct current—one that flows in one direction—in the external circuit in following way: Replace the two continuous metallic rings with a single ring composed of two segments that are insulated from each other. (See Fig. 275.) If now the two brushes, which are insulated from each other, are so mounted that they rest upon the insulation between the segments when the induced E. M. F. in the loop is zero, the connection of the external circuit with respect to the loop will be reversed at the same instant the direction of the induced E. M. F. in the loop changes and then the induced E. M. F. in the loop always acts to send a current through the external circuit in one direction.

Such a machine as just described constitutes a direct current generator, because it forces electricity through the external circuit in one direction only. The two segment rings constitute a simple commutator, and its purpose, as pointed out, is to reverse the connection of the loop with respect to the external circuit as the induced E. M. F. in the loop changes. A single loop machine as just described can not be put to any satisfactory use and is of importance only in showing the principles of a generator.

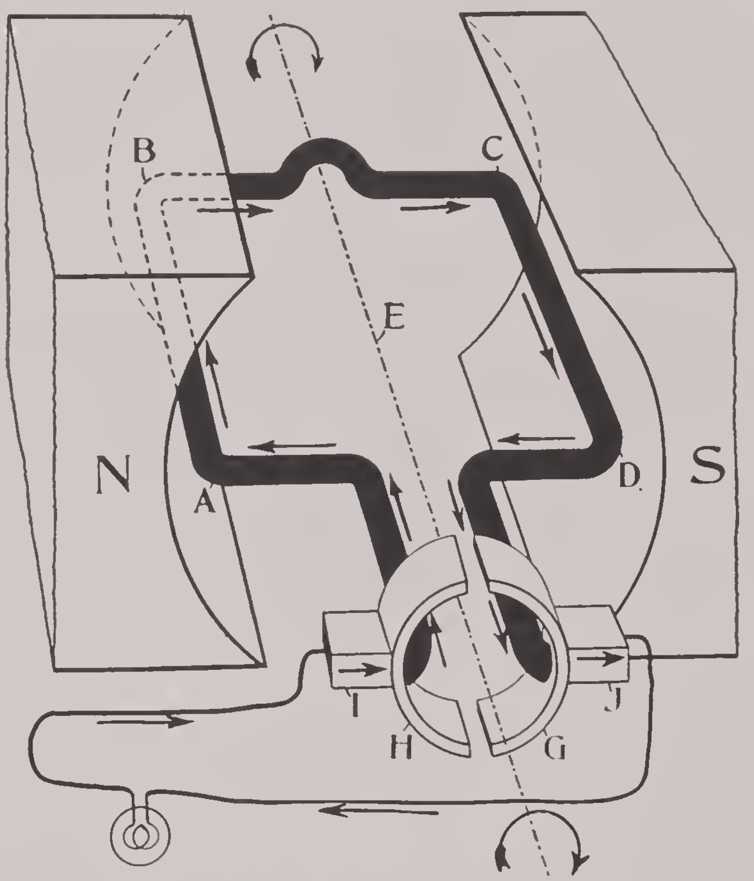


FIG. 275

Ring Wound Armature

A better form of armature winding for direct current dynamos is shown in Fig. 276. This armature is called a ring wound armature since the coils which revolve in the magnetic field are wound around an iron ring. The iron ring supports the coils, and forms a path of low reluctance for the lines of force from one pole to the other. Because of the low reluctance offered to the flow of the lines of force by the iron ring, it is possible to set up many more lines in the space in which the coils revolve than would be possible were the ring not provided. The path of the magnetic lines of force is out of the north pole through the air gap between the pole and the ring, into the ring, around the ring in both directions to the opposite side, through the air gap between the side of the ring and the south pole, into the south pole, and through the frame back to the north pole.

With the poles magnetized, a magnetic field is set up on both sides of the ring in the spaces between it and the poles. There is no field set up inside of the ring, since the lines of force follow around the ring from one side to the other as shown by the dotted lines in the illustration.

There are as many commutator segments as there are coils on the ring. One end of each coil connects to one commutator segment and the other end to an adjacent segment. All of the commutator segments are connected together through the armature coils, but as they are assembled to make up the commutator, each is carefully insulated from the other.

ture are equal and in opposite directions there is no flow of electricity through the armature until a connection is made from the top of the commutator through an external circuit to the bottom of the commutator.

Connection to the commutator is made by means of soft carbon blocks called brushes. These brushes are held in such position with relation to the poles that, when a coil is moving parallel to the lines of force, the brush rests on the commutator segments to which the coil connects. There are always some of the armature coils cutting magnetic lines of force as long as the ring is revolved in the field between the poles, and the connection between

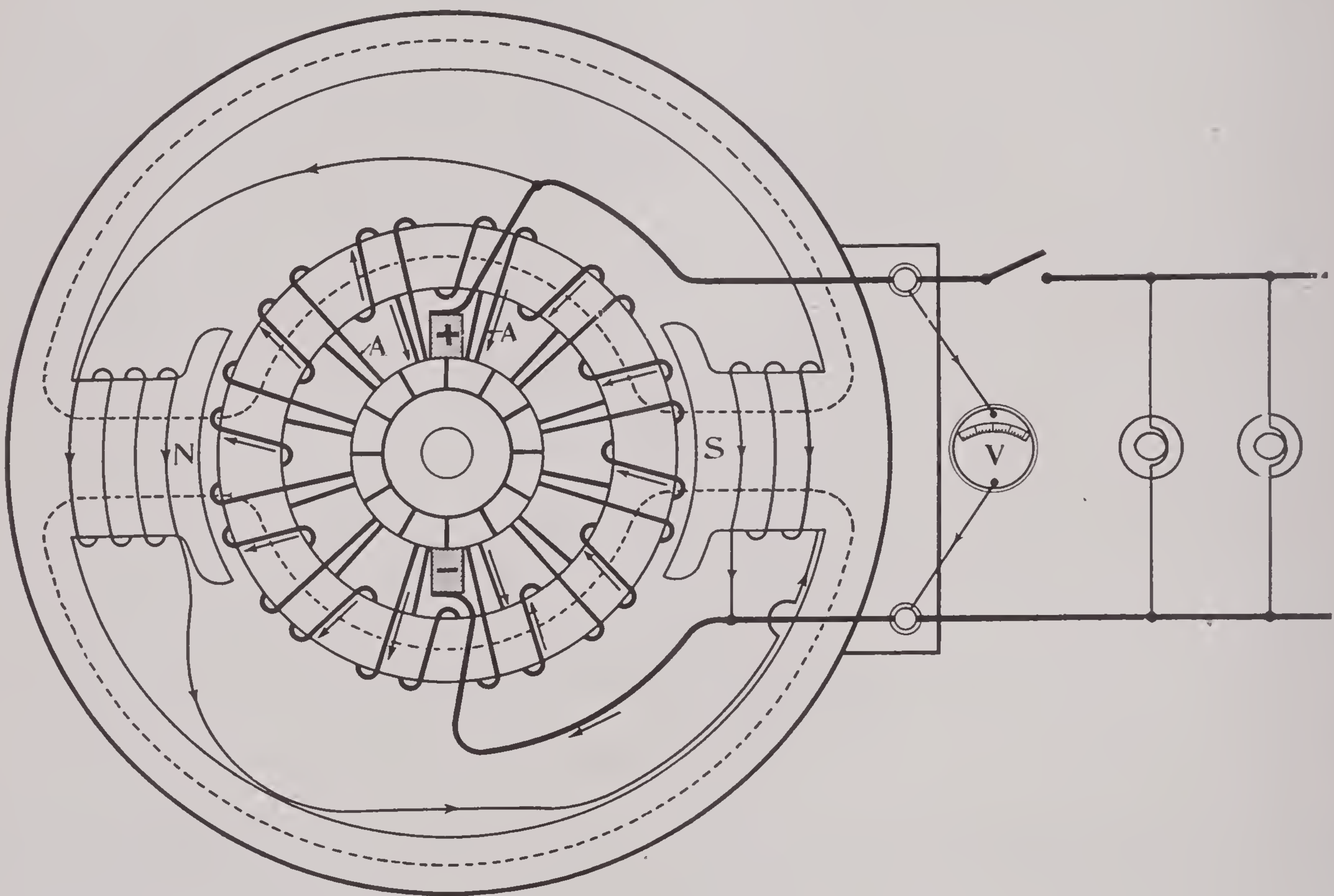


FIG. 276

The action of the ring-wound armature can be studied from Fig. 276. As the armature is revolved, the outsides of the armature coils cut the lines of force, hence E. M. F. is induced in them. Determine the direction of the induced E. M. F. by Fleming's Right Hand Rule. As indicated by arrowheads and as determined by the right hand rule, the induced E. M. F. in one side of the armature tends to pull the electricity through the armature in the opposite direction to that in the other side. Since the E. M. F's. in either side of the arma-

these coils and the external circuit as made through the brushes and commutator segments is switched in such manner that the induced E. M. F. forces electricity through the external circuit in one direction.

Since there are always armature coils cutting the lines of force there is an unbroken E. M. F. in the armature to keep the current flowing through the external circuit. As one coil turns out of the magnetic field into a neutral point (the point where the coil moves parallel to the lines of force) another coil turns out of the neutral point and into the magnetic field.

An armature of this type may have almost any number of armature coils so long as there are an equal number of commutator segments and the ends of the coil are connected to adjacent segments. The more coils and segments the armature has, the more nearly constant will be the generated E. M. F. If there are only a few coils, a varying E. M. F. is generated, which causes the current to pulsate through the circuit.

Drum Wound Armature

The ring wound armature is now out of date and is practically no longer used. However, figures showing the ring wound armature are better for illustrating the principles of generators and motors than the drum winding, as the circuits through the armature are more easily traced. The drum winding has a decided advantage over the ring winding, since the armature can be made more compact, and is more efficient, because both sides of the coils cut the lines of force.

In the drum winding the coils are wound around a core so that both sides of each coil are in slots in the armature. If the armature is wound for a two-pole machine, the sides of each coil are wound in slots about 180° apart, and the ends of the coils connect to adjacent commutator segments.

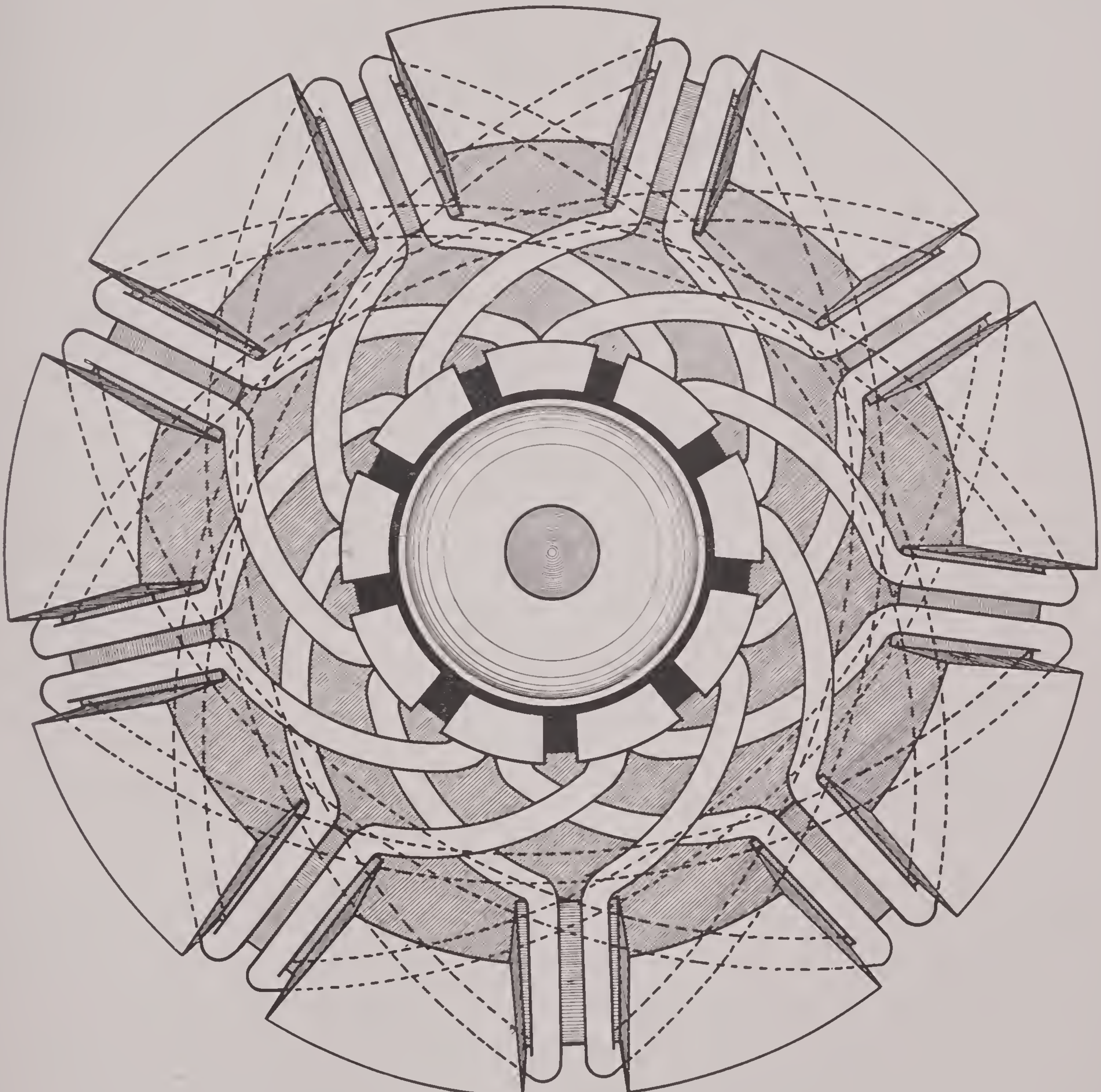


FIG. 277

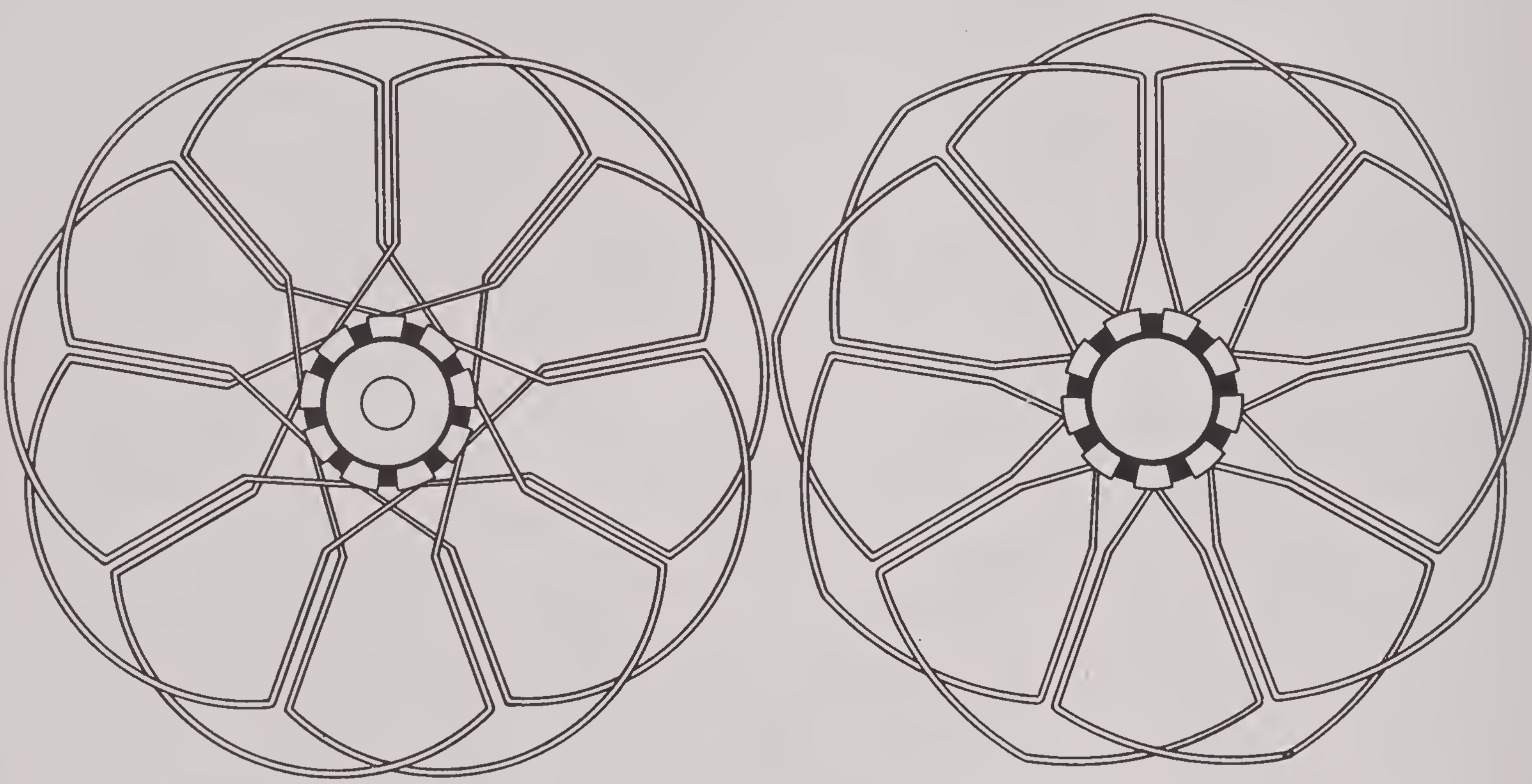
Fig. 277 shows a drum winding for a two-pole armature having nine armature slots, and nine segments in the commutator. The armature is shown cone shaped to make it possible to trace the circuits through the winding from the figure. In practice a cone-shaped armature is seldom used but instead the armature is cylindrical in shape. To make the circuits clear, the figure shows each coil as consisting of one turn, but the coils in armatures for motors and generators usually consist of many turns per coil.

The coils for a two-pole armature are wound with their sides about 180° apart in order that the E. M. F. induced in one side may act in the opposite direction to that induced in the other. If the E. M. F. acts in the same direction in both sides of the coil, the E. M. F. in one side acts against that in the other and no current will flow.

Very few armatures have an even number of armature slots, hence, the coils are not wound so that the sides are exactly 180° apart. This construction causes one side of each armature coil to pass through the neutral point a little before the other side, resulting in better commutation, and thereby reducing sparking at the brushes to a minimum.

Four Pole Armature

The armature coils of a four-pole armature are wound in armature slots in such manner that the sides of each coil are about 90° apart. If the lap winding is used, the ends of the coils are connected to adjacent commutator segments. Fig. 278, right, shows a star projection of a lap winding for a four-pole armature having nine armature slots and nine commutator segments. As many brushes as there are poles in the machine are necessary to complete the armature circuits. Fig. 279, top center, shows the field arrangement for a four-pole machine. There are four neutral points in a four-pole machine instead of two as in a two-pole machine. The brushes are so placed on the commutator that they rest on commutator segments connected to coils which lie in neutral points. The brushes are spaced 90° apart, and the brushes diametrically opposite being at equal electrical pressure are connected to same terminals.



WAVE WOUND FOUR POLE ARMATURE — LAP WOUND FOUR POLE ARMATURE

FIG. 278

If the wave winding is used, the sides of each of the coils are wound in slots about 90 degrees apart the same as in the lap winding, but the ends of the armature coils connect to commutator segments about 180° apart. Fig. 278, at the left, shows a star projection of a wave winding for a four-pole armature having nine slots and nine commutator segments. Only two brushes are necessary to complete the circuits through the armature; however, four brushes may be used as with the lap winding. Where only two brushes are used they are placed 90° apart and in such position with relation to the field poles that they are on commutator segments connected to coils that lie in the neutral points. When four brushes are used, the brushes, as with the lap winding, are set 90° apart, and the brushes diametrically opposite being at the same electrical pressure are connected to the same terminal.

Magnetic Circuits and Field Windings for Generators and Motors

In the previous discussion of the generation of an E. M. F. in the armature of a generator by revolving it in a magnetic field, the field was assumed and nothing was said as to how it is set up. The field may be set up by permanent magnets, or by electromagnets. Permanent magnets are not strong enough to set up a field suitable for any but very small machines. Permanent magnets are used for magnetos. Electromagnets are used for motors and generators.

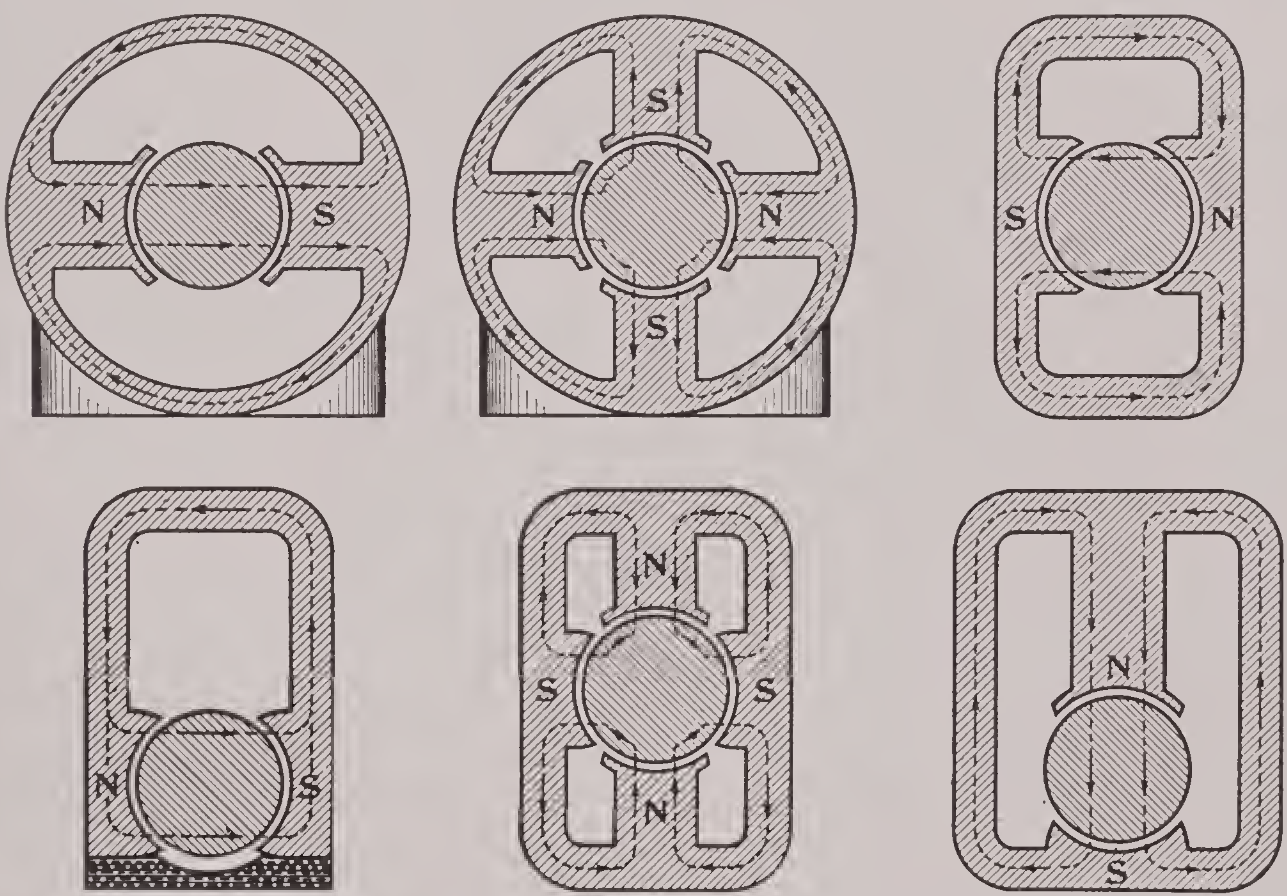


FIG. 279

The term "field" applies specifically to the magnetic lines of force set up between the poles of the field magnets, and in general to the entire magnetic circuit of a machine. Various forms of "fields" (magnetic circuits) are shown in Fig. 279. The upper left illustration shows the magnetic circuit of a two pole round frame type machine. Illustration top center shows the magnetic circuit of a four pole round frame type machine. In each of these two machines, field coils are placed on each of the poles. Illustration, upper right, shows a magnetic circuit of a two pole machine using two field coils. Illustration, lower centre, shows a magnetic circuit for a four pole machine using two field coils. Illustration, lower left, shows a magnetic circuit of a two pole machine using one field coil. Illustration, lower right, shows another arrangement of a two pole field frame arranged for a single field coil.

The magnetic circuit of almost any dynamo is composed of the following parts: The armature core, which is usually a cylinder of laminated iron mounted on a shaft and having slots cut in its surface to carry the armature coils; the air gap, which is the clearance between the armature and the ends of the poles; the pole shoes, or pole pieces, which are sometimes cast integral with the frame, and sometimes fastened into the frame with screws or bolts; and the frame, or yoke, which carries the pole pieces, and at the same time serves as a support for the other parts of the machine.

There are two kinds of field coils—series and shunt. The series field coils are of comparatively few turns of heavy wire, sometimes copper ribbon, and are connected in series with the armature. The resistance of series field coils is very low. Shunt field coils are many turns of comparatively small wire and are connected in parallel with the armature. The resistance of shunt field coils is usually several ohms. Fig. 283 shows a machine with series field coils. The arrows show the direction of flow of current through the field coils and the armature when the machine is run as a motor. Machines having only series field coils are called series wound machines. Series wound generators are not used on the automobile, but series wound motors are used.

Figs. 276 and 280 show machines with shunt field coils. The arrows indicate the direction of flow of current when the machine is run as a generator. When the machine is run as a generator there must be some residual magnetism for it to "build up" from, and the field coils must be so wound and connected that as the generator builds up it forces current through them in the direction to magnetize the poles to a greater strength. If the field coils are not properly connected, the generator will not build up from its residual magnetism, since it tends to force current through them in the direction to demagnetize rather than magnetize the poles.

Machines having both shunt and series field coils are called compound machines. When the series and the shunt field coils are so wound and connected that current in both magnetizes the pole pieces to a greater strength, it is called a cumulative compound machine. If the field coils are so wound and connected that the current in the shunt field coil magnetizes the poles and the current in the series field coils tends to demagnetize the poles, it is called a differential compound machine. Starting motors seldom have the shunt field winding, but when compounded they are always cumulative. Generators used on the automobile are usually straight shunt wound. The generators which are compounded are usually differentially wound. If the field coils are connected so that a machine will run as a compound cumulative motor, it will operate as a compound differentially wound generator.

The straight shunt wound generator gives about constant voltage when driven at constant speed. However, if the load is increased on a straight shunt generator which is driven at constant speed, the voltage will drop slightly because of field distortion and IR-drop. If the machine is driven at variable speeds its voltage varies almost with the square of the speed. That is, doubling the speed causes the machine to generate about four times the voltage —tripling the speed causes the machine to generate almost nine times the voltage, etc. A compound differential wound generator builds up to a voltage that will cause the current to flow through the external circuit at a certain strength but will not build up much beyond this value, even though the speed of the machine is further increased.

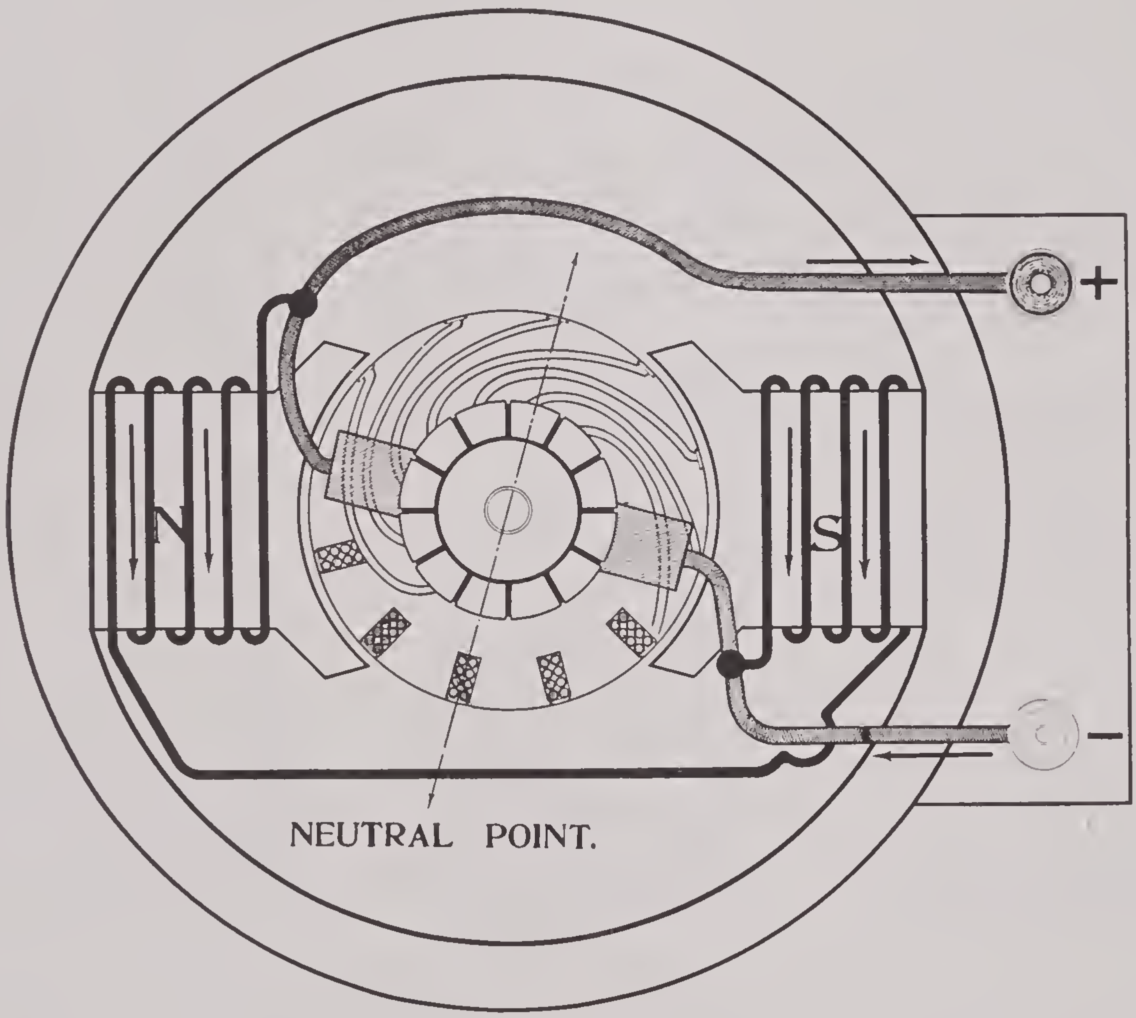


FIG. 280

Field Distortion

As the current passes through the armature of a generator, magnetic lines of force are set up about the armature conductors. The lines about the armature conductors crowd the lines forming the field forward and so twist the field out of its natural path. This twisting of the field is called "field distortion." The degree to which a field is distorted depends on the strength of the current in the armature and the strength of the field. The stronger the field the less it is distorted by the armature current and the stronger the armature current the more the field is distorted.

Field distortion causes the neutral points to shift and so causes the points of commutation to move forward as the load of the generator increases. For this reason the brushes of a generator must be set a little ahead to be on the points of the commutation while the load is on. (See Fig. 280.)

PRINCIPLES OF ELECTRIC MOTOR

When an electric current is passed through a conductor which is lying in a magnetic field at right angles to the lines of force, a force is set up which moves or tends to move the conductor across the field. The cause of this force is shown in Fig. 284. When the current is passed through the conductor, magnetic lines of force are set up about it which crowd the lines forming the field to one side of the conductor. As the lines of force are crowded to one side of the conductor they are pushed out of their natural path, and as they tend to straighten out they exert a force which acts to move the conductor across the field. The strength of the force depends upon the strength of the field and the strength of the current. The direction a conductor is moved, depends upon the direction of the field and the direction of current.

The relation which exists between the direction of the field, the direction of the current, and the direction the conductor is moved, can well be remembered by an application of the Left-Hand or Motor Rule. Rule: Place the thumb, first finger, and middle finger of left hand at right angles to each other. Then place the hand so the first finger points in the direction of the magnetic field, the middle finger in the

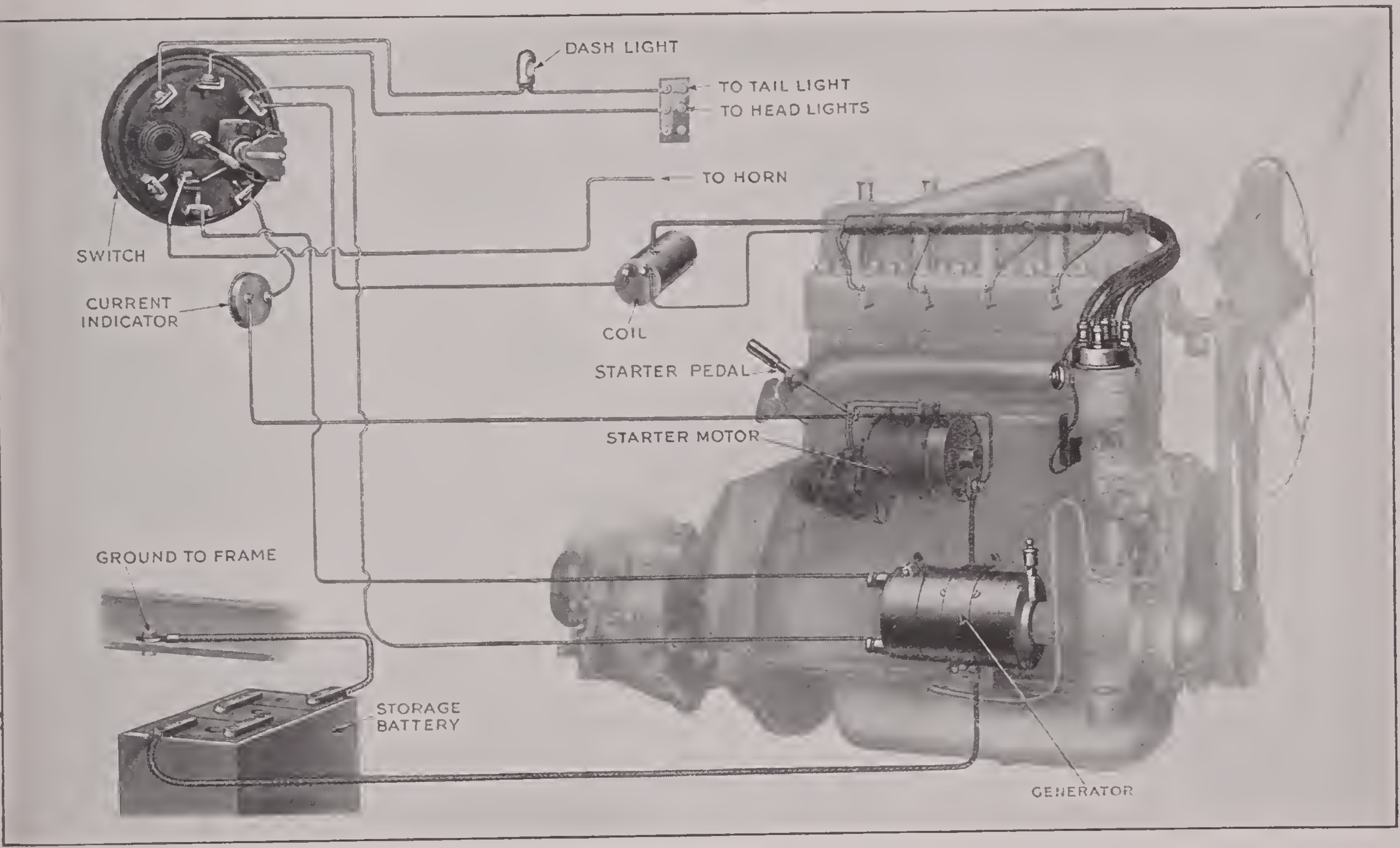


FIG. 281

ESSEX STARTING, LIGHTING AND IGNITION SYSTEM—DELCO direction the current flows, and the thumb will point in the direction the conductor is moved.

Action of Electric Motor

The essential parts of a direct current motor are identical with those of a direct current generator—they are an armature and a magnetic field. A direct current motor can be run as a direct current generator, or a direct current generator can be run as a direct current motor.

The brushes, as in the generator, are placed on the commutator in such position with relation to the field poles that they rest on segments to which the coils in the neutral points connect. As the armature turns, the brushes (H) and (G) are in the neutral points, hence are not in circuit with battery. By applying the left hand or motor rule, the direction the armature conductors are moved can easily be determined. Those beneath the north pole are moved up and those beneath the south pole are moved down. This produces a twisting force on the armature that turns it clockwise. The action of the commutator and the brushes keeps the coils switched into the circuit so there is a constant twisting force maintained in the armature. The strength of this twisting force depends upon the strength of the field, the strength of the current in the armature and the manner in which the armature is wound.

The direction a motor runs depends upon the direction of the current through the arma-

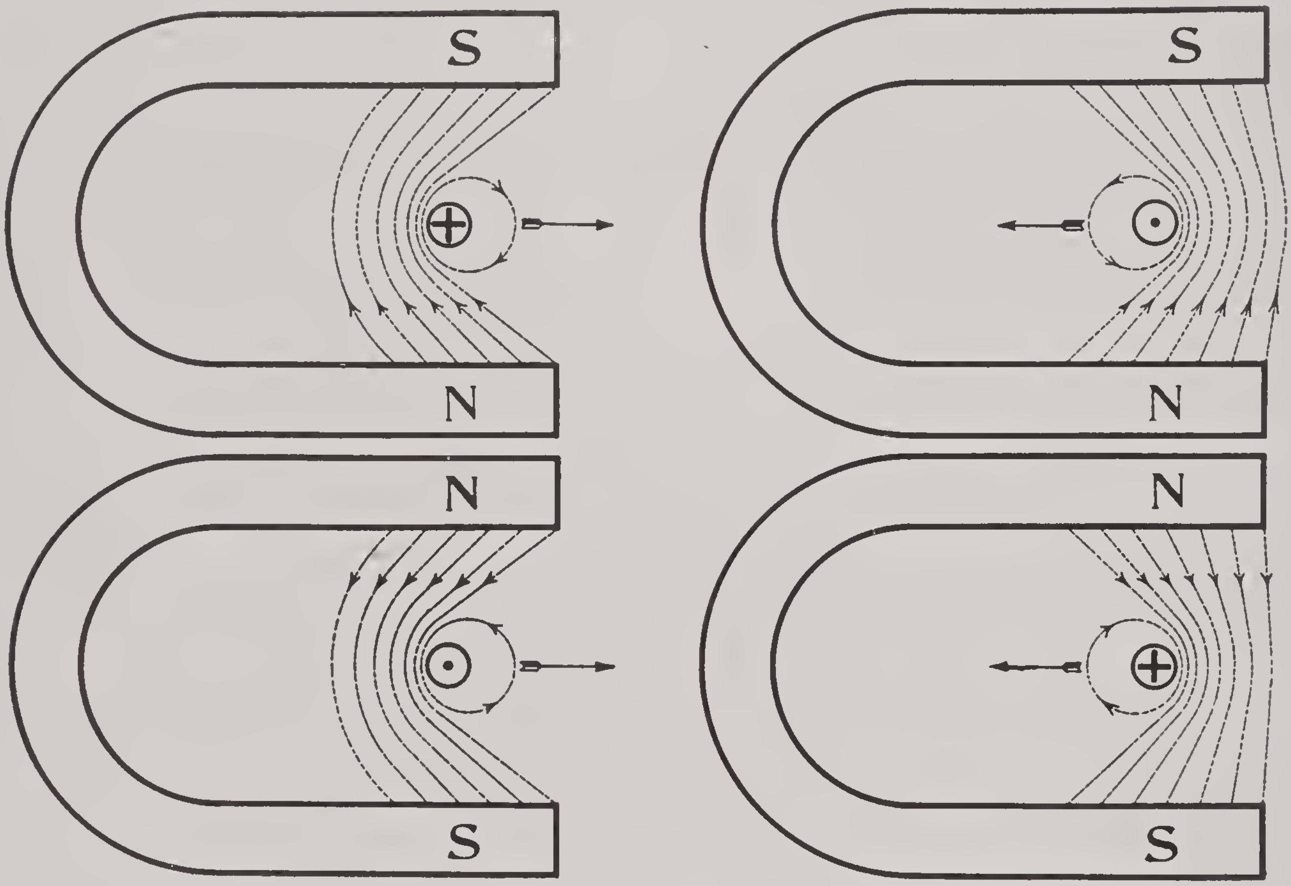


FIG. 282

riding on the commutator segments keep the armature coils switched into the circuit, so that the current in the coils beneath the south pole flows in the opposite direction to the current in the coils beneath the north pole.

Fig. 283 shows a series wound machine with a ring wound armature. When the switch (S) is closed the E. M. F. of the battery causes current to flow through the field coils (F) and through the armature. The current flowing through the field coils magnetizes the poles and so sets up the field. The current in the conductors as they pass positions (A), (B), (C), (D) and (E) flows in, or away from observer, and as they pass positions (I), (J), (K), (L) and (M) it flows out or towards the observer. The conductors as they pass positions

ture and the direction of the magnetic field. If the connections to the battery are reversed, the direction of the current through the armature will be reversed and the polarity of the field reversed. Since the current in both the armature and the field is reversed the motor runs the same direction. This should be verified by the left-hand rule. If the polarity of the field is reversed without reversing the current through the armature, the motor runs in the opposite direction. Or, if the direction of the current through the armature is reversed without reversing the polarity of the field, the motor runs in the opposite direction. Verify these statements by the left hand rule.

The action of the drum wound armature is about the same as a ring wound armature, since it is so wound that the current through the conductors beneath the south pole will be in the opposite direction to the current in the conductors beneath the north pole. The drum windings for a motor armature are fundamentally the same as those for the generator.

Armature Reaction in Motor, Field Distortion

When current flows in the armature winding of a motor, a magnetizing effect is produced on the armature core, which twists the field out of its direct path through the armature core from pole to pole. This twisting of the field out of its natural path is called field distortion. Distortion of the field causes the neutral points to shift, and in turn, the points where the brushes must rest will move. In the motor the field is distorted in the direction opposite to which the armature turns. (See Fig. 284.) Therefore the neutral points, when the motor is running, are back of the position they would be in if the field was not distorted by the armature current. The distance the neutral points move depends upon the degree of field distortion and the distortion depends upon the strength of the field and the strength of the armature current.

Points of Commutation

The points of commutation are the points on a commutator where the brushes should be placed. The points of commutation are determined by the neutral points. The brushes should be so placed on the commutator that they rest a little back of commutator segments which connect to coils that are in the neutral points. The true points of commutation can only be found by adjusting the brushes while the motor is running. If the brushes are not on the points of commutation the motor will not develop full power, and there will be sparking at the brushes.

To find the points of commutation the brush rigging is loosened, and with motor under load, the brushes moved forward or backward till the sparking is reduced to a minimum and the motor develops maximum power. Then lock brush rigging in that position. The brush rigging of some motors is so set at the factory that it cannot be moved, hence is not adjustable. In this case, the points of commutation are determined at the factory and then the brush holder fastened securely to the end plate of motor. The brush rigging of other motors is slotted and so is adjustable. If the brush rigging is to be removed it should be marked so that

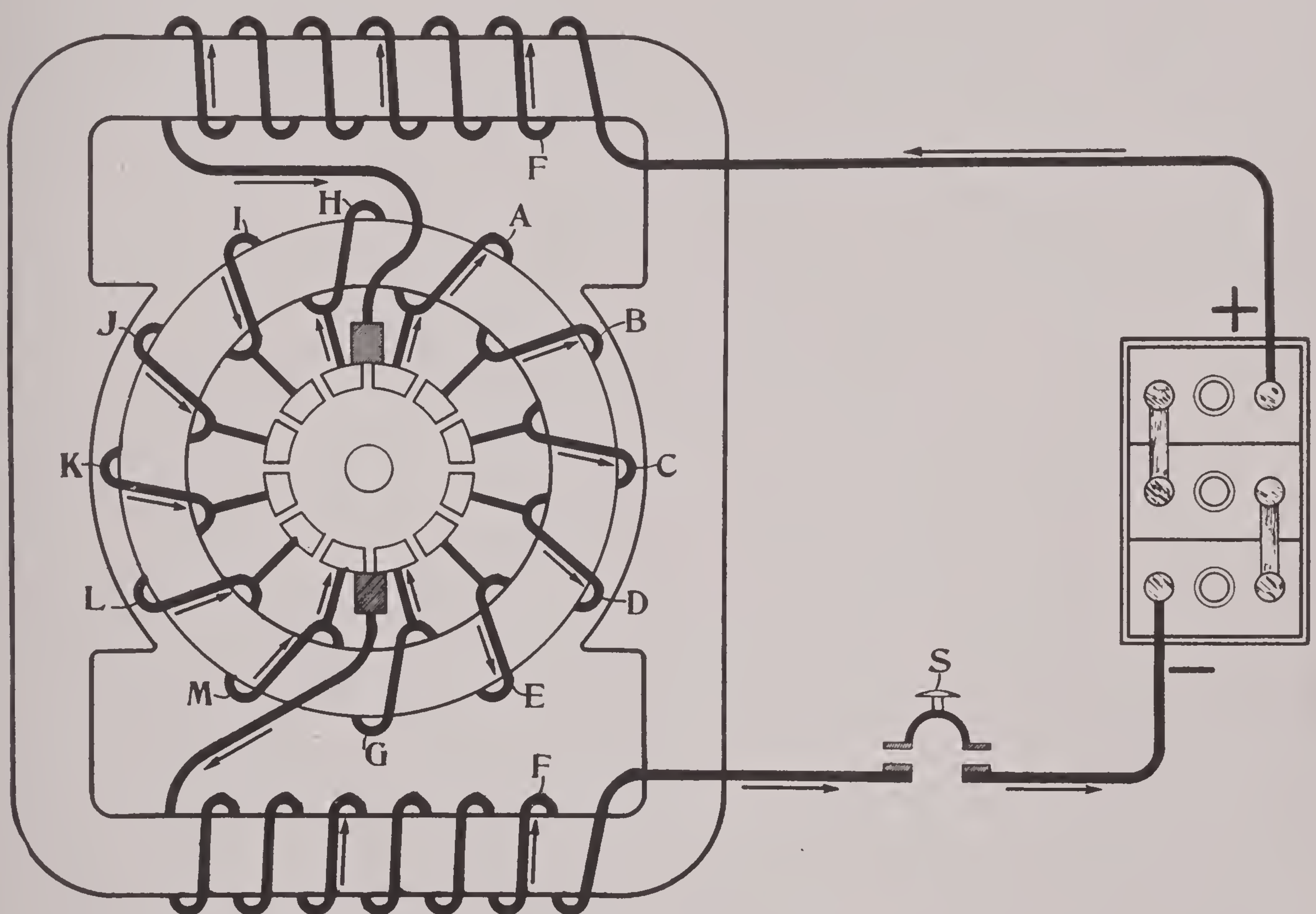


FIG. 283

it can be replaced with less difficulty. If, for some reason, the brush rigging becomes so loose that the brushes have moved off of the points of commutation, the commutator is likely to be badly burned.

Counter Electromotive Force

When the armature of a motor revolves in the magnetic field, an E. M. F. is generated in the coils, much the same as the E. M. F. generated in the armature coils of a generator. This E. M. F. is induced in the sides of the coil as they cut the lines of force while the armature revolves. The direction of this E. M. F. is counter, or against, the flow of current through the armature, and so is called counter E. M. F. The counter E. M. F. of a motor depends upon the same things as the generated E. M. F. in the armature of a generator,—strength of field, speed of armature, and manner armature is wound. It increases with an increase in speed, and decreases with a decrease in speed, all other conditions remaining the same. It also increases with an increase in the field strength, if the speed remains the same, and decreases with a decrease of field strength, if the speed remains the same. Under normal conditions, the counter E. M. F. cannot equal or exceed the voltage of the circuit in which the motor is connected.

Speed of Motor

The speed of a motor is always such that the torque produced is just ample to drive the load connected to the motor. Since the torque depends upon the strength of the field and the strength of the armature current, the speed of motor increases till the counter E. M. F. reduces the armature current to a value that gives just enough torque to drive the load. When a heavy load is thrown on the motor, the speed decreases. As the speed of motor decreases the counter E. M. F. decreases, permitting more current to flow through the armature thereby increasing the torque. The speed of motor then decreases till the armature current reaches a strength that gives torque enough to drive the load. If the load is made less, the speed of the motor increases, increasing the counter E. M. F. until the armature current is reduced to a value that gives just torque enough to drive the armature under the lighter load.

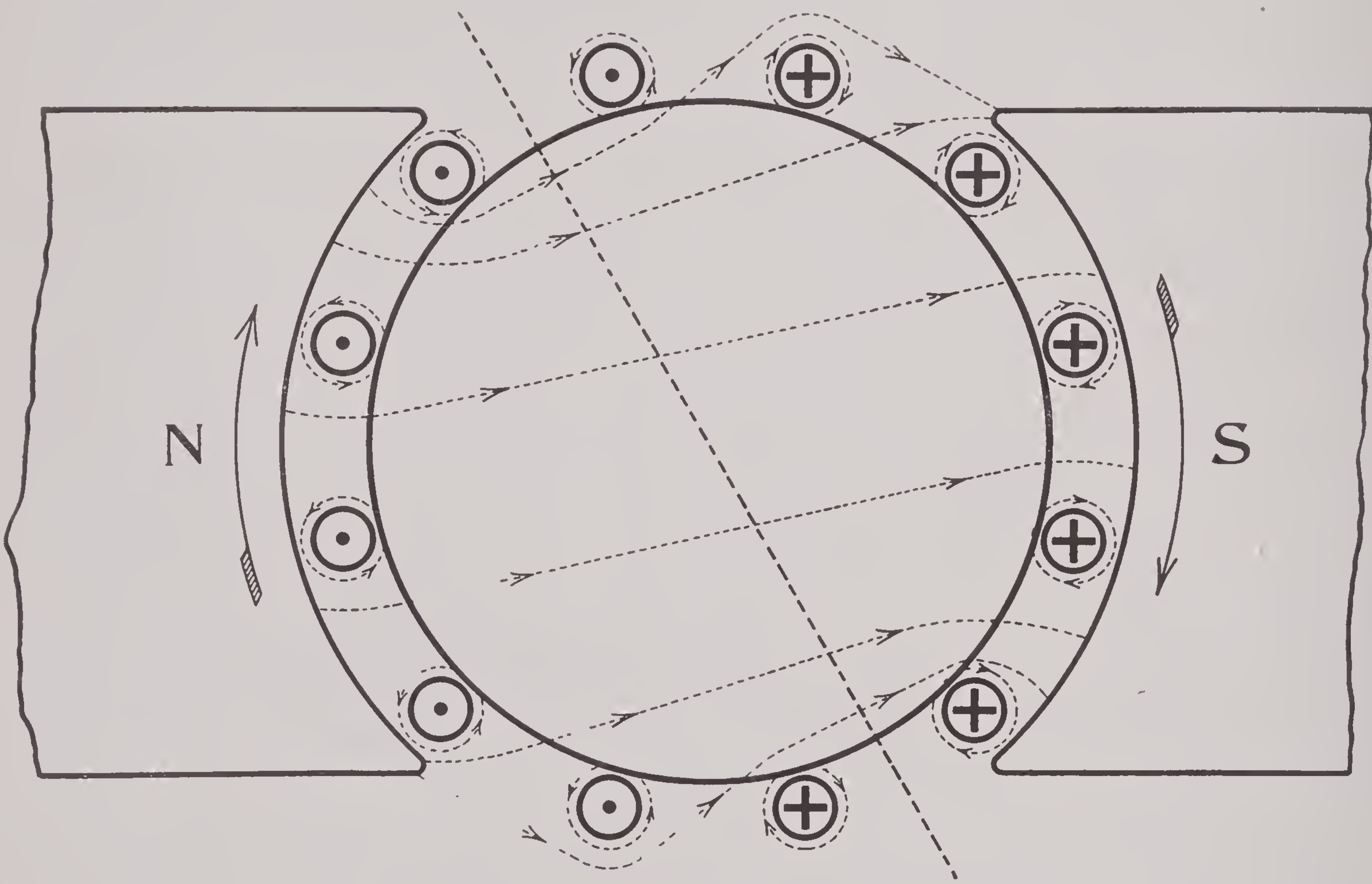


FIG. 284

Output of Motor

The output of the motor depends upon its torque and the speed at which it is operating. If the torque is measured in foot-pounds, by a prony brake, and the speed in revolutions per minute is known, the output of the motor in horsepower can be determined by the following formula. Output in horsepower

$$= \frac{6.2832 \times \text{lbs.} \times \text{length of arm} \times \text{R. P. M.}}{33{,}000}$$

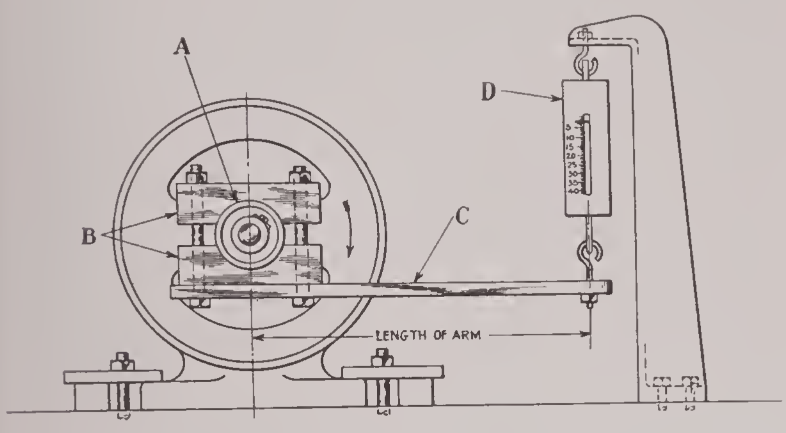


FIG. 285

PRONY BRAKE

A. Motor pulley.
B. Wooden clamping blocks.
C. Torque arm.
D. Spring scales.

Operation of Shunt Motor

When a motor having a shunt field winding is connected in circuit with a suitable source of E. M. F., current builds up through the shunt field coils and through the armature. The strength of the current in the shunt field coils depends upon their resistance and the voltage of the circuit. The current in the armature before the armature starts depends upon its resistance, and the voltage of the circuit. The torque produced by the reaction of the current in the armature coils on the field set up by the current in the field coils, causes the armature to turn. As the speed of the armature increases the counter E. M. F. increases and so decreases the strength of the armature current. As the strength of the armature current decreases the torque becomes less. The speed of the armature then increases to a point where the torque is just ample to drive the load. The shunt wound motor does not have strong starting torque so it is not suitable for a starting motor.

Operation of Series Motor

When a series motor is connected in circuit with a suitable source of E. M. F., current equal to the voltage of the circuit divided by the resistance of the motor is produced in the series field coils and the armature. The current remains at this strength for an instant only, since counter E. M. F. is generated, when the armature begins turning. As the counter E. M. F. increases with the speed of the armature, the current is decreased in both the series field coils and the armature. As the current in the field coils and the armature decreases, the torque decreases, hence the speed of the motor increases till the torque is just ample to drive the load. The variation of the speed of a series motor is more than that of a shunt motor, when the load is varied, since the field coils are in series with the armature and the strength of the field varies as the armature current varies.

Compound Motor

The compound motor is a combination of the series and the shunt. The characteristics of the cumulative compound motor are between those of the shunt and the series. A machine used as a starting motor is seldom compound, unless it is used as a generator also. If the machine is used as a motor-generator it runs as a cumulative compound motor, and a differential compound generator.

Motor-Generators

Some motor-generators have a double armature winding and two commutators. The armature winding used when run as a motor is one made up of coils of few turns and heavy wire. These coils connect to the segments of the heavier commutator. The armature winding used when run as a generator is made up of twice as many coils, each having more turns and wound with smaller wire. These coils connect to the smaller commutator which is made up of twice as many segments as the large commutator. Most of these machines use both field windings when run as a motor, but when running as a generator only the shunt field coils are used. The Delco motor-generator is of this type. When the starting motor and generator is combined in one machine the starting and lighting system is usually called a single unit system. If separate machines are used for motor and for generator, the system is called a two unit system.

FIG. 286

REMY STARTING MOTOR EQUIPPED WITH BENDIX

Characteristics of Starting Motors

The starting motor must develop sufficient starting torque (twisting force) to "break the engine loose" even in the coldest weather, and sufficient power to drive the engine at a speed at which it will begin the cycle of operations or start. Series field coils are used on all starting motors to give them the necessary starting torque. Some starting motors have both series and shunt field coils; that is, are compound wound. If the starting motor is compound, it is always cumulative.

Heavy current must pass through starting motors to give them the required starting torque and power. To carry this heavy current the series field coils are wound of heavy copper conductors, sometimes heavy copper ribbon and the armature coils are wound of heavy copper conductors. Since the motor runs at comparatively high speeds there are usually few turns in the armature coils. The commutator is built up of heavy commutator segments, usually much heavier than those used for the generator commutator. The brushes are sometimes copper plated to reduce their resistance. The resistance of the starting motor must be low, since the E. M. F. of the battery is not high enough to force the heavy current through much resistance. Where the four pole machine is used there are usually four brushes, even though the armature be wave wound. The extra brushes provide a greater area of contact on the commutator to carry the heavy current.

ELECTRICAL AND MECHANICAL CONNECTIONS OF THE STARTING MOTOR

The electrical connection between the starting motor and the battery must be made through heavy conductors which have very low resistance. It is necessary to pass from 200 to 400 amperes through six volt starting motors to give them torque enough to break the engine loose and put it in motion and usually requires from 100 to 200 amperes to keep the engine turning after it is in motion. The strength of the current necessary to give a motor the required torque, depends upon how hard the engine is to turn. The harder the engine is to turn the stronger the current must be, to give the motor the necessary torque.

Divide 6, the number of volts a six volt battery gives, by 300, the number of amperes required to give a motor the necessary starting torque, and the quotient is 1/50, the maximum resistance the starting motor circuit can have. Therefore, if the resistance of the circuit is over 1/50 of an ohm, the E. M. F. of the battery will not be strong enough to send sufficient current through the motor to give it the torque

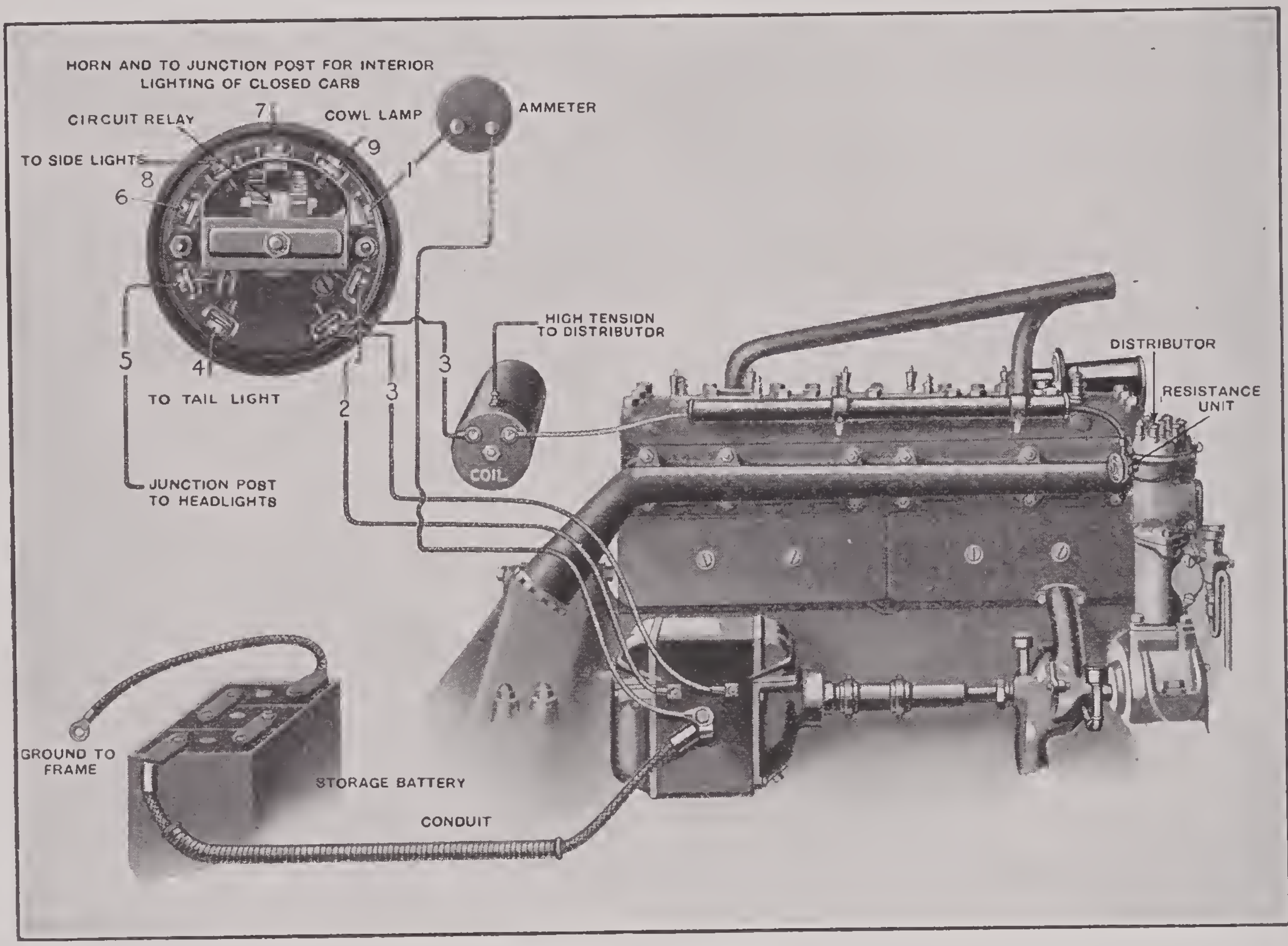


FIG. 287

HUDSON—DELCO STARTING, LIGHTING AND IGNITION required for starting the engine. In fact, the resistance of the starting motor circuit must be kept under 1/50 of an ohm, as the battery does not give full six volts when discharging at a rate of 200 or 300 amperes.

The conductors used to connect the battery to the starting motor are usually insulated copper cables (No. 1 to No. 00 Brown & Sharpe Gauge). The connections are heavy and must be well made. The starting switch is also of heavy construction. The frame of the car is sometimes used for one side of the circuit. When the frame is used for part of the circuit, the ground connections must be heavy and well made. The construction of the starting switch varies with the different tems. For this reason the cables connecting the battery to the starting motor are not as large. The starting motor is then constructed to work under twelve volts pressure instead of six.

Mechanical Connections of Starting Motors

Mechanical connection between the starting motor and the engine is made in several ways, varying with the different systems and different types of motors and motor-generators. Some machines which are used both as a motor and a generator are virtually built into the engine, the armature forming the flywheel as in the old U. S. L. installation, and some, the flywheel containing the field, as in the Owen

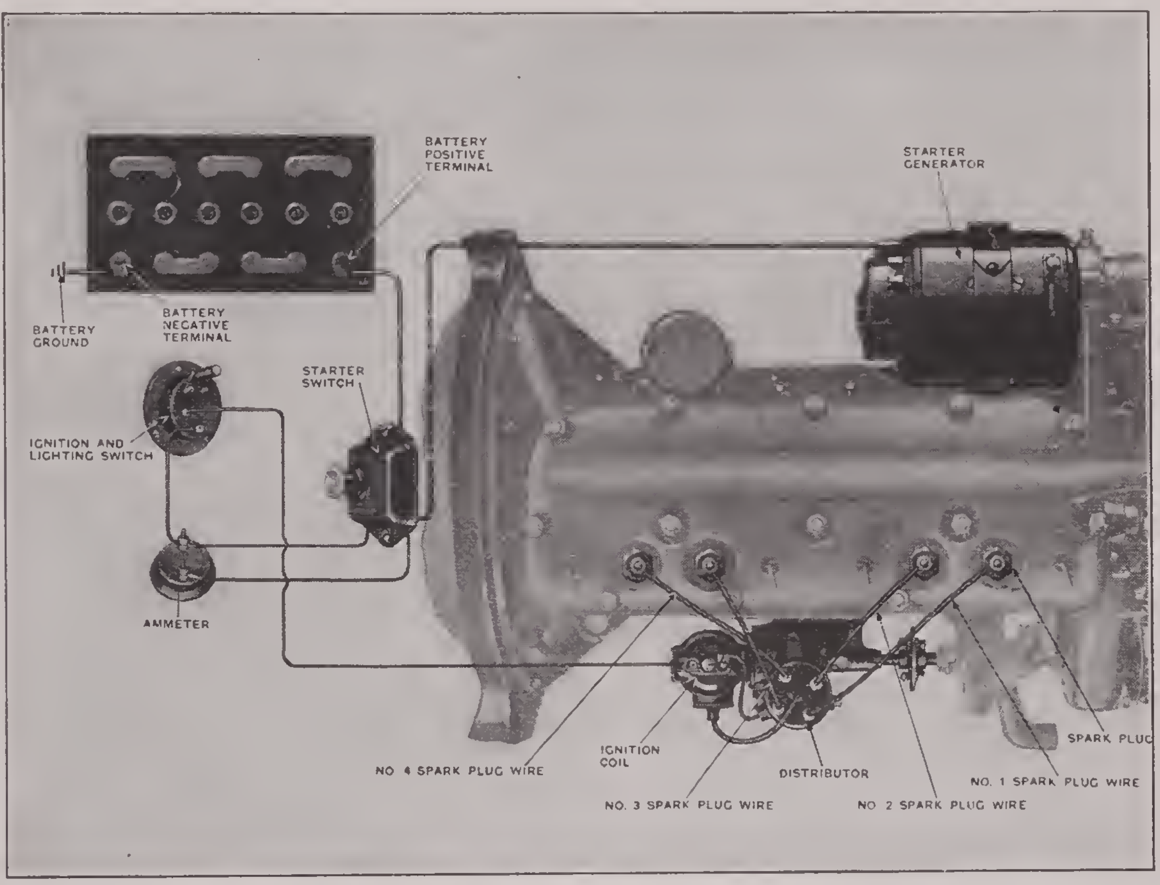


FIG. 288

DODGE—NORTHEAST STARTING, LIGHTING AND IGNITION

systems. The starting switches used on early systems are nearly all of complicated construction, but the tendency now is to make them of as simple construction as possible. Some do not even use a starting switch, but instead, lift the brushes of the starting motor off the commutator to open the circuit and lower the brushes onto the commutator to close the circuit.

If the storage battery is moved to another part of the car where it is necessary to use longer cables to connect to the starting motor, proportionately larger cables should be used. On systems using twelve volt batteries it is only necessary to carry a current of one-half the strength that is necessary for six volt systems.

