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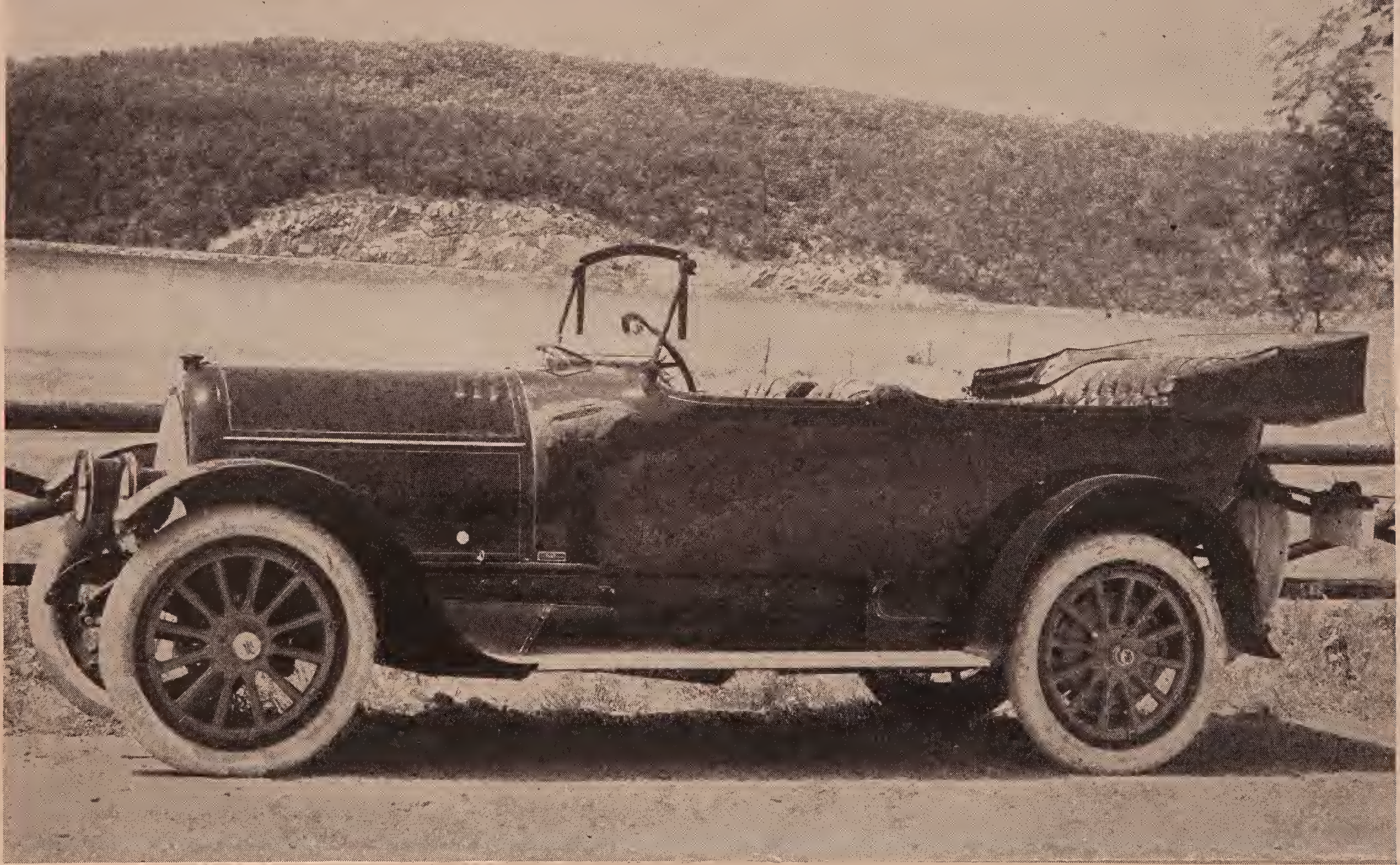

FIAT SEVEN-PASSENGER TOURING CAR

Courtesy of F. I. A. T. Company, Poughkeepsie, New York

Cyclopedia
of
Automobile Engineering

A General Reference Work on

THE CONSTRUCTION, OPERATION, CARE AND REPAIR OF GASOLINE, ELECTRIC AND STEAM AUTOMOBILES, COMMERCIAL VEHICLES, MOTORCYCLES, AND MOTOR BOATS; IGNITION, STARTING, AND LIGHTING SYSTEMS; EXPLOSION MOTORS; DRIVING; TROUBLES; GARAGES; REPAIRS; WELDING

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

FIVE VOLUMES

CHICAGO
AMERICAN TECHNICAL SOCIETY
1916

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, Motor Boats, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

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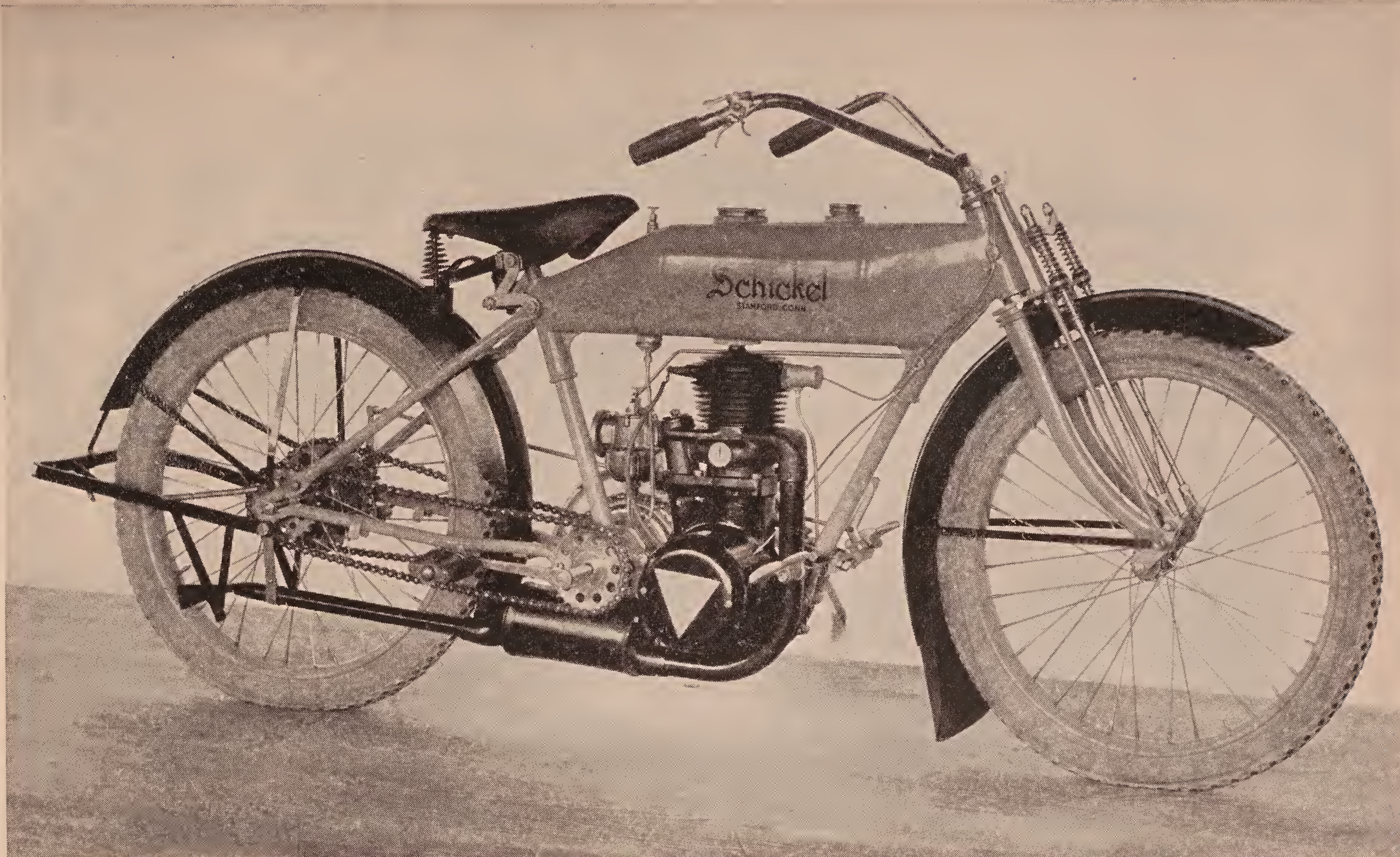
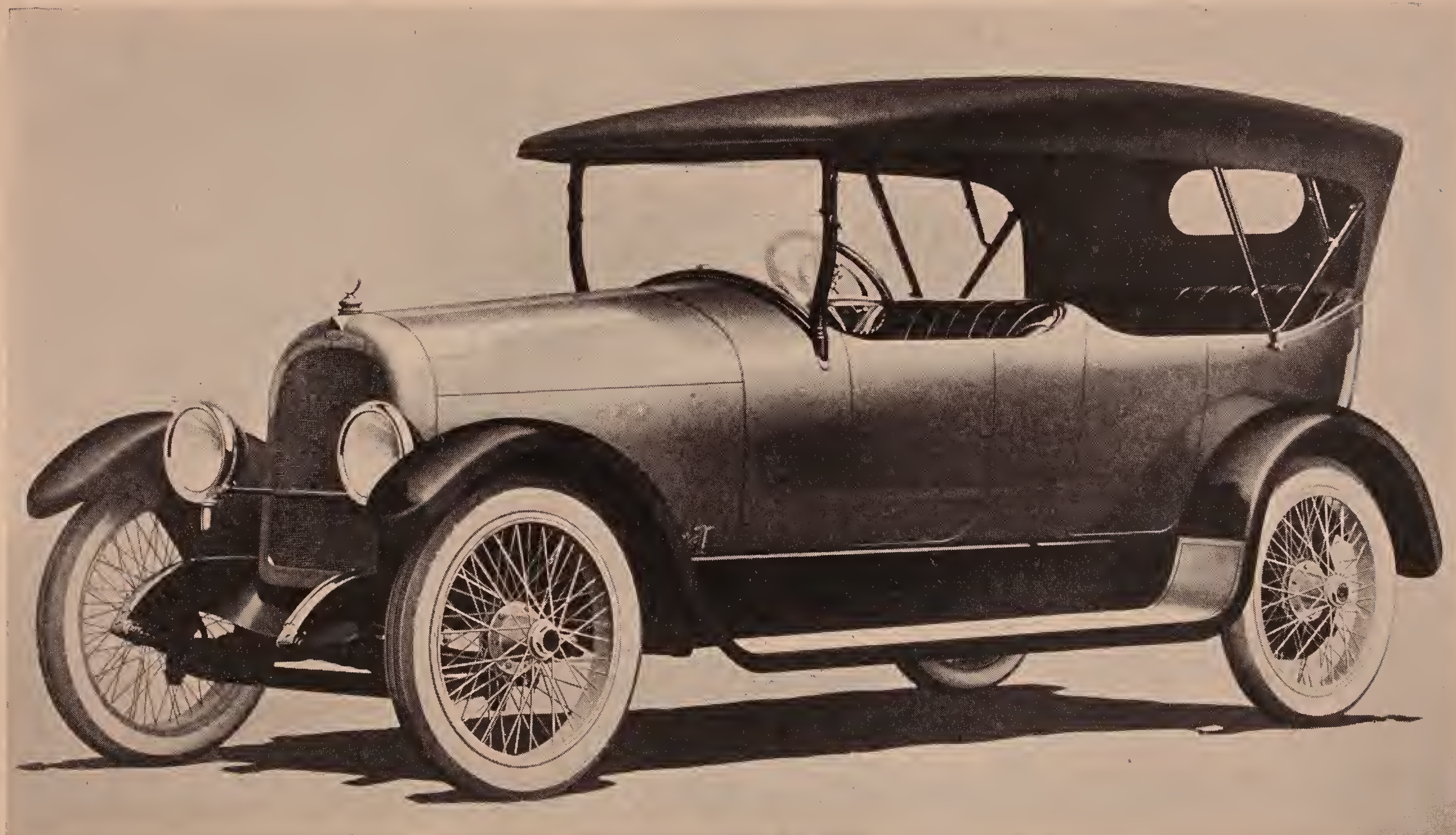


SCHICKEL MOTORCYCLE EQUIPPED WITH 6-HORSEPOWER SINGLE-CYLINDER VALVELESS MOTOR
Courtesy of Schickel Motor Company, Stamford, Connecticut



MARMON SEVEN-PASSENGER TOURING CAR
Courtesy of Nordyke and Marmon Company, Indianapolis, Indiana

Foreword

WITHIN recent years the internal-combustion motor and the self-propelled vehicle have become such important factors in the evolution of industrial, commercial, and social life, that a distinct need has been created for an authoritative work of reference on this subject. Such a work should treat of the results and methods of the latest approved practice in the construction, care, and operation of the various types of motor cars and other vehicles driven by gas, electricity, and steam, and of the allied branches of this rapidly developing field of apparently unlimited possibilities. It is the purpose of the Cyclopedia of Automobile Engineering to fill this acknowledged need.

¶ The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of types of mechanically-propelled road carriages and motor boats, is a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Today the automobile is a wonderfully reliable and efficient machine. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced novice, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. Astonishing refinements in the ignition, starting and lighting systems have been lately effected, thus adding not only to the reliability of the electrical equipment of the automobile but adding greatly to the pleasure in running the car. With the possibility of extending the electrical control to the shifting of gears and other important functions, the electric current assumes a much more important position in connection with the gasoline automobile than heretofore. Altogether, the automobile as a whole has become standardized and, unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ Special effort has been made to emphasize the treatment of the Electrical Equipment of gasoline cars, not only because it is in this direction that most of the improvements have lately taken place, but also because this department of automobile construction is least familiar to owners, repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the principal systems. In addition to this instructive section, much valuable information to garage and repair men has been included in connection with the analysis of the details of the car.

¶ For purposes of ready reference and timely information so frequently needed in automobile operation and repair, it is believed that these volumes will be found to meet every requirement.

¶ Grateful acknowledgment is due the corps of authors and collaborators — engineers of wide practical experience, and teachers of well-recognized ability — without whose co-operation this work would have been impossible.

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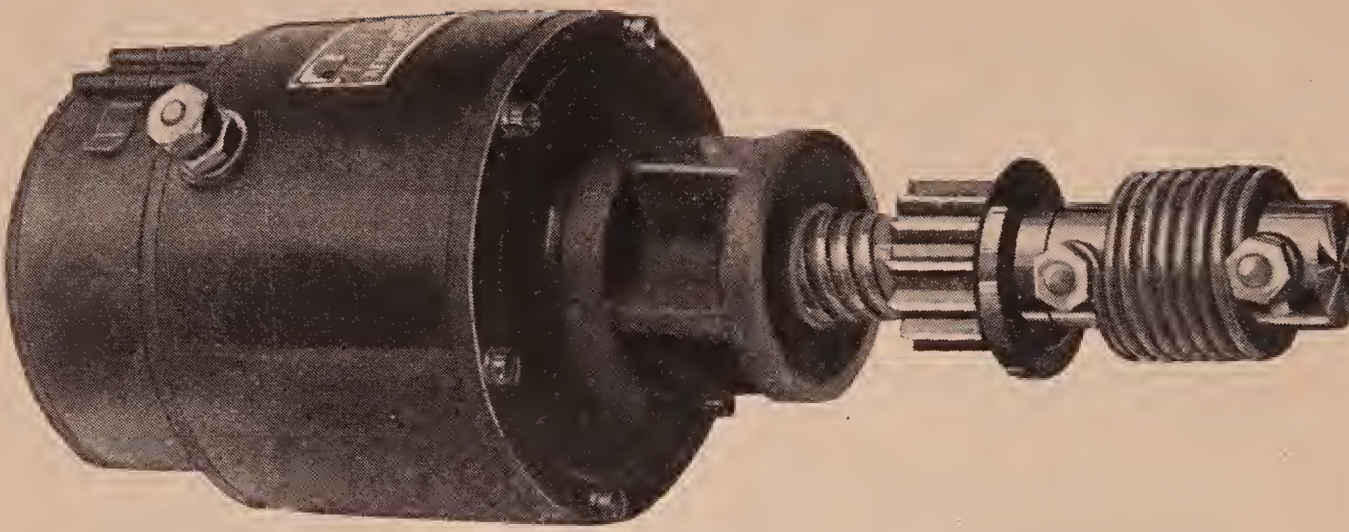
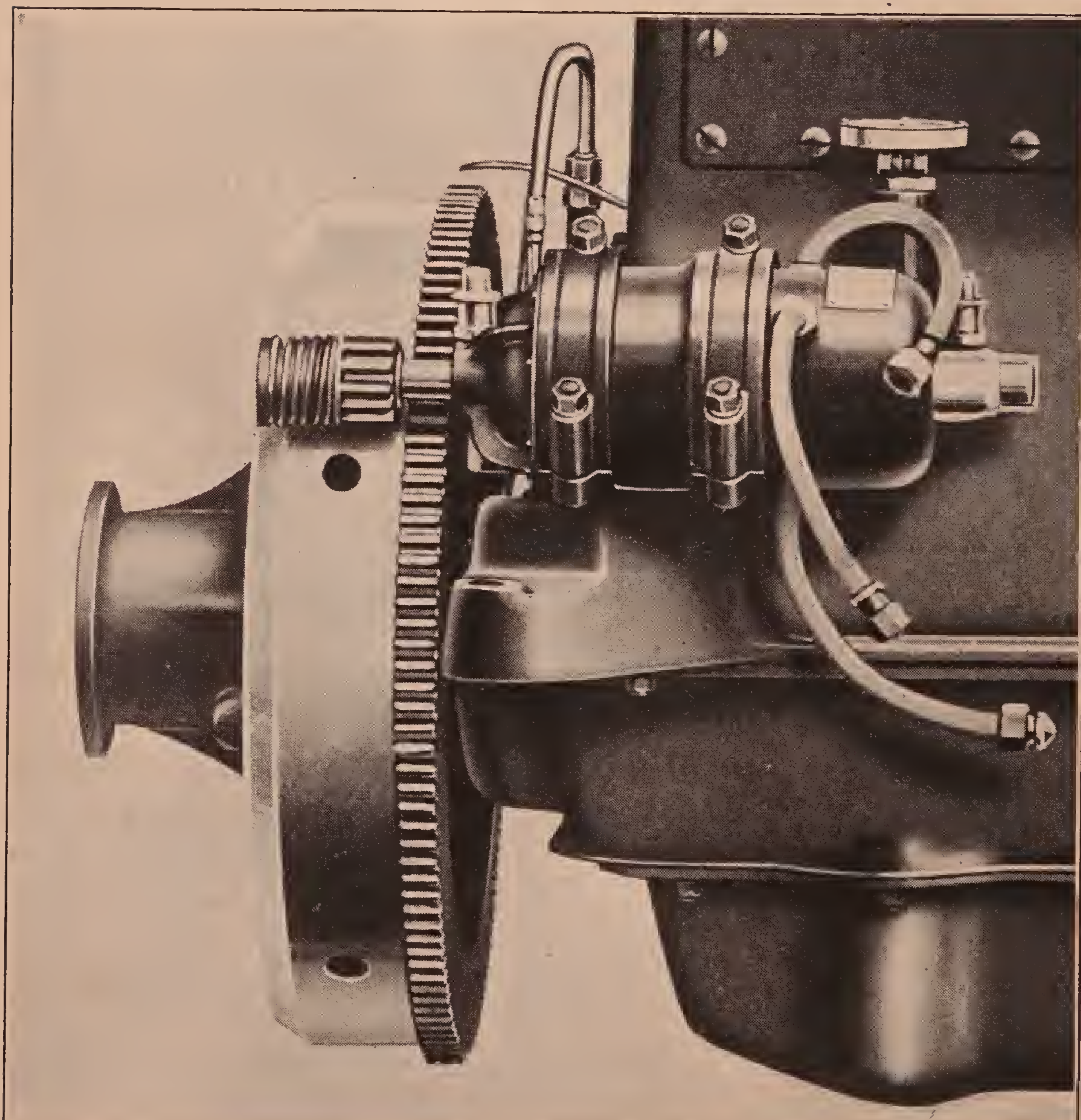


REMY STARTING MOTOR WITH INBOARD TYPE BENDIX PINION
Courtesy of Remy Electric Company, Anderson, Indiana



BOSCH STARTING MOTOR MOUNTED ON MARMON SIX-CYLINDER MOTOR
Courtesy of Nordyke and Marmon Company, Indianapolis, Indiana

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART I

INTRODUCTION

Importance of Electricity on Automobiles. Starting with nothing more than a few dry cells and a wiring system that would have shamed an itinerant bellhanger, the electrical equipment of the automobile has constantly increased in importance, until within the last year or two it has become the most essential auxiliary there is on the machine. Electricity now starts the motor, ignites the charge in the cylinders, lights the car and the road ahead, sounds the horn, and in some instances shifts the gears and applies the brakes. It has even gone as far as to displace the flywheel, clutch, and gearset altogether, in addition to performing the numerous functions already mentioned, and it seems quite likely that along this line is to be one of the most important developments of the next few years. The details of this equipment are described under "Transmissions", so that no further mention is made of them here.

Inherent Weakness of Electrical Devices. Even in the present highly perfected state, the electrical equipment still constitutes the weakest element among the motor auxiliaries. In fact, it is subject to more frequent defection than any other single element of the entire construction of the automobile. This must not be taken as implying that it is defective in any sense, as it is quite the contrary, ignition, lighting, and self-starting systems having been developed to a degree of reliability that was undreamed of in the earlier days. But owing to its nature, the electrical equipment is more susceptible to derangement. Consequently, a rather substantial proportion of the minor troubles of automobile operation that still survive to harass the motorist arise from some failure of the electrical system. Of course, many of these are due to the inexperience or ignorance of the motorist himself, and for this reason it behooves the student to give more than the usual amount of attention and study to this branch of the subject.

ELEMENTARY ELECTRICAL PRINCIPLES

Knowledge of Principles Necessary. To acquire a good practical working knowledge of electricity as applied to the automobile today, it is essential not merely to find out *how* things are done, either by watching the other fellow do them, or by studying "pictures in a book", but also to learn *why* certain things are done and *why* they are carried out in just such a way. In other words, the man whose knowledge is based upon theory and principles applies knowingly the cause to produce the effect and is certain that the desired effect will be produced. On the other hand, the man who works only with his hands aimlessly goes from one thing to another trusting chiefly to luck to accomplish two things. One of these is to strike upon the remedy for the trouble the cause of which is sought, and the other is to deceive the spectator—usually the owner of the car—into believing that the fumbler really knows what he is about.

There are accordingly two distinct classes of knowledge as regards the electrical equipment of an automobile—one which is picked up by rote, an isolated point at a time, and applied in the same manner, and the other which is based upon a clear insight into the underlying reasons for the various actions and reactions that make up the different electrical phenomena involved. If we want to know what is wrong with an electric motor, it is essential that we should know what makes an electric motor operate when everything is right. In the same way, it would be groping in the dark to attempt to investigate the reasons for the failure of a dynamo to generate current, or a storage battery to give up its charge, if we had no knowledge of why a dynamo, when run by an outside source of energy, normally produces a current, or why an accumulator literally "gives back" what has been put into it when its circuit is closed after charging.

It will accordingly be the function of this introductory chapter to give a brief résumé of the principles underlying the operation of what has come to be the most important auxiliary of the gasoline motor as applied to the automobile—its electrical equipment.

A thorough understanding of these principles will go a long way toward enabling one to remedy the various minor ills that afflict the apparatus, and to recognize at once those of a nature serious enough to be beyond the first aid which even the best equipped garage is capable of giving. It is worse than a waste of time to hunt for a short circuit or a ground as the cause of failure of the dynamo to generate, when an inspection of its parts reveals the fact that its armature winding has been burned out. Again, one can hardly expect the motor to continue starting the gasoline engine when the owner's neglect of the storage battery has permitted the plates to sulphate so badly that they are practically worthless. Contempt of "book knowledge" is not wholly a thing of the past, and many men consider themselves "practical" in insisting upon learning how to do things with their hands alone. The best-paid man, however, and he who can instruct others how things should be done, is the man who uses his head to acquire a knowledge of the theory upon which practice is based, and then employs his hands to much better effect by letting his brain guide them.

THE ELECTRIC CIRCUIT

Current. Just what electricity is we do not know—maybe we never shall know—but it is a matter of common knowledge that it is one of nature's prime forces and as such is universal. The air, the earth, the water, the clouds, our bodies and those of animals, as well as inanimate objects such as trees, houses, and the like are all electrified to a greater or less degree all the time. The amount of electricity that any given object possesses at a given moment depends upon its capacity (the electrical meaning of which is given later) and the conditions of surrounding objects. For example, a room will hold a certain amount of air; if it is uninfluenced by other conditions, we know that the room is full of air at an approximate atmospheric pressure of 15 pounds to the square inch (the usual pressure at sea level). The room may be considered in a normal "state of charge".

There is nothing that differentiates the air in this room from that of the room adjoining. It is perfectly quiet and nothing is disturbing it; there is no tendency for it to move. If, however, all the openings of the room are tightly closed with the exception of a duct for the admission of more air under the impulse of a powerful compressor, in a very short time there will be a marked difference between the air in this room and the air in the other rooms. Instead of the normal atmospheric pressure of 15 pounds per square inch, there will be a pressure against all parts of the room—floor, walls, and ceiling—of 50, 60, or 100 pounds, according to the length of time the compressor has been working and the degree of tightness with which the various openings have been closed. Thus there will be a great deal more air in the one room than in its neighbors. If it were electricity instead of air, the room would be said to be highly charged.

The air in this room, on account of the pressure which it is under, is constantly seeking an outlet, and it will gradually leak out through various small openings, probably without its escape being noticed. The same conditions obtain when a body becomes electrified beyond its capacity to hold a charge—the charge of electricity will leak away without giving any indication of its passing. Turning again to the room containing the compressed air, if a door or window of that room is opened suddenly, the pressure is immediately released through that opening and anyone standing in front of it would say that a strong current of air blew out. In the case of electricity, if any easy path of escape is provided, the entire charge will rush away from the body, and there is then said to be a current of electricity "flowing" from this point of escape to whatever other object equalizes the pressure by becoming charged. An electric current is accordingly electricity in motion; it is simply said to flow. But to cause it to do so there must be pressure. The electrical term for this pressure is *potential* or *voltage*.

Electrical Pressure. Every day in the year the earth transmits a greater or less proportion of its electrical charge to the atmosphere, or receives a charge from the latter, but unless the conditions are favorable there is no visible indication of this *difference of potential* as it is termed. It must be borne in mind that this difference of potential, or difference in electrical pressure, between two points is what causes a current to flow. Given a hot day in summer, however, when the air is heavily charged with moisture and low cumuli, or rain-charged clouds form in great masses, then the electrical charges from the earth and the air accumulate in these great banks of dense water vapor instead of passing up to the higher regions of the atmosphere. When the charge exceeds the capacity of the clouds, and the electrical pressure, or difference of potential, between two neighboring clouds or between a cloud and the earth becomes very great, we have the familiar phenomenon of lightning, the electricity escaping in a several-mile-long flash instead of by means of the little spark with its snap as it passes from one object to another under similar conditions.

Resistance. It is thus apparent that electricity is an element that can be expressed as a quantity, and likewise one that can be subjected to pressure. The unit of current is the *ampere;* the unit of electrical pressure is the *volt;* the unit of quantity is the *coulomb,* equal to one ampere per second. Resuming the simile previously given, 500 cubic feet of air forced into the room under a pressure of 100 pounds to the square inch, may be likened to a current of 500 amperes at 100 volts. And, just as the opening allowed determines the quantity of air that will escape at a time, so the electrical outlet influences in the same manner the current that will flow. From this it is evident that there is another factor to be considered. This is resistance.

If a half-inch hole is bored in the door of the room, the air will escape at a pressure of 100 pounds to the square inch, but only a few cubic feet per minute can pass through the orifice. If a very fine wire is used to tap the given charge of 500 amperes at 100 volts, the current will have a potential of 100 volts, but very few amperes will pass through the fine wire. If the pressure back of the air is increased, however, more air will be forced through the small opening in the same time; and if there is a greater potential back of the electrical current, more current will be passed through the fine wire. Thus the factors of electrical quantity, pressure, and flow are all related and are all dependent on the factor of resistance. The unit of resistance is the *ohm.*

Ohm's Law. From this interrelation has been deduced what is known as Ohm's law, usually expressed as $I=\frac{E}{R}$, or current equals voltage divided by resistance, E denoting the electromotive force, which is only another term for voltage or potential—the electrical moving force back of the current I.

As a practical application of the preceding formula, take the case of a small conductor connecting the battery and starting motor of the electrical starting system on an automobile. The diameter of the wire is such that the length required to connect the two points has a resistance of 10 ohms. One ampere is that amount of current which will pass through a conductor having a resistance of one ohm under a pressure of one volt. The starting system in question operates at 6 volts. Hence, $I = \frac{6}{10} = .6$, that is, the battery would be able to force only .6 ampere through that small wire, and the starting motor would not operate.

It is apparent from the foregoing that the formula for Ohm's law may be transposed to find any one of the three factors that may be unknown. For example, given the conditions just mentioned, we may determine how much resistance the wire in question has. The resistance equals the voltage divided by the current: that is, $R = \frac{E}{I}$, or resistance equals $\frac{6}{.6} = 10$ ohms. Or again, if it is desired to learn what voltage is necessary to send a current of .6 ampere through a resistance of 10 ohms, the solution calls for an equally simple transposition of the formula. Given any two factors, then the third may be readily determined.

Ohm's law is absolutely fundamental in all things pertaining to electrical operation, and the man who wants to make his knowledge of the greatest practical use will do well to familiarize himself with it. Naturally it does not enter into repair work to more than a small fraction of the extent that it enters into the design of motors, generators, and other electrical devices, but a knowledge of it is of distinct value.

Power Unit. To go back to the simile of air under pressure, it is apparent that the energy released by the lowering of this pressure may be made to perform useful work, such as driving a compressed-air drill, running a small air motor, or the like. So with the electric circuit, the drop from a higher to a lower potential, which causes a current to flow, is a source of power. Electrical power is the product of the amperage or current multiplied by the voltage at which it is applied. The power unit is the *watt* and it is equivalent to one ampere of current flowing under a pressure, or potential, of one volt. There are 746 watts in a horsepower.

Electrical computations, however, are based on the metric system to a large extent, so that instead of being figured in horsepower, electrical energy is figured by the kilowatt, or a unit containing one thousand watts, and the charge therefor is based upon the length of time for which this amount of energy is employed. From this comes the now familiar expression "kilowatt-hour".

The power equivalent is expressed as $P=I\times E$, current multiplied by electromotive force (potential), and, as in the case of Ohm's law, with any two of the factors given, the third may be readily determined. For example: How much power is developed by a 6-volt starting motor if 125 amperes of current are necessary to turn the automobile engine over fast enough to start it? The amount of current given is an arbitrary average taken simply for the purpose of illustration, for in overcoming the inertia of an automobile engine a great deal of current is required at first, the drain on the battery often exceeding 250 amperes for a few seconds, then dropping as the engine turns over to about 50 or 60 amperes. Taking 125 as the average, we have $125\times 6=750$ watts $=.75$ kilowatt, or slightly over one horsepower.

Granting that one horsepower is necessary to turn over a $3\frac{1}{2}$ by 4-inch six-cylinder motor at 75 r.p.m.—a speed that has been predetermined as necessary to cause it to take up its own cycle under the most adverse starting conditions—and given a 6-cell storage battery capable of developing a potential of 12 volts, then we have: $I=\frac{P}{E}$, or current $=\frac{746}{12}=62.1+$ amperes, which represent the average demand upon the storage battery to start that engine under normal conditions. This illustration and the previous one show the working of Ohm's law; doubling the voltage halves the amount of current necessary. As the life of a storage battery is largely determined by the rapidity as well as by the number of its discharges, and as the storage battery is the weakest element in any electric lighting-and-starting system, it may well be asked why the 12-volt standard is not universally adopted, or why, as is done in some cases, a 24-volt battery is not employed and the current consumption again reduced by half. Just why this is not done is explained in detail in the section on the voltages employed in electric starters generally.

Conductors. To lead steam or air under pressure from a boiler or compressed-air reservoir to the point at which it is to be utilized as energy, it is desirable to use a conductor that will not waste too much of this energy in useless friction. That is, the conductor must be of ample size in proportion to the volume to be conveyed, smooth in bore, and free from sharp turns or bends. The transmission of electrical energy involves some of the same factors. While neither the smoothness of the bore nor the presence of bends and turns has any effect, they have their counterpart in the conductivity of the material of which the wire is made, the size of the wire in proportion to the amount of current to be carried being also a matter of prime importance.

Resistance of Materials. Materials differ greatly in their ability to conduct an electric current, or, to put it the other way around, they differ in the amount of resistance that they offer to the passage of the current. Silver in its pure state heads the list in the table of relative conductivities, and it is accordingly said to possess a relative resistance of one, or unity; the resistance of every other material may be expressed by a number which represents the resistance of that particular substance as compared with pure silver. Naturally silver does not represent a great possibility for commercial use, and so copper, which is second on the list, is almost universally employed. Pure copper is very soft and is lacking in tensile strength; it is therefore alloyed, and it is also hardened in the drawing process; both of these processes increase its resistance slightly over the factor usually accorded it in the standard table of specific conductivities of materials. In this table, German silver (which is an alloy containing no silver whatever and having but a few of its properties), cast iron, steel, carbon, and similar substances will be found well down toward the end. They are known as "high-resistance" conductors and are usually used where a certain amount of resistance to the current is desirable.

It must be borne in mind that ability to conduct a given amount of current without undue loss through resistance depends upon the size and the length of the conductor quite as much as upon the material. In other words, if a steel rail is only one-thirtieth as good a cönductor as a copper cable, it will require a cross-section of steel thirty times as great as that of a copper cable in order to conduct the current with the same ease—that is, to make a conductor of equal resistance. An illustration of this may be seen in the overhead copper wire of the usual trolley system. This wire of about one-half inch diameter forms one of the conductors, while the two steel rails form the "return". A similar example may be found in what is known as the single-wire system of installation for an electric starter in automobiles. A single copper cable conducts the current from the battery to the starting motor, while the steel frame of the automobile is the return side of the circuit, or vice versa.

Voltage Drop. It is evident that the resistance of a circuit varies inversely as the size of the conductor—the larger the cross-section of a conductor, the less its resistance—and increases directly as its length, besides depending upon the specific resistance of the material. The specific resistance of the metals constituting electrical circuits on the automobile are (silver being 1.0); copper 1.13, varying more or less with its hardness; aluminum 2.0; soft iron 7.40; and hard steel 21.0. Thus, 9.35 feet of No. 30 copper wire are required for a resistance of one ohm, while only 5.9 inches of hard steel wire of the same gage are required to present the same amount of resistance to the current. If the length of the conductor is doubled, its resistance is doubled, which accounts for the placing of the storage battery as close as possible to the starting motor. Furthermore, the heavy starting currents which are required by the motor demand the use of heavy copper cable for this circuit. If two wires are of the same length but one has a cross-section three times that of the other, the resistance of the former is but one-third that of the latter. If a circuit is made up of several different materials of different sizes joined in series with one another, the total resistance will be the sum of the resistance of the various parts.

In addition to being affected by the cross-section and the length, the resistance is also influenced by the temperature. All metals increase in resistance with an increase in temperature, that of copper increasing approximately .22 per cent per degree Fahrenheit. The change of resistance of one ohm per degree change in temperature for a substance is termed its *temperature coefficient.* Metals have a positive temperature coefficient; some materials, like carbon, have a negative temperature coefficient, that is, they decrease in resistance with an increase in temperature.

It is consequently necessary to employ wires of proper size to carry the amount of current required by the apparatus in circuit —such as lamps—without undue heating, which would cut down the amount of current flowing. For the same reason it is also desirable to make the circuits as short as practicable, since in addition to cutting down the current, the resistance also cuts down the effective voltage. That is, there is a fall of potential, or drop in voltage, between the source of current supply and the apparatus utilizing it, due to the resistance of the conductors between them. This voltage drop is further increased by joints in the wiring and by switches. It is apparent that the lower the voltage of the source of supply, the more important it becomes to minimize the loss, or voltage drop, in the various circuits. For this reason lighting or other circuits on the automobile should never be lengthened where avoidable. When necessary to extend a circuit for any reason, wire of the same diameter and character of insulation as that forming the original circuit must be employed, and the joints should be as few as possible, all mechanically tight, and well soldered. The voltages employed in the electrical systems of automobiles are so low—varying from 6 to 24 volts, with a strong tendency to standardize the 6-volt system—that any increased resistance is likely to cause unsatisfactory operation.

Nonconductors. In going down through a table of specific conductivities of various materials, the vanishing point is reached with those that cease to be conductors at all. Such materials are known as nonconductors or insulators, and some substances vary in the degree of insulation they afford quite as much as other materials do in their ability to conduct a current. Glass, rubber, shellac, oil, paraffin wax, wood, and fabrics are all good insulators when perfectly dry. Distilled water has such a high resistance as to be almost an insulator, but in its natural state water contains alkaline salts or other impurities that make it a conductor. Consequently, when any otherwise good insulating substance is wet, the current is likely to leak across the wet surface of the insulator. This is particularly the case with a current of high potential, or high tension, and explains why it is of the greatest importance to keep all parts of the secondary side of the ignition system perfectly dry. The potential which causes the current to arc across the gap of the spark plug is so high that it will leak across even slightly damp surfaces, such as the porcelains of the plugs. This leakage is often visible, especially in the dark, and it may also be detected by placing the bare hand on the porcelain.

Just as the amount of current to be carried determines the size of the conductor to be employed, so the potential or pressure under which this current is transmitted determines the amount of insulation that will be necessary. The latter is also affected, however, by mechanical reasons, for example, by the liability of the conductor to chafing or abrasion. The best grades of copper cable employed for both ignition and starting-lighting systems on automobiles today are stranded, that is, composed of a number of fine wires, to make them flexible. The stranded cable is then tinned to prevent corrosion due to the sulphur in the insulation, after which it is covered with a soft-rubber compound of a thickness dependent upon the purpose for which the wire is intended. For high-tension ignition wiring this rubber covering will be fully one-half inch thick. This covering is vulcanized and is then further protected by braided linen, or silk-cotton thread which is made waterproof by being impregnated with shellac or some other insulating compound.

Circuits. When air under high pressure escapes from its container, it simply mingles with the atmosphere, and as soon as the difference in pressure is equalized there is no distinction between it and air in general. But to equalize a difference in potential of an electric current there must be a conducting path between the points of high and low potential. This is termed a circuit. Current to operate trolley cars is fed to the motors of the car from the overhead wire and returns through the tracks to the generators at the power house. This is known as a *ground-return* circuit. In the single-wire electric starting system of an automobile, current from the storage battery reaches the starting motor through the starting switch and a single heavy cable, and returns through the frame and other metal parts of the car itself, or *vice versa*. This is another instance of a ground-return circuit.

Both the primary and secondary sides of the ignition system of an automobile are also grounded circuits. In contrast with this, the circuit may be composed of copper cables directly connecting both poles of the battery and switch with the starting motor. The highly insulated cable employed for both ignition and starting systems is expensive and the use of a single wire greatly simplifies the connections, considerations which account for the general use of this type of circuit. A circuit is said to be open when there is a break in it which prevents the current from flowing, as

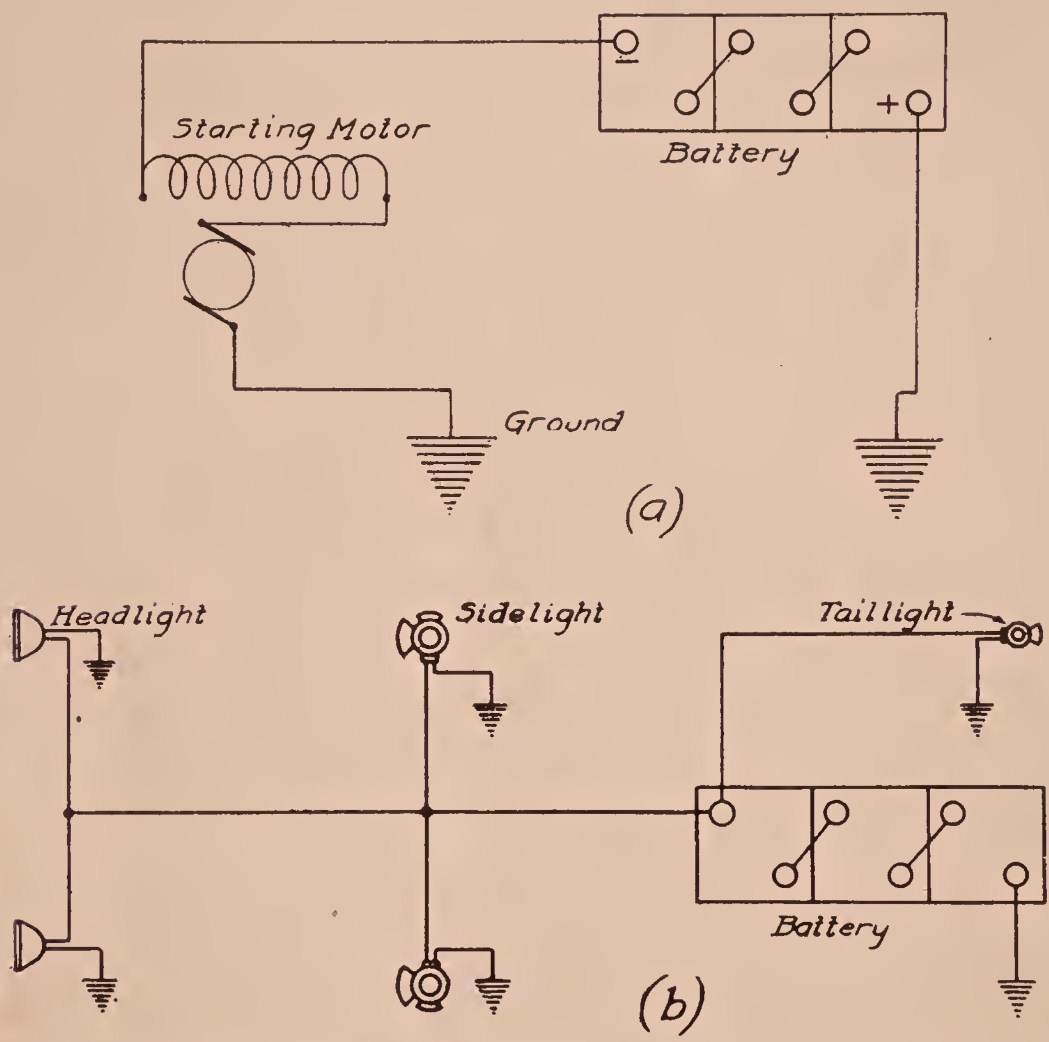


Fig. 1. Typical Starting-Lighting Wiring Diagrams. (a) Series Circuit of Starting Motor; (b) Multiple Circuit of Lamps

when the switch is opened, or when a connection or the wire itself is broken.

Series Circuit. The connections between a storage battery, switch, and starting motor, comprise the simplest form of circuit, in which the motor is said to be in series with the battery, and the cells of the battery are in series with one another. This is termed a series circuit and a break in it at any point opens the entire circuit. The starting motor, Fig. 1 (a), requires the entire output of the storage battery for its operation.

To make clear the distinction between this and other forms of circuit, it must be borne in mind that, in equalizing a potential difference, electric current flows from the positive or plus side of the source of supply, whether a battery or generator, to the negative or minus side (plus and minus being arbitrary signs employed to distinguish the positive and negative sides of a circuit or of an instrument). The current is said to flow out on the positive side of the circuit and to return on the negative side. In the case of a series circuit as described, the current flows through each piece of apparatus in turn; each receives all the current in the circuit at a potential proportioned to the resistance of the apparatus in question. For example, in the simple starter circuit referred to above the starting motor receives the entire output of the 3-cell storage battery at its full voltage of 6 volts, less the drop in voltage due to the resistance of the circuit. If there were two starting motors instead of one in the circuit, both in series, both would receive all the current but at only half the voltage.

Multiple or Shunt Circuit. As opposed to this, in a multiple circuit, Fig. 1 (b), in which every piece of apparatus is connected to both sides of the circuit "in parallel", each piece of apparatus in the circuit receives current at the same voltage but draws from the circuit the current determined by its resistance. The failure or withdrawal of any one or more instruments in a multiple or parallel circuit has no effect on those remaining. The lighting circuits of an automobile equipped with a 6-volt starting system are an example of this. Each lamp is designed to burn to its maximum illumination at 6 volts, but the 25-candle-power headlights take more current than the 5-candle-power side lights or the 2-candle-power taillight, owing to the difference in the size and resistance of their filaments. Removing any one of the bulbs has no effect on any of the others, because all are in parallel.

Series-Multiple Circuit. A combination of the two forms of circuits is sometimes necessary to accommodate different devices designed for varying voltages. For example, it is usually found expedient to burn 6-volt lamps on the 12-volt starting systems. In such a case, the starting motor is in series with the battery and receives the full voltage as well as the full current. The lamps are divided into two groups, each group comprising a parallel or multiple circuit of its own, and these two groups are connected in series so that the lamps in each circuit receive 6 volts, but the circuit as a whole takes the battery current at 12 volts. Such a combination

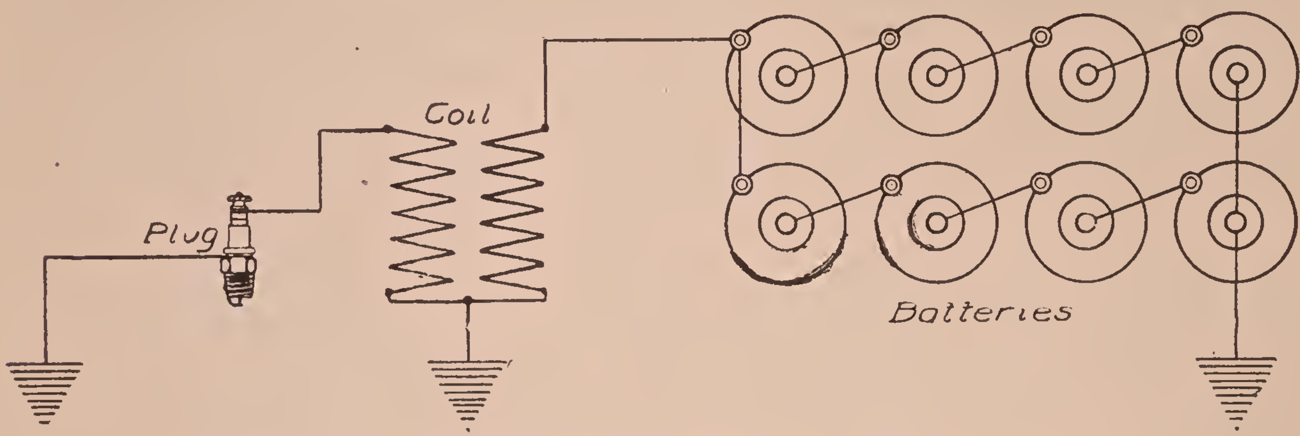


Fig. 2. Dry Cells in Series-Multiple for Ignition Circuit

is known as a series-parallel or series-multiple circuit and is more or less commonly used for connecting dry cells for ignition use, Fig. 2.