Magnetic. These machines are large, and have armatures wound with coils of many turns, hence they turn at a comparatively low speed, and develop strong torque.

Most motors and generators are built separate from the engine, and connect mechanically to it through gears or a chain. (Some generators are driven by a belt, but belts are not used to connect starting motors to the engine.)

The speed ratio between armature and engine on some installations is about 3 to 1. These machines are a little larger than the average, and have armatures wound with many coils, of many turns. They run at comparatively low speed, and develop strong torque.

For example, the North-East motor-generator used on the Dodge car connects to the engine with a silent chain. The speed ratio is 3 to 1. When the machine runs as a motor, the armature turns under no load about 800 R. P. M. When cranking the engine the armature turns from 150 to 450 R. P. M. depending upon how hard the engine is to turn. Since the speed ratio is 3 to 1, the engine is driven from 50 to 150 R. P. M.

When the engine starts its speed increases, hence drives the armature faster than it runs as a motor. With the engine running 500 R. P. M. the armature is then driven 1500 R. P. M. At this speed, a higher E. M. F. is produced than that of the battery and it has therefore changed automatically from a motor into a generator, and is charging the battery. The Dyneto motor-generator, as used on the Franklin, is much the same type of installation.

Other motors have armatures wound with coils of comparatively few turns, so they run at high speeds, and do not develop very strong torque. These machines are small, and drive the engine through a comparatively high gear reduction, varying from 10 to 1, to 40 to 1.

When a starting motor drives the engine through a gear reduction giving a speed ratio between armature and crankshaft from 10 to 1, to 40 to 1, it is necessary to have the mechanical connection so made that when the engine starts, it cannot drive the starting motor. Unless some device is provided in the mechanical connection between the motor and the engine that will permit the engine to run without driving the motor, the mechanical connection is likely to be broken or the motor driven at a speed that will damage the armature when the engine starts.

Overrunning Clutch

Fig. 289, right, shows an illustration of the starting motor and the engine. (P) is a small pinion on the armature shaft. (I) is a larger gear meshing with (P) and is mounted on the splined shaft (K). This shaft also carries the pinion (S) that is moved by the shifting fork (SF) to engage with the gear cut on the face of the flywheel (F). (1) is one of the four steel rollers carried in slots cut in the outer surface of the inner portion of the clutch. In each slot the depth varies, with the deepest part near the plunger (3), which has a small spring that prevents the roller from dropping back into the deeper part of the slot where it will not touch both inner and outer portions of the clutch. The inner portion of the clutch is keyed to shaft (K).

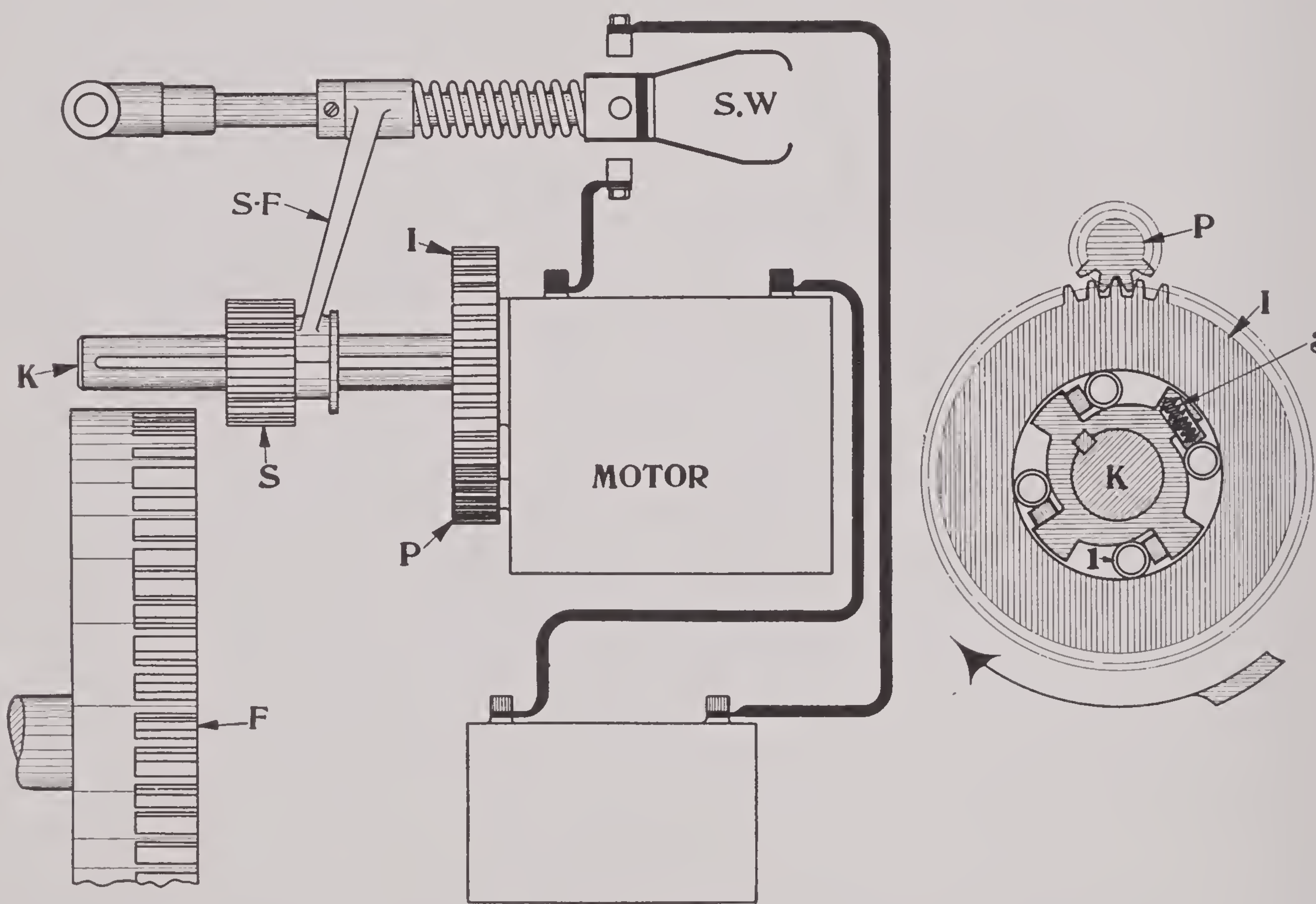


FIG. 289

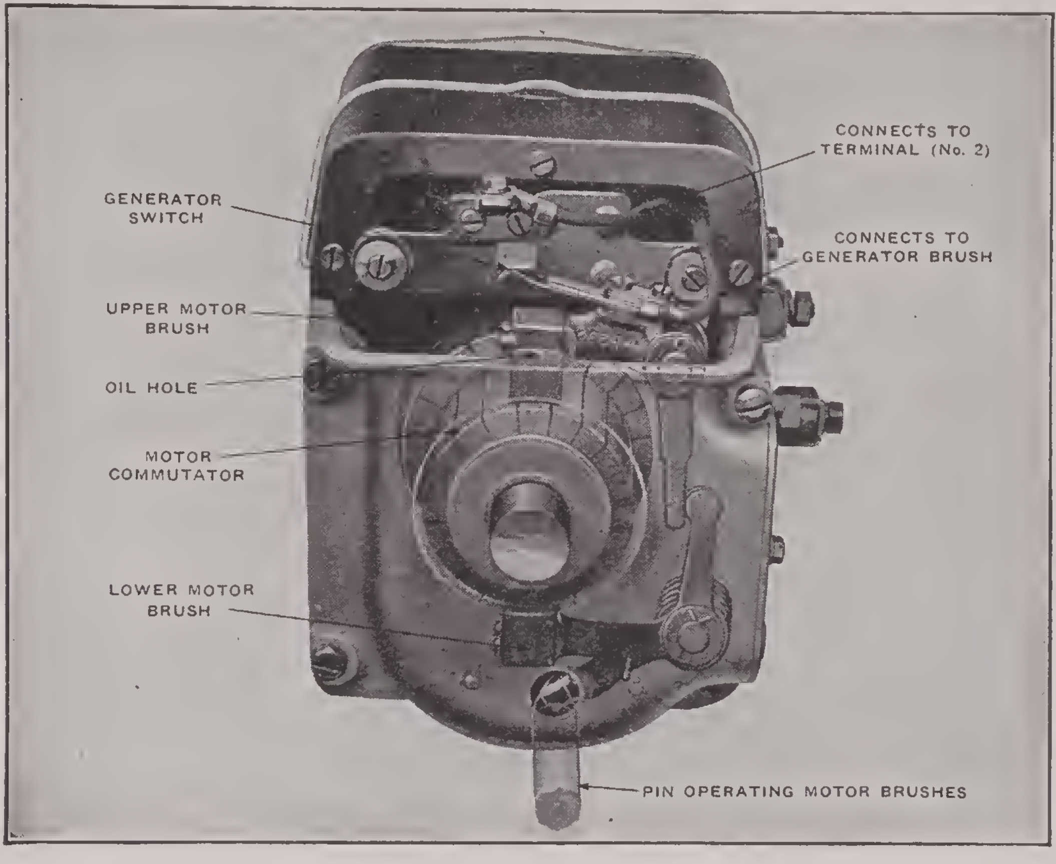


FIG. 290

HUDSON—DELCO MOTOR-GENERATOR MOTOR COMMUTATOR END

The operation as shown in the figure, is for pinion (P) to drive shaft (K) in a clockwise direction through the gear (I) of the clutch. As the pinion (P) drives gear (I), the steel rollers are caused to roll out into the narrow part of the slot, and so lock the ring to the inner portion of the clutch. If shaft (K) is driven faster than gear (I), the rollers are caused to roll back against the plungers into the wider part of the slots, releasing the inner portion of the clutch from gear (I).

With the proper arrangement of this overrunning clutch in the mechanical connection between the starting motor and the engine, the starting motor can drive the engine, and the engine can overrun the starting motor when it starts. This type clutch is used in practically all mechanical connections between the engine and the motor where sliding gears are meshed to make the connection.

Fig. 289, left, shows a common type of mechanical connection between starting motor and engine using sliding gears which are shifted by the starting pedal. The starting pedal connects to the sliding gear through the shift rod, spring, and shifting fork. When the starting pedal is pressed the gears are brought into mesh before the starting switch is closed. If the gears are in such position that the shift cannot be accomplished till one of the

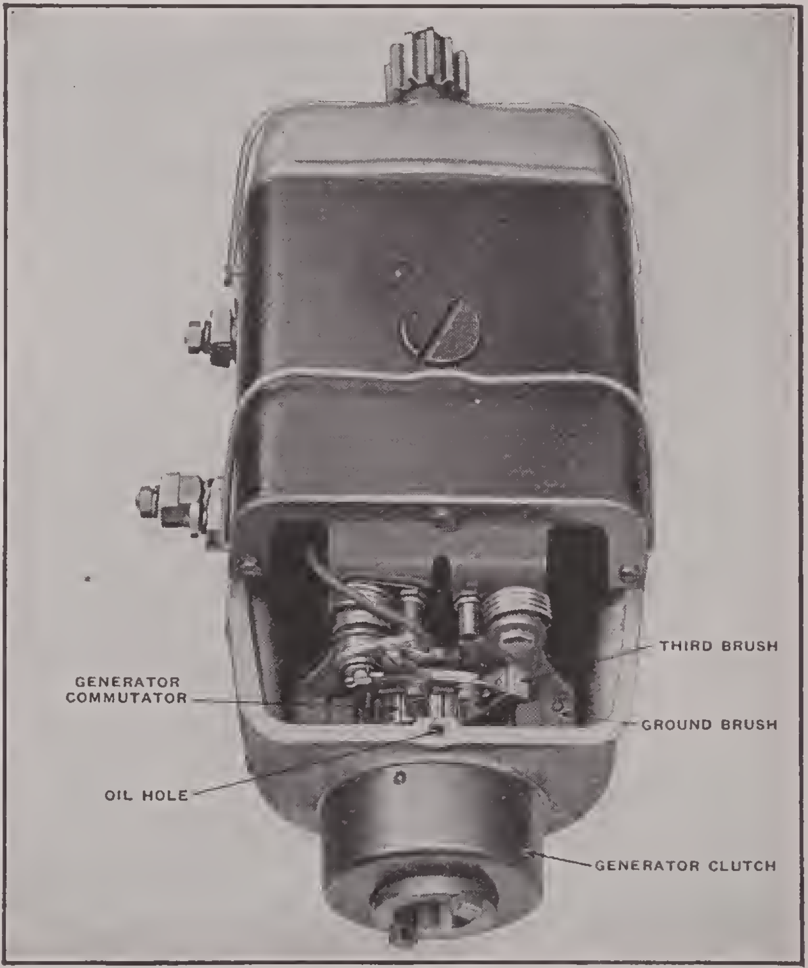


FIG. 291

HUDSON—DELCO MOTOR-GENERATOR GENERATOR COMMUTATOR END

gears is moved a little, the spring behind the shifting fork, is compressed as the starting pedal is pressed. As soon as the pedal is pressed far enough to close the switch, the motor starts. A slight forward movement of the motor moves the pinion enough for the gears to be thrown quickly into mesh by the spring.

Without the spring behind the shifting fork, the shift could not be accomplished at times, until one of the gears was moved a little. The spring must be strong enough to throw the gears into full mesh before the motor turns far enough to take up the play, or the starting strain will come on the gears when only partly meshed, which is likely to cause them to be stripped. Another spring (return spring), provided to bring the pedal back to neutral position, draws the gears out of mesh, and opens the starting switch when pedal is released.

Fig. 292 shows another type of mechanical connection using a sliding gear (F), shifted by the starting pedal. The starting switch is so constructed that it closes the circuit through the motor and the battery, through a resistance (A) when the starting pedal (B) is pressed part way down. This causes the motor to turn slowly, and with little power. Slowly turning gears are easily pushed into mesh as the pedal is pressed further forward, and the power of the motor, while the resistance is in series with it, is not enough to tear the corners from the teeth of the gears as they are brought into mesh. When the pedal is pressed far enough down to fully mesh the gears, the starting switch shorts the resistance in series with the motor and then current of sufficient strength flows through the motor giving it the torque required to turn the engine.

An overrunning clutch is carried in the sliding gear, which permits the engine to run

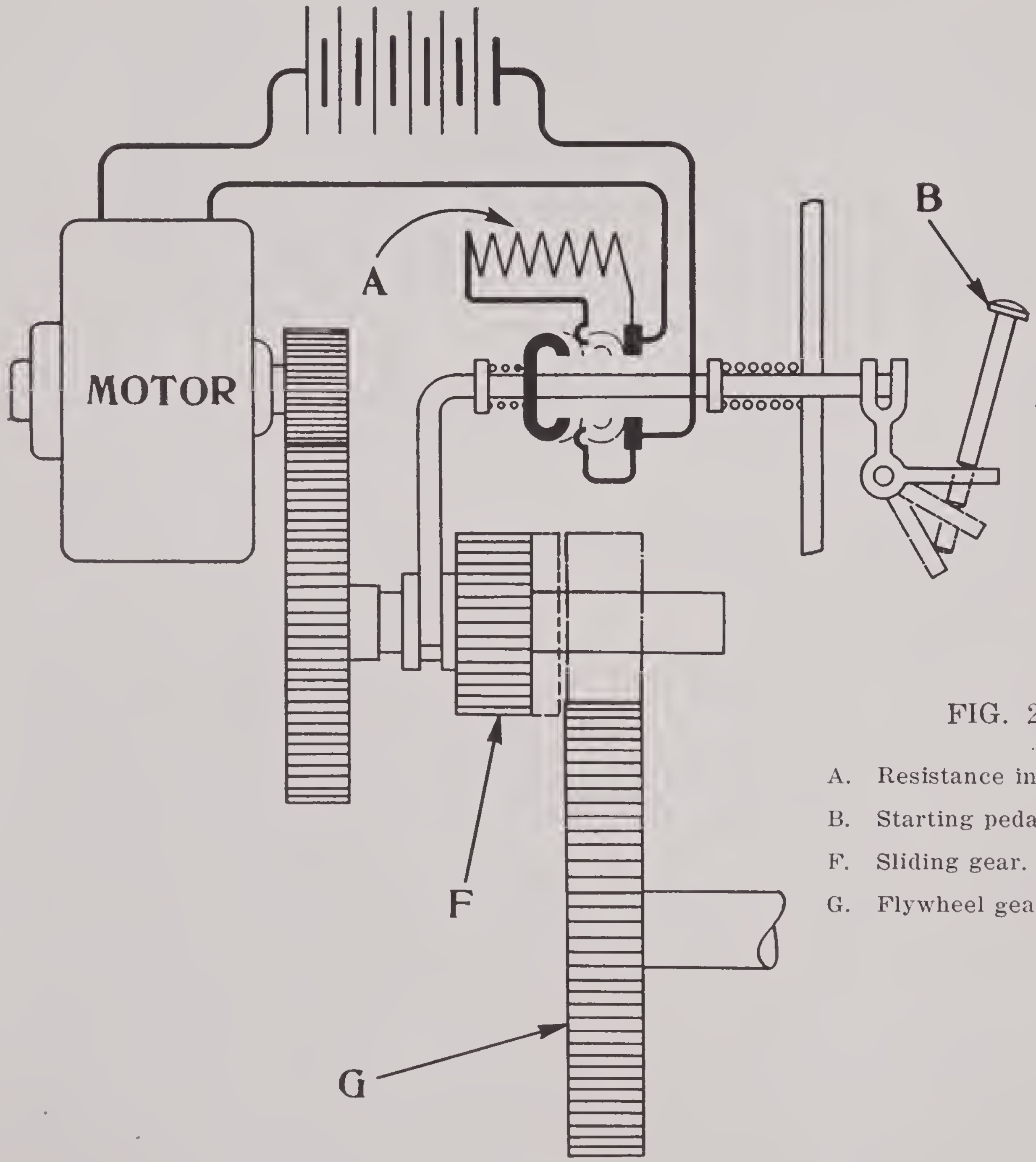


FIG. 292

A. Resistance in switch.

B. Starting pedal.

F. Sliding gear.

G. Flywheel gear.

faster without driving the motor. When the starting pedal is released a spring throws it back to neutral position, drawing the sliding gears out of mesh, and opening the starting switch, so that the motor stops.

The Delco motor-generators are connected to the engine when running as a motor, through sliding gears controlled by the starting pedal. These machines are of comparatively heavy construction, and have armatures that are double wound and carry two commutators. One winding is made up of a single coil per slot, which is wound of heavy copper wire. This winding connects to the commutator segments of the large commutator. The other winding is made up of two coils per slot, wound of small wire, and many turns. This winding connects to the segments of the smaller commutator. The heavy winding is used when the machine runs as a motor, and the lighter winding when the machine runs as a generator. Instead of using a starting switch, the motor brushes are lifted off the commutator when machine is not running as a motor. The generator armature and the shunt field connects through the ignition switch to the battery.

ing gear at the end next to flywheel can easily be pushed into mesh with gear on flywheel as the starting pedal is pressed, and the turning force of the armature is not enough to knock the corners off the teeth of the gears. When the starting pedal has been pressed far enough down to slide the gears into full mesh,

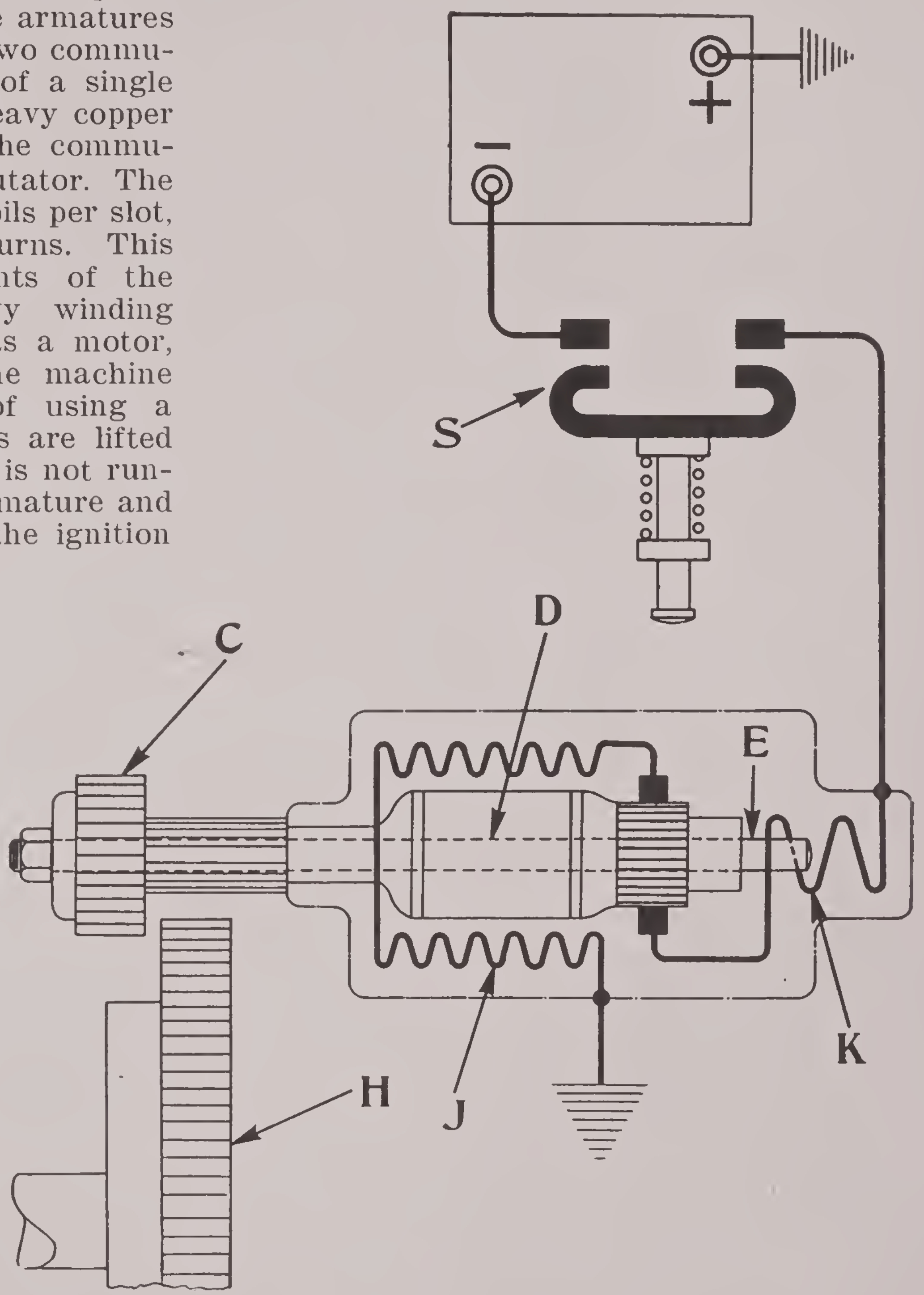


FIG. 293

C. Pinion.
D. Armature.
E. Shift rod.
H. Flywheel gear.
J. Field coil.
K. Solenoid.
S. Starting Switch.

When the ignition switch is closed, the generator armature and shunt field are switched in circuit with the battery which forces current through them, causing the armature to rotate. Since the generator armature is of many coils and of small wires, the armature turns slowly, and with little force. The armature is permitted to overrun the pump shaft by an overrunning clutch between the pump shaft and the motor-generator.

With the armature slowly rotating, the slid-

the motor brushes are forced down on the motor commutator, and the connection to the generator commutator is broken. On the Buick motor-generator the generator armature connection is broken by raising the positive generator brush. On others the connection to the positive generator brush is broken by a switch arrangement on the brush holder of one of the motor brushes which is opened when the brush is forced down on the commutator. (See Figs. 290-291.)

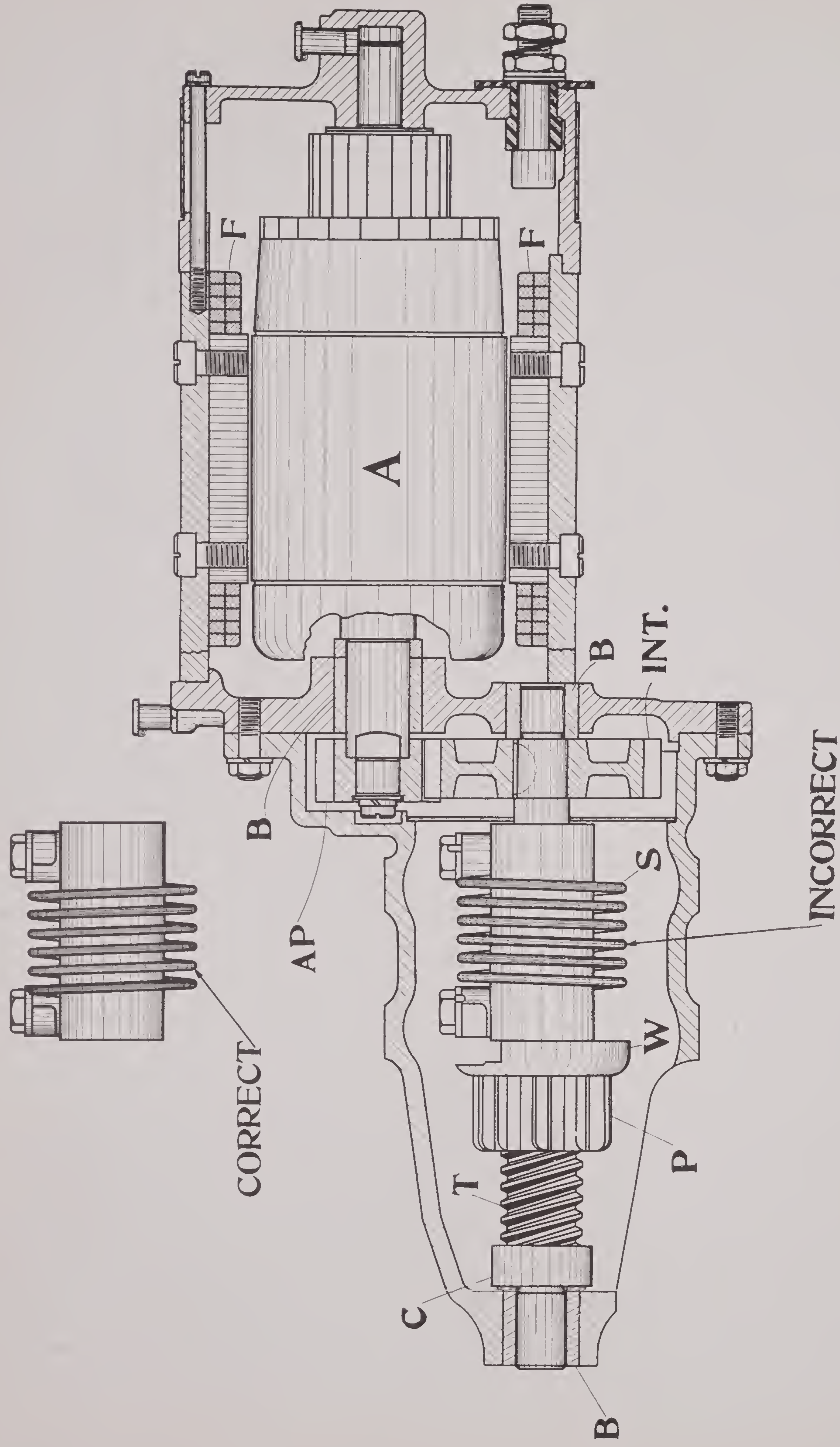


FIG. 294

A. Armature.
B. Bearing bushings.
C. Thrust collar.
F. Field coils.

P. Bendix pinion.
S. Bendix spring.
T. Threaded sleeve.

W. Bendix pinion weight.
AP. Armature pinion.
INT. Intermediate gear.

With the motor brushes on the commutator, the heavy series field coils, and the heavy armature winding are switched in circuit with the battery, and, being of low resistance, the E. M. F. of the battery causes a heavy current to flow through them that gives the armature torque enough to drive the engine through the sliding gears and the gear on the flywheel.

An overrunning clutch is carried in the sliding gears to prevent the engine from driving the armature at high speed when it starts. When the starting pedal is released it is drawn back to the neutral position by a spring, which draws the sliding gears out of mesh, raises the motor brushes off the commutator and at the same time, closes the switch making the connection to the positive generator brush. With the engine running, the armature is driven fast enough to generate a higher E. M. F. in the generator armature winding than that of a battery, hence the machine runs as generator and charges the battery.

Electromagnetic Shift

Fig. 293 shows the principle of the electromagnetic shift used on some of the Westinghouse starting motors. The soft steel shaft (E) passing through the hollow armature shaft, shifts the drive pinion (C.) The solenoid (K) at the commutator end of the motor is a few turns of heavy wire, and is connected in series with the motor. When the starting switch (S) is closed, the heavy current passing through the solenoid sets up magnetic lines of force that draw the shift rod through the hollow armature shaft, pulling the pinion into mesh with the gear on the flywheel. As soon as the engine starts, the load is thrown off the motor so that its speed increases and a stronger counter E. M. F. is generated. The stronger counter E. M. F. so decreases the current in solenoid that the sucking effect of the solenoid is not enough to hold the pinion in mesh against the spring that pushes the shift rod back to neutral position. When the pedal is released, a spring opens the starting switch and the motor stops. This system is sometimes equipped with a starting switch that is operated electromagnetically instead of with the foot. A solenoid is provided which is wound of many turns of small wire. This solenoid connects across the battery terminals through a small push-button switch on the dash. When the button is pressed the solenoid is energized so the plunger operating the switch is drawn into it, closing the starting switch.

Bendix Drive

Fig. 294 shows the Bendix drive. The pinion (P) is not keyed on the armature shaft but is carried on a heavy screw (T) which is mounted on the armature shaft or an intermediate shaft. When the starting switch is closed, by pressing the starting pedal, the motor starts very quickly. The pinion being heavy and weighted will not start to turn immediately but slips along the screw as the screw starts with the armature. The screw turning in the pinion pushes it along far enough to mesh with the gear on the flywheel. As the pinion meshes with the flywheel gear, it turns against the thrust collar at the end of the screw, which causes it to turn with the shaft, and so drive the engine. When the engine starts, it drives the pinion faster than the screw turns. The pinion overrunning the screw, is thrown back to the neutral position. When the starting pedal is released a spring opens the switch and the motor stops. The pinion is usually weighted on one side so it will not turn on the screw while the engine is running and be thrown against the gear on the flywheel causing a clattering noise. If there is mud or gum on the Bendix, the pinion will not slip on the screw, so the gears will not be brought into mesh when the motor starts.

A heavy strain is thrown on the gears just as the pinion turns against the thrust collar at the end of the screw, which is likely to strip the gear on the flywheel. This "jerk" is partly absorbed by the heavy Bendix spring through which the motor drives the screw. The Bendix spring should be coiled with the lay of the screw or the strain will break it. (See Fig. 294 for correct and incorrect springs.) Instead of using the Bendix spring, some manufacturers use a friction clutch. The clutch discs are held together with a spring, and the side thrust of the screw on the Bendix. The clutch slips enough at the start to prevent the "jerk" from breaking teeth out of the gear.

The Bendix sometimes "jams." This is usually caused by the starting motor being out of line with the crankshaft, or the pinion not meshing properly with the flywheel gear. The strong side thrust of the screw on the pinion forces the gears so tightly into mesh when the motor is not properly aligned that the engine cannot be turned. Sometimes a jammed Bendix can be loosened by putting the transmission in third speed and then rocking the car back and forth. At other times it may be necessary to knock the Bendix out with a hammer. When the Bendix jams, the starting motor should be realigned.

ELECTRICAL CONNECTIONS BETWEEN GENERATOR AND BATTERY

The "charging circuit" includes the generator, battery, usually an ammeter or an indicator, and a switch to open the circuit when the generator is not running so that the battery cannot discharge back through the generator.

The ammeter is included in the circuit to indicate the strength of the charge or discharge of the battery. The ammeter, or battery indicator, is a trouble indicator. The ammeter indicates the strength of the charge current or the strength of the discharged current, while the indicator just indicates that the battery is being charged or is discharging. Figs. 311 and 312 show typical ammeters used in the charging circuit. Fig. 313 shows a battery indicator.

The switch used to open the circuit when the generator is not charging, may be hand operated or automatic. A good example of the hand operated switch is found in some of the Delco systems. In these systems the ignition switch opens the charge circuit when in "off" position and closes the circuit when in "on" position. The automatic switch is usually called the cut-out relay, though sometimes called the cut-out, the circuit breaker, or reverse-current relay.

The wire used for the charge circuit is usually about No. 14 insulated copper wire. The resistance of the charging circuits varies with the different systems but is usually about one-tenth of an ohm. The connections should be well made, since loose connections on some systems cause the generator voltage to rise, at high speeds, to a point that burns out the lamps or the ignition circuit.

Cut-Out Relay

Figs. 295, 296 and 297 show the fundamental construction of a cut-out relay. There are two windings, voltage and series, on the core of the electromagnet which automatically closes the relay.

The voltage winding is of fine wire and many turns (500 to 1,500 turns) and is connected to the positive and negative terminals of the generator. The resistance of the voltage winding is often as high as 50 ohms. The series winding is of heavy wire and comparatively few turns. The series winding together with the contacts is connected in series with the generator and the battery. The resistance of the series winding is very low, so low that it is practically negligible.

Operation of Cut-Out Relay

(See Fig. 295.)

As a generator builds up, it forces current through the voltage winding. As soon as the generator voltage goes above that of the battery, the current through the voltage winding reaches a strength that magnetizes the core strong enough to draw the contacts (C) together against the tension of the spring (S) which tends to hold them apart. When the contacts close, the circuit through the generator and battery is completed and the higher voltage of the generator causes an electric current to flow through the battery in the direction to charge it. The series winding is so wound and connected that the charge current flows through it in the same direction as the current flows in the voltage winding, hence assists the current in the voltage winding in magnetizing the core and holding the contacts together.

When the generator voltage drops below that of the battery so that the battery discharges back through the generator, the current reverses in the series winding, but not in voltage winding, and thus partly demagnetizes the core so that the spring draws the contacts apart, opening the circuit.

Adjustments on Cut-Out Relay

There are two adjustments that can usually be made on a cut-out relay. The tension of the spring is first adjusted so that the contacts are drawn apart before the strength of the discharge goes above one ampere. (The contacts should separate when the strength of discharge is between zero and one ampere). Then the stop (see (A) in Fig. 296 and (B) in Fig. 297) against which the arm drops when the spring draws the contacts apart, is so adjusted that the contacts close on six volt systems when the generator generates between 6½ and 7¾ volts. On twelve volt systems, the contacts should close when generator generates from 13 to 15 volts. If the contacts close too early, the arm does not drop back away from the end of the core far enough. If the contacts close too late the arm drops back away from the end of the core too far.

Tests for Terminals of Cut-Out Relay

(See Fig. 295.)

There are three terminals on the cut-out relay. If the relay is used on systems using the frame of the car as one side of the circuit,

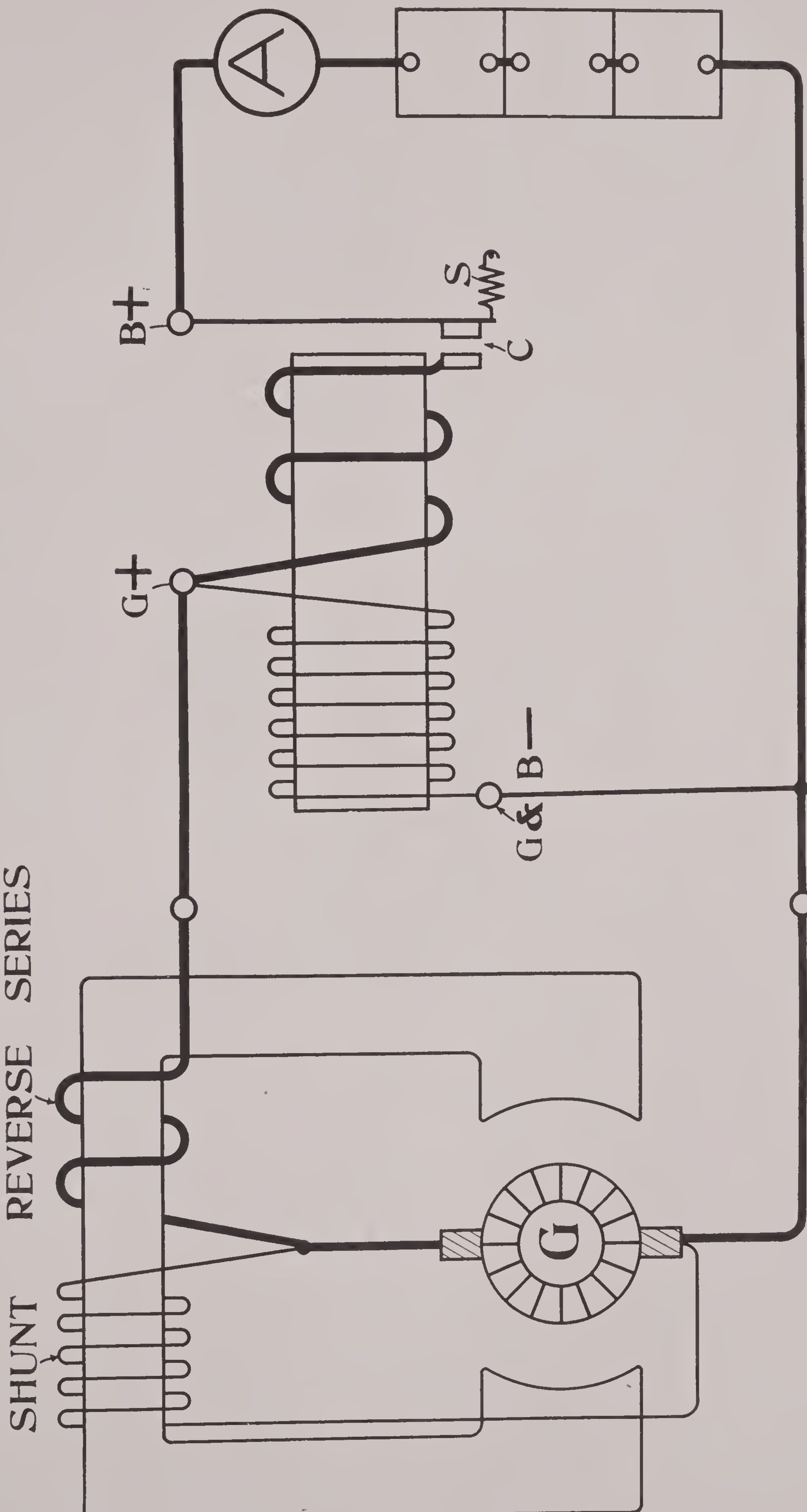


FIG. 295

(one wire system) one of the terminals is grounded. The terminal that grounds, (connects to frame) connects to one end of voltage winding, but not to the series winding. To distinguish this terminal from others it will be called terminal (G & B) in the notes. Some cut-out relays used on one wire systems have this end of the voltage winding connected to the metal base, and so does away with terminal (G & B.) One terminal connects to both the series and voltage windings. This terminal is called terminal (G.) The terminal that connects to the series winding through the contacts is called (B.)

The tests can be made best with a test lamp. Place the test points on two of the terminals of the relay. If the lamp lights and the contacts close, one of the terminals the test points are on, is (G) and the other is (G & B.) Terminals (G) and (G & B) must connect to the generator. Shift one test point to the third terminal on the relay. The lamp will not light now till the contacts are pushed together. If when the contacts are closed, the lamp lights and is bright the test points are on terminals (G) and (B.) If the lamp lights but is dim and contacts stay together as long as test points are on the terminals, the test points are on terminals (G & B) and (B.) Terminal (B) connects through the ammeter to the terminal of the battery that is not grounded. Terminal (G) connects to the generator terminal that is of the same polarity as the terminal of the battery which connects to (B), and terminal (G & B) connects to other terminal of generator. The terminal of generator to which (G) connects must not be grounded. The terminal of generator to which (G & B) connects may or may not be grounded.

REGULATION

Regulation of a generator has to do with the automatic controlling mechanism, either mechanical or electrical, that prevents the generator from generating excessive voltage at high speeds.

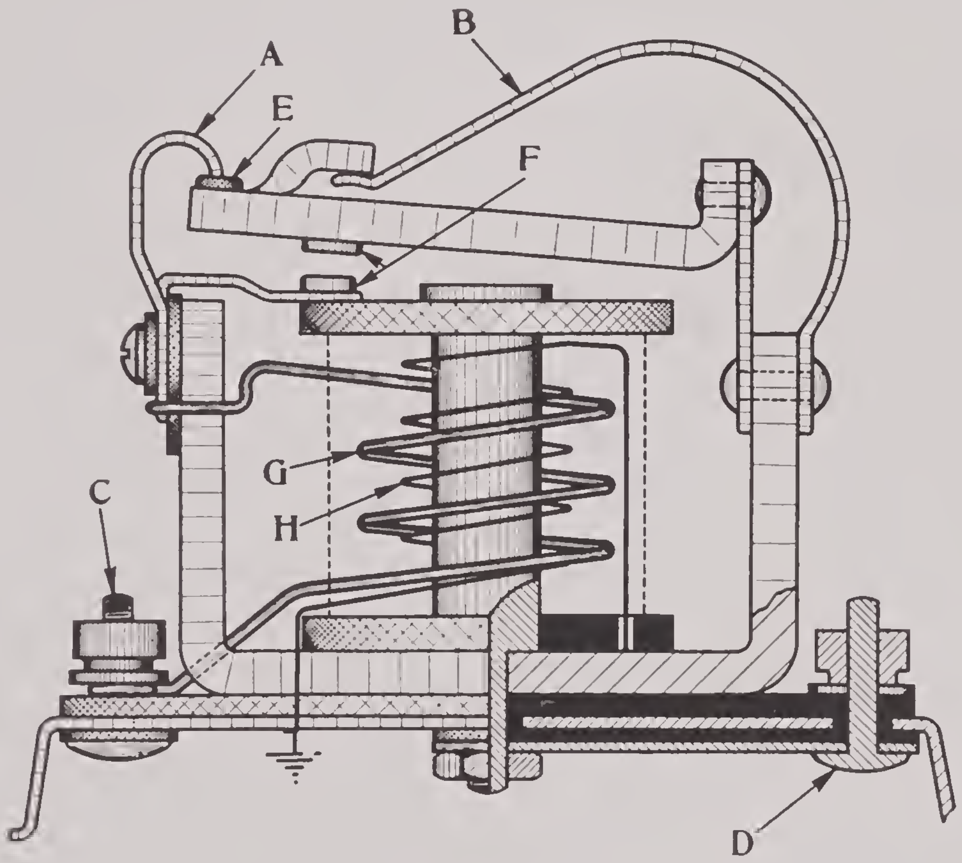


FIG. 296

CUT-OUT RELAY

A. Stop which prevents bar from dropping back away from core too far. Make air gap adjustment here.
B. Spring.
C. Battery terminal.
D. Generator terminal.
E. Fiber block which insulates bar from stop.
F. Contacts.
G. Series winding.
H. Voltage winding.

The automobile generator always has a shunt field winding and in addition to the shunt, some have the series field winding, and so are compounded. Practically all automobile generators are coupled to the engine, so that the speed of the armature varies with the speed of the crankshaft. A few of the earlier types (1914 and 1915) were driven through friction clutches controlled by governor mechanisms for the purpose of regulation. These types now are practically obsolete.

The automobile generator is usually designed to generate from 6½ to 7 volts if used on systems with a 6-volt battery, from 13 to 14 volts if used on systems with a 12-volt battery, when the car is running at a speed of from 7½ to 10 miles per hour. This is necessary if the generator charges the battery at low engine speeds, as well as high engine speeds. When the speed of the car is increased,

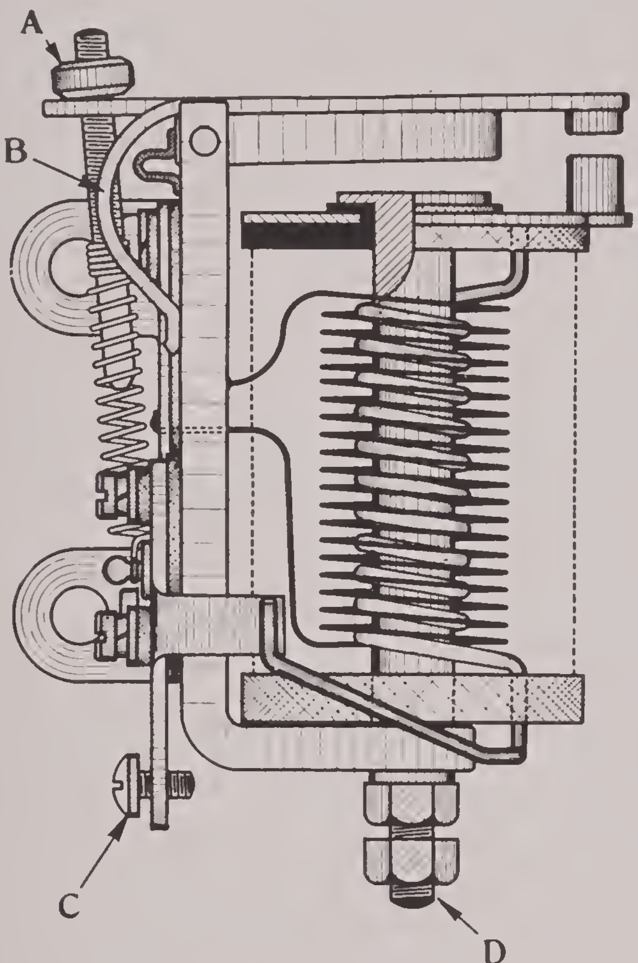


FIG. 297

A. Spring tension adjustment.
B. Arm which prevents contacts from separating too far.
C. Battery terminal.
D. Generator terminal.

the speed at which the armature is driven is increased correspondingly. As the speed of the armature increases the generated voltage increases. The voltage of a straight shunt generator increases almost with the square of the speed. Therefore if the generator was not regulated, it would generate high voltage at and above average running speed, so that parts of the system, such as the shunt field of generator, voltage winding of cut-out relay, lamps, ignition coil, etc., would be burned cut.

The cumulative compound generator builds up even faster with an increase in the speed than a straight shunt generator, hence is even less suitable for the automobile than the straight shunt generator. The straight series generator is in no way suitable for the automobile. Because of the demagnetizing effect of the current in the series field coils of the differential compound generator, it has a natural regulation that makes it suitable for use on the automobile. However, in some respects, the differential compound generator is unsuitable.

The ideal generator for the automobile would be one which would give the same voltage at all speeds of the car, and this voltage to be such that would force the current back through the battery at a rate that would just keep the battery in a fully charged condition. Such a generator as this is impracticable to build. Instead, generators regulated by some appliance to give about constant current, or constant voltage, are used. Regulation includes the different appliances used to control the generator so that it will give about constant current, or about constant voltage.

The strength of the E. M. F. (voltage) which a generator produces depends upon the way the armature is wound, speed of armature and the strength of field. Since the armature winding cannot be varied while machine is in operation, regulation must be accomplished by controlling the speed of armature or weakening the field as speed of armature increases, and vice versa.

Friction clutches carrying governor mechanism for controlling the speed of the armature so that the engine cannot drive it fast enough for generator to generate an excessive voltage, were used; but, since the facings of these clutches were worn very quickly—such clutches are slipping practically all the time at average engine speeds—this method of regulating generator was but little used. All other appliances for regulating the generator output weaken the field as the speed of the armature increases.

The more important appliances for weakening the field are as follows:

(1) Reverse-Series Field Coils. Generators having reverse series field coils are those which are differential compound.

(2) Vibrator Regulators. The vibrator regulator inserts resistance in series with the shunt field at higher armature speeds. These vibrators may be controlled by the current which the generator forces through the battery to charge it; by the voltage which the generator generates; or by both the current and the voltage; or mechanically operated by cam on armature shaft.

(3) Third Brush.

Reverse-Series Field Coils

Differential compound generators have an inherent or self-regulation, which is usually called "Reverse Series" or "Bucking Coil" regulation. (See Fig. 295.) The shunt field coils are so wound and connected that as the generator builds up from residual magnetism, the current forced through them magnetizes the poles stronger, and so sets up a stronger field. The series field coils are so connected that the current forced through them tends to demagnetize the poles.

With the generator connected to a storage battery through a cut-out relay, there is practically no current in the series field coils until the cut-out relay contacts close; but since the shunt field coils are shunted around the armature, current builds up in them which strongly magnetizes the field poles, before the generator

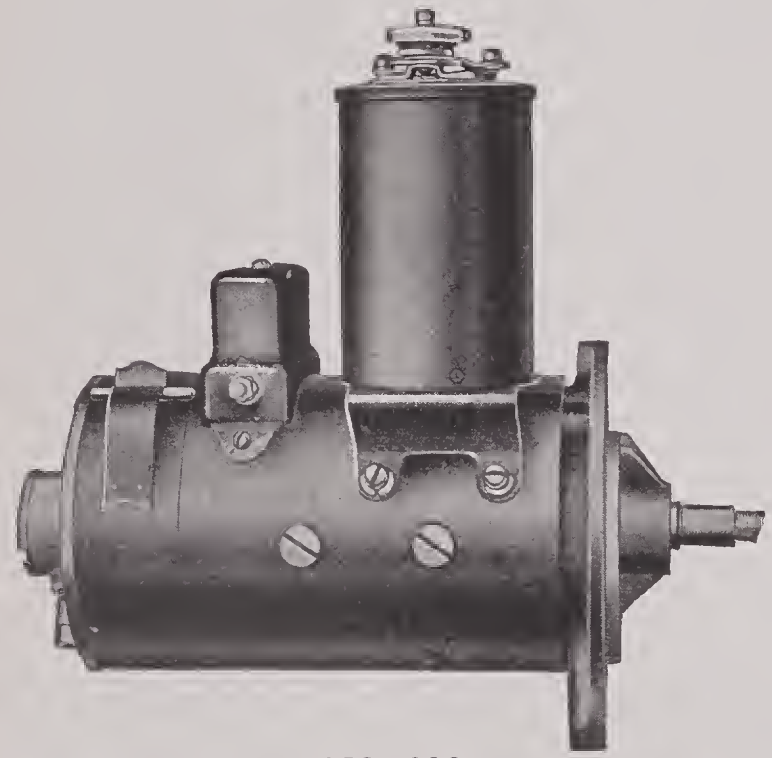


FIG. 298

CUT-OUT RELAY AND IGNITION COIL MOUNTED ON GENERATOR—REMY

builds up to high enough voltage to close the cut-out relay contacts. Therefore a strong field is built up before the speed of the armature becomes high enough for the generator to begin charging the battery. As the speed of the armature is further increased, the generator voltage rises high enough to close the cut-out relay contacts and force current through the battery in the direction to charge it.

The voltage, so long as the battery is connected to generator, cannot rise more than a few volts above that necessary to close the cut-out relay contacts, since the current that is forced through the battery, flows through the series field coils tending to demagnetize the poles, hence weakening the field. Further increasing the speed of the armature will not cause the generator to force current through the battery at a much higher rate, as an increase in the current so weakens the field that even though the armature is turning at a higher speed, the armature conductors cut the lines of force at practically the same rate.

The strength of the current which the generator of this type forces through a battery depends largely upon the ratio between the number of turns in the shunt field coils and the number of turns in the series field coils. The field coils of generators are so wound at the factory that the machine will force the current through the battery at a rate that experience has shown, will just about keep the battery charged. Should this charge rate be too low to keep the battery charged, because of unusual driving conditions, it will be necessary to have the battery charged occasionally at a service station. Or, if the charge rate of the generator is too high, so that it is overcharging the battery, it may be necessary to burn the lights, even in the day time, when making long trips.

Under unusual conditions, the rate may be lowered by inserting a special resistance in series with the shunt field circuit of the generator; or the rate may be increased by connecting a conductor in parallel with the reverse series field coil. In either instance the exact resistance to be used must be determined by experiment.

Another method by which the output of a reverse series generator may be changed, is to change the number of turns in the reverse series field winding. Decreasing the number of reverse series field turns, increases the charging rate. Increasing the number of reverse series turns, decreases the charging rate. When this method is used, the field coils must be rewound. Adding turns to the shunt field winding will not increase the charge rate.

Some generators of this type—Bosch Rushmore, for example—have a small coil of iron wire connected in parallel to the series field coils. This coil of iron wire is called ballast resistance. Since it is in parallel to the series field coil, part of the current which the generator forces through the battery passes through it, instead of all going through the series field, consequently has no direct effect on the field. The part going through the ballast coil depends upon its resistance and the resistance of the series field coils. The higher the resistance of the ballast coil the less current passes through it, and the more passes through the series field coils. The lower the resistance of the ballast coil the more current passes through it, and the less passes through the series field coils. By changing the ballast coil to one of different resistance, the charge rate of the generator can be changed—if a coil

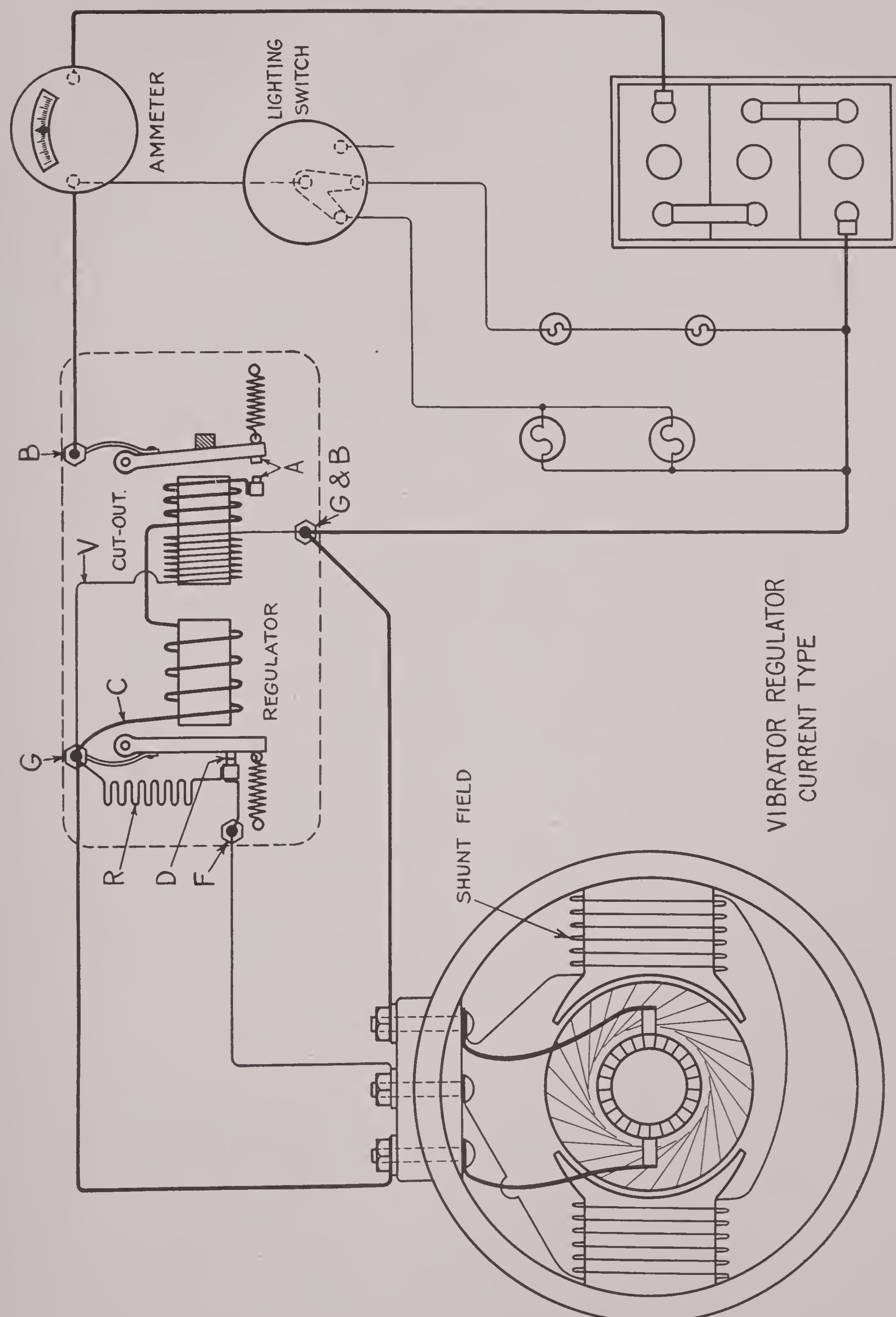

AMMETER
LIGHTING SWITCH
B
A
CUT-OUT.
V
G & B
REGULATOR
C
G
R
D
F
SHUNT FIELD
VIBRATOR REGULATOR
CURRENT TYPE

FIG. 299

of higher resistance is used, the charge rate is decreased, or if one of lower resistance is used the charge rate is increased.

Generators having reverse series regulation give about constant current at average running speeds and so are called constant current generators.

Vibrator Regulator—Current Type

The vibrator regulator is a small appliance which weakens the field by intermittently inserting resistance in series with the shunt field coils as the speed of the armature increases. When resistance is inserted in series with the shunt field coils, the current through them is weakened, hence fewer lines of force are set up in the field.

The fundamental construction of the current type vibrator regulator is shown in Fig. 299. The regulator consists of an electromagnet, the winding of which is large wire and comparatively few turns and is connected in series with the generator and the battery.

A small bar of soft iron is mounted near one end of the core of the electromagnet and normally held away from the core by a spring. The contact carried on the soft iron bar is held against another contact by the spring which holds the bar away from the core of the magnet. A coil of several ohms resistance is connected in parallel to these contacts and the contacts are connected in series with the shunt field circuit. As long as the contacts are together, the coil of resistance is shorted by them hence the resistance of the shunt field circuit is practically the same as the shunt field coils. If the bar is pulled over against the core, the contacts are separated, and the coil of resistance is thrown directly in series with the shunt field coils, adding several ohms resistance to the shunt field circuit, which decreases the field current and therefore weakens the field.

The operation of the regulator is as follows: As the speed of the armature increases, the strength of the generated E. M. F. increases; and, when it has reached a value ample to charge the battery, the cut-out relay contacts are drawn together, closing the charge circuit. The rate at which the generator forces current through the battery depends upon how much the generator voltage exceeds the voltage of the battery. As the generator voltage continues to rise with an increase in the speed of the armature, the strength of the charge current increases.

As the strength of the charge current increases, the core of the regulator is magnetized more strongly. When the charge current reaches a strength that magnetizes the core strongly enough to attract the bar against the tension of the spring, the regulator contacts are drawn apart, and the resistance coil is thrown in series with the shunt field. This added resistance in series with the shunt field coils so weakens the field that the generated E. M. F. drops to about that of the battery. As the generated E. M. F. drops, the strength of the charge current becomes less and the core of the regulator partly demagnetizes, permitting the spring to pull the bar away from the end of the core, and again close the contacts. When the contacts close, they short the resistance coil which was in series with the shunt field, and the generator again builds up to a voltage higher than that of the battery, forcing current through the battery. When the charge current again reaches a strength that magnetizes the core strong enough to attract the bar against the tension of the spring, the regulator contacts are separated and the operation is repeated.

The operation of the regulator is such that at speeds above that at which the generator forces a current through the battery strongly enough to just about magnetize the core and attract the bar, the bar will vibrate, inserting resistance intermittently in series with the shunt field. Intermittently inserting resistance in series with the shunt field coils in this manner, so weakens the field that the generator cannot generate a voltage higher than that which forces the current through the battery at the determined rate, even though the armature be driven at a very high rate of speed. This regulator is called a constant current type regulator, since it so regulates the generator that it gives about constant current at average running speeds.

The rate at which the regulator permits the generator to force current through the battery is determined by the tension of the vibrator spring. If the charge rate is too low, it can be increased by increasing the tension of the spring; if the charge rate is too high, it can be decreased by decreasing the tension of the spring.

Vibrator Regulator—Voltage Type

Fig. 300 shows the fundamental construction of a vibrator regulator of the straight voltage type. This type regulator differs from the current type regulator in that the winding on the core is of many turns of fine wire, and is connected in parallel to the battery. This type regulator gives about constant voltage regulation, since the strength of the current in the winding on the core depends directly upon the strength of the generator voltage and not upon the strength of the current passing through the battery.

On systems using a 6 volt battery, the ten-

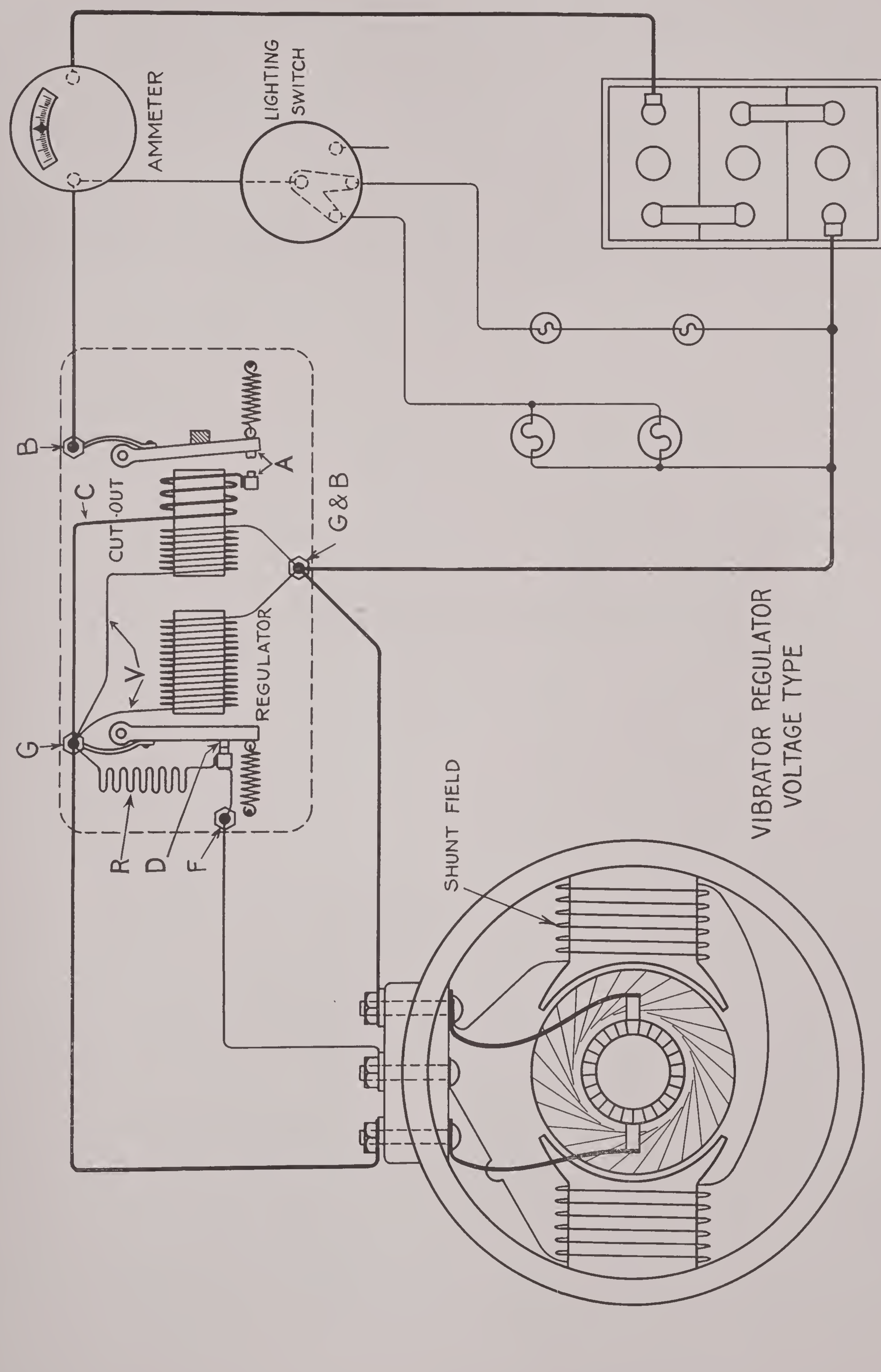

AMMETER
LIGHTING SWITCH
B
C
CUT-OUT
A
G & B
REGULATOR
V
G
R
D
F
SHUNT FIELD
VIBRATOR REGULATOR
VOLTAGE TYPE

FIG. 300

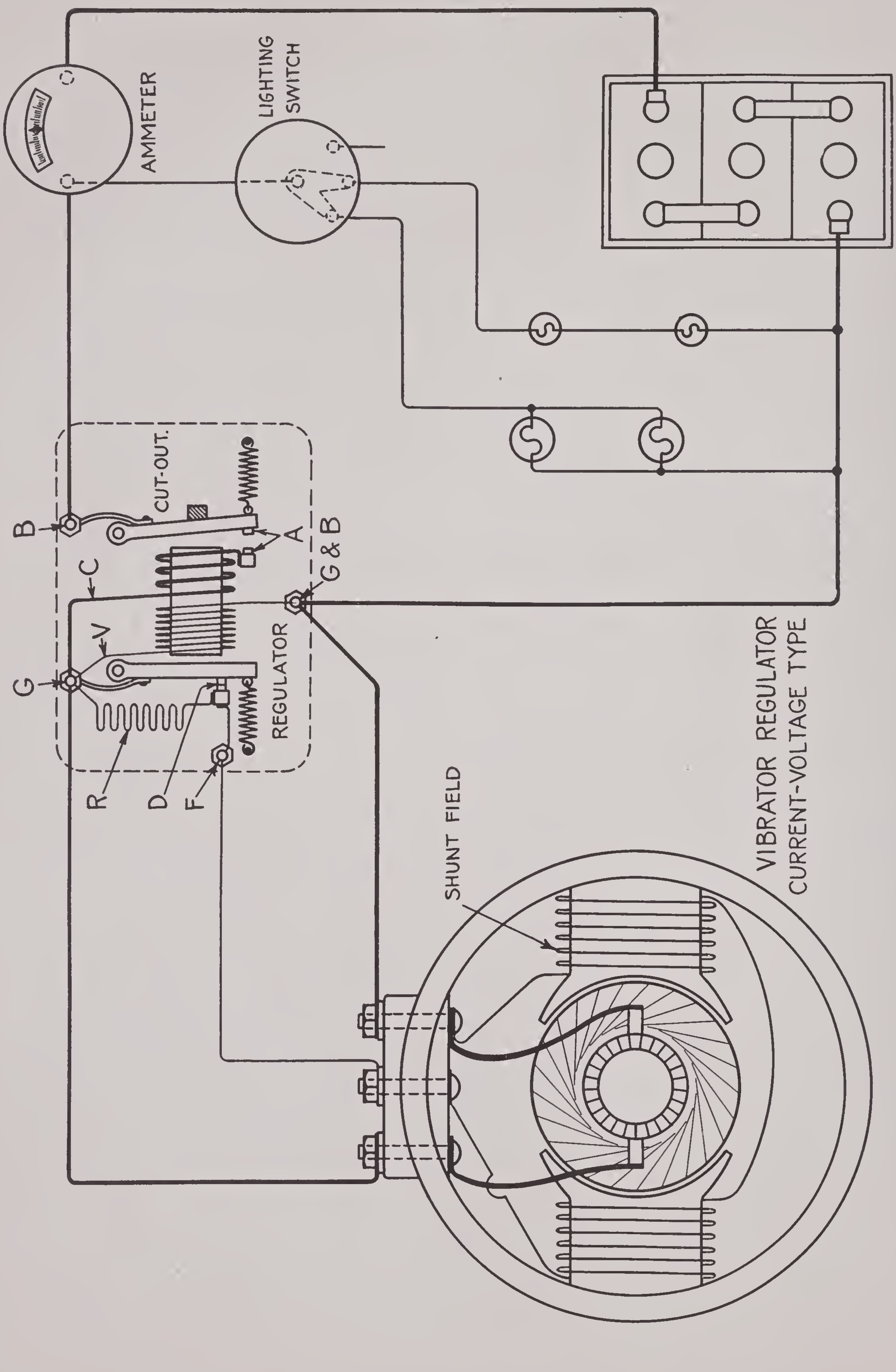

AMMETER
LIGHTING SWITCH
CUT-OUT.
B
C
A
G & B
G
V
REGULATOR
R
D
F
SHUNT FIELD
VIBRATOR REGULATOR
CURRENT-VOLTAGE TYPE

FIG. 301

sion of the vibrator spring is so adjusted that the current which flows through coil on the core when the generator voltage is from $7\frac{1}{4}$ to $7\frac{1}{2}$ volts, magnetizes the core strong enough to draw the contacts apart. With this adjustment the regulator permits the generator to build up to $7\frac{1}{4}$ to $7\frac{1}{2}$ volts, but prevents it from building up to a higher voltage.

Generators equipped with this type regulator are not likely to overcharge the battery since the back E. M. F. of the battery rises to about that of the generator when the battery becomes fully charged. As the back E. M. F. of the battery rises, the difference between the voltage of the generator and the voltage of the battery becomes less, since the in the series winding depends upon the strength of the charge current; and since there must be current in both the voltage and series windings to magnetize the core strong enough to draw the regulator contacts apart.

The characteristics of this regulator lie between those of the current and voltage types.

Care and General Characteristics of Vibrator Regulators

The charging rate of all systems using a vibrator type regulator may be changed by changing the tension of the spring that holds the regulator contacts together.

Keep the contacts clean by the use of fine sand paper.

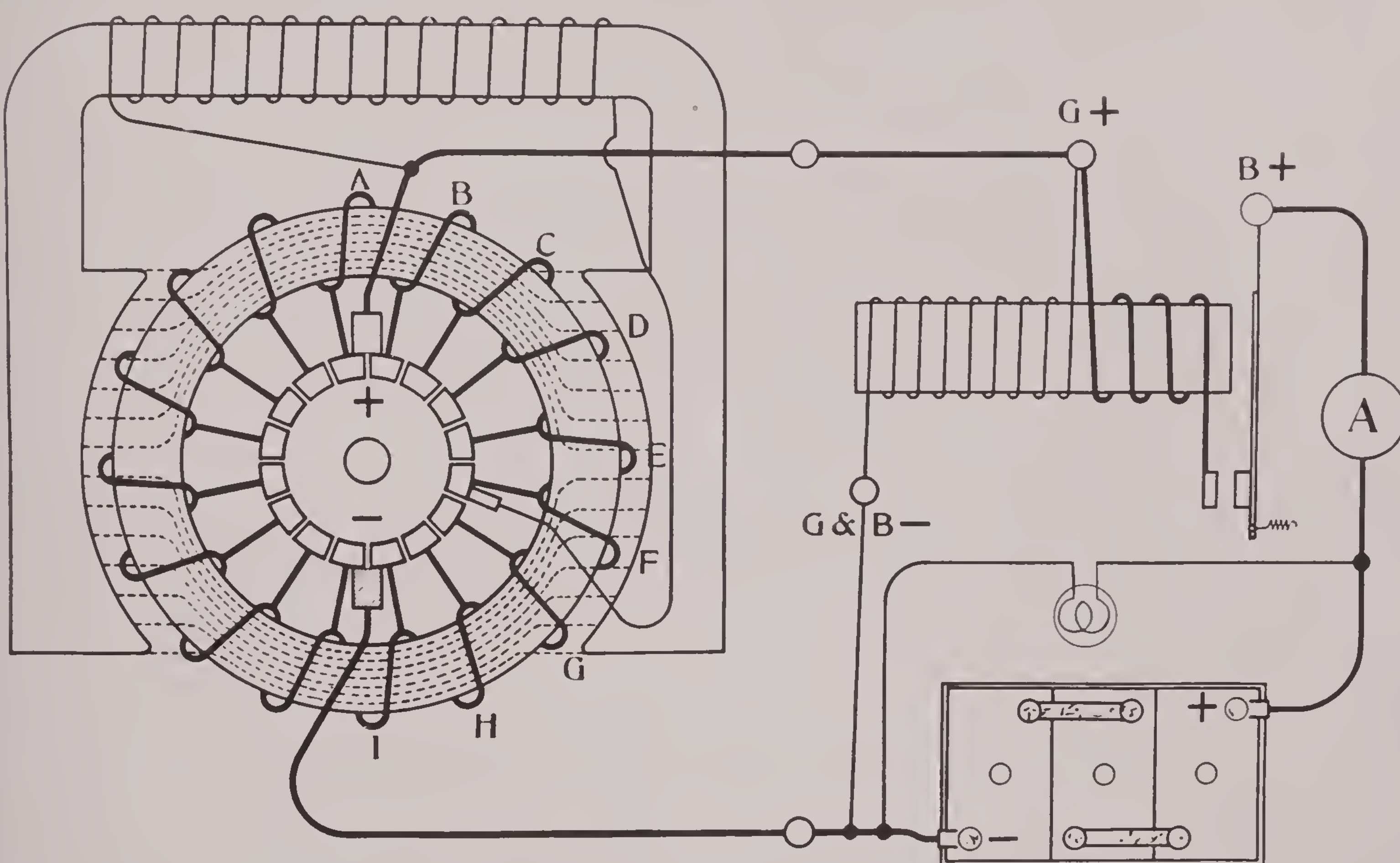


FIG. 302

voltage of the generator cannot rise beyond that which forces current through the coil on the regulator core at a rate that magnetizes the core strong enough to draw the contacts apart.

Vibrator Regulator—Current-Voltage Type

Fig. 301 shows the fundamental construction of the current-voltage type regulator. This regulator is combined with the cut-out relay, so that the same windings and the same core can be used for both. This regulator is called current-voltage type, since the strength of the current in the voltage winding depends upon the voltage of the generator, and the current

If the regulator contacts stick in a closed position, the charging rate will be excessive. If they fail to close, the rate will be either very low, or will cut out altogether.

If the resistance burns out, the contacts will become badly burned and often stick.

Many vibrator regulators are equipped with two sets of contacts, which give longer life. In this case one set separates a little before the other.

Field Distortion Regulation

A general idea of field distortion produced by the reaction of the armature current on the field can be gained by comparing Figs. 302

and 303. In Fig. 302 the field is of uniform strength on both sides of the armature, but in Fig. 303 the lines of force are crowded towards the upper tip of the north pole and toward the lower tip of the south pole. This twisting of the lines of force out of their natural path is caused by the magnetic field set up by the current in the armature coils. The current sets up lines of force about the armature conductors which push the lines forming the field forward, distorting the field. The stronger the current in the armature coils the farther the lines are pushed out of their path, and the more the field is distorted.

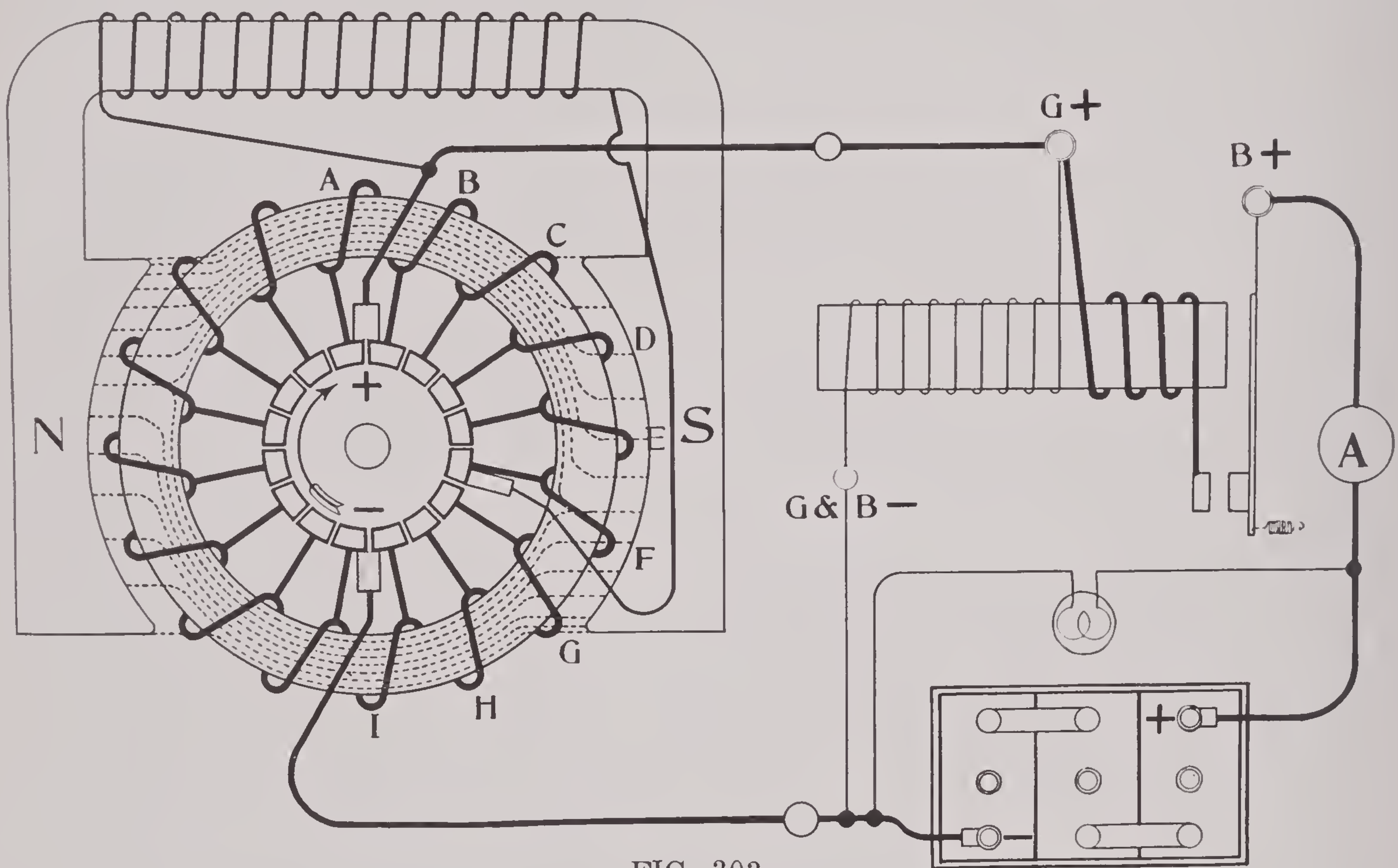


FIG. 303

In Fig. 302 it is assumed that the generator is running just fast enough to generate six volts, a voltage that is not high enough to close the cut-out relay contacts. The only current now passing through the armature is the shunt field current, which is comparatively weak, and not strong enough to distort the field to a noticeable extent. In Fig. 303 it is assumed that the generator is running faster, generating about 7½ or 8 volts, a voltage that is high enough to close the cut-out contacts, and charge the battery at about a 15 ampere rate. The current now passing through the armature is 15 amperes plus the field current. Current flowing through the armature at this rate is strong enough to distort the field considerably.

When use is made of field distortion for regulation, an odd brush, called the third brush, is added. One end of the shunt field connects to this brush, and the other end to one of the main brushes. The third brush is not placed on the point of commutation (neutral point) but instead, is placed around in the direction the armature turns, from the main brush that connects to the shunt field and near the other main brush. With this arrangement the current in the shunt field coils will become less as the field distorts, hence the field weakens.

The manner in which the field is caused to weaken as the speed of the armature increases is described in general in the following. It is not possible to give in the description exact values for the E. M. F. in the armature conductors or the strength of the charge current, since Figs. 302 and 303 are merely illustrative and do not show as many armature conductors as must be used in a generator. However values have been given which will illustrate the conditions in a generator having field distortion regulation while it is in operation.

In Fig. 302 the speed of the armature is such that 6 volts are generated. The strength of the E. M. F. induced in the conductors as they pass points (C), (D), (E), (F) and (G) are respectively about ½, 1½, 2, 1½ and ½ volts. The conductor while passing point (C), will not have as high an E. M. F. induced in it as when passing point (E), since at (C) it is not moving directly across the lines of force as it is at (E). These armature coils are in series, so their combined E. M. F. is equal to their sum, or 6 volts, the force drawing the current through the armature from the negative brush, and forcing it to the positive brush.

The E. M. F. induced in conductors under north pole is equal to the E. M. F. induced in the conductors under the south pole to which they are diametrically opposite; hence the E. M. F. either side is the same. The force drawing the current from the third brush through the armature, and forcing it to the positive brush, is only the sum of the E. M. F.'s in the conductors passing points (C), (D) and (E), or 4 volts. Since the shunt field connects to the positive brush and the third brush, there is an E. M. F. of 4 volts acting to cause current to flow through shunt field coils.

When the voltage is increased by further increasing the speed of the armature, the cut-out relay closes and the generator forces current through the battery in the direction to charge it. When the armature reaches the speed at which the voltage is about 7½ volts, the charge current is about 15 amperes. As the current of 15 amperes is drawn through the armature, the field is so distorted that the condition represented in Fig. 303 is produced. Since the lines of force are now crowded toward the top of the north pole and toward the bottom of the south pole, the conductors as they pass points (C) and (D), cut fewer lines than when passing points (F) and (G). The values of the E. M. F. induced in the conductors now as they pass points (C), (D), (E), (F) and (G), are about ¼, ¾, 2, 2½ and 2 volts respectively. Their combined E. M. F. is 7½ volts, which is the force drawing the current through the armature from the negative brush and forcing it to the positive brush. The E. M. F. drawing the current from the third brush to the positive brush is the sum of the E. M. F. in the conductors passing points (C), (D) and (E), or 3 volts. The force now drawing the current through the shunt field is less than before the field was distorted, hence the current in the shunt field is less and the field is weaker.

Generators having this type of regulation usually reach their maximum output when the car is running about 25 miles per hour. At speeds above 25 miles per hour, the output falls off, because the field is then so weakened that less current in the armature distorts it to the point of regulation.

If the battery is disconnected from a generator of this type, the generator has no regulation and if run without battery will likely burn out the field. If car is to be run without battery, either short the generator or open the field.

The E. M. F. induced in the armature conductors as they pass the north pole is equal and opposite to that induced in them while passing the south pole, and assists in drawing the current through the armature from the negative brush to the positive. But, since with connection shown in illustration the current in the field coils is produced by the E. M. F. induced in armature conductors under the south pole, the right side of armature was considered in the explanation. Practically the same results could be obtained were the third brush placed on the opposite side of commutator. The end of field coils which connects to positive brush in the figure, should then be connected to the third brush and the other end of field coils connected to the negative brush.

The charging rate is increased by moving the third brush in the direction the armature rotates and is decreased by moving the third brush in the opposite direction to that in which the armature rotates. After shifting the brushes on any machine, whether a third brush, or main brushes, refit them to the surface of the commutator.

Care of Commutator and Brushes

By far the greater per cent of the troubles peculiar to motors and generators, is with the commutators and the brushes. If they are kept in proper operating condition other troubles are considerably in the minority. The commutator must be smooth, round and concentric to the shaft so that the brushes will ride on its surface and make a good contact.

To true up a commutator, it should be placed on the centers of a lathe and the surface turned off until it is accurate. The shape of the lathe tool is shown at the upper left in Fig. 304. It should have a keen diamond shaped point of approximately the shape shown in the illustration. Light cuts should be taken until the surface is made accurate. When making the last or finishing cut, the tool should have a very keen edge and the cutting point should be rounded slightly with an oilstone.

The finishing operation, after the final cut has been made, may be done with fine sandpaper. After the turning operation is completed, the mica between copper segments should be "undercut." The proper way to undercut the mica segments is shown at (C). The mica should not be undercut below the surface of the copper bars more than 1/32″. This may be done with a piece of hacksaw blade with a suitable handle. (See (E) in Fig. 304.) If the hacksaw blade is too thick to fit between the copper segments, grind the sides of the blade on an emery wheel.

It is seldom necessary to undercut the mica between the segments of starting motor commutators. Starting motors are used so little that trouble seldom arises from "high mica" in the commutator.

Brushes should be fitted to a commutator by drawing a strip of sand paper between the brush and the commutator as shown at (D). There should be some pressure applied to the top of the brush to facilitate rapid grinding. Coarse sandpaper may be used to grind the brush to an approximate fit, after which No. 00 sand paper should be used for the finishing process.

GENERAL RULES AND SUGGESTIONS

Keep the commutator round, smooth and free from oil and grease.

Keep the brush spring tension sufficient to maintain proper brush contact at all times.

Keep ALL connections clean and tight.

See that the bearings are properly lubricated and not worn.

Do not over-lubricate the bearings. Too much lubrication is sure to result in the commutator and brushes becoming gummed.

See that the armature core does not drag on the pole pieces.

TEST LAMP AND BUZZER

A test lamp or test buzzer are often quite necessary for testing electrical equipment of all sorts, especially automotive equipment.

The correct way to connect a test lamp is shown in Fig. 305. The most suitable pressure

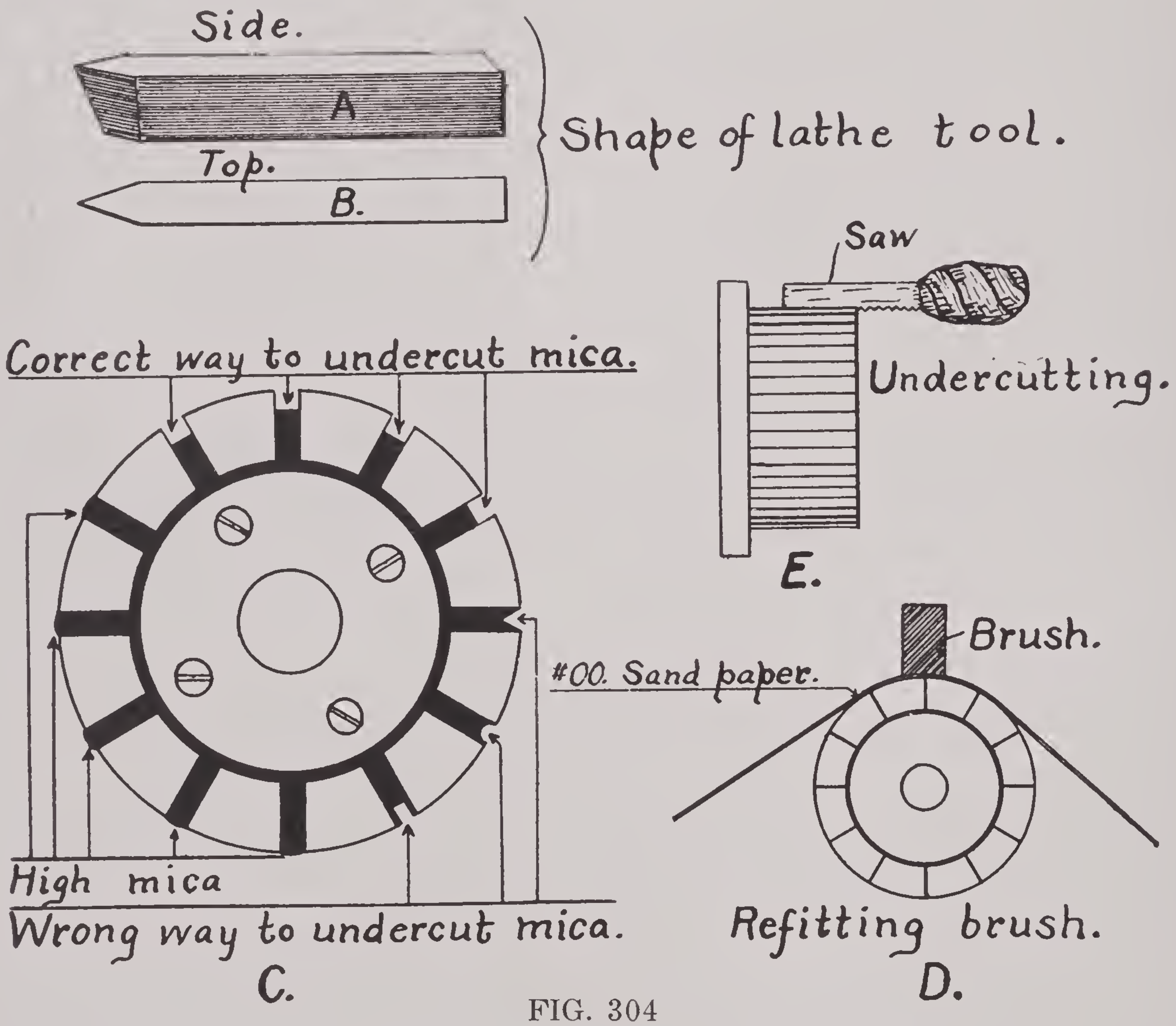


FIG. 304

Keep the brushes free in their holders so the brush spring will keep them against the commutator.

Keep oil and grease off the brushes.

Keep dirt out of the grooves between the commutator segments when the mica is undercut.

See that the small flexible conductors ("shunts" or "pig tails") are properly connected to the brushes and the brush holders.

to use for a test lamp is 110 volts, and direct current is preferred. The lamp is in series with one of the conductors leading to the test points. If the circuit is a 220 volt circuit, both lines which lead to the test points should be cut and a 110 volt lamp connected in series with each test point.

The internal circuit as well as the external wiring of a buzzer outfit is shown in Fig. 306. The buzzer has two binding posts (G) and (F).

One of the test points is connected directly to one of these binding posts. Four dry cells are connected in series to serve as a source of E. M. F. for the buzzer. The other test point is connected to one terminal of the dry cell battery, and the remaining terminal of the battery is wired directly to the other binding post of the buzzer.

The buzzer consists of a metal base upon which is mounted a U-shaped electromagnet. An armature of soft iron (A) is mounted upon a spring (B) near the poles of the magnet. A contact is attached to this armature by spring (H). This contact stands normally against the end of a screw (E).

The operation of the buzzer is as follows: When the test points (K) are placed together, the electric circuit is completed and the current flows from the positive side of the battery to (F), through the two coils on the magnet core to (C), through spring (B) and (H), contacts (E) to (D), thence to (G), and through test points (K) to the negative side of the battery. This flow of current magnetizes the core of magnet, which then attracts armature (A), thus causing contacts (E) to separate. The separating of the contacts breaks the circuit and the core of the magnet becomes demagnetized. The armature is then drawn away from the core by the spring (B), closing the contacts; thus the circuit is again established and the operation is repeated. This device will continue to operate so long as the test points (K) are held together. A buzzer is very convenient for testing circuits of few ohms resistance to determine whether they are complete or open.

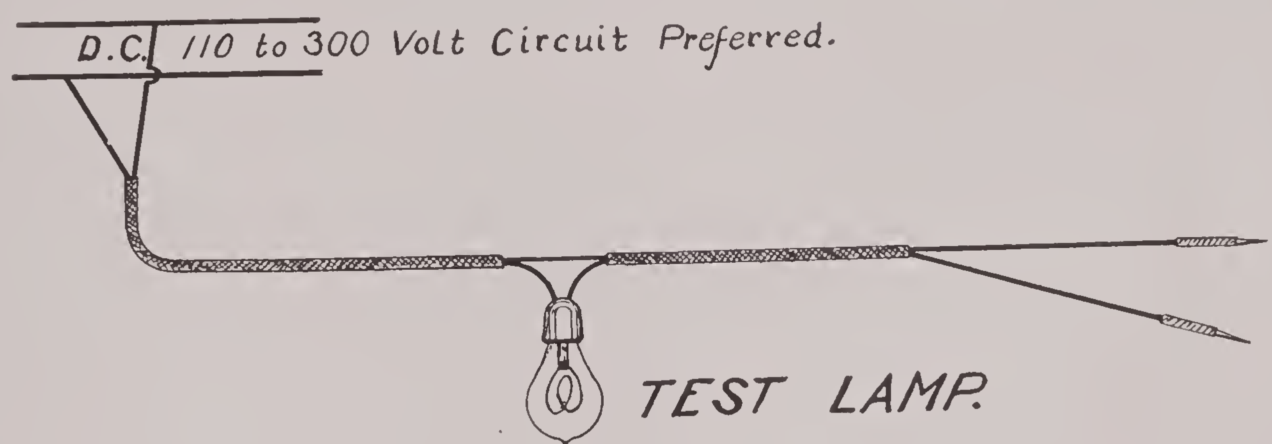


FIG. 305

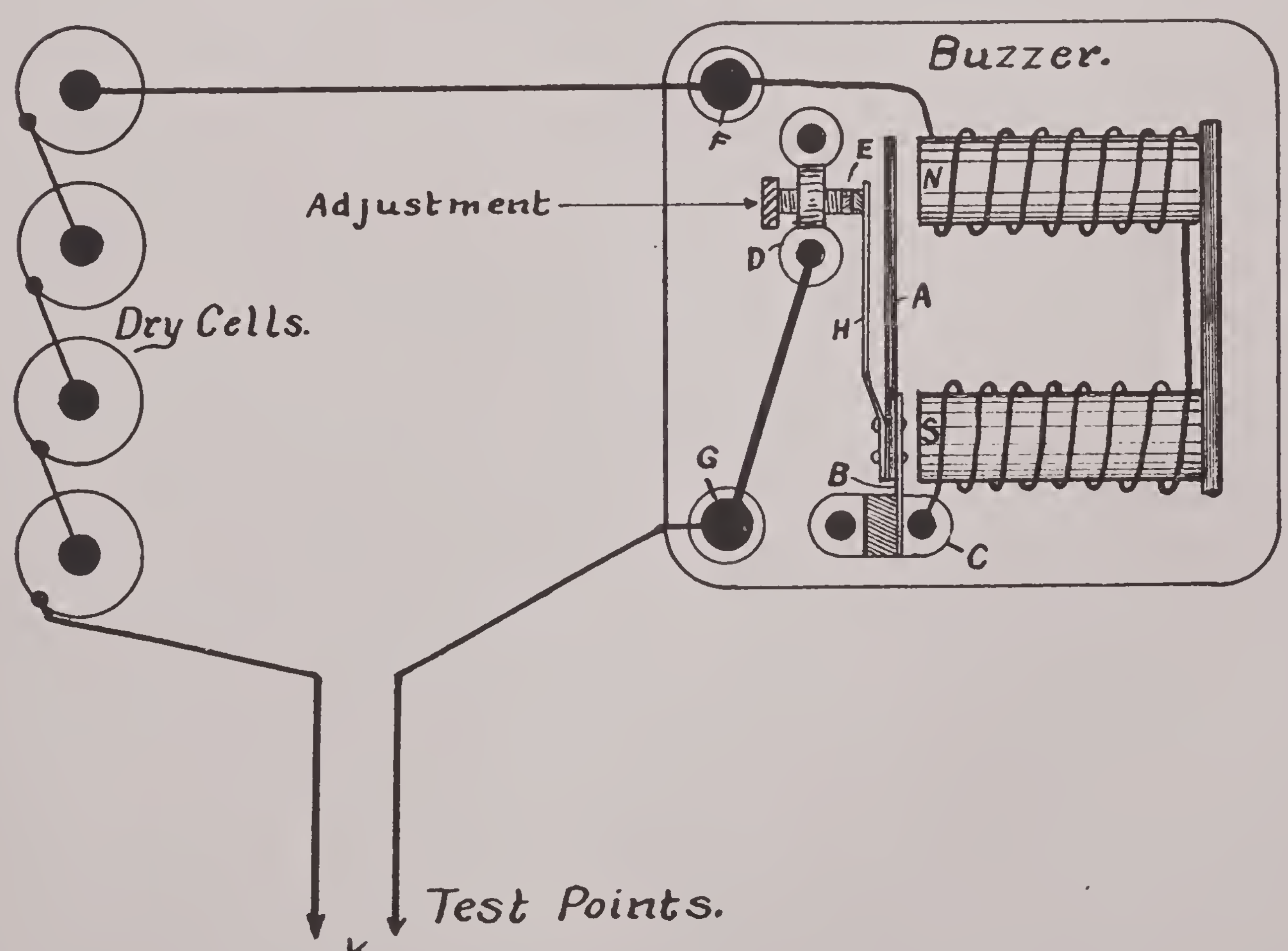


FIG. 306

MISCELLANEOUS ELECTRICAL APPLIANCES

Electric Horn

There are several types of electric horns used on motor cars. The simplest is the vibrating type. The construction of one type of vibrating horn is shown in Fig. 307. The mechanism consists of an electromagnet (J), near the poles of which is mounted an armature (A) upon a spring (L) and bracket (H). The armature carries a contact (C), which normally closes the circuit through the magnet coils by resting against another contact mounted on bracket (G). Mounted between the flanges of the housing (K) and the megaphone attachment is a diaphragm (D). In the center of this diaphragm is rigidly connected a post (B). One end of this post extends to a point near armature (A).

The external circuit of the horn is completed by suitable conductors from (E), through a horn button (switch) and the battery, back to terminal (F) of the horn.

The operation of the horn is as follows: When the circuit is closed by pressing the horn button, the current flows into the horn at (E), through the magnet winding, armature (A) contacts (C) and back to the battery.

The flow of current magnetizes the core of the magnet (J), which attracts armature (A) and draws it towards the core. This separates the contacts (C), thus causing the magnet core to become demagnetized. When the core loses its magnetism, the contacts (C) again establish the circuit and the operation is repeated.

Each time the armature is drawn towards the magnet, it strikes the end of the rod (B), causing the diaphragm (D) to vibrate rapidly, this causing the sound.

The Ford horn is illustrated in Fig. 308. The mechanism of this horn consists of an "E" shaped electromagnet (B) with a winding on the center leg of the core. Near the poles of this electromagnet is a soft iron disc (G) fast-

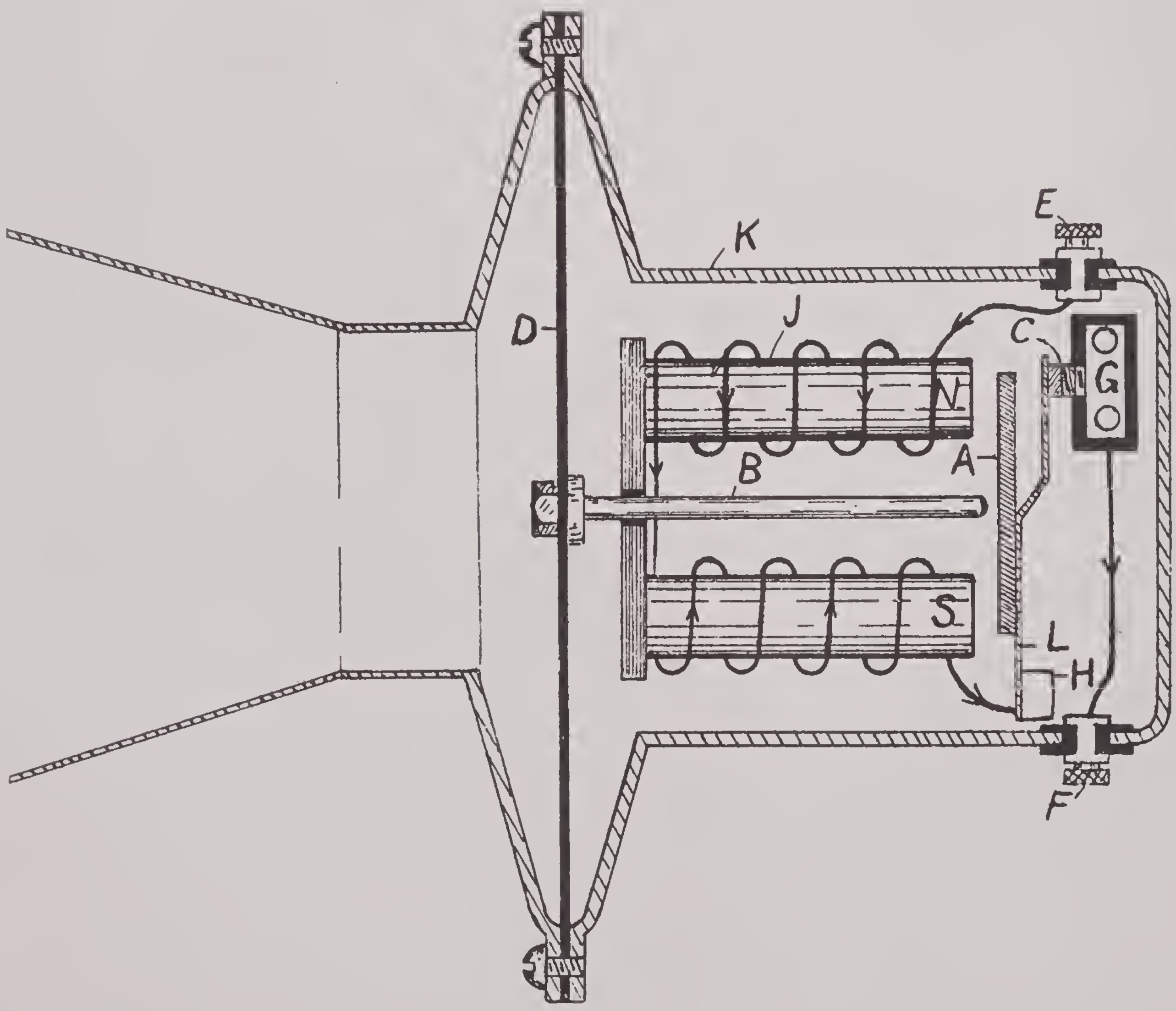


FIG. 307

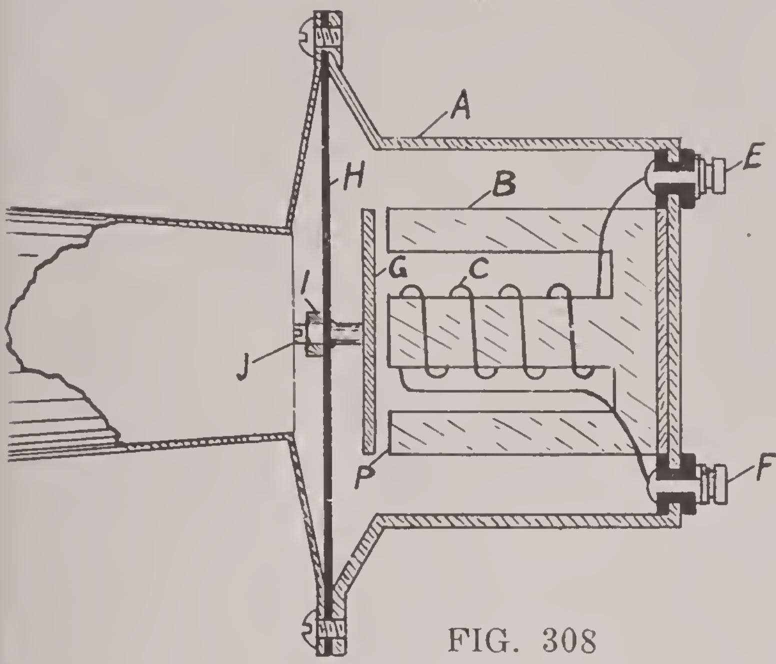


FIG. 308

to (F) it magnetizes the core in such a direction that the pole over which the wire is wound becomes of north polarity and the two outside poles of the (E) shaped core of south polarity. The soft iron disc (G) will be attracted, thus drawing the diaphragm (H) towards the poles. When the E. M. F. wave of the magneto is finished, the current in the coil of the horn ceases to flow and the core of the electromagnet becomes demagnetized. When the core loses its magnetism, the iron disc being no longer attracted, moves away from the magnet. The induced E. M. F. of the magneto reverses and the current then flows through the horn from (F) to (E). The pole of the core over which the wire is wound becomes of south polarity and the outside poles (one of them is marked (P) become of north polarity. The iron disc

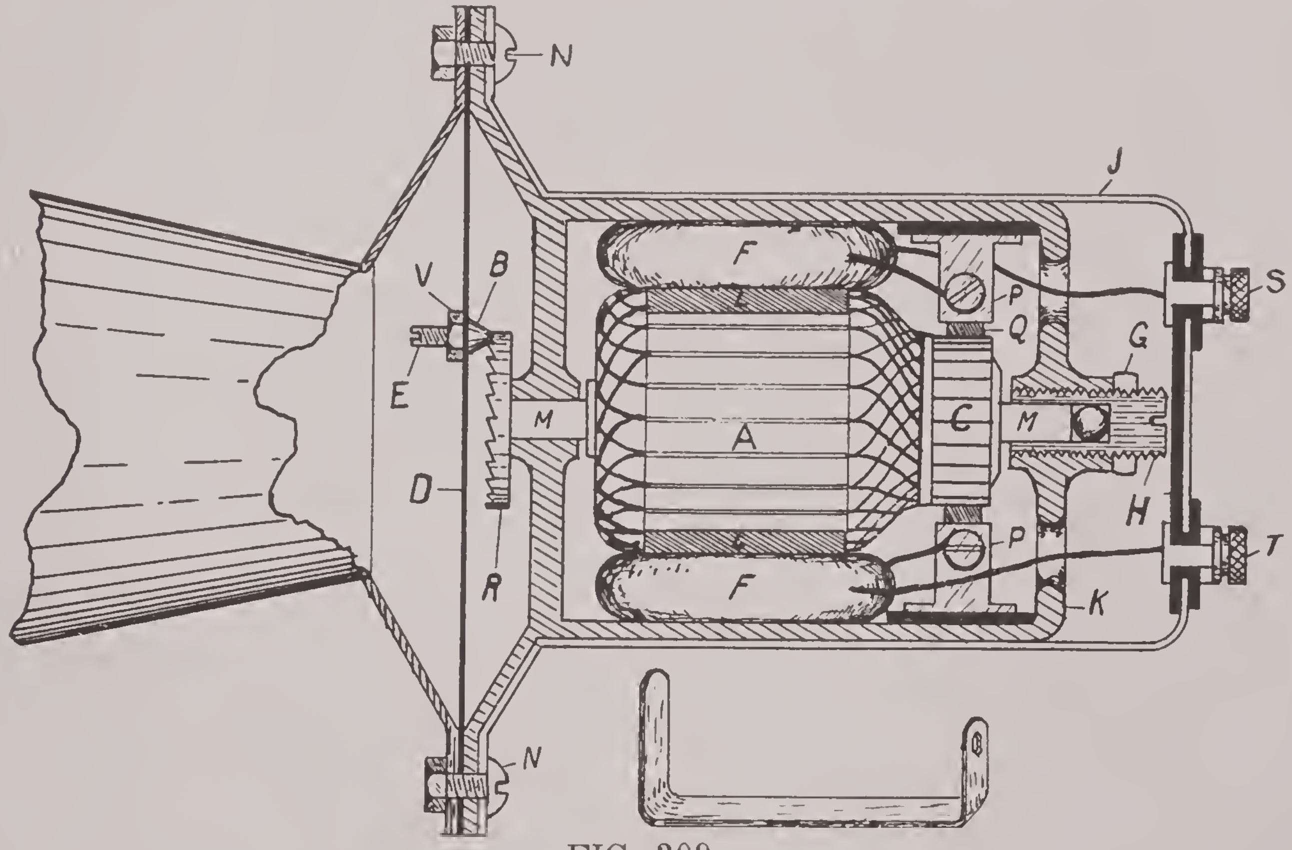


FIG. 309

ened rigidly to a diaphragm (H). The circuit through the horn is from (E) to (F) through the magnet coil (C). The complete horn circuit is from the magneto to (E), through horn winding (C) to (F), thence through a wire to the horn button (switch) and ground, through the frame of the car and back to the grounded end of magneto armature winding.

To understand the operation of the Ford horn, it is essential that one should bear in mind that the Ford magneto produces an alternating current; that is, the current surges back and forth in the circuit. This horn will not operate on direct current.

Operation of the Ford horn is as follows: As the current flows through the coil from (E) to (F) it magnetizes the core in such a direction...

(G) is again attracted to the magnet, but as soon as the induced E. M. F. drops to zero, the current will cease to flow and the disc will move away from the poles.

The operations described are repeated over and over each time the current alternates; thus, the diaphragm of the horn vibrates in synchronism with the alternations of the current, which accounts for the change in its tone when the speed of the engine is changed.

Motor Driven Horn

Fig. 309 shows the essential parts of a motor driven horn.

The motor which drives the horn is a miniature series wound motor of the two pole type.

The armature is shown at (A), the field poles at (L), the series field coils at (F) and the brush holders and brushes at (P) and (Q) respectively. (C) is the commutator. The armature is supported by the shaft (M). On one end of the armature shaft is a hardened steel rachet wheel (R). (D) is a diaphragm with a hardened steel cone shaped piece (B) mounted upon it and is held in place by screw (E) and lock nut (V).

The circuit through the motor is from (S) to the upper field coil, through the coil and brush holder (P) to the commutator (C) and the armature. The current passes out of the armature at the lower brush, through the lower field coil and out at terminal (T).

When the horn circuit is closed by pressing the horn button (switch), the armature (A) is caused to revolve, thus driving the ratchet wheel (R) at a high rate of speed. When the ratchet wheel impinges against the hardened steel piece (B) on the diaphragm, it causes the diaphragm to vibrate rapidly, emitting sound.

Motor Horn Adjustments

The adjustments for changing the tone of the motor driven horn are found either at the end of the armature shaft at (H) or within the megaphone at (E). The adjustments on the Klaxon are at (H) and on the Stewart at (E).

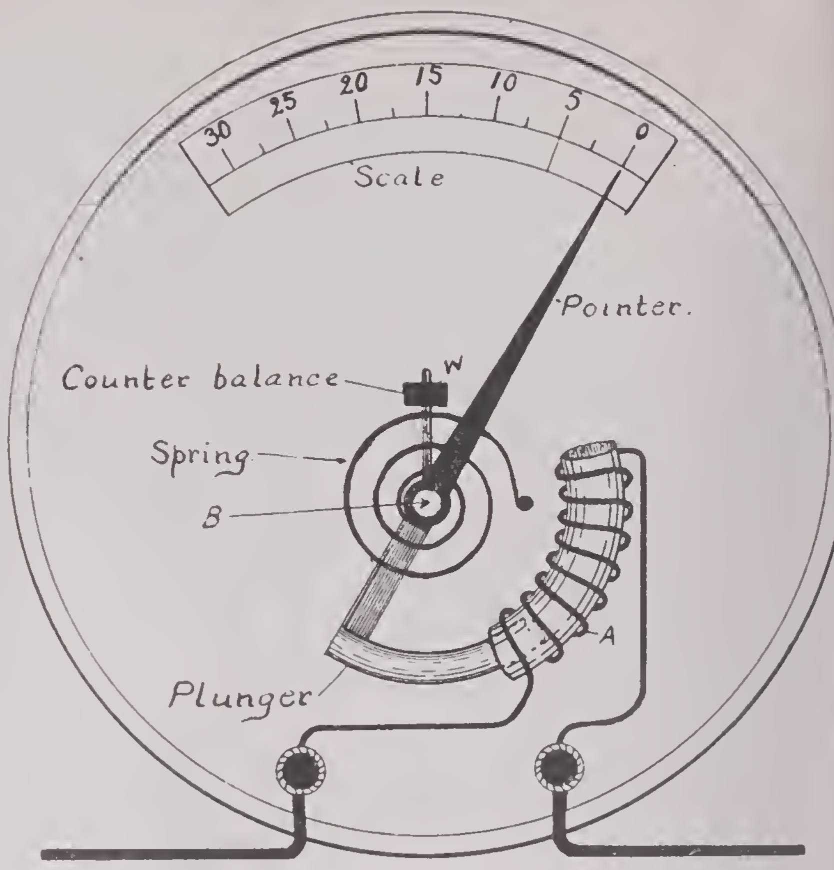
If the armature of the horn motor revolves and the horn fails to emit sound, it is a sure indication that the ratchet wheel (R) does not strike the steel projection (B) on the diaphragm. On the Klaxon the locknut (G) should be loosened and the armature bearing turned in or out, as the case requires, until the proper tone is obtained. On the Stewart the adjustment is made with a screw driver and a special wrench shown below the illustration of the horn. Loosen locknut (V) and turn screw (E) one direction or the other until the proper tone is obtained. After making adjustments be sure the lock nut is tightened.

Plunger Type Ammeter

Fig. 310 shows one of the simplest types of ammeters. It is called the plunger type meter. It consists of a case or housing in which is mounted a movable needle pivoted at (B). On the lower end of the needle is a soft iron plunger counter-balanced by a weight (W). The needle is held on the zero mark of the scale by a small spring which is similar to the hair spring of a watch.

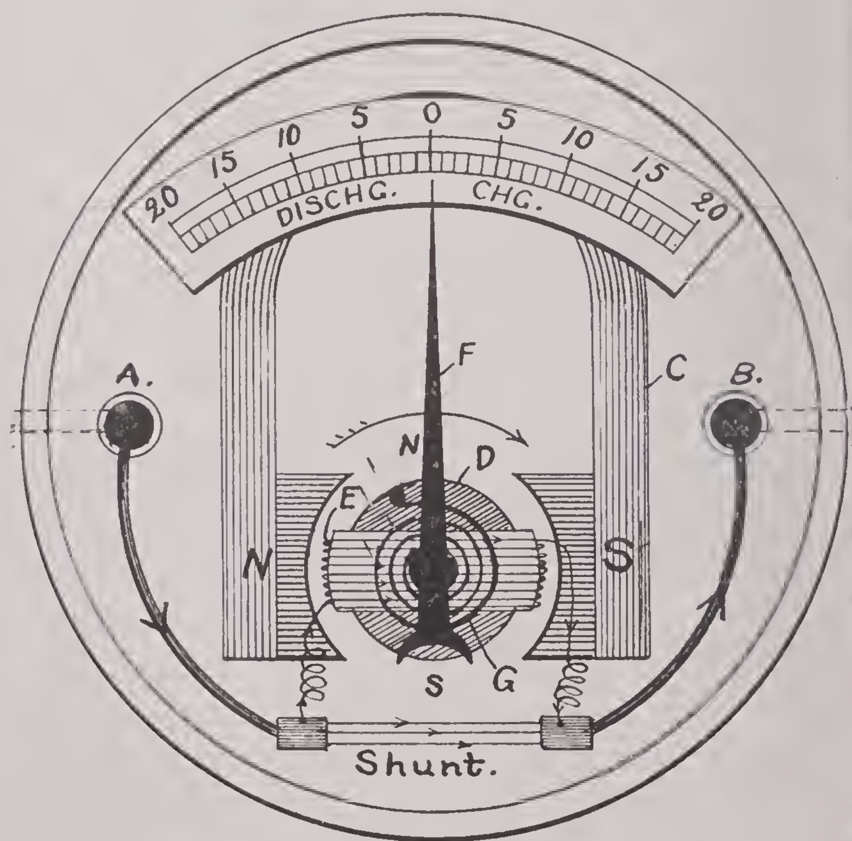
Between the two binding posts of the meter is connected a helix or solenoid (A) of the shape shown. When the current flows through the solenoid, a magnetic field is set up about it, which draws the plunger into the coil, causing the needle to move across the scale. The scale is calibrated in such a manner that the amount of current flowing in the coil is indicated by the position of the needle.

This type of meter may be designed to measure either alternating current or direct



PLUNGER TYPE AMMETER.

FIG. 310



MOVABLE COIL AMMETER.

FIG. 311

current. It is seldom, if ever, used on the automobile.

Movable Coil Ammeter

The movable coil ammeter is illustrated in Fig. 311. It consists of a suitable housing with the meter mechanism within. The mechanism consists of a permanent magnet (C), between the poles of which is mounted a stationary core (D). Surrounding this core is a small coil of fine wire (E), which is pivoted at the center of the core (D) in such a manner that it is free to move. Needle (F) is secured to coil (E) so when the coil twists in the field, the needle is swung across a calibrated scale. The meter coil (E) is in parallel with a very low resistance shunt as shown. A very small per cent of the total current flows through the meter coil (E), the greater per cent flowing through the shunt. The scale is so calibrated that the needle deflections indicate the total current through the meter. A spring is depended upon to hold the needle on zero of the scale.

Ammeters of this type are designed to operate on D. C. altogether, and will not operate on A. C. The ammeter, as applied to the automobile, is designed to indicate both charge and discharge, depending, of course, upon which way the current flows through it.

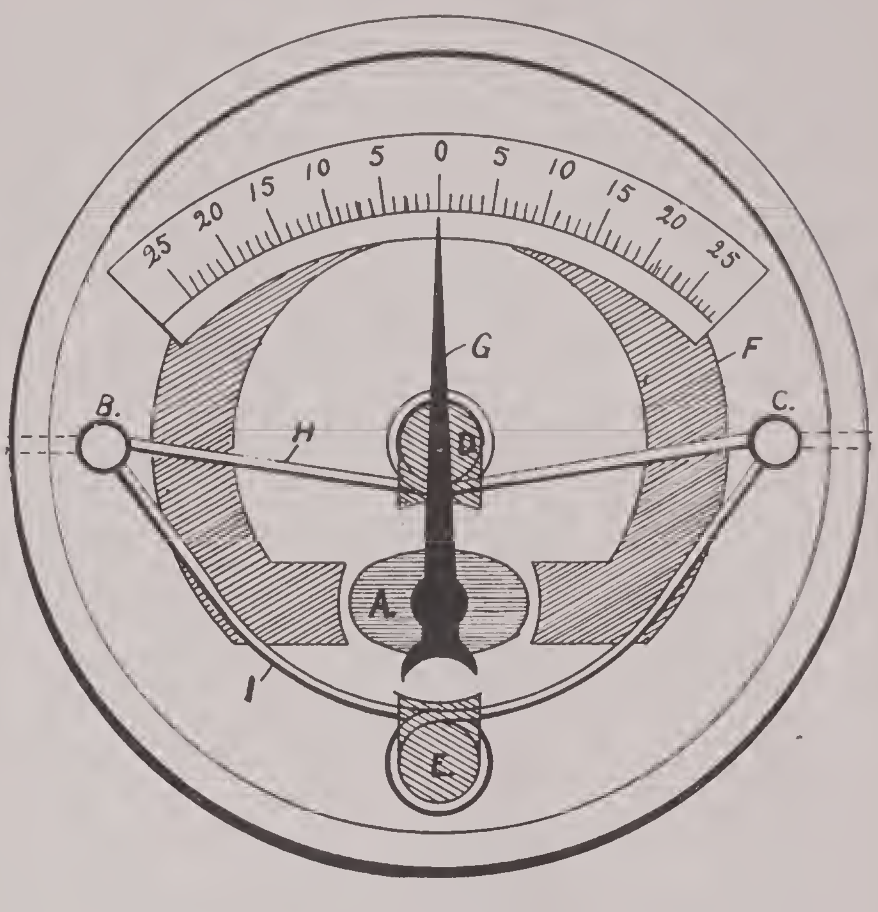


FIG. 312

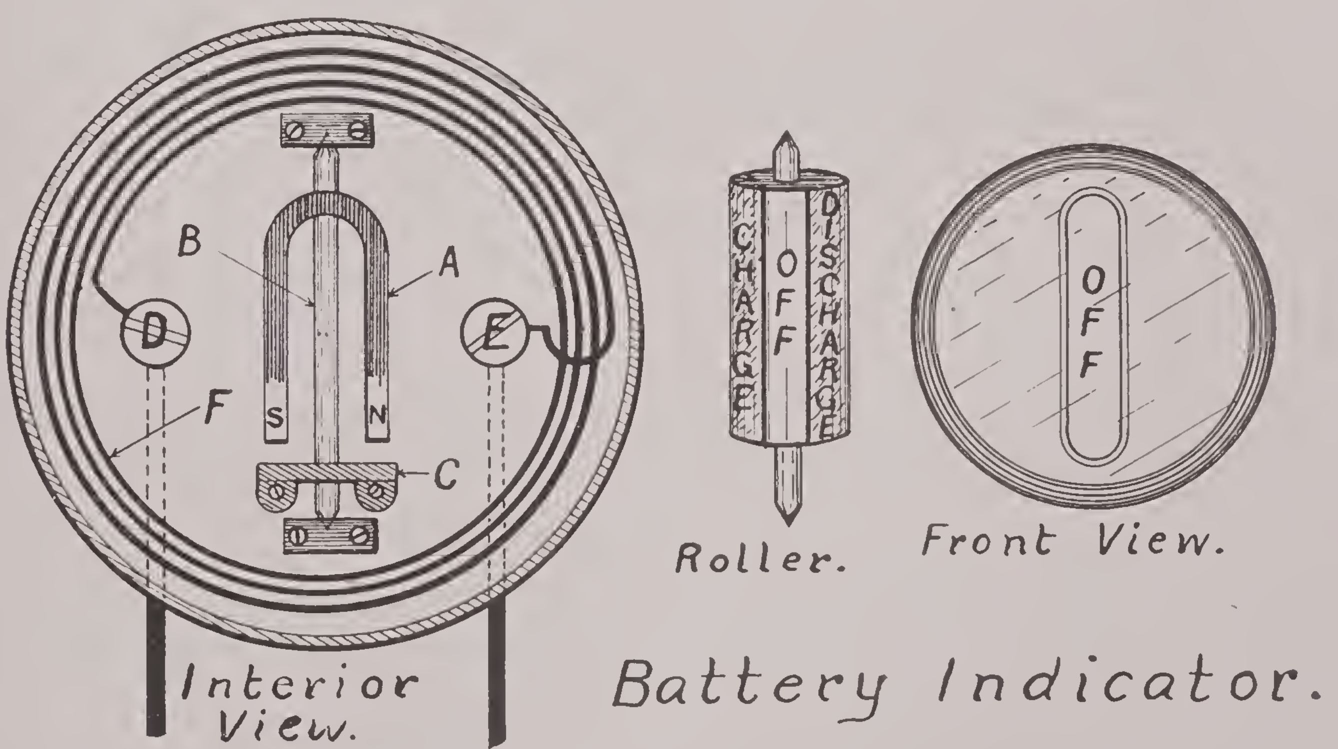


FIG. 313

The principles involved, which cause the meter coil to move and deflect the needle, are the same as the principles of the electric motor. When current passes through the coil, it is caused to twist proportionately to the strength of the current, the direction the coil twists depending upon the direction of the current.

The Magnetic Vane, or Field Distortion Ammeter

The magnetic vane or distortion type ammeter is shown in Fig. 312.

It consists of a suitable case containing a permanent magnet (F), between the poles of which is pivoted an elliptical piece of soft iron (A). The needle is supported by the same pivot rod that supports piece (A). The needle is held on zero by the attraction of the magnet for piece (A), holding it aligned between its poles as shown; that is, so that it forms a magnetic path of low reluctance.

(B) and (C) are the meter binding posts, between which are two parallel circuits (H) and (I). These two paths are of very low resistance. (D) and (E) are the poles of an electromagnet, the coils of which are in the two circuits (H) and (I).

The magnetism of the permanent magnet holds the soft iron piece (A) normally in the position shown. When current flows through the circuits (H) and (I), the poles (D) and (E) become magnetized and distort the magnetic field between the poles of the permanent magnet. The soft iron piece (A) follows the distorted field and as a result, the needle moves across the scale. If the current through the meter is reversed, the field will be distorted in the opposite direction; hence, the needle will move across the scale in the opposite direction. This makes it possible to register both charge and discharge.

The Battery Indicator

The mechanism of the battery indicator is shown in Fig. 313.

The right hand illustration shows the appearance of the front of the instrument. The center illustration shows the drum which surrounds the small horseshoe magnet (A) in the left hand illustration.

"CHARGE," "OFF" and "DISCHARGE" are marked on the drum. The small horseshoe magnet in the illustration at the left is mounted in pivoted bearings, and near its poles is mounted a piece of soft iron (C). The attraction of the poles for piece (C) causes the magnet to stand normally in the position shown. In this position no current is flowing, and the mark "OFF" appears in the opening in the front of the instrument.

Between the binding posts (D) and (E) is a coil of wire (F). When the current passes through this coil, a magnetic field is set up, which is at right angles to the field of the permanent magnet (A). Magnet (A) will then turn so that its north pole points in the direction the lines of force of the coil flow. When the current is reversed, the magnetic field about the coil also reverses; hence, the magnet (A) will turn in the opposite direction. The instrument indicates only charge, discharge or off; it does not indicate the amount of current flowing. It can be connected in the same manner on the car as the ammeter.

The Automatic Ignition Switch

Fig. 314 shows the mechanism of a typical Connecticut Automatic Ignition Switch. These switches are operated by a thermostat.

The primary ignition circuit is as follows: When switch button (A) is pressed down, lever (I) drops into notch (F) and contacts (E) are closed. The current flows from the battery to (B), up through the contacts (E), then through the heater coil (L) and thermostat blade to (C), thence through the primary winding of the coil and the breaker points to the ground, then to the grounded side of the battery.

If the ignition switch is left on when the breaker points are closed and the engine is not running, the current in the primary circuit becomes greater than normal and heats the thermostat blade (M). As the temperature of the blade is increased, the blade bends upwards until contacts (K) are closed, at which time a circuit from the battery is completed through the coils (N) of a buzzer. The current in these coils causes the armature (P) to be attracted so that hammer (H) strikes trigger (Q), forcing lever (I) out of notch (F), thus opening contacts (E) and cutting off the flow of current through all parts of the switch. If the first stroke of hammer (H) does not release the switch, the buzzer mechanism continues to vibrate until contacts (E) separate.

Pressure on push button (D) will cause spring (R) to be forced down, which will release lever (I) from notch (F), allowing button (A) to move back and open contacts (E). A ground on the primary circuit causes more than normal current through the switch and will cause it to release.

Later types of these switches operate with a double thermostat instead of a buzzer, making them practically noiseless.

A thermostat consists of two blades of unlike metal, as (M) Fig. 314, usually brass and steel, either welded together throughout their entire length, or riveted together at their ends. Brass expands more than steel when heated; consequently, the blades will bend in such a direction that the brass becomes longer. In the illustration, the lower blade of the thermostat would be the brass blade and the upper one the steel blade.

Any two metals having unequal expansion when heated can be used to form a thermo blade.

The adjustment of the switch is made by changing the distance between contacts (K). The farther apart they are set, the longer the current must flow and the hotter the thermostat must become before the switch is opened, and vice versa.

The Magnetic Gear Shift

The principles of the magnetic gear shift are plainly set forth in Fig. 315. The operating

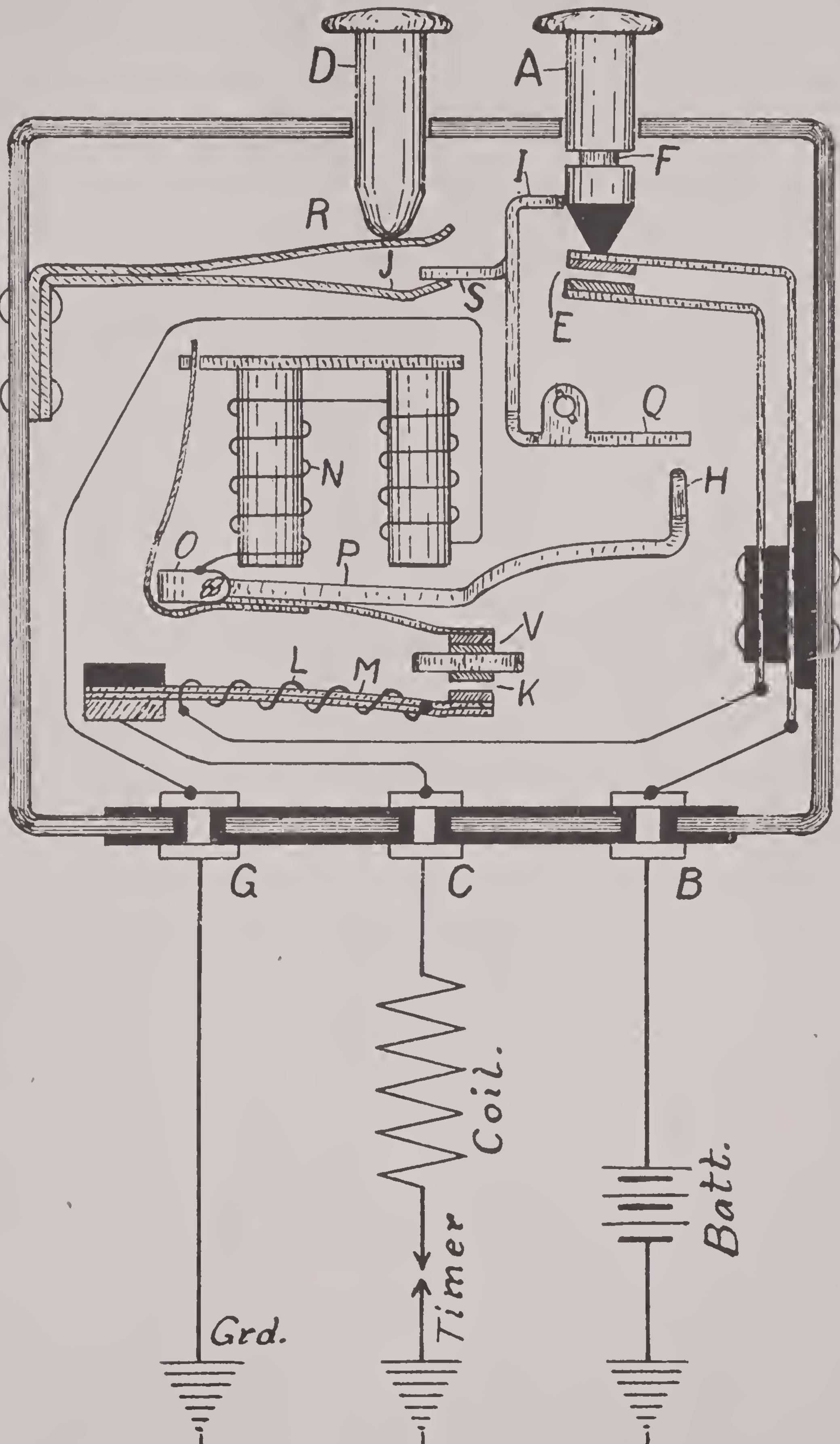


FIG. 314

A. Switch button.
B. Battery terminal.
C. Ignition terminal.
D. Release button.
E. Switch contacts.
F. Slot in which locking lever drops.
G. Ground terminal.
H. Hammer.
I. Locking lever.
J. Locking lever spring.
K. Thermo blade contacts.
L. Heater coil.
M. Thermo blade.
N. Electromagnet coil.
O. Support for vibrator arm.
P. Vibrator arm.
Q. Trigger.
R. Release button spring.
V. Vibrator contacts.

mechanism consists of a battery (H), a selector switch (G), four solenoid coils (A), (B), (C) and (D), two soft iron plungers (E) and (F), and a master switch (J).

The master switch is controlled by the clutch pedal of the car. The selector switch is in easy reach of the driver.

The solenoids and plungers are mounted on top of the transmission, the plungers being interconnected with the regular shifting bars of the transmission. When it is desired to start the car or to shift from one speed to another, the desired speed is selected by pressing the proper selector switch button. When the button is pressed, a circuit is completed through the selector switch, thus throwing one of the solenoid coils in series with the battery, with the exception of the break in the circuit at the master switch (J). As soon as the clutch pedal is pushed all the way forward, the master switch is closed and one of the solenoids becomes energized and the plunger is drawn into the coil, thus shifting the gears in the transmission.

The circuit shown in the illustration is from the battery, through selector switch No. 1, solenoid (A) and master switch (J). Under these conditions, coil (A) will be energized and plunger (E) drawn into it.

The neutralizing mechanism is purely mechanical and operates by pushing the clutch pedal half way down. This action draws the plungers (E) and (F) into the positions shown. The (N) button of the selector switch is to release any of the switch connections made by pressing the selector buttons. The clutch should not be pushed all the way forward when driving, unless shifting gears. The clutch is properly disengaged when the clutch pedal is pushed forward a little more than half way.

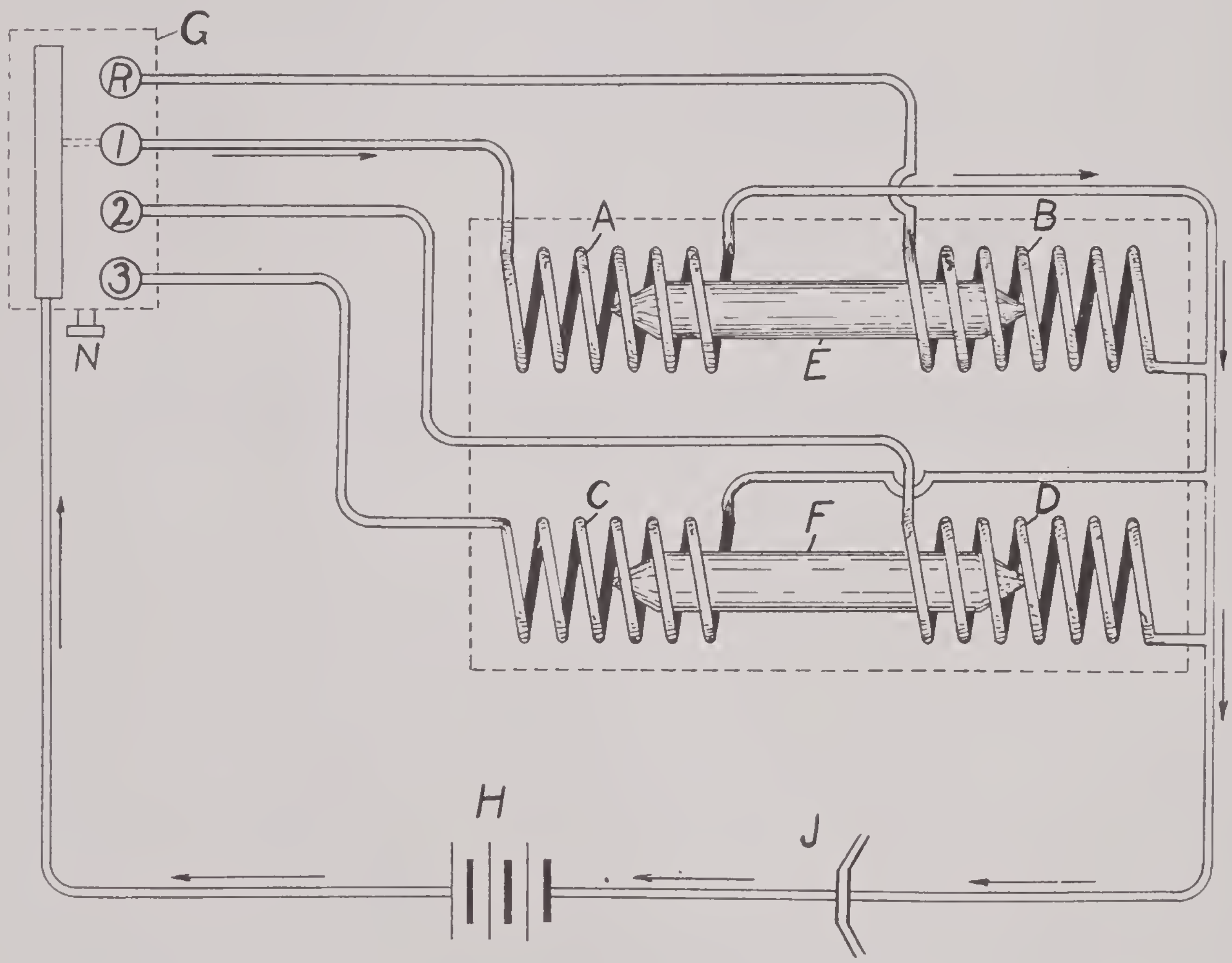


FIG. 315

The arrangement of the solenoids and the selector switch connection is correct for an S. A. E. standard gear shift. The (A) coil is for low speed, the (B) coil is for reverse, the (C) coil is for third or high speed and the (D) coil is for second speed.