Circuits may also be interdependent, that is, practically a circuit on a circuit. The method of connecting up the voltmeter that is mounted on the dash of the car is an instance of this, a wire being led from each side of the main circuit to the instrument. The instrument is then said to be *in shunt*, Fig. 3, and the amount of current that is diverted to it is entirely dependent on the resistance. As a voltmeter is wound to a high resistance, Fig. 4, it is designed to take very little current for its operation. The

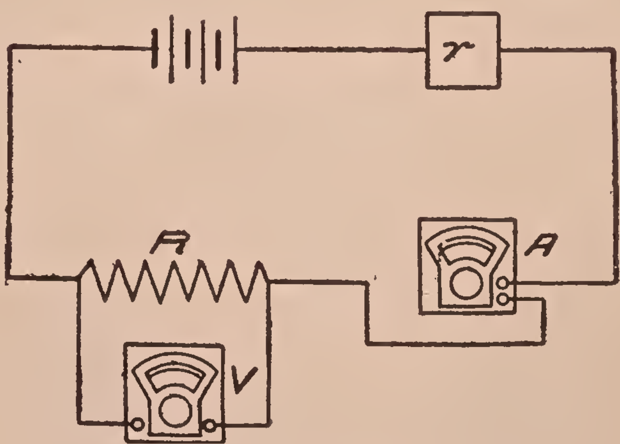


Fig. 3. Diagram Showing How Voltmeter Is Shunted in the Circuit

ammeter, Fig. 5, on the other hand, is intended to indicate the entire current output of the generator on charge or discharge, and is accordingly connected in series so that all the current passes through it. (Owing to the heavy rush of current taken by a starting motor in overcoming the inertia of the gasoline engine, the ammeter is not included in this circuit.)

Short Circuits and Grounds. The previous paragraphs have made clear the necessity for having a complete path or circuit for the current in order that its power may be utilized. There must be a connecting cable on one side and there must be a return on the other (grounded circuit). If instead of passing through the apparatus, such as the starting motor, the current finds an easier path through an abrasion in the insulation of the cable and some metal part against which that touches, it is said to be *short-circuited*. A case such as that cited, where a stripped cable touches a metal part, so that the current completes the circuit without passing through the motor, is usually termed a *ground*. This should not be confused with the ground return previously mentioned as a characteristic of the wiring of many of the starting and lighting systems in use on automobiles today. It is indeed a ground return but not an intentional one. It is also true that a ground of this type is a short circuit, but it does not necessarily follow from this that

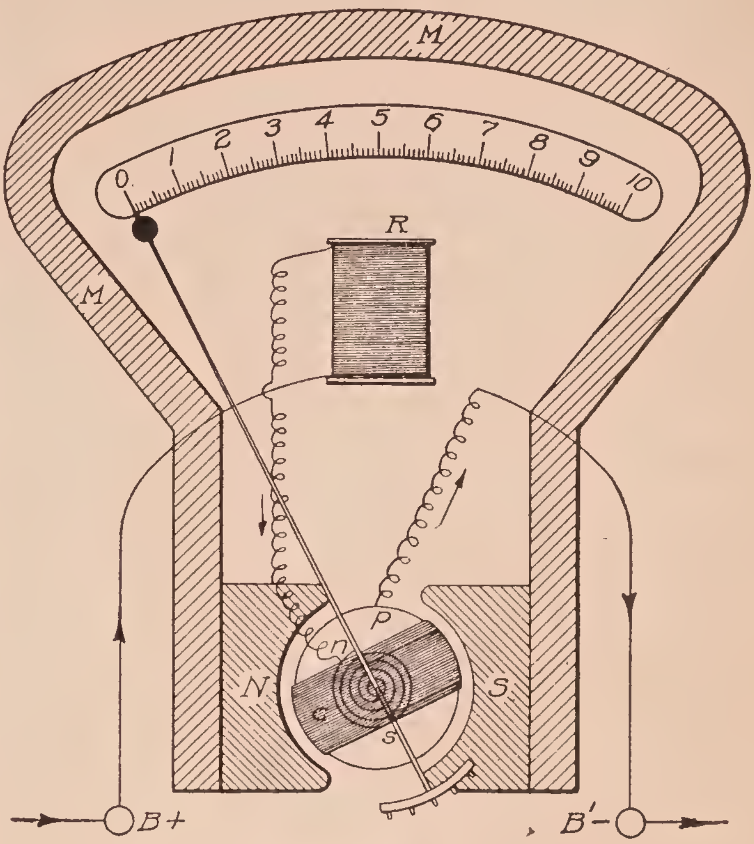


Fig. 4. Diagram of Voltmeter Principle

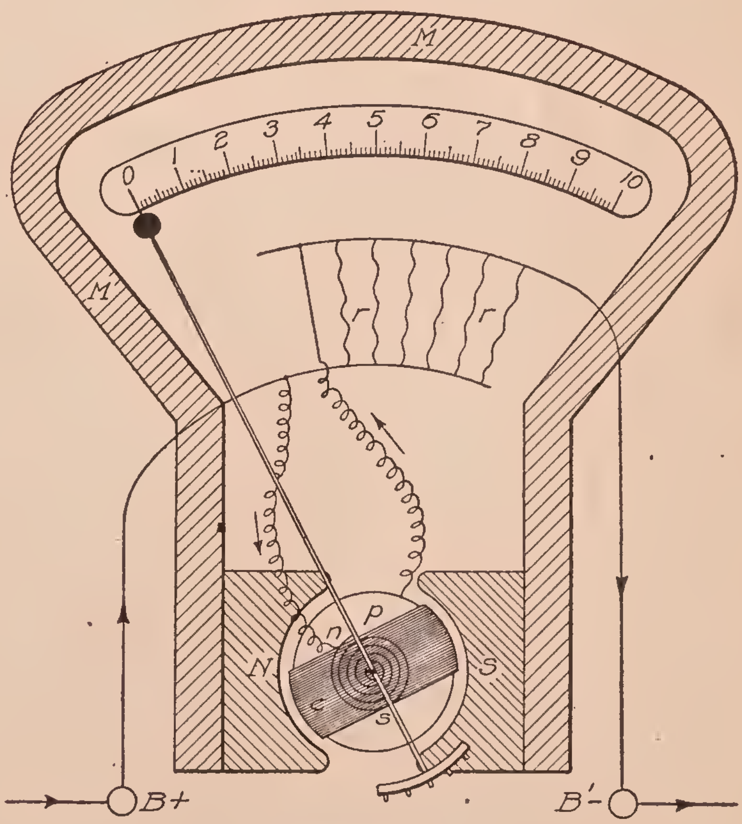


Fig. 5. Diagram of Ammeter Principle

all short circuits are grounds, as short circuits may occur from many other causes—for instance, where two wires touch at uninsulated points or where stray metal makes contact with connections, etc.

Size of Conductors. The influence of the factor of resistance makes plain the reason for using wires of different sizes for the various circuits of the ignition starting and lighting systems of the automobile. If an ample flow of compressed air is desired for power purposes, a liberal outlet must be provided, while if only a small spray is required, as for cleaning purposes, a small-bore tube will suffice. If we try to employ the small-tube line for power purposes, we shall not gain the desired result because its resistance is so great that it will not permit a sufficient flow of air. For the same reason a conductor of much larger diameter and, therefore, of correspondingly low resistance must be employed to handle the heavy current necessary to operate the electric starting motor, than is needed for the comparatively small current which is demanded by the ignition system.

Whether it is mechanical or electrical in its nature, the power necessary to overcome resistance is liberated in the form of heat. Mechanical resistance is friction and its presence between moving bodies always generates heat. Electrical resistance may, for the purpose of illustration, be termed internal or molecular friction, and it also results in heat. The extent of the rise in temperature of a conductor or wire, depends entirely upon the proportion that its size and, consequently, its current-carrying ability bear to the amount of current that is sent through it. Roughly speaking, if a wire is three-fourths the size it should be to carry the starting current, it will become uncomfortably warm to the hand after the motor has been operated several times in succession. If it is only one-half the size it should be, continuous operation of the starting motor for a few minutes will doubtless burn off most of the insulation. Further reducing its size would cause the wire to become so hot as to set fire to the insulation the moment the current was turned on, and any great decrease in diameter would result in the immediate fusing of the wire itself. The wire would literally "burn up" and in a flash.

It would not be practical to attempt to conduct live steam

TABLE I

American Wire Gage (B. & S.)

No.	Diameter in		Circular Mils	Ohms per 1000 Ft.	No.	Diameter in		Circular Mils	Ohms per 1000 Ft.
	Mils	Mm.				Mils	Mm.		
0000	460.00	11.684	211600.0	.051	19	35.89	.912	1288.0	8.617
000	409.64	10.405	167805.0	.064	20	31.96	.812	1021.5	10.566
00	364.80	9.266	133079.4	.081	21	28.46	.723	810.1	13.323
0	324.95	8.254	105592.5	.102	22	25.35	.644	642.7	16.799
1	289.30	7.348	83694.2	.129	23	22.57	.573	509.5	21.185
2	257.63	6.544	66373.0	.163	24	20.10	.511	404.0	26.713
3	229.42	5.827	52634.0	.205	25	17.90	.455	320.4	33.684
4	204.31	5.189	41742.0	.259	26	15.94	.405	254.0	42.477
5	181.94	4.621	33102.0	.326	27	14.19	.361	201.5	53.563
6	162.02	4.115	26250.5	.411	28	12.64	.321	159.8	67.542
7	144.28	3.665	20816.0	.519	29	11.26	.286	126.7	85.170
8	128.49	3.264	16509.0	.654	30	10.03	.255	100.5	107.391
9	114.43	2.907	13094.0	.824	31	8.93	.277	79.7	135.402
10	101.89	2.588	10381.0	1.040	32	7.95	.202	63.2	170.765
11	90.74	2.305	8234.0	1.311	33	7.08	.108	50.1	215.312
12	80.81	2.053	6529.9	1.653	34	6.30	.160	39.7	271.583
13	71.96	1.828	5178.4	2.084	35	5.61	.143	31.5	342.433
14	64.08	1.628	4106.8	2.628	36	5.00	.127	25.0	431.712
15	57.07	1.450	3256.7	3.314	37	4.45	.113	19.8	544.287
16	50.82	1.291	2582.9	4.179	38	3.96	.101	15.7	686.511
17	45.26	1.150	2048.2	5.269	39	3.53	.090	12.5	865.046
18	40.30	1.024	1624.1	6.645	40	3.14	.080	9.9	1091.865

at high pressure through a cardboard tube. Nor is it any more so to attempt to send a heavy current through "any old piece of wire". Electric lighting and starting systems as they exist on cars today are of all degrees of merit. The cars themselves have reached a stage of reliability where their useful life is now on the average from five to ten years or more. Consequently, there are a great many cars in service equipped with electric systems that were brought out several years ago. These are the cars on which the repair man will get a great deal of his early experience, and he need not take it for granted that just because the electric systems have worked for a certain length of time they were properly designed at the outset. Overheated conductors not only indicate excessive resistance caused by small wires or poor joints, but they also indicate a waste of power that is being drawn from the battery and dissipated in the air. The utilization of this energy or rather the prevention of its transformation into heat would mean all the difference between poor and good operation between an efficient and a wasteful system.

TABLE II

Carrying Capacity of Wires

B. & S. Gage	Circular Mils	Rubber Insulation	Other Insulation
		Amperes	Amperes
18	1,624	3	5
16	2,583	6	8
14	4,107	12	16
12	6,530	17	23
10	10,380	24	32
8	16,510	33	46
6	26,250	46	65
5	33,100	54	77
4	41,740	65	92
3	52,630	76	110
2	66,370	90	131
1	83,690	107	156
0	105,500	127	185
00	133,100	150	220
000	167,800	177	262
0000	211,600	210	312

MAGNETISM

Natural and Artificial Magnets. It has been known for many centuries that some specimens of the ore known as magnetite (Fe_3O_4) have the property of attracting small bits of iron and steel, Fig. 6. This ore probably received its name from the fact that it is abundant in the province of Magnesia in Thessaly, although the Latin writer Pliny says that the word magnet is derived from the name of the Greek shepherd Magnes, who, on the top of Mount Ida, observed the attraction of a large stone for his iron crook. Pieces of ore which exhibit this attractive property for iron or steel are known as natural magnets.

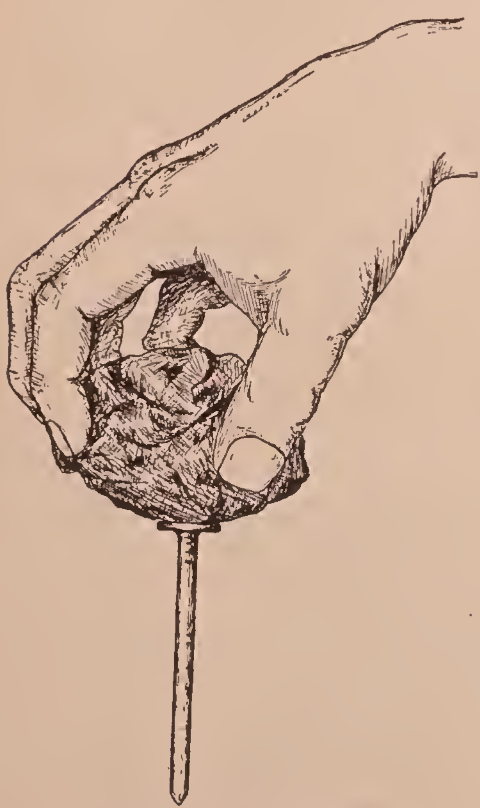


Fig. 6. Natural Magnet or Lodestone

It was also known to the ancients that artificial magnets could be made by stroking pieces of steel with natural magnets, but it was not until the twelfth century that the discovery was made that a suspended magnet would assume a north-and-south position. Because of this property, natural magnets came to be known as lodestones (leading stones); and magnets, either artificial or natural, began to be used for determining directions. The first mention of the use of a compass in Europe was in 1190. It is thought to have been introduced from China.

Fig. 7. Bar Magnet

Artificial magnets are now made either by repeatedly stroking a bar of steel, first from the middle to one extremity with one of the ends, or poles, of a magnet, and then from the middle to the other extremity with the other pole; or else by passing electric currents about the bar in a manner to be described later. The form shown in Fig. 7 is called a bar magnet, that shown in Fig. 8 is a horseshoe magnet.

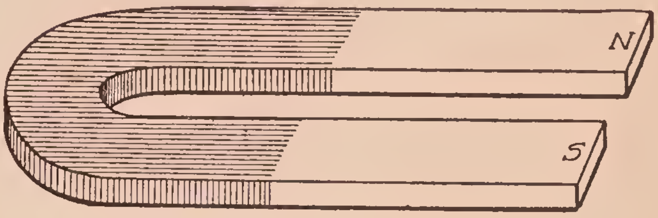


Fig. 8. Horseshoe Magnet

Poles of a Magnet. If a magnet is dipped into iron filings, the filings are observed to cling in tufts near the ends, but scarcely at all near the middle, Fig. 9. These places near the ends of the magnet, in which its strength seems to be concentrated, are called the poles of the magnet. It has been decided to call the end of a freely suspended magnet which points to the north, the north-seeking, or north pole, and it is commonly designated by the letter N. The other end is called the south-seeking, or south pole, and is designated by the letter S. The direction in which the compass needle points is called the *magnetic meridian.*

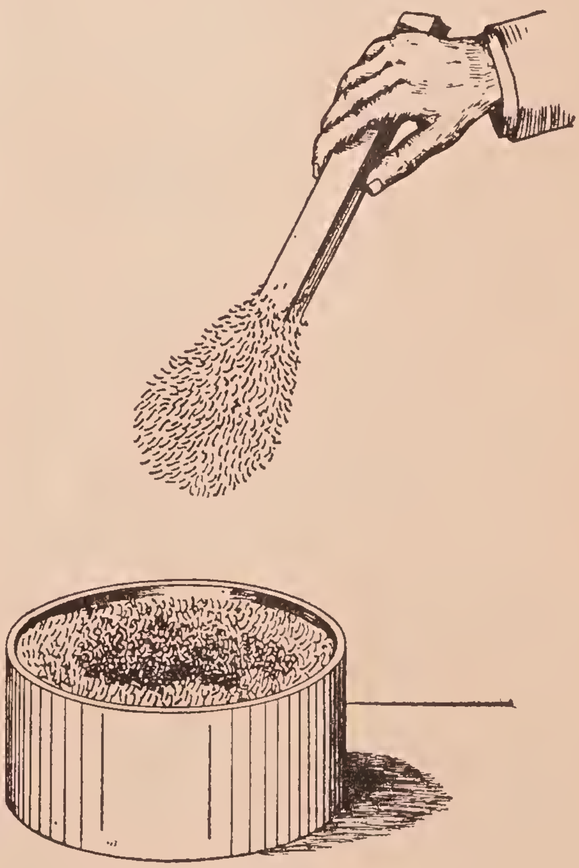


Fig. 9. Location of Poles of a Magnet

Laws of Magnetic Attraction and Repulsion. In the experiment with the iron filings no particular difference was observed between the action of the two poles. That there is a difference, however, may be shown by experimenting with two magnets, either of which may be suspended, Fig. 10. If two N poles are brought near each other, each is found to repel the other. The S poles likewise are found to act in the same way. But the N pole of one magnet is found to be attracted by the S pole of the other. The results of these experiments may be summarized in the general law: *Magnet poles of like kind repel each other, while poles of unlike kind attract.*

This force of attraction or repulsion between poles is found, like gravitation, to vary inversely as the square of the distance between the poles; that is, separating two poles to twice their original distance reduces the force acting between them to one-fourth its original value, and separating them three times their original distance reduces the force to one-ninth its original value, etc.

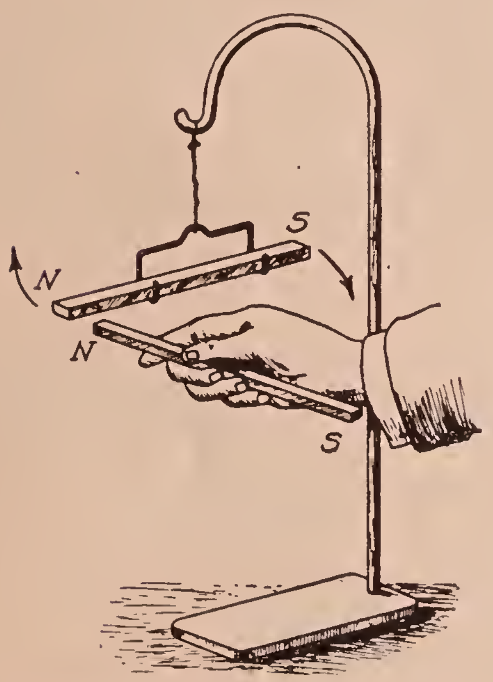


Fig. 10. Experiment Proving the Law of Magnetic Attraction and Repulsion

Magnetic Substances. Iron and steel are the only common substances which exhibit magnetic properties to a marked degree. Nickel and cobalt, however, are also attracted appreciably by strong magnets. Bismuth, antimony, and a number of other substances are actually repelled instead of attracted, but the repulsion is very small. Until quite recently, iron and steel were the only substances whose magnetic properties were sufficiently strong to make them of any value as magnets. Recently, however, it has been discovered that it is possible to make rather strongly magnetic alloys out of non-magnetic materials. For example, a mixture of 65 per cent copper, 27 per cent manganese, and 8 per cent aluminum is rather strongly magnetic. These are known as the *Heussler alloys.*

Electromagnets. The identity of magnetism with electricity is readily established by some very simple experiments that have been repeated so often as to become classics. By taking a bar of iron and winding some insulated wire around it in the form of a coil and then connecting the terminals of this coil with a battery or other source of current, the bar becomes magnetic. One end of it is the positive, plus, or north pole of the magnet, and the other the negative, minus, or south pole. Break the connections or otherwise "open the circuit" and the magnetism instantly disappears. Reverse the connections to the battery by attaching the wire previously at the positive pole to the negative, and vice versa, complete the circuit again, and the bar is once more magnetic, but now the pole that was previously north or positive is south. The bar is once more a magnet, but its polarity has been reversed by reversing the direction of flow of the magnetizing current. This bar of iron with a coil of wire wound around it is known as an electromagnet because it becomes magnetic only when a current is passing through the coil. If a rod of hard steel is substituted for the bar of soft iron and the current passed through it, the bar will be found to be strongly magnetic after the current has been shut off. That is, the bar of steel has, through the action of the current, become a permanent magnet like that shown in Fig. 7. This method is often used for making permanent magnets from hardened steel.

To determine the polarity of a magnet it is only necessary to hold a small pocket compass near it; let the compass needle come to rest normally and then bring the compass near to one end of the magnet. If the needle continues to point in the same direction and gives evidences of being strongly attracted to the magnet, the end to which it is being held is the south pole. Bring the compass near to the other end of the magnet, and the needle will turn away sharply, showing that like poles repel each other.

Magnetic Field. If a bar magnet is placed on a sheet of glass and a handful of fine iron filings thrown around it, they will automatically assume the position shown by Fig. 11. As originally dropped on the glass some of the filings may not be within reach of the influence of the magnet, but if the glass be gently tapped and tilted slightly, first one way and then another, they will arrange themselves in the symmetrical pattern shown. This gives a graphic illustration of the *field of influence* of the magnet, usually termed the magnetic field. This field is most powerful at the poles, as will be noted by the attraction of the filings at the N and S points, representing the north and south poles of the magnet. At intermediate points along the length of the magnet the filings will be seen to have placed themselves as if to indicate a circular movement of the lines of force. This is the magnetic circuit and these concentric circles represent the magnetic flux, or flow. If the magnet is then removed from the glass and the north pole extension of it placed

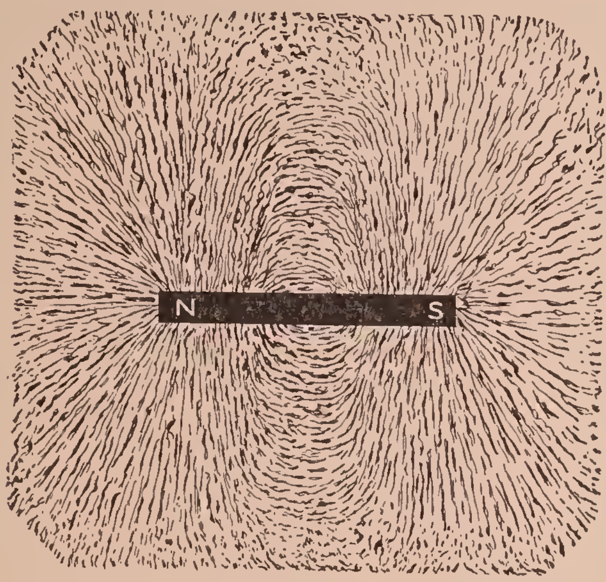


Fig. 11. Field of Force about a Bar Magnet

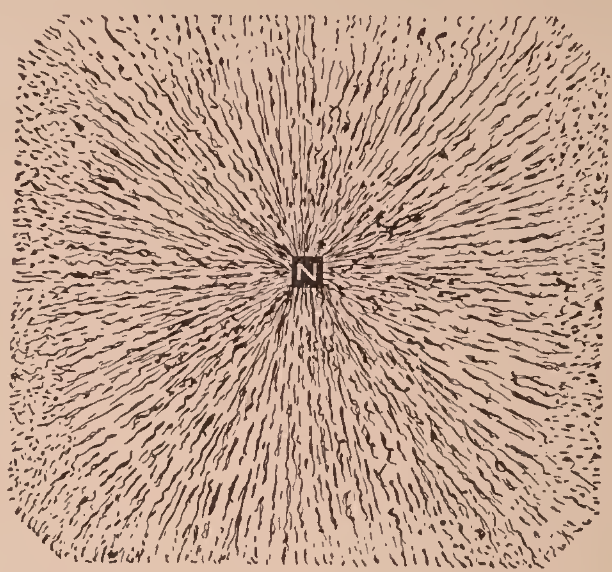


Fig. 12. Field of Force about a Single Pole

centrally under the glass, a striking illustration is given of the magnetic field around the pole, Fig. 12. A bar magnet has been shown here for purposes of simplicity, but a common horseshoe magnet such as can be had for a few cents will serve equally well for the experiments.

By carrying the experiments a little further, the identity of magnetism and electricity is strikingly shown. Take a piece of

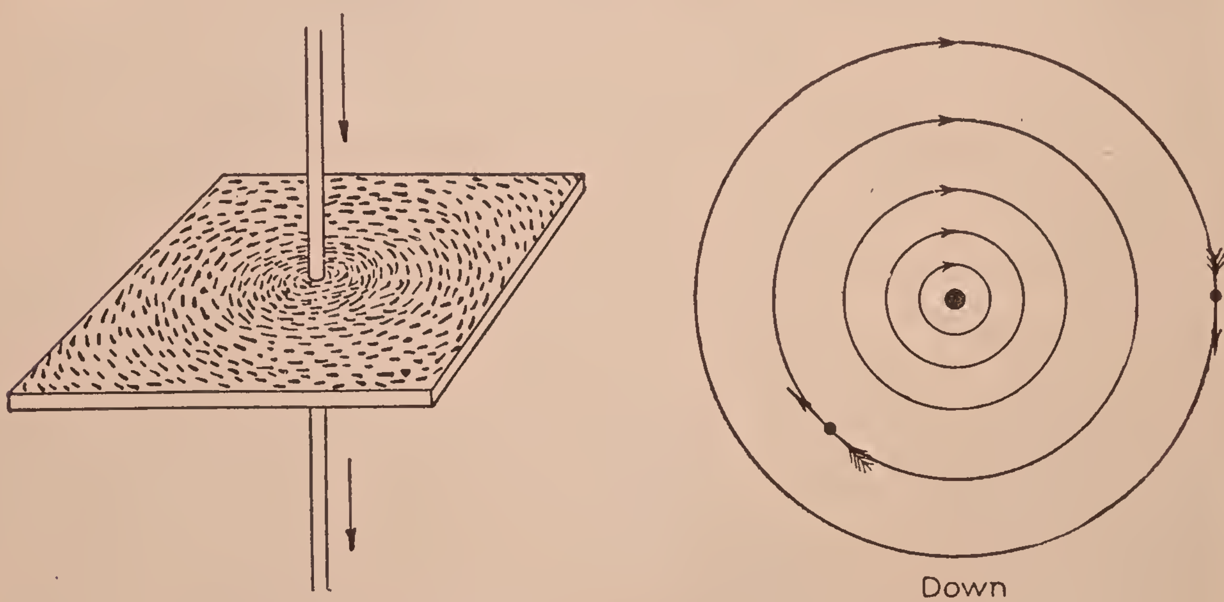


Fig. 13. Field about a Conductor Carrying a Current

cardboard or heavy paper, punch a hole through its center and pass through this hole a wire connected to two or three dry cells. Scatter on the paper the filings used in the previous experiments, then complete the circuit by touching the end of the wire to the other terminal of the battery. The filings will immediately arrange themselves as shown in Fig. 13, illustrating the magnetic field which is always present around any current-carrying conductor.

Lines of Magnetic Force. Punch another hole through the cardboard and rearrange the circuit of the dry cells so that the wire passes from the positive battery terminal up through one hole of the cardboard and down through the other hole to the zinc or negative. Scatter the filings as before and touch the loose end of the wire to the negative terminal. The arrangement of the filings will then be that shown in Fig. 14, the positive field being at the left and the negative at the right. The fact that the magnetic fields overlap in the curious alignment indicated is simply due to the proximity of the conductors carrying the current.

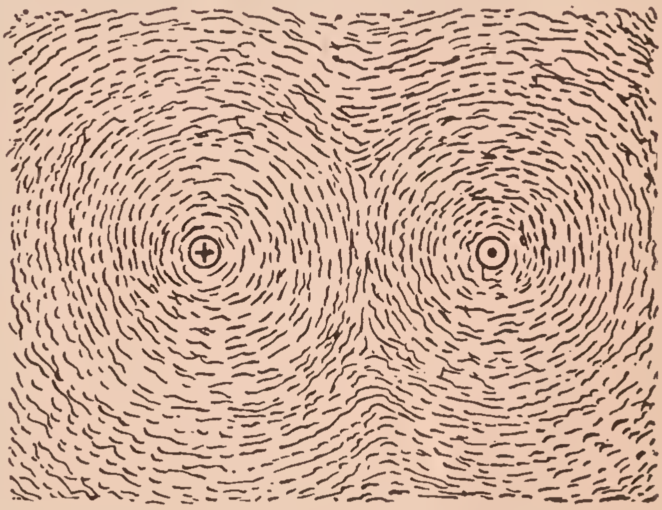


Fig. 14. Field about a Coil

Another simple method of demonstrating the identity of electricity and magnetism is to place an ordinary pocket compass near a wire carrying a current. If this is a direct current and the needle of the compass whirls around when its north pole is presented to the wire, it is evidence that the current in the wire is positive, since like poles repel. Present the other end of the needle and it will remain stationary even though the compass be shaken, since unlike poles attract. This experiment is accordingly a simple polarity test as well.

All of the arrangements which the filings assume under the influence of either a magnet or a current, as shown by the various llustrations, indicate that the stresses in the medium surrounding a magnet or current-carrying conductor follow certain definite lines, the lines showing the direction of stress at any point. These are termed lines of force.

Solenoids. It has been determined that the direction of the current and that of the resulting magnetic force are related to one another as the rotation and travel of an ordinary, or right-hand, screw thread. Consequently, if the conductor be looped instead of straight, the lines of magnetic force will surround it as shown in Fig. 15. The field of such a loop, if outlined with the aid of filings or explored with a compass needle, will be seen to retain the general character of the field surrounding a straight conductor, so that all the lines will leave by one face and return by the other, the entire number passing through the loop. Hence one face of the loop will be equivalent to the north pole of a magnet and the other face to the south pole. In fact, the loop will act exactly as if it were a thin disk magnetized perpendicularly to the plane. By winding a number of these loops to make a hollow coil, there is formed a solenoid, Fig. 16. Exploring its field shows that the lines of force pass directly through the center or opening of the hollow coil, leaving by one end and returning by the opposite end, as indicated.

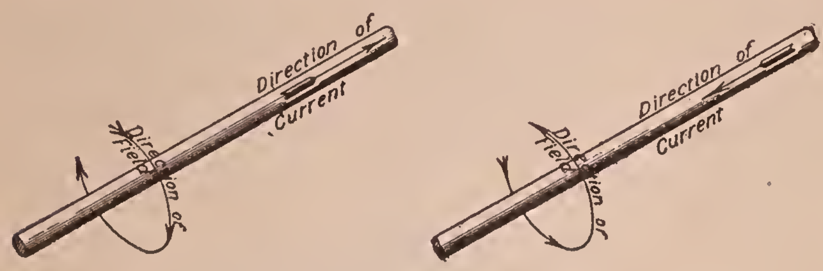


Fig. 15. Direction of Magnetic Lines about a Conductor

If such a solenoid is held vertically and a bar of soft iron placed so that it extends for an inch or so into the lower end of the solenoid, a current passed through the latter will cause the iron to be violently drawn up into the coil and held there. As long as the current flows, this rod is strongly magnetic and has all the properties already described. But the moment the current is shut off, the magnetism practically disappears and the rod immediately drops out of the coil by its own weight. Reversing the direction of the current reverses the polarity of the solenoid; increasing or decreasing the amount of current sent through it increases or decreases correspondingly the strength of its magnetic field. The principle of the solenoid is used in starting systems to operate electromagnetic starting switches.

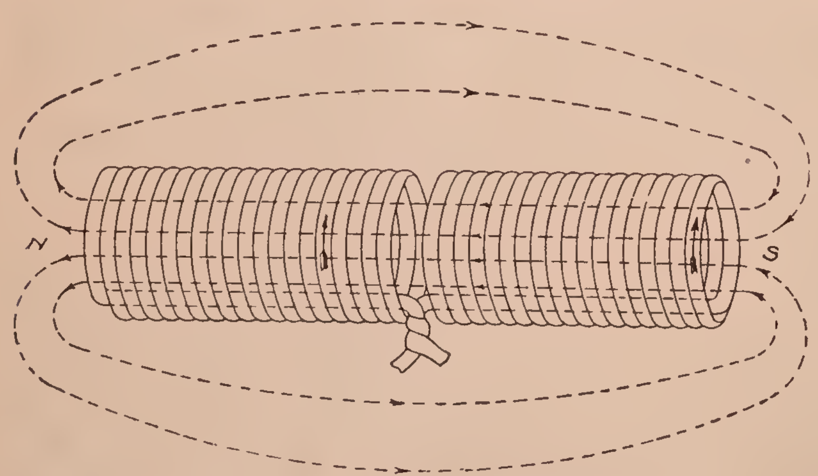


Fig. 16. Magnetic Field about a Solenoid

Effect of Iron Core on Strength of Solenoid. The magnetic flux or flow of lines of force through a solenoid is much greater when an iron core is present than when the coil is empty or a core of wood is inserted. The magnetism flows through the iron as a current would. Soft iron is said to have a high *magnetic permeability.* The magnetic permeability of air (or a vacuum) is taken as unity and other substances rated accordingly: for very soft iron it may be as high as 2500, while for substances such as silk, cotton, wood, glass, brass, copper, and lead, it is unity, the same as for air. Such metals are said to be non-magnetic. All insulators are likewise non-magnetic.

INDUCTION PRINCIPLES IN GENERATORS AND MOTORS

Induction. When a wire carrying a current is placed close to another wire, a delicate measuring instrument such as a galvanometer will indicate the presence of a current in the second wire. When the current in the first wire ceases, that in the second will likewise cease immediately. This phenomenon is known as induction, and a current is said to have been induced in the second wire.

Winding the first wire in the form of a coil and bringing this coil close to the second wire, will give the induced current considerably greater strength. The induced effect is still further increased in three other ways: *first,* by inserting an iron core in the coil; *second,* by winding the second wire in the form of a coil; and, *third,* by bringing these coils as close together as possible by winding one directly over the other.

Transformer Principle. The arrangement just discussed is termed an induction coil or transformer (step-up) and is universally employed in connection with ignition systems. The character of the induced current depends upon the relation that the first coil, termed the *primary,* bears to the second coil, known as the *secondary.* In the usual ignition coil the primary consists of a few turns of comparatively heavy wire, and a heavy current—10 to 20 amperes or more—is sent through it at a low voltage, one seldom exceeding 6 volts. The secondary coil, however, consists of a great number of turns of exceedingly fine wire, and the current induced in this is proportional to the relative number of turns between the two and the value of the current in the primary. The secondary current is accordingly of extremely high potential but of only nominal current value.

In the commercial step-down transformer, the relations described above are reversed, the primary being a coil of many turns of fine wire, while the secondary is a comparatively small coil of few turns. In this case, the current is received at the transformer at high voltage and correspondingly reduced amperage, and it steps the voltage down to the standard generally employed, 110 or 220 volts, and increases the amount of current proportionately.

Self-Induction. It has already been pointed out that electricity may be put under pressure or potential, and that the greater this pressure, the greater the amount of work a certain amperage of current will perform, thus affording a direct analogy with steam, water, or air under pressure. An electric current also possesses other characteristics corresponding to mechanical equivalents. Chief among these is inertia and it is the latter that is responsible for what is known as self-induction.

When a current is passed through a coil of wire, a strong magnetic field is set up in the coil owing to the concentration of a great many turns of wire in a small compass. By inserting a core of soft iron wires into this coil, the magnetic field is greatly strengthened, since the permeability of the iron affords a path of slight resistance for the magnetic circuit. There is, of course, a magnetic field surrounding every conductor in a circuit when the current is passing, but the iron core of the solenoid converts a certain part of this current into magnetism. An appreciable time is necessary after the circuit is closed for such a coil "to build up". This "building up" consists of saturating the core with magnetism.

When the circuit is suddenly opened, the current that has been stored in this core in the form of magnetism is as quickly retransformed and its value is impressed upon the circuit, causing a flash at the break. The flash is also aggravated by a certain amount of inertia which the current possesses. We may illustrate this by a stream of water flowing in a pipe. If the water is suddenly shut off by the closing of a valve, it tends to keep on flowing and momentarily causes a great increase in the pressure against the face of the valve, resulting in the familiar "water hammer". The same thing happens when a circuit is suddenly broken, and the higher the potential the more marked this effect will be. The current tends to keep on flowing, and the extra potential which this self-induction gives it will cause it to arc or bridge the gap at the break, unless a condenser is provided to take care of this. Every circuit possesses self-induction but it is only marked in circuits having considerable inductance, that is, in coils, and especially those with iron cores such as induction coils, circuit breakers, etc.

Capacity of Condensers. Every conductor of electricity has capacity to hold a charge just as a vessel holds water. But the capacity of a conductor is dependent upon its surface area rather than its cross-section or cubic volume and is also influenced by surrounding conditions. Where it is desired to accumulate a considerable charge, as for an ignition spark, a special form of capacity is utilized. This is known as a condenser (a detailed description of which is given later in connection with ignition coils). The ability of a condenser to absorb the rise in potential that occurs through self-induction whenever a circuit containing inductance is opened, is also utilized to prevent sparking at contact points. Comparatively small condensers are necessary for this purpose and they are shunted around the contact points, that is, connected in parallel with the latter. When the circuit is opened the excess energy of the circuit passes into the condenser instead of forming a hot spark at the contacts. The occurrence of any undue amount of sparking at contacts should accordingly be made the subject of an investigation of the condenser connections, or of the condenser itself.

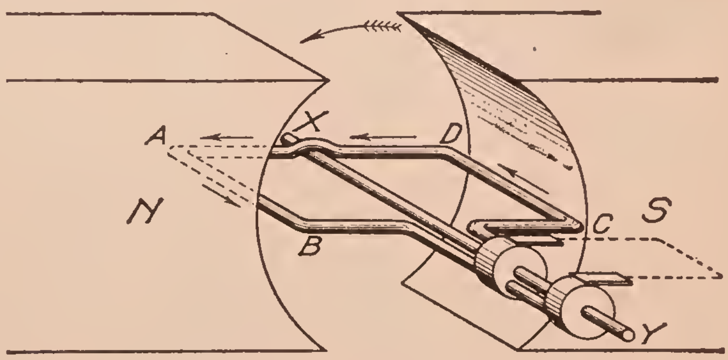


Fig. 17. Elementary Principle of Generator

GENERATOR PRINCIPLES

Elementary Dynamo. Whenever lines of magnetic flux are cut by a conductor, for example, a wire passing through them, an e.m.f. (electromotive force) is produced in the conductor, and the strength of this e.m.f. is entirely dependent upon the speed at which the conductor passes through the magnetic field. If, at the time that this is done, the ends of the wire are brought together to form a circuit, a current will be induced in the conductor. The simplest form of generator would consist of a single loop of wire *ABCD* arranged to rotate in a magnetic field, as shown by Fig. 17. Having its plane parallel to the direction of the magnetic flux, the loop, if it be rotated to the left as shown, will have an e.m.f. induced in it that will tend to cause a current to flow in the direction shown by the arrows.

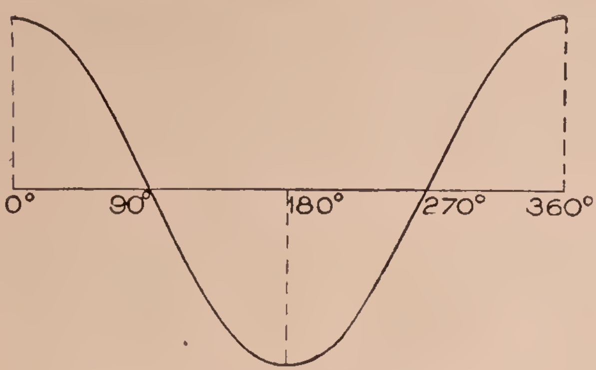


Fig. 18. Dynamo E. M. F. Curve

The value of this e.m.f. depends upon the speed, and as the loop approaches the 90-degree or vertical position, the e.m.f decreases because the rate of cutting is diminishing, until when the loop is vertical both the cutting of the magnetic flux and the generated e.m.f. are at zero. If the rotation is continued, the rate again gradually increases, until at 180 degrees it is once more a maximum. The cutting, however, in the two quadrants following the 90-degree position has been in the opposite direction to that occurring in the first quadrant, so that the direction of the e.m.f. generated is reversed. Plotting this through an entire rotation gives the curve shown in Fig. 18. Such an e.m.f. is termed *alternating* because of its reversal from positive to negative values, first in one direction and then in the other, through the circuit. It cannot be utilized for charging a storage battery, and hence it is not employed in connection with starting and lighting dynamos and motors. To convert an alternating current into a direct or continuous current, a commutator must be added.

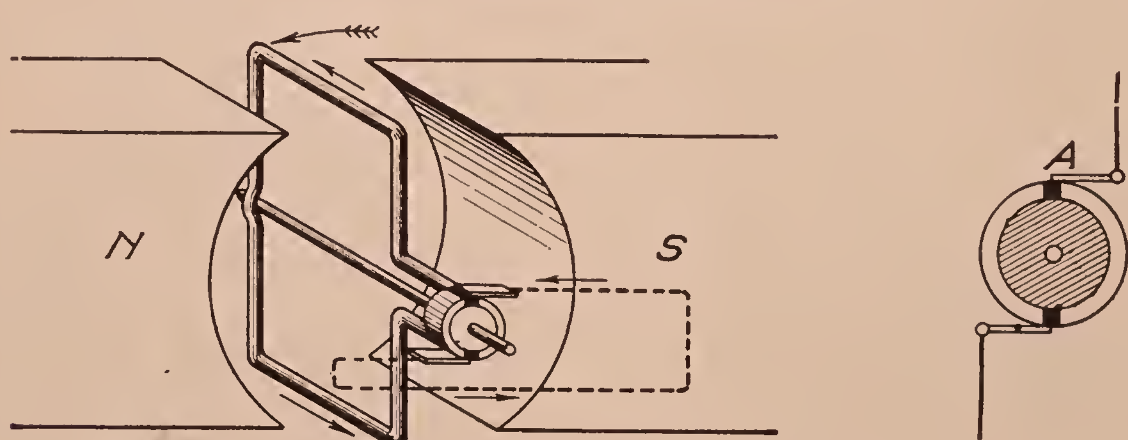


Fig. 19. Simple Form of Generator Showing Arrangement of Brushes in Contact with Commutator

Commutators. Fig. 19 illustrates a commutator in its simplest form. It may be imagined as consisting of a small brass tube which has been sawed in two longitudinally, the halves being mounted on a wooden rod. The wood and the two cuts in the tube insulate the halves from each other. Each one of these halves is connected to one terminal of the loop, as shown in the illustration, Fig. 20. Against this commutator, Fig. 19, two brushes bear at opposite points and lead the current due to the generated e.m.f. to the external circuit. If these brushes are so set that each half of the split tube moves out of contact with one brush and into contact with another at the instant when the loop is passing through the positions where the rate of cutting is minimum (as indicated in the enlarged end view of the commutator shown at *A*), a unidirectional current will be produced, but it will be of the pulsating character as indicated by the curve for one cycle shown in Fig. 21.

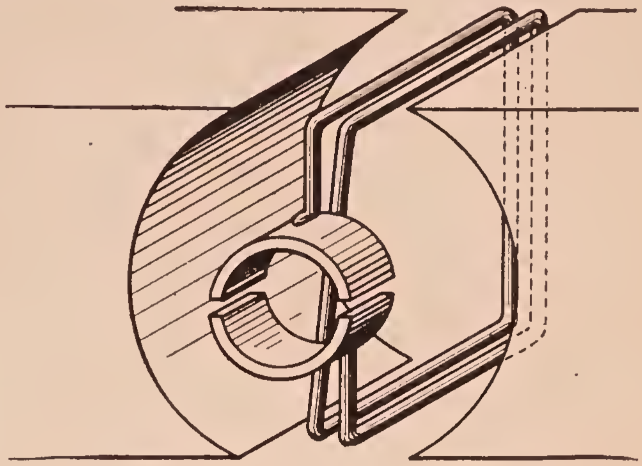


Fig. 20. Commutator with Double Turn

This would also be the case, if instead of the single loop, a coil wound on an iron ring be substituted, as in Fig. 22, the only effect of this being to increase the e.m.f. by increasing the number of times the electrical circuit cuts the magnetic flux. Now assume that two coils are connected to the commutator bars, instead of the single loop, shown in Fig. 22. This arrangement will give the simple device shown in Fig. 23, called an armature. The two coils are

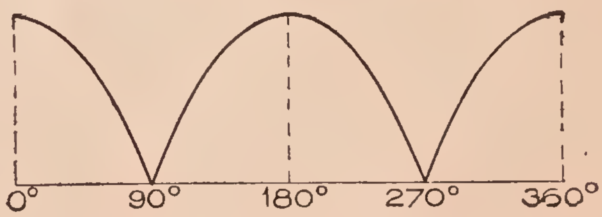


Fig. 21. E. M. F. Curve with Commutator

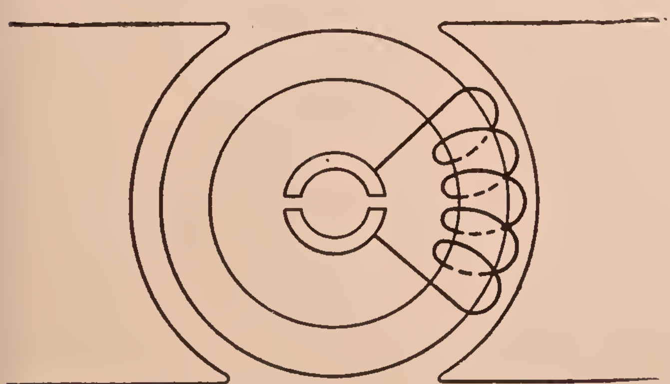


Fig. 22. Armature with Single Coil

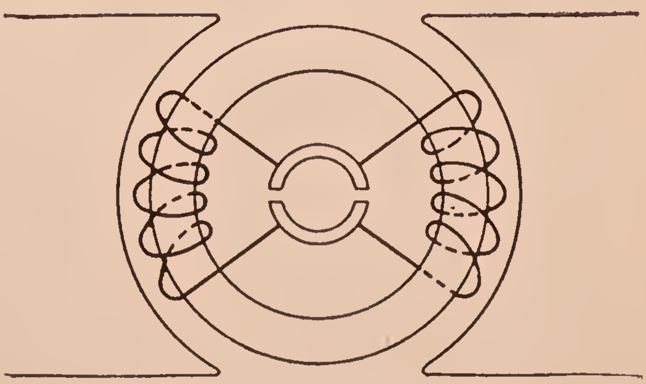


Fig. 23. Two-Coil Armature

in parallel and while the voltage generated by revolving this winding with two coils is no greater than with one coil, the current-carrying capacity of the winding is doubled. The current generated by this form of armature would still have the disadvantage, however, of being pulsating. As in the case of the automobile motor, the number of cylinders must be increased to make the power output a continuous unbroken line, so armature coils and their corresponding commutator brushes must be added that one set may come into action before the other "goes dead". By placing an extra pair of coils on the armature, at right angles to the first, as shown in Fig. 24, one set will be in the position of maximum activity when the other is at the point of least action. While this armature would produce a continuous current, it would not be steady, having four pulsations per revolution, and it is consequently necessary to increase the number of coils and commutator segments still further to generate a steady, continuous current. This is what is done in practice.