LIGHTING

Lamp Bulbs, Sockets and Plugs

The lamp ordinarily used on modern cars has a base known as the "Ediswan bayonet base." This lamp base is shown in Fig. 316, upper right. The base of the lamp has two small anchor pins which project about 1 16″. These pins slide into suitable slots in the socket as shown. To insert the bulb, engage the anchor pins in the slots, push bulb in as far as it will go, then turn slightly to the right. The spring plunger in the socket pushes the bulb outward, causing the anchor pins to lock the lamp into the socket.

To remove the bulb, push in on it and turn slightly to the left. The lamp will then easily slide out of the socket.

The left hand illustration shows a double contact bulb and the type of socket required. The base of the lamp has two contacts, which connect to the filament of the lamp. The socket is equipped with two spring plungers which make contact with the two contacts on the base of the lamp when the bulb is properly installed. This type of socket is designed to be used in connection with a straight two wire system, but is used also in a number of instances in the single wire systems (ground system return).

The illustration at the lower right is of the single contact lamp bulb and socket. This lamp and socket is used in the single wire systems. The socket has only one wire leading to it, the return circuit being the ground. One of the "leading in" wires of the bulb is connected to the base of the lamp and the other is connected to the single contact (C). The ground symbol and dotted line represent the frame return circuit.

One should be certain when installing new lamp bulbs that they are designed for the socket into which they are being placed. If there are two contacts in the socket, the double contact bulb should be used. If there is only one contact in the socket, the single contact bulb should be used.

The arrangement shown in the illustration at the left is used for leading in connections to the head light socket on a two wire system, and to make the leading in connection for the two bulb (head and auxiliary) lights in a single wire system.

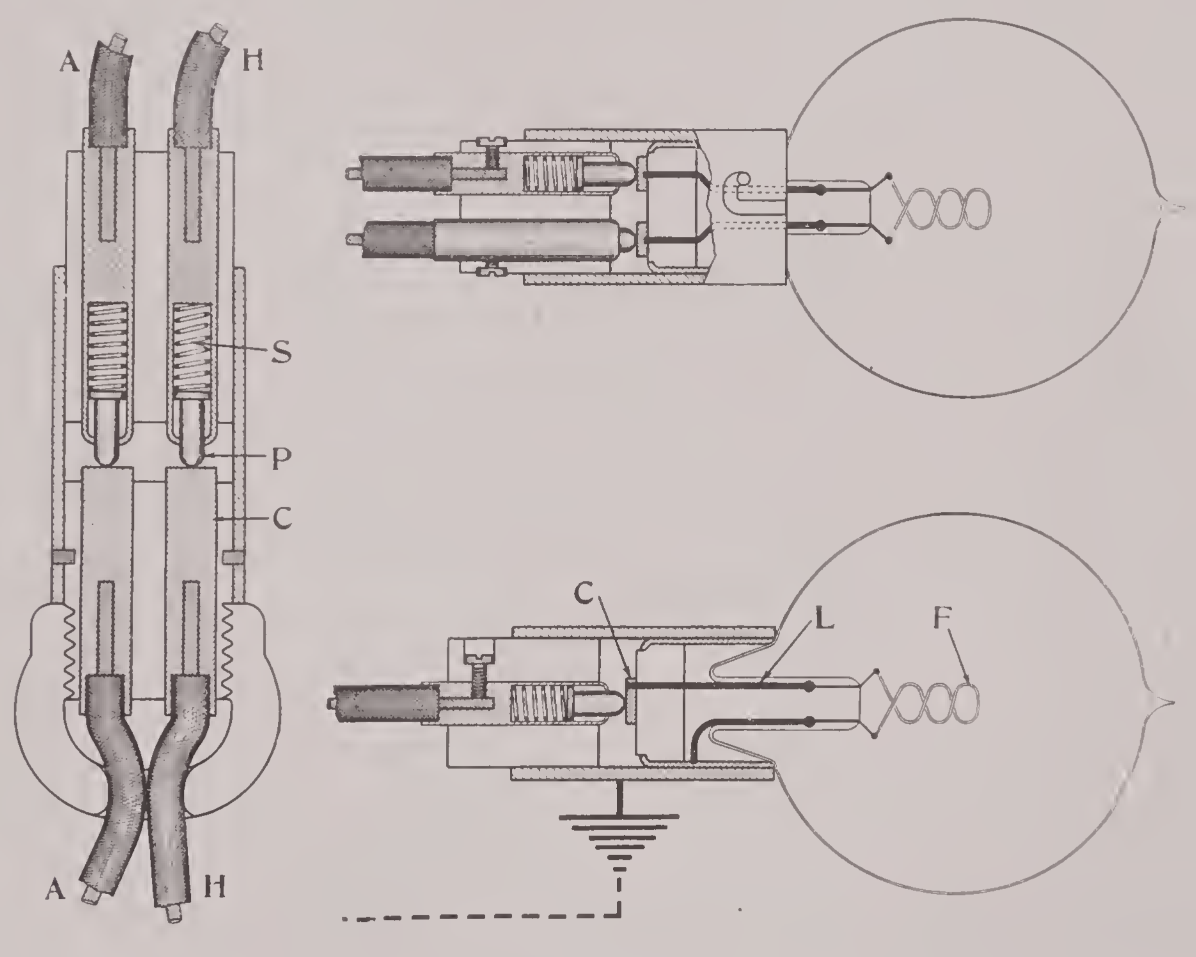


FIG. 316.

Lamps—Sizes, Candle Power, Etc.

There are two types of lamps that can be obtained for cars. These are known as the "Mazda type B," and the "Mazda type C." The "Mazda type B" is a lamp from which the air has been exhausted. The filament is arranged in a double spiral order. The "Mazda type C" is a lamp from which the air has been exhausted and nitrogen gas substituted in its place. The filament is arranged in a "V" shape.

The "Mazda type B" consumes about 1¼ watts per candle power and the "Mazda type C" about 1 watt per candle power. The type "C" lamp is, therefore, the more efficient. Lamps of either the "B" or "C" type can be obtained for any range of voltage used on cars.

Methods of Dimming Headlights (Electrically)

The four methods used for obtaining dim headlights are as follows:

(a) By changing the lights from a parallel connection for bright to a series connection for dim.

(b) By inserting resistance in series with the headlights.

(c) By the use of auxiliary headlights. The main headlights, which are usually of high candle power and placed in the focus of the reflector, are turned off and small candle power bulbs, which are out of the focus of the reflector, are turned on.

(d) By using a bulb equipped with two filaments of different candle power, either of which may be placed in use by turning lighting switch to the proper position.

The first three methods are shown in Fig. 317, in the same order as described above.

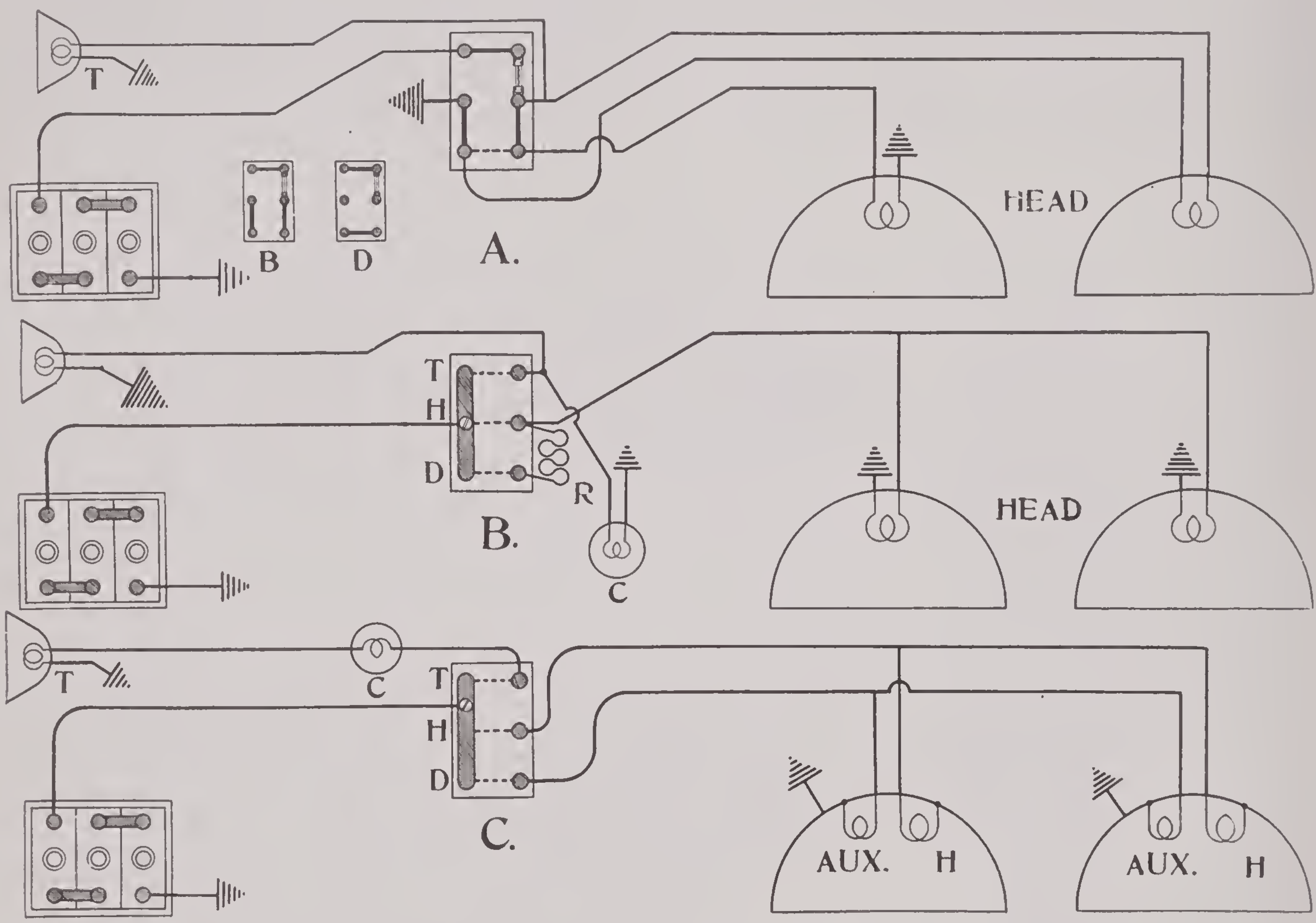


FIG. 317

Focusing Headlights

The lower illustration in Fig. 318 shows a section through a parabolic reflector. A straight line drawn through the center of the lens and the apex of the reflector is called the axis of the reflector.

The source of light (the filament of the lamp) should always be on this line. The focal point is a point on this line where the

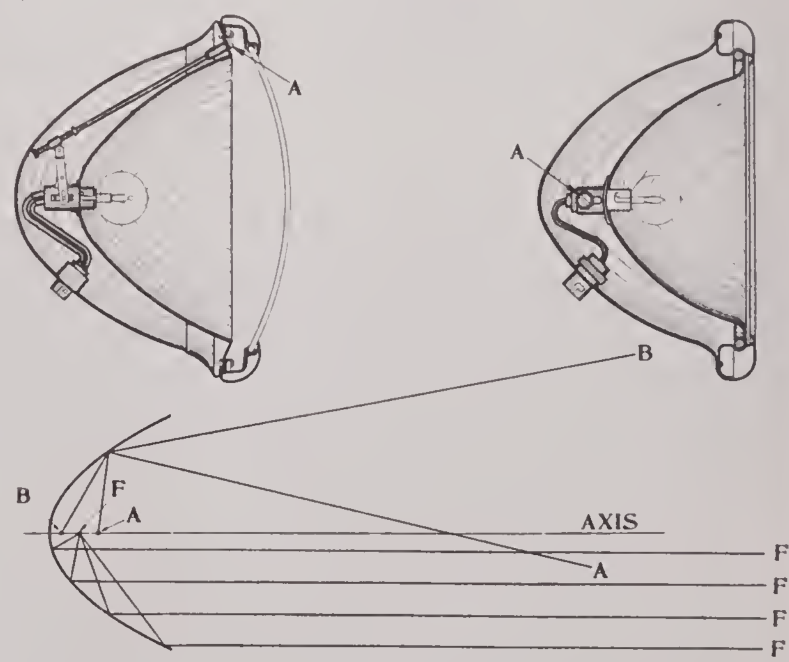


FIG. 318

source of light should be placed, as at (F), in order that the reflected light will be projected ahead of the car in parallel rays, indicated by the parallel lines marked (F). If the source of light is placed ahead of the focal point, as at (A), the reflected light will be in the direction of the line (A), which crosses the axis. When the source of light is back of the focal point, as at (B), the reflected light will form a diverging pencil of light, as indicated by the long line (B).

To focus the lamps, place the car so that the lights strike squarely against a light colored wall 40 to 75 feet ahead of the car. Adjust the bulbs by moving them either forward or backward along the axis until the proper spot on the wall is obtained. The spot should not be less than 3½ feet in diameter and should be free from dark rings. Tip the headlights forward at the top if possible so that the light will be thrown on the road. This can be done in some instances by bending the head lamp brackets.

The two upper illustrations, Fig. 318, show two common points at (A) where the lamp focusing adjustments are located. On some cars, as the Ford and Overland "4," a small screw is located on the outside of the lamp housing just above the apex. Turning the screw at this point moves the lamp along the axis of the reflector.

Care of Reflector

Never allow the fingers to touch the silvered surface of a reflector.

Dust may be removed by a stream of clean water from a hose, but do not allow the water to strike the surface under pressure.

Jeweler's rouge and a perfectly clean chamois skin, or a wad of absorbent cotton moistened with alcohol, may be used to clean a reflector which is badly tarnished.

ARMATURE TESTING

Fig. 319 illustrates a few common tests made on armatures. Tests (B), (C), and (D) apply particularly to Delco motor-generator armatures which have two sets of armature windings and two commutators, although tests (C) and (D) apply equally well on other armatures. The test shown at (A) is to determine in a rough way whether an armature is shorted or open circuited, without removing the dynamo from the car. See that the commutator is clean and in good condition, open the shunt field circuit and connect a sensitive ammeter in series with the armature and a good dry cell. Note the reading of the ammeter. Turn the armature slowly, watching the ammeter closely. If the armature is in good condition, there should be only a slight variation in the reading, if any at all. If there is quite a variation, the armature is either open or short circuited. This test will not determine the nature of the trouble.

The test at (B) is to determine if there is a short circuit between the motor and the generator windings of a Delco motor-generator armature. These windings normally have no

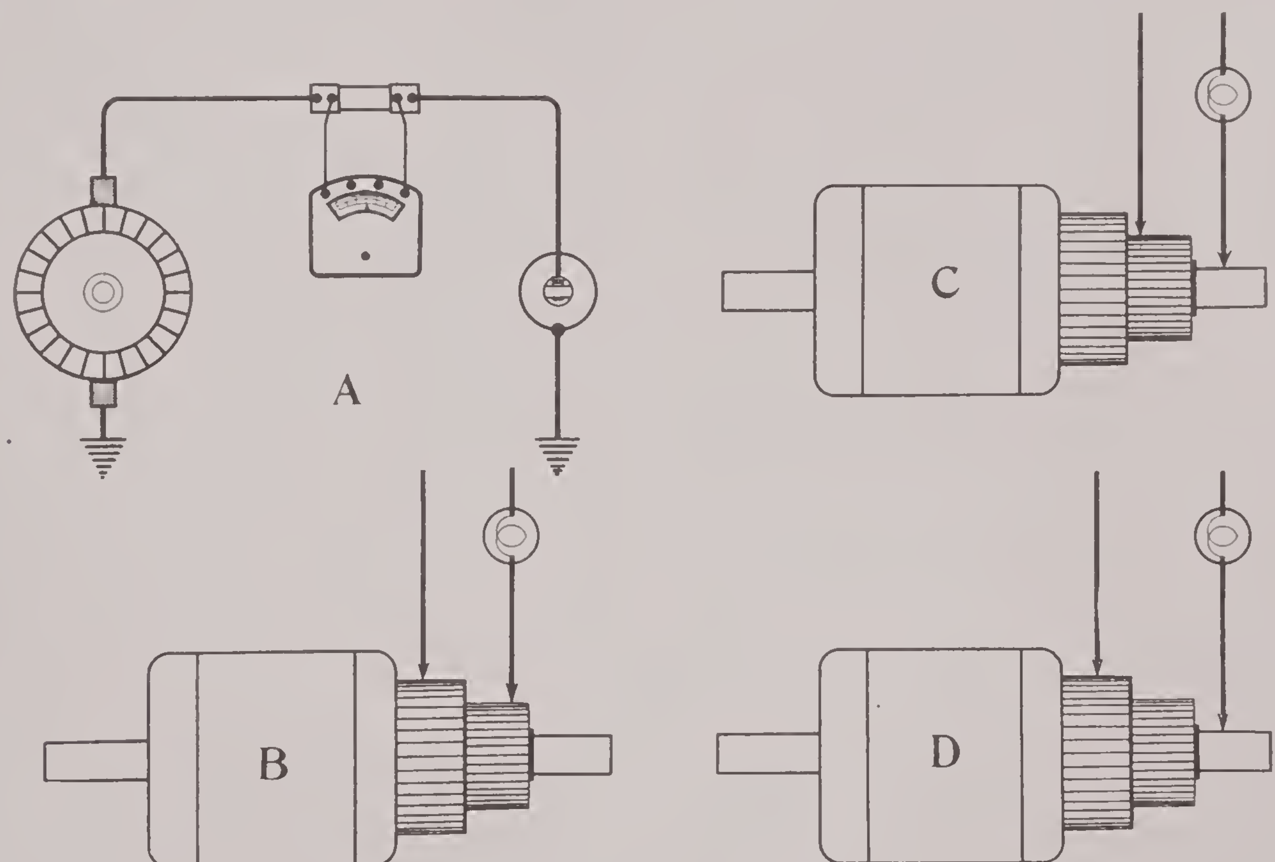


FIG. 319

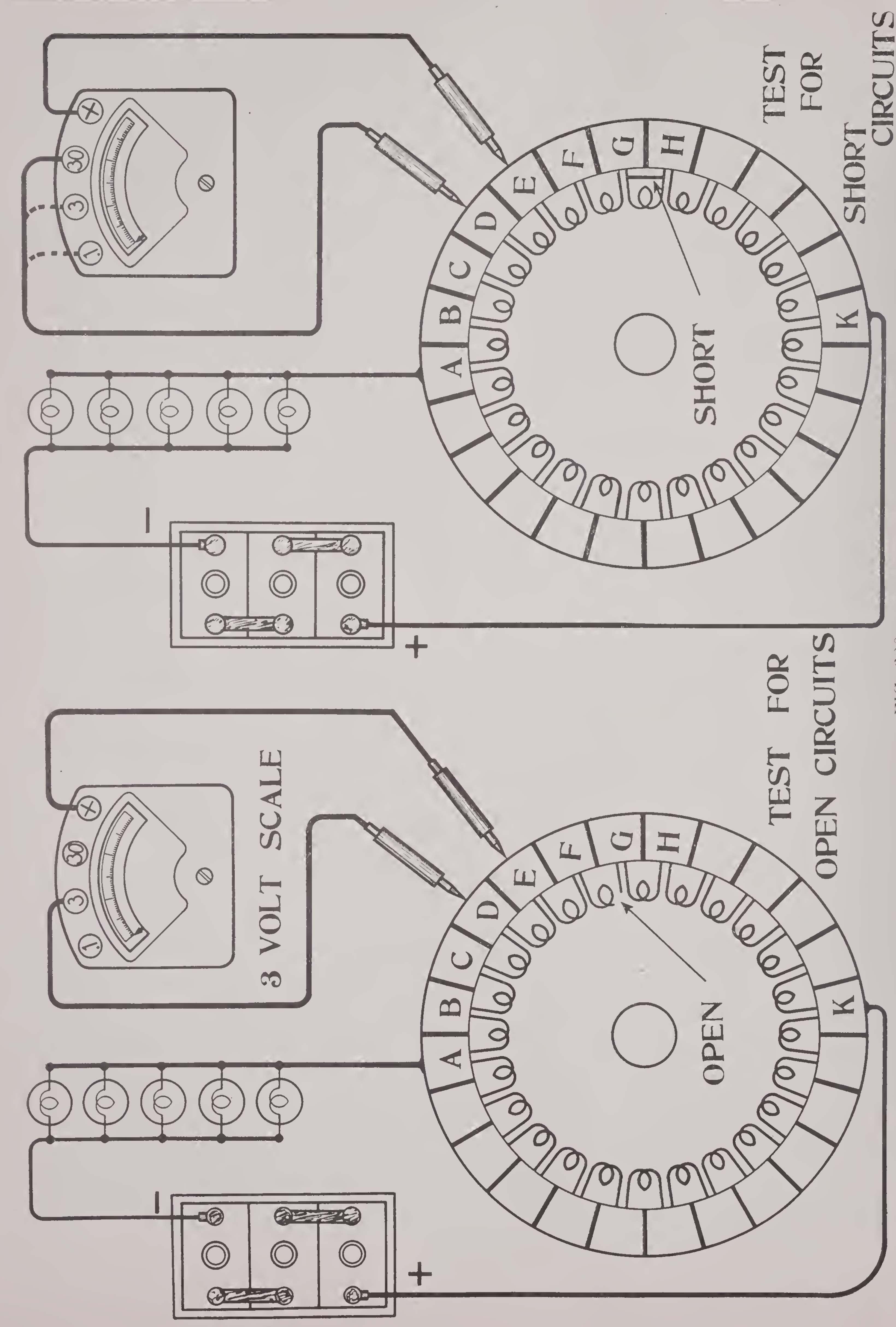

TEST FOR SHORT CIRCUITS
SHORT
TEST FOR OPEN CIRCUITS
OPEN
3 VOLT SCALE
A
B
C
D
E
F
G
H
K
30
3
.1
+
−

FIG. 320

connections from one to the other. If the test lamp lights, the motor and generator windings, because of a break in the insulation, are touching and thus short circuited.

The test at (C) is to determine if the generator windings or commutator are grounded. If they are not grounded, the lamp should not light.

The test shown at (D) is for the motor winding.

Bar to Bar Test

The tests shown in Fig. 320 are called "bar to bar" tests to locate shorts or opens in an armature. The meter used for these tests should be very sensitive and capable of quite a range. A millivoltmeter is required as a rule to make the test for shorts.

The test points of the meter are preferably made of steel and have keen points which may be pricked into the copper commutator bars, insuring a perfect contact.

Connect a bank of headlight bulbs, a six volt storage battery and the armature to be tested, in series as shown. The wires connected to the commutator bars should be soldered to them, to insure that there will be no variation in the flow of current. The lamps control the flow of current through the armature, as the armature resistance alone is usually too low to limit the current to a suitable strength.

The test for open circuits should always be made first, then the tests for short circuits should follow. If the test for shorts is made first and an open exists in the armature winding, the meter will be more than likely burned out, when it is connected across the bars of the commutator to which the open coil is connected.

The 30 volt scale may be tried out first and if the deflection from bar to bar is less than 3 volts, the 3 volt scale may be used. If it is found when the 3 volt scale is used, that the deflection of the meter needle when the instrument is connected from bar to bar is less than .1 volt, then the .1 volt scale may be used. The connections for the 30 volt scale is indicated in full lines. The 3 volt and .1 volt scale connections are shown in broken lines. The wire on the meter terminal marked 30 should be transferred to either the terminal No. 3 or .1, depending upon the scale to be used. The wire on meter terminal marked with the positive sign should never be changed. When the 30 volt scale is used the full scale of the instrument is 30 volts. When the 3 volt scale is used, the full scale of the instrument is only 3 volts, etc.

When making the bar to bar test for shorts (when no opens or shorts exist) there will be a circuit through each side of the armature from (K) to (A). The total pressure which acts between (K) and (A), acts equally on both sides of the armature. The voltage acting across each of the armature coils is equal to the voltage across (K) and (A) divided by the number of armature coils between these two points. In the illustration we have 12 coils in each side of the armature between the two points, hence 1/12 of the pressure between (K) and (A) acts upon each of these coils. In the bar to bar test the meter should register 1/12 of the total pressure between (K) and (A) across each of the armature coils, if they are in good condition as in the left side of the armature.

Test for Opens

With the circuit connected as shown, it is evident that current will flow from (K) to (A) through the left side of the armature and that no current will flow through the right side of the armature, as the armature coil between (F) and (G) is open.

A bar to bar test around the right side of the armature will give no reading on the meter until the meter is connected across the two bars between which is the open circuited coil. When the meter is connected across the two bars (F) and (G), a reading equal to the pressure acting between segments (K) and (A) is obtained.

If the armature resistance is equal to the resistance of the lamps, one-half of the full pressure of the battery would be registered by the meter. The higher the joint resistance of the bank of lamps in proportion to the resistance of the circuit through the armature, the lower the reading on the meter. The lower the resistance of the bank of lamps in proportion to the resistance of the armature, the higher the reading of the meter. The joint resistance of the lamps may be decreased by increasing the number of lamps in parallel.

Test for Short Circuited Armature Coil

The test for short circuited armature coils illustrated at right is practically the same as the test for open circuits, with the exception that a different meter scale may be required.

In the right side of the armature it should be noted that one of the armature coils is short circuited, leaving only 11 coils in this side of the armature, hence 1/11 of the total pressure between (K) and (A) would act upon each of these coils.

When making the bar to bar test equal deflections of the meter needle should be obtained across all of the points, (A) to (B), (B) to (C), etc., until the test from (G) to (H) is made. The deflection across these points will be practically zero, as the resistance of the coil between these points is shorted out of the circuit.

SUMMARY

GENERATORS

A generator is a machine which converts mechanical energy into electrical energy. The generator as applied to automobiles is always of the revolving armature type. The field magnetism is produced by electromagnets instead of permanent magnets as in the magneto. The term "dynamo" is used to designate either a generator or a motor.

There are three distinct types of generators and motors — series wound, shunt wound and compound wound. The compound type is subdivided into the "cumulative compound" and the "differential compound."

The cumulative compound is a machine in which the magnetizing effect of both the series and shunt field windings tend to magnetize the field poles of the same polarity. In the differential compound machine the series and shunt field windings tend to magnetize the field poles oppositely, that is, the series field and the shunt field coils oppose each other.

The type of generator or motor is always determined by the type of field windings and not by the armature.

ARMATURE

The armature of a generator or motor may be of either the ring or drum wound type, although there are at present no ring wound armatures used in automobile equipment.

Drum windings are sub-divided into the lap winding and the wave winding. Lap windings can be used on any motor or generator, but the wave winding can not be used in two pole machines.

In four pole machines using lap wound armatures, there are as many brushes resting upon the commutator as there are field poles, but with the wave wound armature there may be only two brushes resting on the commutator, in which case brushes are spaced around the commutator 90 degrees one way and 270 degrees the other.

There are as many magnetic circuits through a lap wound armature as there are brushes on the commutator. There are only two through a wave wound armature.

THE NEUTRAL POINT

The neutral points of a generator or motor are the points at which the armature conductors move parallel to the path of the magnetic lines of force.

The neutral points of a generator are forward in the direction of rotation from a point half way between the field poles. The neutral points of a motor are slightly back of the points half way between the field poles, opposite to the direction of rotation. If a generator is producing voltage only and not delivering current, the neutral points will be midway between the field poles. The reaction of the magnetism produced by the current in the armature causes the field magnetism to be distorted.

The brushes should be set on the commutator so that they short circuit the armature coils as the coils pass the neutral points.

The points of commutation of a generator are the points at which the brushes rest when the generator produces the greatest output at a given speed, with the least sparking at the brush contact on the commutator, the commutator, brushes, etc., being in good condition.

The points of commutation of a motor are the points at which the brushes rest on the commutator when the motor will develop its greatest torque, with a minimum consumption of energy and with the least sparking at the commutator and brush contacts, the commutator, brushes, etc., being in good condition.

MOTORS

An electric motor is a machine that converts electrical energy into mechanical energy.

The electric motor is designed in practically the same way as the generator. Either of the machines will operate as the other, although the details of the two machines vary, because of the difference in the work they are required to do.

The single unit systems are a compromise between the regular generator and starting motor design.

Series wound machines are used as starting motors only, with the exception of their application to driving the signal horn.

Shunt machines are used on cars as generators only.

Compound machines have the combined characteristics of the series and shunt machines, hence this type is used as a motor-generator. When this machine is operated as a motor, it operates as a cumulative compound machine; when operated as a generator, it operates as a differential compound machine. There are exceptions to this rule.

GENERATOR DRIVES

Generators are sometimes driven by means of a belt and in other instances by a silent chain; still, in other instances they are driven by means of suitable gearing.

See that the belts do not slip when belt driven.

MOTOR TO ENGINE MECHANICAL CONNECTIONS

The most common motor to engine mechanical connections are as follows:

(1) Chain and sprockets, with an overrunning clutch.

(2) The manual gear shift, with an overrunning clutch.

(3) The Bendix drive.

REGULATION

Regulation of the generator output is necessary to prevent the generator from overloading itself and from charging the battery at an excessive rate, at high speeds.

With generators having electromagnetic field poles the voltage builds up very rapidly as the speed increases. The increase in voltage in some cases is proportional to the square of the speed, according to the field winding.

The voltage of a generator depends upon the number of active armature conductors, the strength of the magnetic field and the speed of the armature.

The number of armature conductors are determined by the manufacturer and the speed of the generator depends upon the speed at which the engine runs, hence these two factors can not be easily changed.

The strength of the field can be easily changed, consequently, advantage is taken of this and the result is that the generator voltage is regulated by a variation of field strength. The generator field magnetism is decreased (weakened) as the engine speed increases, thus maintaining a more nearly constant output.

There are several methods of regulation employed on modern electrical systems, among which are:

(1) Reverse-series field regulation.

(2) Regulation by vibrating type regulator.

(3) Field distortion or third brush regulation.

The charging rate of a reverse series regulated generator can be decreased, by inserting a resistance unit in series with the shunt field circuit of the generator. To increase the charging rate, a conductor should be connected in parallel with the reverse series field winding. These changes in the charging rate are made by experimenting, as there are no set rules to follow regarding the resistance to use in either case.

To increase the charging rate on a system equipped with a vibrating type regulator, increase the tension of the spring that holds the regulator contacts closed.

To decrease the rate, decrease the spring tension.

To increase the charging rate on a system where the generator has field distortion or third brush regulation, move the third brush **in the direction** of armature rotation.

To decrease the rate, move the brush in the **direction opposite** to the armature rotation.

It is not recommended that the charging rate be changed until sufficient test has been made showing it to be incorrect; one should always be sure that everything else is in good condition before changing the charging rate.

CUT-OUT RELAY

The cut-out relay is an automatic switch in the charging circuit of an electrical system.

The purpose of the cut-out relay is to close the charging circuit when the voltage of the generator is slightly in excess of the voltage of the battery, and to open the charging circuit when the voltage of the generator drops slightly below the voltage of the battery.

The cut-out relay consists of an electromagnet which is compound wound, and a set of contacts in series with the charging circuit. These two windings are called the voltage and series windings. The voltage winding is sometimes referred to as a shunt winding.

The purpose of the shunt winding is to close the relay contacts. The purpose of the series winding is to cause the relay to open.

The cut-out relay should close at a pressure of 6½ to 7¾ volts on six volt systems and 13 to 15 volts on twelve volt systems.

The cut-out relay should open when the discharge current is as near zero as possible, usually one ampere or less.

There are usually two adjustments on a cut-out relay; these adjustments are:

(1) Spring tension.

(2) Air gap.

The air gap and spring tension control the closing of the cut-out relay.

The spring tension controls the opening.

In making adjustments, it is advisable first to make them roughly, then to make the final adjustments. The opening adjustment should be made first, by changing the spring tension. If the relay then closes incorrectly, the air gap should be changed until the correct closing is obtained.

Keep the contacts clean and adjusted so that they strike squarely together.

ELECTRIC HORNS

There are three types of electric horns in common use, as follows:

(1) The ordinary type vibrating horn.

(2) The Ford vibrating horn.

(3) The motor driven horn.

The Ford vibrating horn will operate only on alternating current, such as is obtained from the Ford Magneto. See main text for adjustments and full descriptions of construction and operation.

DIMMING HEADLIGHTS

There are several methods used to dim the headlights; some are of a mechanical nature, while in others the lights are dimmed electrically.

The mechanical methods consist of special shutters, special lenses, special reflectors, etc.

When dimmed electrically, it is usually accomplished in one of the following ways:

(a) By changing the headlights from a parallel connection for bright lights, to a series connection for dim lights.

(b) By inserting a special resistance in series with the headlights.

(c) By the use of small bulbs called auxiliary headlights, placed out of the focus of the reflector.

(d) By having a bulb equipped with a double filament, one of high candle power and the other of low candle power.

QUESTIONS

144. What is a dynamo?

145. Is there any difference between a motor and a generator?

146. What is meant by the field of a motor or generator?

147. What is the armature of a motor or generator?

148. What is the purpose of the armature core? Of what material is the core made?

149. What is a commutator? What is its purpose?

150. What is the fundamental difference between the ring wound armature and the drum wound armature?

151. How many brushes are necessary for a four pole lap wound armature? Four pole wave wound armature?

152. What are the general requirements of a starting motor?

153. Why are series field coils necessary on starting motors?

154. Why are large conductors necessary for connecting the starting motor to the engine.

155. Name and describe four mechanical arrangements for connecting the starting motor to the engine.

156. What causes the Bendix pinion to jam?

157. What is an overrunning clutch? Where is it used and for what purpose?

158. Why do some starting switches have a resistance coil placed in them?

159. Explain how shunt field coils differ from series field coils.

160. What appliances are included in the charging circuit?

161. What is a cut-out relay?

162. How many windings has a cut-out relay?

163. Is there any difference in the windings?

164. What are their purposes?

165. How many terminals has a cut-out relay?

166. To what do the terminals connect in the charging circuit?

167. How is the cut-out relay tested?

168. Through which winding is current passed to close the cut-out relay?

169. How do cut-out relay points normally stand?

170. Does the current flowing from the battery close or open the points on cut-out relay?

171. Do cut-out relays have electromagnets?

172. What causes the cut-out relay points to open after they have been closed?

173. At what voltage should the relay points close?

174. What is used to find at what voltage the cut-out points close?

175. If points close late what adjustment should be made?

176. Should a buzzer close the cut-out contacts in testing if the points are adjusted to close properly?

177. Where and what kind of an instrument should be inserted to determine the strength of discharge of the battery at the time contacts open?

178. Is the cut-out relay to keep the battery from overcharging?

179. What causes cut-out relay contacts to burn?

180. What can be inserted to protect these contacts?

181. How many adjustments on a cut-out relay?

182. What controls the opening? What controls the closing?

183. If a cut-out relay closed at 9 volts and

opened at 3 amperes discharge what adjustment should be made?

184. What method can be taken to determine whether or not the voltage winding of the cut-out relay is open?

185. What is meant by the term "regulation"?

186. Why is regulation of the generator necessary?

187. How is regulation of the automobile generator accomplished?

188. How many field windings are there in a generator having a reverse-series regulation?

189. Will generator of this type charge battery if the shunt field is open? If series field coils are shorted?

190. What effect do corroded battery terminals have on systems using generator of this type? What is the effect of loose connections in the charging circuit?

191. How can the charging rate of a generator of this type be increased? Decreased?

192. Explain how a vibrator regulator controls a generator.

193. Do the vibrator regulator points normally stand open or closed?

194. What causes the vibrator regulator points to stick? How could this affect the output of the generator?

195. How could a combined current and voltage type regulator be distinguished from a current type regulator?

196. How could a voltage type regulator be distinguished from combined current and voltage type regulator?

197. Do all three types of vibrator regulators affect the same circuit of the generator for regulation?

198. How can a vibrator regulator be distinguished from a cut-out-relay?

199. What would be the difference in the sound of buzzer if testing between the generator positive terminal and shunt field terminal if the regulator points are open?

200. Do regulators have electromagnets?

201. Why is the resistance of a regulator sometimes divided?

202. Will a regulator keep the generator from overcharging a battery when battery tests 1.300?

203. With a combined current and voltage type regulator does the series winding assist the voltage winding or act in opposition to it after the cut-out points close?

204. What will indicate the spring tension has been increased too much?

205. Why do regulator points sometimes have a condenser across them?

206. How could the generator with vibrating type regulation be distinguished from a generator with reverse series or field distortion regulation?

207. What is field distortion? What causes it?

208. Explain how field distortion is used to regulate a generator.

209. Can the direction of rotation of armature be determined from the position of the third brush?

210. If the battery is disconnected from the generator, will the generator have regulation?

211. If a car is to be run without the battery, what precaution should be taken?

212. Must a generator having field distortion regulation or a vibrator regulator have series field coils?

213. Can the shunt field of a generator be tested with a buzzer?

214. Can the series field coils of a starting motor be tested with a buzzer?

215. In what ways do starting motors differ from the generators?

216. Explain how to test for (a) open field coils; (b) shorted field coils; (c) grounded field coils.

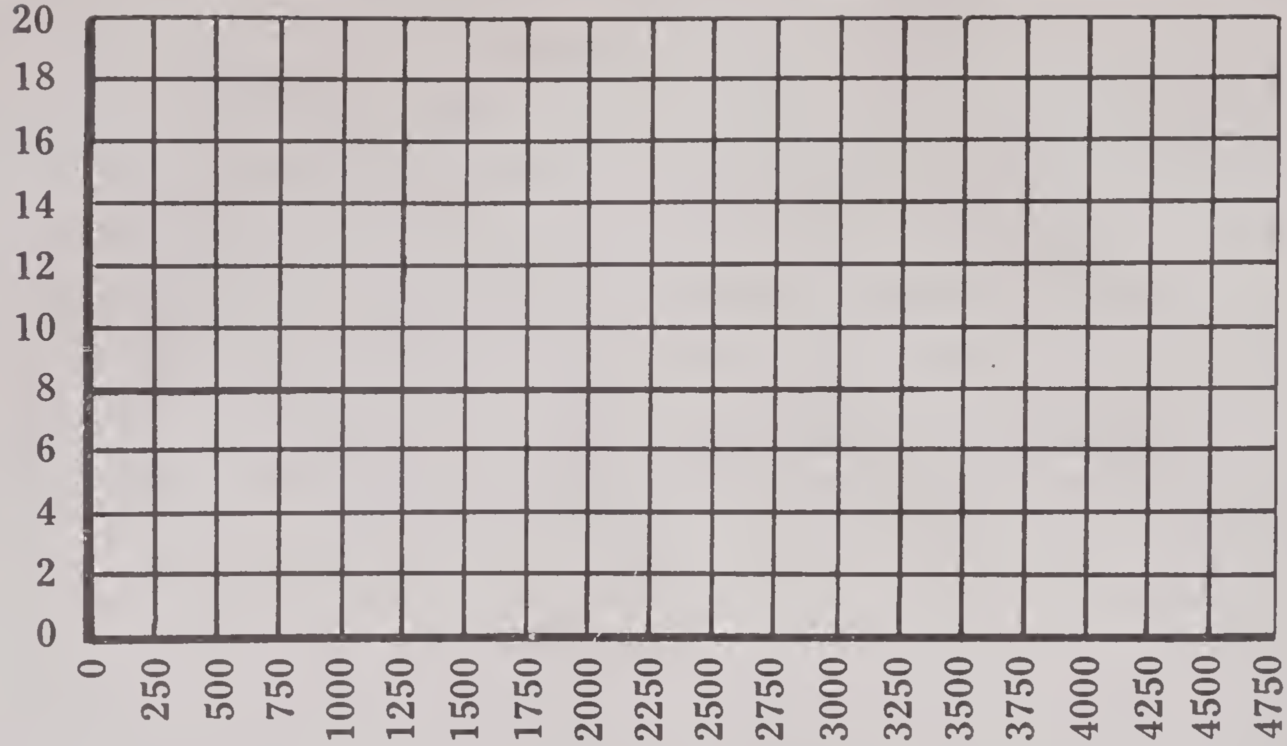
217. What effect do partially shorted field coils have on starting motors? On generators?

218. Explain how an armature may be tested for (a) shorted coils; (b) open armature coils; (c) grounded armature coils.

219. Explain why a Ford horn will not operate on a direct current.

220. What are the adjustments on a motor horn?

221. Describe three ways of dimming the headlights.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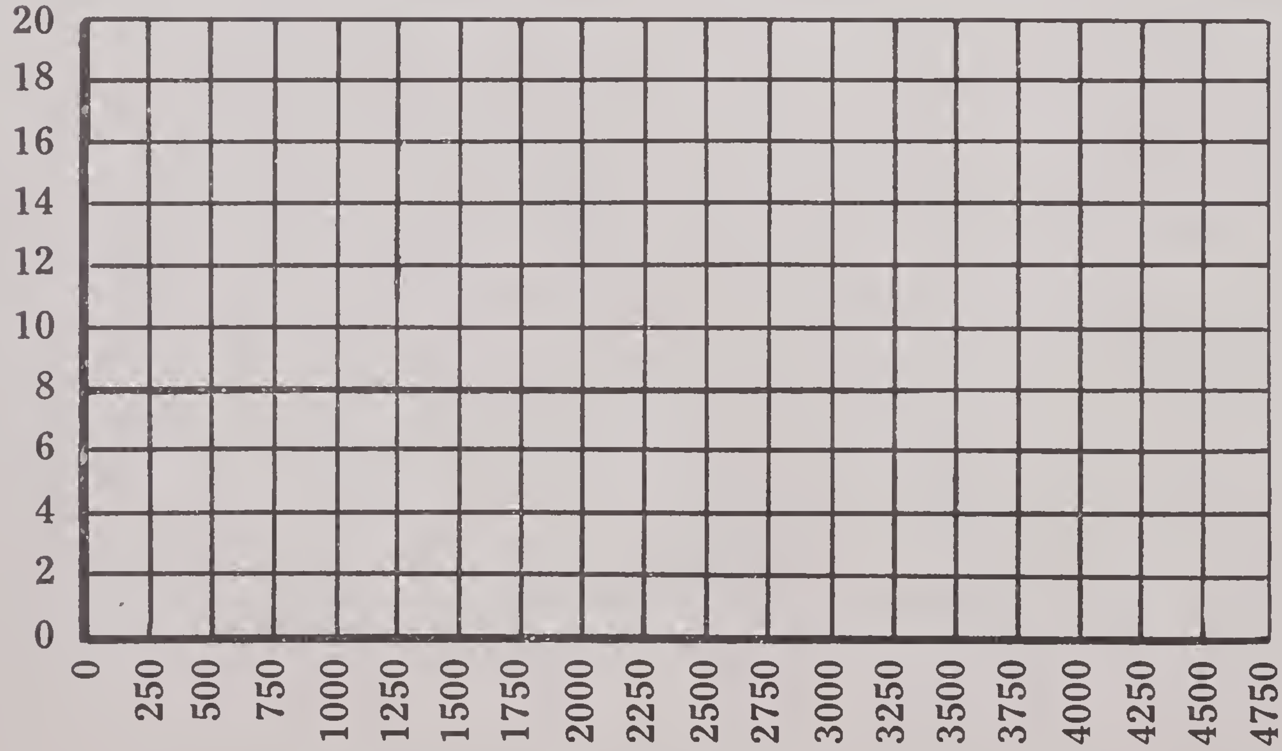
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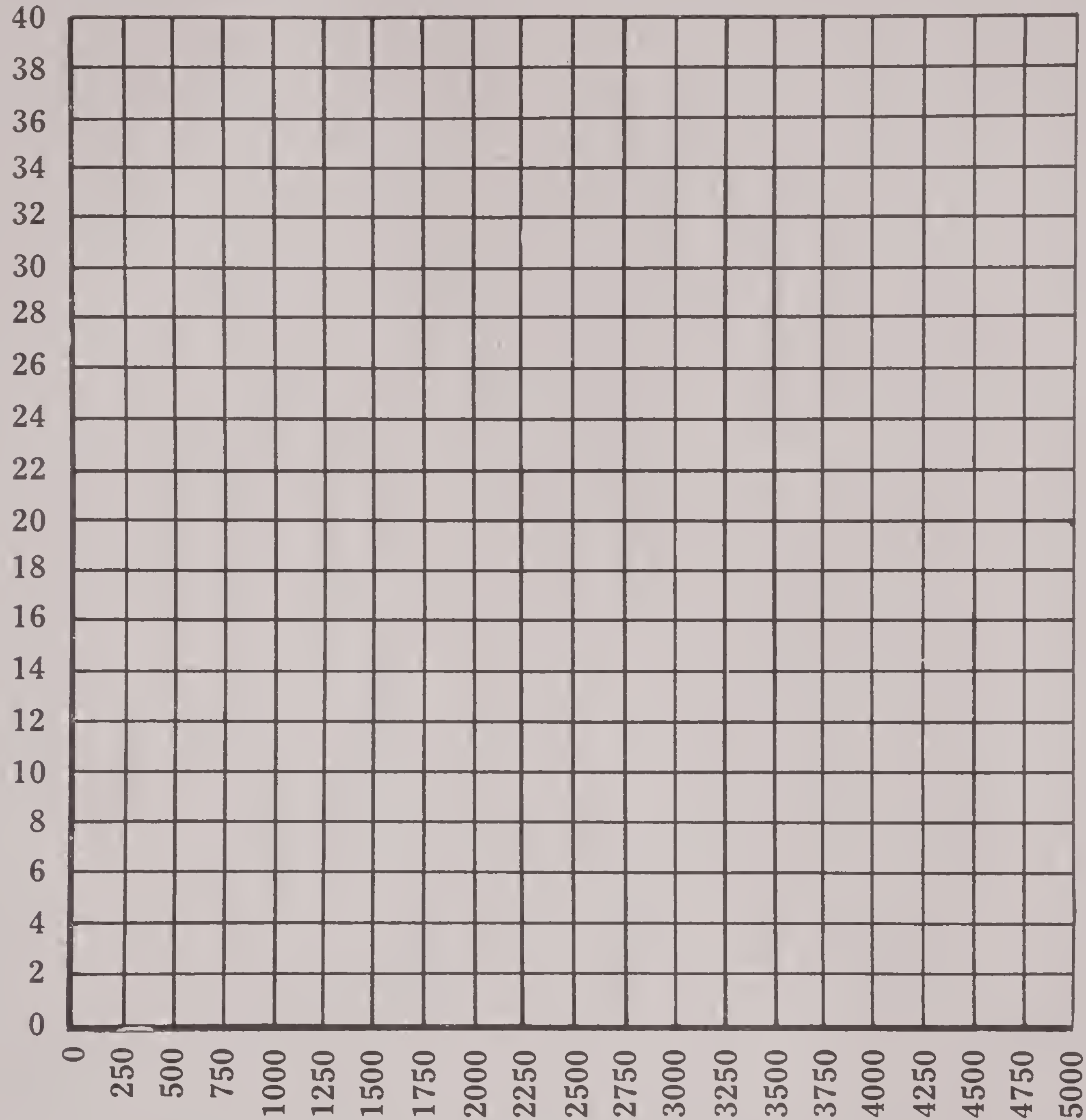
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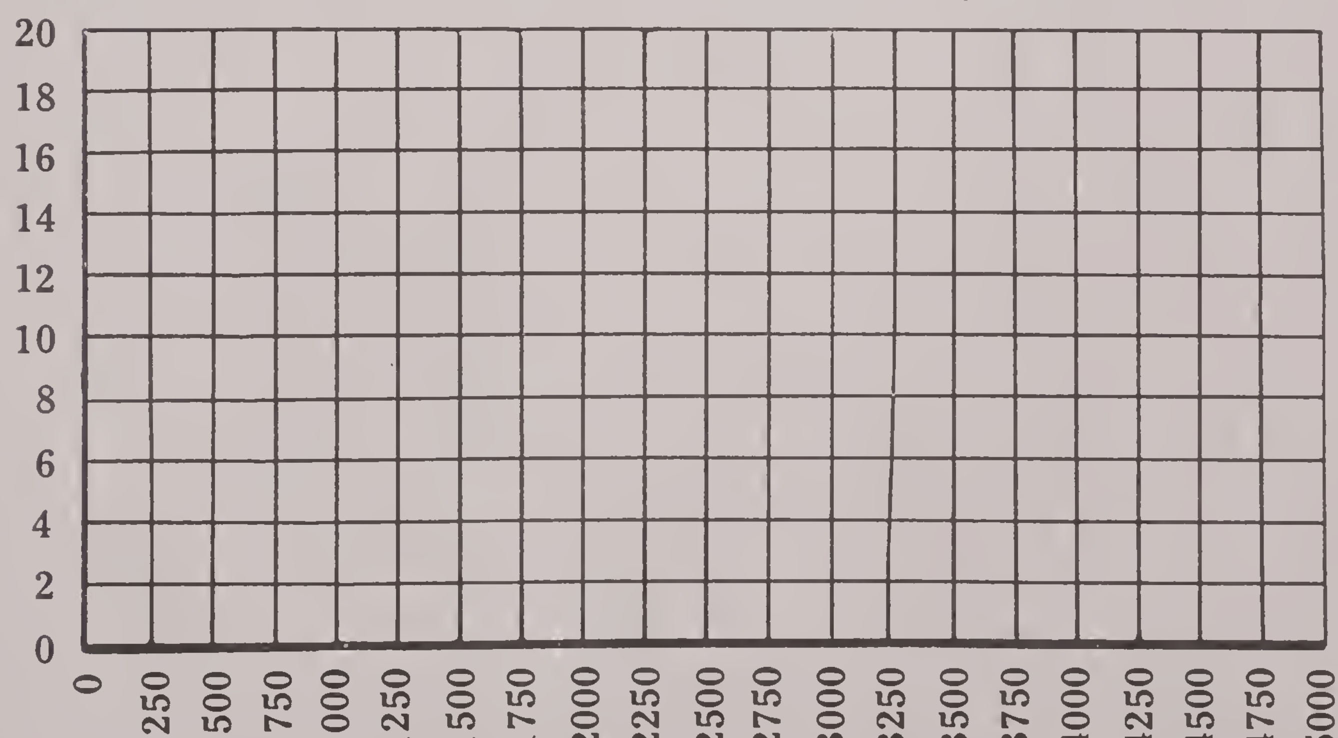
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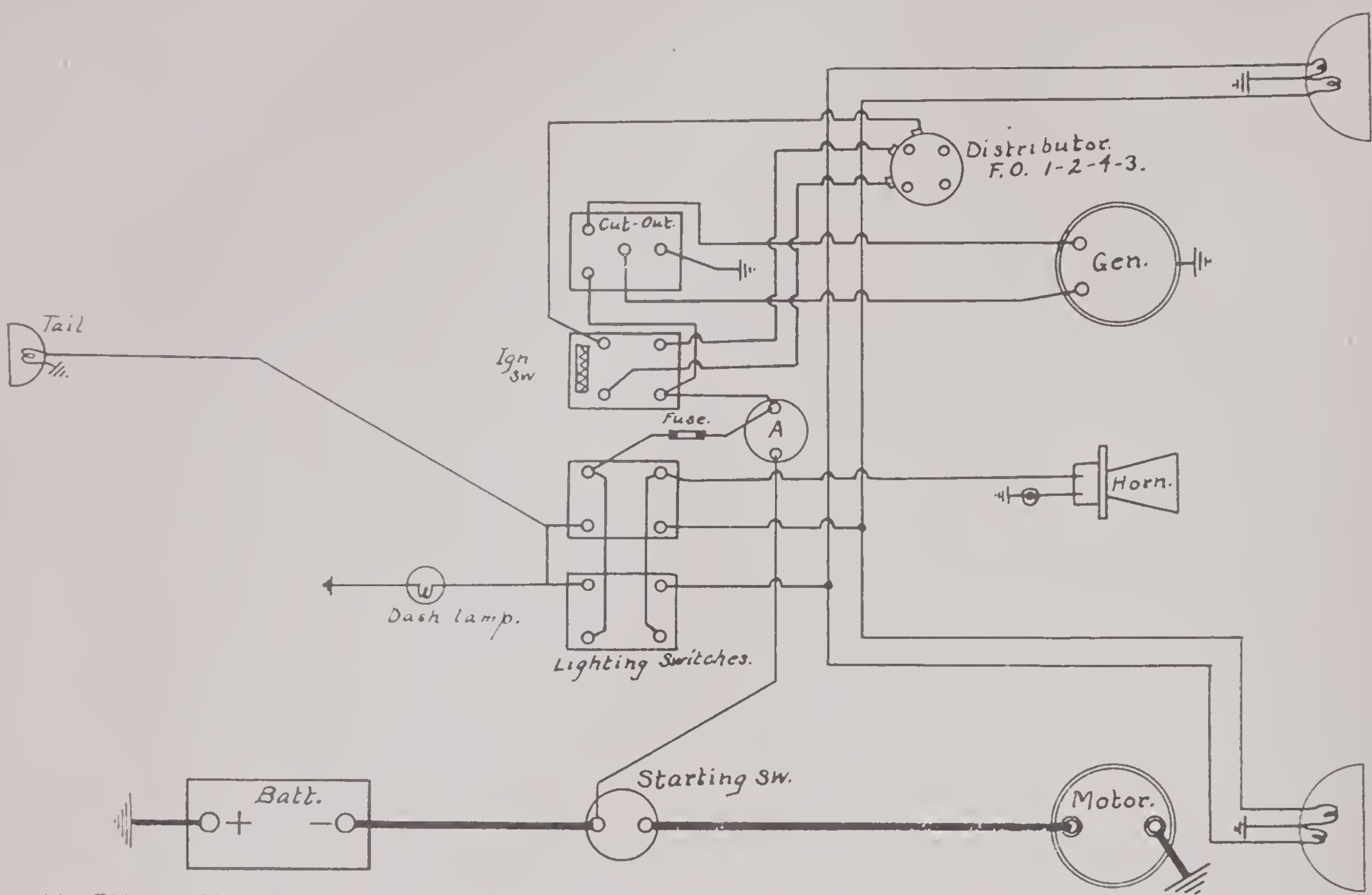
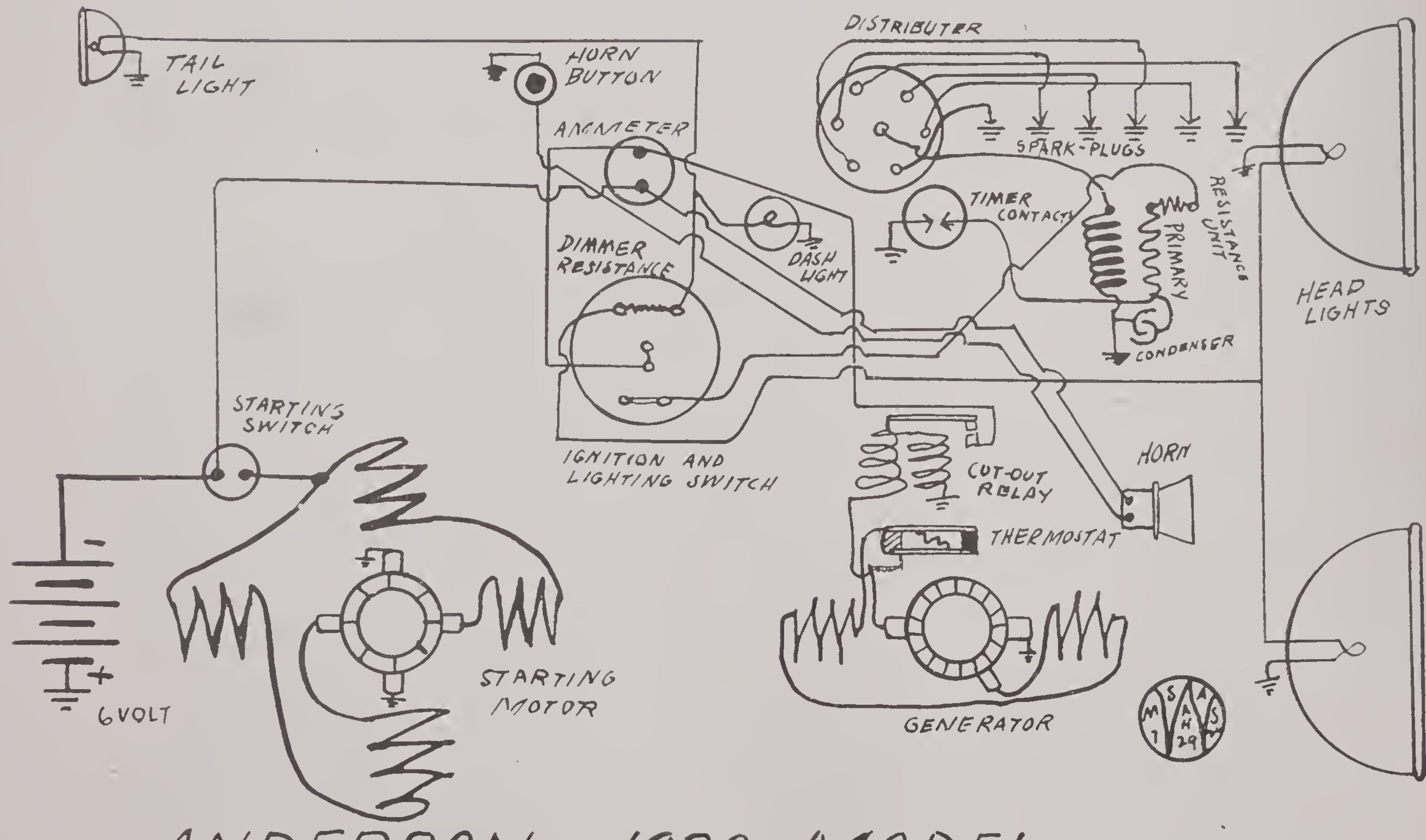
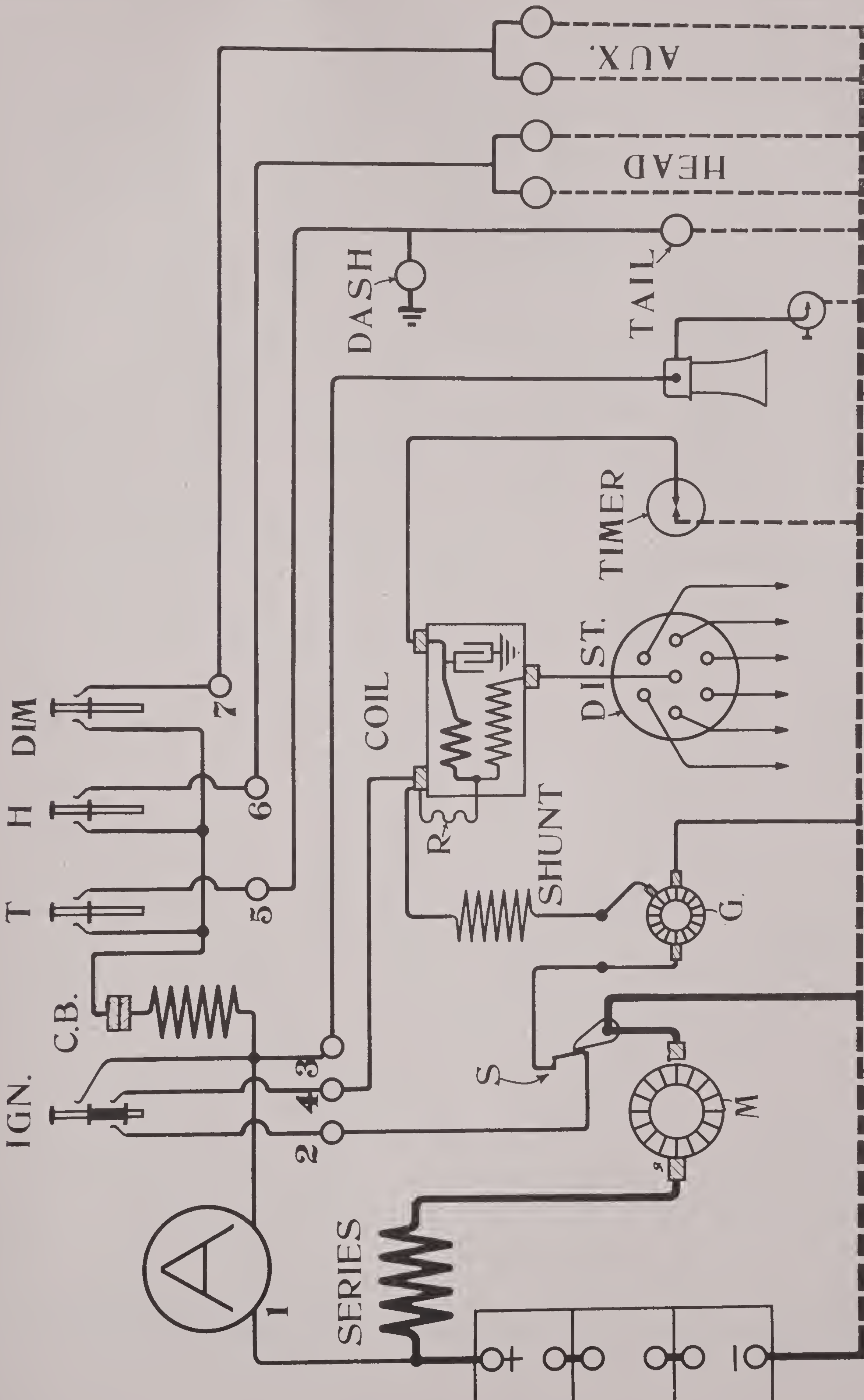


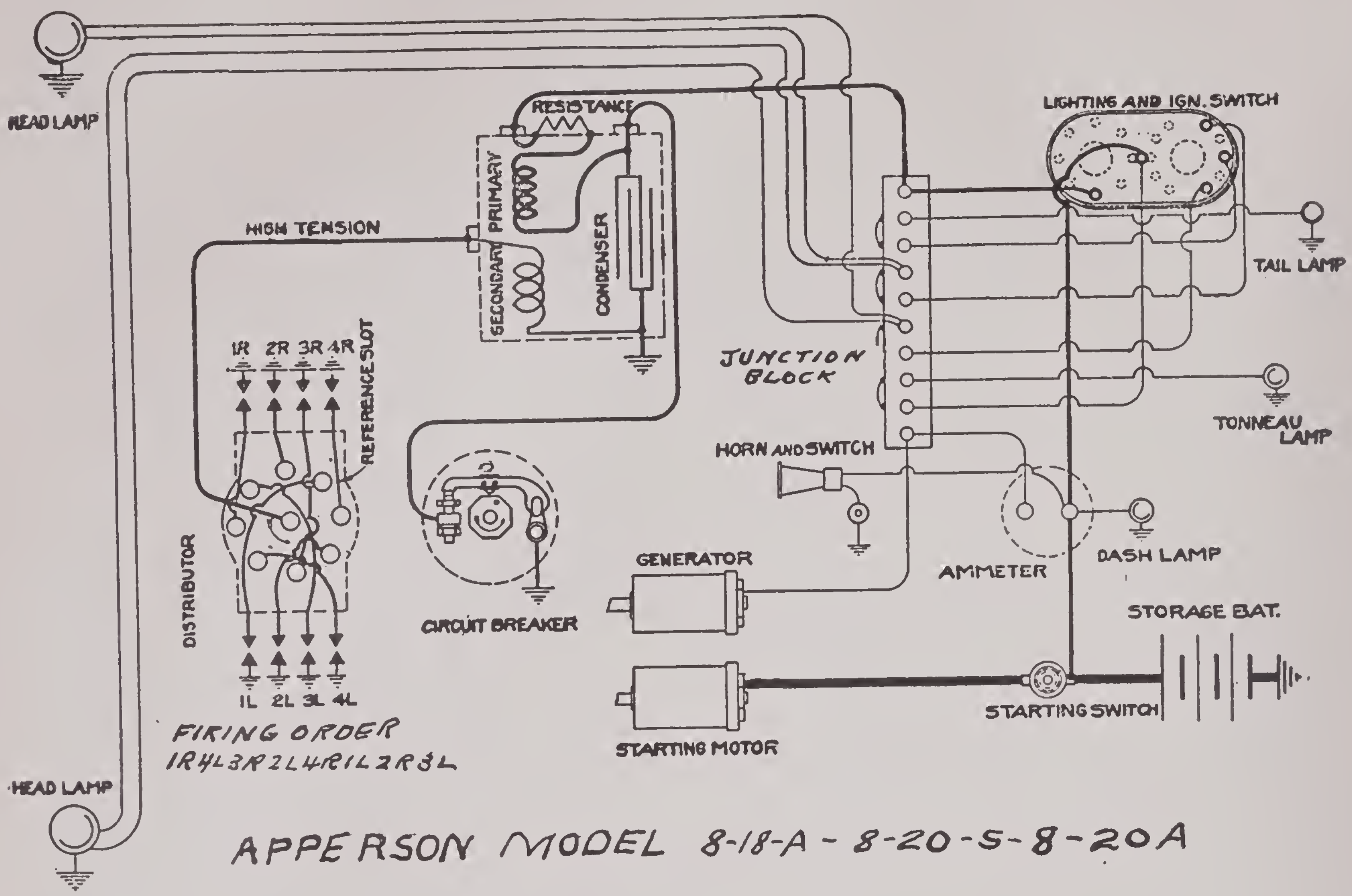
ALLEN Classic Model 1917 Westinghouse Starting — Lighting and Ignition.



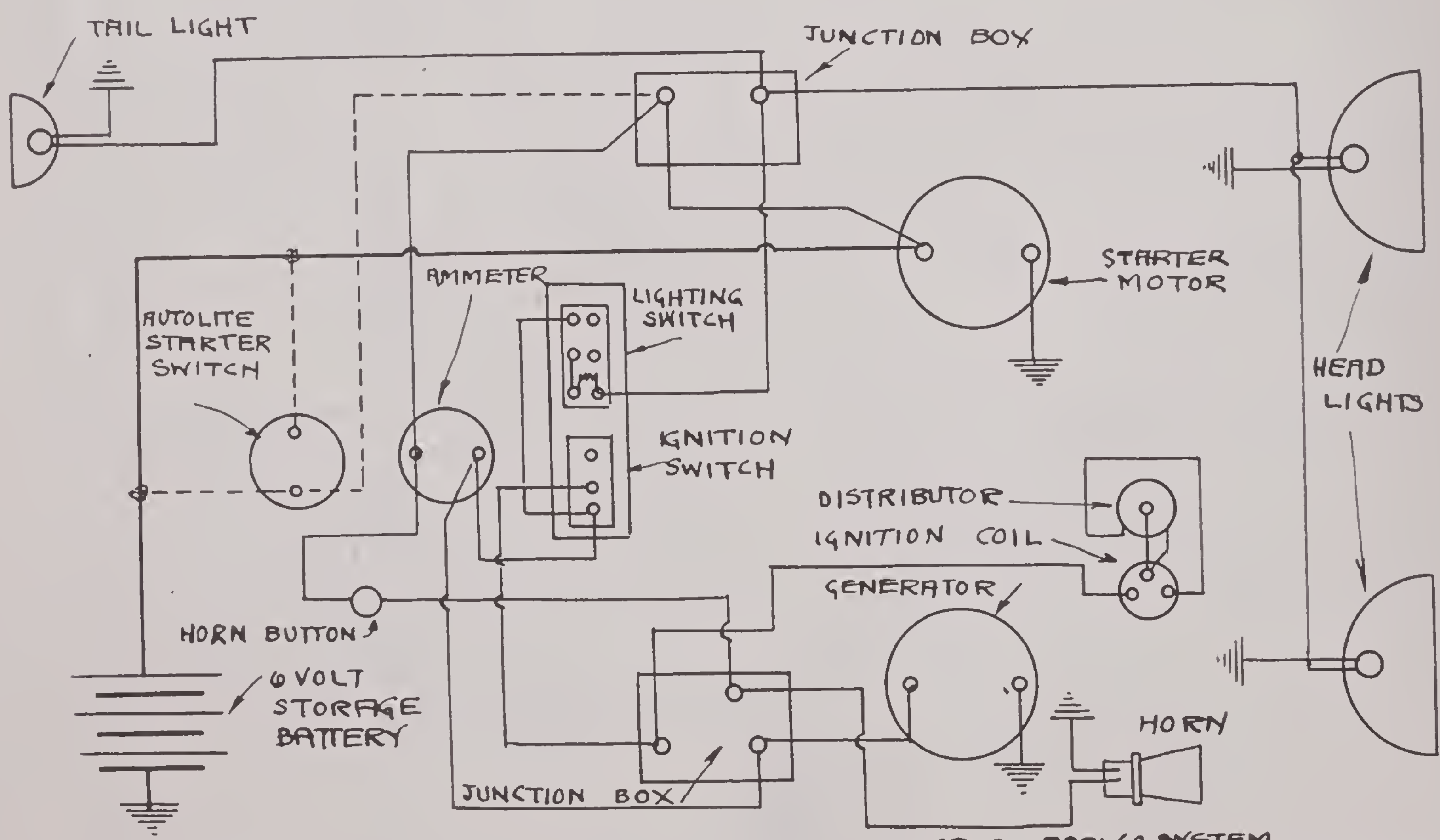
ANDERSON 1920 MODEL



AUBURN—6-40-A—DELCO STARTING, LIGHTING AND IGNITION

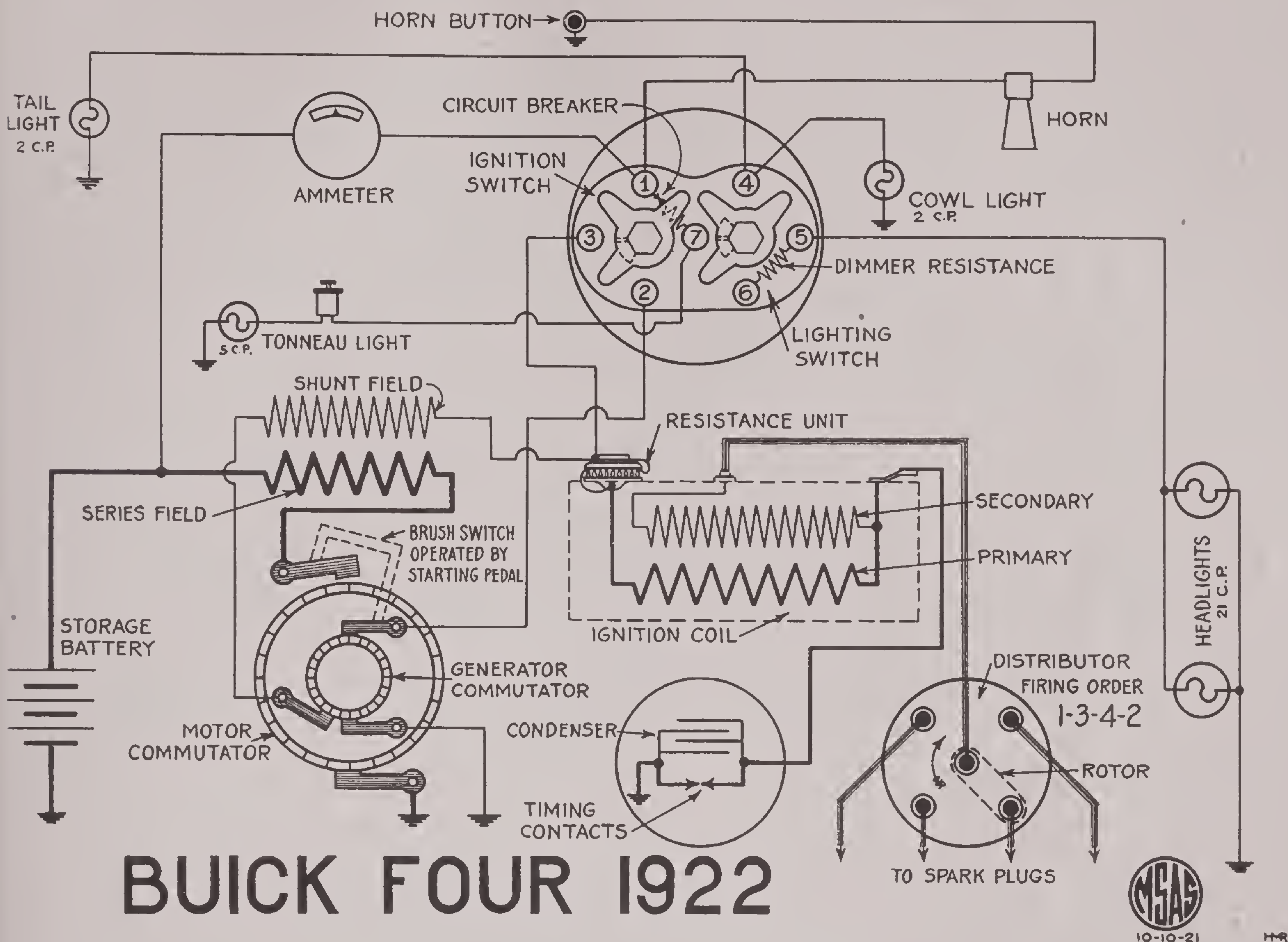


APPERSON MODEL 8-18-A - 8-20-S-8-20A

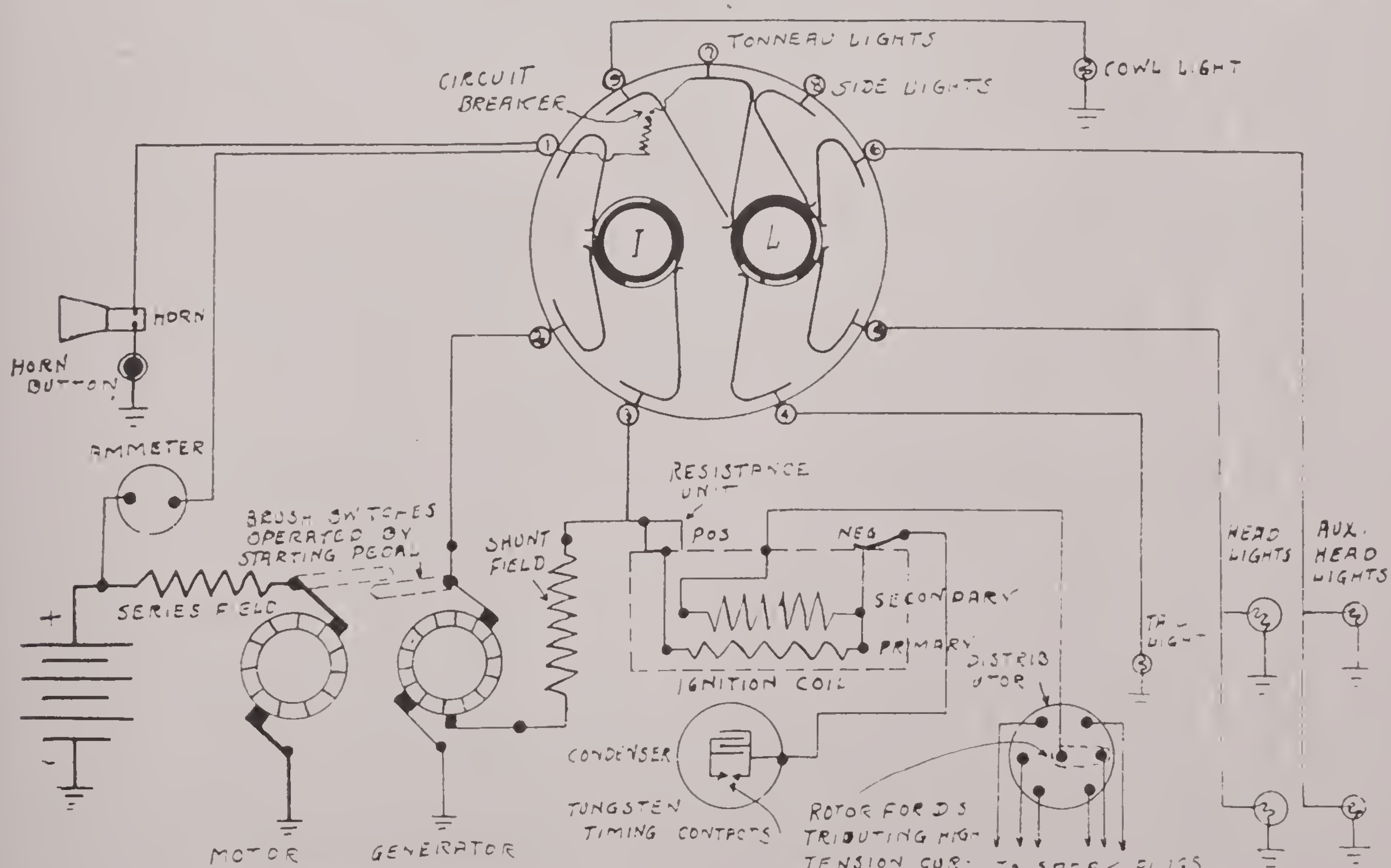


BRISCOE "MOD. 4-24" 1917-18-19

SPLITDORF-APELCO SYSTEM
CONNECTICUT IGNITION ON 1919 MODELS.
CHANGES FOR AUTOLITE SYSTEM
SHOWN IN DOTTED LINES.

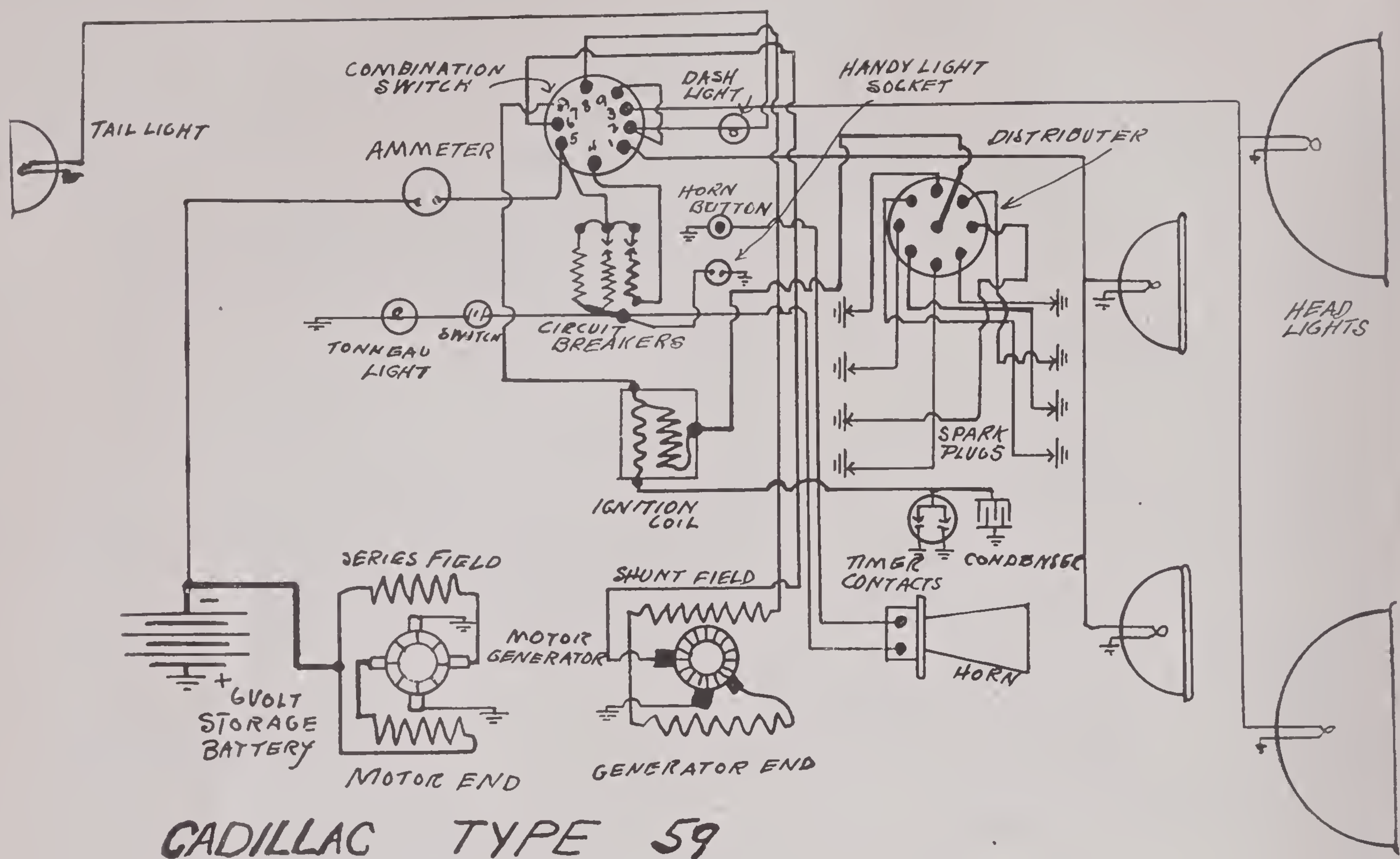


BUICK FOUR 1922

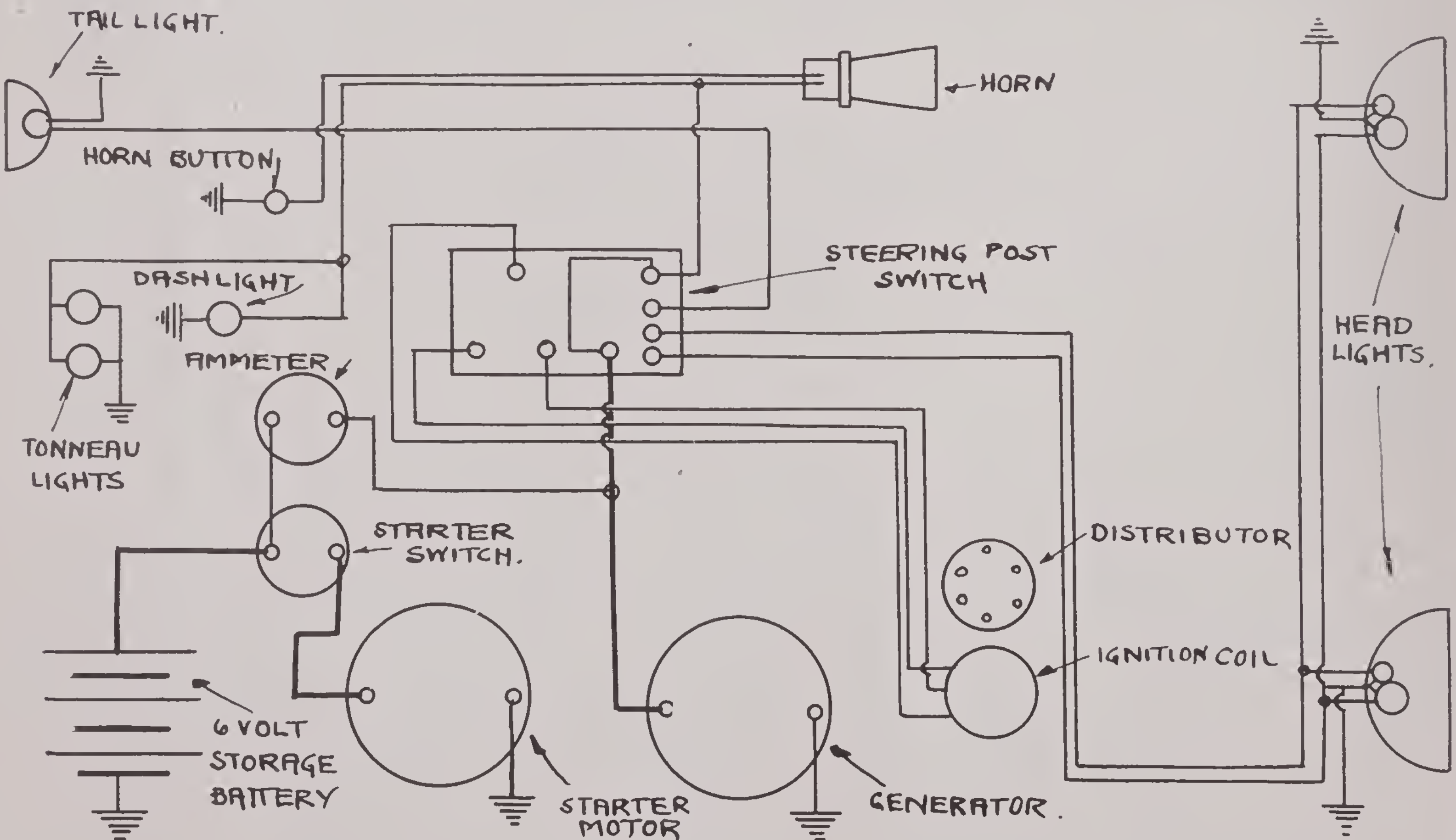


ALL 6 CYLINDER MODELS

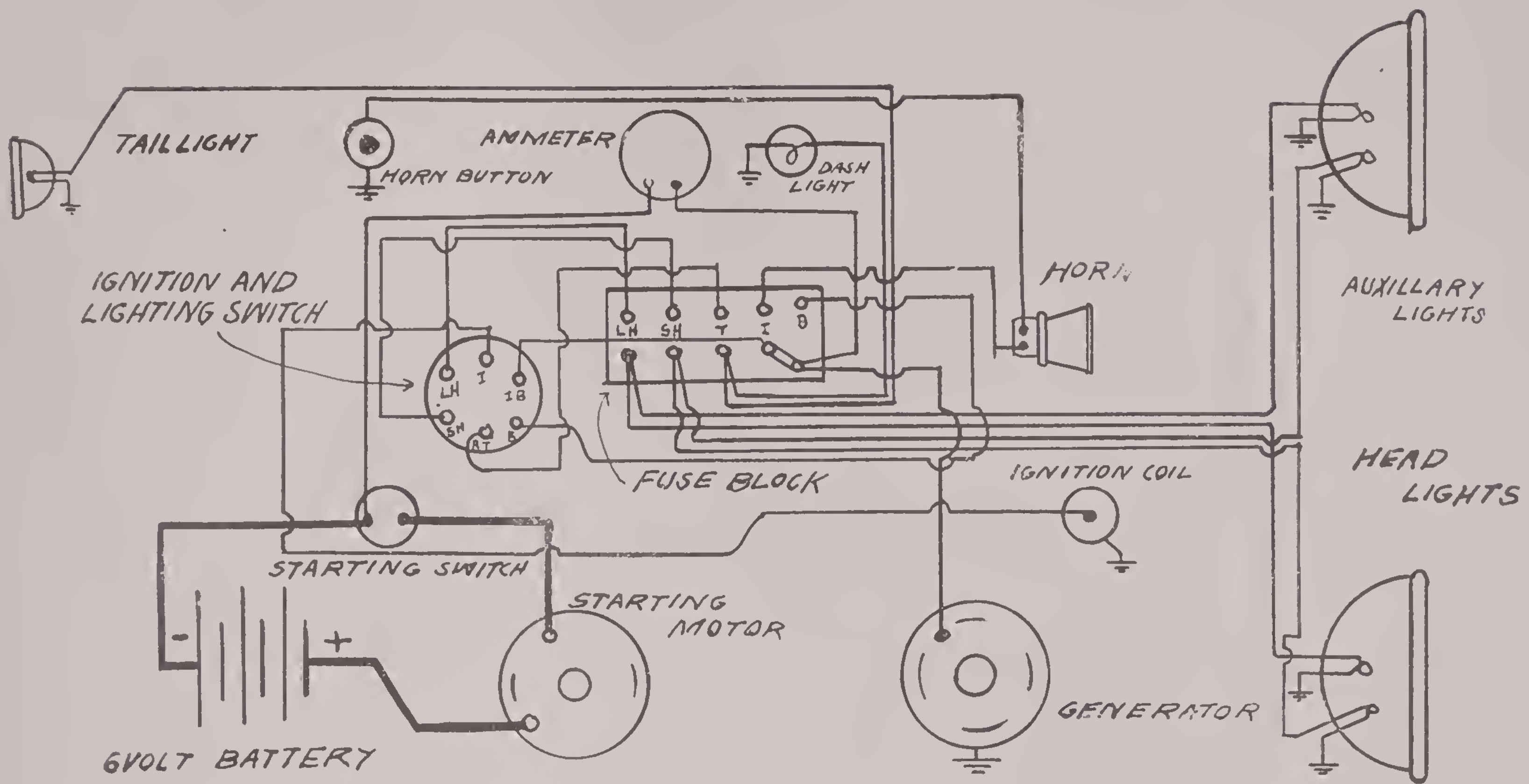
BUICK 1921- OPEN MODELS - DELCO SYSTEM



CADILLAC TYPE 59



CASE MODEL "U" 1918 WESTINGHOUSE SYSTEM



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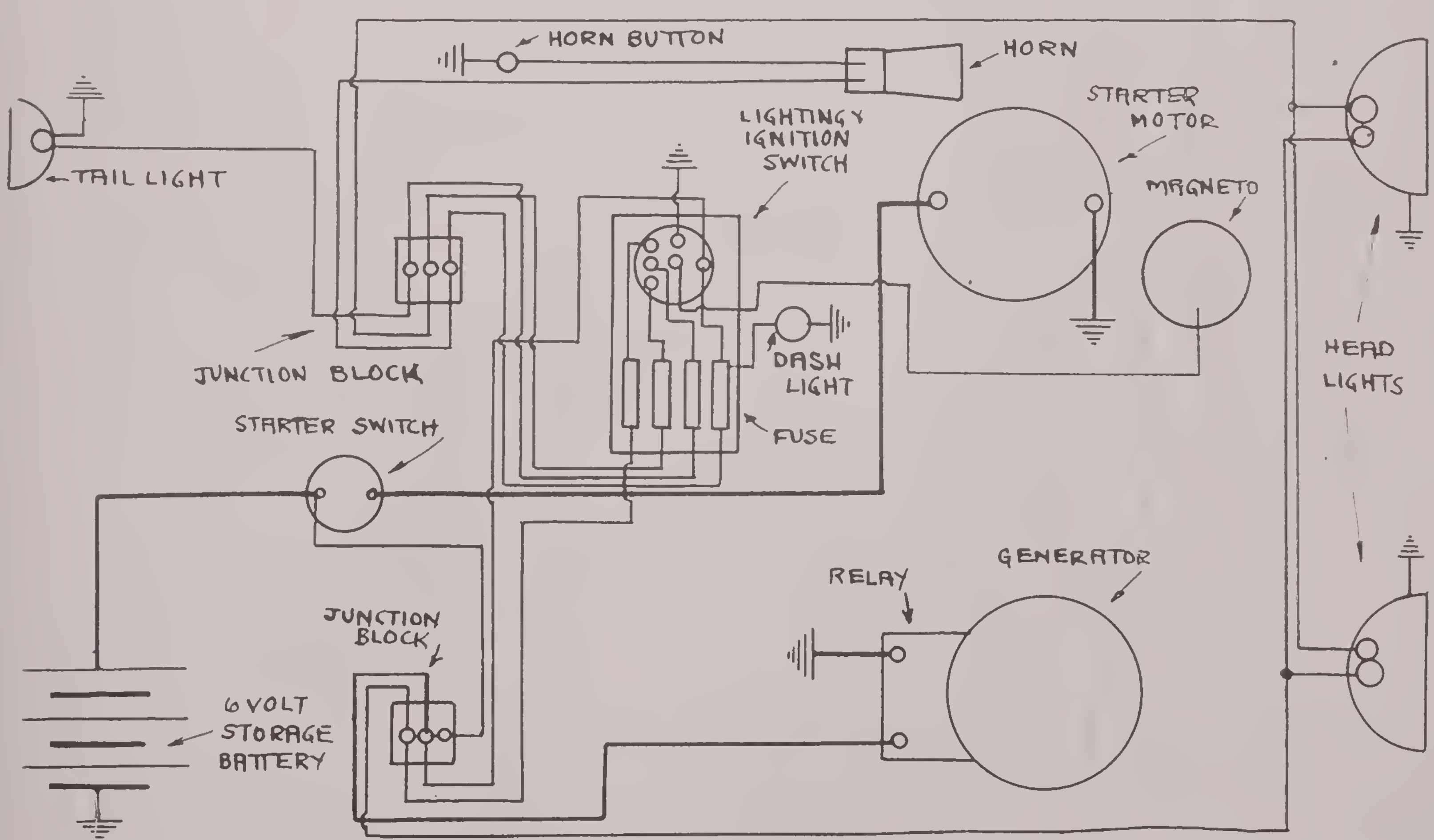
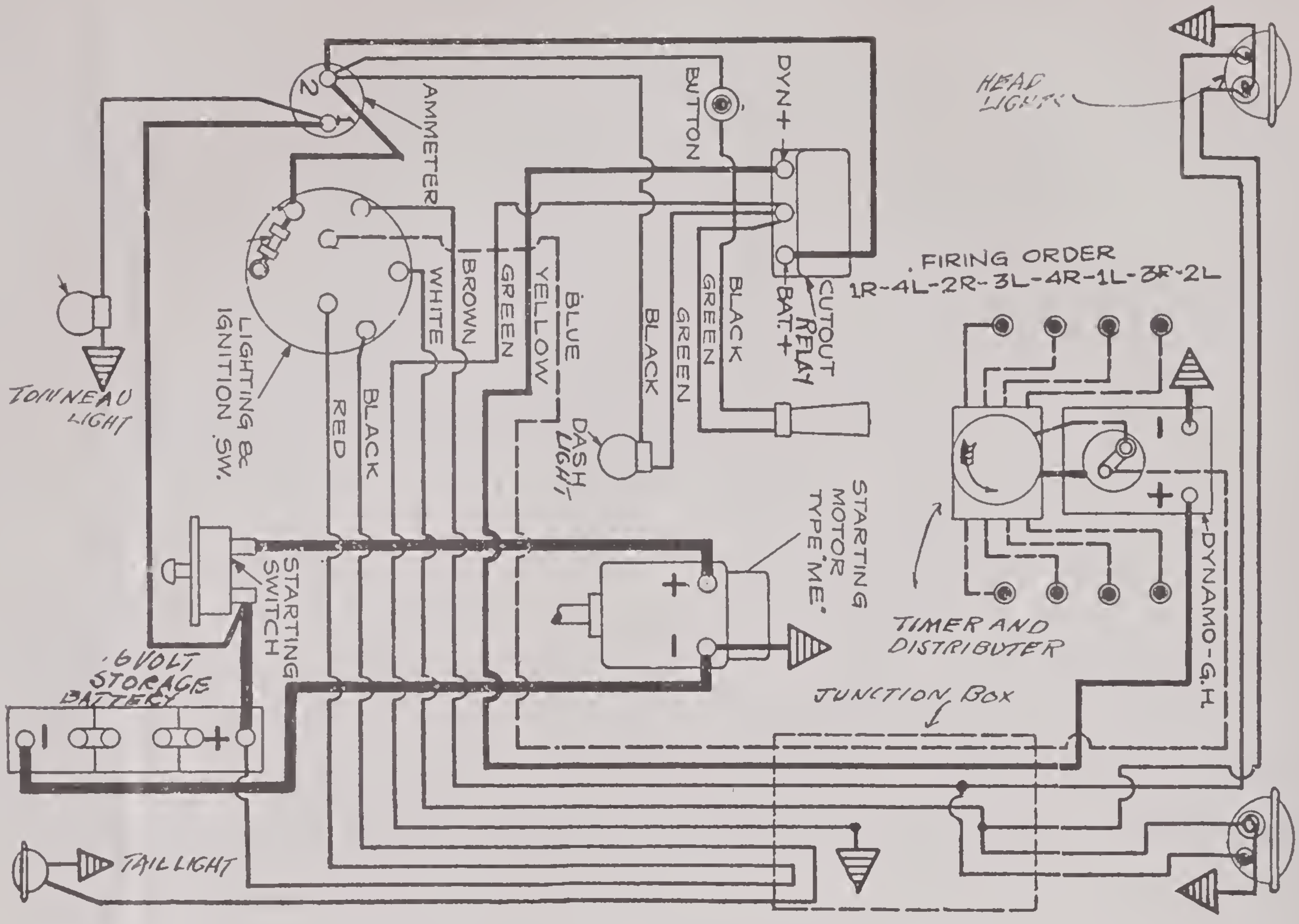
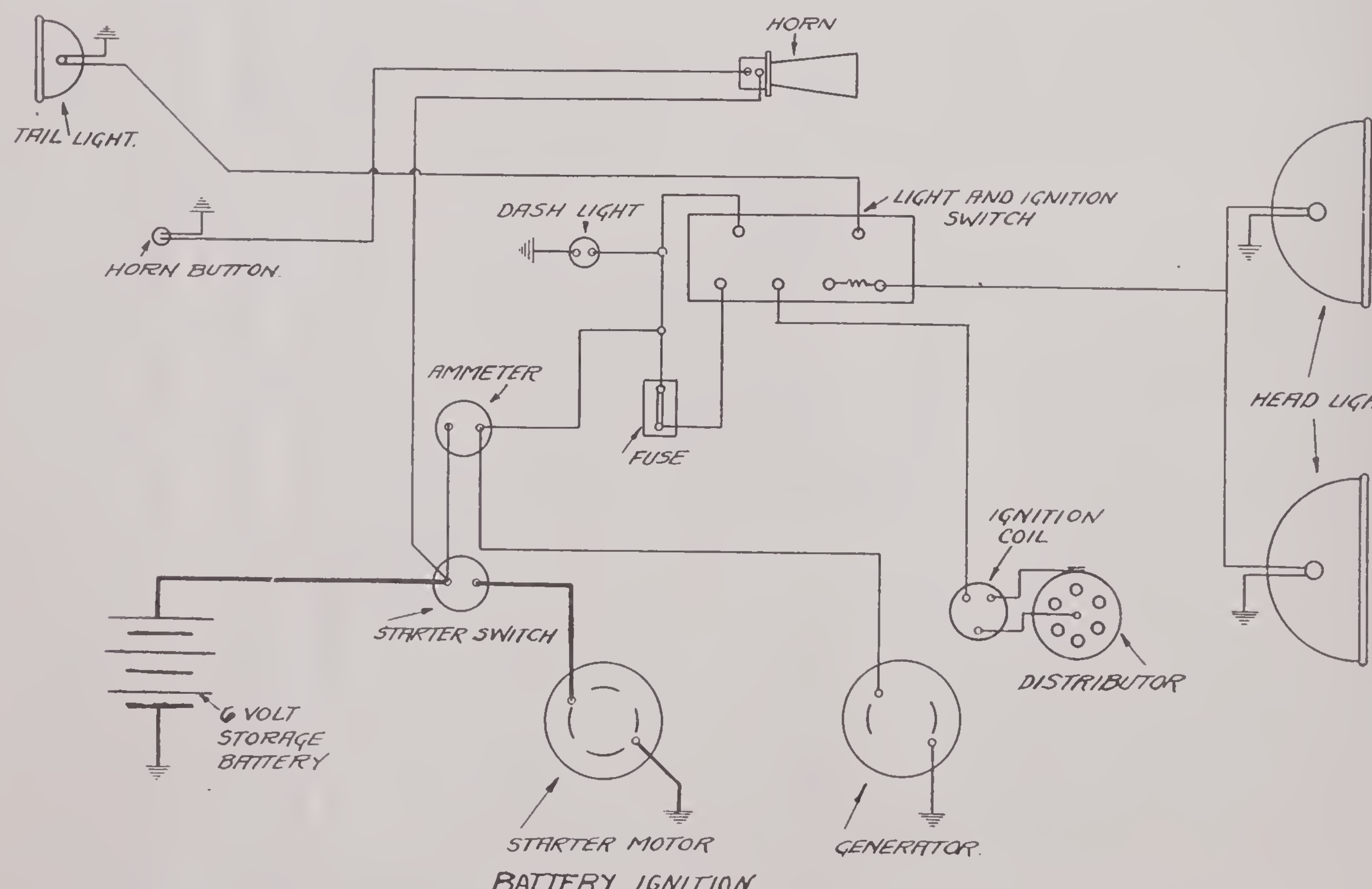


CHANDLER LIGHT SIX 1917-18 SERIAL No's 35001 & UP.

GRAY-DAVIS GENERATING, STARTING AND LIGHTING SYSTEM. BOSCH MAGNETO IGNITION.



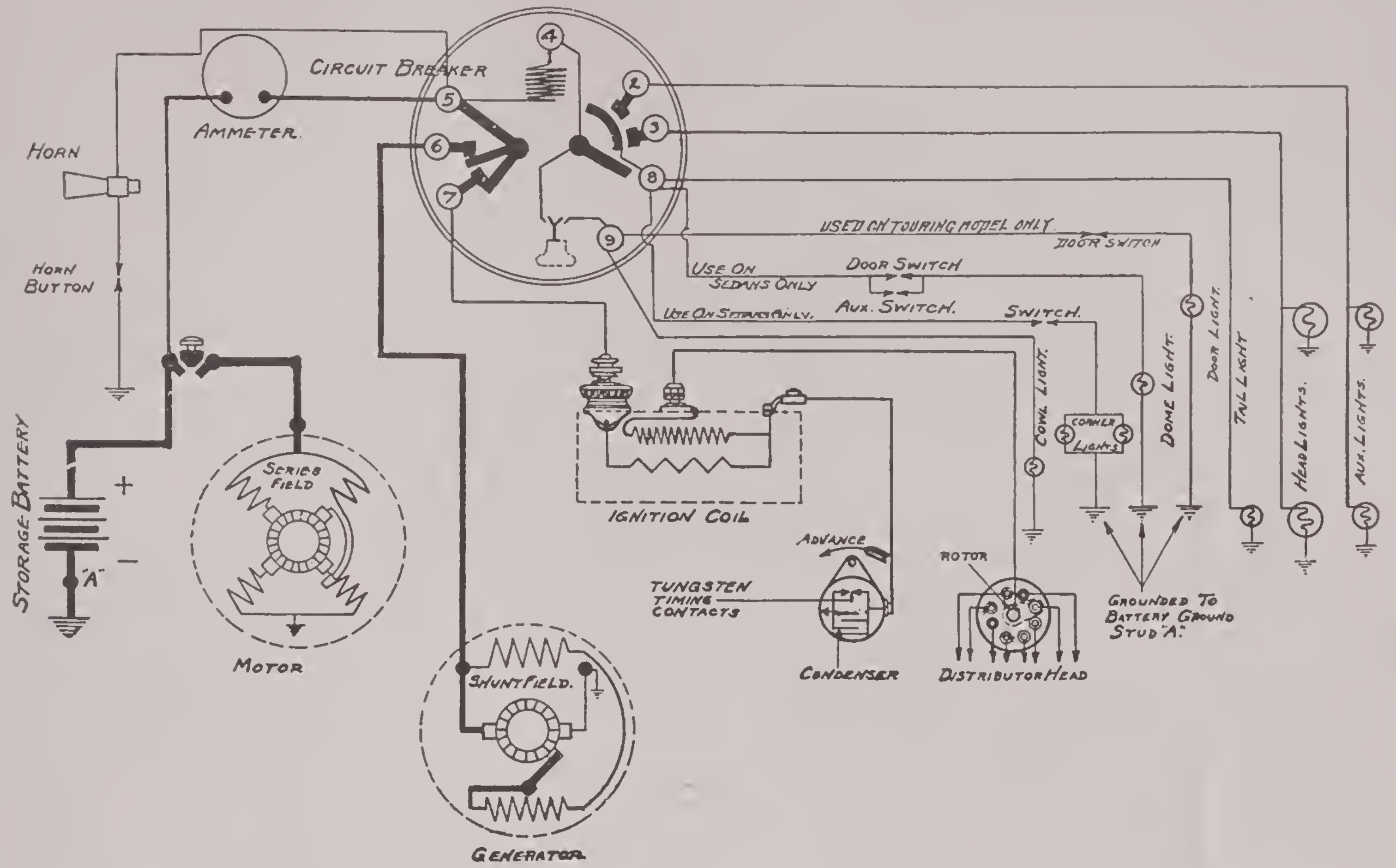
CHEVROLET MODEL 'D' 8CYL 1918 AFTER 1ST 1000 CARS



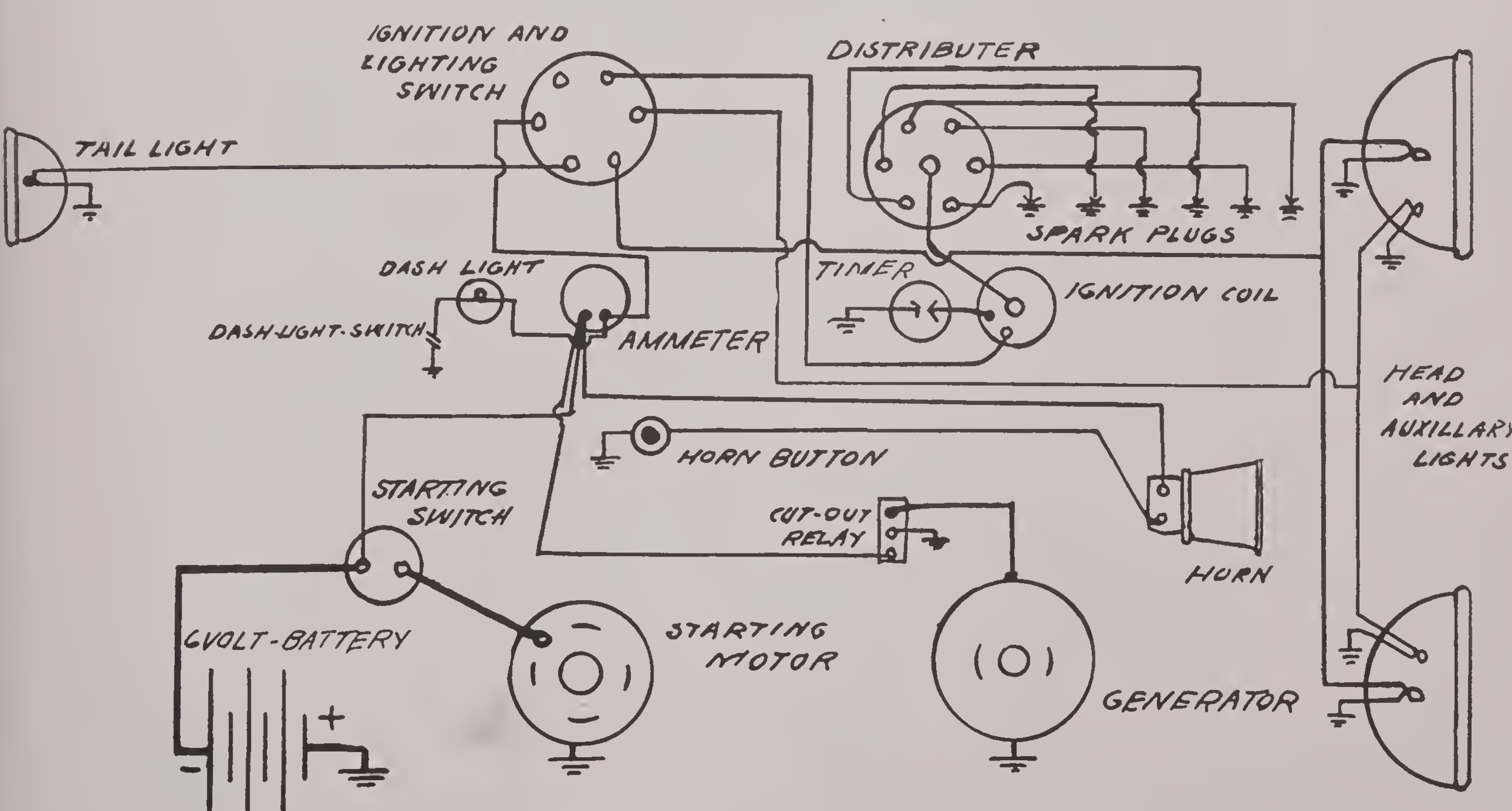
BATTERY IGNITION

CLEVELAND MODEL 1919 & 1920

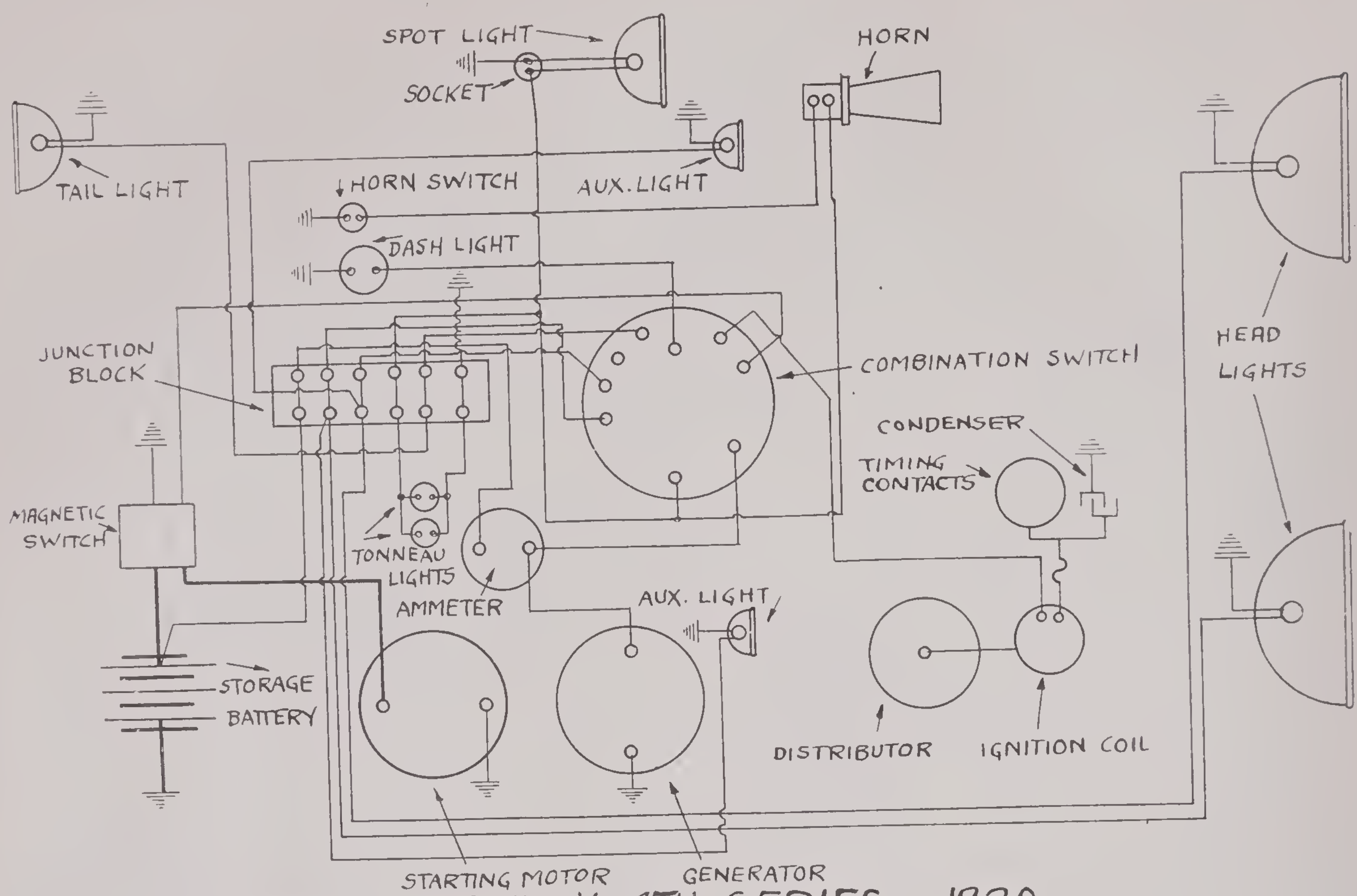
FIRING ORDER 1-4-2-6-3-5.



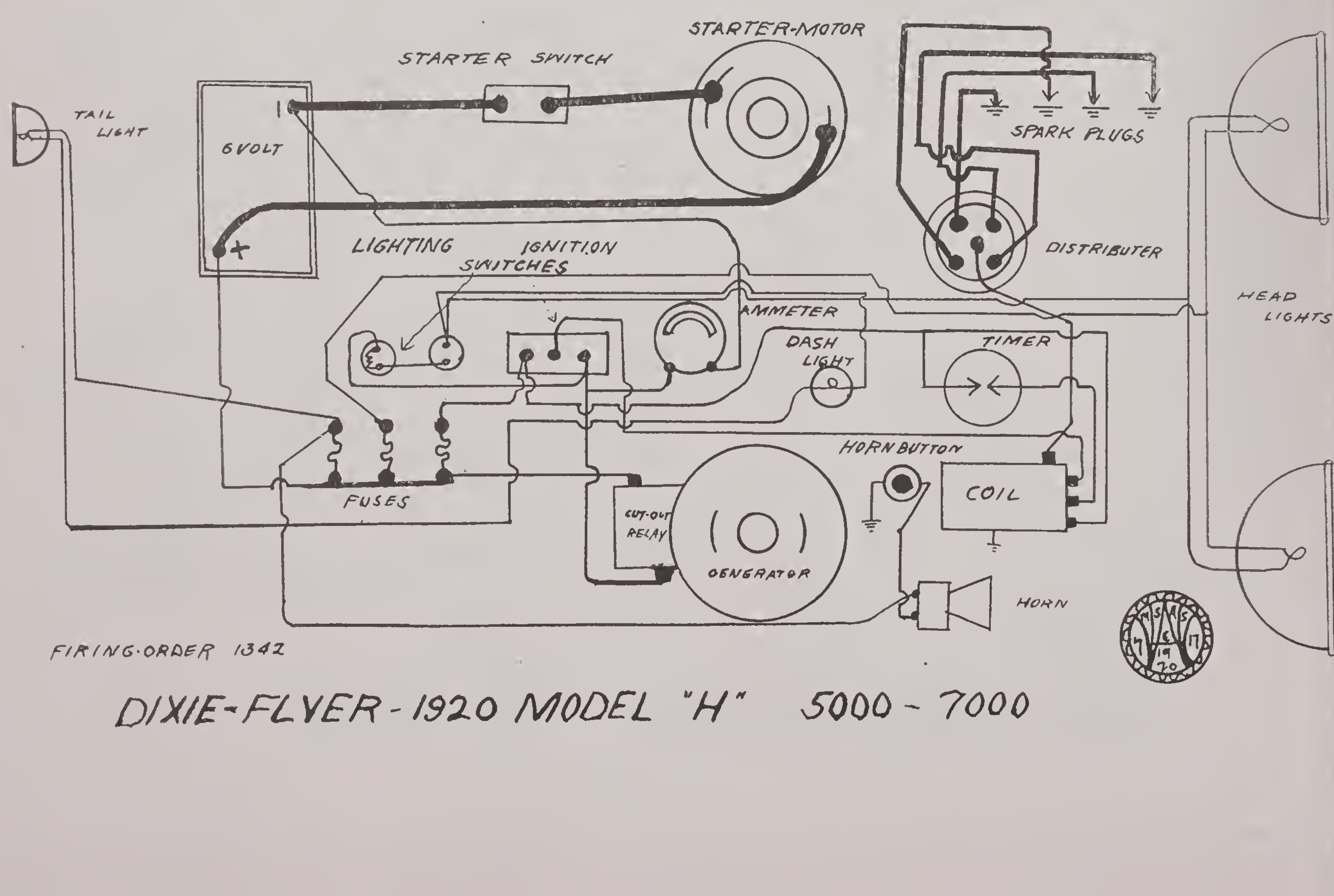
COLE MODEL 8-70 1919 SERIAL 51001 TO 54000 DELCO SYSTEM



COLUMBIA - SERIES 7R 1920

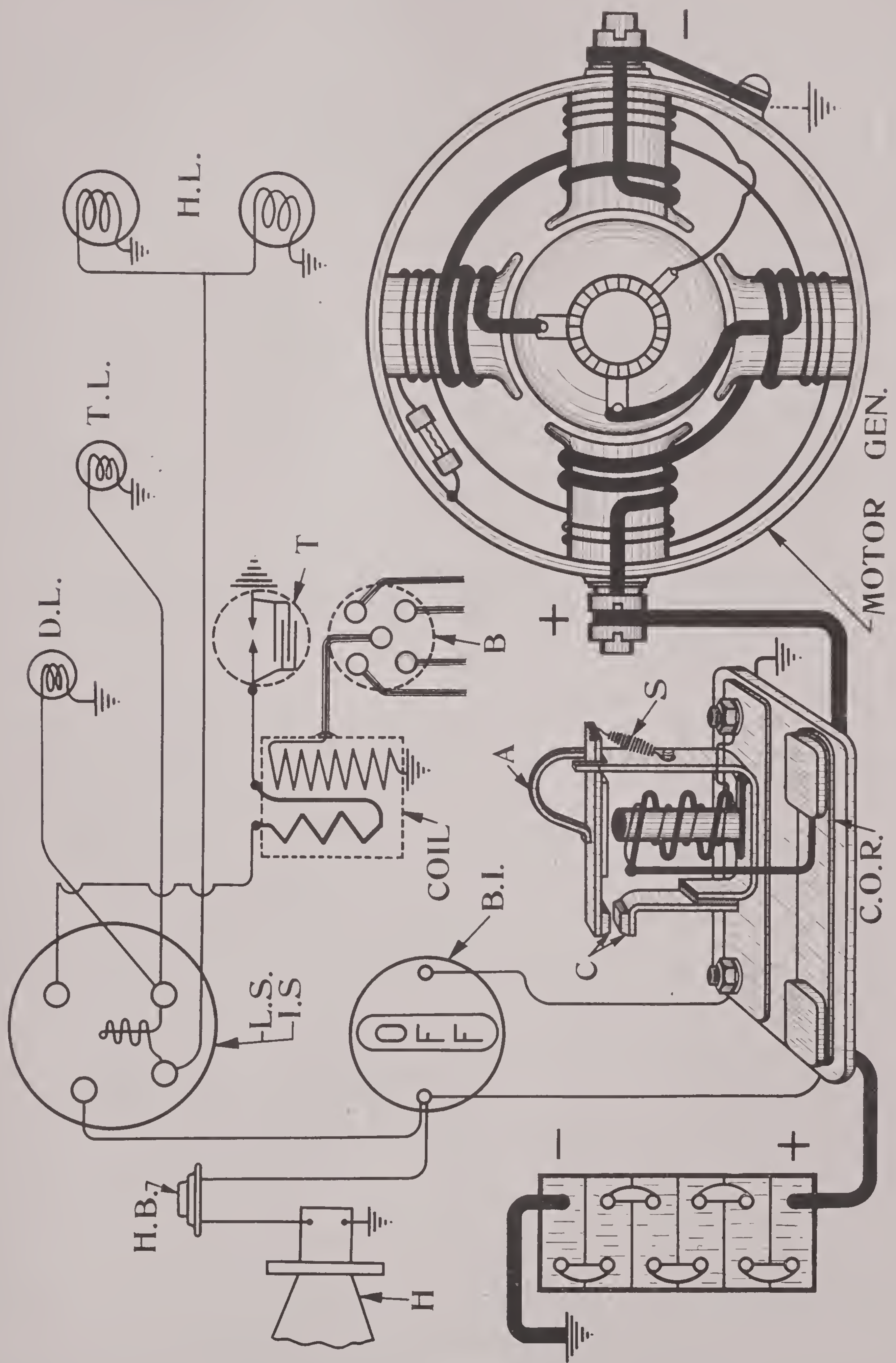


CUNNINGHAM MODEL V 4TH SERIES 1920

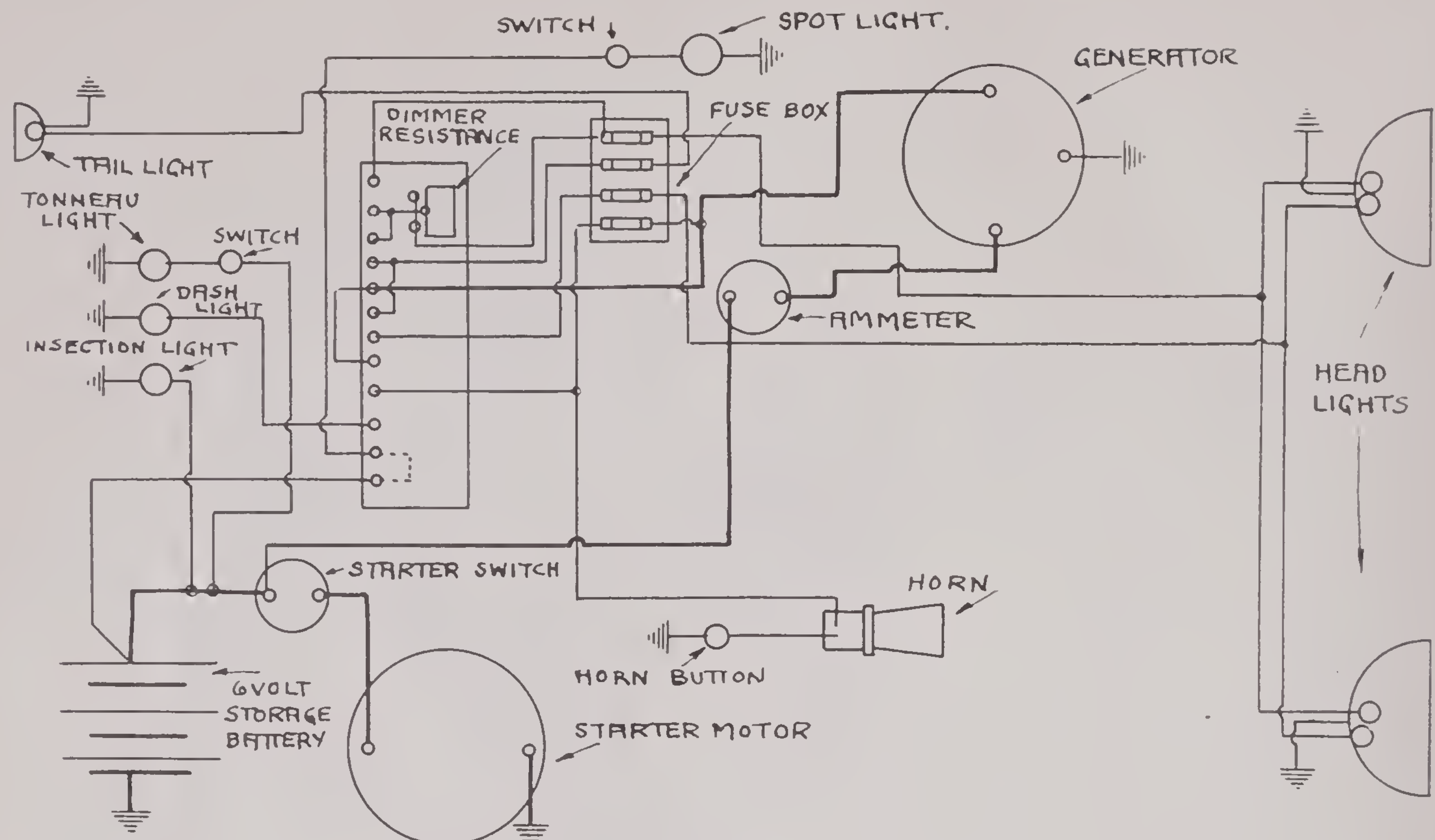


FIRING ORDER 1342

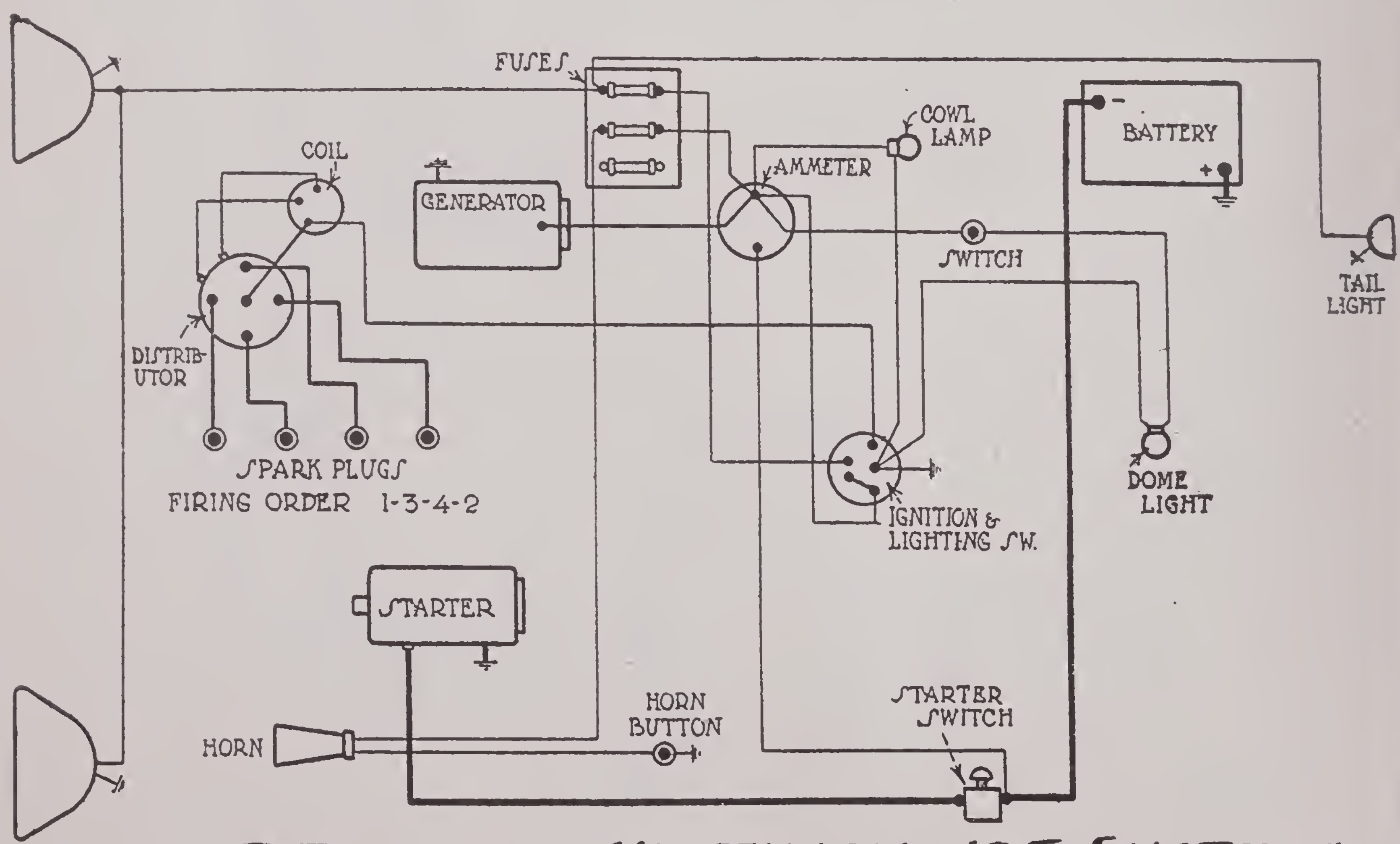
DIXIE-FLYER-1920 MODEL "H" 5000-7000



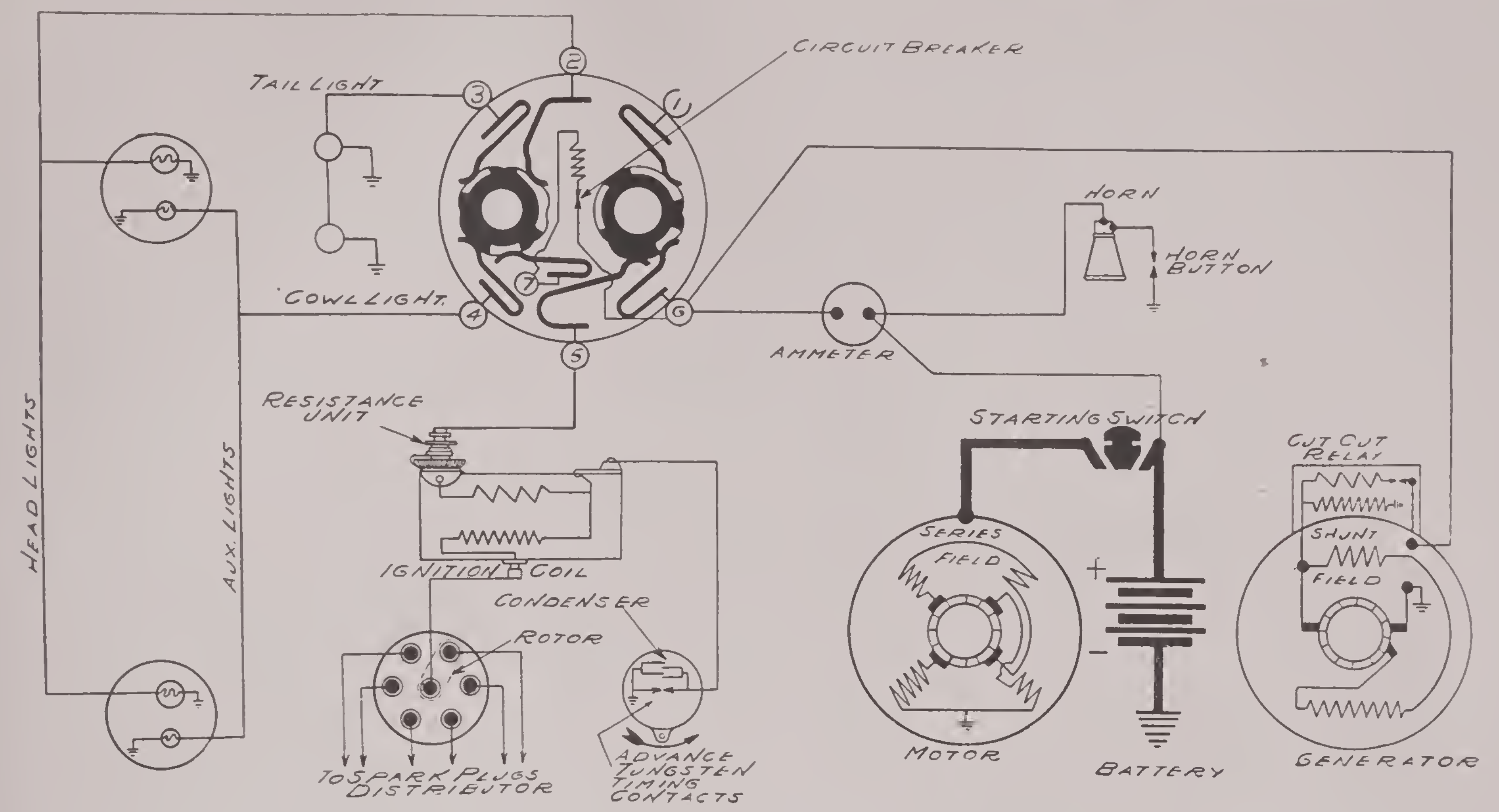
DODGE—NORTH-EAST STARTING, LIGHTING AND IGNITION. SINGLE UNIT STARTING AND LIGHTING SYSTEM



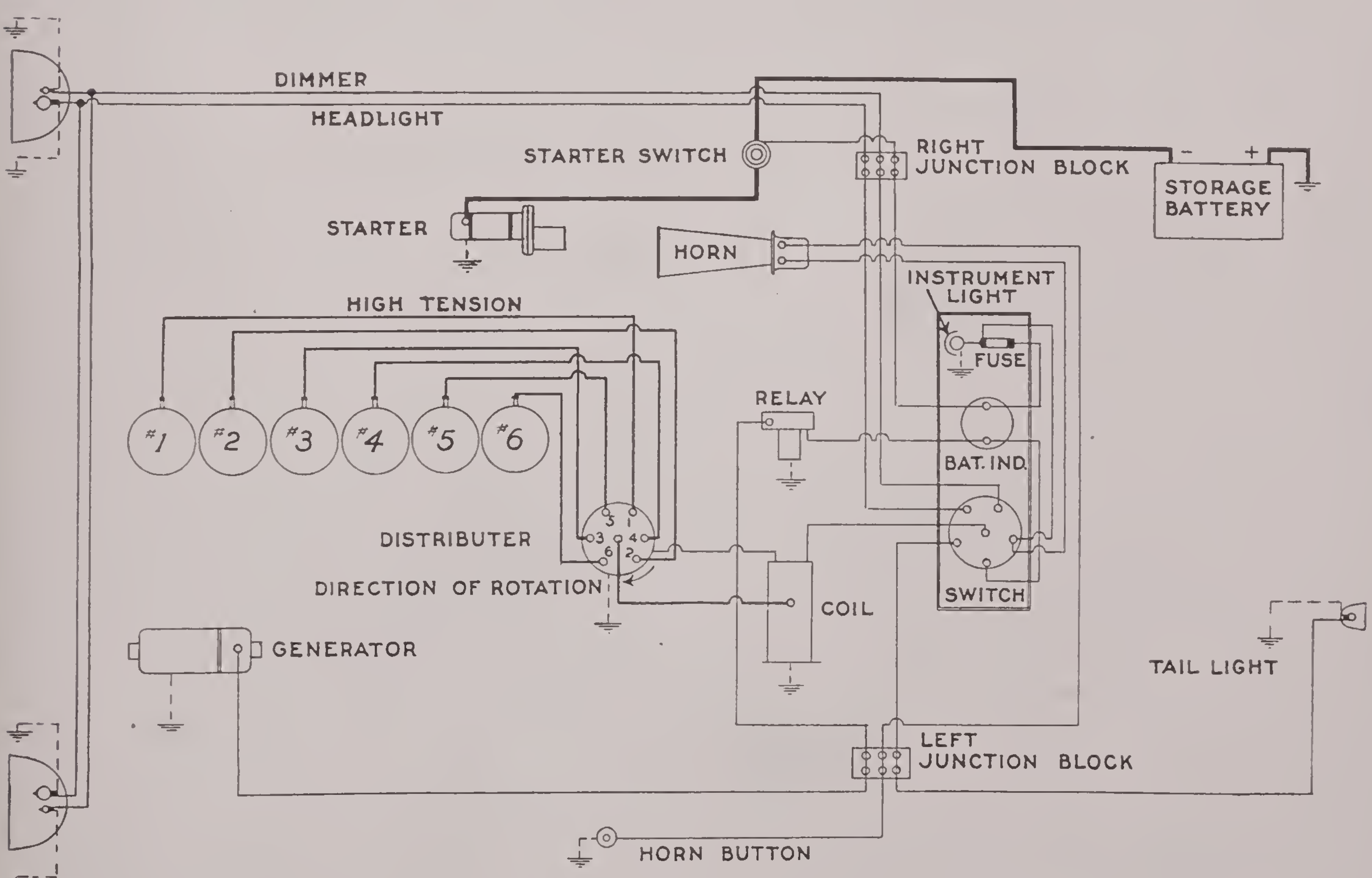
DORRIS "I-C-6" 1918. 1919 EARLY MODELS. WESTINGHOUSE SYSTEM.