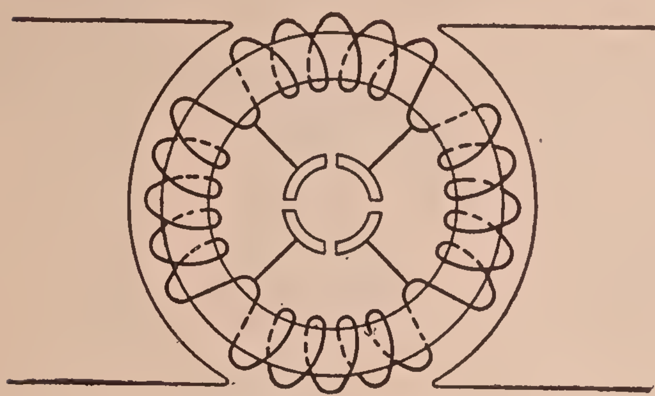


Fig. 24. Four-Coil Armature

A commutator consists of a number of copper bars or segments, equal to the number of sections in the armature. These bars are separated by sheets of insulating material, usually mica, and are

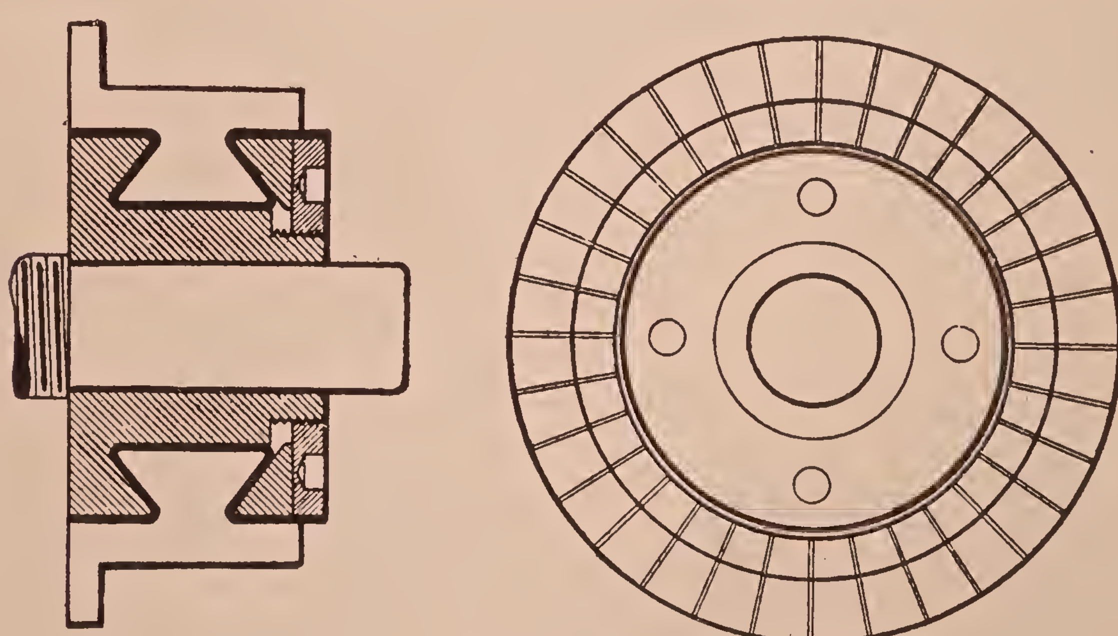


Fig. 25. Sectional and End Views of a Commutator
Courtesy of Horseless Age

firmly held together by a clamping device consisting of a metal sleeve with a head having its inner side undercut at an angle, a washer similar in shape to the head of the sleeve, and a nut that screws over the end of the sleeve, as shown in the left-hand or sectional view of Fig. 25. The sleeve is surrounded by a bushing of insulating material, and washers of the same material are placed between the assembly of commutator bars and the two clamping heads. Each bar is then completely insulated from every other bar and from the clamping sleeve. Commutators are also made by pressing the entire assembly of copper segments together, or molding them, in insulating material (Bakelite), which thus forms the hub or mounting of the commutator as well as the insulating material between the segments. After assembling, the commutator is turned down in a lathe to a true-running cylinder and then sand-papered on its outer cylindrical surface to present a smooth bearing surface for the brushes. At the inner end of the commutator which is closest to the armature windings, the commutator bars are provided with lugs as shown in the sectional view; these lugs are slotted and the armature leads are soldered to them. At the right, Fig. 25, is shown an end view of the same commutator.

From the repair man's point of view, the commutator is the most important part of the generator or the motor, since it is one of the first with whose shortcomings he makes acquaintance. Practically all lighting and starting motors now have their armature shafts mounted on annular ball bearings, so that the commutator and the brushes are the only parts that are subject to wear. If the time devoted in the garage to the maintenance of automobile electric systems were to be divided according to the units demanding attention, the battery would naturally come first, brushes and commutators next, then switches, regulating instruments, connections, and wiring, about in the order named. After all of these come, of course, burnt-out armatures or other internal derangements which necessitate returning the units to the manufacturer; but troubles of this nature are quite rare. While this list gives the order of precedence, it has no bearing on the relative importance of the troubles; with respect to the total time taken by each, the battery is responsible for not far from 90 per cent, the commutator for about 5 per cent, all other causes comprising the remaining 5 per cent.

Armature Windings. In the simple illustrations given to show the method of generating e.m.f. in the armature and leading the current to the external circuit, what is known as the ring type of winding is shown. This is inefficient because half the length of the conductor—the portion inside the ring—does not cut any lines of force and hence does not aid in generating the current. The design, moreover, does not lend itself to compactness, so that it would not be adapted to automobile work even if there were no objection to it on the score of inefficiency. A slotted type of armature core is very generally employed for the small generators and starting motors used on automobiles and the wire is either wound directly in the slots, or is "form wound", that is, the wire is placed on a wooden form shaped to correspond to the position the coil will take when in place on the armature. After winding the necessary length of conductor on this foundation, the wire is taped together, and varnished or impregnated with an insulating compound, and baked.

Owing to its high magnetic permeability, iron is universally employed for the core of the armature, since the function of the core is to carry the magnetic flux across from pole to pole of the field magnets, as well as to form a foundation for the coils. However, when a mass of iron is rotated in the field of a magnet what are known as "eddy currents" are set up in the metal itself, and these prevent the inner parts of the mass from becoming magnetized as rapidly as the outer and also cause the interior to retain its magnetism longer. As the efficiency of the generator depends upon the rapidity with which the sections of the armature become magnetized and demagnetized as they revolve, the lag due to these eddy currents is a detriment. To reduce this effect to the minimum, the armature cores are always laminated, that is, built up of thin disks of very soft iron or mild steel, these disks having the necessary slots punched in them to accommodate the windings when assembled on the shaft. The disks are insulated from one another either by varnishing them or by inserting paper disks between them. They are assembled on the shaft and are put together under considerable pressure, various means being employed to hold them in place. These disks are so thin that hundreds of them are required to make an armature core only a few inches long, and when pressed together in place they are to all intents and purposes a solid mass.

Armature winding, however, is something that is entirely beyond the province of either the car owner or the repair man, no matter how well equipped a shop he has. It is a job for the expert in that particular line, and on the rare occasions when an armature does go wrong, it should always be returned to the manufacturer, if possible, if not, to a shop making a speciality of such work.

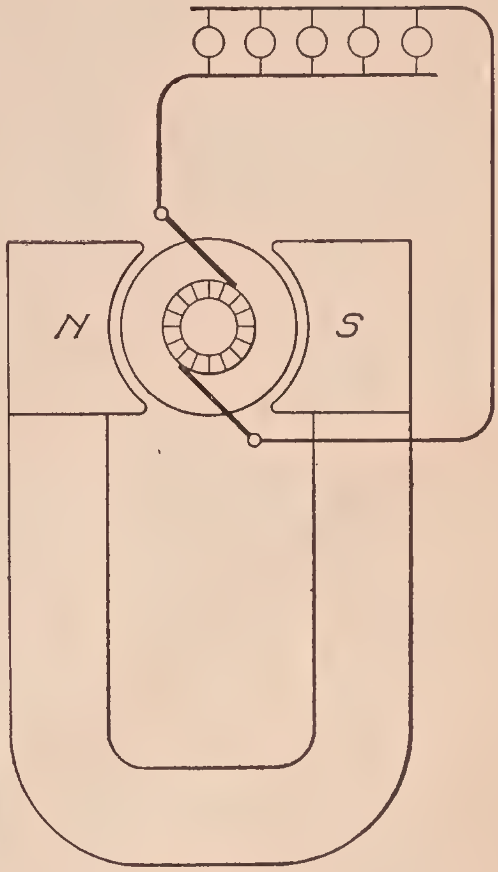


Fig. 26. Diagram of Magneto

Field Magnets. In the foregoing explanation of the generation of an e.m.f. in a conductor when rotated in a magnetic field and the leading out of the current through a commutator, the presence of the field has been assumed and nothing has been said regarding the method of providing it. The term field is applied interchangeably to the magnetic flux between the pole faces of the field magnets and to the magnets themselves, but it is more generally understood to refer to the latter directly and to the former by inference. There are various methods of maintaining the flux, usually described as "field magnet excitation", but only two of them are applicable to the electric generators employed on the automobile.

Permanent Field Used in Magneto. The simplest of these, and the first to be designed, employed permanent magnets, from which such a generator takes its name, *magneto*. Fig. 26 is a diagrammatic representation of an early form of the magneto-generator. Since magnetism cannot be maintained permanently at the high flux-density or strength which can be produced by an exciting coil fed by a current, this method is only employed in very small generators, as its bulk for large powers would be excessive. Its great advantage is its simplicity and constancy. The magneto-generator shown in Fig. 26, however, is designed to produce a continuous current, and is not the type in general use on the automobile today.

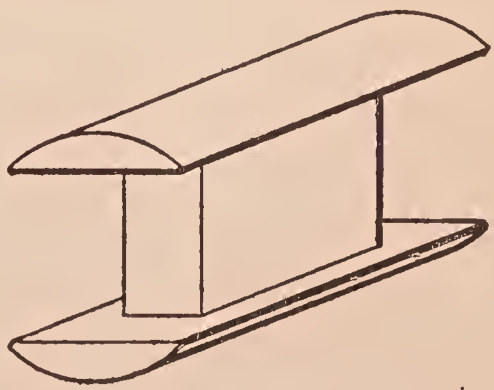


Fig. 27. Sketch Showing Shape of Armature Core
Courtesy of Horseless Age

The type usually installed is made with a two-pole armature, as shown by Fig. 27. This figure illustrates the core known as a "shuttle" type because the wire is wound around the center of the core in much the same manner as thread is put on a shuttle. These cores are laminated as already described, in all well-built magnetos. The space on the core is filled with a single coil of comparatively coarse wire on the majority of magnetos, which generate a low voltage current that is subsequently stepped up through an outside transformer. In some instances, in what may be termed the true high-tension type of magneto, there is a second winding of fine wire on the core so that the magneto generates a current

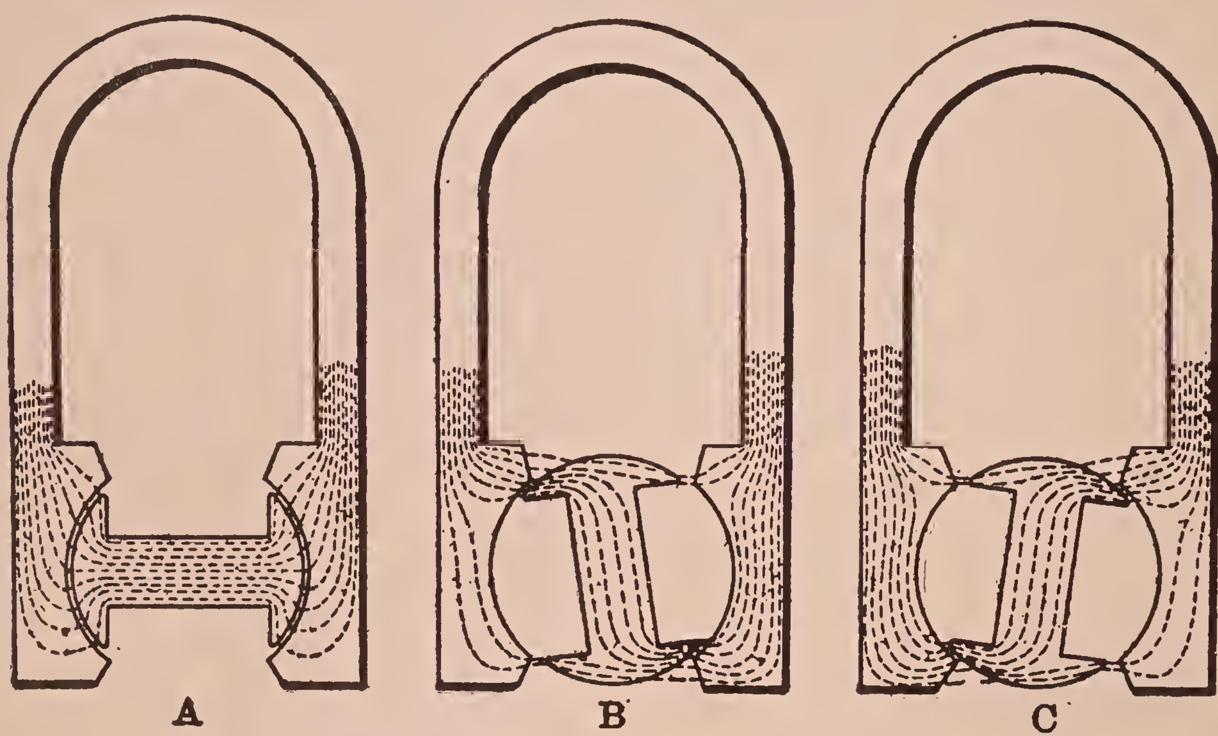


Fig. 28. Diagrams Showing Distribution of Magnetic Flux for Various Positions
Courtesy of Horseless Age

and steps it up without the aid of any outside devices. In either case, one end of the winding is "grounded on the core", that is, connected to it electrically, so that the core and other metal parts of the machine form one side of the circuit, while the other end is connected to a stud against which a spring-controlled carbon brush bears, to collect the current. Detailed descriptions of various types of magnetos are given later so that nothing further concerning the construction need be added here.

Principle of Operation of Magneto. Under "Generator Principles", the principle of the operation of the magneto has already been explained, the method by which the rotation of the conductors in the magnetic field generates an e.m.f. and a current is induced in them. But as the actual operation of the magneto as designed for ignition purposes is radically different from any other form of generator, it is given here. If unrestricted, the armature of the magneto will always assume the position shown at *A*, Fig. 28, and considerable effort will be required to turn it from this position as the magnetic flux through the armature is then a maximum. When the armature is rotated a little over 90 degrees from this horizontal position so that the armature poles leave the field poles, as at *B* in the same figure, the flux decreases, and when in a vertical position no lines of force pass through it. At this point, the direction

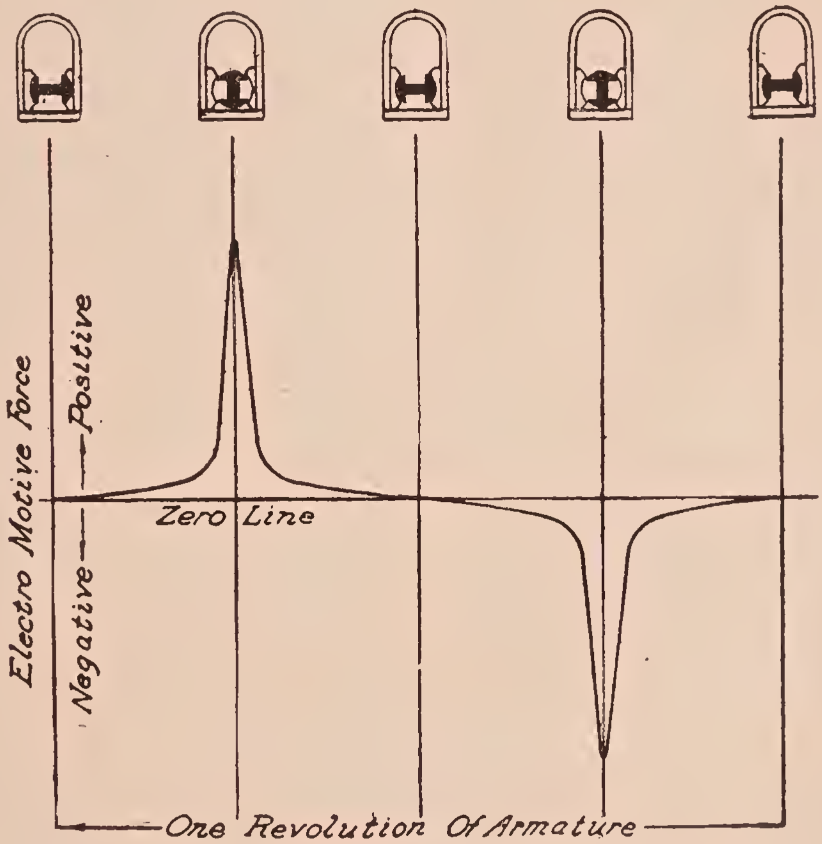


Fig. 29. Curve of Primary E. M. F. in Magneto on Open Circuit
Courtesy of Horseless Age

of the magnetic flux through the armature core reverses. Having a two-pole armature, the magneto produces an alternating current of two complete cycles per revolution, as shown by the curve, Fig. 29, which illustrates the electromotive force generated at the different positions in the rotation of the armature. The similarity between this curve and the one generated by the elementary dynamo, Fig. 17, will be noted. With the armature in the horizontal position there is a dead point, the e.m.f. curve only starting as the pole pieces of the armature begin to cut the edges of the field magnet poles. It then rises very sharply to a peak, and as sharply drops away to zero again, thus completing one cycle, which is then repeated in the opposite direction. As the present discussion comprises only an introduction to elementary principles and theories, further details of construction and operation of the magneto are given later in the section on "Ignition".

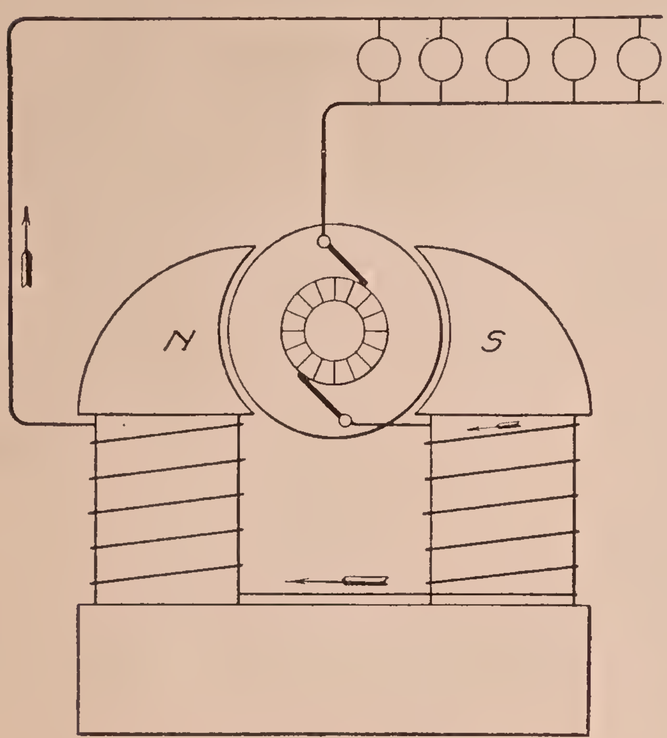


Fig. 30. Diagram Showing Series Generator

Self-Excited Fields. In a machine of the magneto type, the only method of varying the current output is to vary the speed of the armature, and it is therefore not well adapted to the majority of uses for which a generator is employed. Consequently, other methods of exciting the fields have been developed, which may be roughly divided into two classes: *first,* those separately excited, in which current from an independent source is supplied to the field windings. This is now practically restricted to large alternating-current generators and so need not be considered further here. *Second,* self-excited fields, which are now characteristic of all continuous current generators. In this method all or a part of the current induced in the armature windings is passed through the field coils, the amount depending on the type of generator.

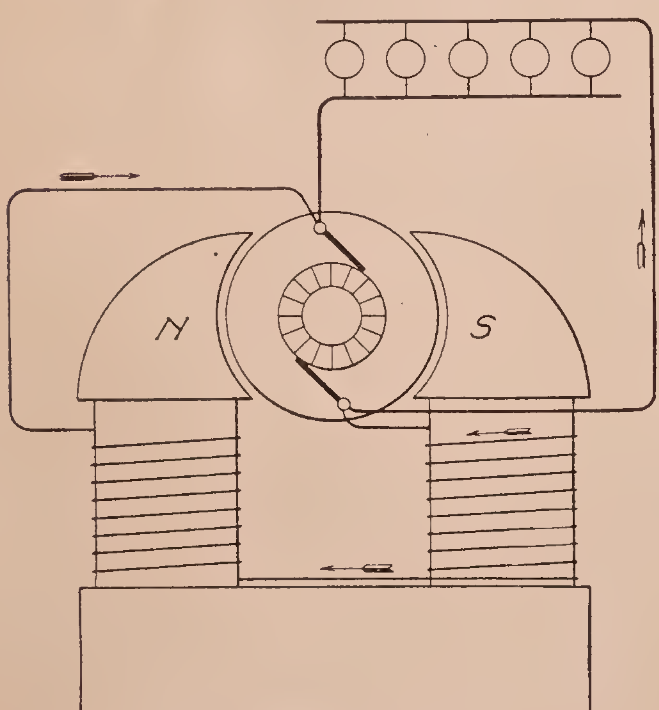


Fig. 31. Diagram Showing Shunt-Wound Generator

Series Generator. Where the entire current output is utilized for this purpose, the dynamo is of the series type, and a reference to the section on "Circuits", in connection with the illustration, Fig. 30, will make this plain. There is but a single circuit on such a dynamo and while it has the advantage of simplicity, it does not generate a current until a fairly high speed is reached, or unless the resistance in the external circuit is below a certain limit. It is also likely to have its polarity reversed so that it is not fitted for charging storage batteries. As the only series generators put into commercial use have been for supplying arc lamps in series for street lighting, they need not be considered further.

Shunt-Wound Generator. By winding the generator with two circuits instead of one and giving that of the fields a relatively high resistance as compared with the outside circuit on which the generator is to work, a machine that is self-regulating within certain limits is produced. As shown by Fig. 31, the main circuit of the generator is that through the armature with which the field winding is in shunt. The current accordingly divides inversely as the resistance and only a small part of it flows through the field coils, while the main output of the generator flows through the external circuit to light the lamps, to charge a battery, or the like, the resistance of this external circuit being much less than that of the fields. But in this type, as well as in the simple series form, the e.m.f. generated varies more or less with the load, and as the latter is constantly changing, it is necessary to provide some means of varying the e.m.f. generated to suit the load, in other words, to make the generator self-regulating. Of the several available methods of doing this, the only one applicable to the small direct-current generators used in automobile lighting and starting systems, is that of varying the magnetic flux through the armature.

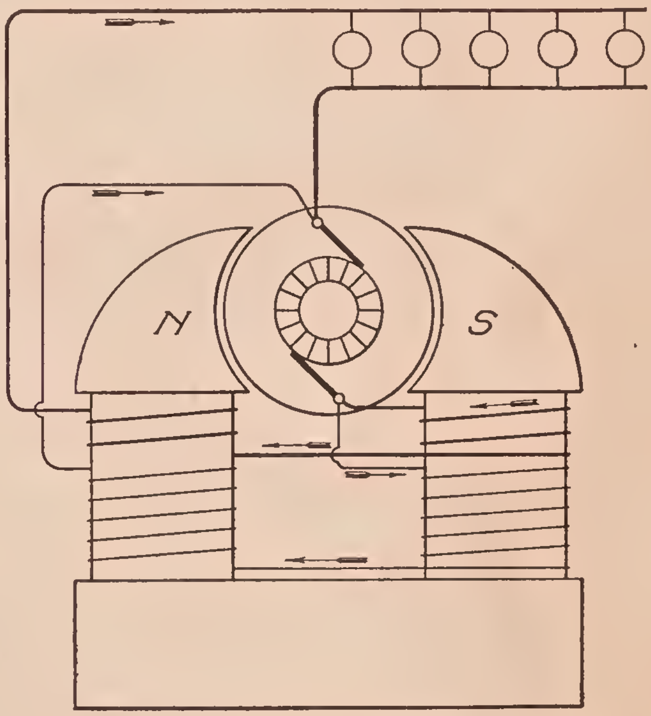


Fig. 32. Diagram Showing Compound-Wound Generator

Compound-Wound Generator. There are also several methods of effecting this variation of the magnetic flux, but the most advantageous and consequently the most generally used, is to vary the amount of current in the energizing coils on the field magnets.

By adding to the shunt winding a few turns of heavy wire in series with the armature so that all the current passes through them, the magnetic flux may be made to increase with the load as it is directly affected by the current demanded by the latter. This combination of the shunt and series is termed a compound winding, and the usual method of affecting it is shown by Fig. 32. Such a machine

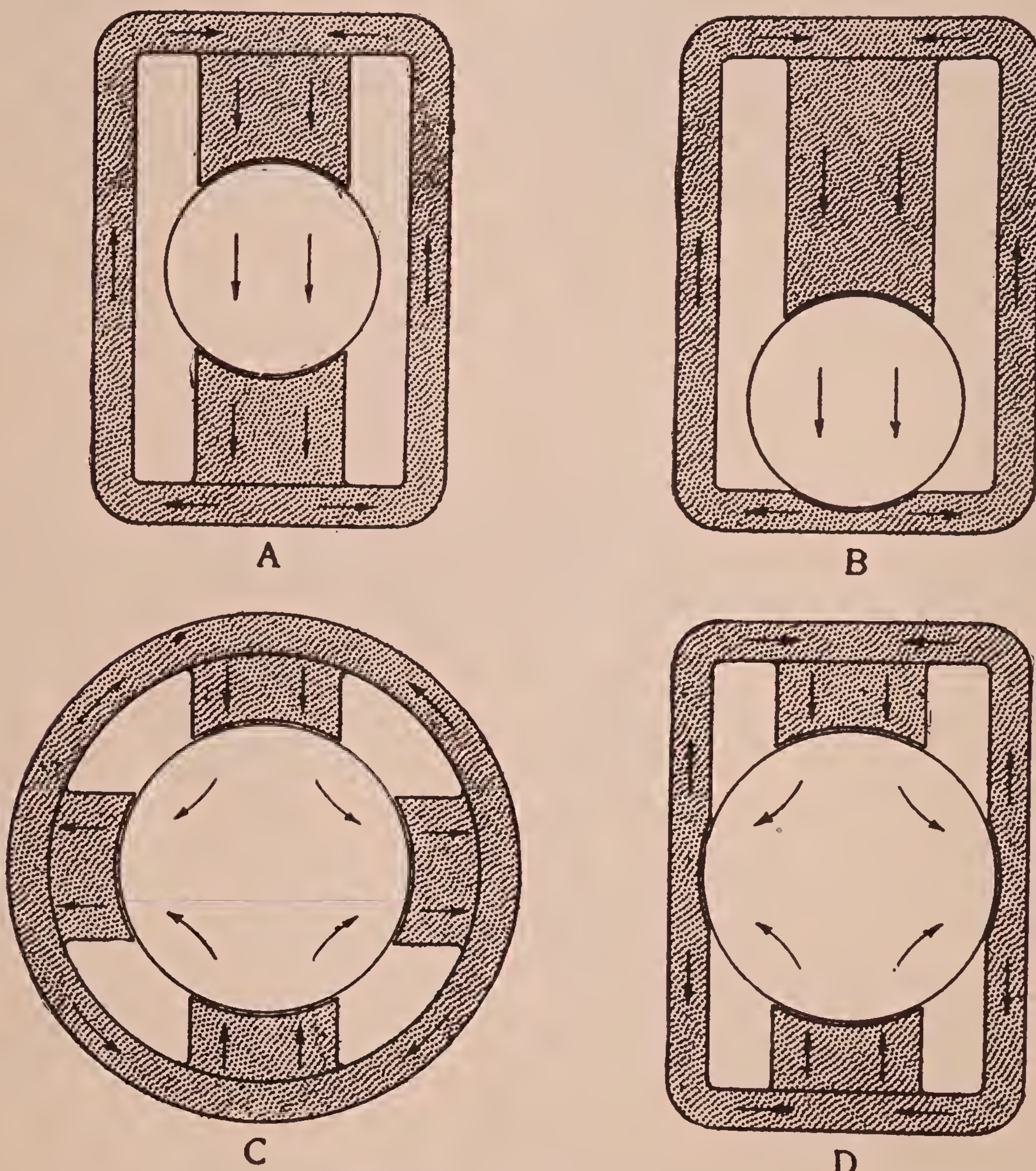


Fig. 33. Forms of Field Frames

is called a compound generator, and is the type almost universally used for lighting and for charging the storage batteries of automobiles. In view of the great range of speed variation of the automobile motor, this compound wiring is sometimes reversed so as to act against the shunt instead of with it, in order to prevent an excessive amount of flux and a current that would be dangerous to the windings themselves due to a very high speed. The compound winding then opposes the shunt-winding and is termed a *bucking-coil* or winding. This is referred to later in connection with the discussion of methods of regulating the generator on the automobile.

Forms of Field Magnets. For greater simplicity, all of the illustrations shown in connection with the explanation of the various types of generators are of the old bipolar type in a form long since obsolete. The field frame, as it is designated may, however, take a number of different forms depending entirely upon the designer's conception of what best meets the requirements of ample power in the minimum of space and with the minimum weight. Fig. 33 shows some typical forms of field frames in general use on automobile generators, and it will be noted that in addition to providing a magnetic circuit the field frame also serves to enclose the windings. These are known as "ironclad" types from the fact that all parts are thoroughly enclosed and protected. The arrows in each case indicate the paths of the magnetic circuits, the number of the circuits varying with the number of pole pieces. The form at *A* has two opposed poles, each of which is designed to carry an exciting coil or winding. This is a bipolar machine. Field frame *B* is also of the bipolar type but only one pole carries an exciting winding, the other being known as a consequent pole. In both of these field frames, it will be noted that the magnetic circuits are long, which adds to the magnetic reluctance and tends to decrease the efficiency. To overcome this, multipolar types of field frames are very generally employed. One of these, with two wound or salient poles and two consequent poles, is shown at *D*, the extra poles making four short instead of two long magnetic circuits. *C* is a multipolar type with four salient poles.

Brushes. Brushes serve to conduct the current generated by the armature to the outer circuit and to the field coils in order that the excitation of the latter may correspond with the demand upon the generator. The brushes originally employed were strips of copper which bore on the commutator; as generators increased in size these brushes were built up of thin laminations of copper. Plain copper brushes in any form, however, cause an excessive amount of sparking which is ruinous to the smooth surface and true running of a commutator. Built-up copper gauze brushes were then adopted, and they were fitted to bear against the commutator. Though an improvement, these did not meet all the requirements and were in turn superseded by carbon brushes, which are now practically universal. The carbon brushes usually bear directly against the face of the commutator, either through a blunt, squared end, or one that is slightly beveled. The brush holders are generally bronze castings attached directly to the field-frame extensions; in them are placed small helical springs under compression, which serve to press the brush against the commutator. Ordinarily, the brushes are composed of a uniformly smooth and homogeneous compound of carbon that soon acquires a glazed surface at its bearing end and wears indefinitely without requiring any attention, but at times a gritty brush will be found. Such a brush scratches the commutator surface, wears unevenly, and is generally a source of trouble.

Badly worn commutators frequently result from the use of improper brushes, or too heavy a spring pressure—also from too light a spring pressure. The manufacturer has found out by experiment and study just what character of brush is best adapted to his particular generator or starting motor and also the exact amount of spring pressure that is necessary to insure the best results. Consequently, much trouble will be avoided if brushes are replaced only with those supplied by the manufacturer of that particular machine, in connection with the brush springs that were designed for it. There are electrical as well as mechanical reasons for this, since both the resistance and current-carrying capacity of carbon brushes vary. This has been taken into consideration by the manufacturer who has provided a brush especially adapted to his machine.

ELECTRIC MOTOR PRINCIPLES

Theory of Operation. A machine that is designed to convert mechanical into electrical energy or the reverse, is known as a *dynamo-electric machine*. When its armature is rotated by an external source of power, such as a steam engine, hydraulic turbine, or gasoline engine, it is a *generator*. By sending a current through it from another generator or a battery it converts electrical into mechanical energy and is a *motor*. It is evident, then, that a generator and a motor are fundamentally one and the same thing, and that by a reversal of the conditions one unit may be made to serve both purposes. It will naturally depend upon how closely these purposes approach each other so far as their operating conditions are concerned, whether it will be practical to employ the same machine for both. In practice, operating conditions rarely approximate and so before the advent of the single-unit starting-and-lighting system on automobiles the use of the same machine for both generating current and converting it into mechanical energy was practically unknown. Space considerations were the chief factor which led to the development of the single system, as the demands on the machine for charging the battery and starting the engine are radically different.

How Rotation Is Produced. The operation of an electric motor will be clear if the essentials of a dynamo-electric machine and their relations are kept in mind. There is, first, the magnetic field and its poles—two or any multiple thereof, though for space reasons more than four poles are seldom used in starting motors; then the armature, which must also have an even number of poles corresponding to the number of segments in the commutator. Each separate coil in the armature winding magnetizes that section of the armature core on which it is wound, when the current passes through it, as its terminals, connected to different segments on the commutator, come under the brushes. In an electric motor having either two or four field poles, and eight, twelve, or sixteen armature poles, it is apparent that every few degrees in the revolution of the armature an oppositely disposed set of its poles is either just approaching or just leaving the magnetic field of two of the field poles. Bearing in mind that like poles repel one another and that unlike poles attract, and that the polarity of both the fields and the armature coils is constantly being alternated by the commutator, we see that each section of the armature is constantly being attracted toward and repelled from the field poles.

The fundamental law just stated can be easily illustrated by taking two common horseshoe magnets, such as can be bought for a few cents. Placing their north and south poles together it will be found that they have no attraction for each other and cannot be made to adhere in this relation. If they had sufficient force they would actually move apart when placed on a smooth surface in this position. But if one of the magnets is turned around so as to bring the north and south poles of the two opposite each other, the magnets will be immediately attracted and will hold together to the full extent of their force.

What may be called one cycle of the operation of an electric motor may be described as follows: the motor turns clockwise; it is of the bipolar type, that is, it has two field poles; and there are eight coils on the armature. At the moment assumed, the left field pole is the north, and the right south; consequently, the section of the armature just entering the field is of opposite polarity, presenting a south pole to the north pole of the field and a north pole to the south pole of the latter. The armature is therefore strongly attracted. This attraction is maintained by the current in the windings continuing in the same direction until the magnetic attraction reaches a maximum, at which point the stationary and moving poles are practically opposite each other. Unless a change occurred just at that point the armature would be held stationary and could be turned from it only by the expenditure of considerable force, that is, assuming that the field did not lose its exciting current. (This may be observed on a small scale by attempting to revolve the armature of a magneto by turning its shaft by hand.) But either at that point, or just before it is reached, the revolution of the armature brings a different set of commutator bars under the brushes and the direction of the current is reversed in that particular winding and with it the polarity of the armature poles. Instead of being mutually attracted the armature and field poles become mutually repellent. In brief, the armature is first pulled and then pushed around in the same direction by reason of the force exerted both by the field magnets and by its own magnets. The passing of one section of the armature through this change as it enters and leaves the zone of influence of a pair of pole pieces may be said to constitute a cycle of its operation, by analogy with alternating-current generation. The cycles are repeated as many times per revolution as there are coils on the armature and the number of coils miltiplied by the speed will give the number of changes per minute. For example, in a motor assumed to have eight armature coils, as in the present instance, there would be, at a speed of 1,000 r.p.m., 16,000 changes per minute, which makes clear the reason for the very smooth pull or torque that an electric motor exerts.

Counter E.M.F. Though being rotated by means of current obtained from an external source of power, it is apparent that the motor armature in revolving its coils in the magnetic field is fulfilling the conditions previously mentioned as necessary for the generation of an e.m.f. Experiment shows that the voltage and current thus generated are in an opposite direction to that which is operating the motor. It is accordingly termed a counter e.m.f. as it opposes the operating current. This, together with the fact that the resistance of copper increases with its temperature and that the armature becomes warmer as it runs, explains why the resistance of a motor is so much greater when it is running than when standing idle. The counter e.m.f. approaches in value that of the line e.m.f., or voltage at which current is being supplied to the motor. It can, of course, never quite equal the latter for in that case no current would flow. The two opposing e.m.f.'s would equalize each other; there would be no difference of potential.

Types of Motors. Being the counterparts of electric generators, electric motors differ in type according to their windings in the same manner as already explained for generators. The plain series-wound motor is nothing more or less than the simple series-wound generator to which reference has already been made; the shunt and compound motors likewise correspond to the shunt and compound generators. But while the series-wound generator was of extremely limited application and has long since become obsolete, the series-wound motor possesses certain characteristics which make it very generally used. It is practically the only type employed for starting service on the automobile, and it is also in almost universal use for railway service. The reasons for this are its very heavy starting torque which increases as the speed of the motor decreases, the quick drop in the current required as the motor attains speed, and its liberal overload capacity. It is essentially a variable speed motor, and, just as the plain series-wound generator delivers a current varying with the speed at which it is driven, so the speed of the motor changes in proportion to the load. These are characteristics which make it valuable for use both as a starting motor for the gasoline engine, and for a driving motor on the electric automobile, though in the latter case it is seldom a simple series-wound type. As its speed is inversely proportional to the load, however, it tends to race when the load is light; in other words, it will "run away" if the load is suddenly removed, as in declutching from the automobile engine after starting the latter, unless the current is instantly shut off or very much reduced. This is provided for, as will be explained in detail later in connection with the various systems.

Shunt motors and compound-wound motors are the same as their counterparts, the generators of the same types, but as they are not used in this connection, no further reference need be made to them here.

Dynamotors. As the term suggests, this is a combination of the generator or dynamo and the electric motor, and it is a hybrid

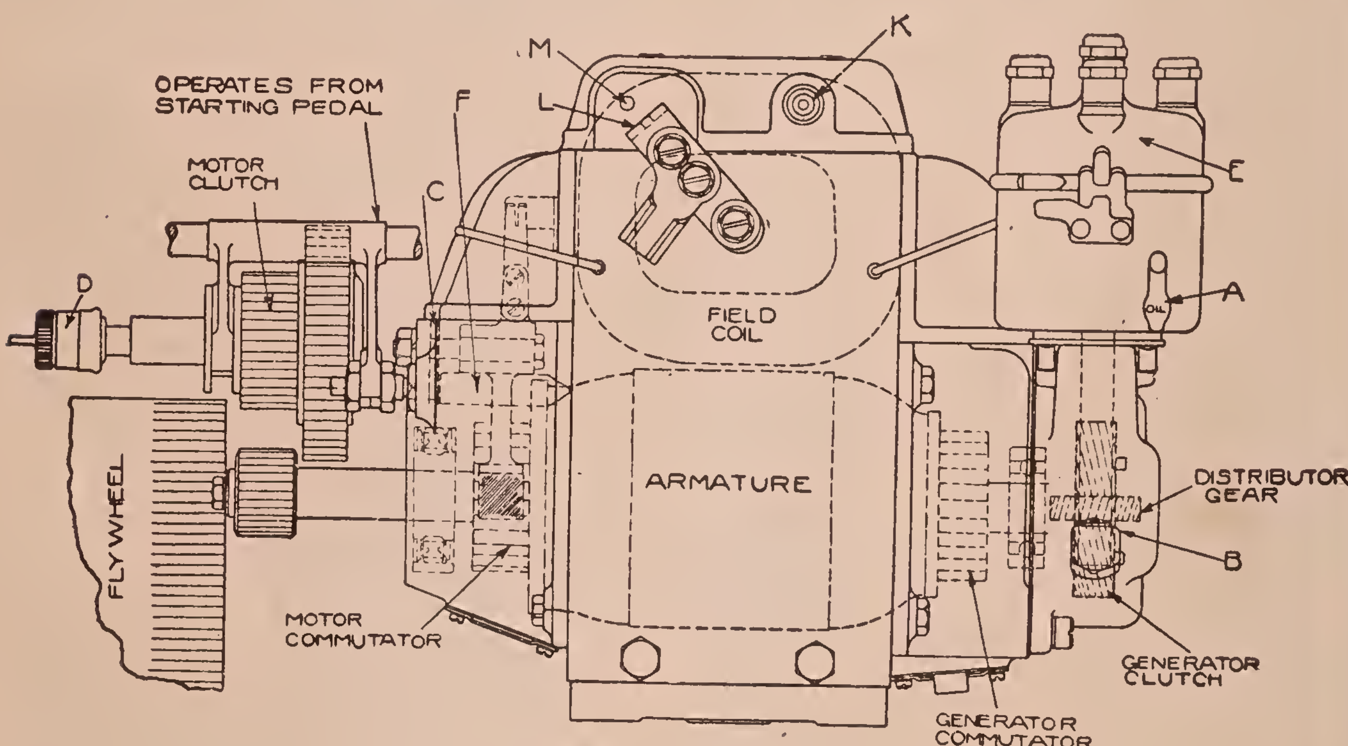


Fig. 34. Dynamotor (Motor-Generator) of the Delco System

for which the automobile starting system has been responsible. It is frequently mistermed a "motor-generator" and while its assumption of the two rôles may justify the name, the use of the term is misleading as it becomes confused with the motor-generators employed for converting alternating into direct current. The latter consist of an a-c. motor on one end of a shaft and a d-c. generator on the other end of the same shaft. The two units are distinct except for their connection, whereas a dynamotor is a single unit comprising both generator and motor, and it can perform only one of these functions at one time. A motor-generator, such as is used in garages for transforming alternating into direct current for charging storage batteries, must carry on both functions at

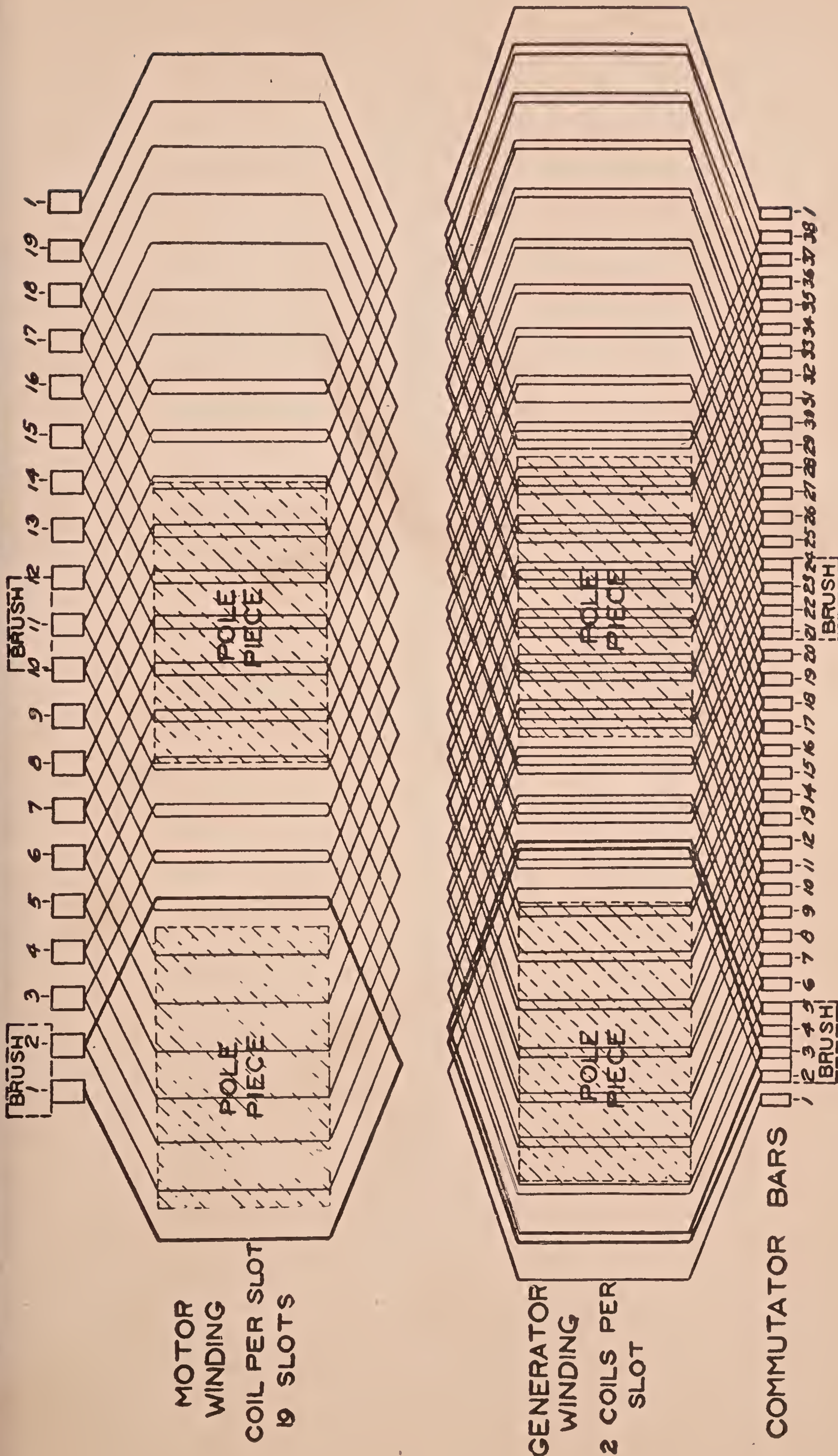


Fig. 35. Windings of Delco Dynamotor

the same time in order to operate. That is, the a-c. motor must run as a motor in order to drive the d-c. generator and cause it to generate a direct current. Hence, the term motor-generator as applied to the single-unit type of electric starting system for an automobile is not in accordance with the accepted meaning of the words and is likely to be confusing.