DORT 1919 WESTINGHOUSE SYSTEM



ELCAR, MODELS D,G,H,K-6.



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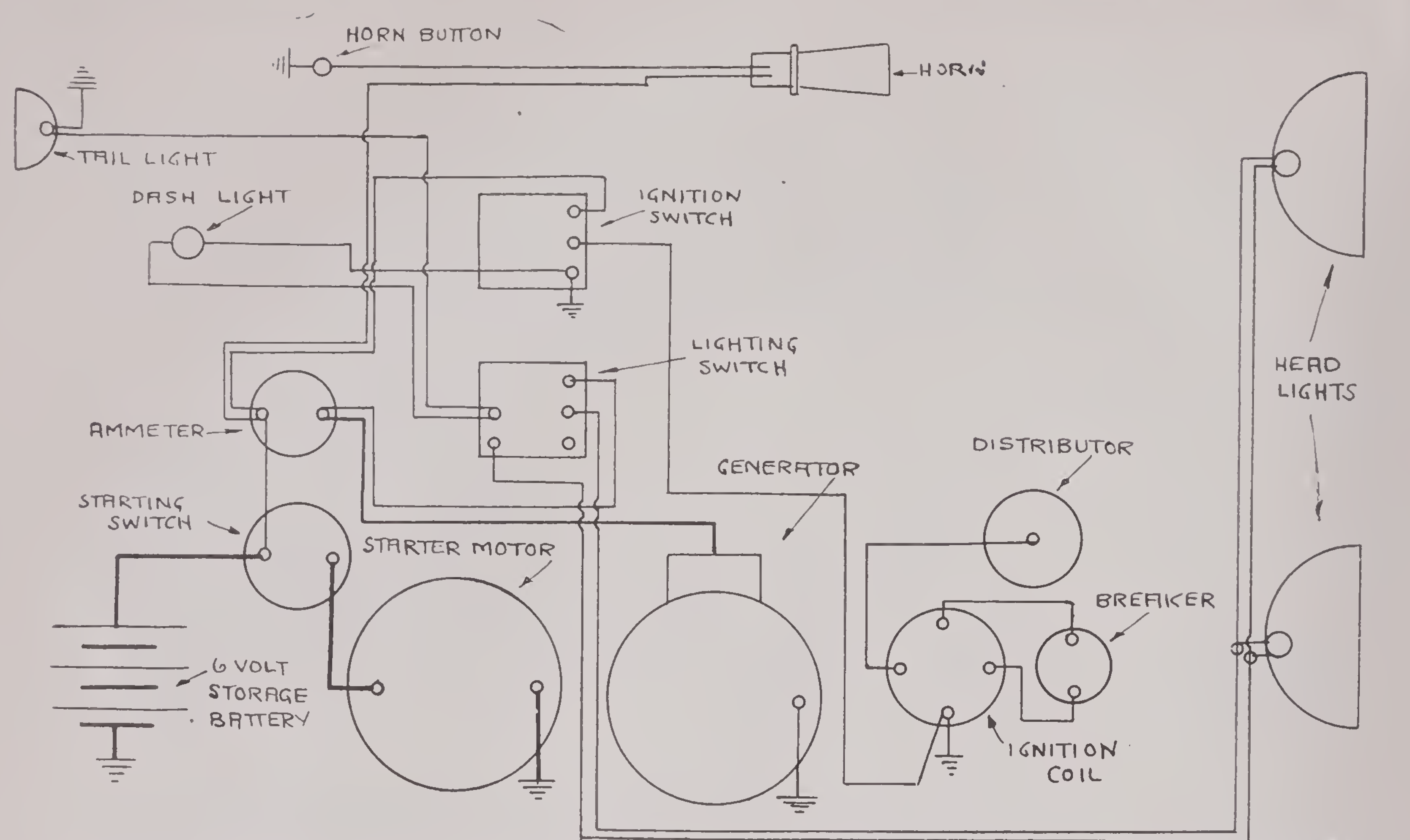

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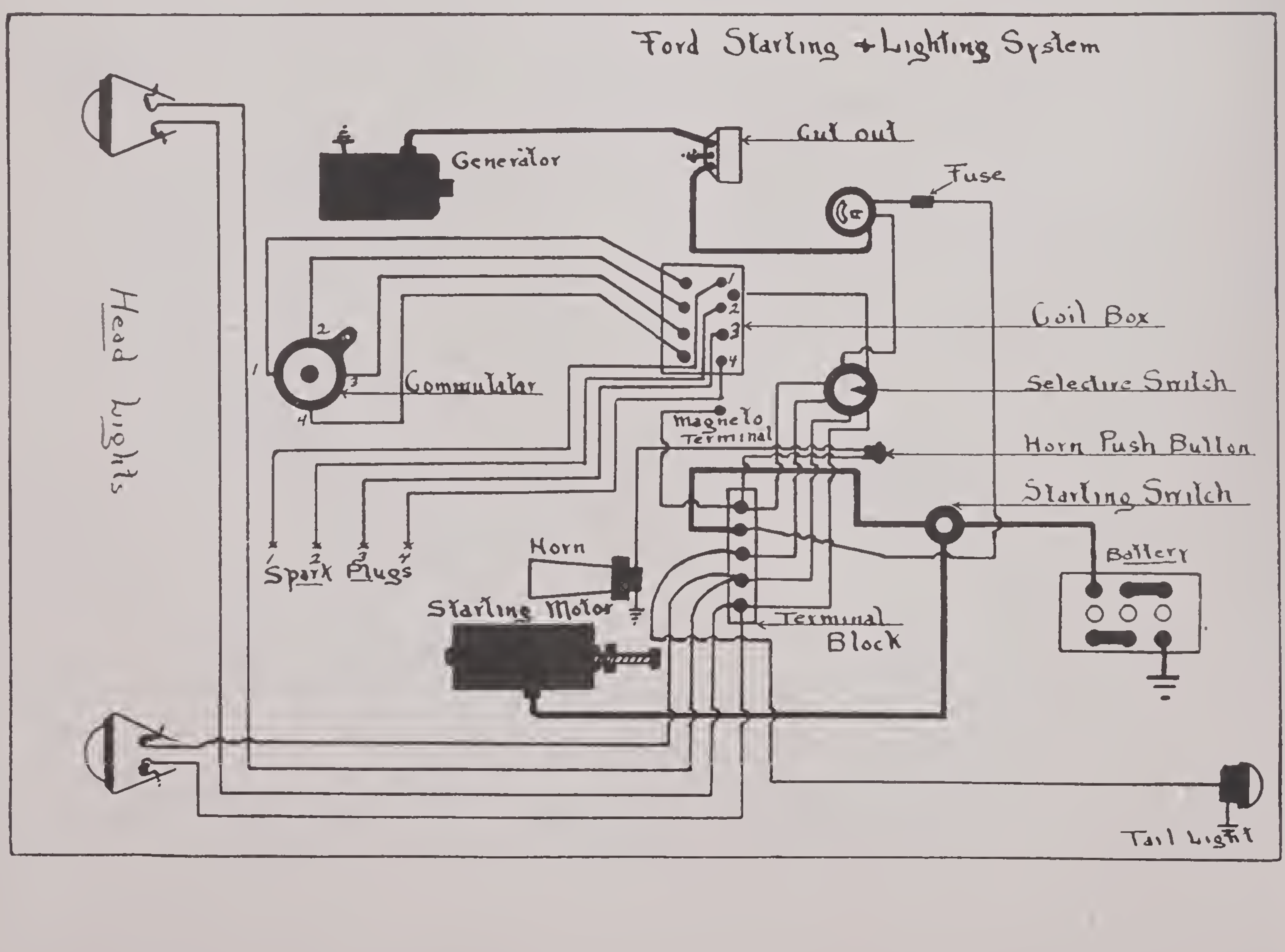
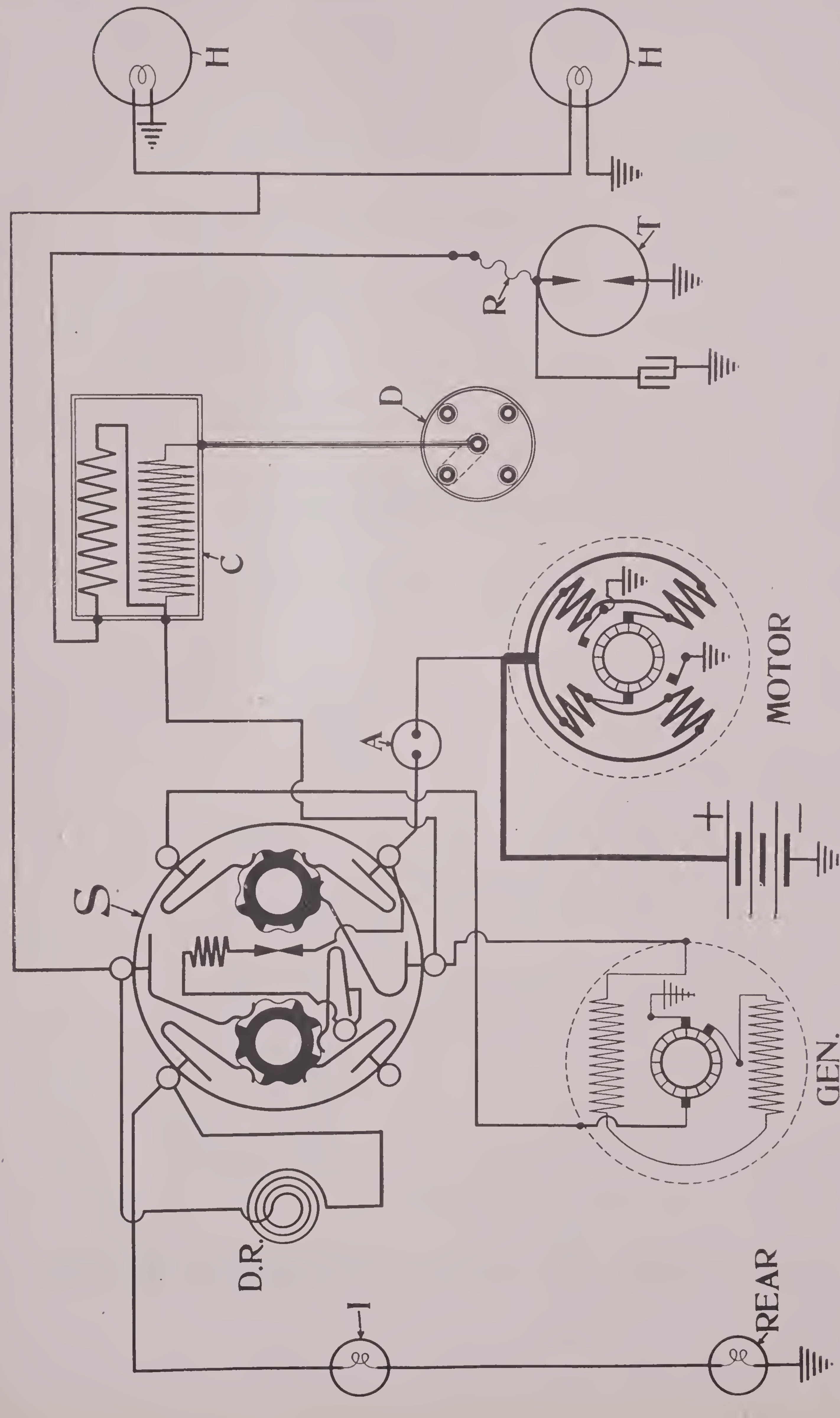
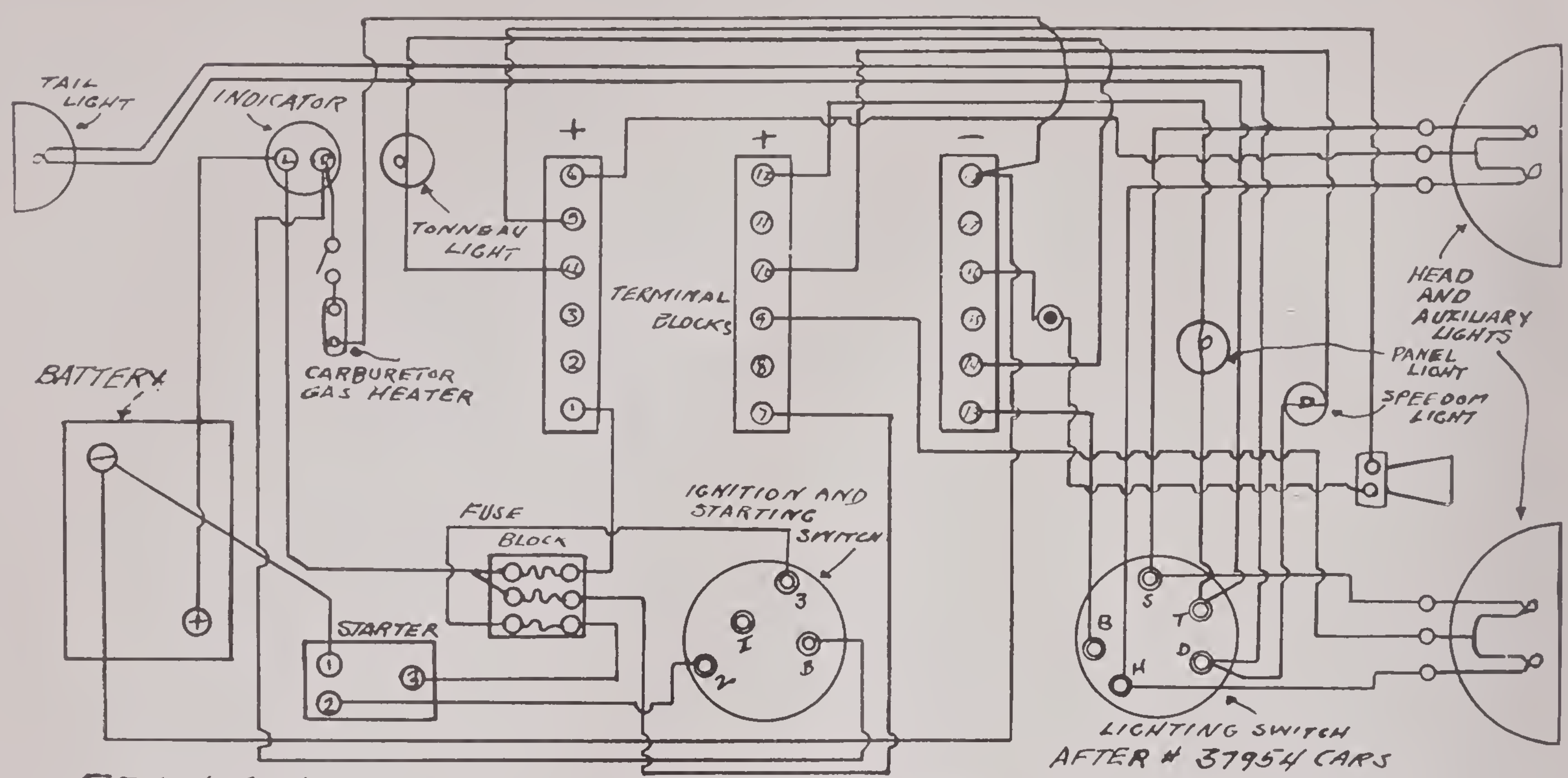
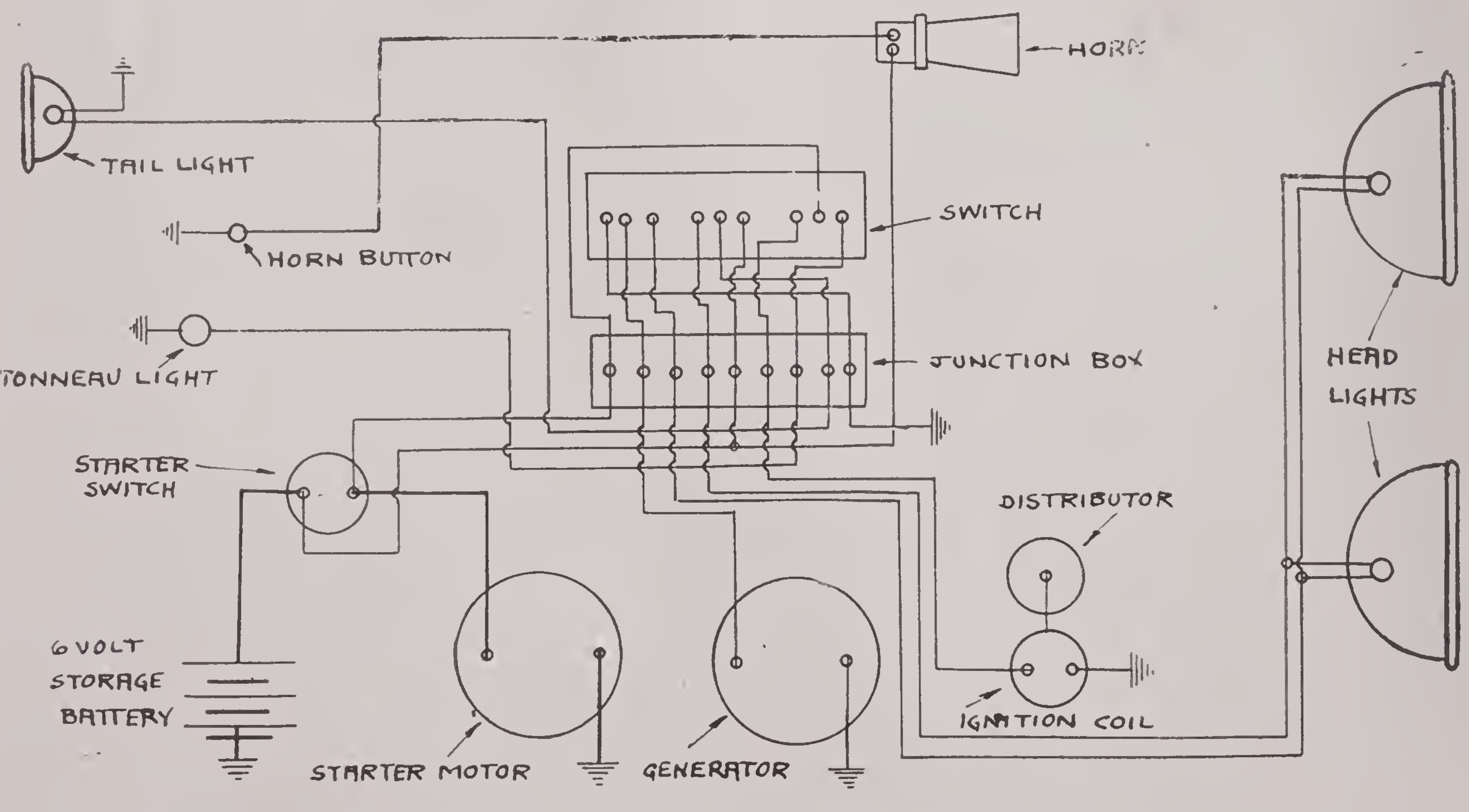




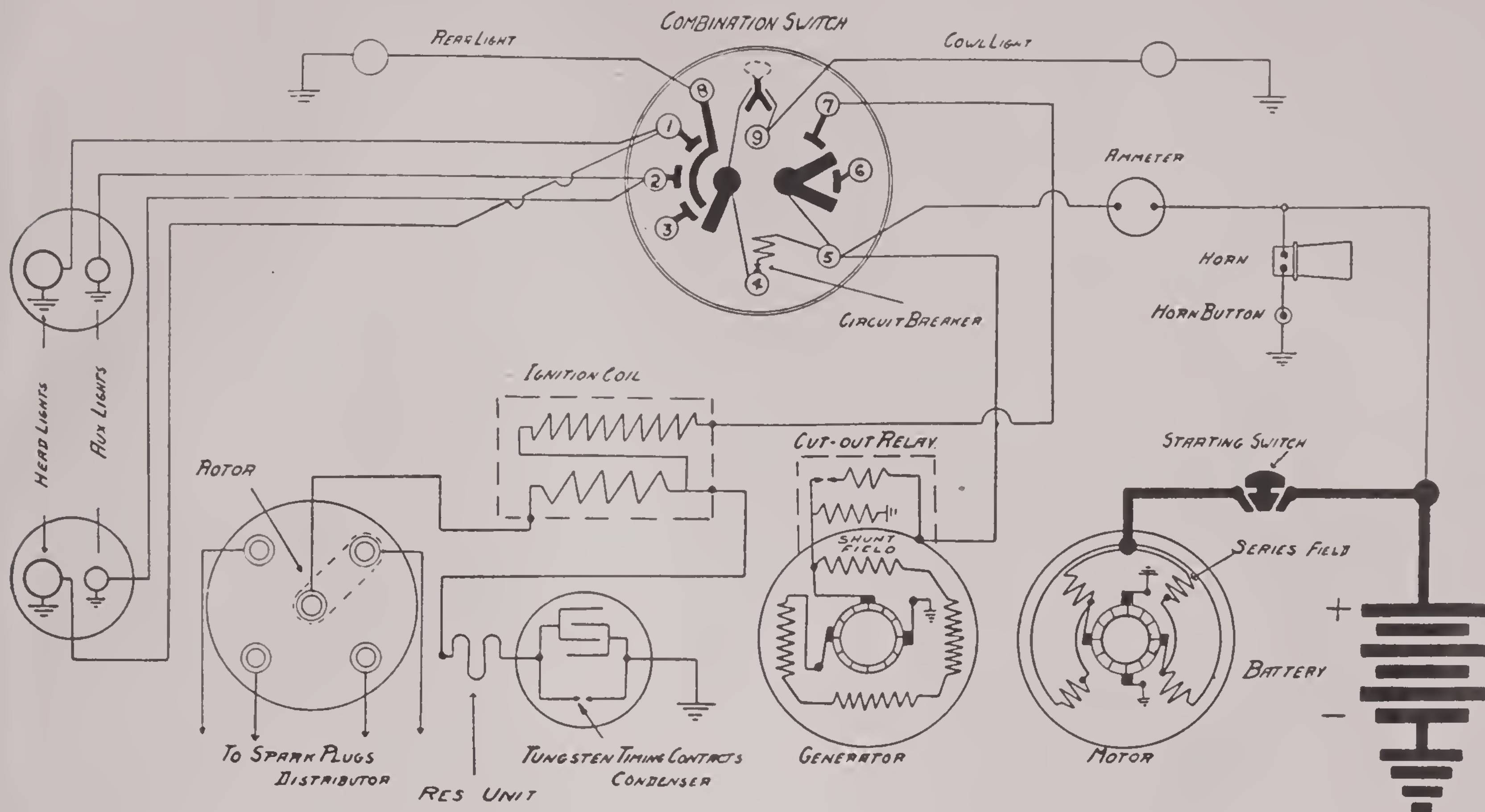
ESSEX—DELCO STARTING, LIGHTING AND IGNITION



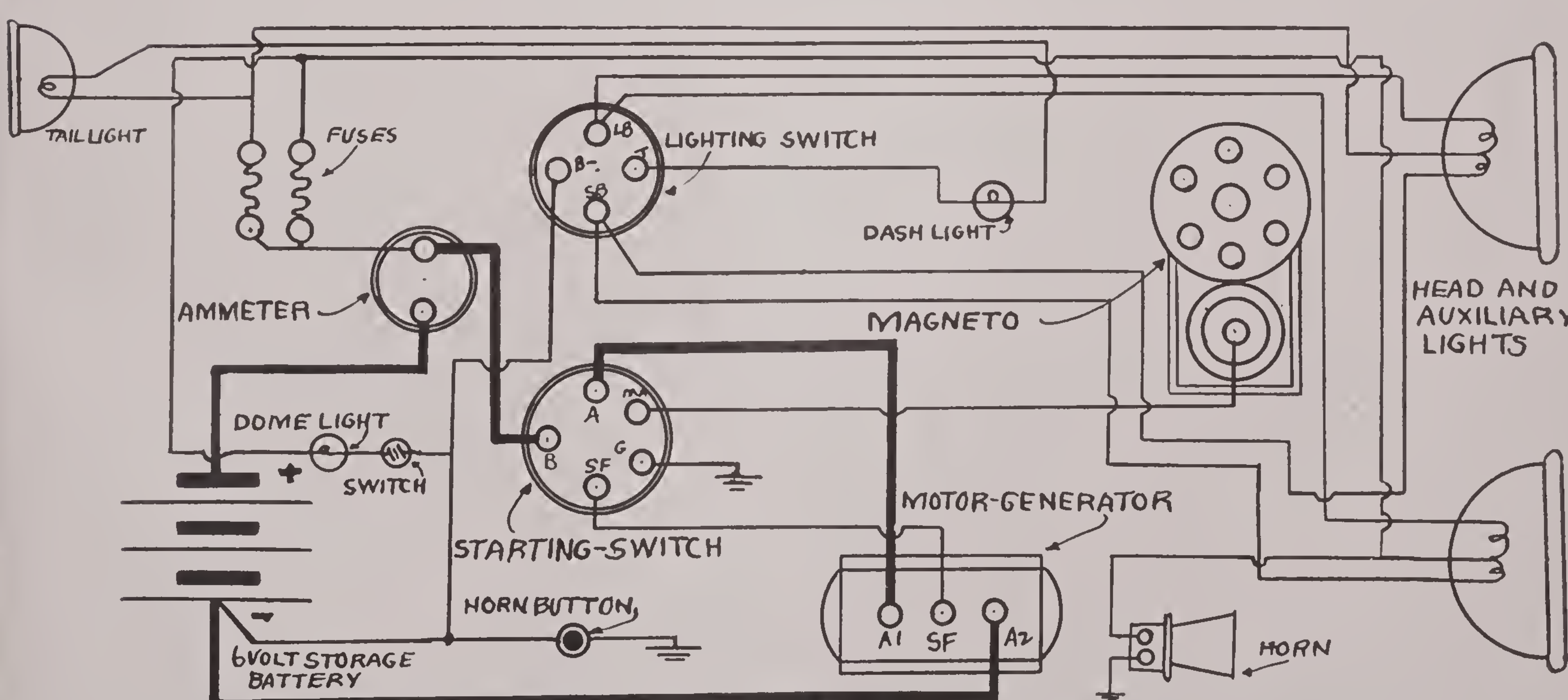
FRANKLIN MODEL S9B 1920 TOURING CAR DYNETO SYSTEM



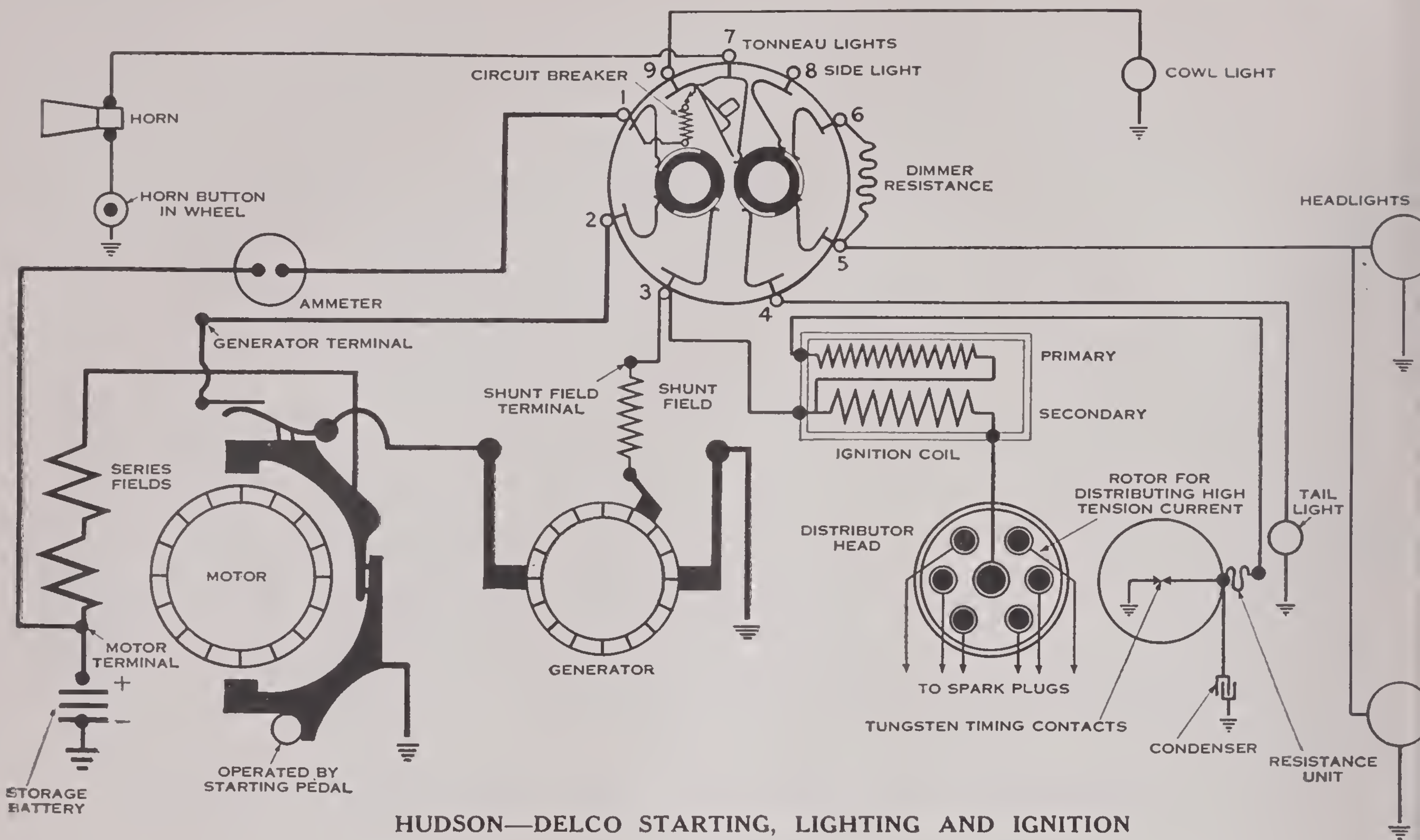
HAYNES. MODEL "47." 1920 - LEECE-NEVILLE SYSTEM.



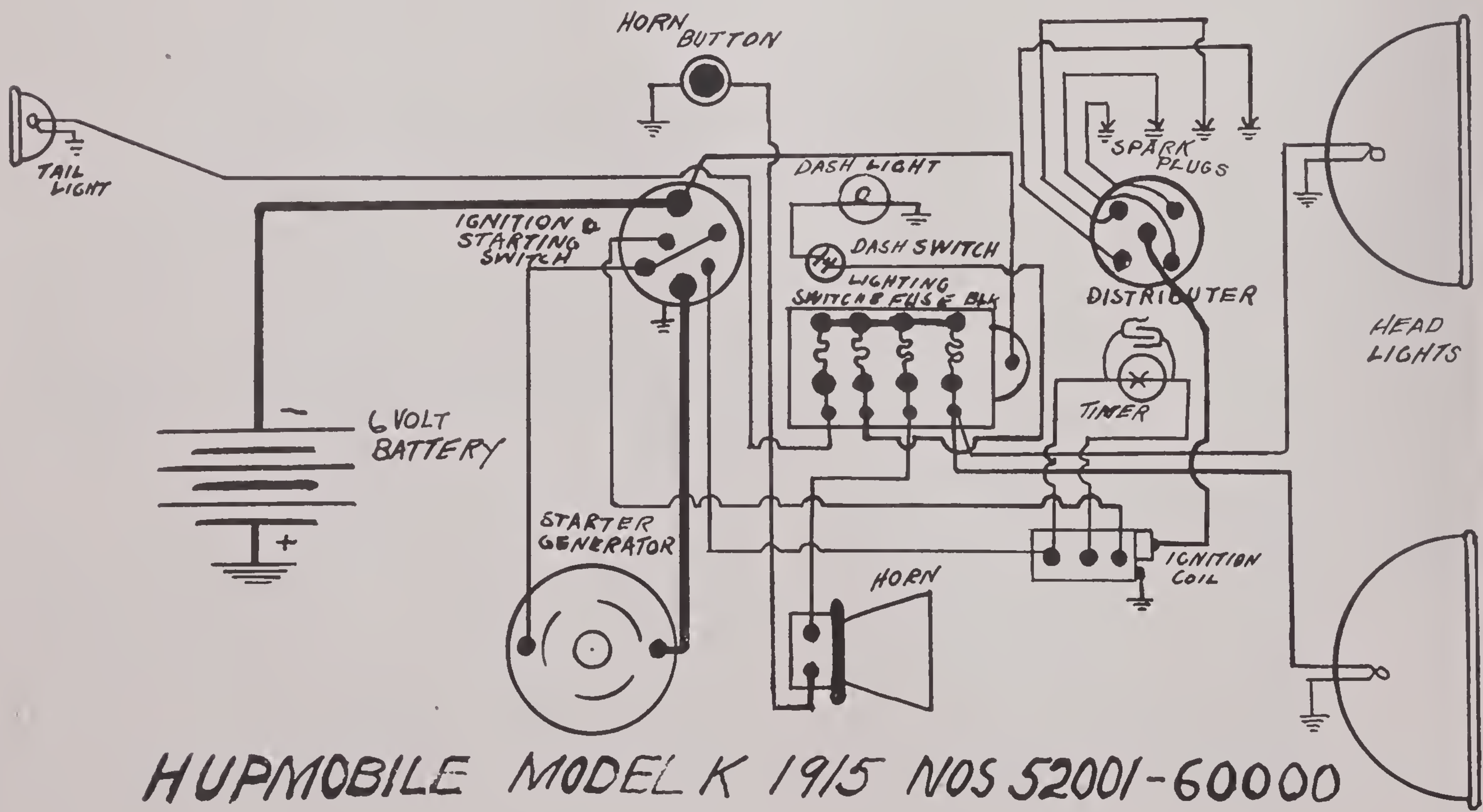
H. C. S. MOTOR CAR COMPANY—1921-1922 Models. Series 2



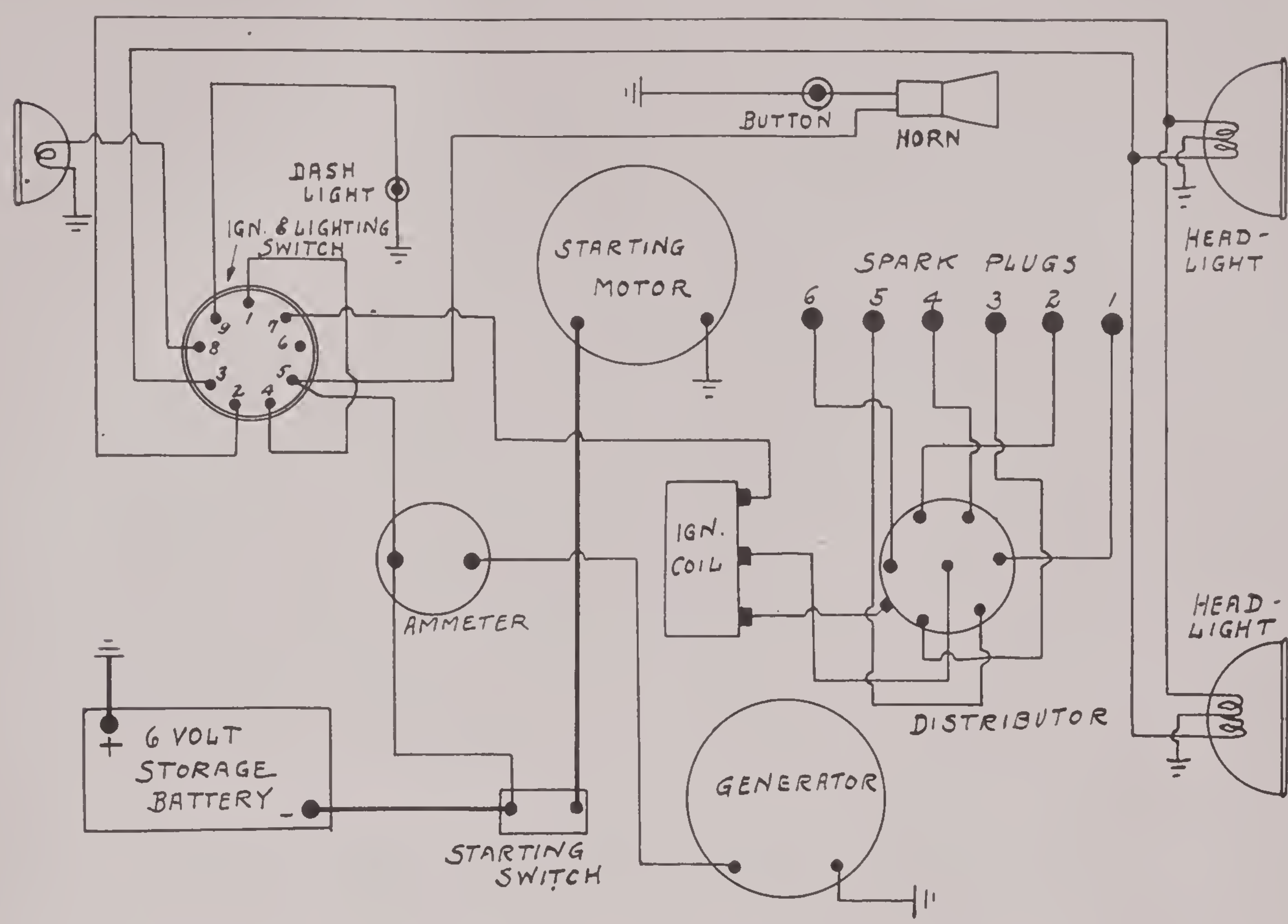
HOLMES 1918-1919 MODELS DYNETO SYSTEM



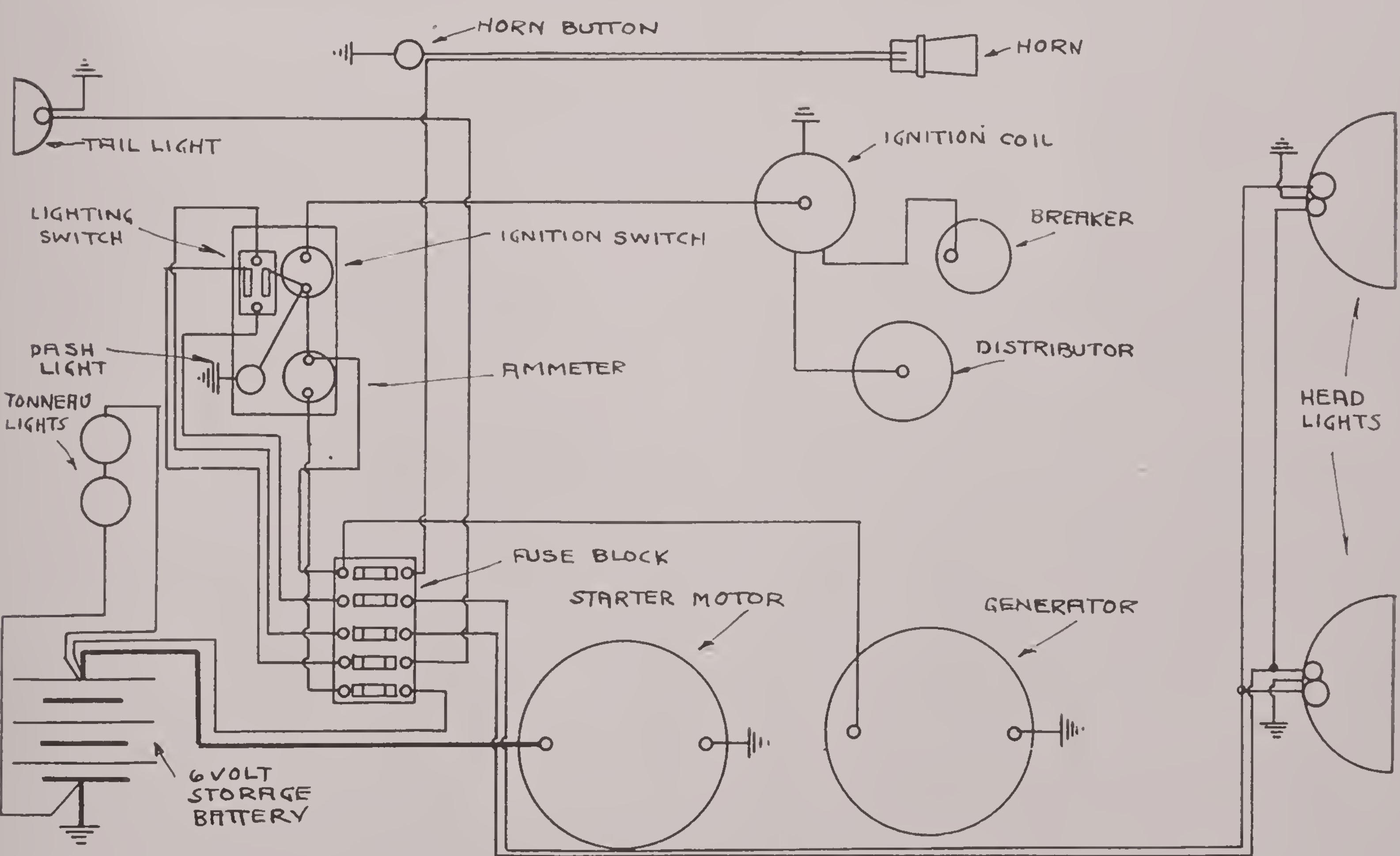
HUDSON—DELCO STARTING, LIGHTING AND IGNITION



HUPMOBILE MODEL K 1915 NOS 52001-60000

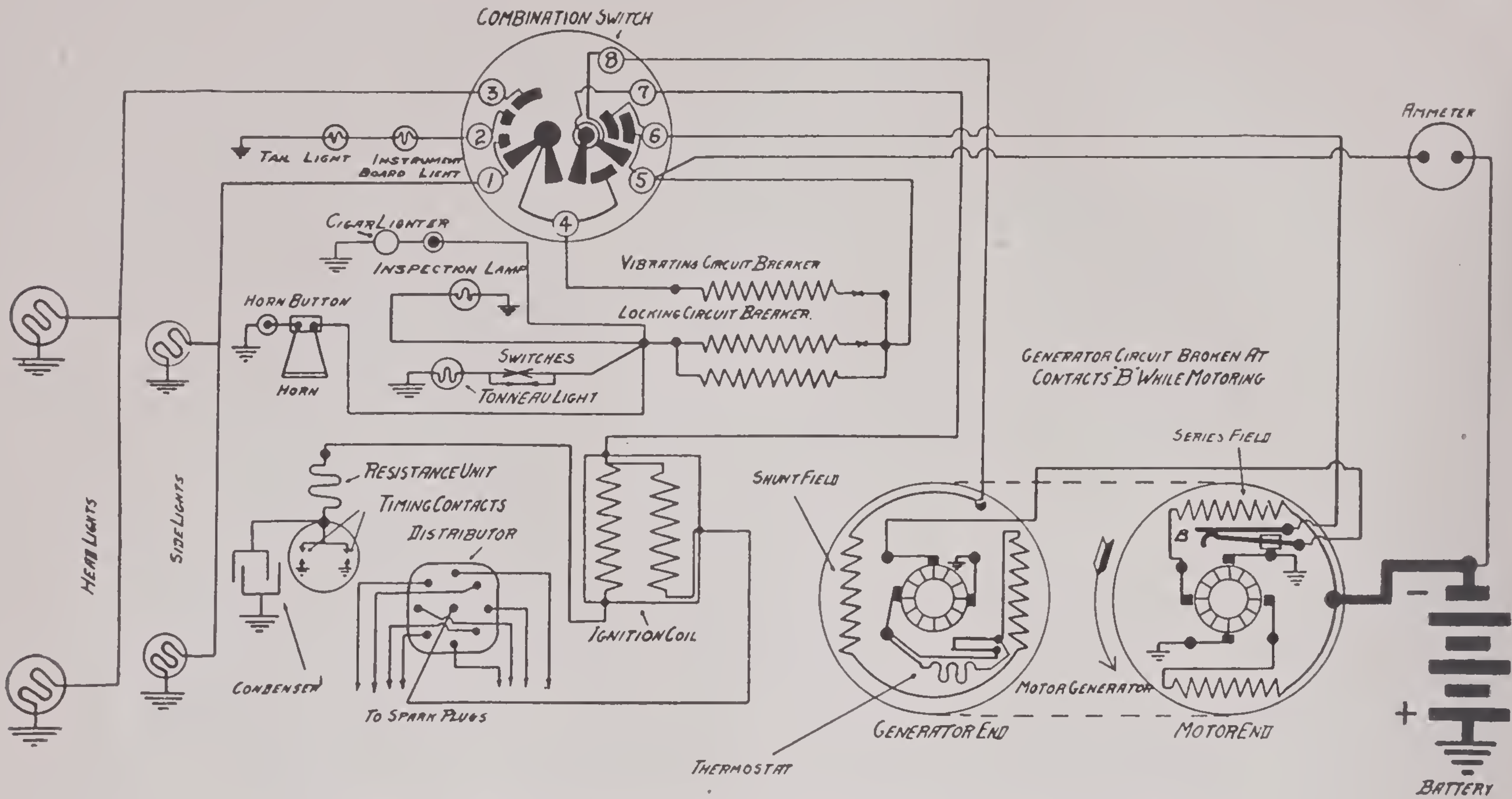


JORDAN "60" 1918 - BIJUR SYSTEM 1919. REMY IGN.

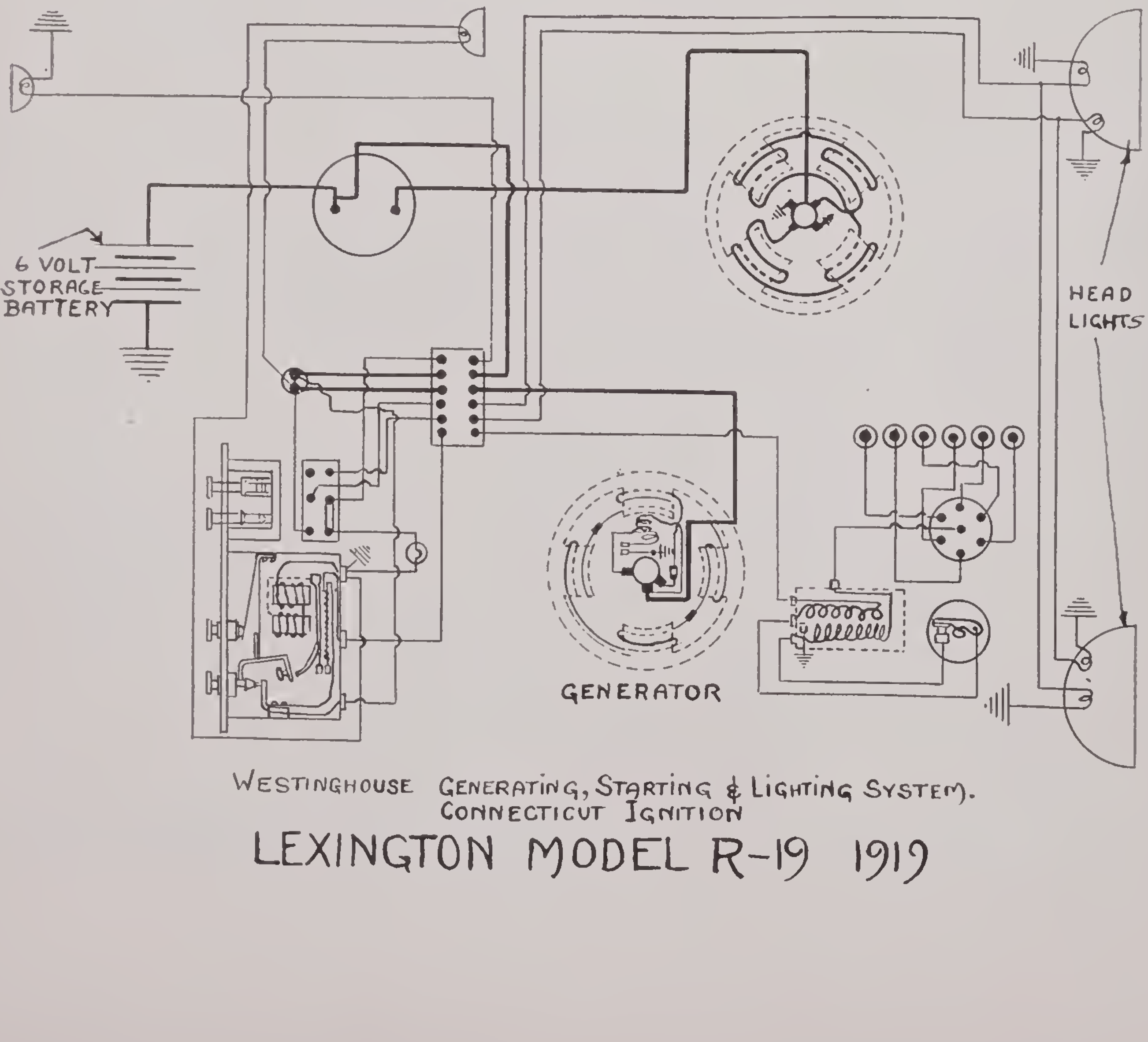


KING MODEL "G" 1919

BIJUR GENERATING, STARTING AND LIGHTING SYSTEM.
ATWATER-KENT IGNITION SYSTEM.

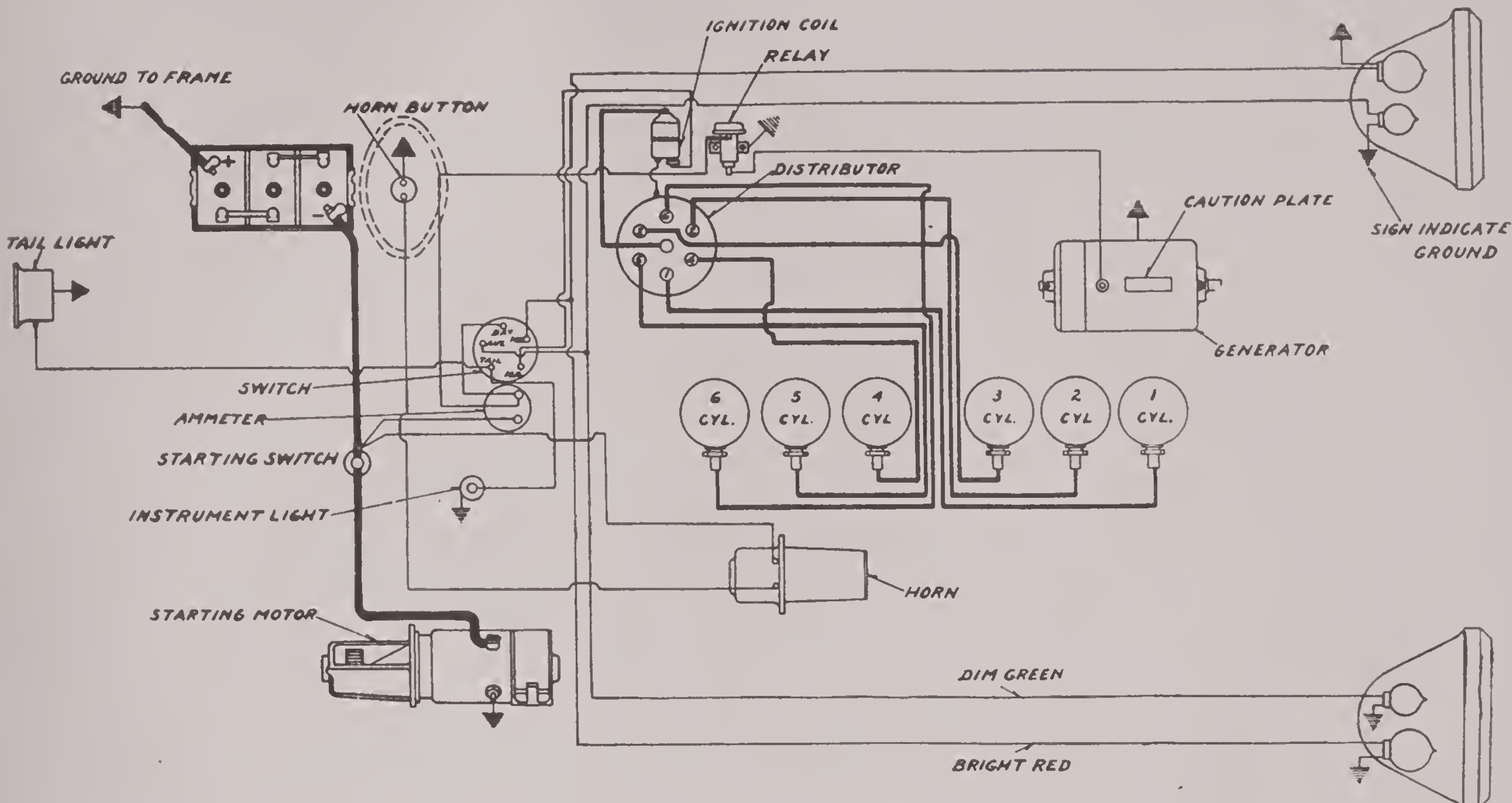


LAFAYETTE MOTORS COMPANY—1921 Model

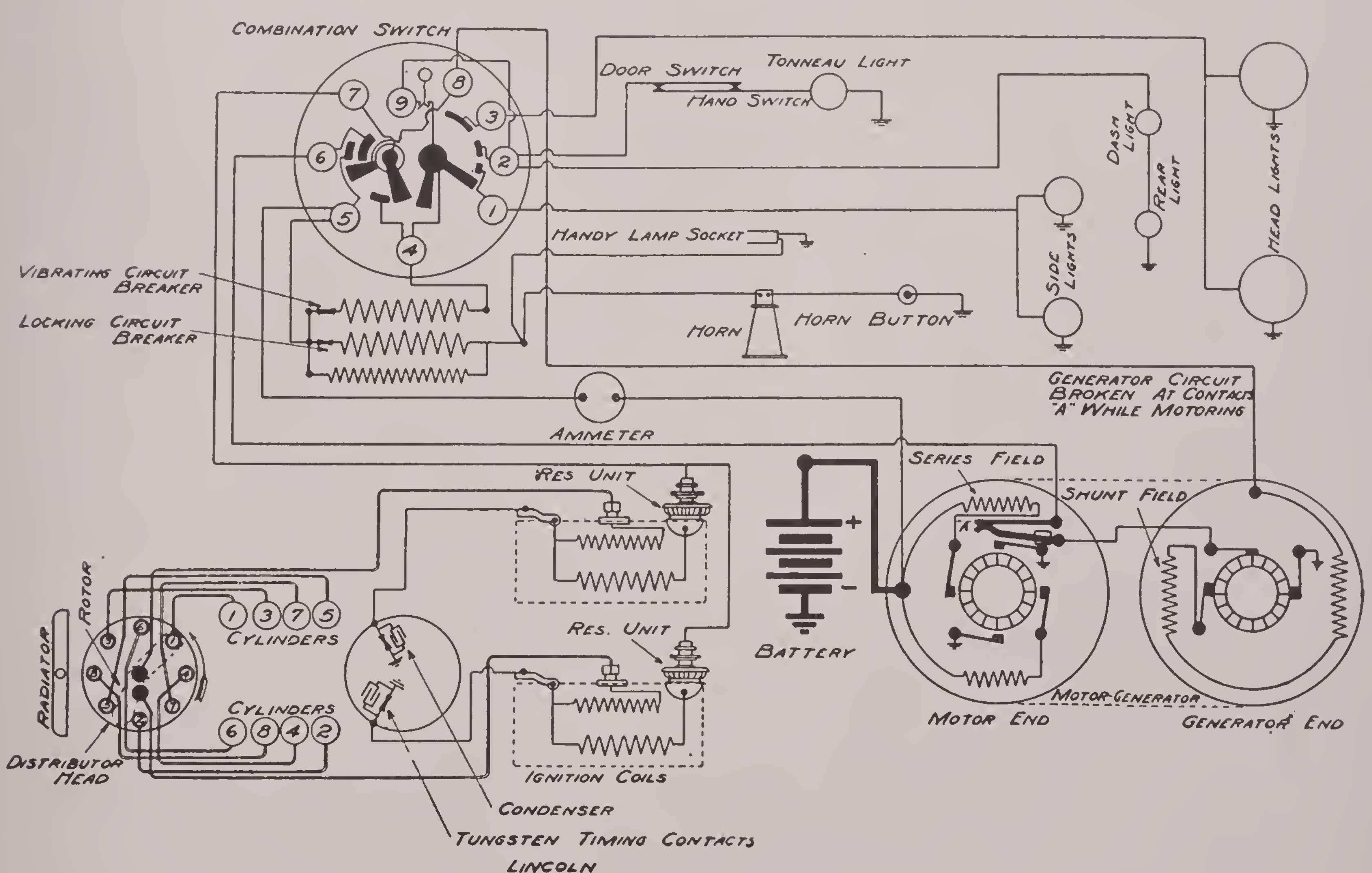


WESTINGHOUSE GENERATING, STARTING & LIGHTING SYSTEM.
CONNECTICUT IGNITION

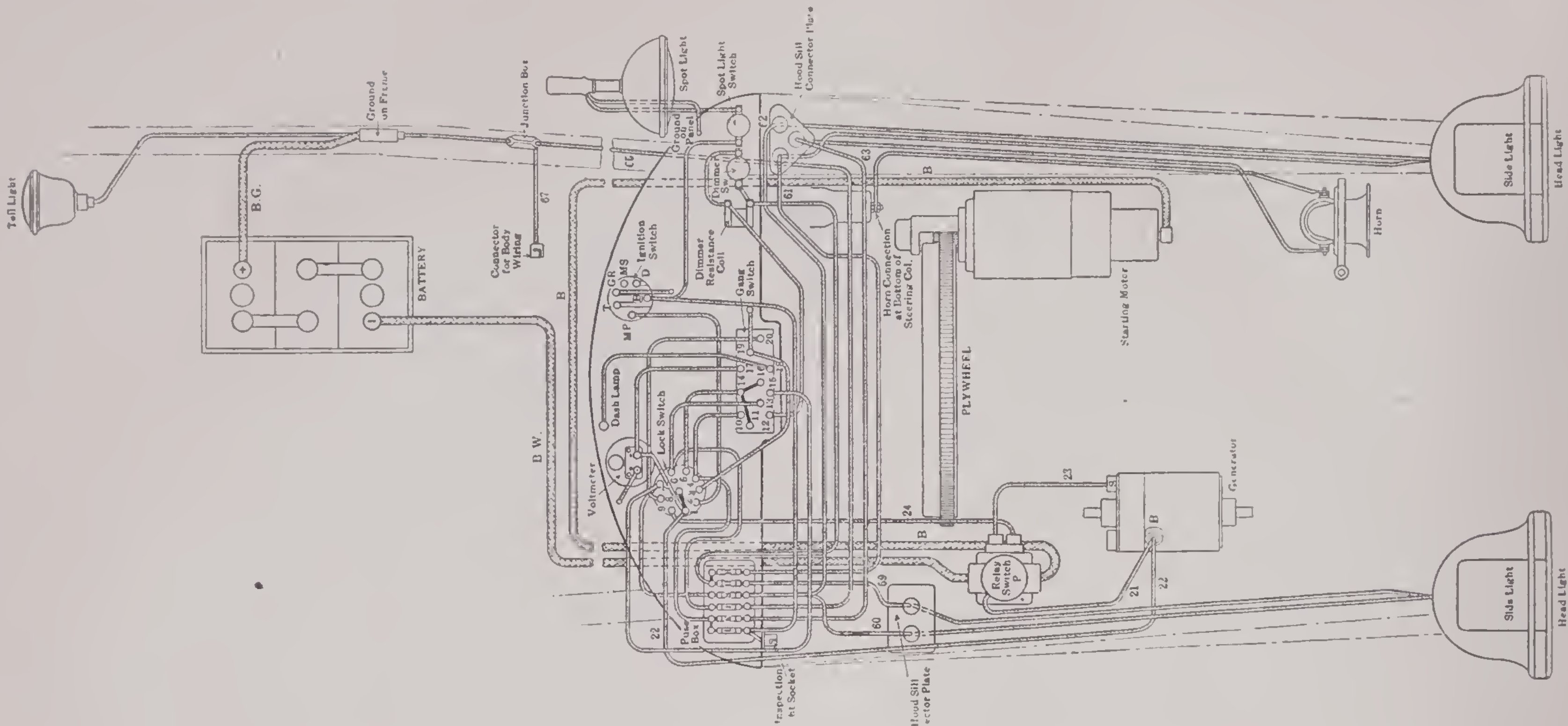
LEXINGTON MODEL R-19 1919



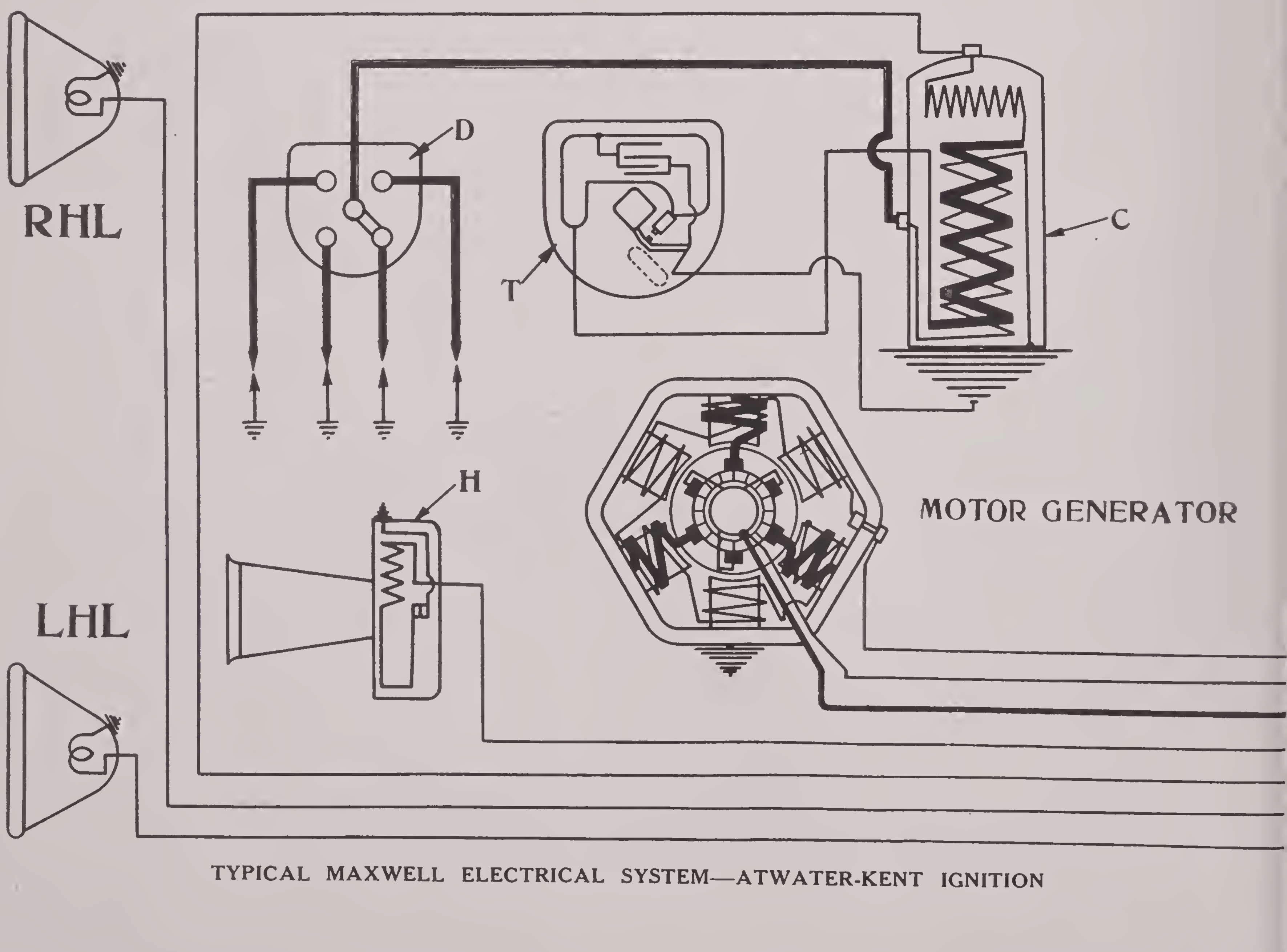
LIBERTY MODEL 10B 1919 WAGNER SYSTEM



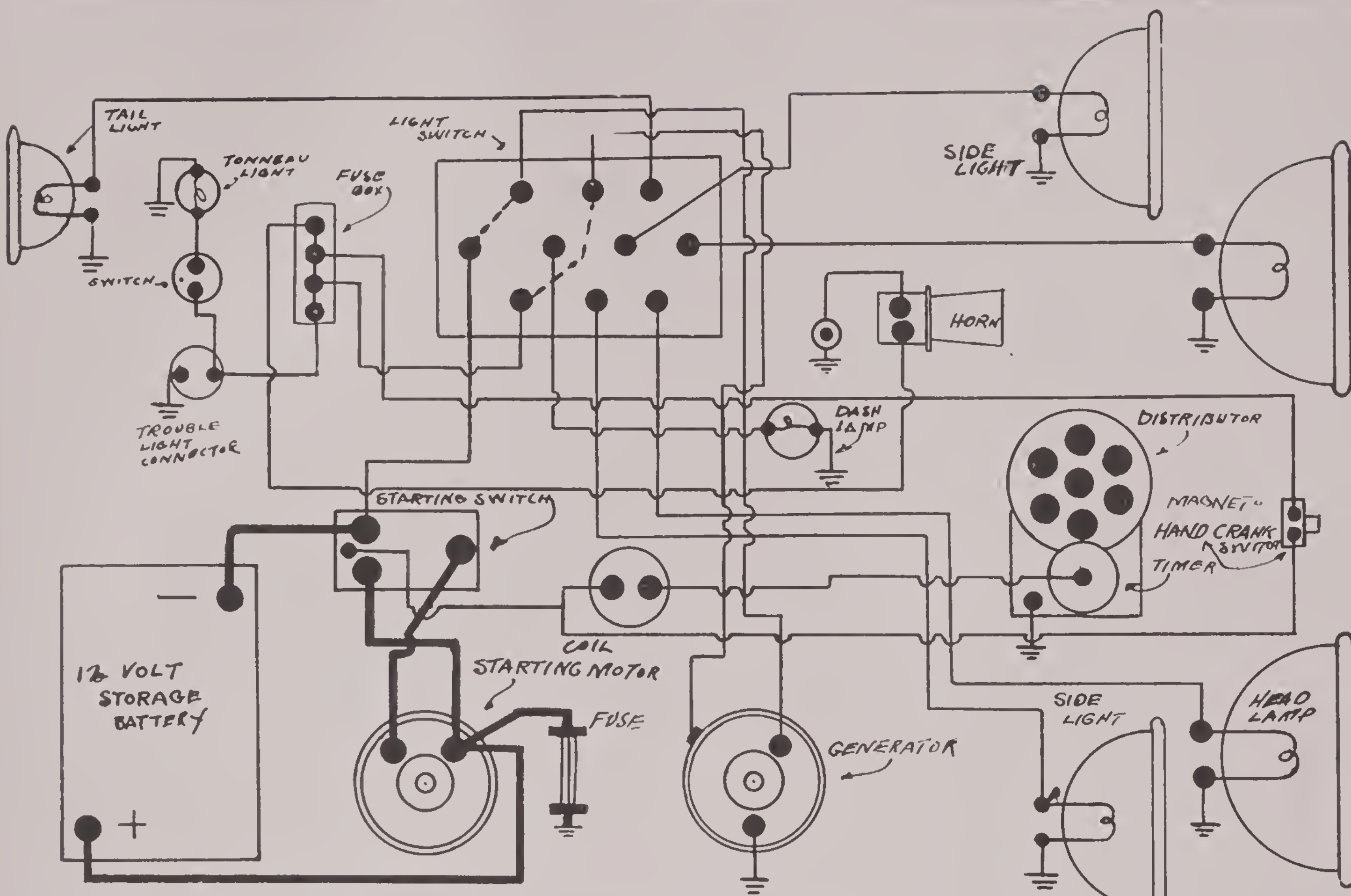
LINCOLN MOTOR COMPANY—"The Lincoln"