A typical example of the dynamotor is to be found in the Delco single-unit system, illustrated in Fig. 34. This is really the windings of two radically different machines, a shunt-wound generator and a series-wound motor, placed on the same armature core and field poles. As will be noted, the terminals of the two sets of windings on the armature are brought out in different directions and two commutators are employed, that at the right-hand end being for the generator windings, and that at the left for the motor. The method of winding the armature is illustrated by Fig. 35, which shows the generator and motor windings projected on a plane. In the preceding illustration the detail at the left shows the gearing and starting connection for coupling the starting motor with the flywheel of the engine, the one at the right an ignition distributor for the high-tension current. Both of these are later referred to at greater length.

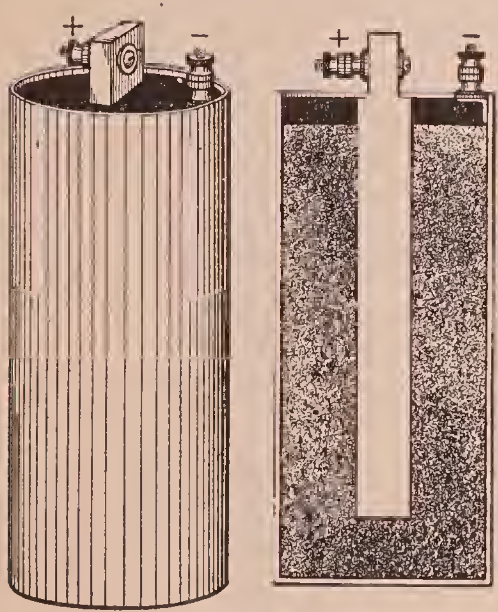
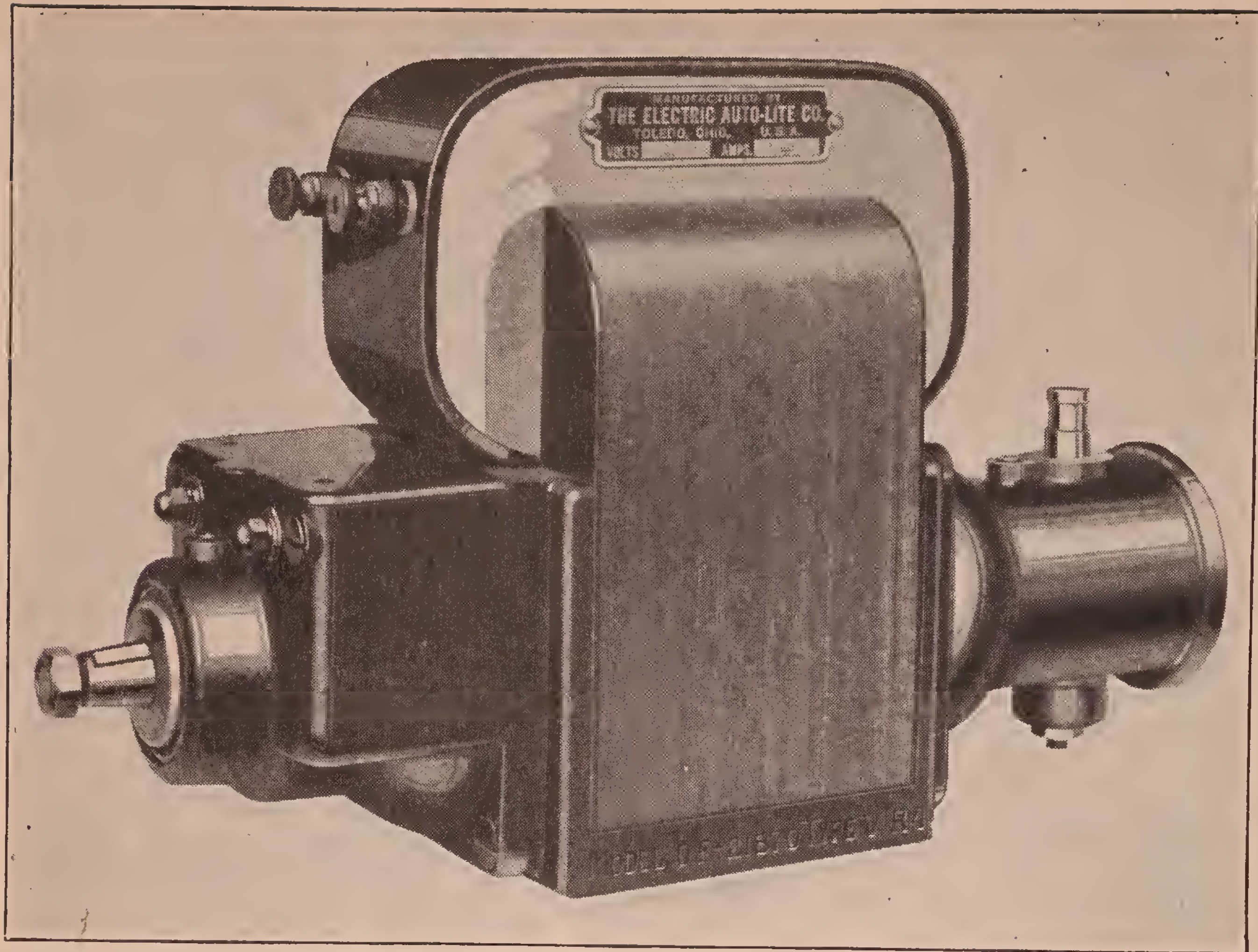


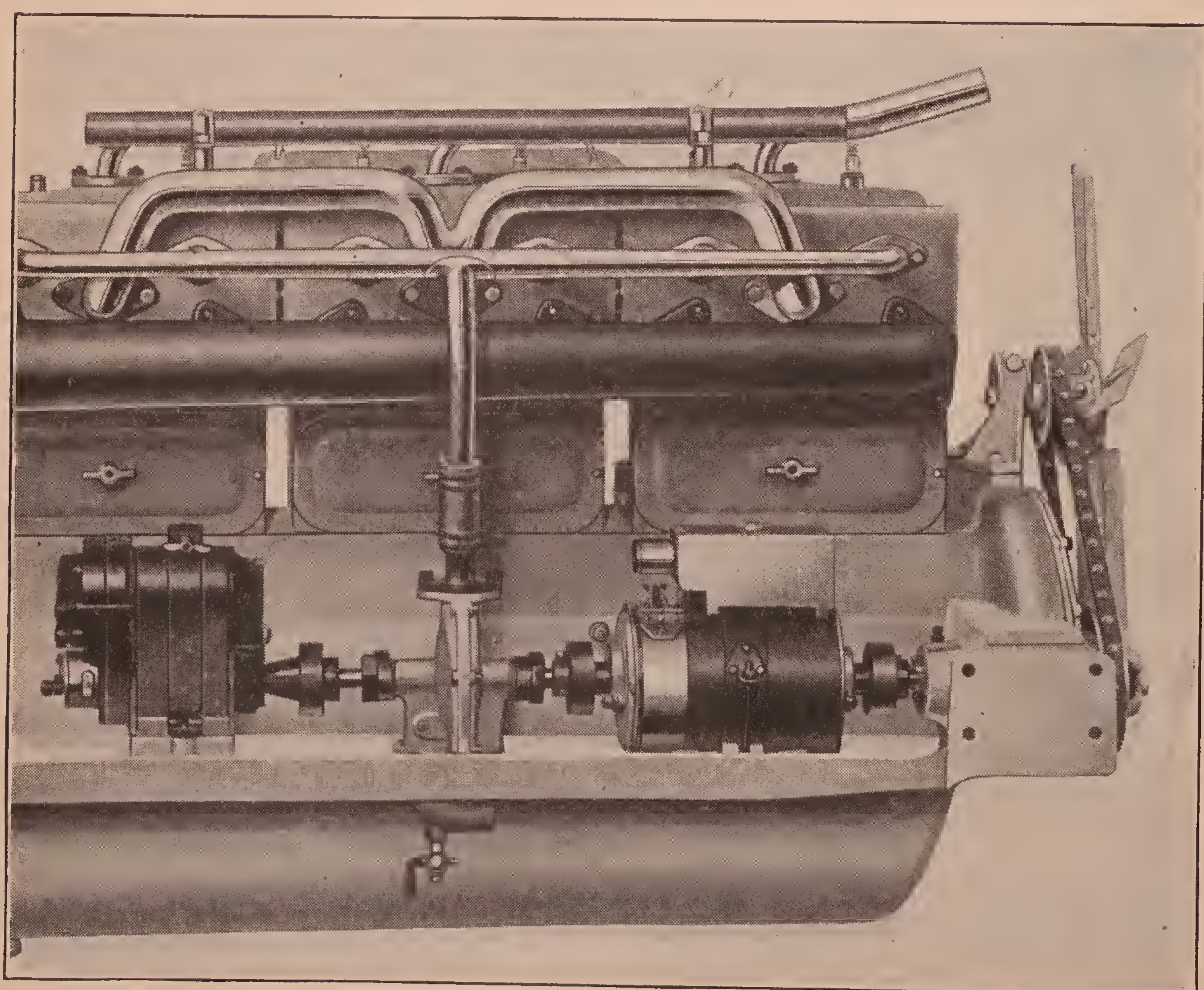
Fig. 36. Typical Dry Battery

Batteries. The only other method known for generating a continuous, direct current is by means of chemical reactions in what are known as primary cells. With the exception of the so-called *dry cell*, a description of these and their workings could be of only historic interest and is accordingly omitted here. As no chemical reaction could take place in perfectly dry substances this part of the name is used simply to distinguish such cells from those using a liquid solution. The dry cell is a zinc-carbon couple, Fig. 36, the zinc acting as the container while the carbon is a heavy rod packed in manganese dioxide, together with some moisture-absorbing material. On the contents of the zinc container as thus filled is poured a solution of sal ammoniac and water which forms the active solution of the battery. The cell is sealed at the top to prevent evaporation, since, when the cell does actually become as dry inside as it is outside it is no longer of any use. Some of its other characteristics are mentioned under "Ignition", Part II.

The storage battery or accumulator does not generate a current in any sense of the word. By means of a much more complicated chemical reaction than that of the primary cell it absorbs a charge of electricity. Upon the completion of the circuit of a storage cell with a suitable load or resistance, such as driving a motor or lighting a lamp, a reversal of this chemical process takes place and the battery redelivers a part of the current which it has previously absorbed. Full details of the characteristics, construction, and working of the storage battery are given in the article on "Electric Automobiles". The storage battery and the dry cell are the only two forms of battery employed on the automobile so that no mention of the other types is necessary, particularly as all but very few of them are practically obsolete.



AUTO-LITE STARTING-LIGHTING GENERATOR
Courtesy of Electric Auto-Lite Company, Toledo, Ohio



RIGHT SIDE OF WINTCN SIX-48 MOTOR WITH BIJUR MAGNETO AND CHARGING GENERATOR MOUNTED ON THE SAME SHAFT
Courtesy of Bijur Motor Lighting Company, Hoboken, N. J.

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART II

IGNITION

FUNDAMENTAL IGNITION PRINCIPLES

Faulty Ignition Cause of Much Early Trouble. More than half of the troubles encountered by the designers and the drivers of the early automobiles were the direct results of the extremely crude ignition systems at first adopted. With knowledge of gasoline-motor operation generally scant at that time, much of this trouble was attributed to causes entirely foreign to its real source or, on general principles, the motor was roundly "cussed" as a deep and unfathomable mystery. Subsequently it became plain that much of this inexplicable tendency to balk was due to the elusiveness of the electric current. Crude insulation and contacts, inherently defective spark plugs, and extremely wasteful current-handling devices, fed from a weak source, were the causes.

Distinctions between Low Tension and High Tension. A low-tension ignition system uses a low-tension current—i.e., the output of a battery or small generator, employed at the voltage at which it was produced, or, in other words, a primary current. A high-tension uses a high-voltage current produced by passing the output of the battery or other source of supply through a step-up transformer (induction coil). As this is taken from the secondary winding of the coil, it is sometimes referred

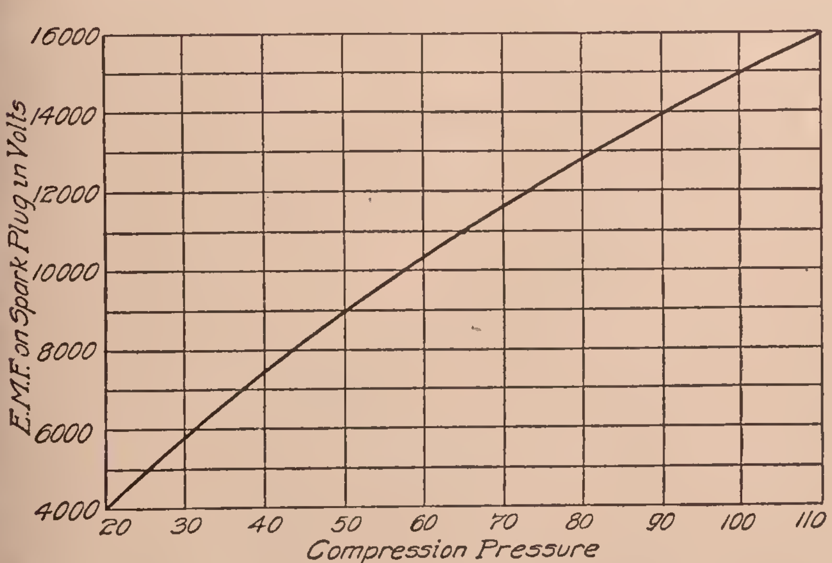


Fig. 37. Voltage Required to Force a Spark Across a .020-Inch Gap Under Different Compression Pressures

to as a secondary current. It is the result of induction and is commonly termed a high-tension current owing to its great voltage or potential. The battery produced current of high amperage value at 6 to 8 volts, which after being passed through the coil became a current of microscopic amperage value at anywhere from 10,000 to 25,000 volts, according to what the designer of the coil thought was sufficient potential to produce a good spark, that is, to enable it to readily jump the gap in the points of the plug. The curve, Fig. 37, shows the voltage necessary to force a spark across a given distance in air under various pressures.

As the low-tension current will not jump an air gap, a further distinction between the two systems is the employment of totally

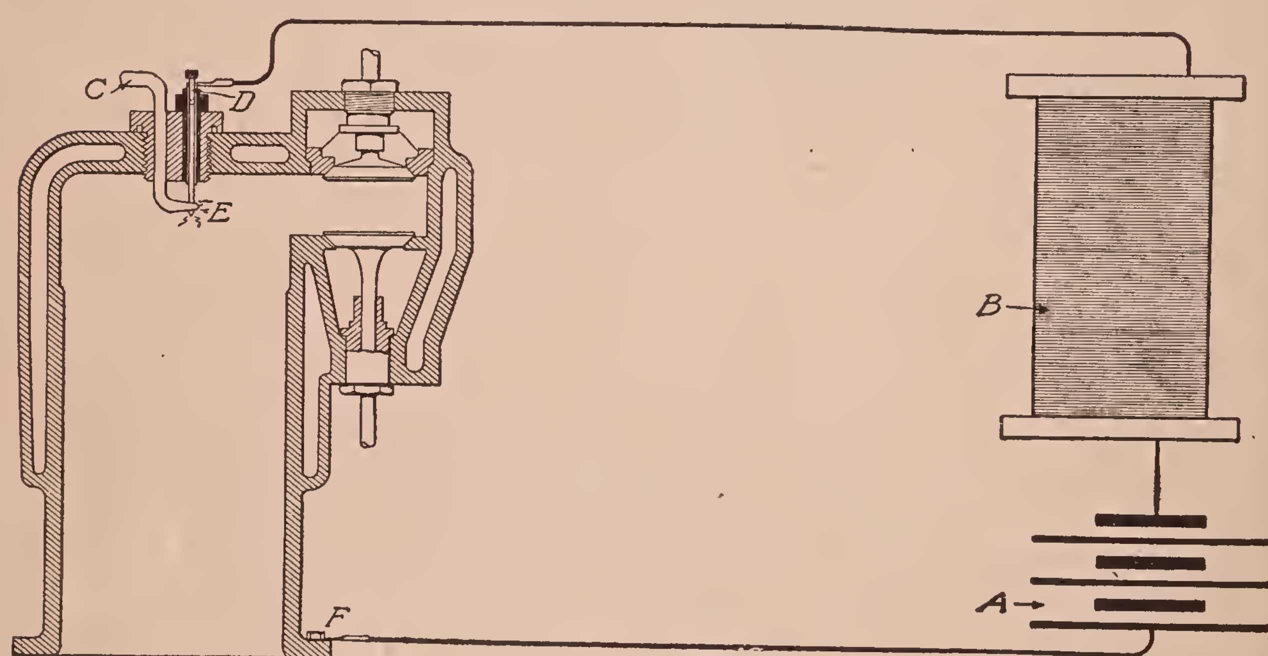


Fig. 38. Diagram of Low-Tension Ignition System

different types of spark plugs. In the former, a mechanically operated plug, i.e., one that is held closed until the maximum current is passing through it and is then suddenly opened by being mechanically tripped by a cam or rod operated by the engine, is essential. Such a plug produces a spark that is immensely superior in heating value and, consequently, in igniting ability, to the usual thin spark that bridges the gap of a high-tension spark plug. But this most desirable quality is likewise quickly destructive of the contact points, necessitating frequent readjustment of the mechanically operated plugs. Moreover, the mechanical lag or time element of operation, due to the inertia of the numerous moving parts, rendered it difficult to make a low-tension spark plug suitable for a high-speed engine without resorting to the most expensive machine work, and much greater skill was necessary for their proper adjustment.

The shortcomings of the original high-tension systems were so glaring, however, that some of the most successful automobiles of earlier days were fitted with low-tension ignition.

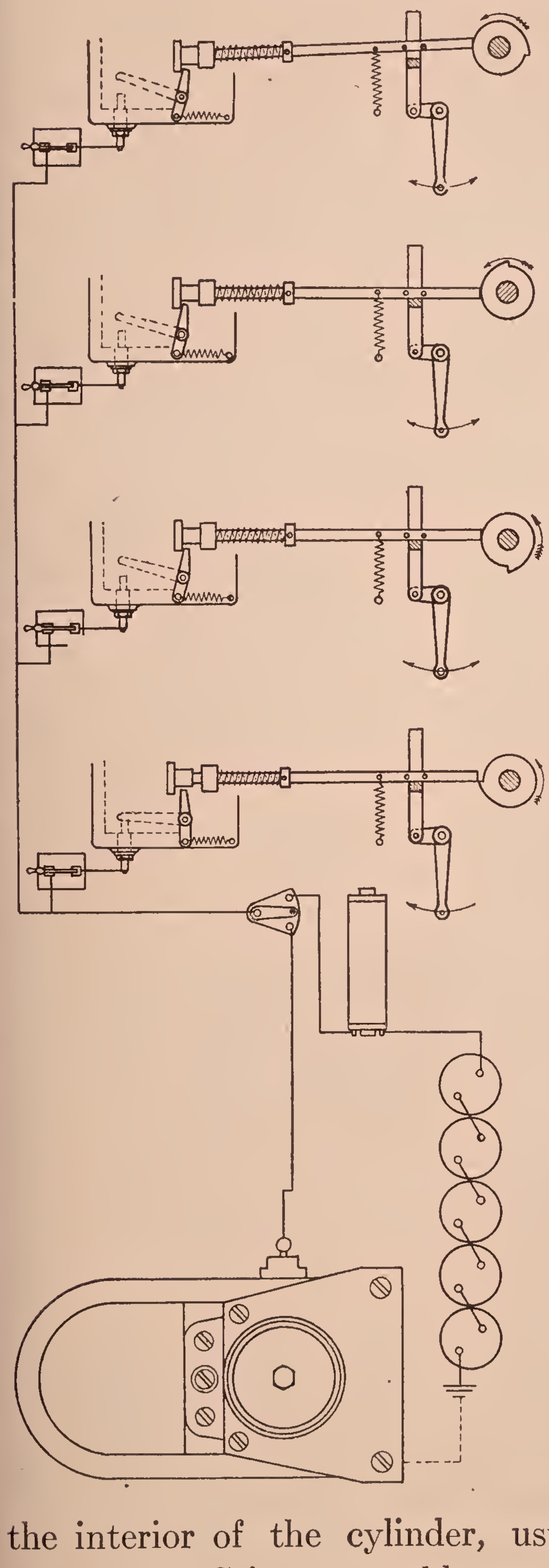


Fig. 39. Four-Cylinder Low-Tension Ignition System (*Horseless Age*)

Low-Tension System. Fig. 38 shows diagrammatically the essentials of a low-tension system for a single-cylinder motor, while Fig. 39 shows a complete low-tension system for a four-cylinder motor. The details of the operating mechanism and the plug are shown in Figs. 40 and 41. Referring to Fig. 38, *A* is the battery (a magneto, dynamo, or any other suitable source of current may be used), *B* is a spark coil, and *C*, *D*, and *E* are the elements of a make-and-break device that is mechanically actuated at regular intervals by the motor itself to produce the sparks within the cylinder. As shown in the drawing, the circuit is completed by grounding the wires from one side of the battery on the cylinder base, or any other portion of the machine, as at *F*. In this figure *D* is a small insulated plug entering the interior of the cylinder, usually through one of the valve caps, while *C* is a movable arm (see also Fig. 40), that makes and breaks contact with *B*, at the point *E*, when it is given a slight rocking movement. For the best results this rocking movement must be very sharp and rapid, in the nature of a snap, and it must, of course, be correctly timed to occur in proper relation to the moment when the spark is required. (See also Fig. 41.)

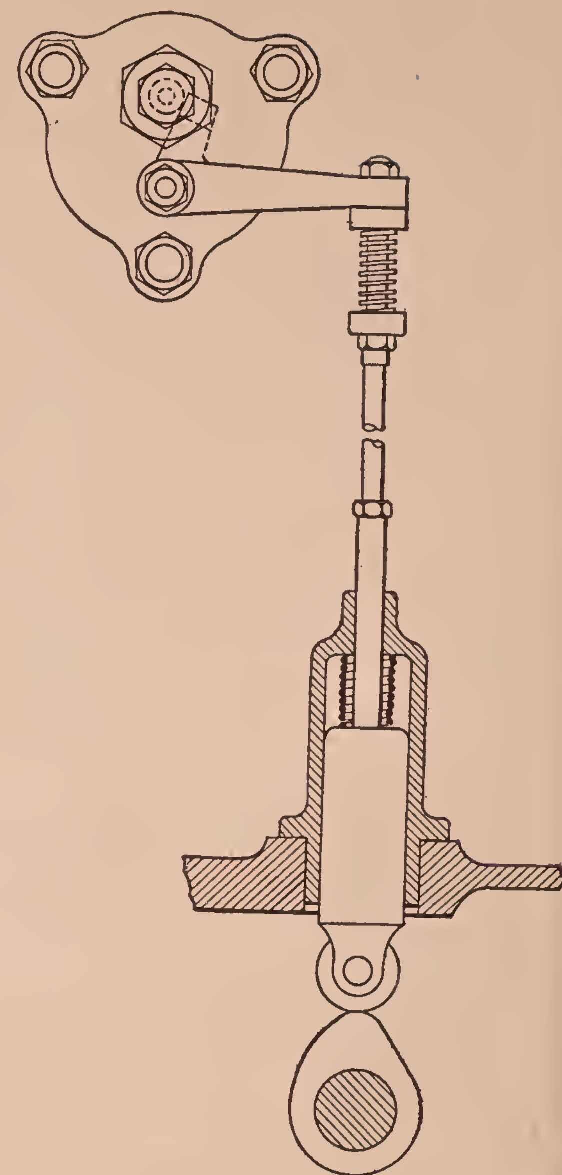


Fig. 40. Make-and-Break Mechanism

The chief advantage of low-tension ignition is its immunity from troubles caused by short-circuiting by leakage of the current through poor insulation or across moistened terminals. This led to its almost universal employment on motor boats for a number of years, but it has since been generally abandoned even for marine use so that it is now only to be found on stationary engines, the low rotative speeds of which make it practical. So far as the automobile is concerned, the low-tension system is only of historical interest as it is already several years since it was wholly discarded.

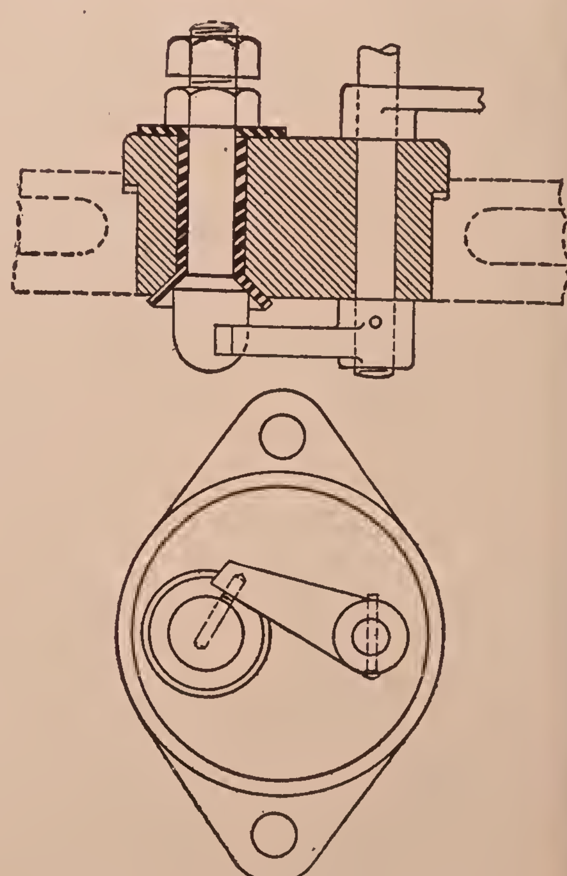


Fig. 41. Low-Tension Spark Plug
(*Horseless Age*)

High-Tension System. High-tension ignition systems are based on the fact that when a sufficiently high potential is impressed upon a current of electricity, it will leap an air gap or other break in the circuit of a width dependent upon the potential or voltage itself. In bridging such a gap, the current becomes visible in the form of an arc, flash, or spark, depending upon its duration and intensity, and it will readily ignite a gasoline or other gaseous fuel mixture. Its very ability to do so, however, was one of the most prolific sources of trouble in the early days, as the designer's conception of the insulation required to conduct such a current without grounding or short-circuiting was far from approaching the reality.

The essentials of a high-tension system are shown diagrammatically in Fig. 42. *A* is the source of current, usually a battery in earlier days, as indicated by the conventional sign, placed in a primary circuit that also includes the contact maker *C*, the primary winding of the coil *B*, and the vibrator *G*. The contact maker *C* is positively driven by a connection with some revolving part of the motor, so that it makes contact at the exact time ignition is required in each cylinder.

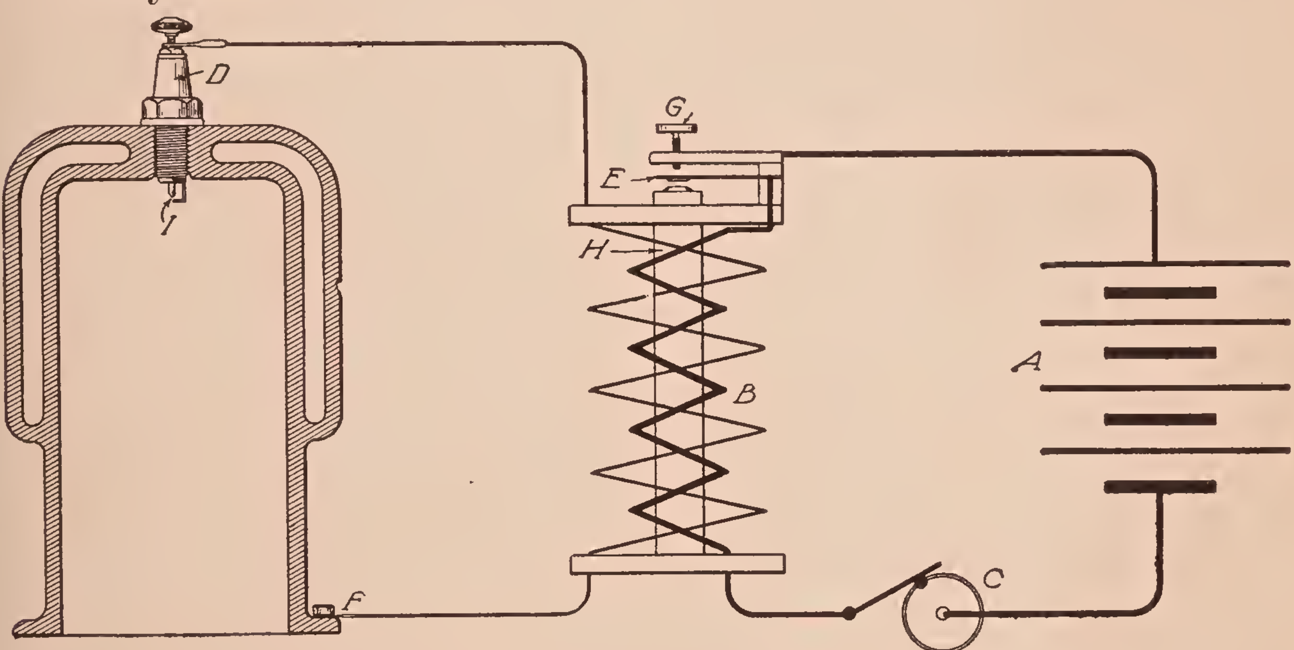


Fig. 42. Diagram of High-Tension Ignition System

With a system of the type described, when contact is made the first result is attraction of the vibrator blade *E* by the magnetized core *H* of the coil. This, by drawing *E* away from the contact screw *G*, at once breaks the primary circuit again, and this demagnetizes *H*, with the result that *E* again springs into contact with *G*. The effect of this is to cause a rapid series of current surges through the coil *B*, as long as the contact maker *C* maintains the contact.

Each time a surge of primary current passes through a coil, a secondary current of very high voltage is induced in the secondary circuit, which is grounded on the cylinder at *F* and connected at *B* with the spark plug. This plug, for high-tension ignition, has an open gap of about $\frac{1}{32}$ inch at *I*, across the resistance of which gap the current will jump, because of its high tension. Ignition is thus effected by a rapid succession of sparks across *I*.

This briefly describes what may be termed the rudiments of a high-tension ignition system and the diagram shows their relation to one another. Of course, this simply has reference to a single-cylinder motor. For each extra cylinder in an ignition system of the type illustrated, there is another contact point on the timer and another coil. The timer or contact maker is sometimes referred to as an interrupter, though this is not technically correct as its function is first to close the circuit.

SOURCES OF CURRENT

Up to about 1905, batteries were universally relied upon in this country for ignition work, the only exceptions to this being a few high-priced imported cars, some of which had magnetos operating low-tension systems with the so-called make-and-break spark plugs, while one or two, notably the Panhard, was equipped with the Eisemann magneto, designed to operate a non-vibrator coil. The writer imported the second of these magnetos to be brought into this country in the latter part of 1902, but the principles of its operation were so little understood, despite the fact that the magneto had been used in hand-ringing telephones for a generation, that automobile designers were frankly skeptical regarding it, and only the few electrical men then in the industry had the slightest conception of its possibilities. In fact, Mr. J. M. Packard, then head of the Packard Company, was the first man out of dozens to whom it was shown to realize what the magneto meant to automobile ignition.

CHEMICAL SOURCES OF CURRENT

Primary Batteries. In the face of the advent of the magneto (1902), the majority of American designers preferred to stick to the battery, usually the dry cell. The term dry cell is really a misnomer, since a cell of this type consists simply of a zinc element constituting the case of the cell, a carbon element centered within this, and an electrolyte composed of a moist paste of suitable chemicals. The top of the cell is commonly sealed with pitch or wax compound to prevent the moisture from evaporating, and if by any chance the cell does become really "dry", its usefulness is then at an end.

Defects of Dry Cells. The chief defect of the dry cell is that it is an "open-circuit" battery, that is, the circuit is normally open and when closed for a brief period the cell will produce a heavy current, at a low voltage, i.e., $1\frac{1}{2}$ volts on the average. But to enable it to do so, the time of contact must be brief and the periods of rest frequent. Otherwise, the cell becomes "polarized". The hydrogen generated as the zinc element passes to the carbon element in such volume as to completely cover and insulate it from the active material of the cell, consisting of a solution of sal-ammoniac and water. The use of a depolarizer, usually manganese dioxide, prevents this to a certain extent, but not sufficiently to avoid having the current output of the cell fall off very rapidly if the contact exceeds a few seconds. But as soon as the circuit is broken again, the hydrogen is rapidly dissipated and the cell is said to recuperate. It was the marvelous ability of the dry cell to recuperate rapidly after having been run down to a point where it no longer produced sufficient current to pass a spark at the plug, that led to so much dissatisfaction and to such a misunderstanding of the gasoline engine in the earlier days. With the extremely wasteful contact makers then used, a set of cells would run an engine satisfactorily for an hour or so, then it would begin to miss firing badly and soon stop. Inspection would reveal no sign of current. If a new battery were installed, the engine would again run satisfactorily, and the motorist usually decided that the old cells were "dead". If, however, the inspection consumed ten or fifteen minutes, the battery recuperated and upon being cranked the engine again ran, only to repeat the performance a short time later.

Liquid Batteries. The dry cell is, of course, one form of primary battery, this term being used to distinguish it from other forms in which the exciting chemicals are in liquid solution. Few attempts have been made to employ the latter type of battery for automobile ignition, due to the violent agitation of the liquid which would necessarily ensue from the vibration and jolting. The Edison-Lalande cell and a few others of similar character, in which the charging chemicals were supplied in convenient units ready for quick replenishing when the battery "died", were tried in isolated instances but never met with general application, except on the motor boat, where the Edison-Lalande cells have been widely used.

Storage Cells. The construction and advantages of the storage cell as well as its operation and handling are detailed at length in the section on "Electric Vehicles". Due to its ability to provide a very much greater supply of current, it soon displaced the dry cell on all except the then lower-priced cars. While it represented a great improvement, the wastefulness of the contact maker and of the coil vibrators proved too much of a drain on even the storage battery, and it was accordingly displaced by the magneto. Since the general adoption of the latter, batteries have been wholly discarded except as a source of starting current, for the magneto does not generate sufficient current at a low speed to make it possible to start the motor without "spinning" it, which calls for considerable manual effort. Magneto practice is given in a succeeding section.

VOLTAGE AND SPARK CONTROL DEVICES

Changes in Ignition Methods. Up to a few years ago, it was generally considered that the magneto practically represented the

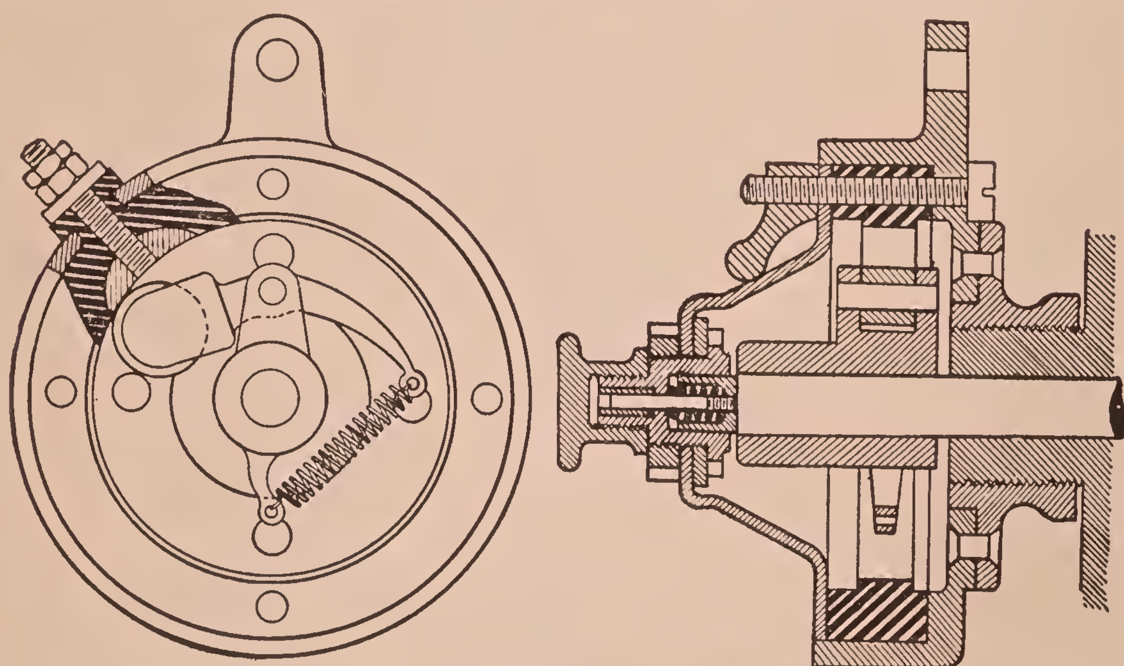


Fig. 43. Roller Contact Timer (*Horseless Age*)

ultimate type of ignition current generator and that batteries would never play anything but a secondary rôle. Small direct-current dynamos had been tried in a number of instances, chiefly prior to the advent of the magneto, but they were not then sufficiently developed for this form of service and proved quite as unreliable as the dry cell. The magneto was entirely dependable, made possible much greater speeds, and had few shortcomings, none of which were of a serious nature, so that its position was deemed impregnable. This was prior to the successful development of electric-lighting dynamos on the automobile, and more particularly the combined lighting and starting systems which are now in such general use.

The latter, in conjunction with improved forms of contact makers, has been responsible for bringing about a reversion to former practice with improved equipment.

Contact Makers or Timers. *Roller Contact Timer.* It was largely due to the crudity of the timing device that so much difficulty was experienced with early ignition systems. As the term indicates, the timer closed the circuit through the coil at exactly the moment necessary to produce the spark in the cylinder ready to fire. But the long wiping or rolling contact usually employed was so wasteful of current that it quickly exhausted even a storage battery. Fig. 43 shows a roller contact timer. The coil vibrators were another serious source of loss.

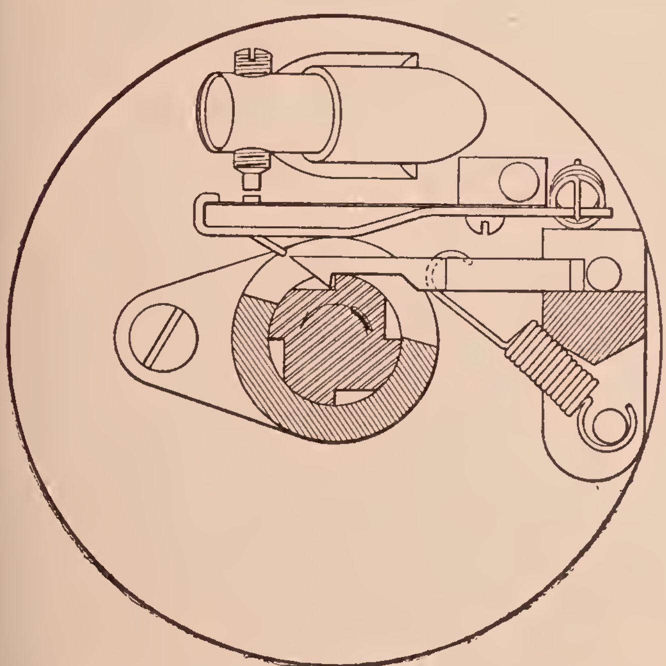


Fig. 44. Atwater-Kent Interrupter
Atwater-Kent Manufacturing Works, Philadelphia, Pennsylvania

Atwater-Kent Interrupter. The difficulties with roller contact led to the adoption of a totally different principle embodied in the Atwater-Kent interrupter, Fig. 44. This affords an exceedingly brief contact with an abruptness of the making and breaking of the circuit that is not secured with any other device. The effect is to produce a strong current surge and a heavy spark, but of the briefest possible duration.

The advantage of the brief duration is that great current economy is realized. The fact that only one spark is required for each ignition is an important contributing element to this economy.

With the Atwater-Kent interrupter, embodied in a distributor termed the "Unisparker", it is possible to run a car much further on a set of dry cells than could formerly be done with a storage battery, two to three thousand miles on four or five dry cells being nothing uncommon. This has led to the development of other devices along similar lines, and, with the unfailing source of current now provided by the lighting dynamo and the storage battery which forms part of the system, battery ignition has been raised to a level where it is now almost the equal of the magneto. But before making further mention of that phase of the subject, it is necessary to refer to the coil in order to give a clear understanding of the matter.

Coils and Vibrators. *Function of the Coil.* Mention has already been made of the function of the induction coil or transformer in stepping up the voltage of the current in order that it may bridge the gap in the spark plug. A coil is also employed in connection with a low-tension system, but it is simply a single winding on an iron core which intensifies the current by what is known as self-induction. Though it raises the voltage by what may be termed the accumulation and sudden release of electrical energy acting in conjunction with a magnetized core, due to the sudden making and breaking of the circuit, it is not an induction coil as that term is ordinarily employed.

As shown by Fig. 42, the latter has two distinct windings, one of a few turns of comparatively coarse wire and the other of many thousand feet of exceedingly fine wire, with high-grade silk insulation. After completing the coil, consisting of two superimposed windings and an iron-wire core passing through their center, it is placed in a wood box which is filled with melted paraffine wax which, upon solidifying, greatly enhances the resisting power of the insulation to breakdown, due to the great difference in potential between various parts of the secondary winding. To set up an induced current in the secondary winding, the primary circuit must be quickly opened and closed.

Necessity for Vibrator. The breaking of the primary circuit is accomplished by the use of a vibrator, a typical form of which is illustrated at *E*, *G*, and *H*, Fig. 42. This consists simply of the thin blade of spring steel at *E*, provided with an armature at the free end to intensify the attraction of the coil *H*, and adjacent to the adjusting screw at *G*, by which the distances between the contact points can be accurately set. In addition to these elements it is usual to provide a screw adjustment for increasing or reducing the tension of the vibrator blades.

Contacts in the best vibrators are made of platinum, or, better still, of platinum-iridium alloys, which are very hard as well as extremely resistant to the very high, though brief and localized, temperatures of the small arcs that form across the terminals each time the contacts are separated. In cheaper coils, German silver, silver, and other metals often are much used for contact points, but the only advantage of these over platinum or platinum alloys is their lower price.

Complication of Multi-Vibrator. A vibrator coil is necessary for each cylinder, each coil being energized as the timer passes over the contact corresponding to it, thus putting it in connection with the battery at the moment that particular cylinder is to fire. Fig. 45 shows a four-unit coil, i.e., for a four-cylinder motor. However, the coil cannot act before its core becomes "saturated", that is, thoroughly magnetized, and it must then pull its armature down against the tension of its spring, so that there is both an electrical and a mechanical lag, or, in other words, an appreciable amount of time elapses between the moment the circuit is closed by the timer and that at which it is again broken by the vibrator to cause the spark in the cylinder. A delicate adjustment is most sensitive and minimizes the lag besides economizing on current, but it is difficult to maintain. A stiff adjustment, on the other hand, will remain operative for a longer time, but its greater inertia makes the motor sluggish in action while the current consumption is increased several times over. Despite the use of platinum contact points, the heat of the spark is such that the latter burn away rapidly, necessitating frequent adjustment. As it is next to impossible to adjust four or six vibrators so that they will operate uniformly, it will be apparent why the vibrator coil was given up as soon as the magneto demonstrated that it was not a mystery beyond the understanding of the average motorist. The vibrator coil is accordingly obsolete and but for the fact that its existence has been extended by the Ford, it would probably be unknown to the majority of present-day motorists.

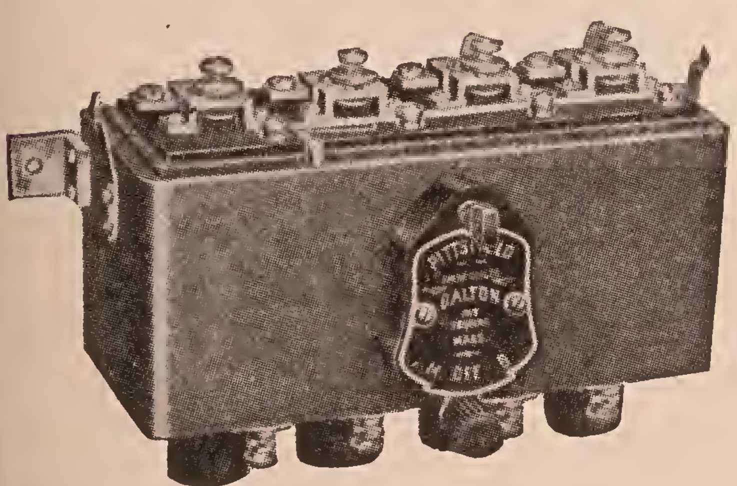


Fig. 45. Pittsfield Multi-Vibrator Coil
Courtesy of Pittsfield Spark Coil Company, Dalton, Massachusetts

Master Vibrator. To overcome the shortcomings of the four-unit vibrator coil, it is necessary to add a fifth coil. The latter is fitted with an especially sensitive and well-made vibrator which takes the place of the four vibrators on the original coils, so that the extra coil is termed a *master vibrator.* In operation, all four of the original vibrators are screwed down hard so as to make a permanent connection, and the fifth coil is connected in the primary circuit so that the action of its vibrator breaks the circuit in the

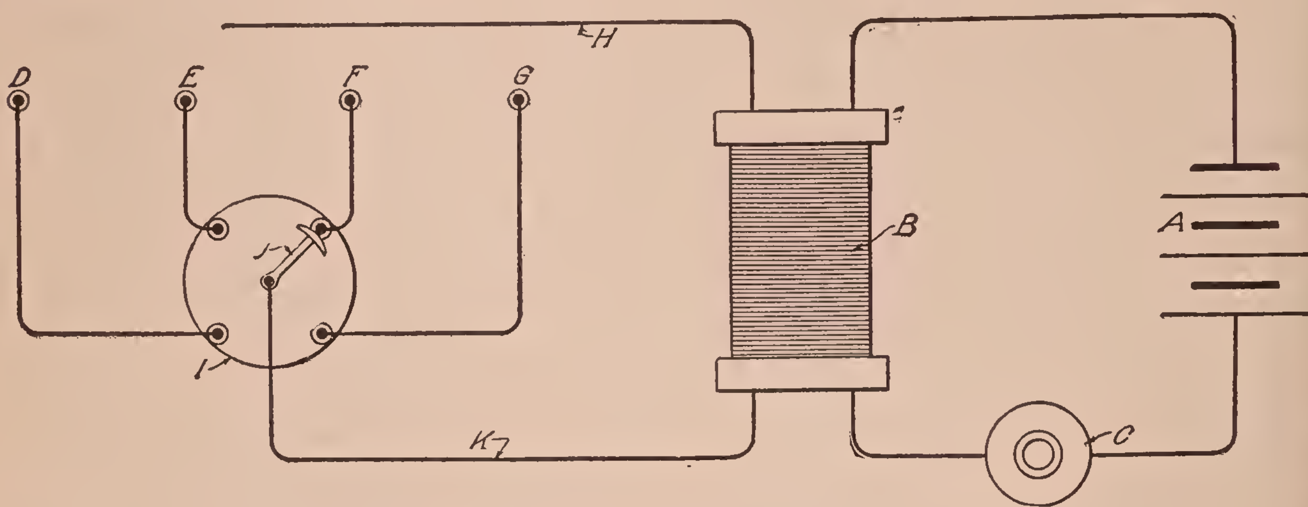


Fig. 46. Wiring Diagram of Non-Vibrator High-Tension System

primary of each one of the coils in turn. It is accordingly only necessary to adjust a single vibrator, and regardless of whether this adjustment be good or bad, it is uniform for all four cylinders so that they fire with the same timing. But at the best, the arrangement is only a makeshift as the vibrator coil long ago ceased to have any legitimate excuse of existence on the automobile.