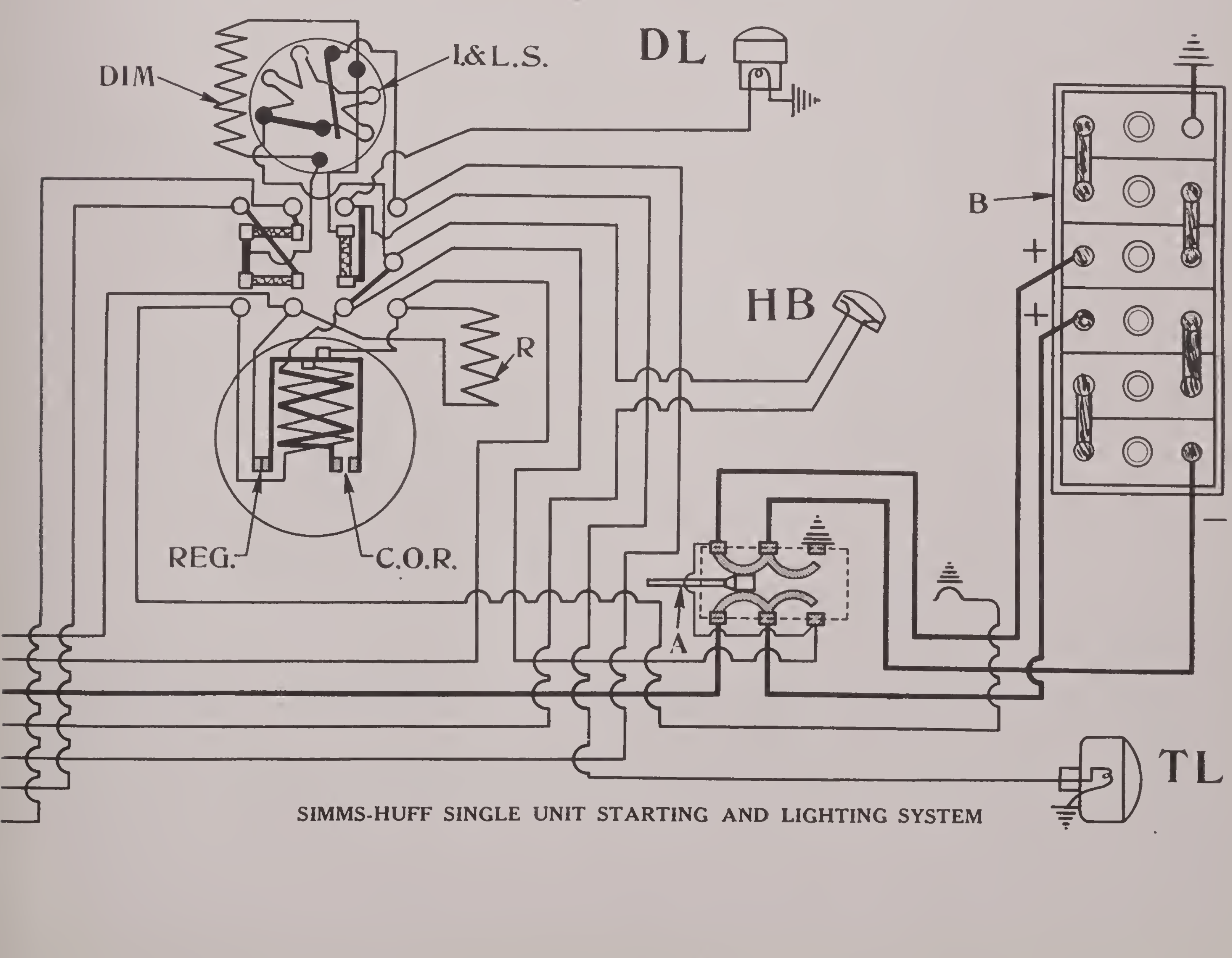
LOCOMOBILE SERIES 7 MODEL 48



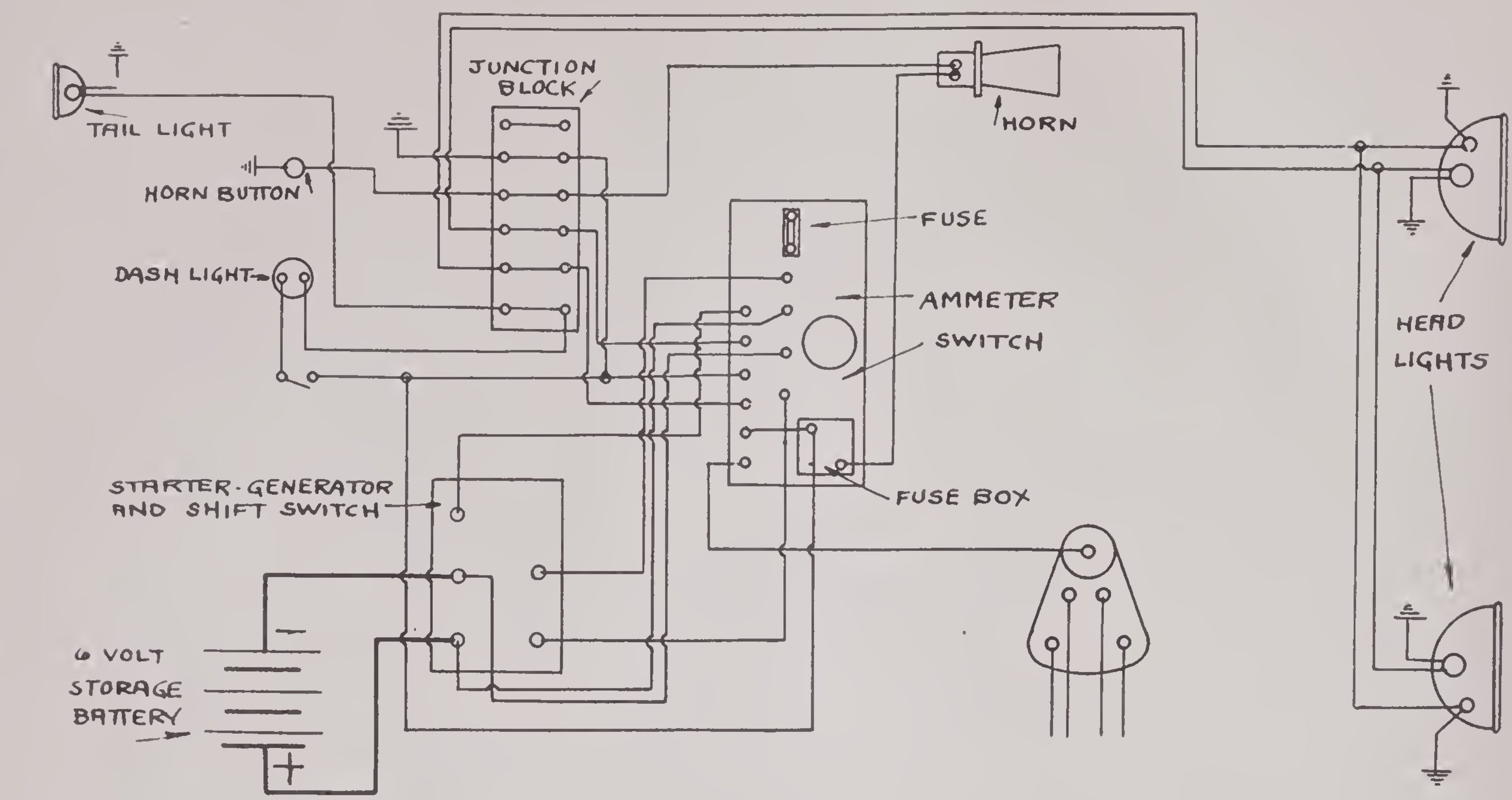
TYPICAL MAXWELL ELECTRICAL SYSTEM—ATWATER-KENT IGNITION



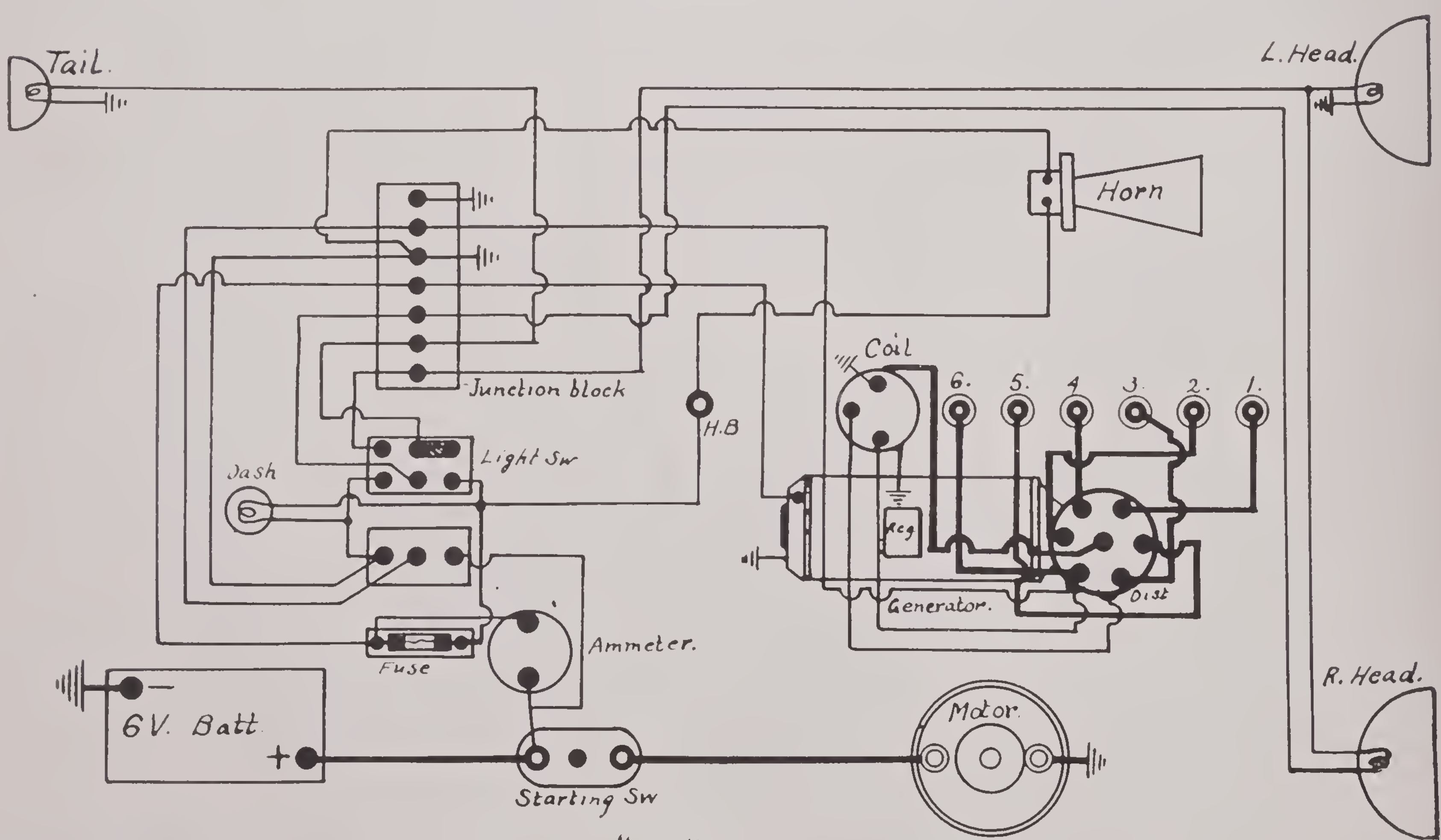
MARMON MODEL 41 1915 BOSCH SYSTEM



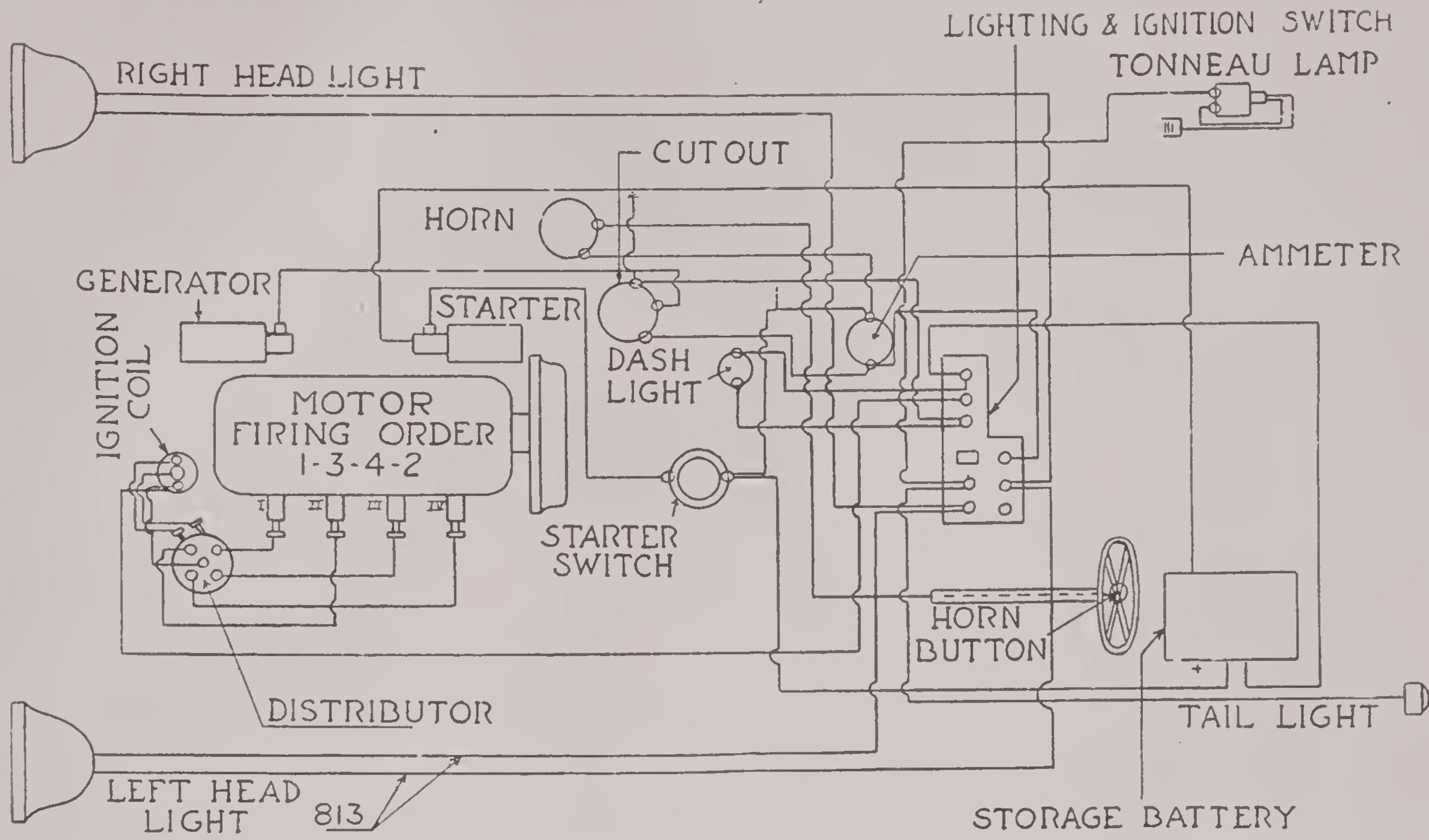
SIMMS-HUFF SINGLE UNIT STARTING AND LIGHTING SYSTEM



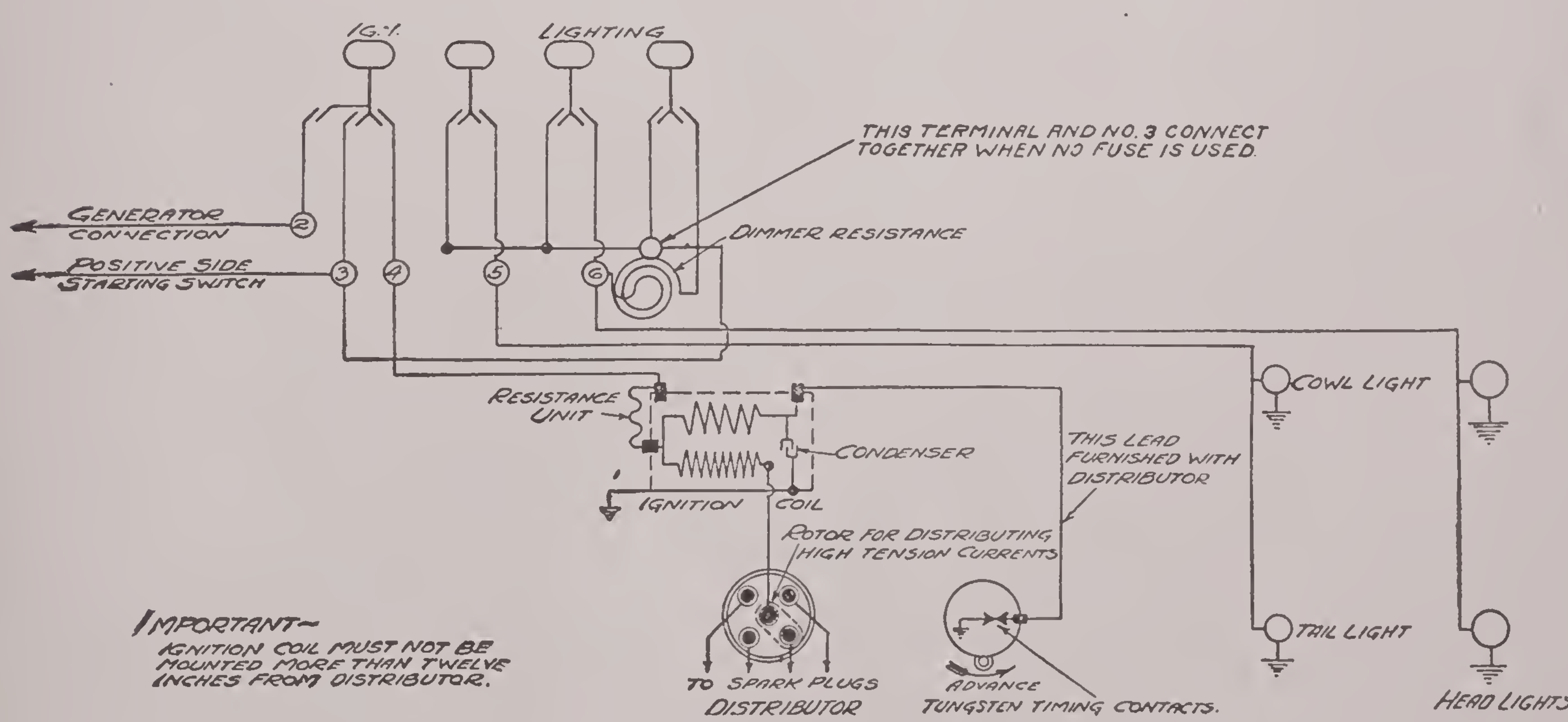
MERCER SERIES 22-73 RACEABOUT-1917. U.S.L.SYSTEM.



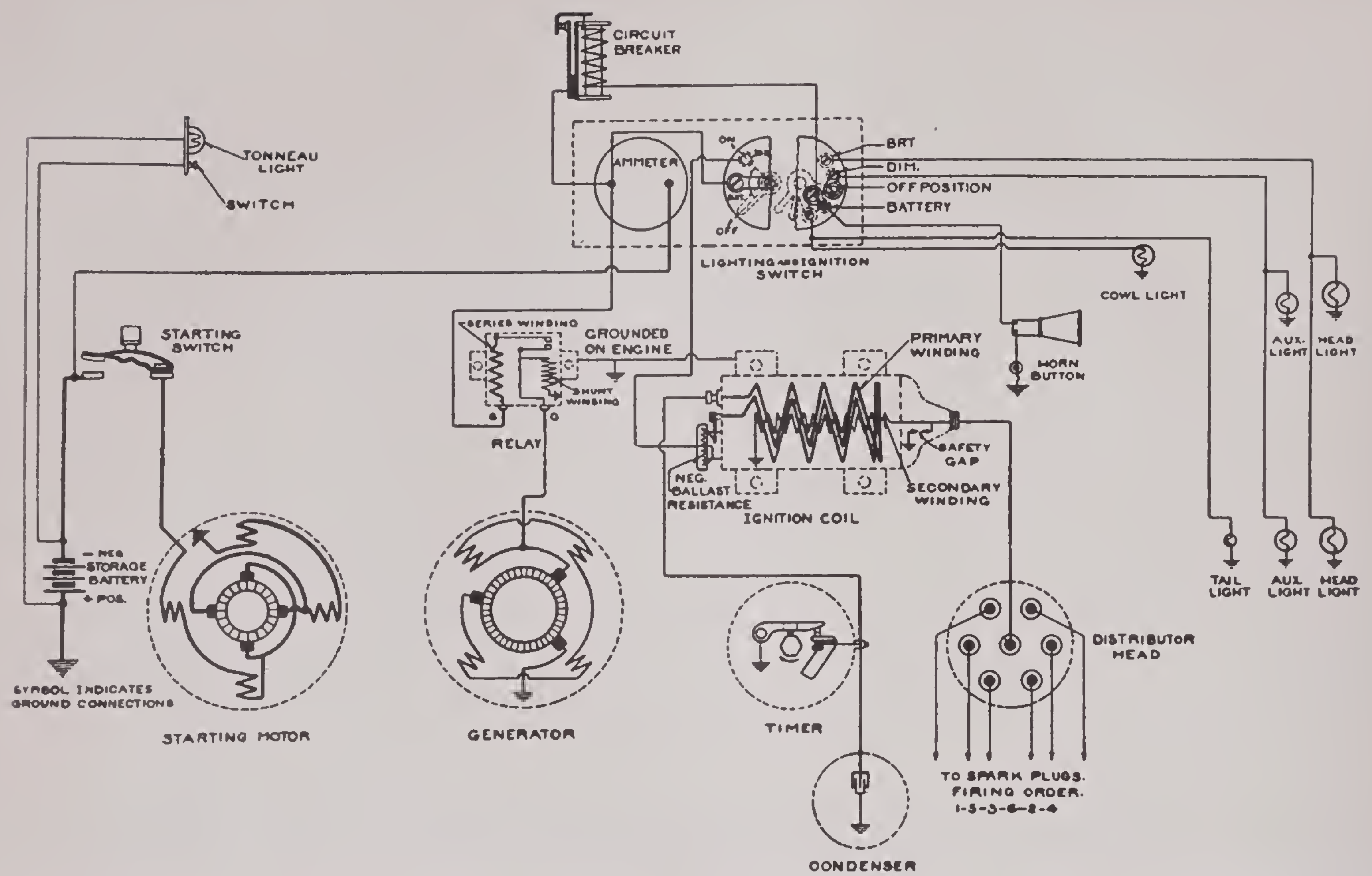
MITCHELL Model D-40 1917-"18 & "19. Splitdorf Elec System.



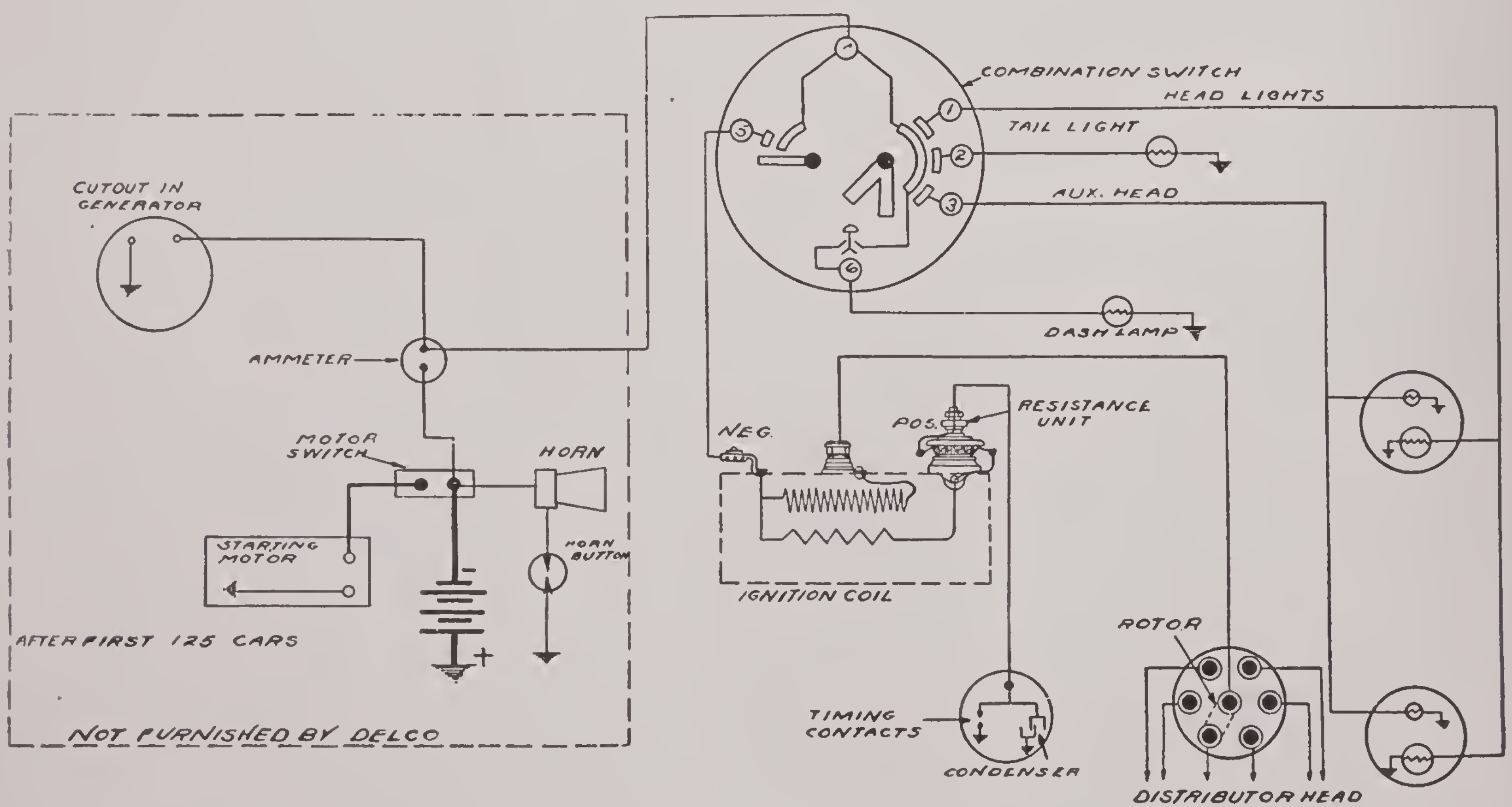
MONROE MODELS 5-9-10-11-12 AUOTO-LITE SYSTEM
1919-1920-1921



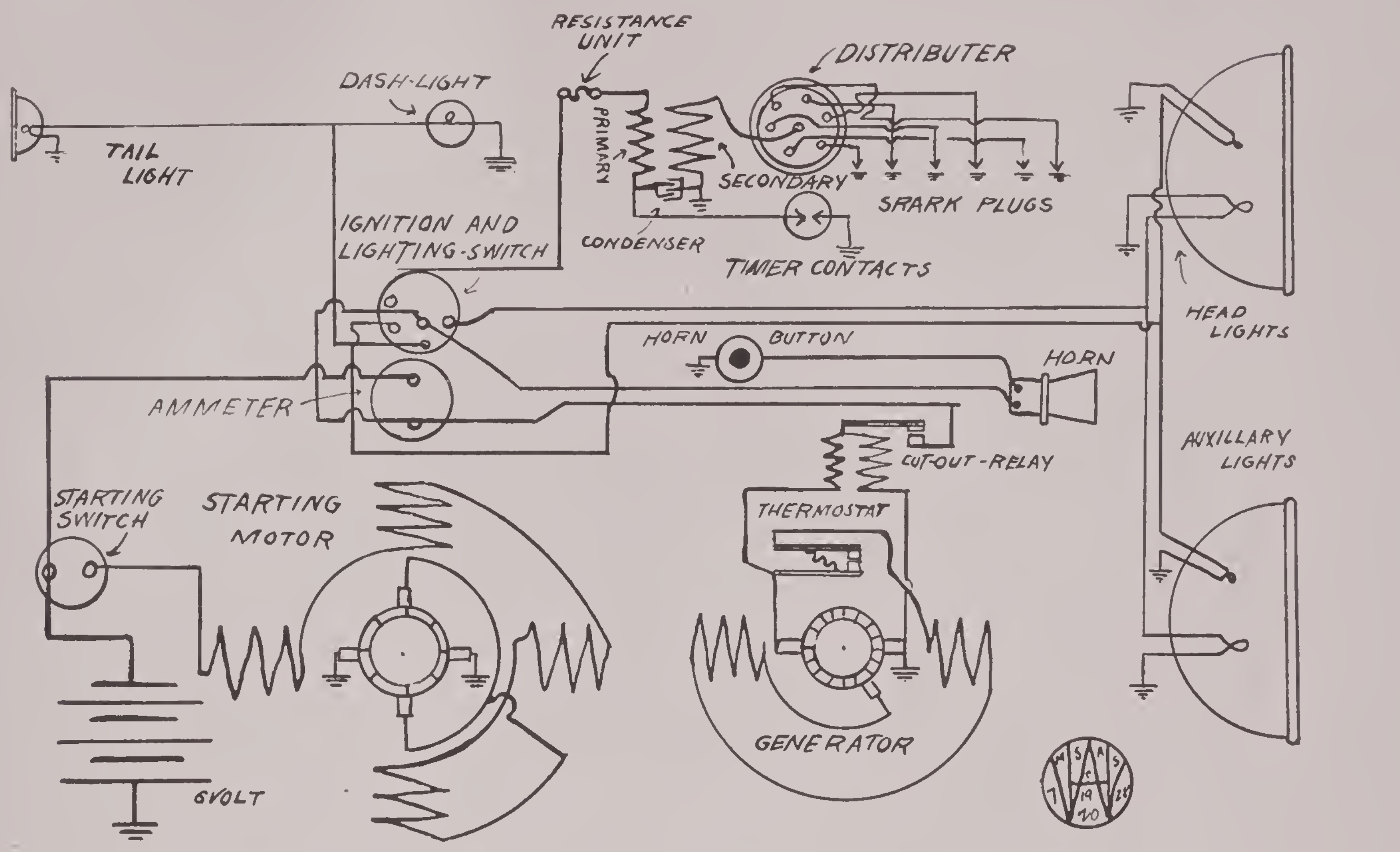
MOON MODEL 6-36-1918 DELCO SYSTEM



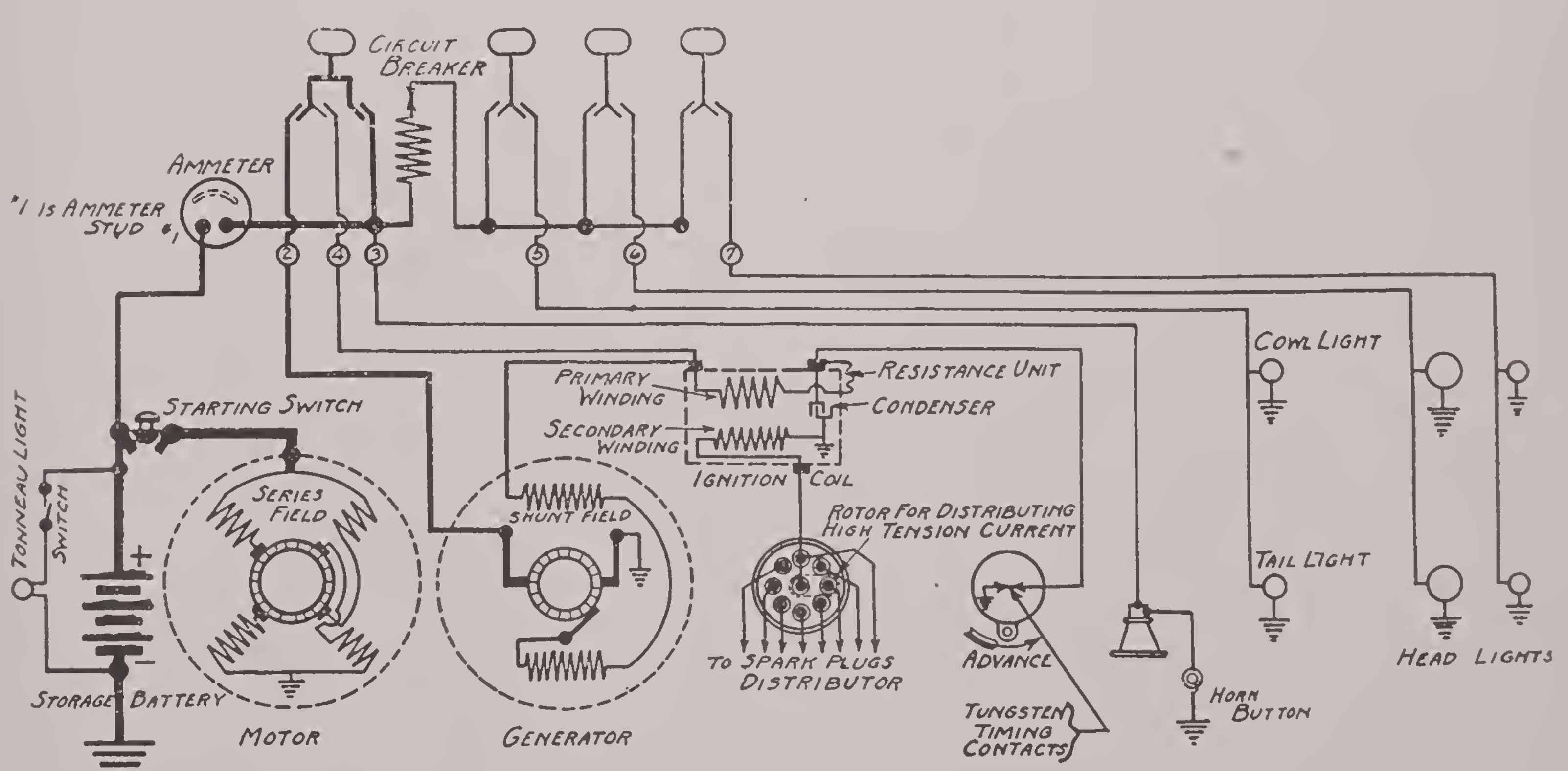
NASH MODEL 6-81 INTERNAL CONNECTIONS



NATIONAL SERIES AF3 1918 DELCO SYSTEM



OAKLAND-34C 1920 REMY



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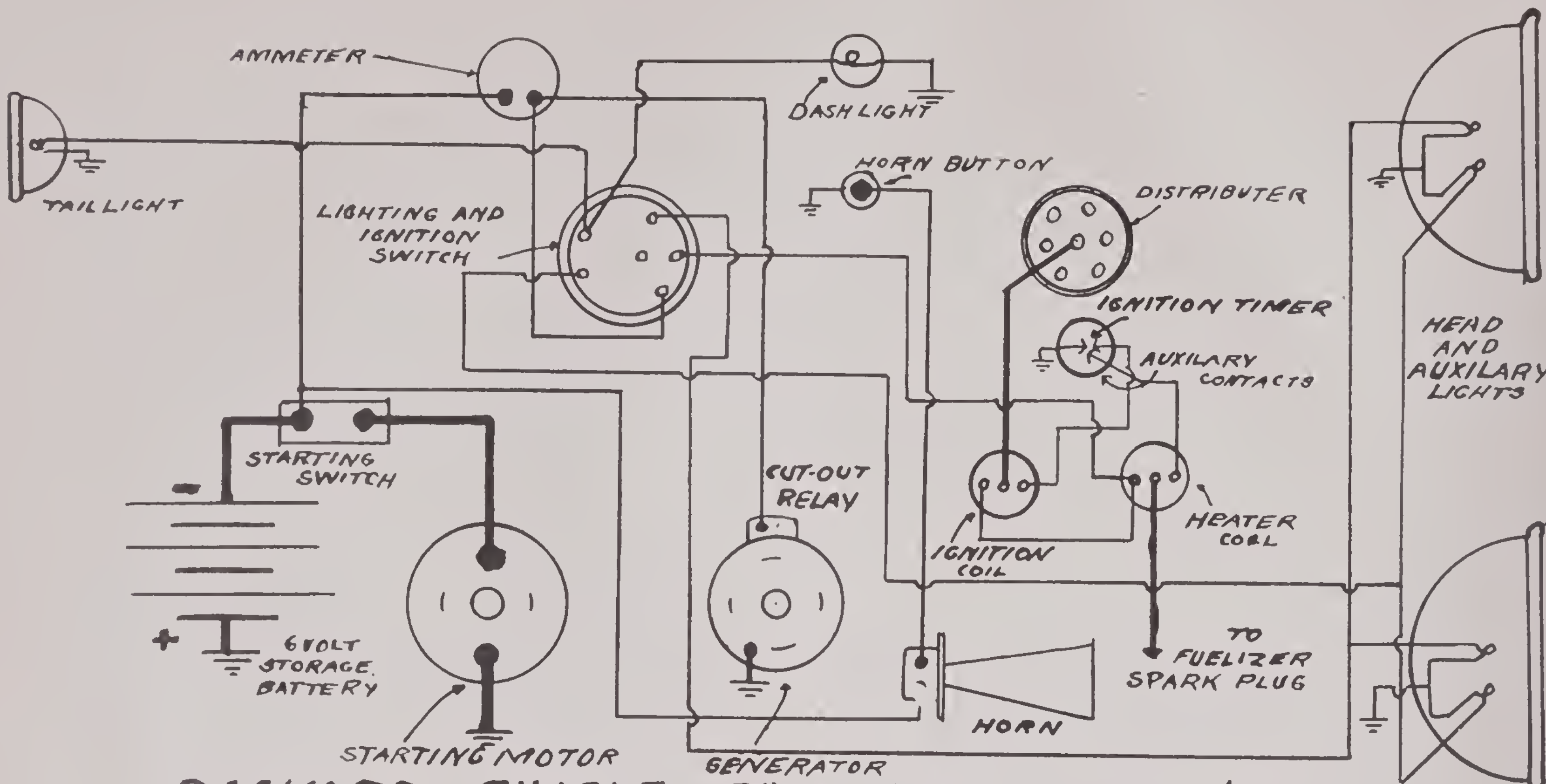
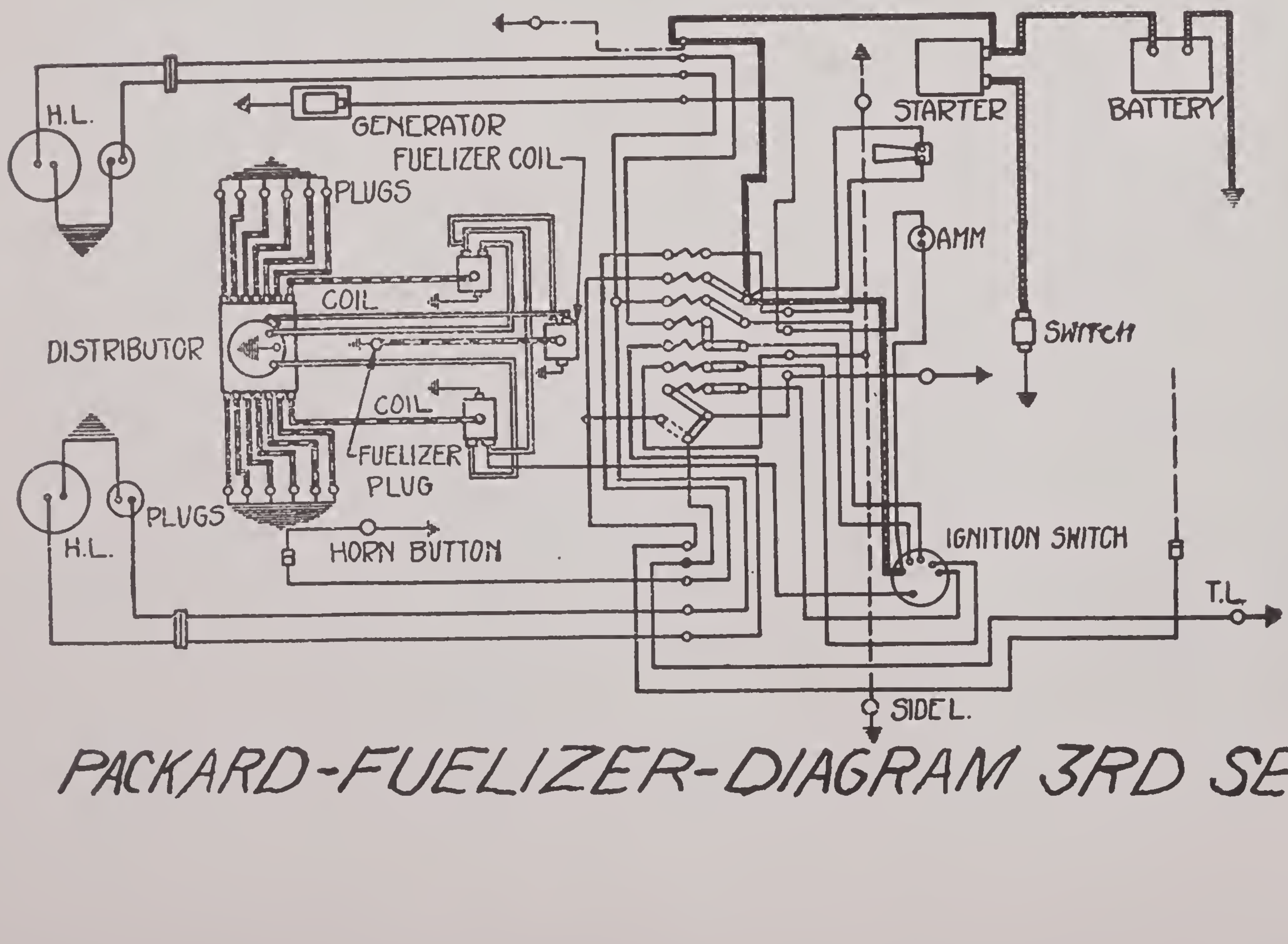
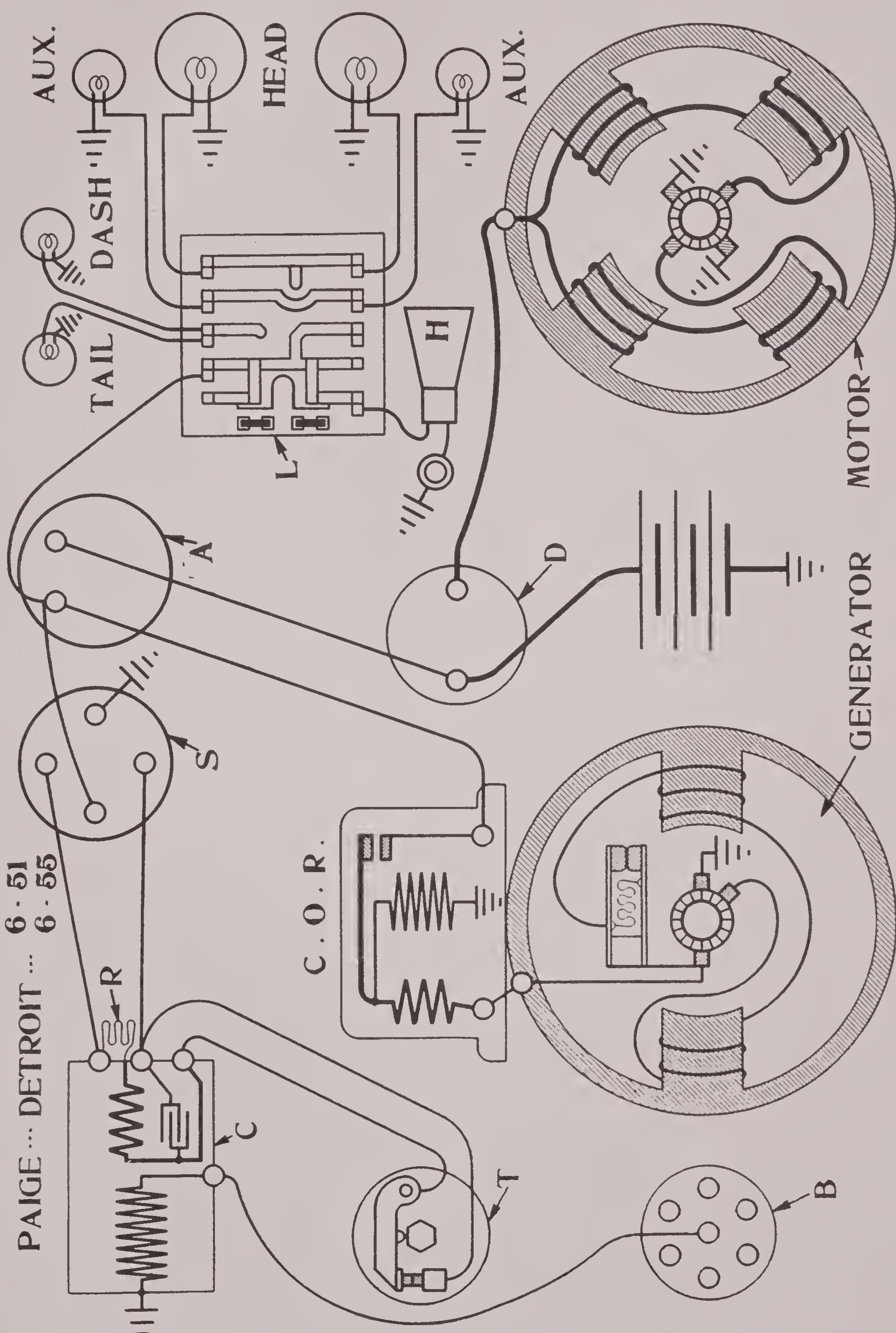
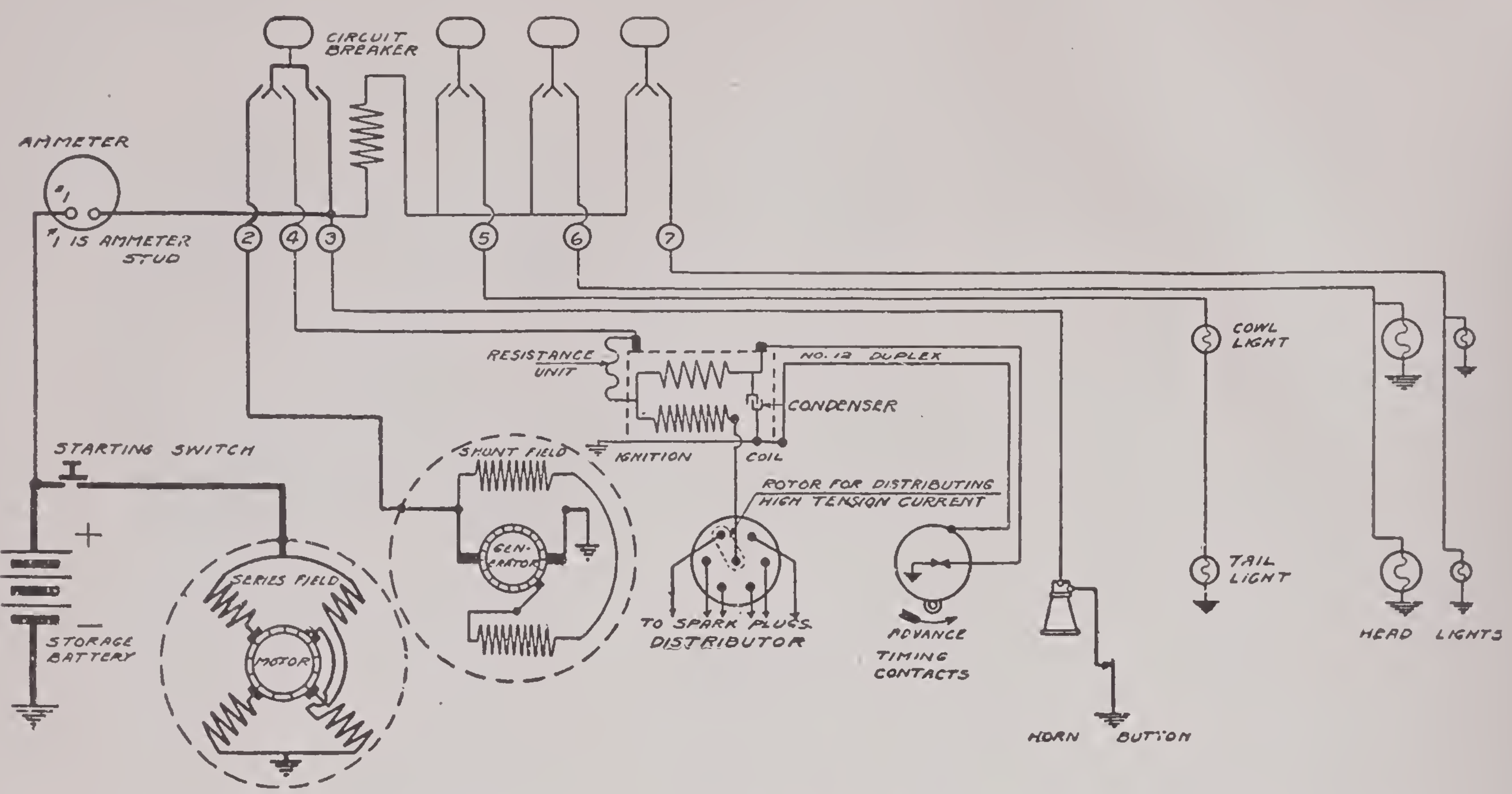


PACKARD SINGLE SIX 1920-1921 MODEL

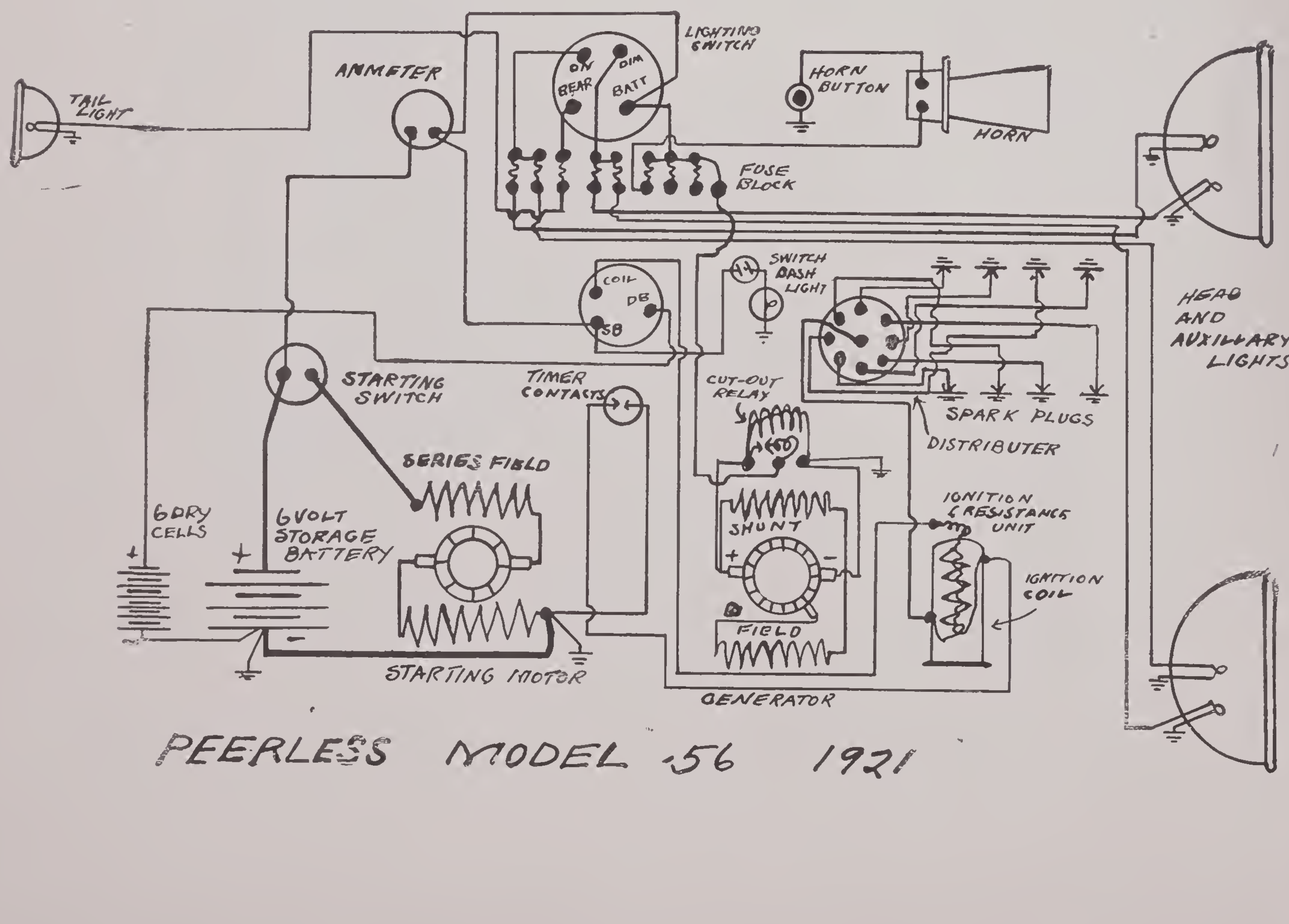


PACKARD-FUELIZER-DIAGRAM 3RD SERIES

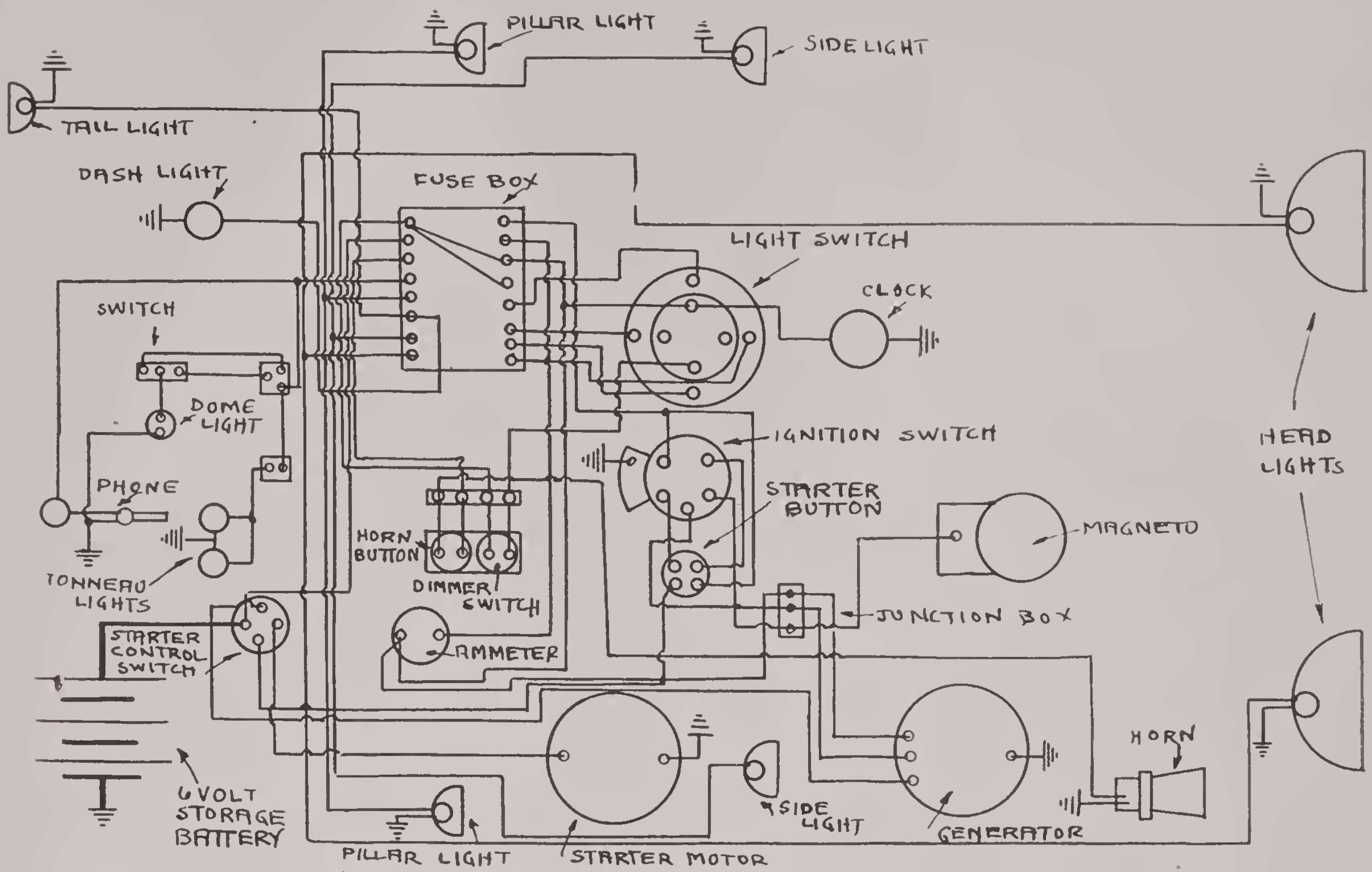

PAIGE ... DETROIT ... 6 - 51
6 - 55
AUX.
DASH
TAIL
HEAD
AUX.
H
L
A
D
S
R
C
T
B
C. O. R.
GENERATOR
MOTOR



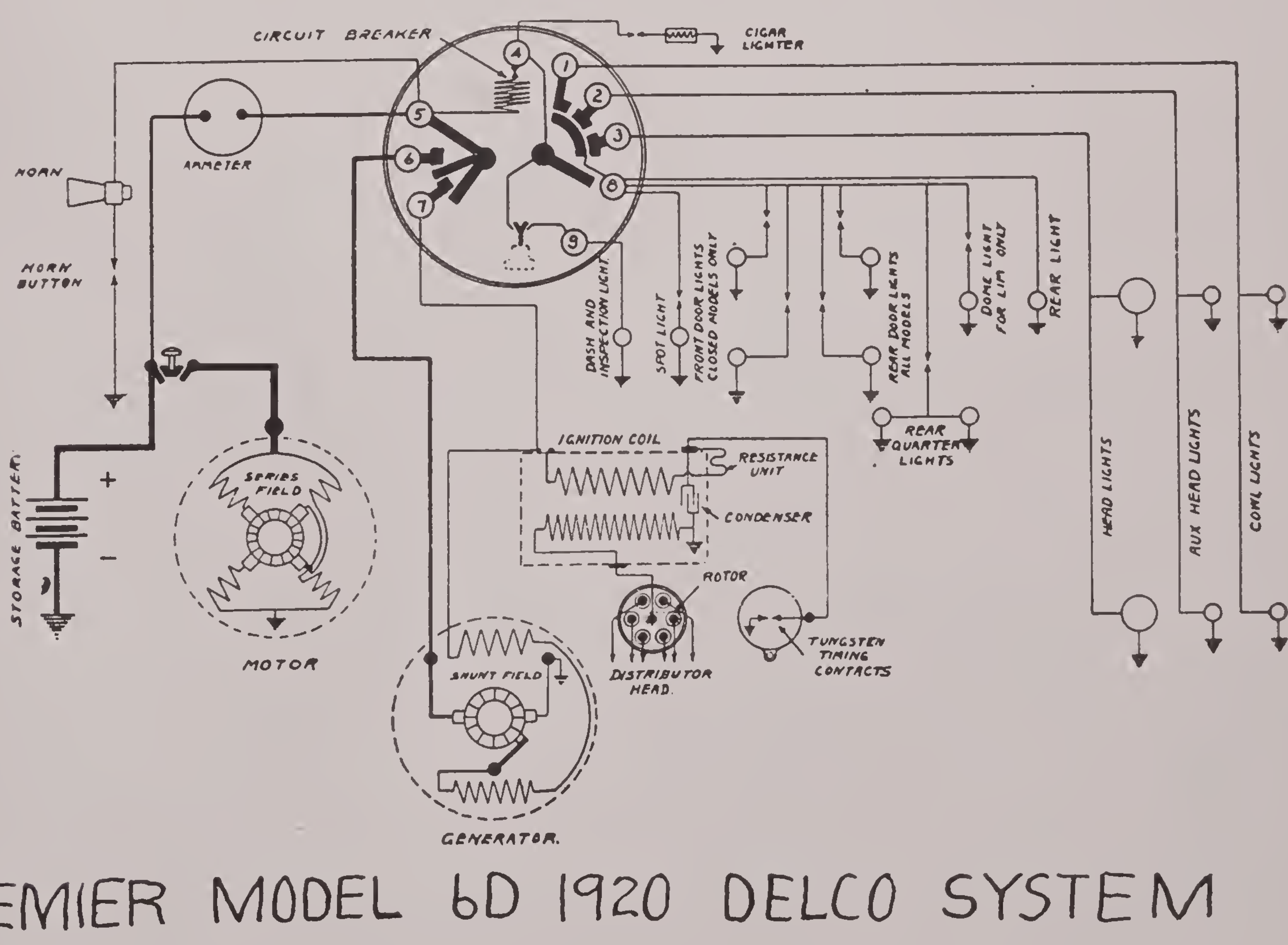
PATTERSON MODEL 6-42 1916 DELCO SYSTEM



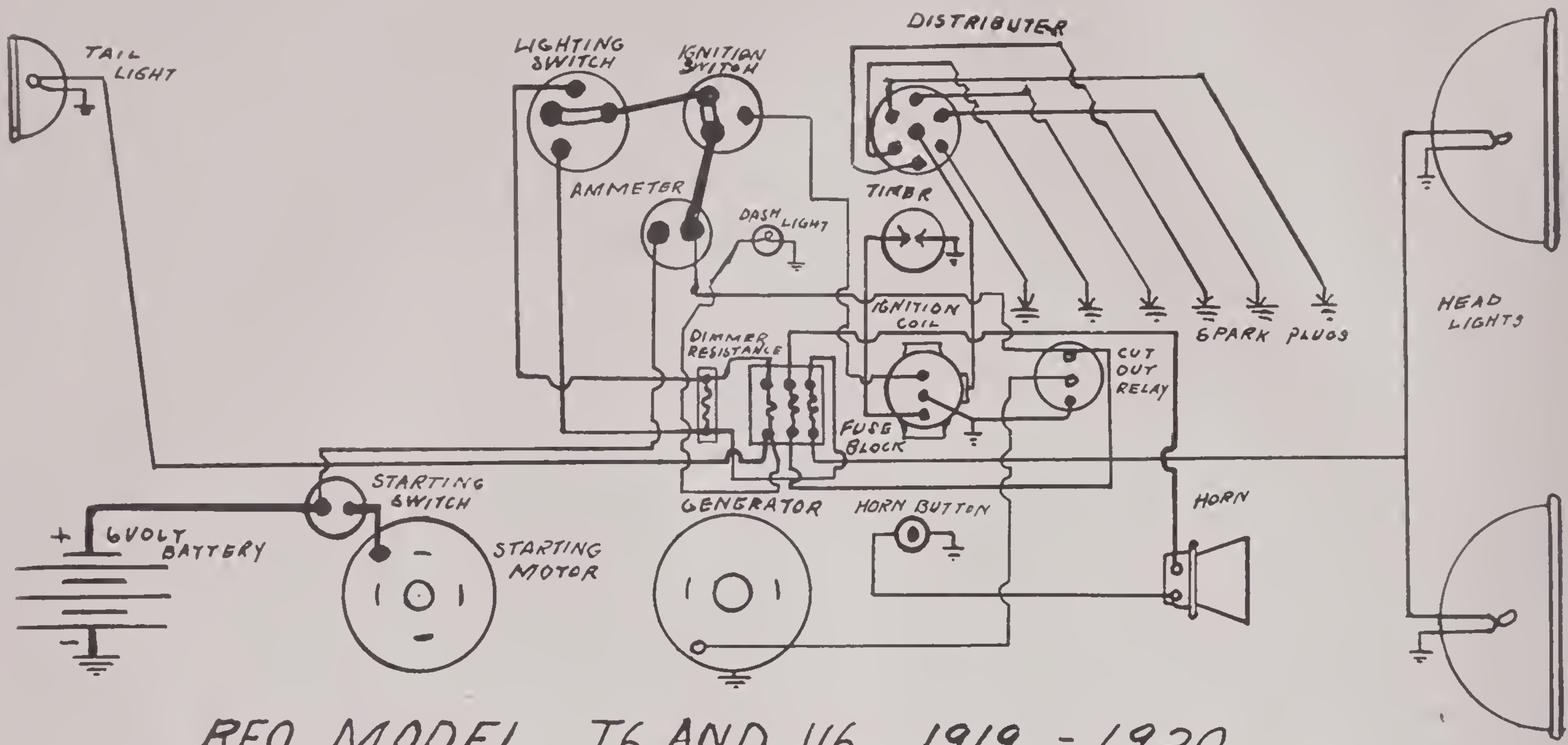
PEERLESS MODEL 56 1921



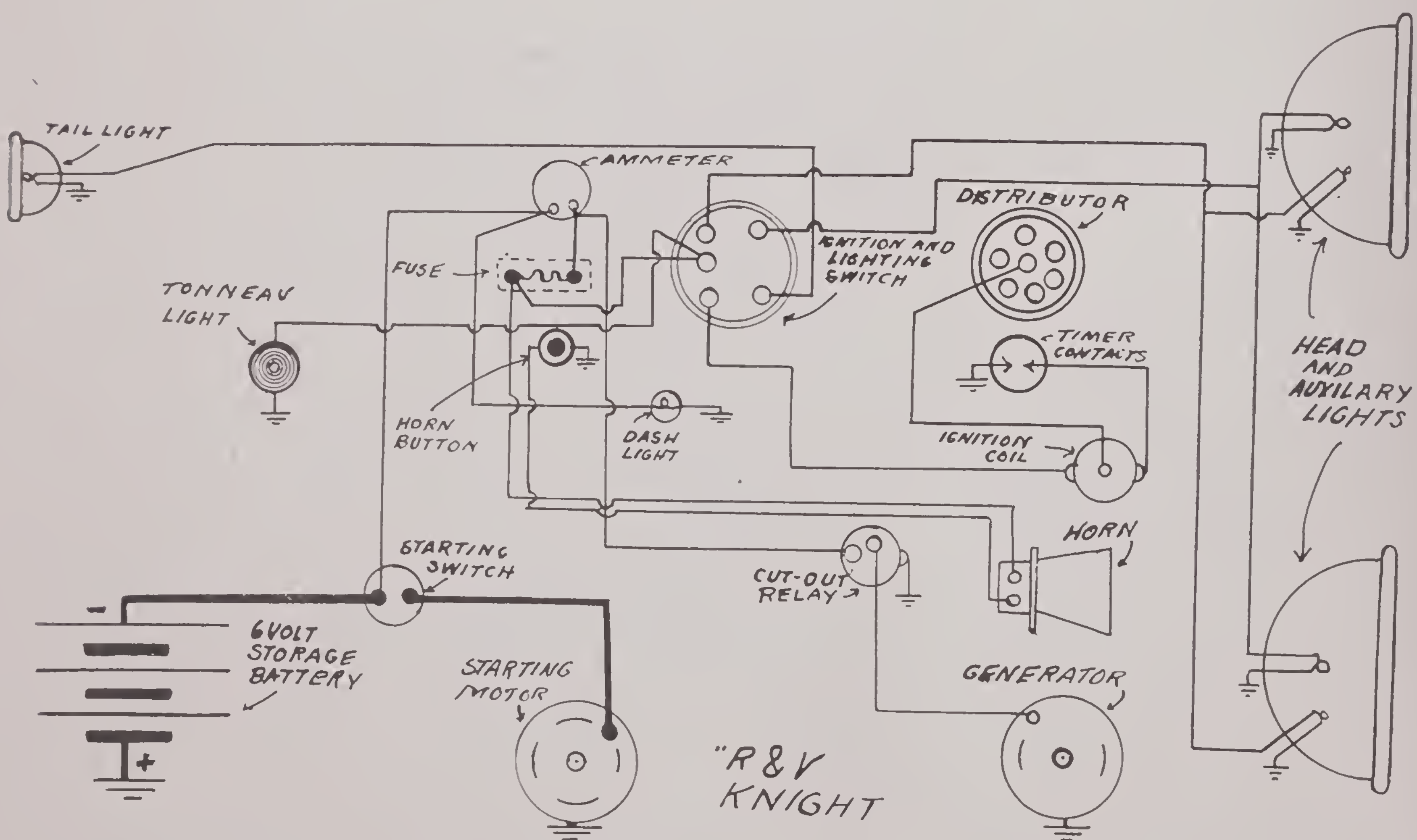
PIERCE-ARROW "38-48-66" WESTINGHOUSE SYSTEM