Fig. 47. Atwater-Kent Distributor

Non-Vibrator Coil. As the term indicates, this is simply an induction coil minus the vibrator. But instead of using four coils, as with the vibrator type, a single coil is employed, and a distributor is inserted in the secondary or high-tension circuit. The essentials of such a system are shown by Fig. 46, a battery being indicated as the source of current. The timer *C* is driven by the camshaft of the motor so that the battery circuit is successively closed and opened in the usual firing order of the cylinders, four contacts being made for each two revolutions of a four-cylinder four-cycle motor. The contact is of sufficient duration to permit the coil to "build up", i.e., to have its soft iron core become thoroughly magnetized, and is then quickly broken. At the instant that the latter occurs, the finger *J* of the distributor is passing the contact of the cylinder F to be fired. The timer and distributor must accordingly be driven synchronously, so that the contacts in both occur simultaneously. This is accomplished by combining them in a single unit, as shown in Fig. 47, illustrating the Atwater-Kent "Unisparker", or as in the various types of magnetos illustrated further along.

Limitations of current supply having been overcome by the adoption of the magneto or the storage battery kept charged by the lighting dynamo, non-vibrator coils are usually wound to a higher resistance than the old vibrator coils, so as to produce a current of higher tension in the secondary. As this type of coil requires no adjustment, it is generally installed horizontally with its face flush with the dash, and on this face is mounted the switch giving three control points, i.e., neutral, battery (for starting), and magneto. The Remy dash coil, Fig. 48, is a typical example.

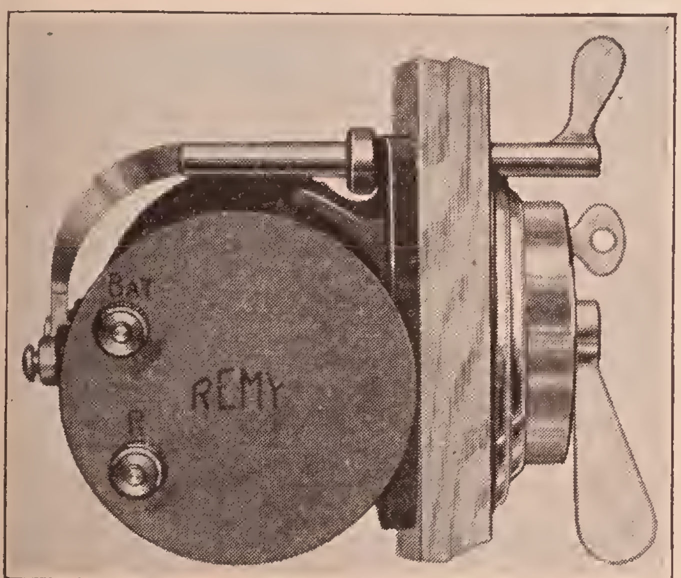


Fig. 48. Remy Single Non-Vibrator Coil Showing Method of Installation

Distributor. This is simply a modification of the timer, designed to handle the high-tension current, or to distribute it to the different plugs. It takes the place of the multi-unit coil in which an independent coil is employed for each cylinder. Owing to the high voltage of the secondary current, actual contact is not necessary in a distributor, a small gap or clearance presenting no obstruction to the passage of the high-tension current, so that wear at this point is avoided. In the earlier types, a brass arm passing close to contact points, or sectors embedded in hard rubber, was usual. Carbon brushes making contact against the disk by means of light springs, were subsequently adopted and are now commonly used. As the carbon is very hard and its contact surface becomes glazed by the friction, the wear is practically negligible. The complete wiring of a distributor system is shown in Fig. 46. H is the ground or common-return connection of the secondary circuit and K is the connection to the distributor I, from which the high-tension current is distributed by the arm J to the spark plug leads D, E, F, and G.

Condenser. The condenser is technically known as an electrical "capacity" in that it has the ability to absorb a quantity of electricity proportioned to the area of its conducting surfaces and to the nature of the dielectric employed. This property is utilized to absorb the excess current passing at the moment the primary circuit of the ignition system is opened by a vibrator, thus bringing about a quick cessation of the current flow and preventing the destructive arcing or burning that would otherwise occur at the contact points. The charge thus absorbed is immediately returned to the circuit in the form of a discharge, when the points come together again and a higher potential value is impressed upon the current. A condenser consists of conducting surfaces placed between insulating surfaces, known as the dielectric. For ignition work, the conducting surfaces are sheets of thin tinfoil cut with conducting tabs which project beyond the ends of sheets of paraffined paper on which the tinfoil is placed. Between each two sheets of paraffined paper is placed a sheet of tinfoil, the latter being arranged so that the tabs project at alternate ends, Fig. 49. The paraffined paper overlaps the tinfoil all around to the extent of an inch or more to prevent a discharge over the edges of the sheets. The capacity of the condenser depends upon the number and the size of the sheets of tinfoil and the thinness and the character of the dielectric separating them; and, when a sufficient number have been assembled, the projecting tabs at each end are riveted or clamped together and a flexible wire lead connected to each. It is then connected in multiple with the vibrator, and, in the case of a coil is inserted in the containing case of the latter and further insulated as well as held in place by having molten paraffine poured around it so as to fill the space. A condenser practically eliminates sparking at the contact points and is also used with the contact breaker of a magneto.

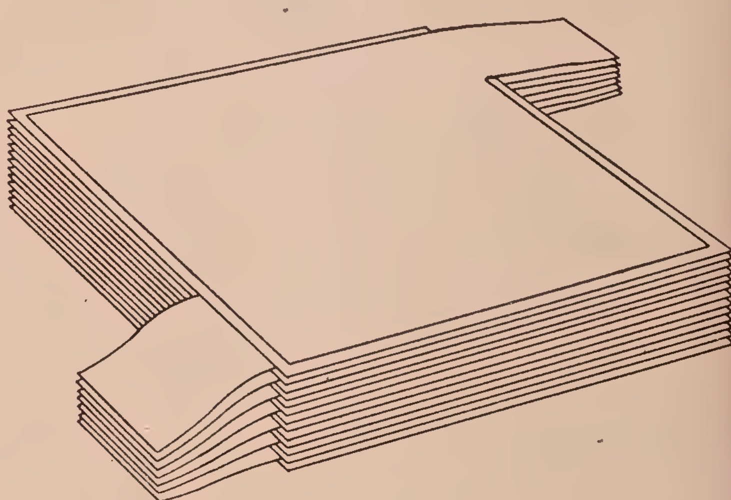


Fig. 49. Sketch of Condenser

Spark Plugs. No small part of the trouble experienced with early ignition systems was due to the defective design of the spark plugs employed. Where an over-rich mixture is delivered by the carbureter, i.e., one containing too much gasoline in proportion to the air, a certain amount of the carbon is unburned and remains in the

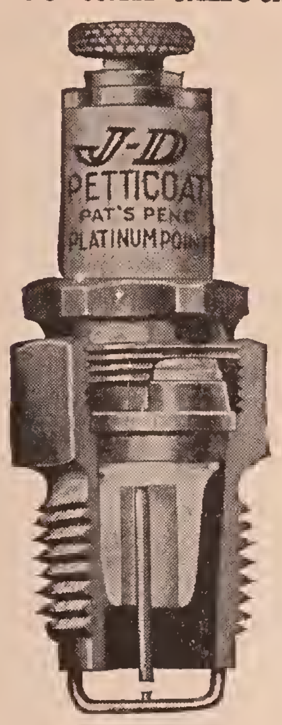


Fig. 50. Chambered-End Spark Plug

Fig. 51. V-Ray Spark Plug

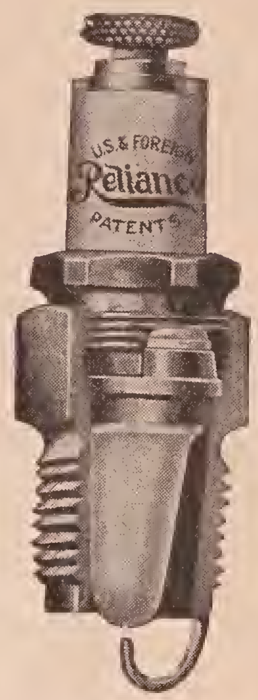


Fig. 52. Open-Point Spark Plug

cylinder in the form of soot. This is greatly increased by an excess of lubricating oil finding its way into the combustion chamber. The heavier carbons of this burn to the same consistency and are also deposited on the piston head, cylinder walls, valves, and other exposed surfaces in the form of a flint-hard coating. The end of the spark plug receives its share and, as the carbon is an excellent conductor, the plug is accordingly short-circuited, so that the current, instead of jumping the gap between the points, takes a path of lower resistance across the carbon-coated insulating surfaces.

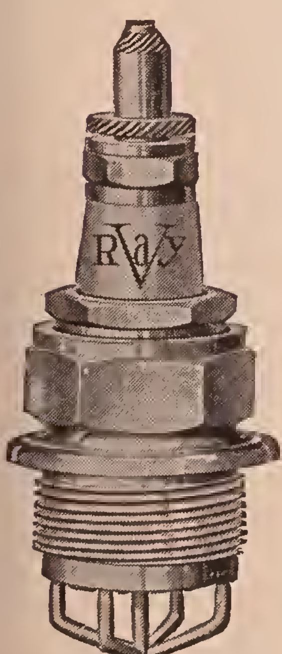


Fig. 53. Multi-Point Spark Plug

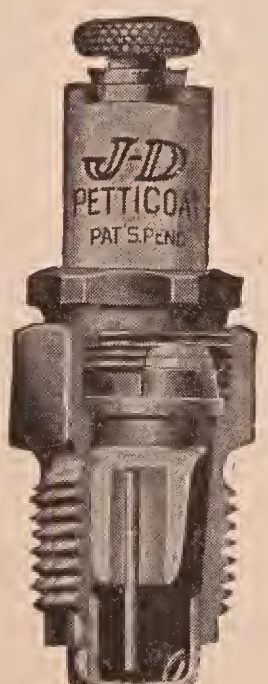


Fig. 54. J-D Spark Plug

Fundamental Requisite. The spark plug is the "business end" of the ignition system and no matter how elaborate or efficient the essentials of the latter may be, its successful operation is governed entirely by that of the plug. As originally designed, the insulating material filled the shell at the sparking end, affording a direct path for the current as soon as this small surface became covered with carbon. Failure was accordingly frequent, it being nothing unusual to have to clean such a plug in less than fifty miles of running. To overcome this, a recess was allowed between the insulation of the central electrode and the outer shell. This simple expedient constitutes a basic patent (Canfield) under which all spark plugs are manufactured. Porcelain, mica, or artificial stone is used as the insulating material, the first-named being most generally employed. This is made in various forms, as shown by the sections, Figs. 50 and 51, and it will be noted that the smaller diameter of the insulated

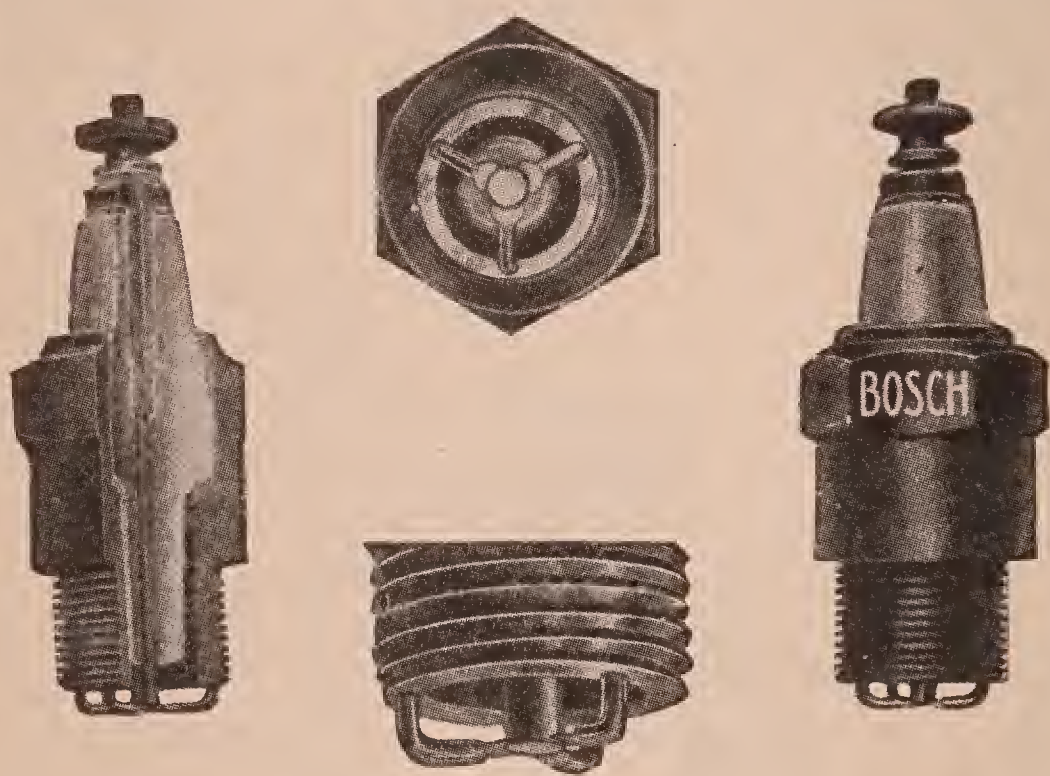


Fig. 55. Bosch High-Tension Spark Plug

electrode in the center greatly increases the area of the surface of both shell and porcelain that must be coated with carbon before a path is formed for the current.

Electrode Arrangement. Practice also varies considerably in the arrangement of the electrodes, taking the form of open points as in Fig. 52, a bridge as in Fig. 50, or a number of points as shown in Figs. 51 and 53. In some instances, the central electrode is enclosed in a chamber, the gas entering through a small hole in the shell, as shown in Fig. 54. Considerable advantage is claimed for the type of plug having a plurality of gaps, the number usually being three, as shown in Fig. 55, or four as in Fig. 53. It is more theoretical than actual, however, as the current always takes the shortest path and the bridging of any one of the gaps by a particle of conducting material, such as carbon, short-circuits all of them.

Series Plugs. As shown in the various wiring diagrams, the shell of the plug is one of the electrodes and forms a part of the circuit by being screwed into the cylinder, the latter constituting part of the common ground return for both the primary and the secondary circuits of all ignition systems. Experiment has shown a slightly increased power resulting from the simultaneous occurrence of two sparks in different parts of the combustion chamber of the cylinder, especially with the T-head type of cylinder in which the two plugs can be located in the oppositely placed valve ports. This is termed double-spark ignition and the type of magneto designed for this purpose is described in the section on "Magnetos". To obtain the same result with the standard ignition circuit designed to produce but one spark in each cylinder, what is known as a "series" type of plug has been developed. One of these is shown in Fig. 56. In this the spark occurs between two central electrodes, as shown, the shell not forming a connection with the cylinder. The lead from the distributor is attached to one of the binding posts of this plug and a second wire connected to the other binding post is led to a standard type of plug, thus completing the circuit and placing both plugs in series so that a spark occurs simultaneously in both. By means of an attachment as shown in Fig. 57, this type of plug can be used with a grounded return, the arm shown connecting the shell in the circuit. As the majority of motors now in use have L-head cylinders, and even at the best the advantage gained is very slight, the use of series plugs has not a great deal to recommend it.

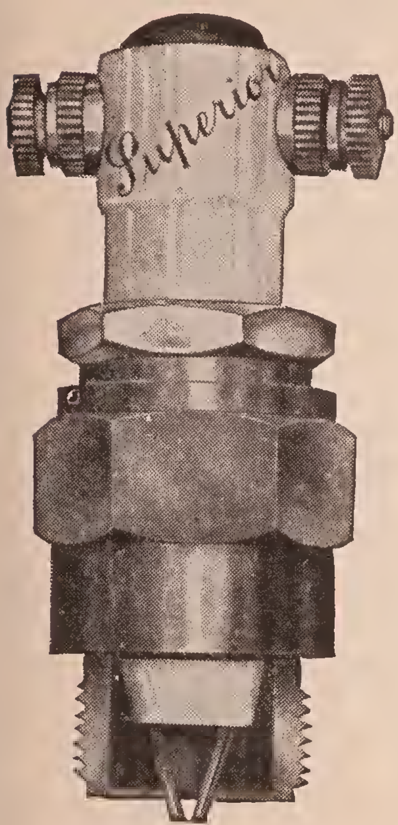


Fig. 56. Series-Type Spark Plug

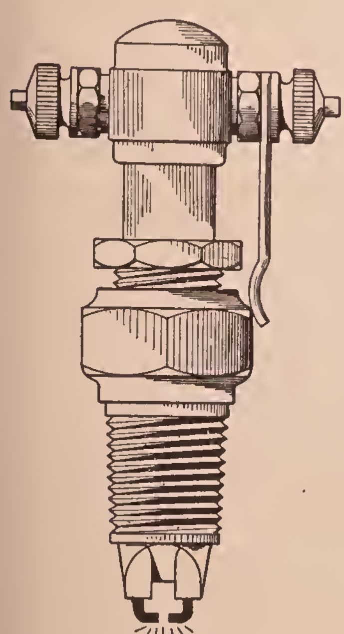


Fig. 57. Method of Converting Series Plug

Magnetic Plugs. With a view to overcoming the defects of the mechanically operated make-and-break plug as used on low-tension ignition systems, an automatic plug was developed. As shown by the section, Fig. 58, this is simply a solenoid *A* and plunger *C*, the latter being held in contact at *D* by a spring *B*. The current passing through the winding *A* lifts the plunger and the spark occurs at *D*. The remainder of the system consists of a low-tension magneto or other source of current supply and a timer. Such plugs have been used to some extent on stationary engines, but have not proved practical on the automobile motor, as the high temperatures drew the temper of the plunger spring and often burned out the insulation of the winding.

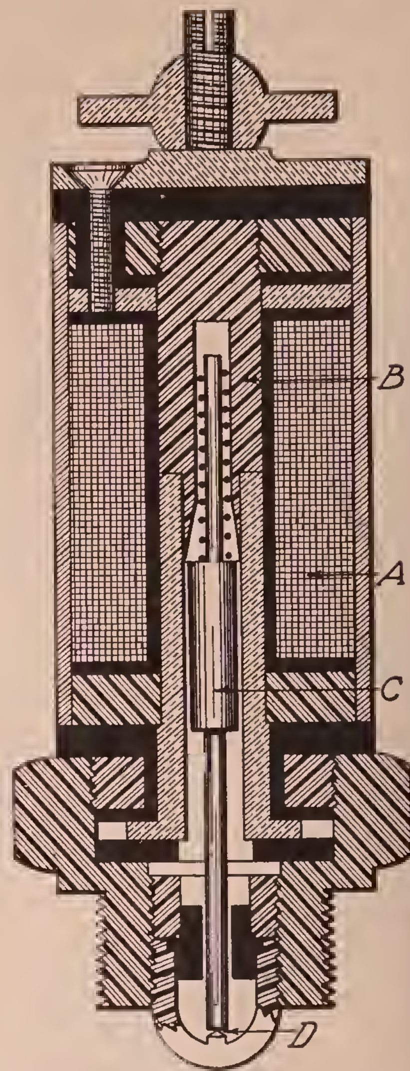


Fig. 58. Low-Tension Magnetic Spark Plug

Priming Plugs. For low-priced motors, such as the Ford, which have no pet cocks or compression-release cocks on the cylinders, a spark plug combined with a pet cock, such as that shown in Fig. 59, can be had. These are usually known as "priming" plugs in that they permit of priming the cylinder with gasoline to render starting easy in cold weather.

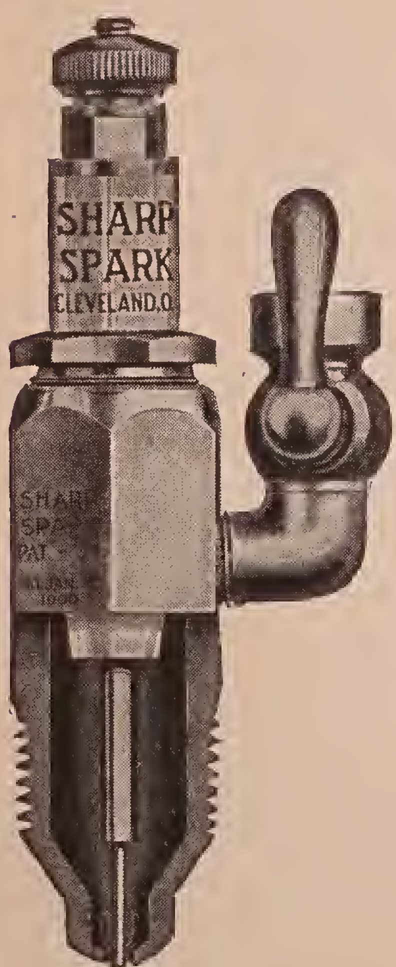


Fig. 59. Priming Type Spark Plug

Waterproof Plugs. Ignition systems, on motor-boat engines in particular, are apt to suffer short-circuiting from spray or dampness, though this often happens on the automobile as well in heavy rainstorms. To guard against this a so-called waterproof type of plug is provided. The precaution usually takes the form of a hood of hard rubber or other insulating material placed over the connection, as shown in Fig. 60.

Plug Threads. European practice has standardized a straight-threaded plug, the thread itself usually being of fine pitch. A plug of this kind is screwed home on a gasket of copper and asbestos or of the latter material alone, which is relied upon to prevent leakage. Foreign types are usually referred to as "metric" plugs, as the thread dimensions are based on the metric standard. As developed at first in this country, all spark plugs were made with an "iron-pipe" thread. This has a taper of three-fourths inch to the foot and the plug is screwed into the cylinder as far as the taper will permit, no other provision being made to hold the compression. As this is a crude expedient, adopted chiefly because of its cheapness, and the metric standard is not employed here, an S.A.E. standard plug has been developed along the same lines, both the plug diameter and the thread itself being made somewhat larger than those used abroad.

Fig. 60. Spark Plug with Waterproof Connections

INDUCTION SOURCES OF IGNITION CURRENT—MAGNETOS

Owing to the failure of either dry cells or storage batteries to supply sufficient current to operate the wasteful contact devices at first employed, mechanically driven current generators were adopted. American practice at first favored the small, high-speed direct-current dynamo, but as proper regulating devices had not then been developed, it was not successful, chiefly because its speed range was so limited. Few of these little dynamos generated sufficient current at less than 1200 r.p.m. to ignite the charge in the cylinder, so that at slow speeds they would not run the motor. If run much faster, they burned out and were accordingly abandoned.

Working Principle. The magneto is simply a small dynamo in which the fields consist of permanent magnets, instead of electro-magnets, the cores of which only become magnetic when a current is passed through their windings. Hard steel, particularly when alloyed with tungsten, retains a very substantial percentage of its magnetism, after having been once magnetized by contact with a powerful electromagnet. Its retaining power is further increased by placing a "keeper", or armature, across the poles or ends. The advantage of a permanent field for magneto use is that it is at its maximum intensity regardless of how slowly the armature is revolving so that a good spark is produced at very low speeds; while its initial value cannot be exceeded no matter how fast the machine is run, so that the armature winding cannot be burned out. All magnetos generate an alternating current so that when used with a coil there is no necessity of frequently making and breaking the circuit, as is done by the vibrator of a coil handling direct current, the alternate surges of current from zero to maximum of opposite polarity producing the same effect more efficiently.

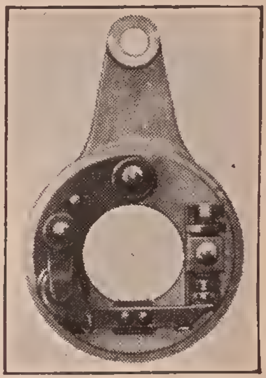


Fig. 61. Remy Magneto Contact Breaker

Low-Tension Magneto. A low-tension magneto is nothing more or less than the simple instrument which formed part of the thousands of telephones of the hand-ringing type still to be found in rural districts. Built with more powerful magnets and wound to give a greater current output at a lower voltage, it was employed in connection with low-tension ignition systems. A magneto of this type is illustrated by

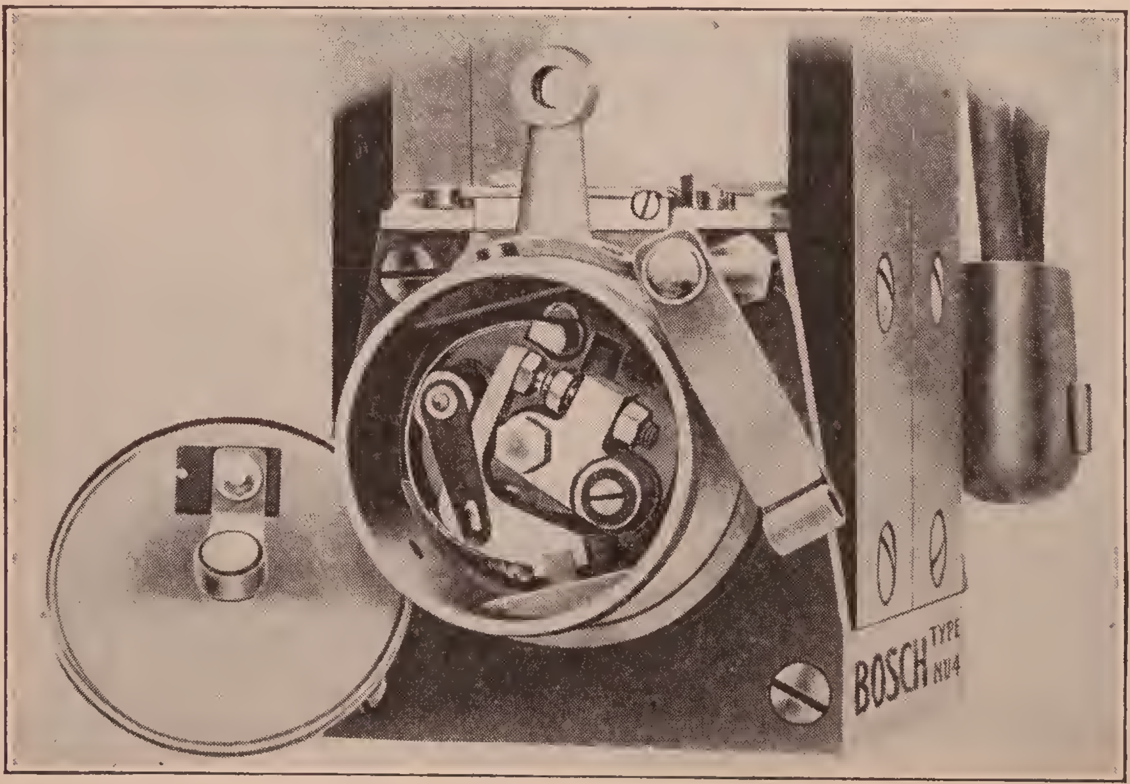


Fig. 62. Contact Breaker of High-Tension Magneto (Bosch)

Fig. 39. As the mechanically operated make-and-break plugs are timed, the magneto is simply revolved continuously without reference to the motor timing, the current being constantly delivered to the circuit through the usual collector ring and brushes. Magnetos

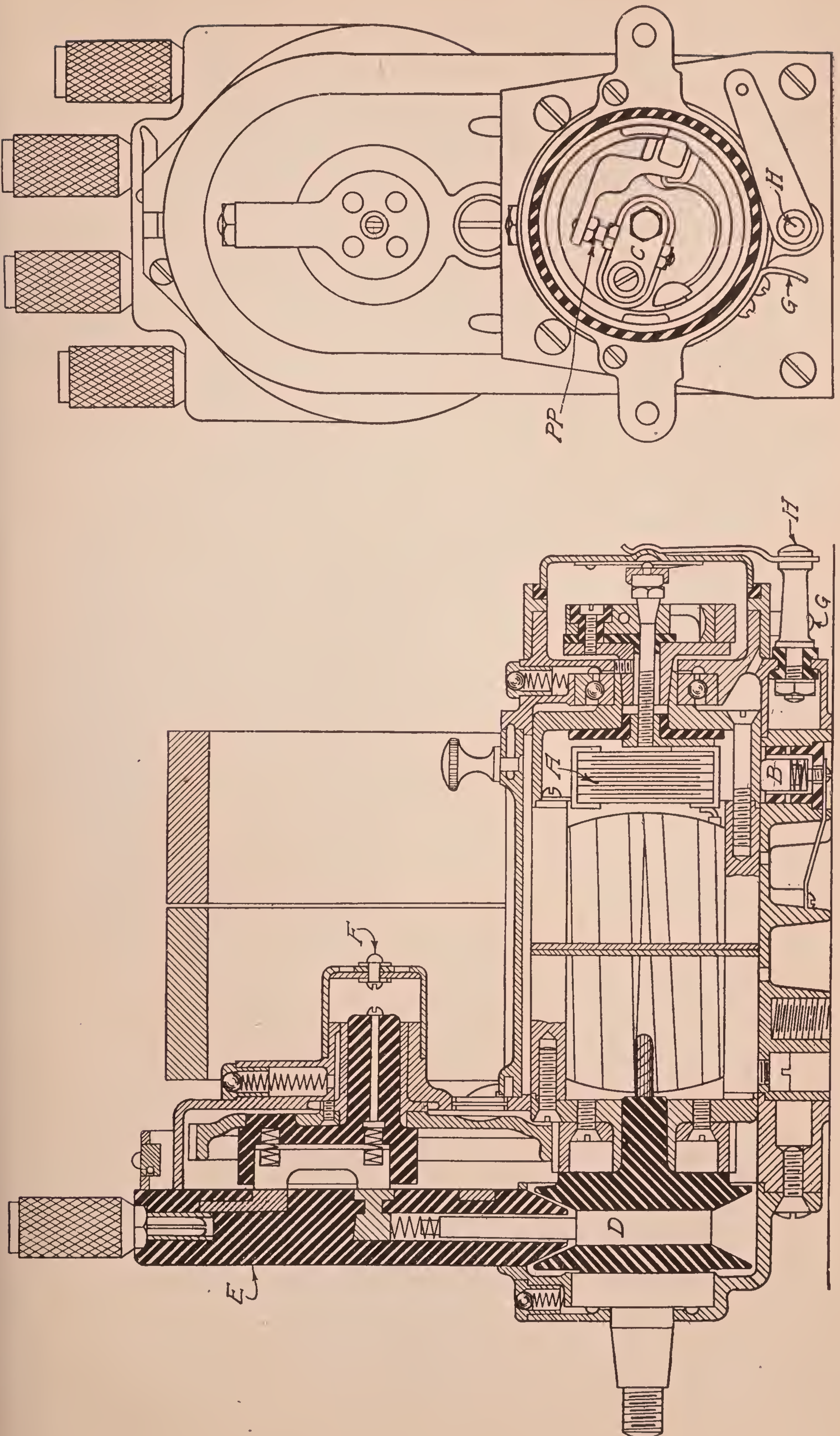


Fig. 63. Sectional and End Views Through High-Tension Magneto (*Horseless Age*)

of this type are still used to a greater or less extent on large, slow-speed stationary engines.

High-Tension Magneto. Essentially all magnetos are the same: that is, they have a permanent magnet field and a two-pole armature. In what may be best identified by terming it the *true high-tension type,* there are two windings on this armature, a primary winding of comparatively coarse wire in which the current is generated, and a secondary winding of fine wire, the same as an induction coil. A magneto of this type is timed with the motor according to the number of cylinders, being driven at crankshaft speed in the case of a four-cylinder motor and at one and a half times crankshaft speed in the case of a six. In addition to the usual current-collecting device, it is equipped with a contact breaker or interrupter, such as that shown in Fig. 61, which is part of a Remy magneto. Fig. 62 shows the same essential of a Bosch light-car type magneto. Except at the point in the revolution at which the spark is to occur in the cylinder, the armature circuit is normally short-circuited upon itself. This permits it to "build up", so to speak; that is, as the armature poles come within the most intense part of the field, the current in the armature winding reaches its maximum value and, at this moment, the contact points of the breaker are opened and a strong current is induced in the secondary winding. As the distributor runs synchronously with the contact breaker, the circuit to one of the plugs is closed at the same time the spark occurs at it.

Description of True High-Tension Type. A sectional view of a true high-tension magneto is shown in Fig. 63. In this the primary and the secondary windings on the shuttle armature are entirely separate to insure better insulation. These windings are not shown in section in the illustration, the usual insulating tape winding being indicated on the armature. Twice during every revolution of the armature, the primary circuit is opened at the platinum points *P P* of the circuit breaker, the interruption occurring substantially at the moment when the primary current is at its maximum. From the primary winding, the current is conducted to the stationary member of the contact breaker *C* through the terminal *B*. *A* is the condenser. One terminal of the secondary winding is connected to the end of the primary winding, as in a coil, and the other connects with the high-tension collector ring *D*, from which it is conducted through a carbon brush to the brush of the distributor above it for distribution to the four brass segments in the distributor plate *E*. These segments are connected to the four terminals shown extending above the magneto in the end view at the right and from them the usual high-tension cables are led to the plugs. The distributor is driven from the armature shaft of the magneto through 2 to 1 gearing so that it only makes one revolution for two turns of the crankshaft in the case of four-cylinder four-cycle motor, as in the latter but two explosions occur per revolution. To vary the time of occurrence of the spark in the cylinders, the contact breaker may be turned through part of a revolution by means of a rod and linkage fastened to one of the extensions of the contact breaker box, as shown in the end view. This connects with the spark timing lever on the steering wheel and, to stop the action of the magneto, it is only necessary to move this lever to the extreme retard position, which brings the spring *G* in contact with the bolt *H* and short-circuits the secondary winding.

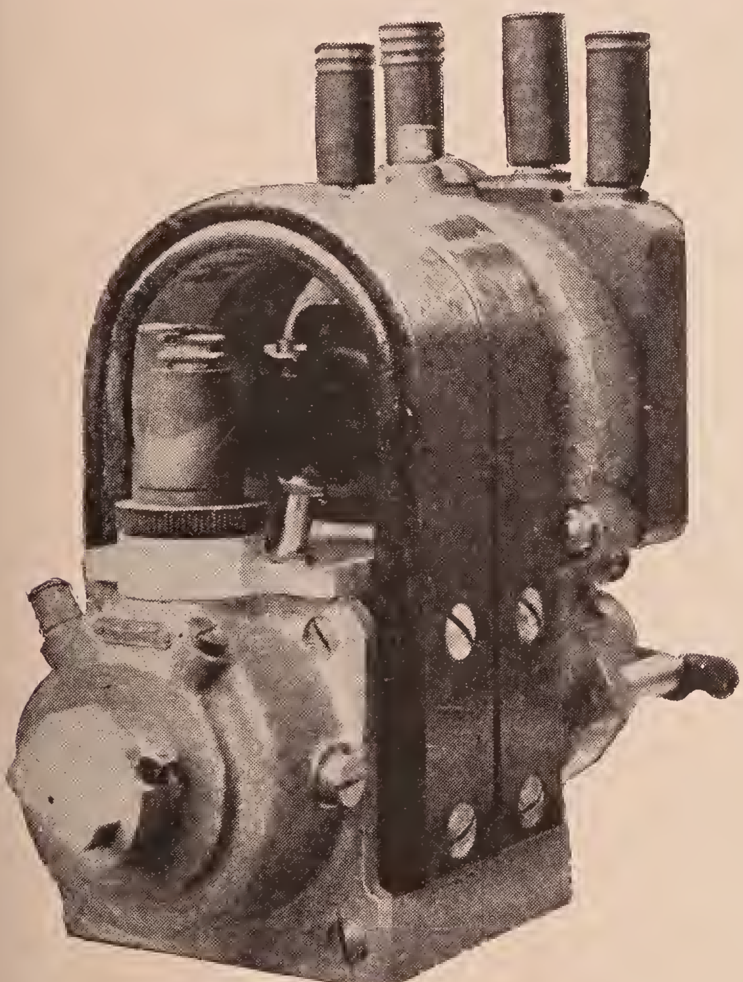


Fig. 64. Contact-Breaker End, Nilmelior Magneto

The magneto, Fig. 64, differs from the section, Fig. 63, chiefly in detail. The vertical plug just back of the contact-breaker box incorporates the safety gap.

Typical High-Tension Magneto Circuit. Fig. 65 is the wiring diagram for a high-tension system, using a true high-tension type magneto. *C* and *B* are the wires of the primary circuit, in which circuit there are also included, besides the current-generating coils of the armature, an induction coil built into the magneto, for raising the current tension, and a contact breaker *E*, which is carried on the same revolving spindle that bears the armature. The dotted lines indicate the ground return.

High-Tension Type with Coil. This is not actually a high-tension magneto, properly so-called, as it only generates a low-tension current, which is subsequently stepped up through a transformer or non-vibrator coil, but it is commonly so termed as it is always used in connection with a high-tension ignition system. In this case there is only a single winding on the armature and the current is led from the latter through the usual contact breaker and then to an independent coil, generally located on the dash. The condenser is combined with the coil, and from the latter the high-tension current is led back to the magneto to be distributed. Owing to its lower cost, this type of

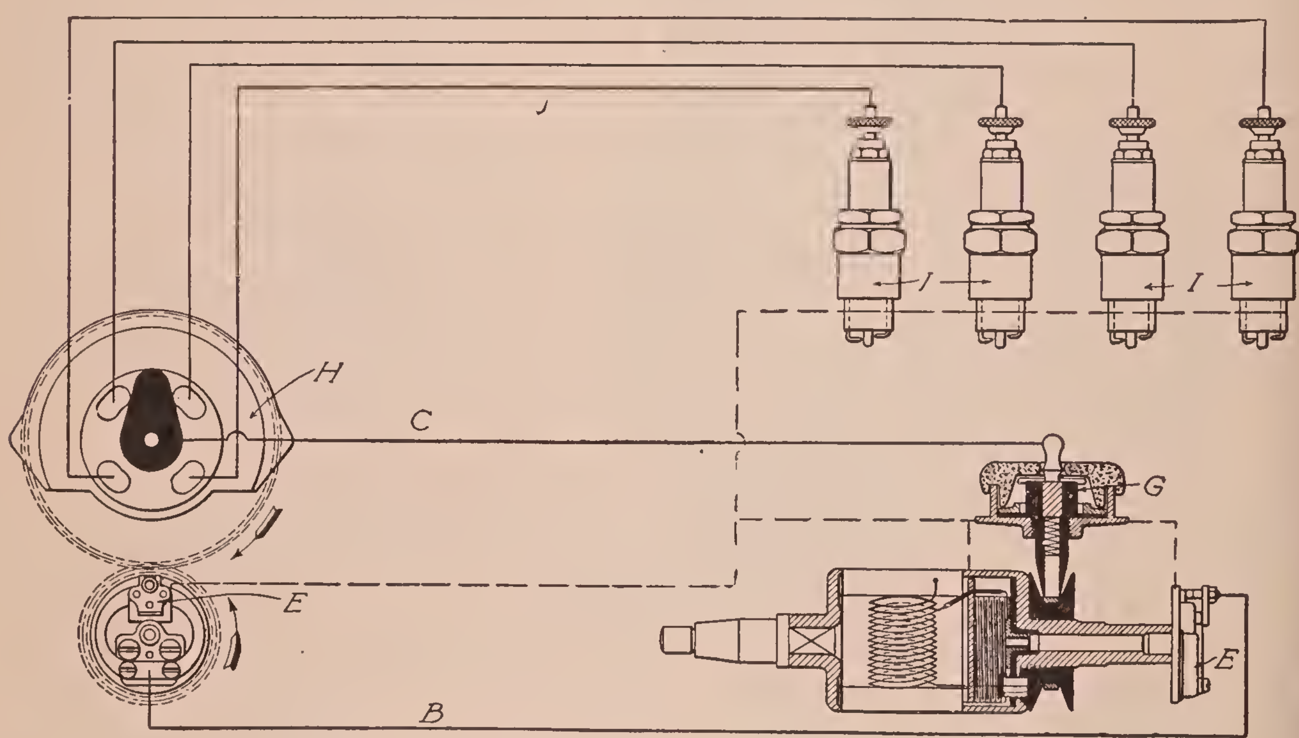


Fig. 65. Wiring Diagram of High-Tension Magneto System

magneto is probably more generally employed, especially on medium-priced American cars, than any other.

Safety Gap. If the current induced in the secondary winding of an induction coil meet with a resistance in the outer circuit in which the coil is connected, greater than the resistance presented by the insulation of its own windings, it will puncture this insulation and the expensive coil will be ruined. The placing of such a resistance in the high-tension circuit occurs when the connection of a spark plug is removed from the plug terminal and is allowed to dangle in the air beside the motor and, unless this were guarded against, it would result in the breakdown of the ignition system. The precaution takes the form of a safety gap. This is an opening inserted in the circuit, and its length is based on the safe maximum distance that the coil can bridge in normally dry air. A safety gap of this kind is shown at *F* in Fig. 63. In the type of magneto just described above it is embodied in the coil. When an opening at any point in the high-tension circuit exceeds the length of this gap, the current takes the path thus provided, thus preventing the imposition of an excessive strain upon the insulation of the secondary windings.

Wiring Connections. For the actual operation of an induction coil, there is no necessity for any electrical connection between the primary and the secondary windings, the electrical energy being transferred from one to the other entirely by induction, i.e., through the intermediary of the magnetic lines of force which interlink both. However, for the sake of simplicity of external connections, the beginning of the secondary winding is usually connected to the end of the primary. Both the primary and the secondary circuits have a "ground return", which necessitates that one end of both the primary and the secondary winding of the coil be placed in positive metallic connection with the engine or car frame. By connecting the two windings, as mentioned, a single wire serves to ground both. The average coil, therefore, has only three terminals, i.e., one primary, one secondary, and one common ground connection.

On cars that are provided with magneto ignition alone, as is the case with French taxicabs and many other French light cars, there would be only two connections between the magneto and the coil, one primary and one secondary; one connection from the coil to a ground, as the motor or frame; and four connections direct from the magneto distributor to the spark plugs. This represents an ignition system reduced to its lowest terms of simplicity. As a matter of fact, it is even more simple in reality, as most French cars use the true high-tension type of magneto so that the four leads from the magneto to the plugs are the only external wires in evidence. Unless a magneto is in excellent condition, however—and the magnets lose their strength more or less rapidly under the influence of the heat and vibration—too much effort is required to start the motor. American manufacturers accordingly supply a battery for starting purposes, and on some of the high-priced cars this takes the form of an entirely independent battery ignition system, i.e., having a battery, coil, timer, distributor, and a separate set of spark plugs. It also constitutes an emergency system that may be resorted to in case of a breakdown of the magneto, but the latter is so rare and the cost and complication of the extra system are such that the latter is not generally used. Instead, the magneto coil, contact breaker, and distributor are utilized with the battery as the source of current.

Inductor=Type Magneto. Mention has been made in the introductory of the fact that if a coil of wire be moved so as to cut the lines of force of a magnetic field, an e.m.f. will be induced in the wire. If, instead of moving the wire, a magnetic flux be made to pass through it first in one direction and then in the other, the same result will be obtained, i.e., an alternating e.m.f. will be produced,

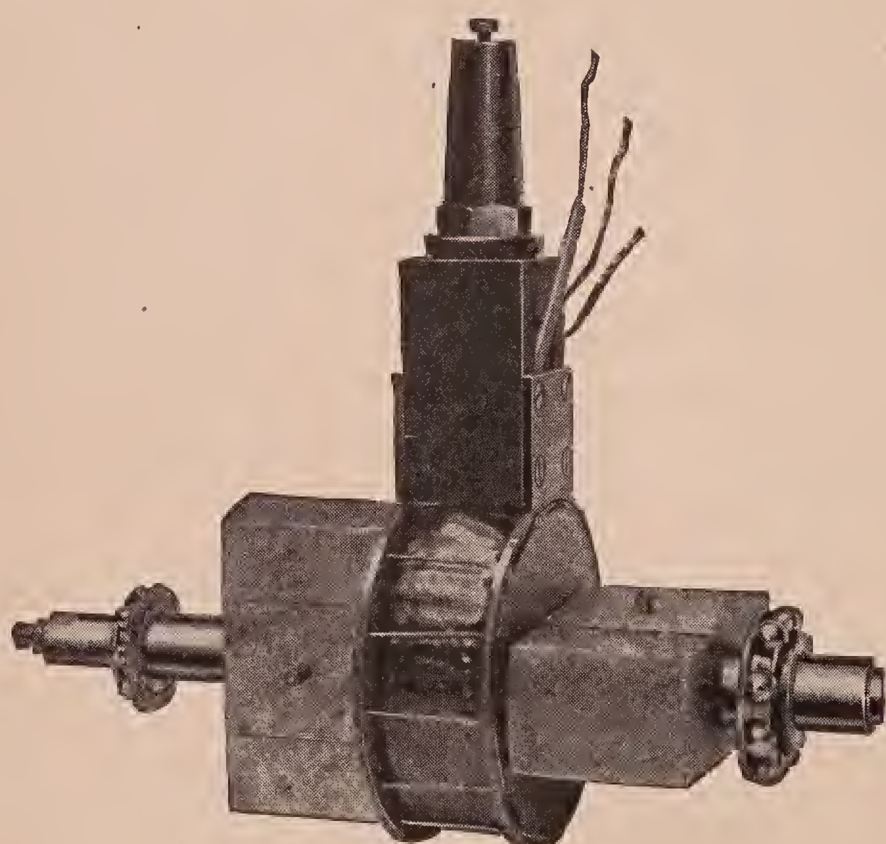


Fig. 66. Rotor and Winding of K-W Inductor Magneto
Courtesy of K. W. Ignition Company, Cleveland, Ohio

and, if the wires be connected to an outside resistance, a current will flow. This is the principle of the *inductor magneto* which is so termed because the current is induced in its winding instead of being directly generated in the latter.

Typical Construction Details and Current Production. The magnetic field is produced by permanent magnets in the same manner as on other types of magnetos and a mass of laminated soft iron is rotated between the pole pieces while the winding is stationary. The moving element is termed the rotor, and this part of the K-W high-tension magneto is shown in Fig. 66. The stationary winding in the center is mounted on the shaft of the rotor and consists of a primary and secondary coil.

There is no mechanical or electrical connection between the windings and the rotor shaft, nor between the laminated blocks of the rotor and the windings. As shown in the illustration these are placed at right angles to one another and are riveted to the shaft. It will be evident that in the position shown in the illustration the right-hand member of the rotor will be bridging the pole pieces of

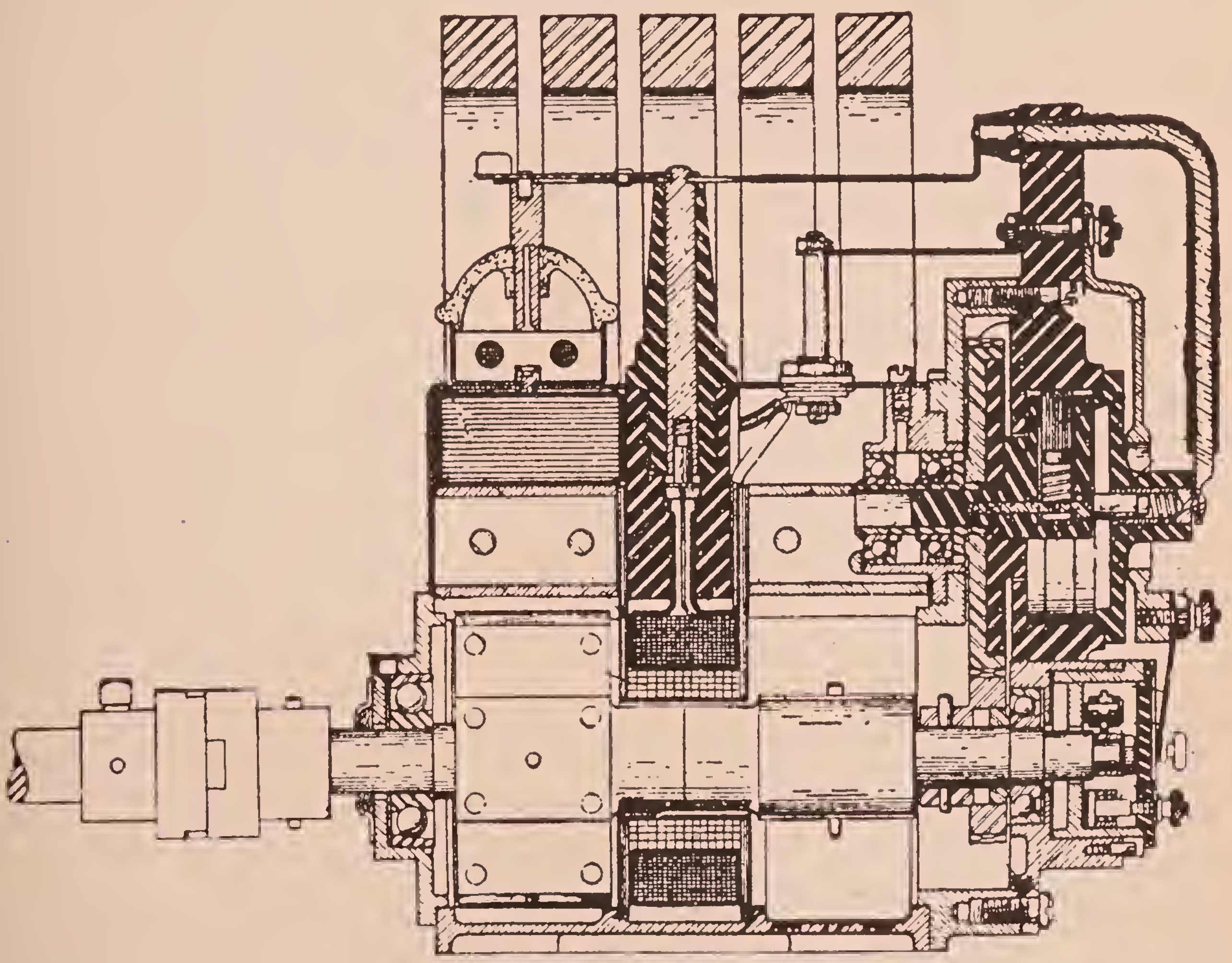


Fig. 67. Section through K-W Inductor Magneto
Courtesy of K. W. Ignition Company, Cleveland, Ohio

the magnetic field; by giving the shaft a quarter turn the two rotor members will have their ends facing opposite poles of the magnetic field, thus completing the magnetic circuit through the center of the windings. Consequently, a current wave will be produced each time the rotor revolves through a quarter-turn, or 90 degrees, so that this inductor magneto produces four impulses per revolution instead of two as in the ordinary type having a wound bipolar armature of H form. Apart from the method of producing the current, the remaining essentials of the magneto are the same, except that no collector brush is necessary as is the case where the current is generated in a revolving winding on an armature.

The details of construction of the K-W high-tension magneto are shown in Fig. 67. While, from an external view of the rotor, it apparently consists of two independent parts, it will be seen in the section that it is practically one piece, the connecting part passing through the center of the winding so that the magnetic circuit is completed through the latter. The primary winding, consisting of four layers of comparatively coarse wire, will be noted close to the rotor; just outside of this is the secondary winding of many layers of fine wire and from the latter the connection is carried upward to a horizontal strip of copper termed a bus bar. At the right, this bar connects with the distributor for the high-tension current; at the left it connects with the safety gap, directly beneath which is the condenser.

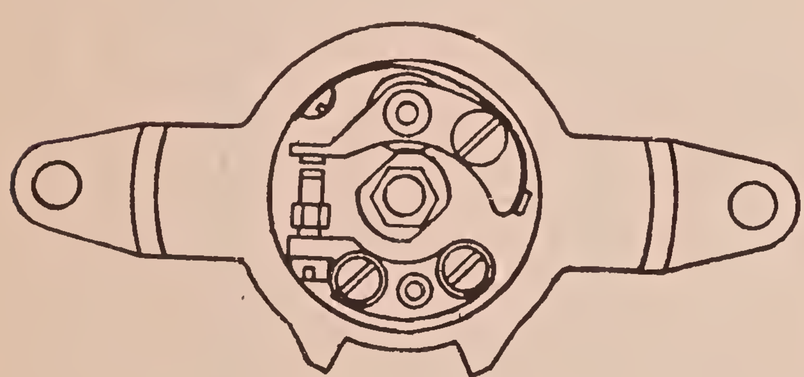


Fig. 68. K-W Interrupter

Timing. The magneto is timed by an interrupter operated by a cam on the rotor shaft in the usual manner; the details of this interrupter are shown in Fig. 68. As is the case with all ignition magnetos, these points remain closed, thus short-circuiting the primary winding, until the current reaches its maximum, and then are opened suddenly, thereby inducing a current in the secondary winding. The firing point of the magneto is just as the contact points begin to separate, as shown in Fig. 68, which is exaggerated to make this clear. At the same moment, the distributor arm is passing one of the segments connected to a spark plug, as shown in Fig. 69, the firing order of the motor in this case being 1, 2, 4, 3. While the magneto produces four waves per revolution, these are not necessarily all utilized; the cam (*c* in Fig. 69) opens the interrupter twice per revolution, giving two sparks for each turn of the crankshaft, as required by a four-cylinder four-cycle motor. In a four-cylinder two-cycle motor, a four-sided cam would be employed thus producing four sparks per revolution.

The letters on the illustration are: *A* contact breaker box; *c* cam;

P contact points of interrupter; *R* cam roller to lessen friction at that point; *B* distributor arm; *S* distributor segments; *RH* and *LH* referring to the direction of rotation, as either right hand—also termed "clockwise" or from left to right—and left hand, anti-clockwise.

Dixie Magneto. *Essential Elements; Circuits.* While based on the inductor principle, this differs from an inductor type of magneto in that the pole pieces themselves are revolved and they do not reverse their polarity as in the case of an inductor or an armature.

The rotating element of the Dixie is shown in Fig. 70; *B* is a brass block which prevents any magnetic flux flowing directly from

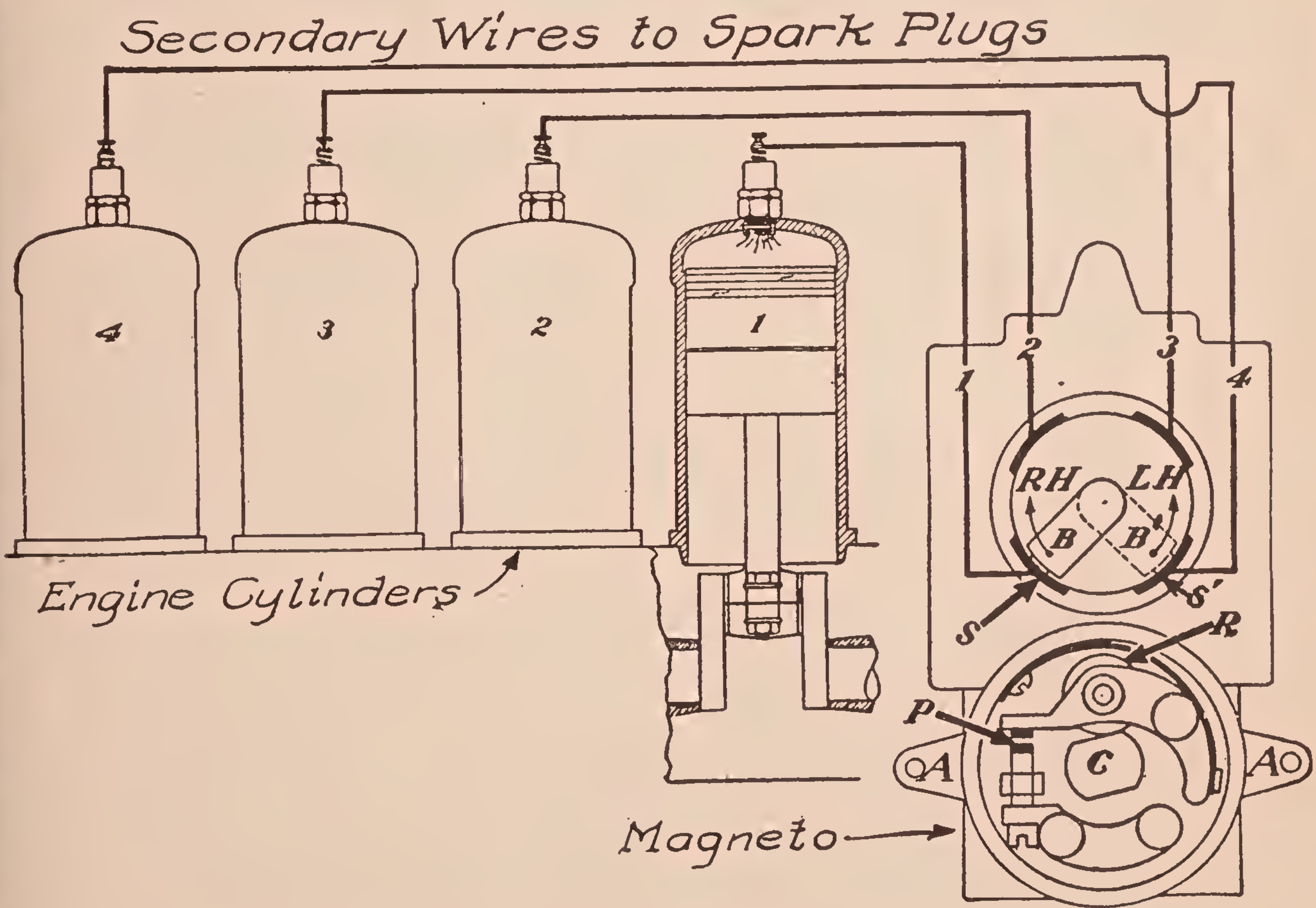


Fig. 69. Wiring Diagram for K-W Magneto Circuits

N to *S*, which are the rotating pole pieces. The coil with its primary and secondary windings is placed directly above this rotating element, in the hollow of the magnets, as shown in Fig. 71. At the right in the same figure is shown the relation between the rotor, the magnets, and the coil. It will be noted that the core of the coil *C* bridges the stationary pole pieces *F* and *G* and that the shaft of the rotor passes through the magnets in a plane at right angles to that of the usual magneto. The reversal of the magnetic flux, with varying positions of the rotor, is shown in the right-hand sketch of Fig. 71, and in Fig. 72.

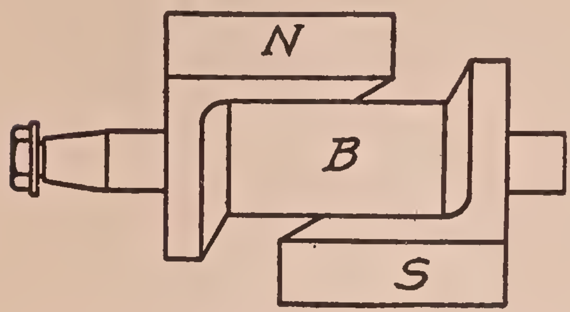


Fig. 70. Rotating Element of Dixie Magneto

The primary circuit of the Dixie is shown in Fig. 73; *A* being the core of the coil, *P* the primary winding, *R* the condenser, *X* and *Y* the points of the interrupter or contact breaker. The terminal *D* is a screw on the head of the coil, and the wire *Z* connects directly with the contact *Y* of the interrupter. Fig. 74 shows the details of this interrupter, the housing of which is attached to the mounting of the windings, while the details of the secondary circuit are shown in Fig. 75. *C* is the end of the high-tension, or secondary winding of

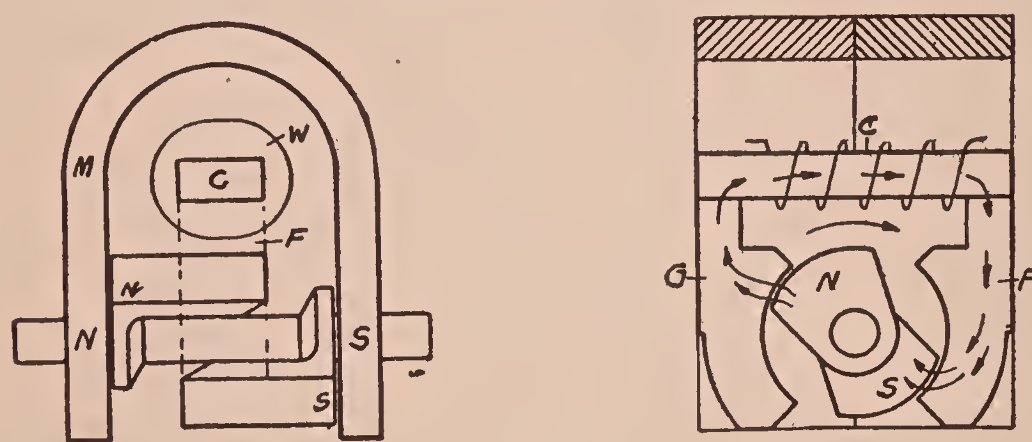


Fig. 71. Details of Dixie Magneto
Courtesy of Splitdorf Electrical Company, Newark, N. J.

the coil, which is connected to a metal plate *D* embedded in the hard-rubber end piece of the coil *A*. A small coil spring holds the

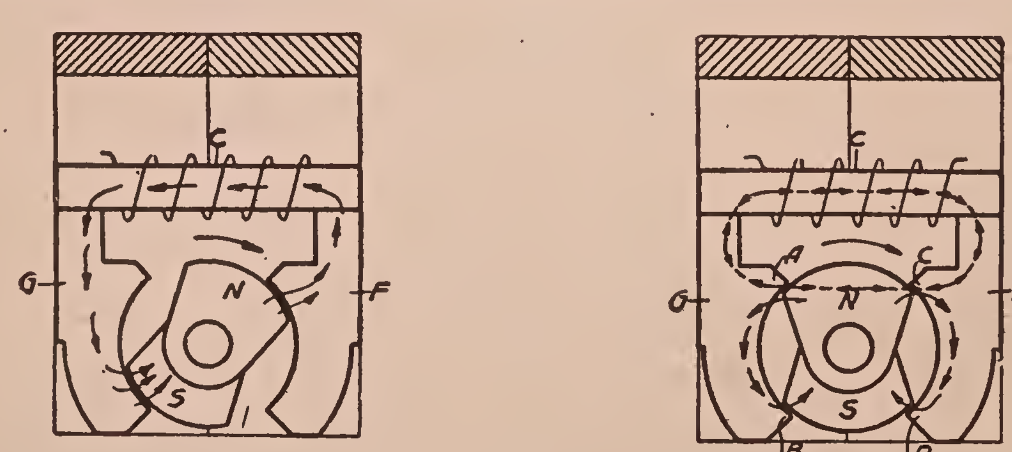


Fig. 72. Diagram Showing Reversal of Magnetic Flux in Dixie Magneto

connection *F* in contact with *D* and at its outer end *F* connects with *J* which is the distributor brush. The latter revolves, successively passing over the segments leading to the corresponding spark plugs.

But one of these segments is indicated by *L*, the dotted lines indicating the completion of the circuit through the ground connections.

Timing. As the contact-breaker box is attached to the mounting of the coil, the latter moves with it when the former is partly

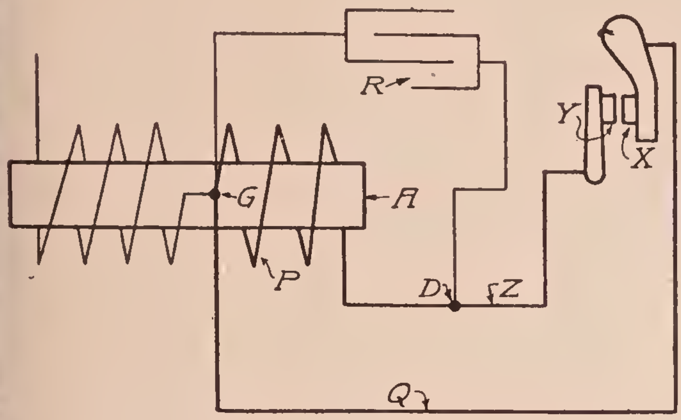


Fig. 73. Primary Circuit of Dixie Magneto

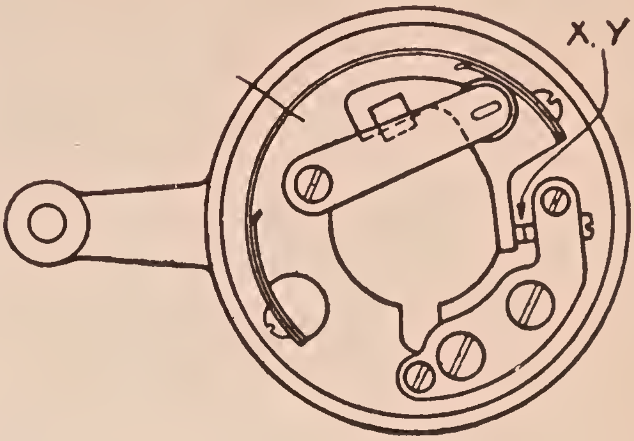


Fig. 74. Dixie Interrupter

rotated to advance or retard the occurrence of the spark in the cylinders, so that the opening of the contact points always takes place at the point of maximum current. This is shown diagrammatically in Fig. 76. As the contact points are opened by the revolution of the cam, it will be apparent that a movement of the mounting of these points with relation to the cam will alter the time at which they will operate. For example, assuming that the

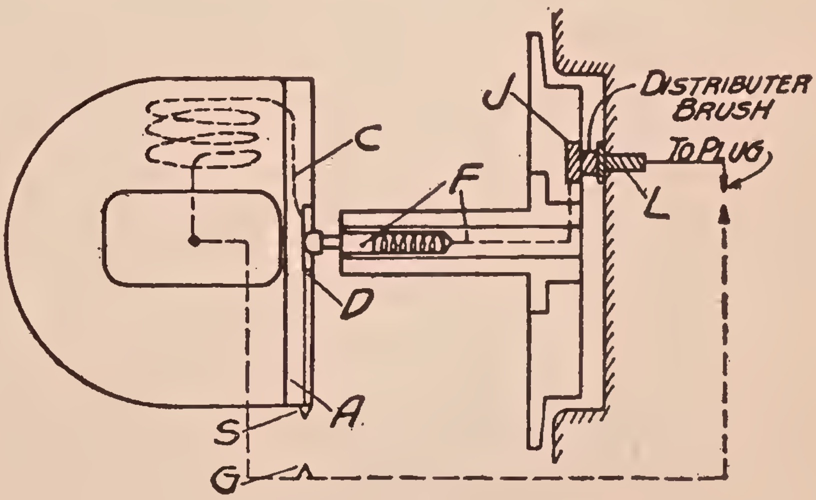


Fig. 75. Diagram of Secondary Circuit in Dixie Magneto

magneto is designed to run clockwise, moving the interrupter in the same direction as the rotation will cause the spark to occur later, as shown by the retarded position in the sketch. Moving the interrupter against the direction of rotation of the cam accordingly would cause the spark to occur earlier. The range of movement is approximately 15 degrees each side of the neutral point indicated by the horizontal position of the lever on the breaker box; the dotted lines show how the firing point may be advanced 15 degrees or retarded an equal amount. The lever in question is connected by means of linked rods to the spark lever on the steering wheel.

Magnetos for Eight-Cylinder and Twelve-Cylinder Motors. It will be evident that, regardless of the number of cylinders to be fired, the principles of current generation, transformation (to high tension), and distribution remain the same, so that a reference to

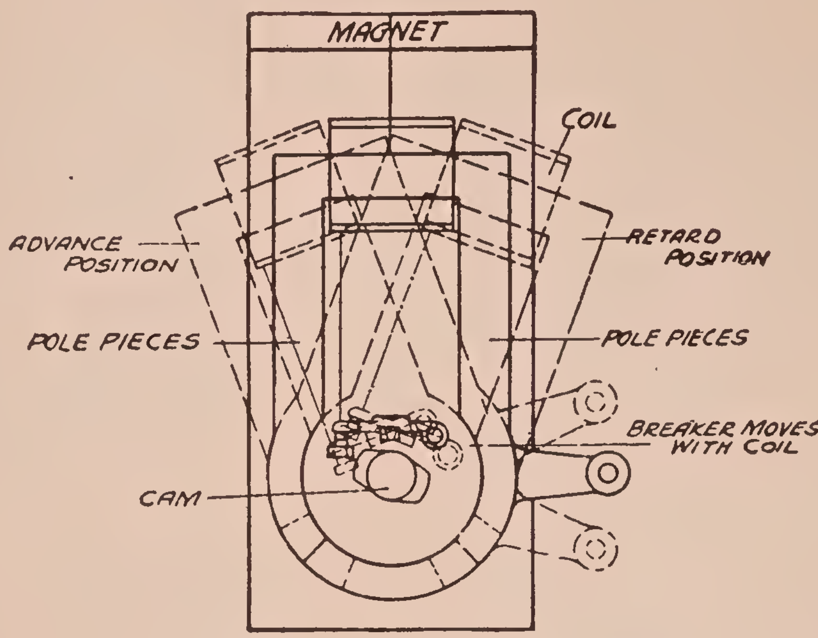


Fig. 76. Diagram Showing Method of Timing Dixie Magneto
Courtesy of Splitdorf Electrical Company, Newark, N. J.

the models of the Dixie for eight-cylinder and twelve-cylinder motors will suffice to cover the modifications required by the increased number of cylinders. To keep the speed of the magneto down, the rotor is provided with four poles instead of two, so that four impulses are generated in the windings per revolution. This permits of

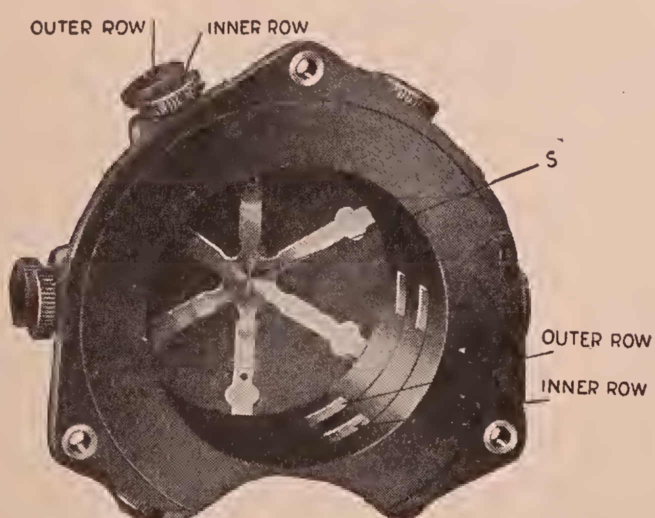


Fig. 77. Stationary Member of 12-Cylinder Splitdorf Distributor

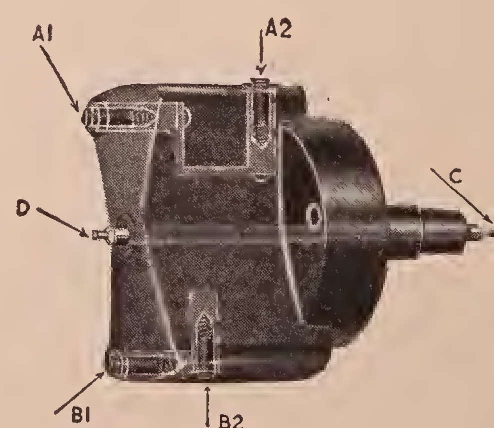


Fig. 78. Rotating Member of 12-Cylinder Distributor

running the magneto at crankshaft speed for an eight-cylinder motor and at $1\frac{1}{2}$ times crankshaft speed for a twelve-cylinder motor.

Compound Distributor. The contact breaker opens every quarter revolution instead of every half revolution—a cam with four lifting faces being provided for this purpose—and the distributor is provided with twice as many segments and spark-plug leads as a magneto designed for four-cylinder or six-cylinder motors. But as the contact segments of the distributor must be sufficiently long to permit of the distributor brush being in contact with them, regardless of the point to which the ignition timing is advanced or retarded, it is impossible to place more than six contact segments in a circle without reducing the insulation between them to a point where there would be danger of the high-tension current jumping the gap and thus deranging the ignition. To avoid this a compound distributor is employed, i.e., two distributors are combined, but instead of being placed on a flat surface as in the magnetos for a smaller number of cylinders, the segments are spaced around the inner periphery of a hollow cylinder. Two radial contact brushes are carried by the revolving member of the distributor, each of which makes contact with one of the sets of segments. Fig. 77 illustrates the distributor itself, while Fig. 78 is the revolving member. The radial brushes *A*2 and *B*2 of Fig. 78 are electrically connected to contact brushes extending laterally (*A*1 and *B*1) from the revolving member. These brushes make contact alternately with the arms of a metal spider sunk flush in the end wall of the distributor, *S* in Fig. 77, with which the central pin of the distributor rotor *D*, Fig. 78, also connects. The high-tension current from the windings is fed to this distributor rotor through the spring brush contact *C*.

Path of Current. The path followed by the current is accordingly as follows: from the high-tension winding of the coil (not shown here) to the distributor rotor through the brush *C;* from brush *D* to the spider *S;* from *S* alternately through brushes *A*1 and *B*1 to the distributor segments representing the inner and outer row of spark-plug leads, through the brushes *A*2 and *B*2. Brushes *A*1 and *B*1 are so spaced that, when one is centrally in contact with an arm of the spider *S*, the other is midway between the second and third arms from the one with which contact is being made.

The relation of the various members of the Dixie magneto will be clear upon reference to the sectional view, Fig. 79, showing one of the four-cylinder models. The contact breaker or interrupter is at the left-hand end of the rotor shaft; just above the rotor itself is the coil, while to the left of this is the distributor.

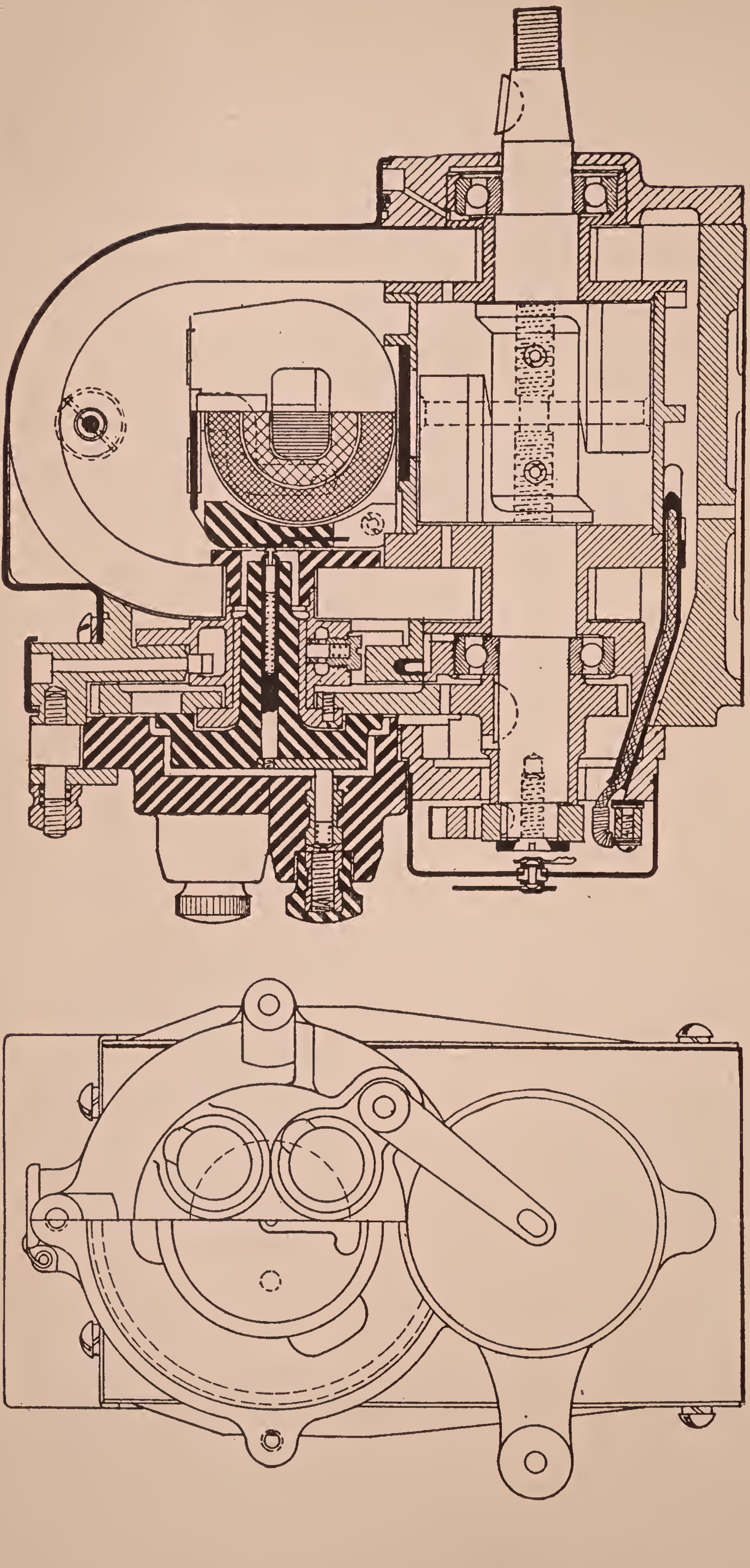


Fig. 79. End Elevation and Section of Dixie 4-Cylinder Magneto Showing Construction and Connections
Courtesy of "The Horseless Age"

IGNITION SYSTEMS

STANDARD TYPES

Dual Ignition System. *Bosch Type.* The dual type of ignition system uses one coil and one set of plugs with either the battery or the magneto as the source of current supply, the magneto contact breaker and distributor being common to both. Fig. 80 illustrates the connections of a dual system. Wire Number *1* is in the low-tension circuit and conducts the battery current from the primary winding of the coil to the contact breaker of the magneto. Low-tension wire Number *2* is the grounding wire by which the primary

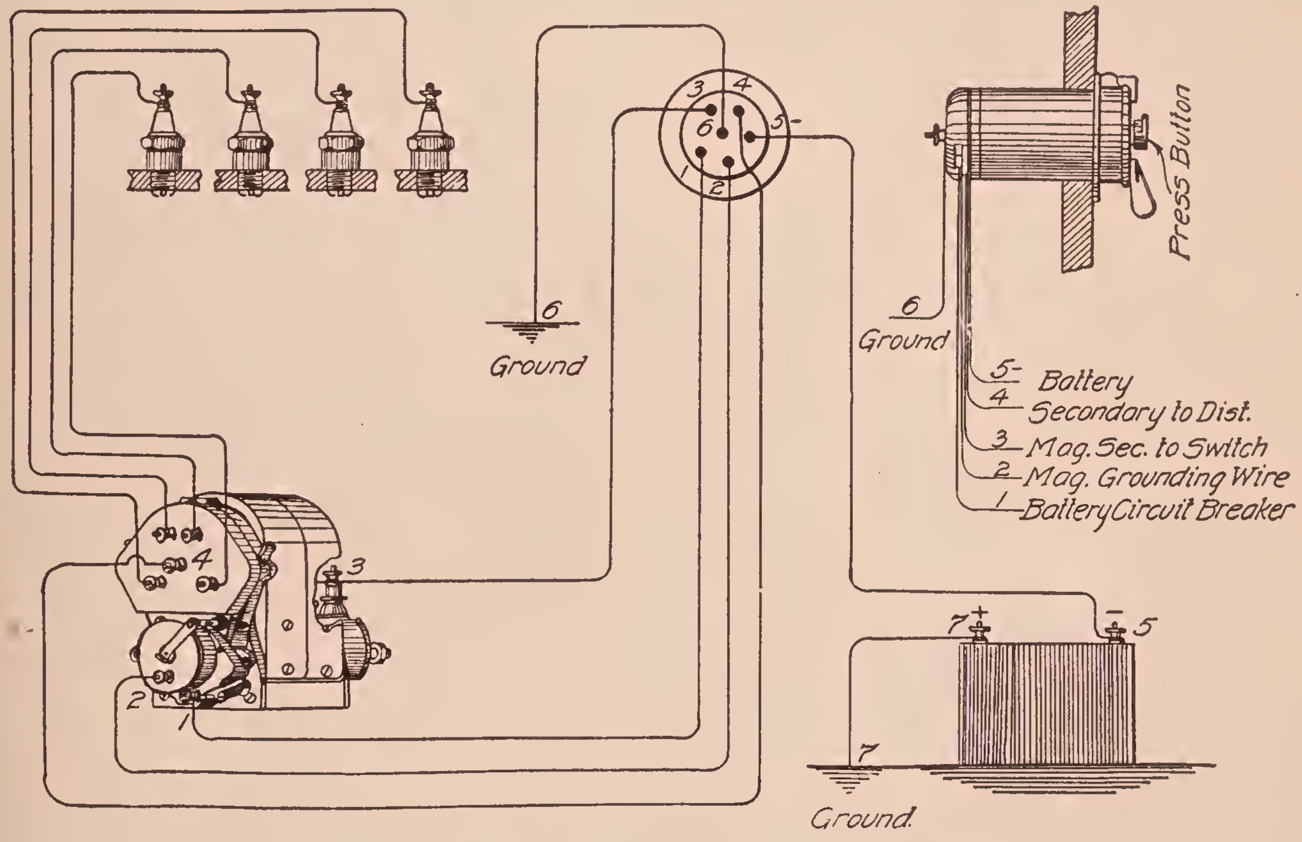


Fig. 80. Wiring Diagram Dual Ignition System

circuit of the magneto is grounded when the switch is thrown to the "off" or "battery" position. Wire Number *3* leads the high-tension current from the magneto to the switch contact, and wire Number *4* is the wire that carries the high-tension current from the coil to the distributor. Number *5* leads from the negative terminal of the battery to the coil, and the positive terminal of the battery is grounded by Number *7*; a second ground wire, Number *6*, is connected to the coil terminal. The press button on the switch cuts in the battery circuit which includes a special vibrator on the coil which is employed simply for "starting on the spark"; i.e., when a charge of gas is left in the cylinders and the crankshaft has stopped with

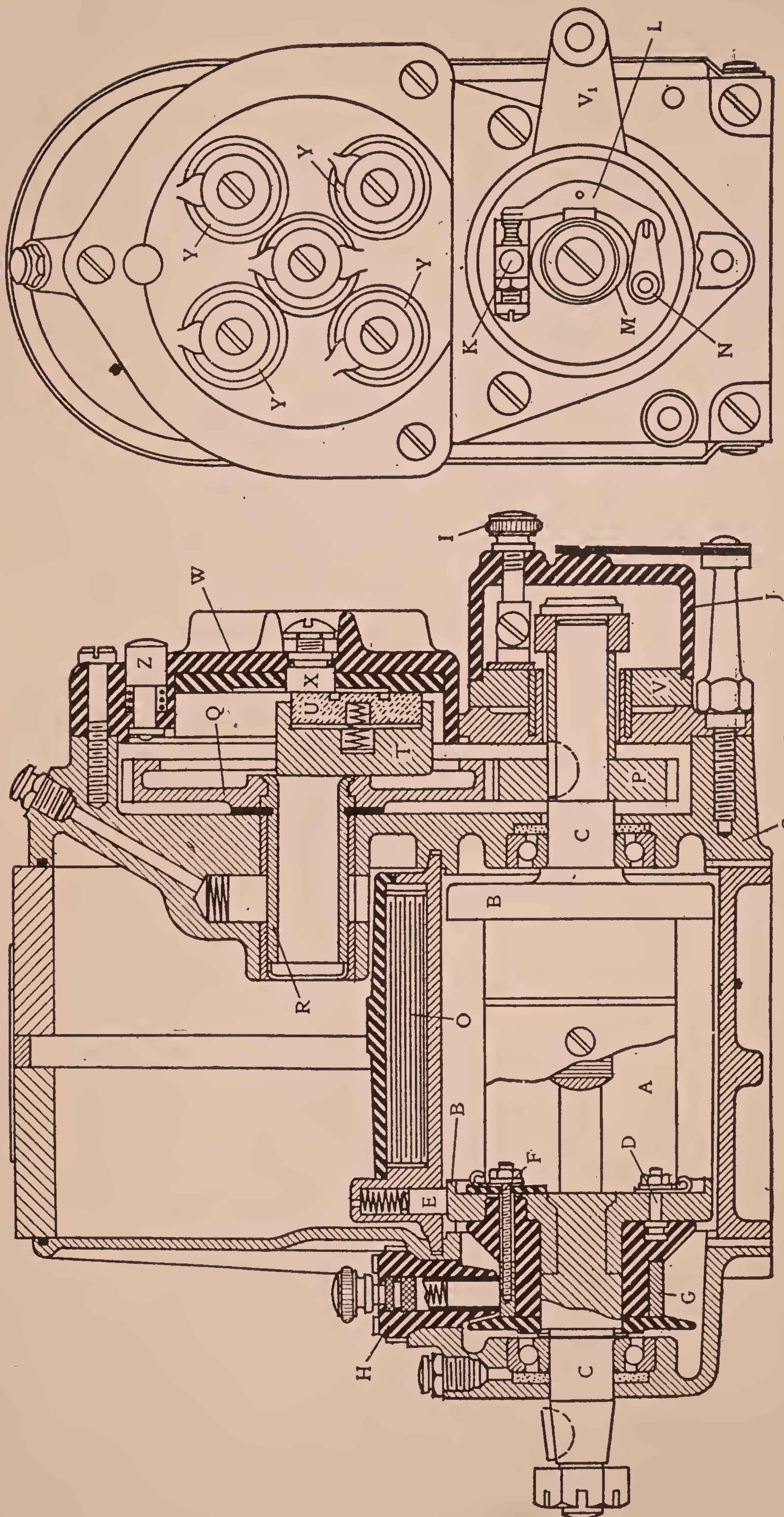


Fig. 81. Section and End Elevation of Remy Dual Type Magneto
Courtesy of "The Horseless Age"

the pistons in the proper position for firing the next one in order, a spark in that cylinder will frequently start the motor.

Remy Type. Prior to the general adoption of electric lighting and starting systems, the dual type of ignition system was almost universally employed on the lower and medium priced cars, many thousands of which are still in service. The Remy magneto, a section and end elevation of which are shown in Fig. 81, is typical of the class used for this service. The armature *A* is of the *H* or shuttle type, of laminated construction fitted with cast bronze heads *B*. It carries a single winding, one end of which is grounded by connecting it to the rear bronze head at *D*, the ground connection being further insured by the carbon brush *E*, pressed against the head by a spring. The other end of the armature winding is connected through an insulated stud *F* to the collector ring *G* from which the current is taken by a carbon brush in the holder *H*. From this brush a low-tension cable runs to the induction coil mounted on the dash.

The other primary terminal of the coil is connected to the terminal *I* on the breaker box at the right-hand end of the magneto. This terminal, which extends through the breaker-box cover *J* of insulating material, forms an integral part of the contact screw *K* which carries one of the contact points of the interrupter. The other contact point is mounted on the free end of the lever *L*, pivoted at its lower end and provided with a fiber contact block bearing against the cam *M* carried on the armature shaft. The contact screw *K*, interrupter lever *L*, and its stud *N* are all supported on the metal plate *V* forming the interrupter base. This plate is supported on a lateral projection from a disc secured to the forward end plate *S* of the magneto and is provided with the radial arm *V*, which is connected by jointed rods to the spark timing lever on the steering wheel. This permits of moving the breaker box through part of a revolution with relation to the cam on the armature shaft to advance or retard the time of ignition, as explained later under Spark Timing. The interrupter lever *L* is grounded to the frame of the magneto through the stud *N*. The condenser *O* is placed in the armature cover plate and has one terminal connected to the stationary contact screw *K* and the other terminal grounded, so that it is shunted or "bridged" directly across the interrupter and serves to minimize the spark or arc caused by the opening of the contacts. The condenser is sometimes combined with the coil.

Details of Typical Distributor. Apart from slight variations in detail, the following description of the distributor is typical of all magneto distributors. At its right-hand end, the armature shaft, Fig. 81, carries the steel pinion *P*, which meshes with the bronze gear *Q* having twice the number of teeth. Rigidly mounted in the bronze distributor gear *Q* is a carbon brush *U* carried in the holder *T*. This brush is pressed by its spring against the inner surface of the insulating cover of the distributor *W*, in which are embedded a central contact block *X* and four or six (according to the number of cylinders) contact blocks *YY*, equally spaced about a circle. At their outer ends these contact blocks carry terminals for the attachment of the high-tension cables. As the distributor revolves it makes contact with the central block *X* and all of the blocks *YY* in succession.

Since the distributor gear *Q* has twice as many teeth as the armature pinion, it makes but one revolution for every two turns of the crankshaft (four-cylinder motor) and of the armature, the latter being driven at crankshaft speed. As the four-cylinder motor fires only twice per revolution, it is only necessary for the distributor to make one complete turn for every two revolutions of the crankshaft. The distributor is so geared to the armature shaft that it operates synchronously with the interrupter, i.e., whenever the contacts of the latter separate to open the magneto armature circuit and permit the current to flow through the primary of the coil, the brush *U* is on one of the contact blocks *Y*. The exact moment of opening is governed by the setting of the timing lever, but the distributor brush *U* is made of sufficient width to cover the contact block throughout the whole timing range. A feature of this model of the Remy magneto is the timing button *Z* fitted into the distributor cover, to facilitate the adjustment of the timing of the magneto to the motor. Most magnetos have to be disconnected from the driving shaft to accomplish this. This button is normally held out by its coil spring. If the button is pressed in and the armature shaft is then turned, the plunger of the button will drop into a recess in the distributor gear. Then the engine must be turned over by hand until the piston of cylinder No. 1 is exactly at the upper dead-center position at the beginning of the power stroke, and while the crankshaft of the engine and the armature shaft of the magneto are in these relative positions, the magneto driving gears must be meshed and the magneto gear secured on the tapered end of the armature shaft by means of a Woodruff key which is held in place by a bushing and nut, as shown in the sectional view, Fig. 81.