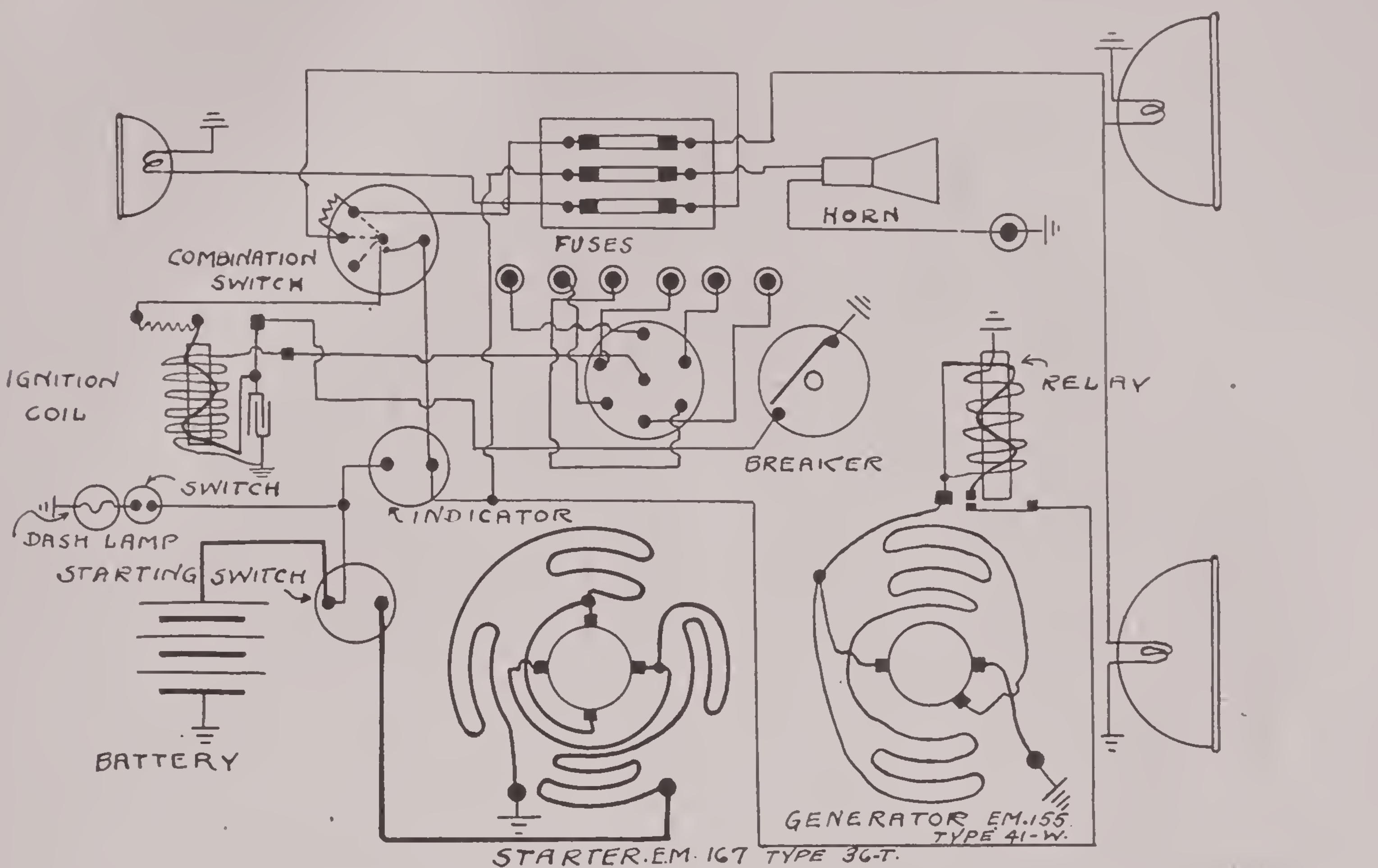
PREMIER MODEL 6D 1920 DELCO SYSTEM



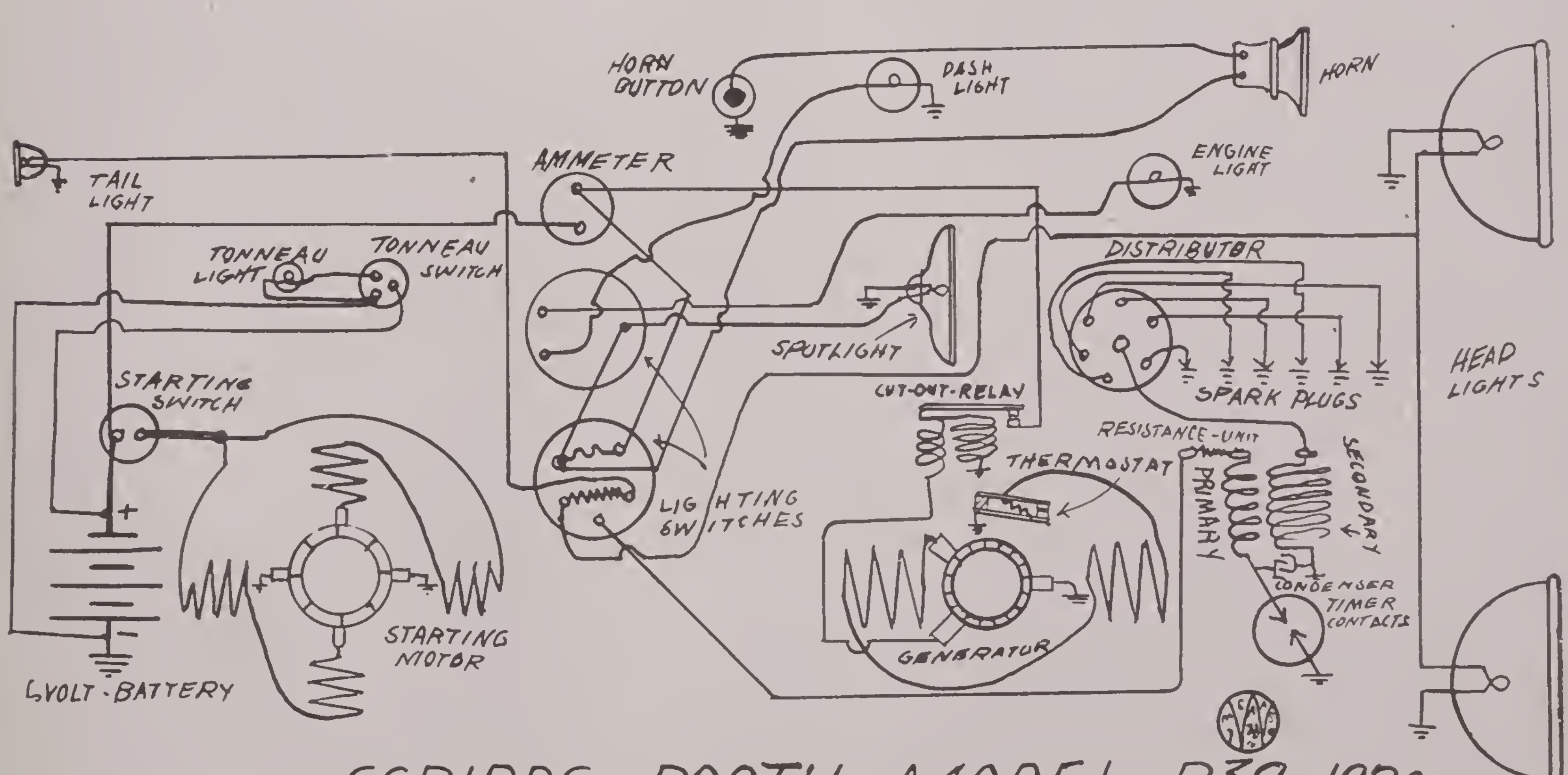
REO MODEL T6 AND U6 1919 - 1920



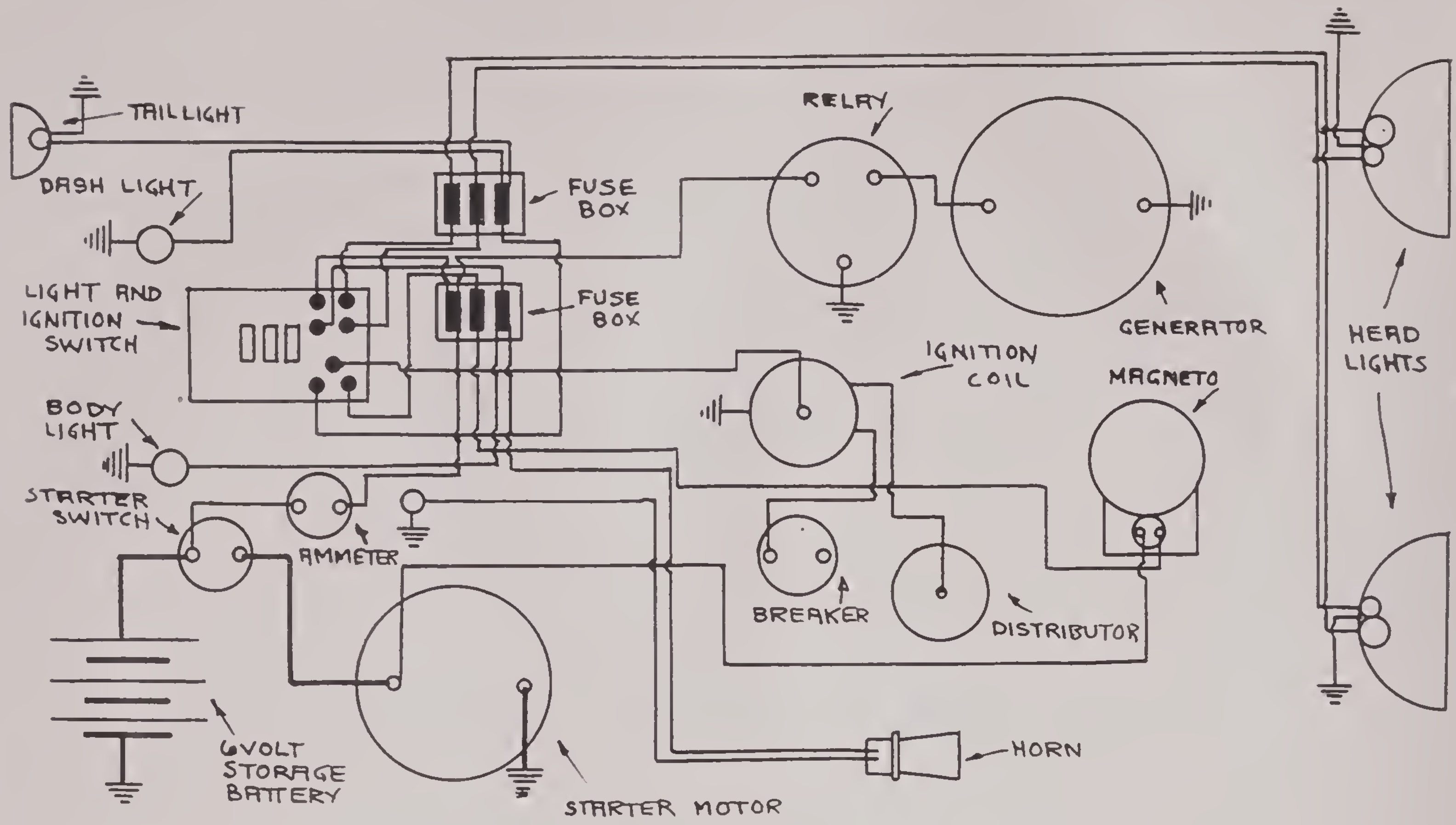
MOLINE-KNIGHT MODEL 'J' SERIES 'I' 1919 1920



SAXON MODEL S2T. - S4T. S4R.-1917-18. Y-18. 1918 WAGNER SYSTEM.

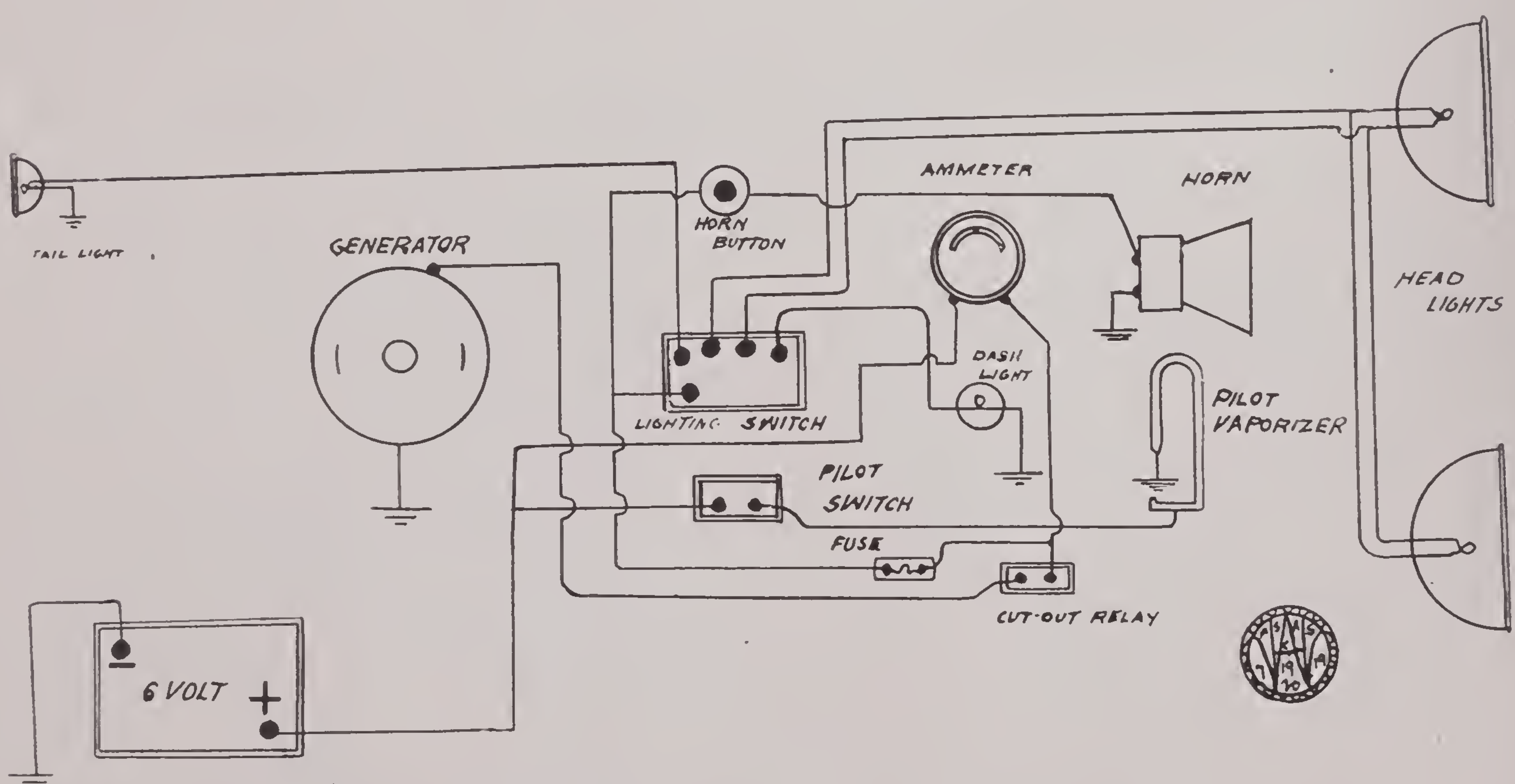


SCRIPPS-BOOTH-MODEL-B39-1920

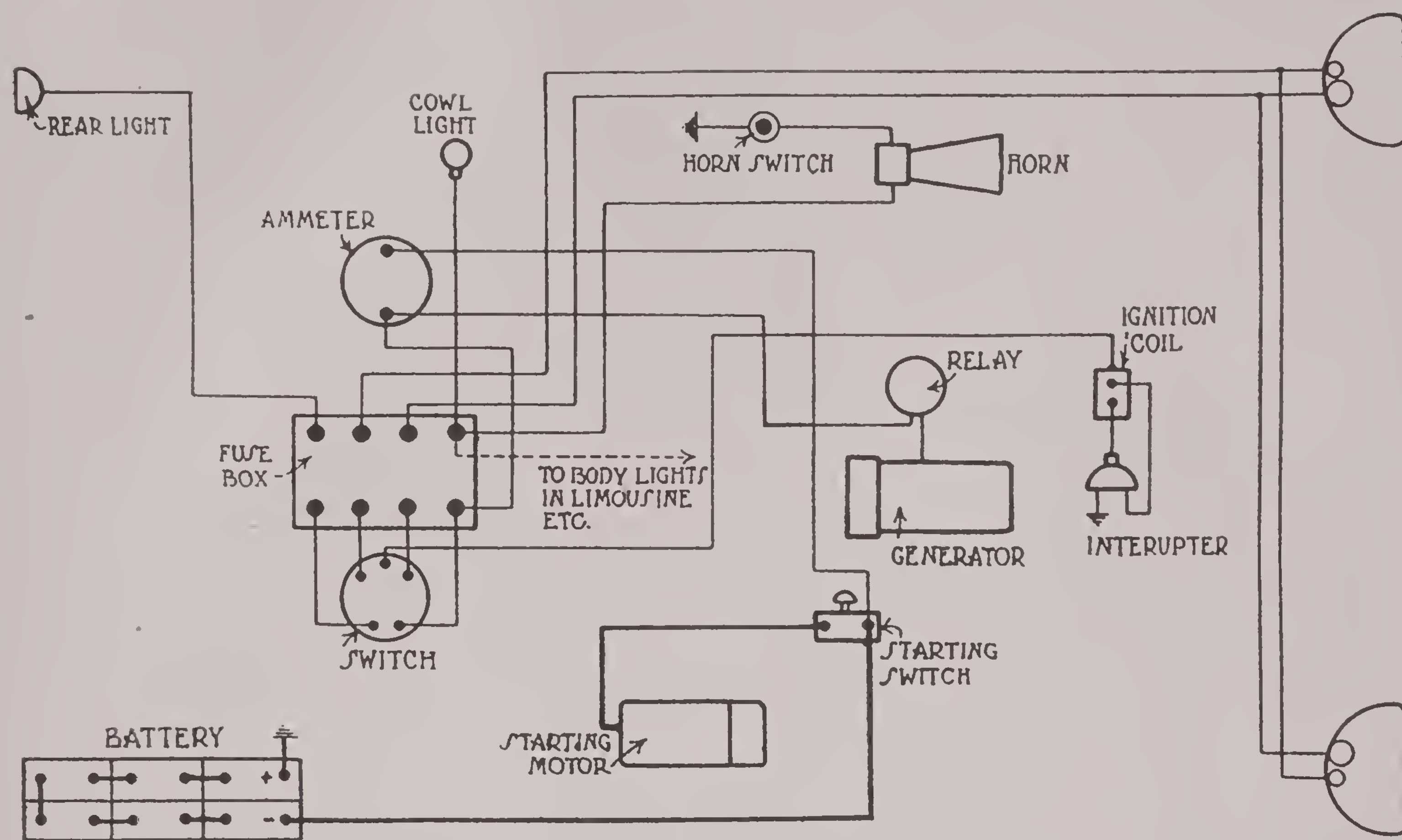


STANDARD MODEL I 1920

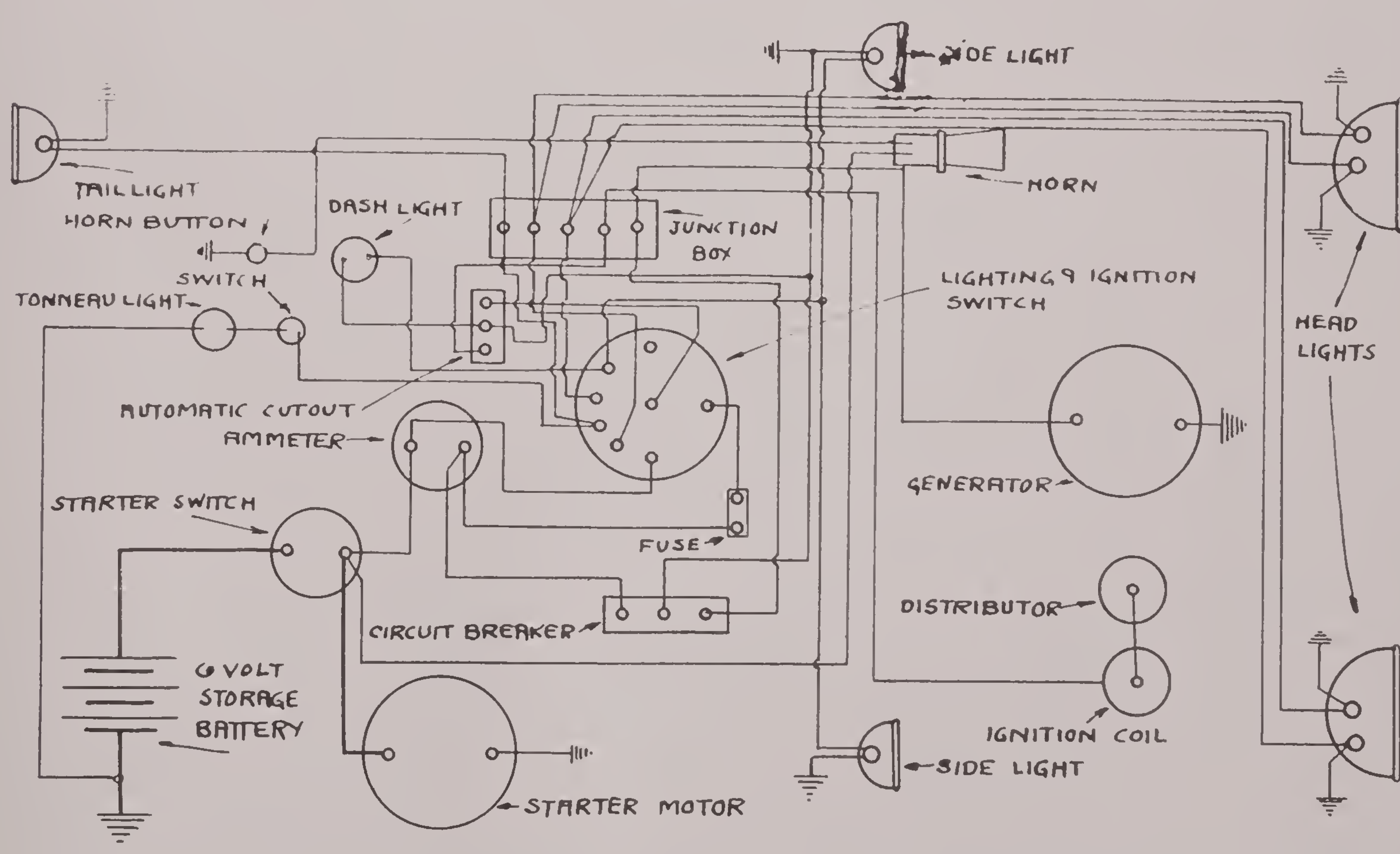
WESTINGHOUSE GENERATING, STARTING AND LIGHTING SYSTEM.
ATWATER-KENT AND SPLITDORF IGNITION.



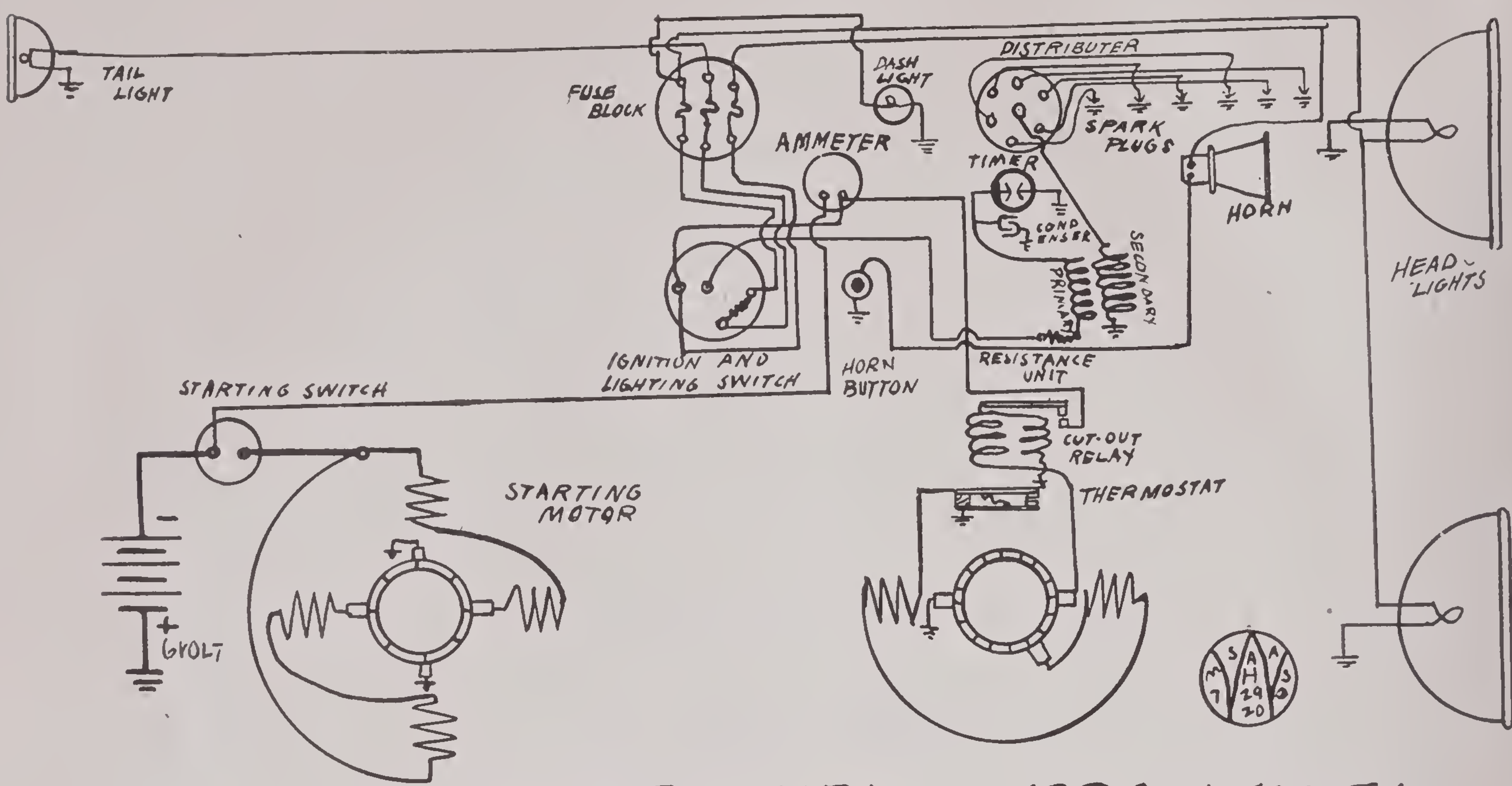
STANLEY-MOTOR-CARRIAGE-CO MODEL 735



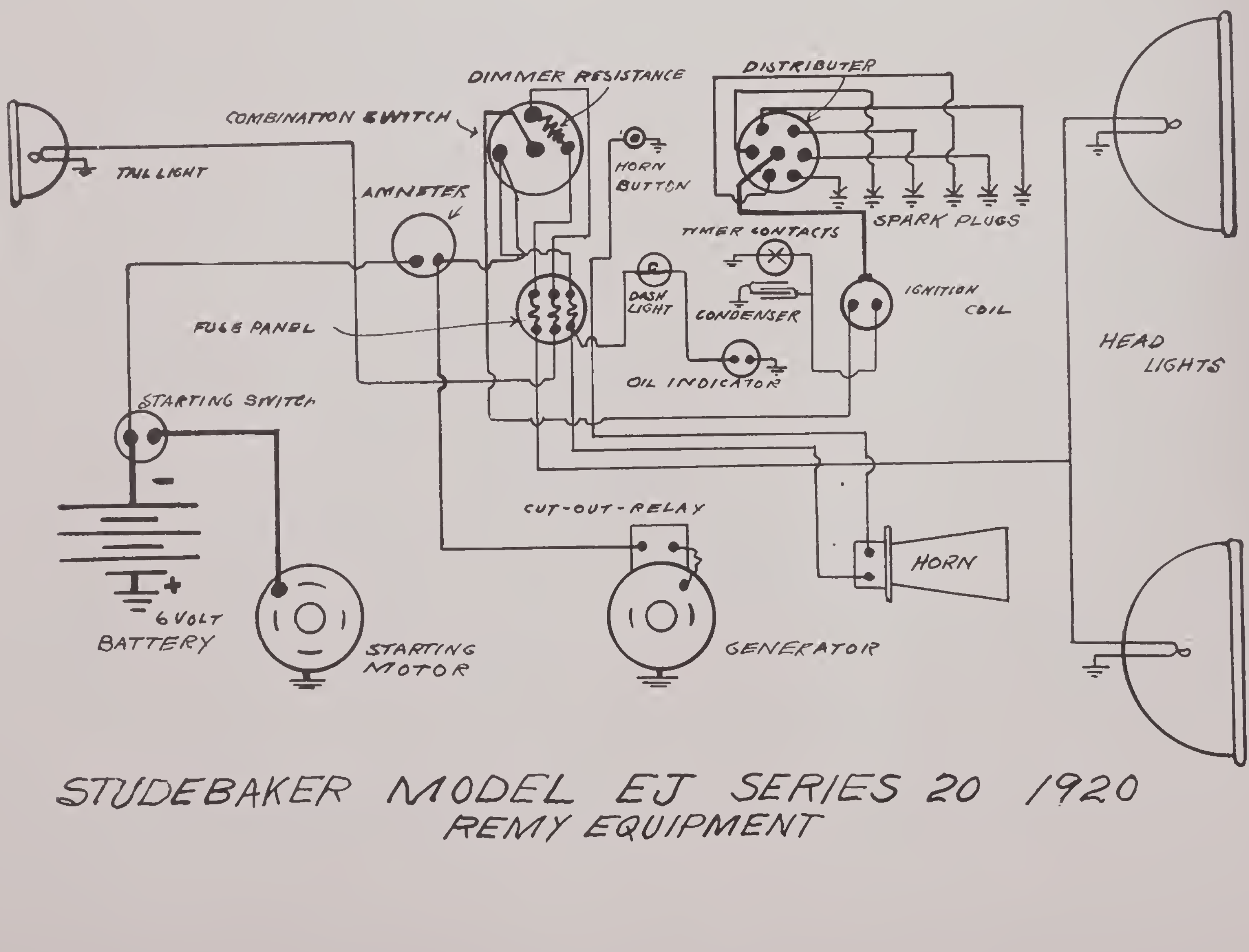
STEARNS - 1920 MODELS - WESTINGHOUSE SYSTEM.



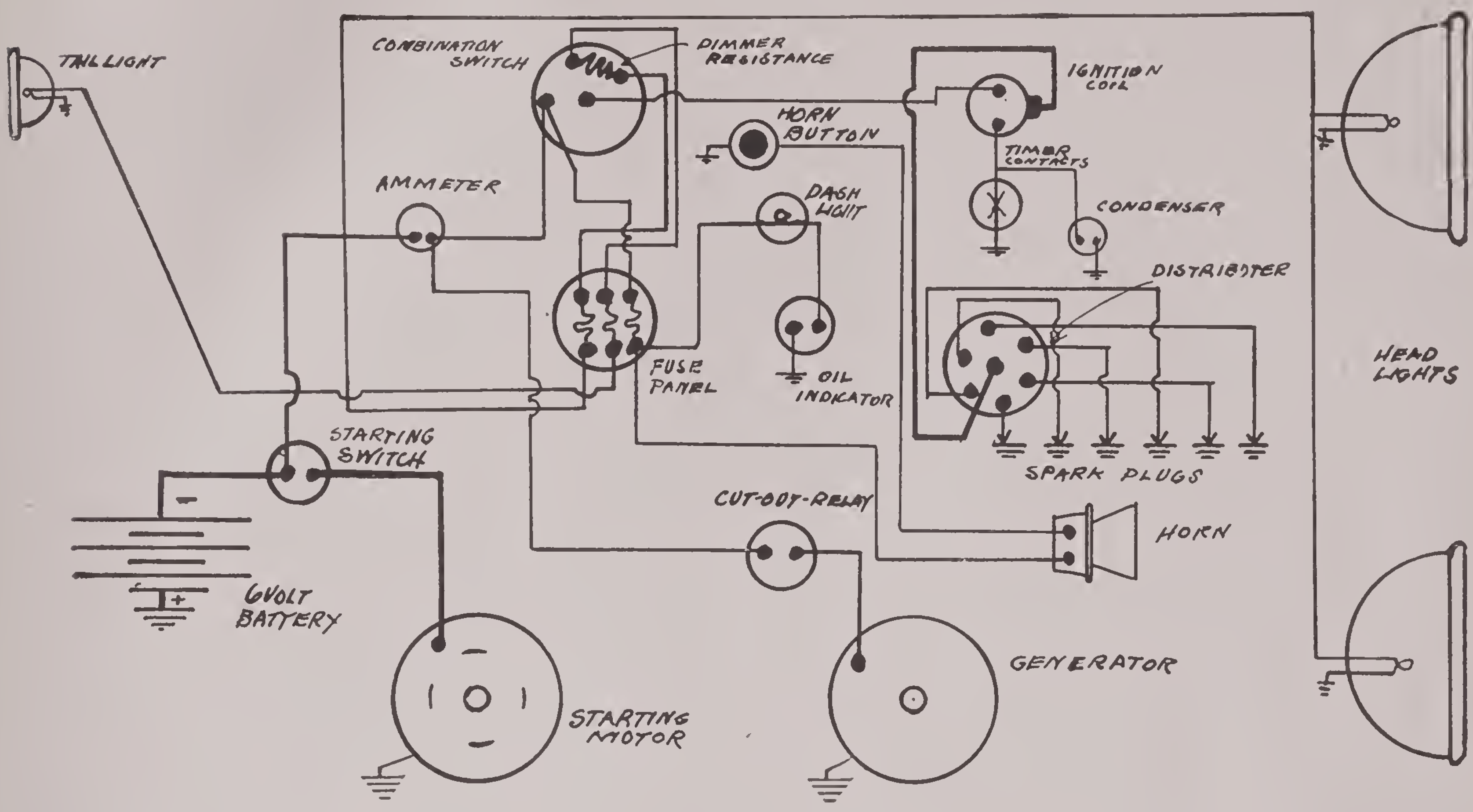
STEPHENS, MODEL "80" SERIES 3&4, 1920, DOUBLE BULB.



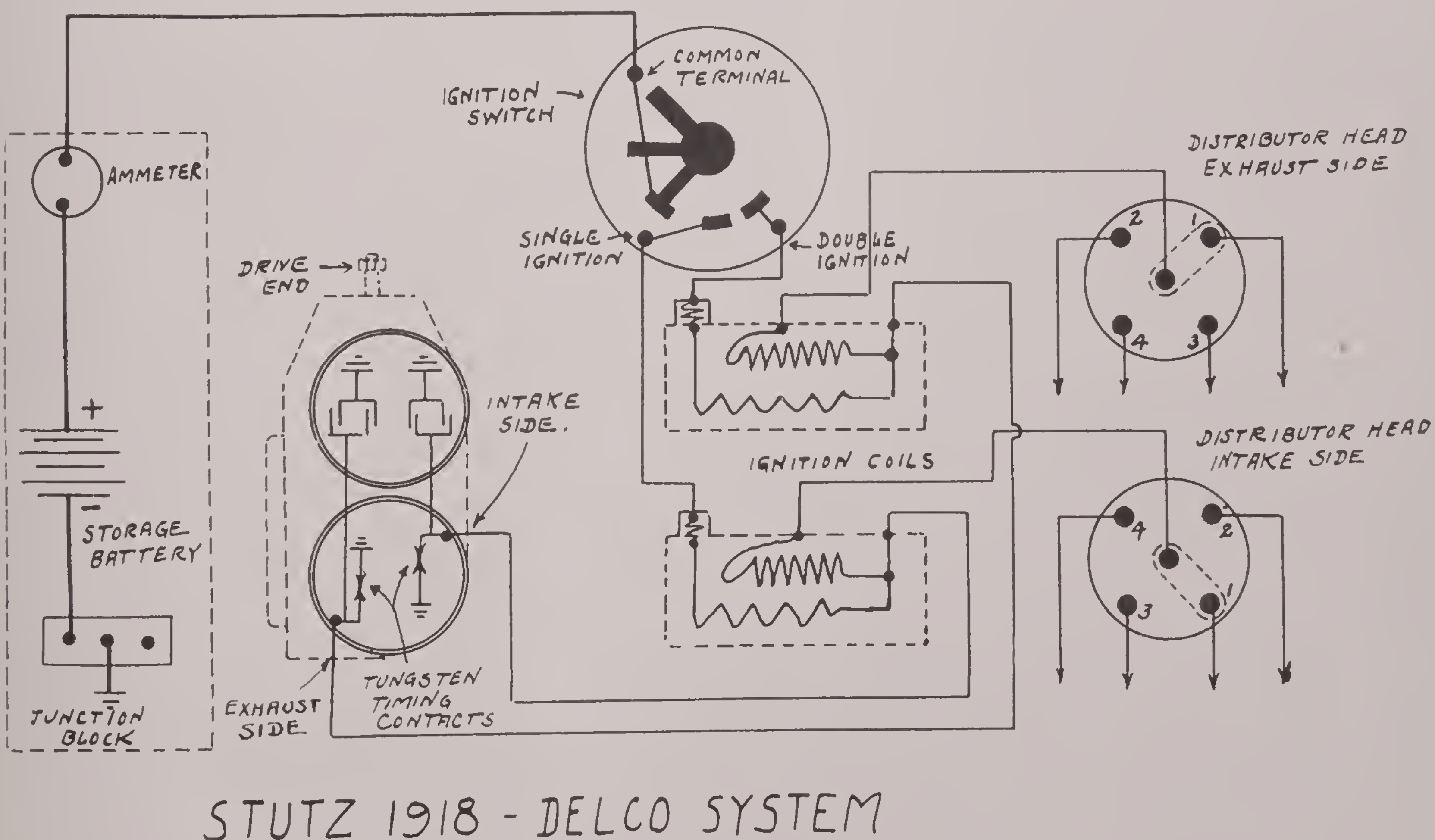
STUDEBAKER 1920 MODEL



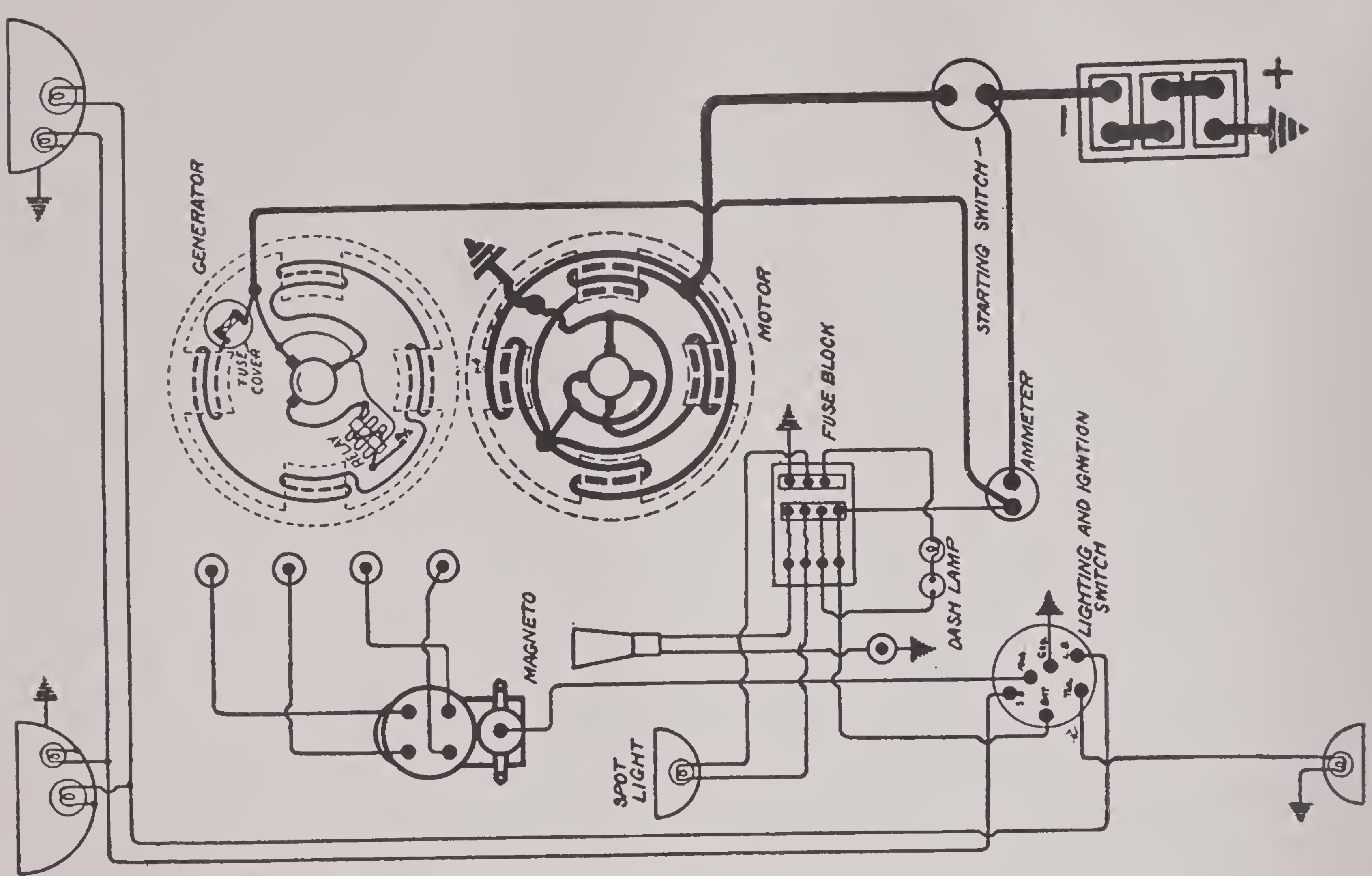
STUDEBAKER MODEL EJ SERIES 20 1920
REMY EQUIPMENT



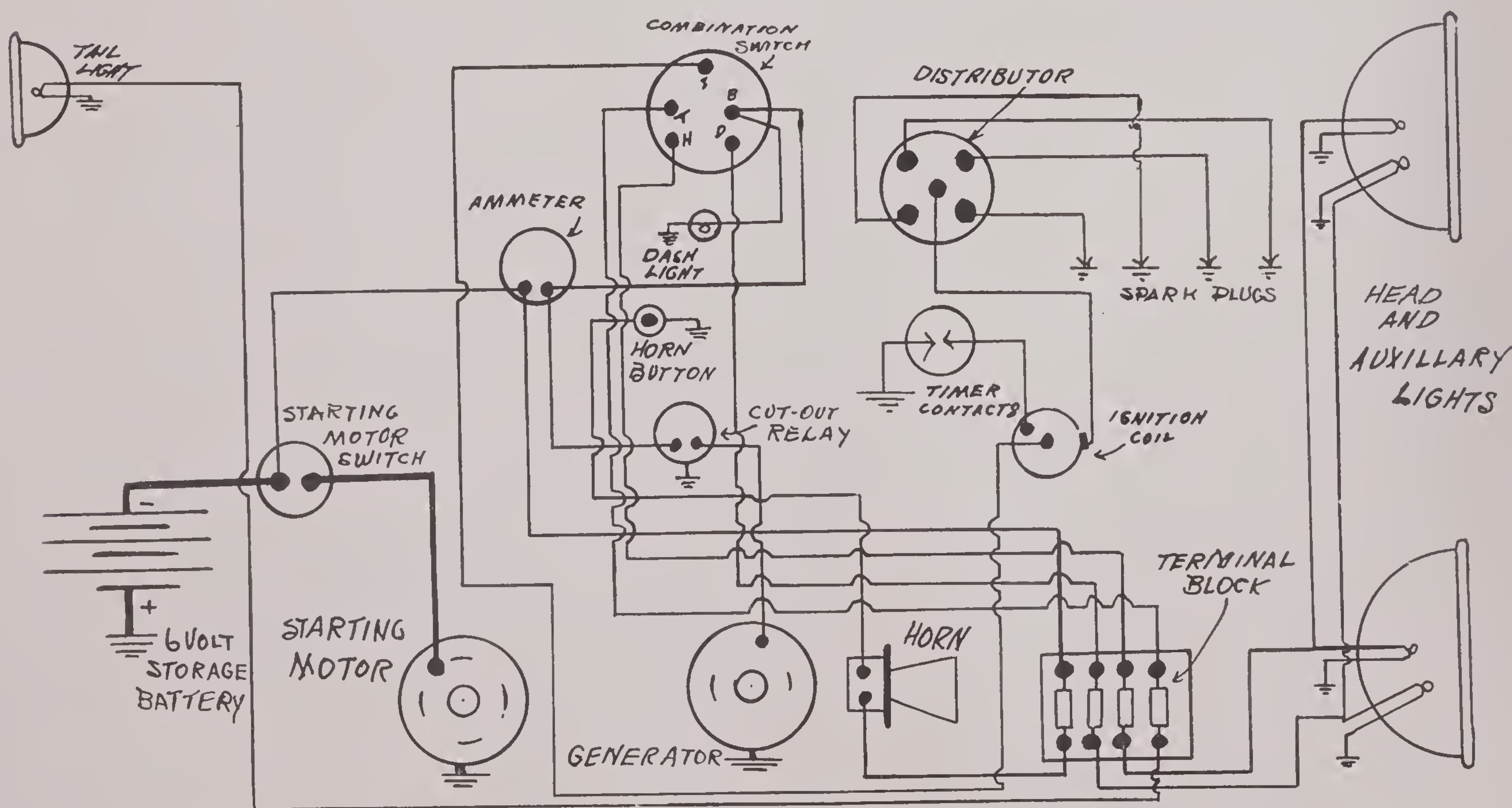
STUDEBAKER MODEL EJ SERIES 20 1920
WAGNER EQUIPMENT



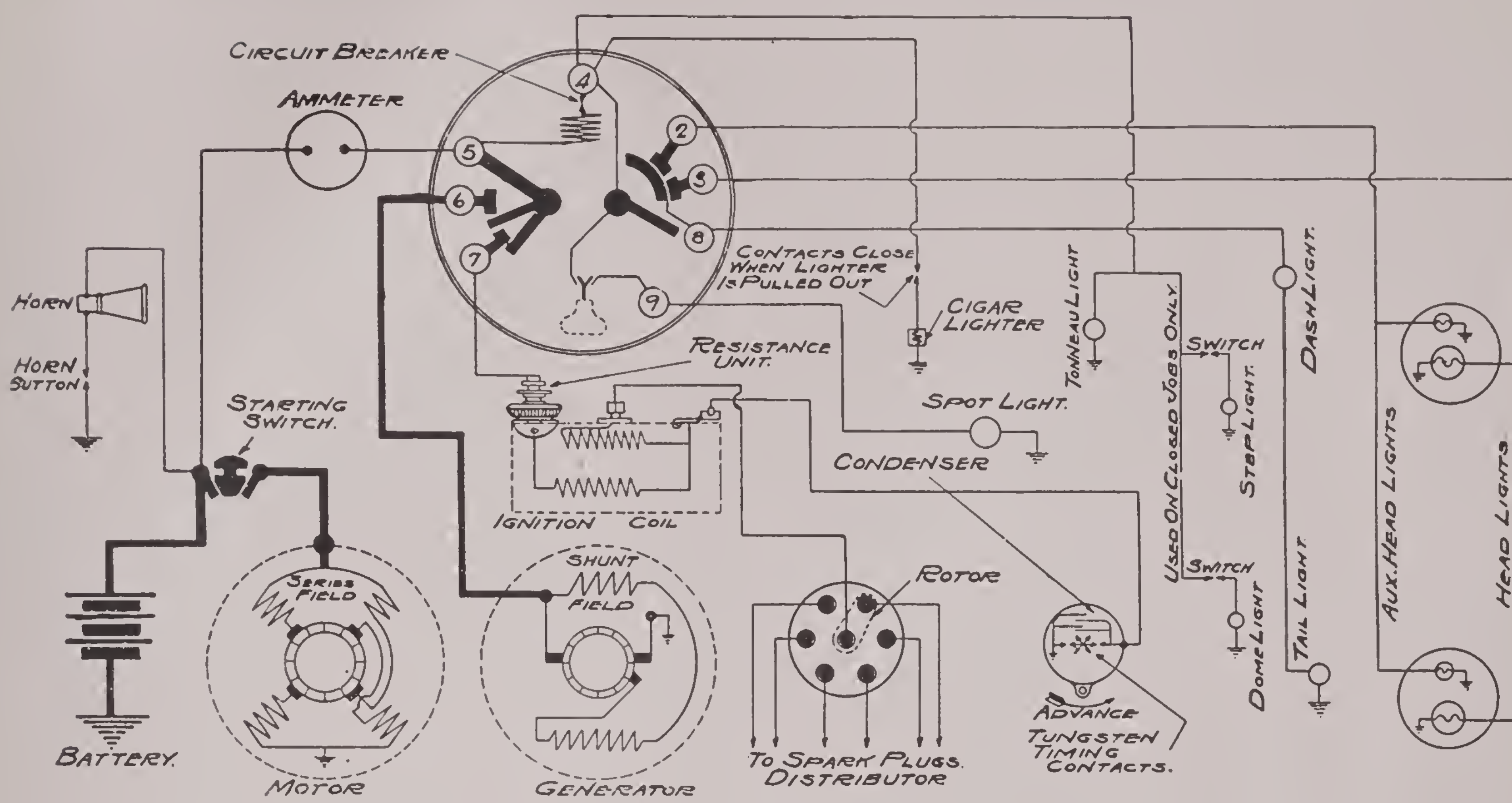
STUTZ 1918 - DELCO SYSTEM



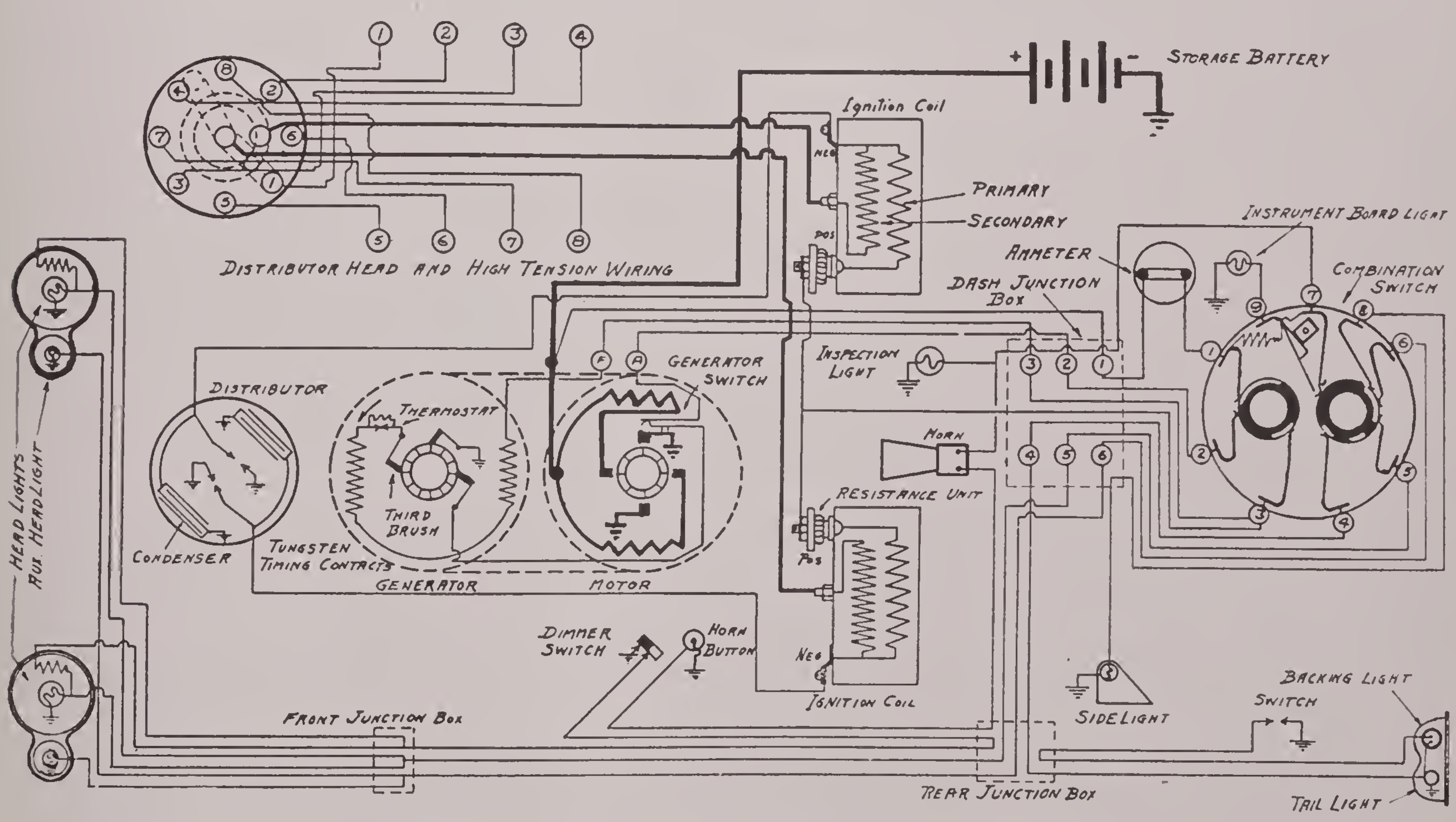
Templar Model A-445, 1920



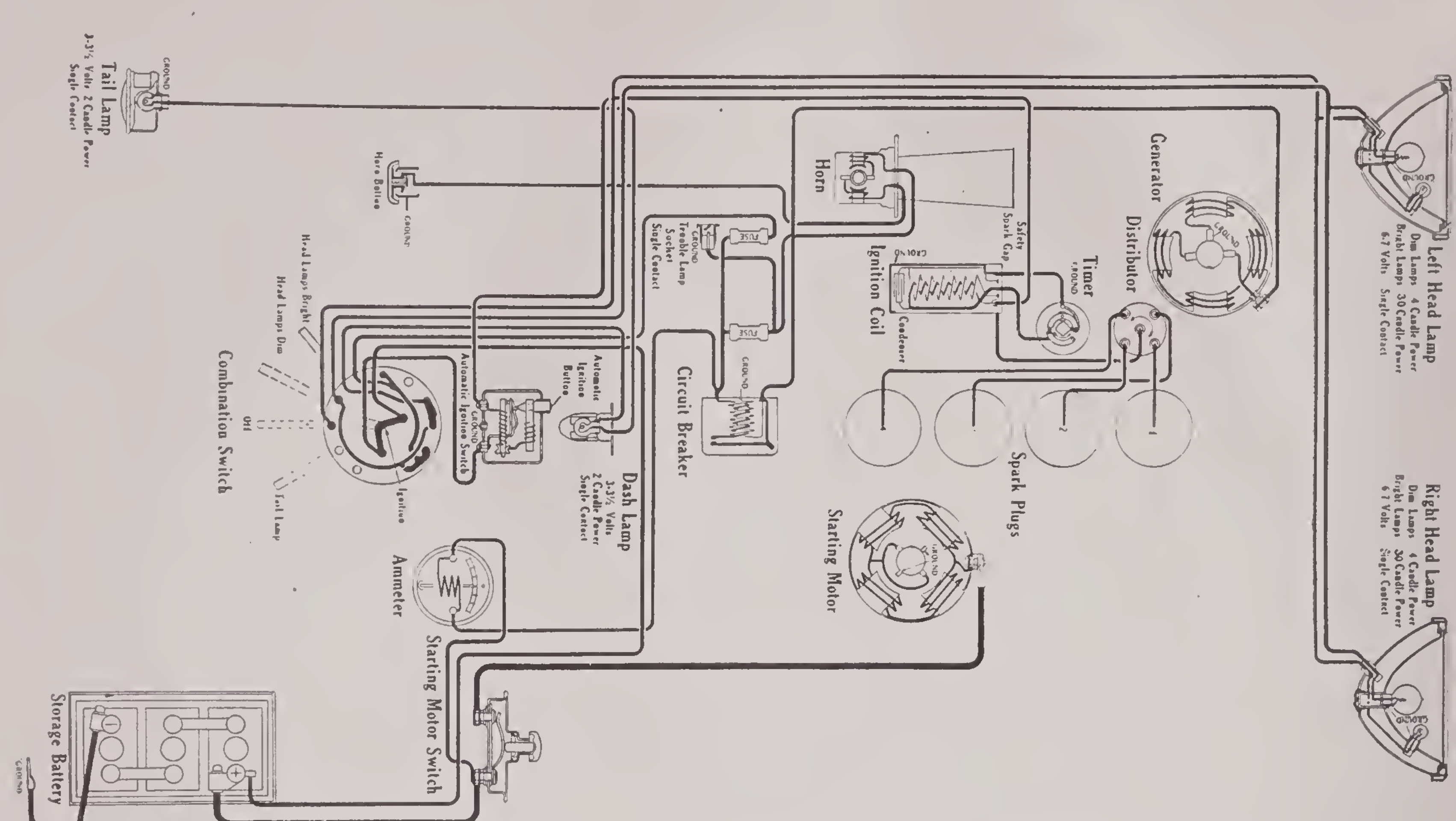
VELIE MODEL 34 1920



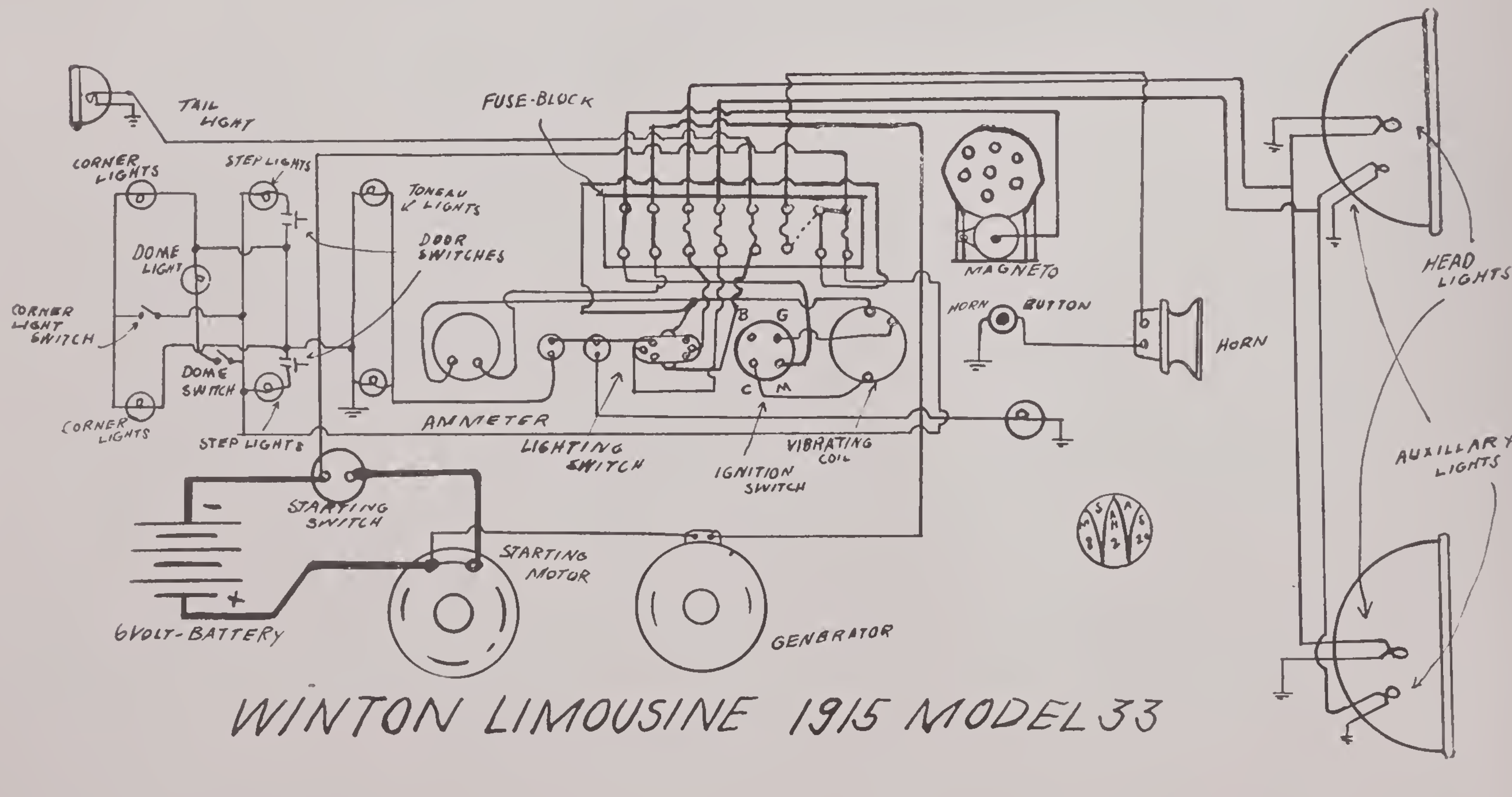
WESTCOTT-TYPE-A48-1919-20-SERIAL-8101 UP-DELCO-SYSTEM



WILLS ST. CLAIRE—1922 Model



WILLYS-KNIGHT MODEL 20 DOMESTIC



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