Typical Wiring Diagram. Fig. 82 is a wiring diagram of a typical dual-ignition system that illustrates the connections in greater detail than in the case of the Bosch system. The switch

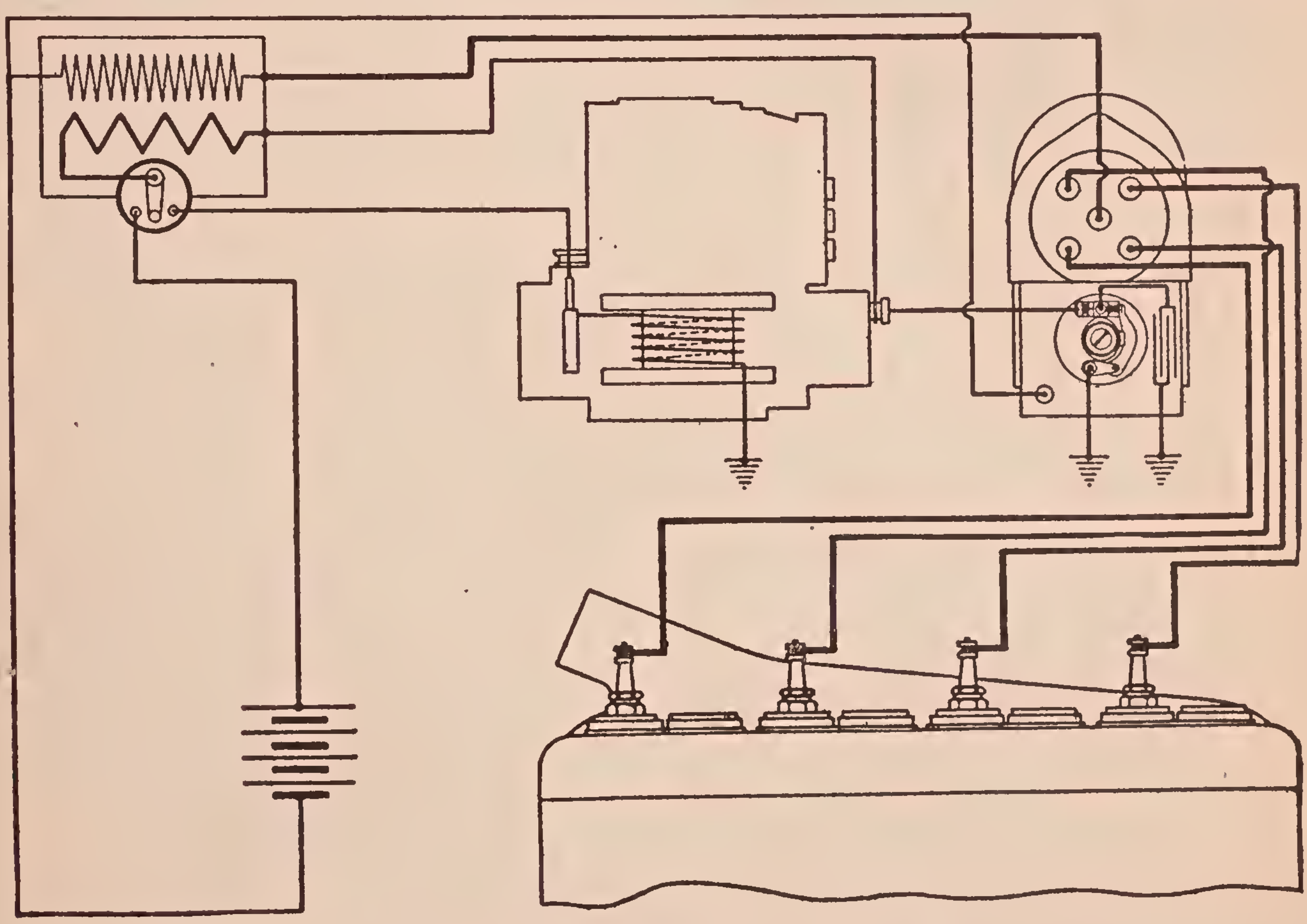


Fig. 82. Wiring Diagram of Magneto and Coil in the Remy Dual System
Courtesy of "The Horseless Age"

shown just below the induction coil has three positions: "OFF" (central); "BATTERY" (left); and "MAGNETO" (right). When the switch is on the BATTERY contact, the current flows from the battery through the switch and the primary winding of the coil to the interrupter, and completes the circuit by means of the ground connection of the latter and the coil. The secondary current is distributed in exactly the same manner as when the armature of the magneto is supplying the low-tension current. As the interrupter has its contacts closed, except for the momentary break when the spark occurs, its demand upon the battery is large, so that the switch should immediately be shifted to MAGNETO as soon as the engine starts. Otherwise a dry-cell battery will be exhausted in a comparatively short time, or an unnecessary drain will be made from the storage battery where the latter is employed for starting.

Duplex Ignition System. This is designed to facilitate the starting of the motor by utilizing the current from a battery as well as that from the magneto when cranking to start. To throw the battery current in phase with that of the magneto, it having previously been stepped up to high tension through a coil on the dash, a commutator is fitted to the magneto shaft. The magneto is of the

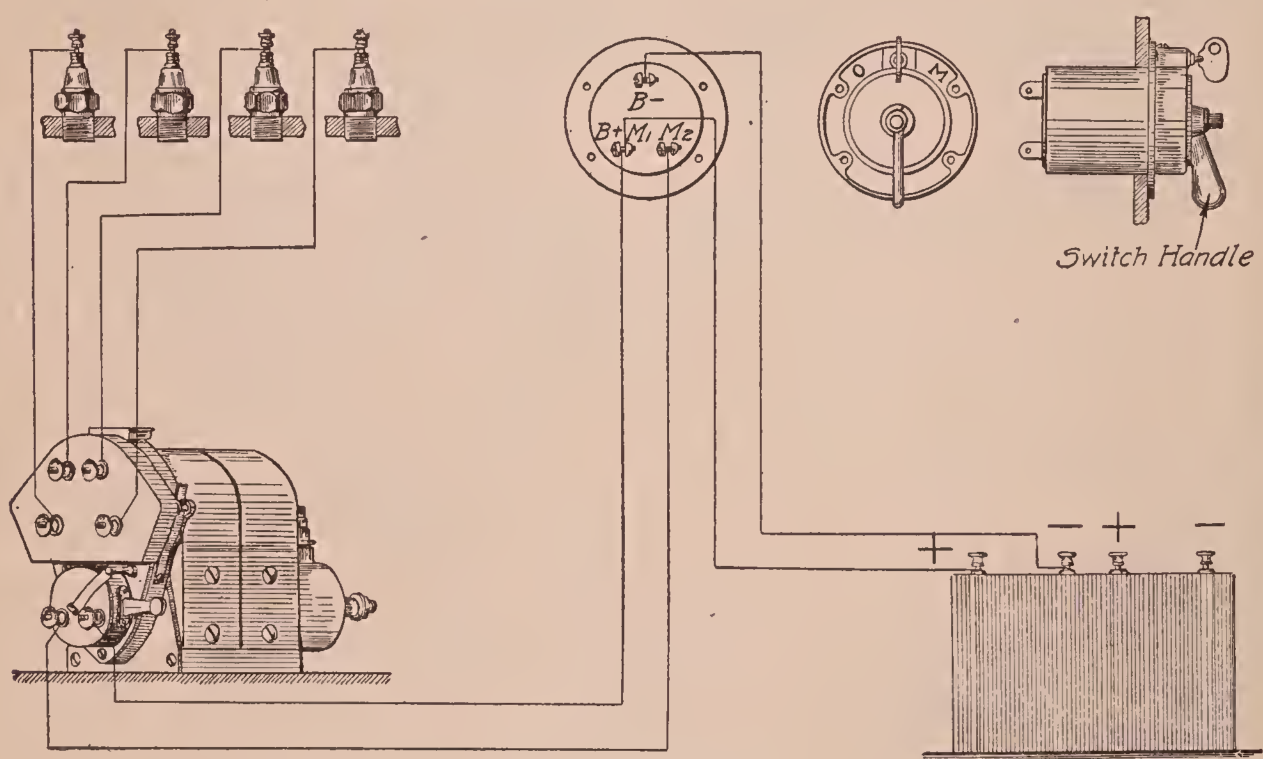


Fig. 83. Wiring Diagram of Bosch Duplex Ignition System

true high-tension or independent type, and by means of this commutator the flow of battery current is in the same direction as the flow of magneto current, a change in the direction of one (alternating current as generated by the magneto) is accompanied by a change in the direction of the other, and they are said to be "in phase," i.e., the cycles of alternation correspond in both. To accomplish this the battery current's polarity must be the same as that of the magneto and the battery must not be grounded, as shown by the wiring diagram, Fig. 83. The necessity for using the battery current to supplement that of the magneto exists only at very low cranking speeds, and the assistance of the battery is no longer needed once the engine starts. This type is not in general use.

Double-Spark Ignition. Mention has already been made of the employment of two sparks occurring simultaneously in the cylinders under the head of "Series Plugs". It will be evident that simply by adding another distributor to a magneto and taking leads from it to a second set of plugs placed at another point in the cylinders, preferably as far away from the first as possible, the same result is accomplished. Fig. 84 shows a Remy two-spark magneto, the distributors being mounted at opposite ends of the field.

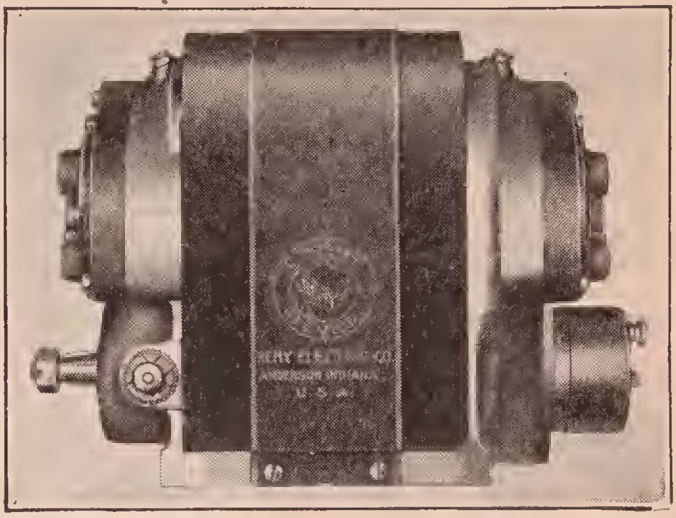


Fig. 84. Remy Two-Spark Magneto

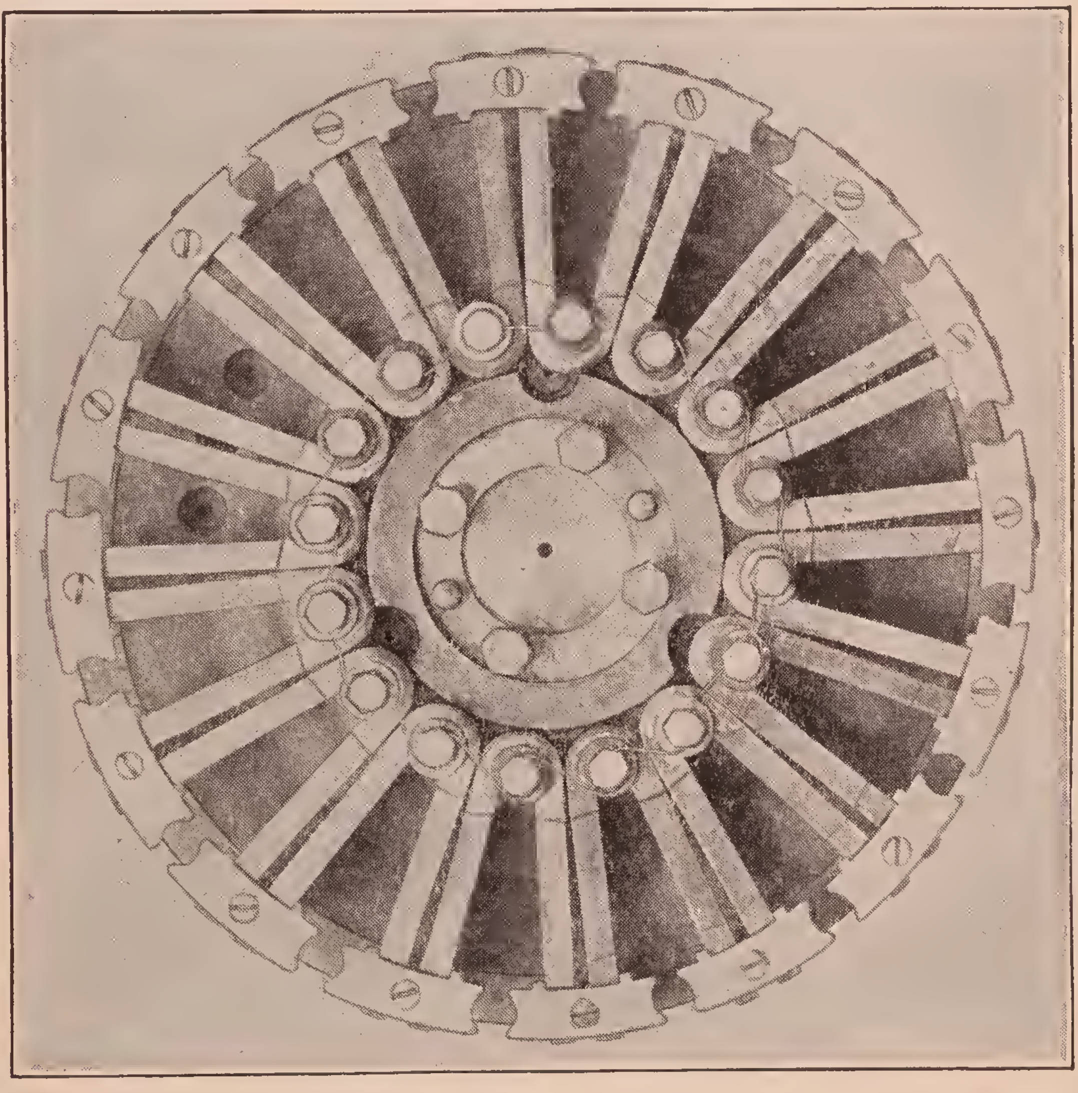


Fig. 85. Magnets of Ford Magneto

Ford Magneto. The Ford magneto is *sui generis*. What the patent lawyers term the "prior art" shows nothing even vaguely resembling it and no ignition current generator used on either

American or foreign cars, past or present, can lay claim to any family ties. Not that its principles differ in any way, but their application is very unusual, and as this magneto is now employed on more

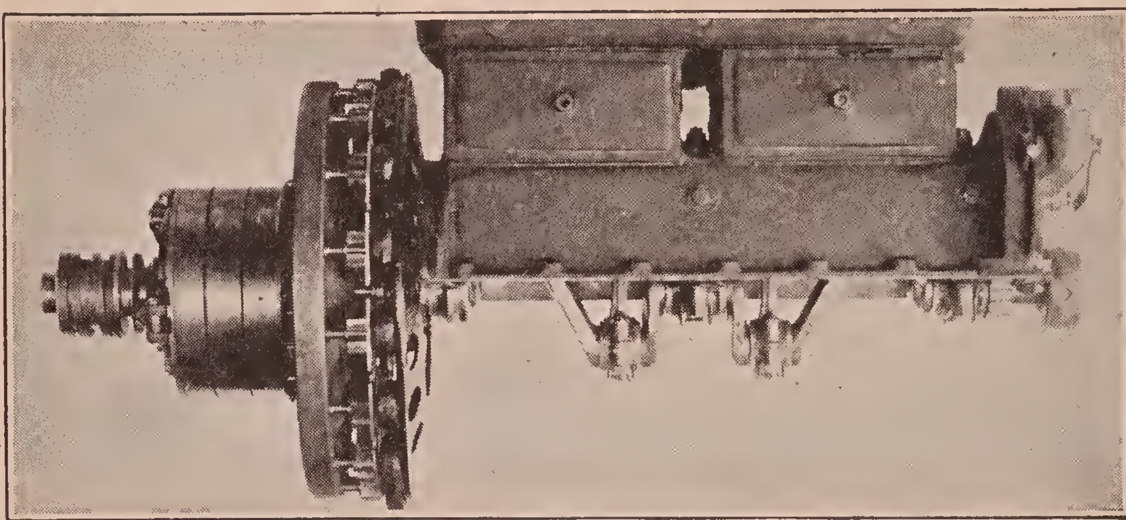


Fig. 86. Ford Magneto as Installed

than a million cars, it is of particular interest. Instead of the two or three horseshoe permanent magnets employed on the ordinary magneto, the Ford has sixteen magnets arranged radially with their poles outward, and all are bolted directly to the flywheel, as shown in Fig. 85. Directly in front of them and separated by a very small

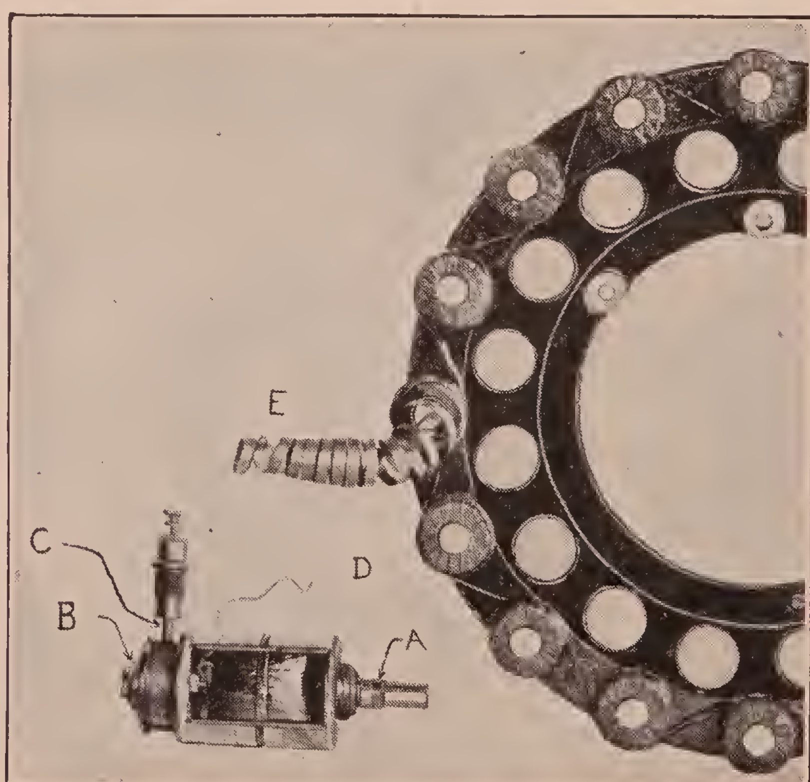


Fig. 87. Copper Ribbon Coils of Ford Magneto

clearance are sixteen coils, wound of copper strip or ribbon and attached to a spider which is bolted to the crankcase of the motor just forward of the flywheel, as shown by Fig. 86. The spider itself and the coils are illustrated by Fig. 87, which shows one of the coils partly unwound at *E*. The spider and its coils remain stationary while the magnets are rotated in close proximity to them at high speed by the flywheel, thus inducing a current in the coil windings. The current is taken from the collector ring *B*, through the single brush *C*, the other side of the magneto circuit being grounded. Fig. 88 shows the complete ignition system as installed on the motor. The magneto is shown with part of its housing removed; at its upper center is the collecting brush mentioned, connected to the four-unit

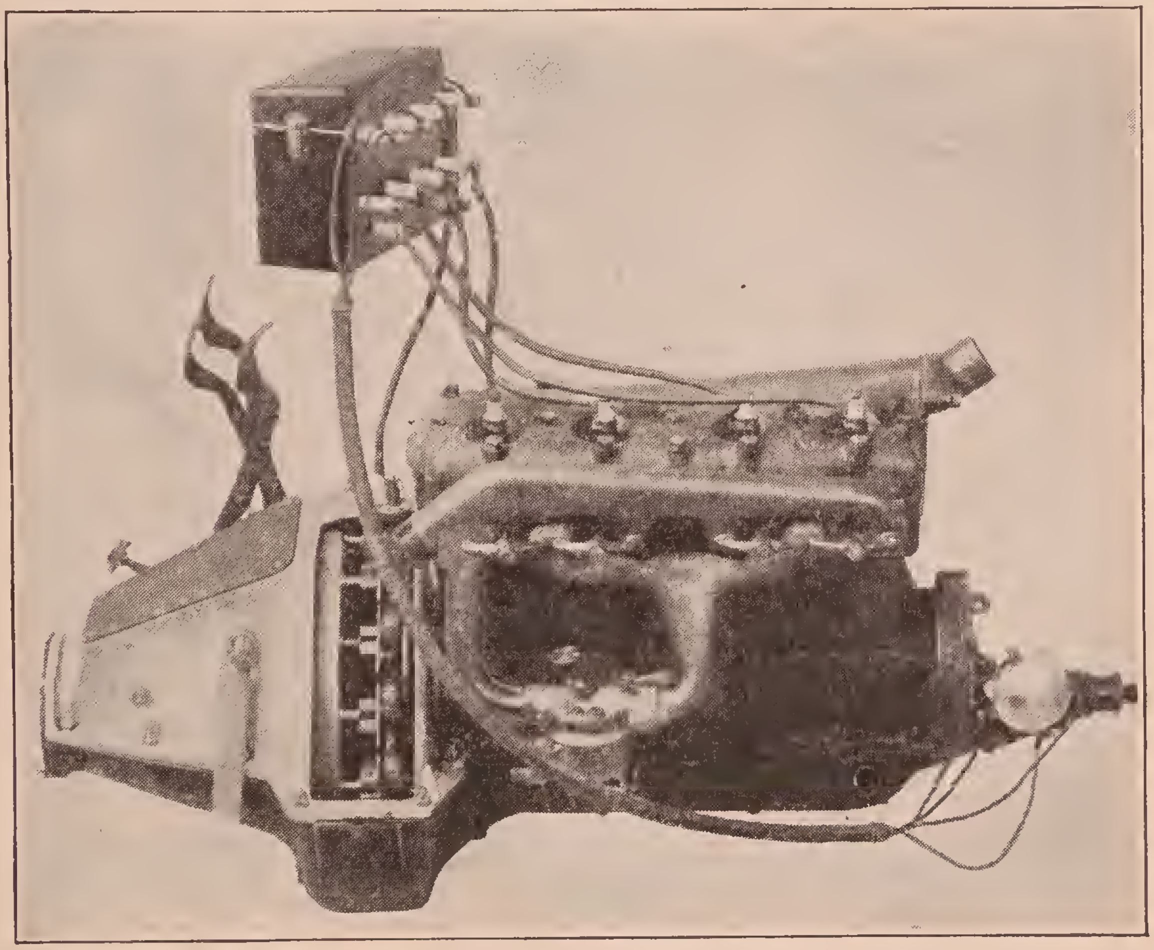


Fig. 88. Complete Ford Ignition System

coil, which in practice is mounted on the dash. From the coil, four primary connections are made to the low-tension timer mounted at the forward end of the motor and driven from the camshaft, and the four high-tension cables for the spark plugs will be noted just below the primary connections. The other two binding posts on the back of the coil are for the current from the magneto and the ground connection. While a battery is ordinarily fitted in addition to facilitate starting, this can be accomplished on the magneto alone, as the latter is very powerful. Replacements are sold at such low prices that when the magnets have lost their strength, new ones often are inserted instead of remagnetizing the old.

Current Supply and Distribution. Except for the use of a magneto to supply the current, the system will be recognized as the ordinary coil-and-battery type now long obsolete (1909 and earlier models). Instead of the direct current provided by a battery, however, the Ford magneto supplies an alternating current which alternates sixteen times per revolution. Between each alternation, there is, of course, a momentary drop to zero so that, at the positions of the crankshaft and field magnets corresponding to this drop, there is no current in the armature, or so little that it is impossible to produce a spark. Assuming that, when the timer completes the primary

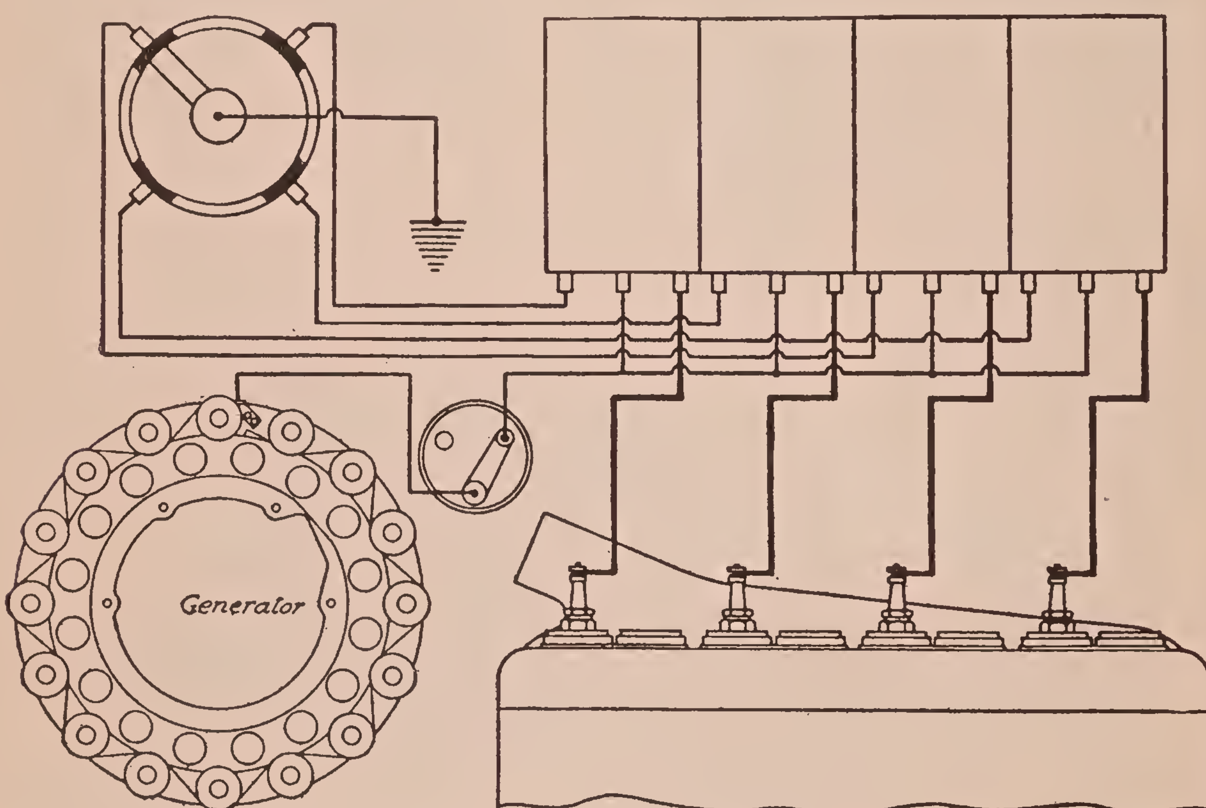


Fig. 89. Wiring Diagram for Ford Ignition System
Courtesy of "The Horseless Age"

circuit, the magneto is at or very near the position of zero e.m.f., the coil vibrator will not respond as the current sent through the coil by this very weak e.m.f. is not sufficient to operate it. As soon, however, as the current attains the minimum value necessary to attract the vibrator, a spark is produced. The result of this is that, as the spark timing lever is moved over its quadrant, the spark is not advanced uniformly with the lever motion. It doubtless also accounts for the fact that the motor will often be found to run much better with the lever advanced but a short part of its travel, instead of at the point of maximum advance as is the case with the ordinary magneto or with the modern battery system.

Fig. 89 shows the wiring diagram of the Ford ignition system, the primary timer being indicated just above the magneto or generator. To operate efficiently, this timer needs oiling daily when the car is in constant service, and in cold weather about 25 per cent of kerosene should be added to the oil used for this purpose, as the low temperature causes the latter to thicken. To the right of the generator are shown the switch, the four vibrator coils, and the spark plugs with their leads. As the magneto has but one collector brush, it is subject to few troubles. The collector brush may loosen up through vibration and may not make proper contact, or dirt and oil may collect on the ring against which it bears, with the same result. Apart from this, the chief trouble will be caused by weakening of the magnets. A current sent through the armature coils from an outside source will tend either to strengthen or to weaken their magnetism, depending upon the direction of the current itself and the relative position of the armature with regard to the magnets. As the armature is always likely to stop in such a position that a current sent through it from an outside source will weaken the magnets, a battery should never be connected to the armature.

Misfiring. Irregular firing can be traced most frequently to the timer and will be caused either by a lack of oil or an accumulation of dirt; with the timer in good condition, misfiring will most often be due to a lack of uniformity in the adjustment of the vibrators, or to worn and pitted vibrator contacts. With the motor running, the vibrator adjustment screws should be turned up or down very slowly until all four cylinders fire uniformly. Instructions for taking care of the vibrator points are given in detail in connection with the description of battery cut-outs and circuit breakers in Part III, Starting and Lighting Systems. Failure to fire is usually due to lack of contact at the collector brush on the magneto. The timer is so located that the primary cables get the full benefit of all oil and dirt, while its movement to advance or retard the ignition is also apt to abrade the insulation from these wires close to the timer, so that irregular firing may also be due to this cause. Complete wiring replacements may be had at such low cost that when the cables become oil soaked and their insulation worn, the easiest way to correct troubles from this source is to install a new set of connections.

SPARK TIMING

Effect of Irregular Sparking. Like a steam engine, an internal combustion motor depends for its power output on the mean effective pressure developed in the cylinder, usually referred to as its m.e.p. This is affected directly by three factors: *first,* the initial compression of the charge, that is, the pressure to which the piston compresses the gaseous mixture on its upward or compression stroke just before firing; *second,* the time at which the charge is ignited; and *third,* the length of the stroke. It is with the second factor alone that this phase of the ignition problem is concerned. In contrast with the steam engine in which the steam as admitted is at a comparatively low pressure and expands gradually throughout the stroke, the pressure developed in the internal combustion motor at the moment of ignition is tremendous, but it falls off very rapidly. The impulse given the piston is more in the form of a sharp blow than a steady push, as with steam. The mean effective pressure developed depends very largely upon the pressure reached at the moment of explosion and this in turn depends upon the time ignition occurs with relation to the stroke. As the speed of an automobile motor varies over a wide range, it will be apparent that means must be employed for varying the time of explosion. To be most efficient it must occur at the point of maximum compression, i.e., when the piston is exactly at the upper dead center on the compression stroke. As both a mechanical and an electrical lag, or delay, must be compensated for, the setting which will give maximum efficiency at 500 r.p.m. will be much too slow at 1500 r.p.m. and the spark would then not take place until after the piston had started down again and the pressure had dropped considerably, causing a great loss in power. On the other hand, an attempt to run the motor slowly with a spark timing that would give the best results at high speed would often result in causing the explosion to take place against the rising piston. This is evidenced by a hammering sound and a great falling off in the power.

Advance and Retard. Means are accordingly provided in the majority of ignition systems for causing the spark to occur earlier or later in the cylinders. This is termed advancing and retarding the spark, the nomenclature being taken from the French, with whom it originated. The explanation given in the preceding paragraph for the necessity of this will make plain the car maker's often repeated injunction to the novice—never to drive *with the spark retarded.* Another and equally important reason is that when operated this way, the combustion is incomplete, the gas continues to burn throughout the stroke, and a greatly increased percentage of its heat has to be absorbed by the water jackets, causing the motor to overheat badly.

Adjusting for Time Factor of Coil. Every induction coil has a certain time constant, which represents the period necessary to completely charge the coil, that is, the time required for the current in the primary winding to attain its maximum value. This time constant depends very largely upon the amount of magnetic energy which can be stored up in the coil. There must be added to this the time required to overcome the inertia of moving parts, such as the timer and the vibrators of a high-tension battery system, or the contact breaker and the distributor in a magneto high-tension system. As these parts are very small and light this would be practically negligible for any other purpose, but when figuring in hundredths of a second, as in the case of the ignition timing of high-speed multi-cylinder motors, it becomes of importance. The object sought, as already mentioned, is to have the spark always occur at the point of maximum compression. To accomplish this with the motor running at high speed, the ignition devices must act while the piston is still an appreciable distance below upper dead center. The timer in the case of a battery system, or the contact breaker of a magneto, is accordingly mounted so that it can be turned through part of a revolution with relation to its driving shaft, or more particularly the cam carried by the latter. For starting the motor by hand, the spark must occur either at or after upper dead center is reached, never before. In the latter case, the piston would be driven backward and the familiar "back kick" result. Hence the manufacturer's admonition—always retard the spark fully before attempting to crank the motor.

Calculation of Small Time Allowance. The relation of spark advance in degrees to piston travel in inches with motors having strokes running from 3 to 8 inches is shown by the accompanying chart, Fig. 90. In this the ratio between the crank and the connecting rod length is 1 to 4.5. The lettering shown indicates the method of using the chart, the problem being to find the piston travel for an advance of 30 degrees in a motor of 6-inch stroke. The vertical line *a*, corresponding to this stroke, is traced upward until it intersects the 30-degree line at *c*; following the latter to the left brings it out at a

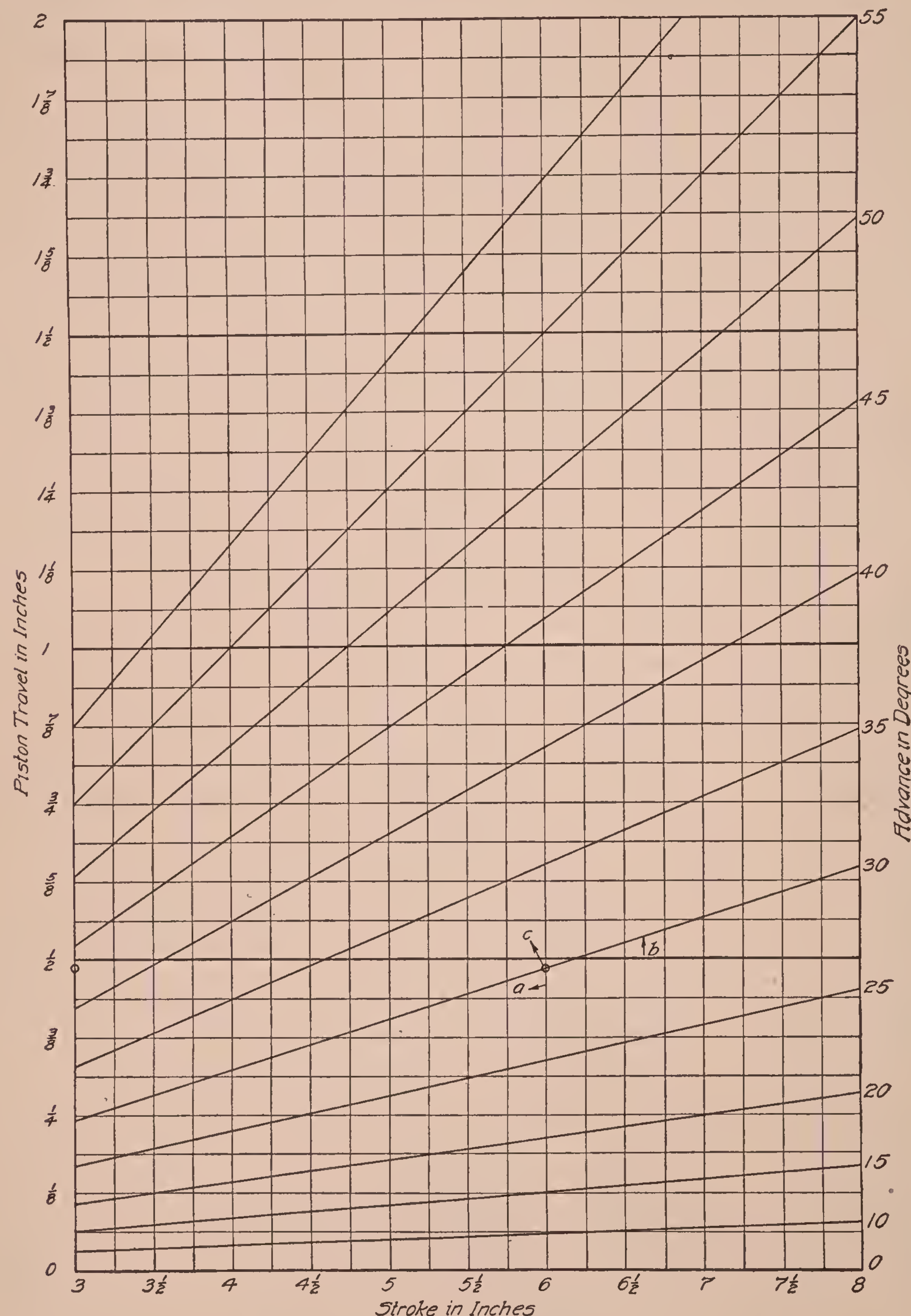


Fig. 90. Relation of Spark Advance to Piston Travel (Bosch)

point just below the ½-inch division, or approximately .46 inch. Assuming that the 6-inch stroke motor were running at 1800 r.p.m., its pistons would be traveling 1800 feet per minute (i.e., stroke doubled or 1 foot per revolution), 30 feet, or 360 inches per second, so that each inch of the stroke would be covered at an average speed of 1 inch in $\frac{1}{360}$ of a second, and the $\frac{1}{2}$ inch in $\frac{1}{720}$ of a second, from which the necessity for a timing allowance will be apparent.

Magneto Timing. Timing is usually 30 to 40 degrees, which means that the spark occurrence can be advanced or retarded half that distance from a neutral line representing the upper dead center position of the piston. As shown by Fig. 91, the allowance is 34 degrees in the Splitdorf magneto, "left" and "right" in this connection having reference to the direction in which the magneto armature is driven. The necessity of providing this allowance, however, introduces a

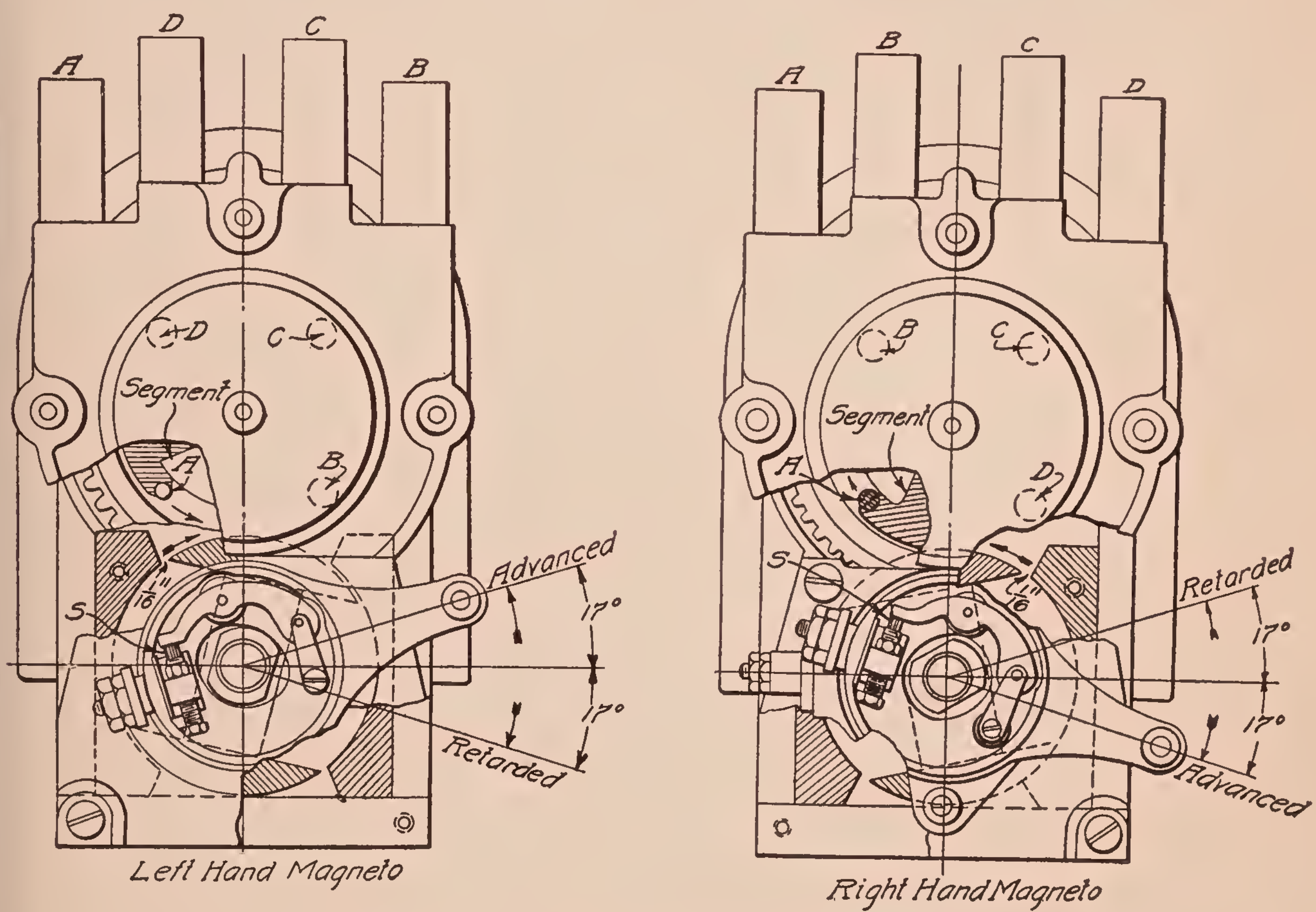


Fig. 91. Method of Advancing and Retarding Spark, Splitdorf Magneto

complicating factor in magneto design. As already mentioned, most magnetos are fitted with bi-polar armatures, i.e., there are two extensions or pole pieces between which the winding is placed. This will be clear upon reference to Fig. 92, which shows the armature core of a Simms magneto. The phases are accordingly 180 degrees apart. That is, the current in the armature winding only reaches its maximum value twice per revolution, and as these maxima are really "peaks", as shown by the oscillograph, Fig. 93, there is not much leeway for variation one way or the other, if the greatest current value is to be utilized.

Analysis of Oscillograph Diagrams. In the oscillograph, the dotted vertical line at the left represents the moment of closing the primary circuit, the current then beginning to increase gradually in value. The resistance of this circuit is such that the current would attain a value of 5 amperes, if the circuit remained closed long enough. However, when the current has attained a value of 4 amperes, the circuit is broken by the vibrator (battery and coil system) and the current then falls off very rapidly. It will be noted that there is no current in the secondary circuit while the primary is attaining its full value, which is due to the fact that the e.m.f. induced in the secondary during this period is not sufficient to break down the resistance of the air gap in the spark plug. The spark occurs when the primary circuit is broken and it is interesting to note that it attains its maximum value instantly, this having been confirmed by numerous oscillograph tests. The right-hand dotted line represents the moment the primary circuit is broken by the timer. With a vibrator coil a series of sparks is produced, as compared with

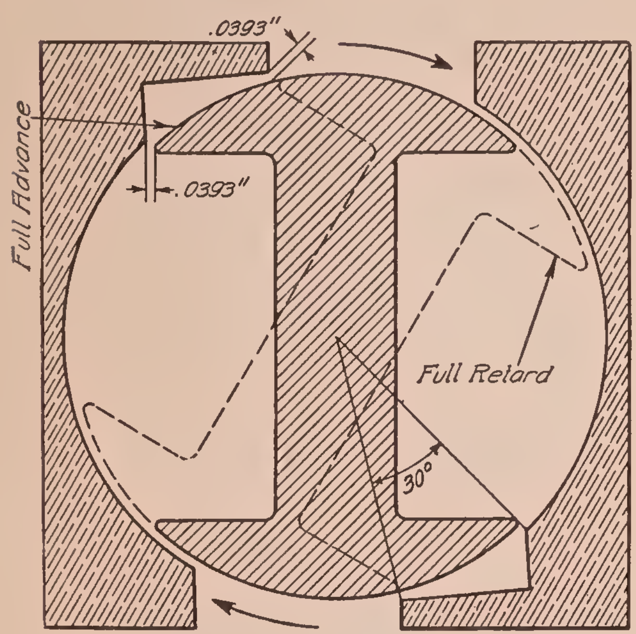


Fig. 92. Section Simms Magneto Armature and Pole Pieces

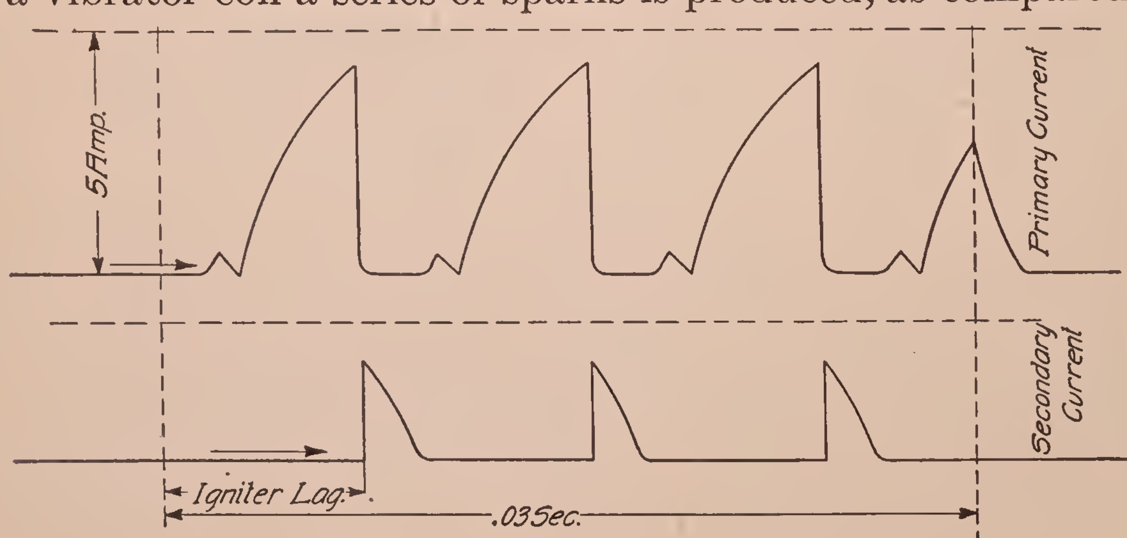


Fig. 93. Oscillograph Diagram of Primary and Secondary Currents (*Horseless Age*)

the single spark of the magneto, but these are of no advantage except at low speeds, as when running at full speed, if the first spark fails to ignite the charge, it is already too late by the time the second occurs.

Oscillograph diagrams taken of a magneto's current and voltage show that both rise to a sharp peak, first in one direction and then in the reverse, as the current is alternating. As the oscillograph illustrated shows that only the peak or maximum value of the current in the primary of the coil can be utilized for producing a strong induced current in the secondary, so the peak of the magneto current must be taken advantage of to produce the most efficient spark. This point of maximum current value in the revolution of the armature occurs when it is cutting the greatest number of magnetic lines of force of the permanent magnetic field, which is when it is just about to pass from the influence of one set of poles into that of the other, as shown

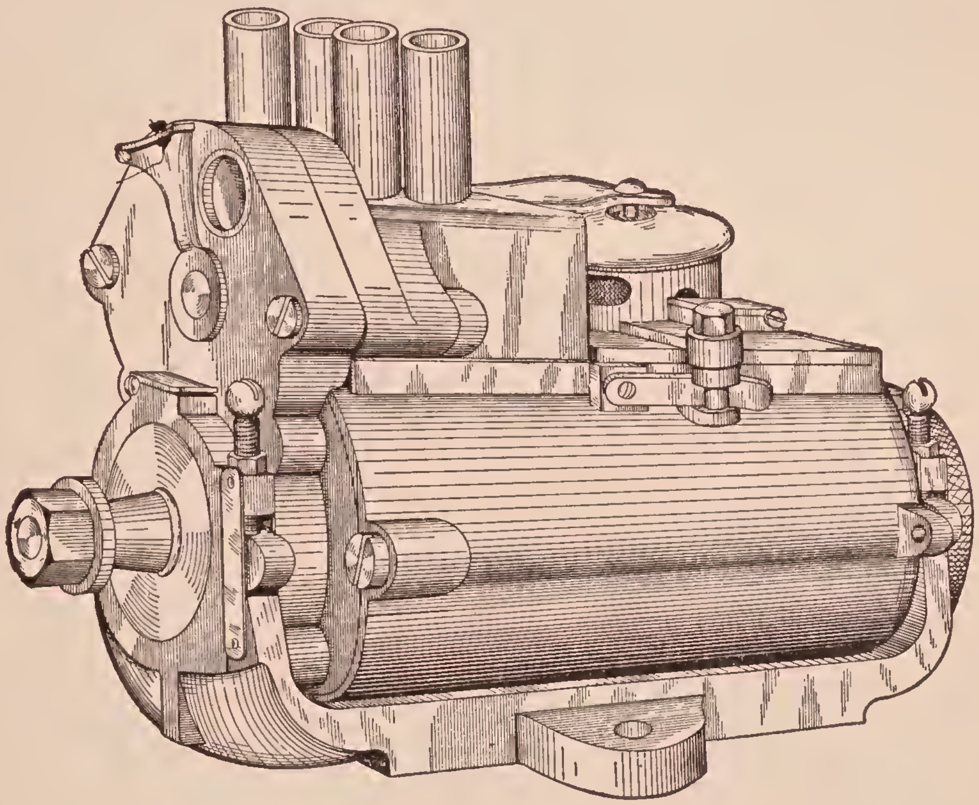


Fig. 94. Mea Magneto in Trunnion Mounting

in the section, Fig. 92. This also shows the relative positions of full advance and full retard and is designed to illustrate the advantages obtained with the patent extended pole pieces of the Simms magneto, most magnetos having the upper and lower faces of both poles in the same plane.

Mea Method of Advancing Spark. Doubtless the most ingenious method of taking care of the necessity for advancing the spark has been developed in the Mea magneto, shown in Fig. 94. Instead of being of horseshoe form, as in the Bosch and Nilmelior magnetos, shown in Figs. 95 and 96, it is bell-shaped, as shown by Fig. 97. The entire magneto is carried in a trunnion mounting so that the field magnets may be turned to the same extent that the contact breaker is moved to give the necessary advance, thus insuring that the circuit will be broken with the armature in the same relative position to the field poles, which is naturally that of maximum current value.

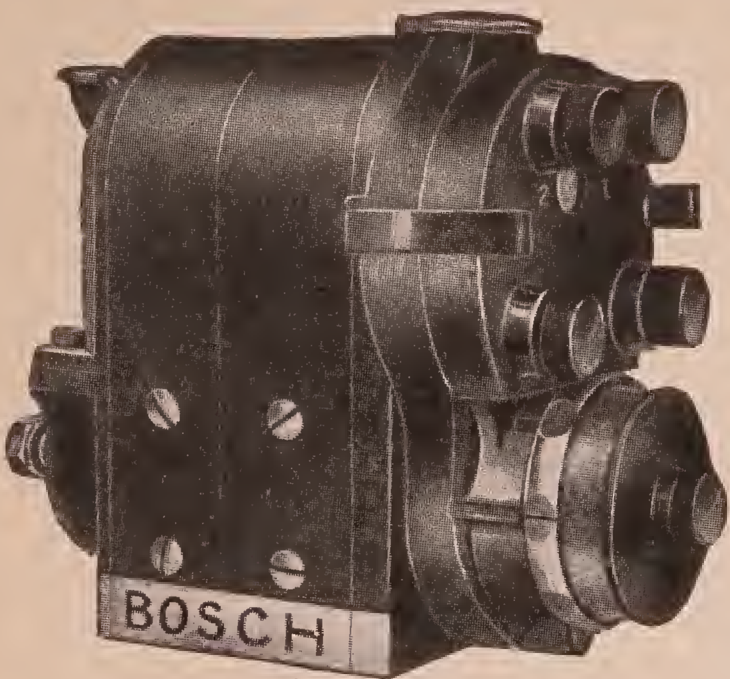


Fig. 95. Bosch Enclosed Type Magneto

Ignition System Fixed Timing Point. It has become more or less general practice with French builders to provide an ignition system having a fixed timing point, i.e., one that cannot be controlled by the driver through the usual spark advance lever as found on practically all American pleasure cars. This is particularly the case with taxicabs. While "fixed" in the sense that they are not variable while running, such systems have two firing points, one of maximum advance, which is always employed when the motor is in operation, and the other of maximum retard to enable the driver to crank the motor without danger of injury. So-called fixed spark ignition systems have come into very general use abroad, more especially on the Continent, but have found very little favor here.

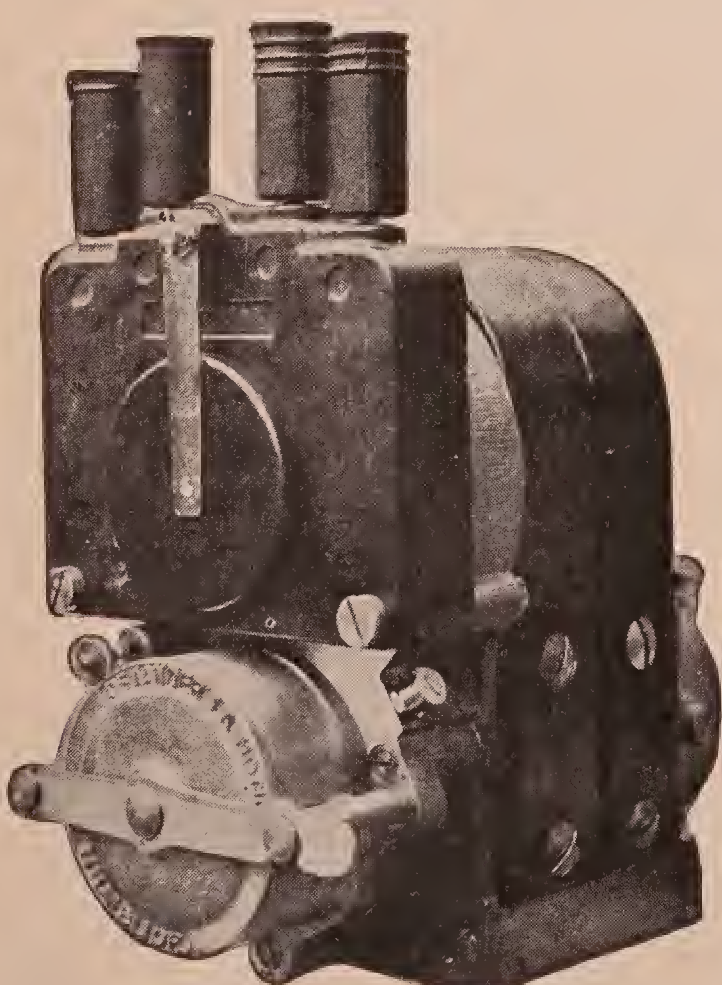


Fig. 96. Front View Nilmelior Magneto

Automatically Timed Systems. The stress laid by automobile manufacturers on their instructions "always retard the spark before cranking the motor", and "always run with the spark advanced as far as possible, except when necessary to retard it owing to the motor slowing down on hills and causing a hammering noise in the cylinders", make it evident that there is a considerable amount of discretion left in the driver's hands where this important point is concerned. It is not desirable that this should be exercised by unskilled drivers, particularly those in charge of large and costly commercial vehicles, and automatically timed systems have accordingly been developed.

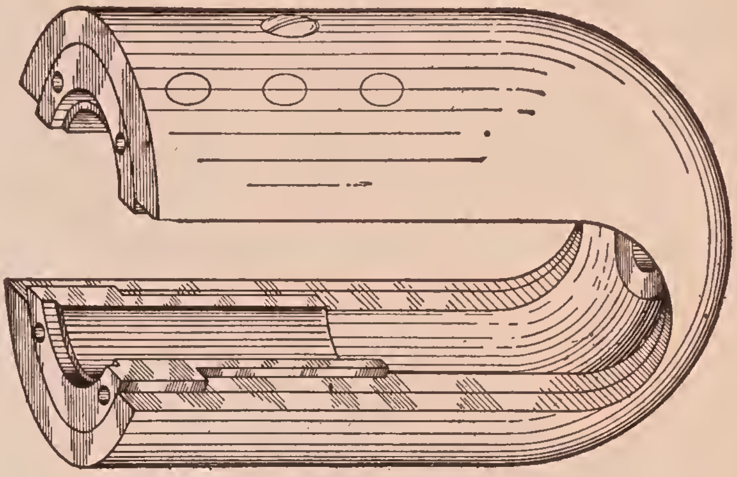


Fig. 97. Bell-Shaped Magnets of Mea Magneto

Eisemann Centrifugal Governor Type. To advance the spark timing automatically, a centrifugal governor has been mounted on the armature shaft in the Eisemann magneto of this type, as shown

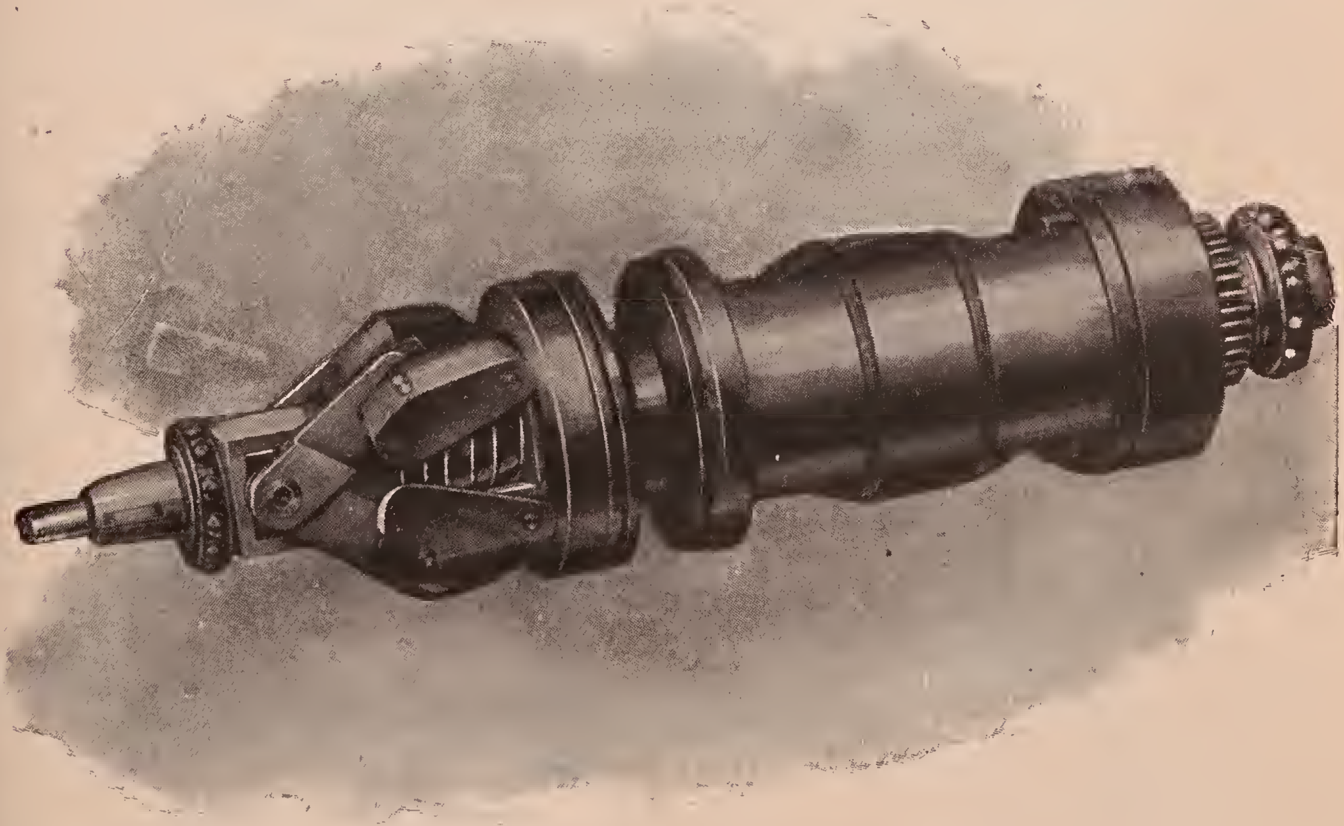


Fig. 98. Armature with Centrifugal Timing Device, Eisemann Magneto

in Fig. 98. Normally, the weights are contracted by the spring and the contact breaker is held at the fully retarded position, so that it is always safe to crank the motor without the necessity of taking any precautions. With an increase in speed, these weights tend to fly apart and in doing so they draw a sleeve and with it the armature along the shaft with them toward the left-hand end. As there are

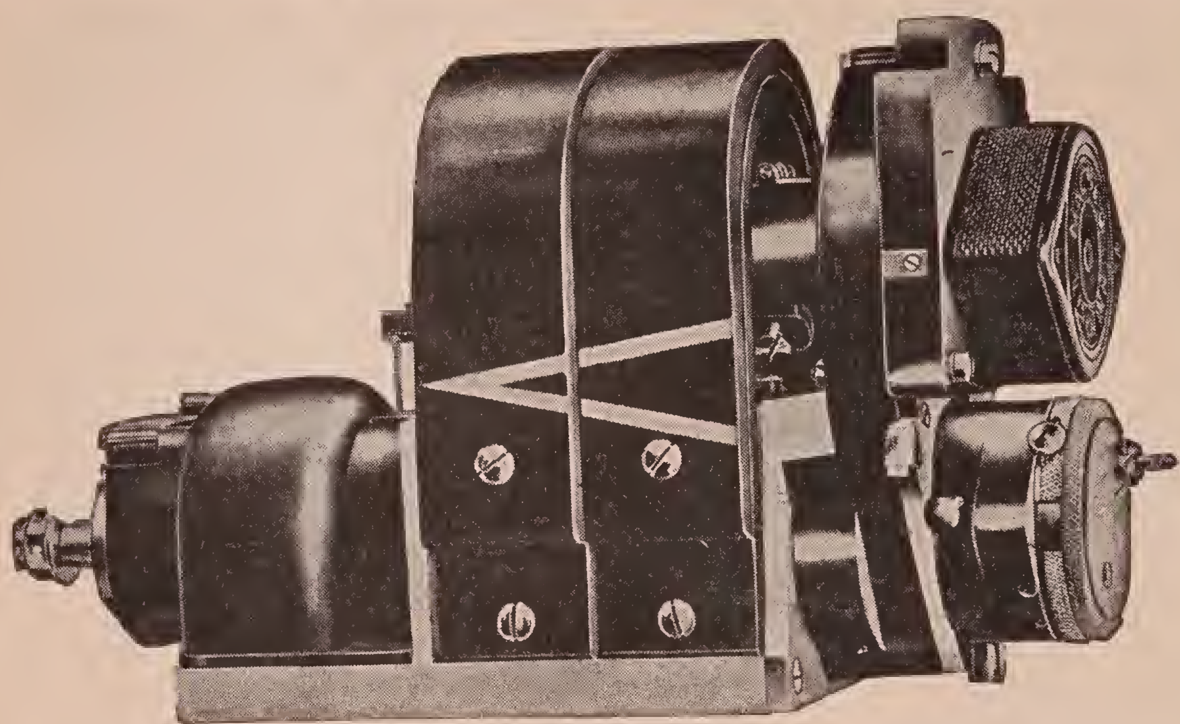


Fig. 99. Eisemann High-Tension Magneto with Automatic Timing

Fig. 100. Herz Automatic Spark Advance Coupling

Fig. 101. Herz Automatic Coupling (Side View)

two helicoidal ridges on the shaft, however, and splines on the inner diameter of the sleeve engaging them, the sleeve is forced to make a partial revolution as it moves along the shaft, thus automatically advancing the ignition timing in accordance with the speed. The contact breaker is in fixed relation to the armature. An Eisemann magneto fitted with the automatic timing device is shown in Fig. 99. The lines drawn on the magnets indicate their polarity, so that in case the machine is taken apart it can readily be assembled again with the magnets in their proper relation.

Herz Ball Governor Type. Another method of accomplishing the same end is the Herz automatic coupling, shown in Figs. 100 and 101. This consists of two juxtaposed disks, each of which is provided with five grooves running in a direction opposite to those of the other disk. Five steel balls are held in these grooves and act like the weights of a governor, being forced outward in direct proportion to the speed of the motor, thus imparting a twisting movement to the magneto armature with relation to its shaft. The device is supplied either as an integral part of the magneto, or as an independent coupling. The range of movement is 40 degrees, the adjustment being varied by altering the curve of the grooves. Fig. 102 shows the Herz magneto. In the Eisemann, spindles having grooved slots of several different pitches are supplied, giving from 19 to 60 degrees of advance. The Atwater-Kent, Connecticut, and Westinghouse ignition systems may also be had with automatic advance operated by a centrifugal governor.

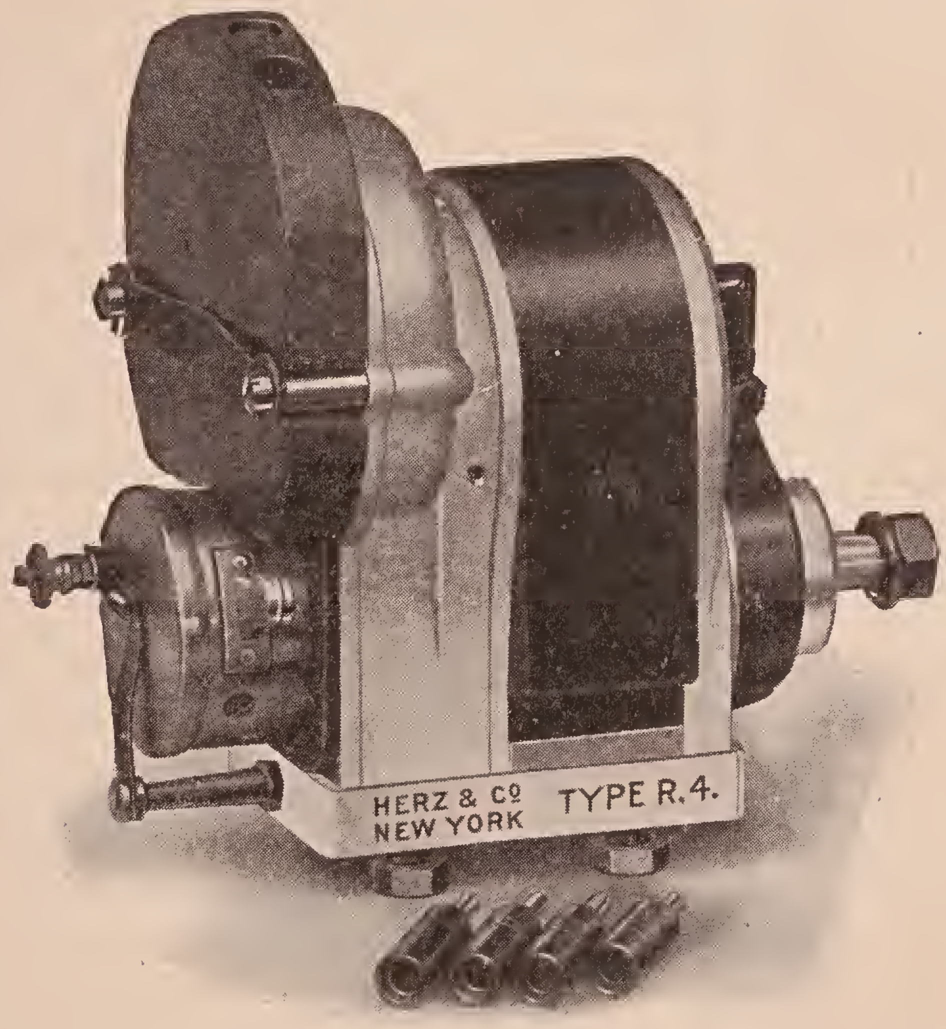


Fig. 102. Herz Magneto

Firing Order. It is naturally quite as important that the sparks occur in the different cylinders of a multi-cylinder motor in the proper order, as that each individual spark should take place at just the right moment. Regardless of the number of cylinders, the crankshaft throws are always in pairs. Hence, the pistons rise and fall in pairs and the cylinders of these pairs (which have no relation whatever to the method of casting the cylinders themselves) naturally cannot follow one another in firing, the firing order alternating from one pair to the other. For example, 1, 3, 4, 2, as in the upper

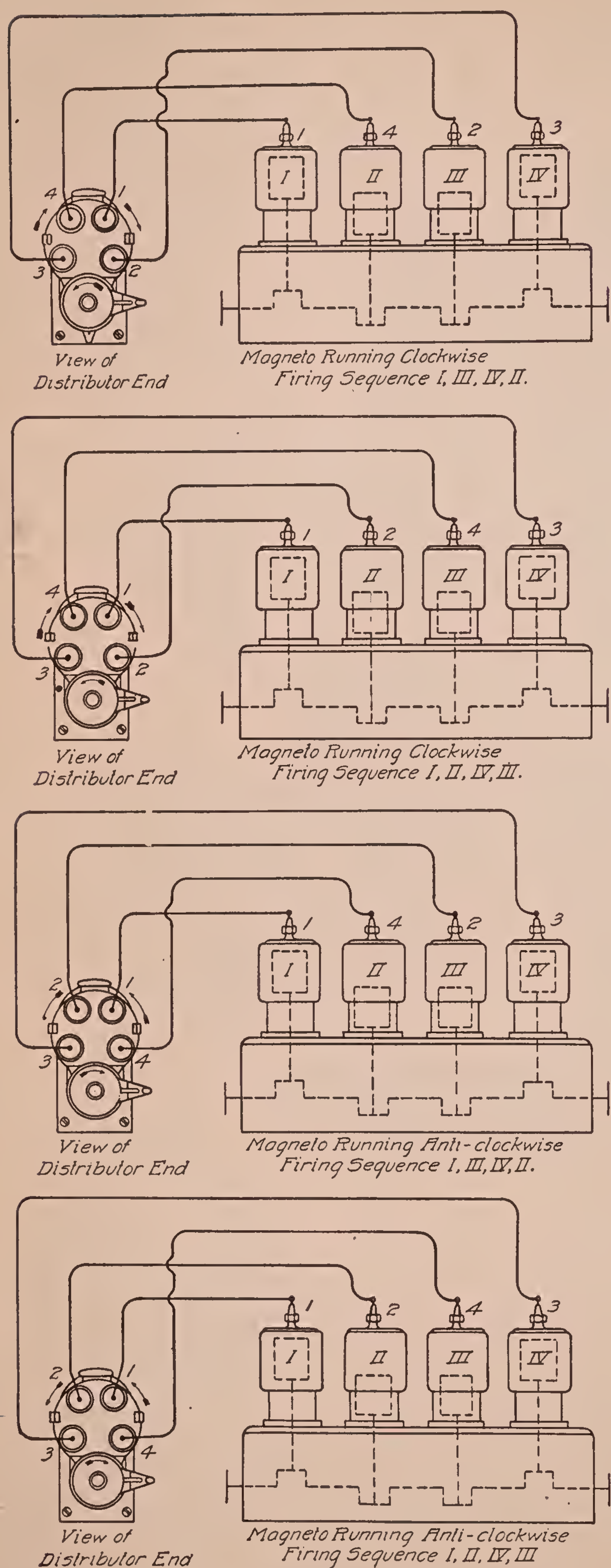


Fig. 103. Firing Order of Four-Cylinder Motors
(*Bosch Magneto Company*)

diagram of Fig. 103, or 1, 2, 4, 3, as in the diagram just below it, the motors in both these instances running "clockwise", i.e., with the crankshaft turning from left to right. A similar variation is possible with the motor turning "anti-clockwise" or from right to left, as shown in the two lower diagrams, which show firing orders of 1, 3, 4, 2, and 1, 2, 4, 3, the changes being made by shifting the distributor connections to the spark plugs of the various cylinders. In the case of a high-tension battery system using unit coils, the timer connections are varied in the same manner. In six-cylinder motors the crank throws are 120 degrees apart, but as the pistons are attached in pairs to cranks in the same plane, the method of distributing the firing order among them is similar to that already given. The Bosch dual ignition system, as installed on the six-cylinder Winton, is a typical firing order for a six. As shown by Fig. 104, this runs 1, 5, 3, 6, 2, 4.

Possible Combinations. There are so many possible firing orders in the six-cylinder motor and likewise in the more recent eight-cylinder and twelve-cylinder motors that one of the most puzzling questions arising in the repair shop frequently has been to determine just which one has been adopted by the manufacturer for his particular motor. So much uncertainty exists that many makers have solved this for the repair man by attaching a plate to the motor or to the dash, giving the firing order. There are eight firing orders possible for the six or eight. With the six these are:

(a)	1	2	3	6	5	4	(e)	1	4	5	6	3	2
(b)	1	2	4	6	5	3	(f)	1	5	4	6	2	3
(c)	1	3	2	6	4	5	(g)	1	4	2	6	3	5
(d)	1	3	5	6	4	2	(h)	1	5	3	6	2	4

While any of these firing orders will give an equally good impulse balance, the question of proper distribution of the incoming charge

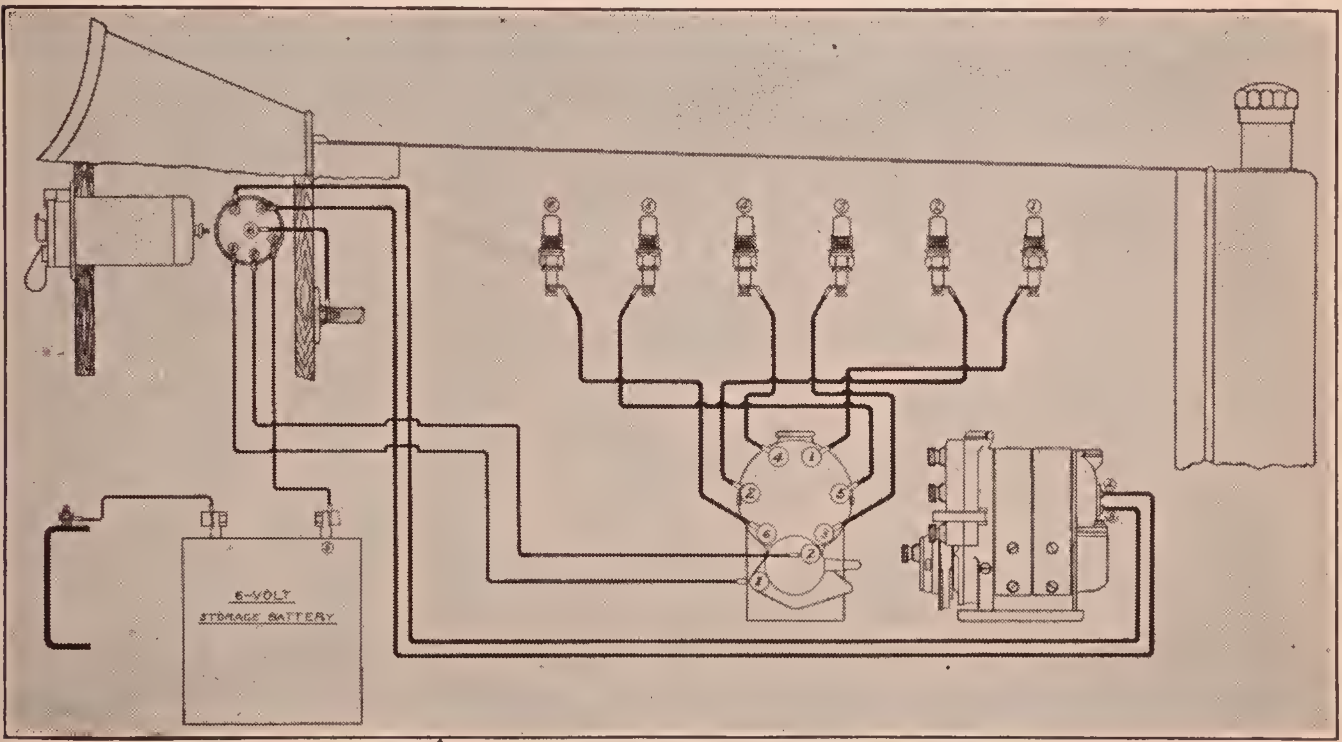


Fig. 104. Firing Order of Six-Cylinder Winton Motor

and the free escape of the exhaust also have an important bearing on the matter, so that the last two orders given are in most general use. The Winton Six, Fig. 104, shows the employment of order (h).

For the V-type eight-cylinder motor, the possible firing orders, as given by "*The Horseless Age*", are as follows:

(i)	1R	1L	2R	2L	4R	4L	3R	3L	(m)	1R	1L	3R	2L	4R	4L	2R	3L
(j)	1R	1L	3R	3L	4R	4L	2R	2L	(n)	1R	1L	2R	3L	4R	4L	3R	2L
(k)	1R	4L	2R	3L	4R	1L	3R	2L	(o)	1R	4L	2R	3L	4R	1L	3R	3L
(l)	1R	4L	3R	2L	4R	1L	2R	3L	(p)	1R	4L	2R	3L	4R	1L	2R	2L

As the last four mentioned involve different firing orders in each set of four cylinders, they need not be considered. With the rocker-arm type of valve lifters using only eight cams, as in the De Dion (French, and the first to use an eight-cylinder motor), Cadillac, and King engines, it is only possible to use the orders k and l, while as a matter of fact, all three employ the order given in l, which is shown diagrammatically in Fig. 105. The other possible

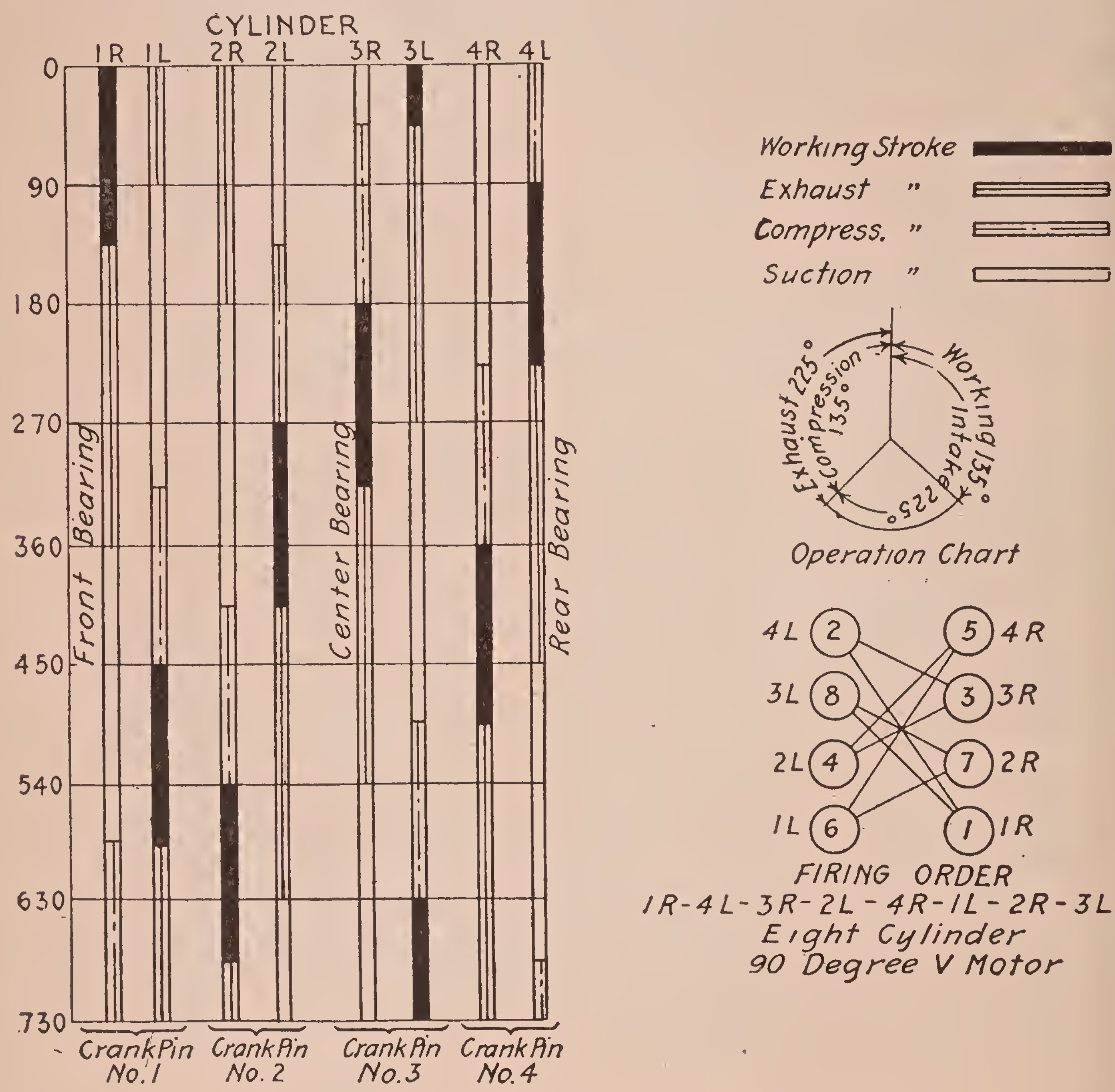


Fig. 105. Firing Order of an 8-Cylinder, V-Type Motor
Courtesy of "Automobile Topics", New York City

order for an eight (k) may be read from the same diagram by turning it around and changing the numbers from 4L to 1R, 3L to 2R, and so on. A curious fact is that in each of these orders the sum of the numbers of two cylinders which fire in succession is always 5. By starting always with a right-hand cylinder, the firing order can readily be determined by noting whether the firing order in one of the groups of four cylinders is 1, 3, 4, 2 or 1, 2, 4, 3.

Just as the eight-cylinder V-type motor is simply a combination of two groups of four cylinders, each of which considered alone would have the standard firing order of a four, so the twelve-cylinder V motor is simply the bringing together on one crankshaft of two six-cylinder motors. The firing order adopted is accordingly one of the two preferred for the six-cylinder motor (g and h), alternating from the right-hand to the left-hand group in the same manner as shown for the eight-cylinder motor.

Wiring. *Necessity for High-Tension Cables.* Mention has been made of the fact that in early days much trouble was experienced

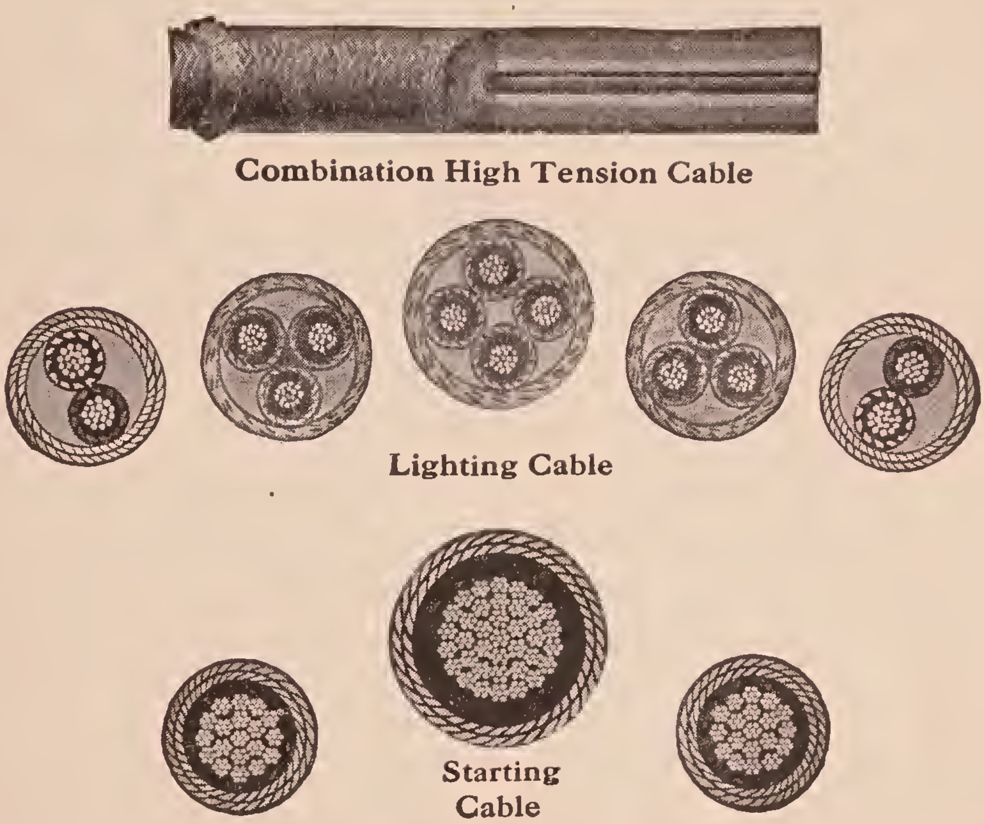


Fig. 106. Type of Cables Employed in Electrical Equipment of Automobiles

with poorly insulated and poorly mounted wires. This was particularly the case with the secondary circuits, the insulation of which was frequently inadequate to carry currents at the high potentials employed, so that there was more or less leakage. This was further aggravated by the chafing or rubbing of these wires against moving parts. The former trouble was eliminated by the adoption of specially constructed cables which are tested to carry 30,000 volts. Cables of this type are illustrated by Fig. 106, which also shows the cables employed for electric lighting and starting installations, where the chief difficulty has usually been the selection of a cable of too small a carrying capacity for the current used.

Methods of Avoiding "Static Kicks". With the adoption of proper high-tension cables and suitable supports to prevent injury, another difficulty was occasionally met with. This arose from static conditions in the wiring. Briefly, the intermittent flow of high-

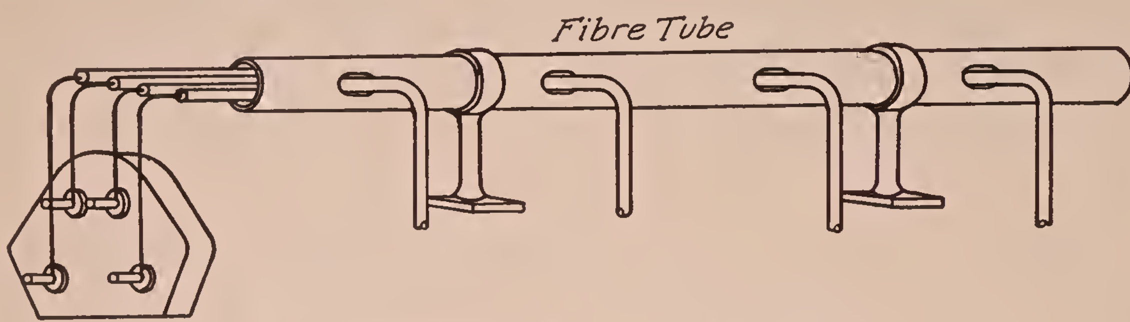


Fig. 107. Wiring Subject to "Static Kicks"
(*Horseless Age*)

tension current through the cables leading to the spark plugs caused the cables themselves to become charged electrically, just as a condenser does. Under certain conditions, this charge may be imparted to adjacent cables, which may in this manner accumulate sufficient potential to discharge at one of the spark plugs out of the proper firing sequence. In the same way the deprivation of some of the electrical energy from a cable may so reduce its potential as not to pass a spark at its plug and result in missing in that cylinder. The underlying phenomena are rather abstruse and are not within the scope of this article, but the remedy is very simple.

The purpose of the high potential impressed upon the current is to enable it to break down the resistance of the air gap in the spark plug, and it necessarily follows that anything tending to retard this discharge at the gap is a detriment to the ignition. Fig. 107 illustrates the condition that has usually been found conducive

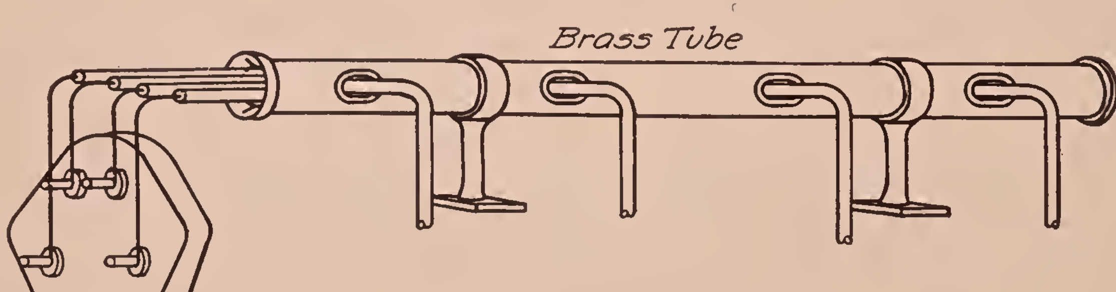


Fig. 108. Use of Brass Tube Provides an Outlet for Static Charge
(*Horseless Age*)

to the production of what are termed "static kicks", i.e., discharges of static or high potential electricity. All the high-tension cables touch one another and are run through a fiber tube, which insulates them from the motor, that is, their outer surfaces, a high-tension current tending to travel on the surface of a conductor particularly where it is a high-frequency current. An improvement on Fig. 107, is shown by Fig. 108, in which a brass tube has been substituted for the fiber. In this, the metal will conduct whatever static charges

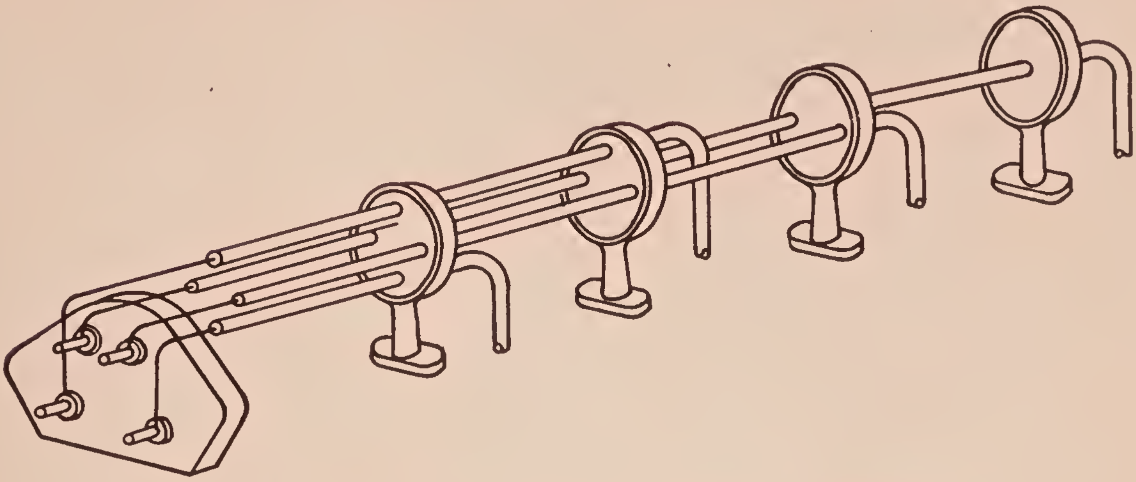


Fig. 109. An Improvement over Figs. 58 and 59
(*Horseless Age*)

collect to the ground and no discharges can take place to adjacent cables. However, to secure the best results, the individual cables must be separated from one another. Two methods of doing this are illustrated by Figs. 109 and 110, the latter representing the ideal arrangement where space permits it. This arrangement, supplemented by a metal cover to protect the cables, has been perfected and is standard practice with a number of manufacturers abroad. It goes without saying that high-tension cables should always be as short and as widely separated from one another as practicable, and likewise as direct, bends or loops being avoided wherever possi-

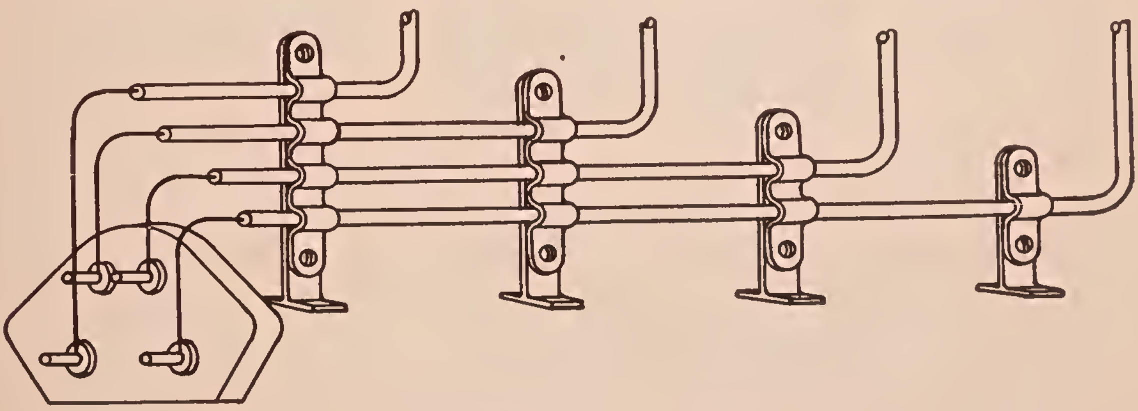


Fig. 110. Ideal Ignition Wiring Arrangement
(*Horseless Age*)

ble, and it will be found that the ignition wiring of up-to-date cars reflects these conditions.

Magneto Mounting. As the magneto is timed exactly with the motor, it must be positively driven synchronously with it at a speed depending upon the number of cylinders. This is crankshaft speed on a four-cylinder and one and one-half times crankshaft speed on a six. It has become standard practice to a very large extent both here and abroad to mount the magneto on a "pad" or shelf attached to the crankcase and drive it from a special auxiliary shaft, usually also utilized for driving the water pump or other motor auxiliary. Variations from this are to be found in the Renault and a few other European as well as American cars, in which the magneto is mounted at the forward end of the motor and driven by a cross-shaft and helical gears directly from the crankshaft of the motor. The only advantage of this is slightly greater accessibility. In any case, the magneto is not permanently fastened, but is simply held, against movement, on its support by dowel pins in the base and a strap clamp tightened with a thumb nut, as shown on the Lozier six-cylinder motor, and the Ariel four-cylinder motor, Figs. 111 and 112, which may be regarded as typical of American and British standard practice, respectively. As the efficiency of the magneto depends to a considerable extent on the very limited clearance between its armature and the pole pieces of the field, usually termed the armature tunnel, precautions are taken to avoid placing any stress on it that could tend to disturb this accurate alignment. The driving shaft is accordingly provided with a universal joint, the long familiar Oldham coupling, much used

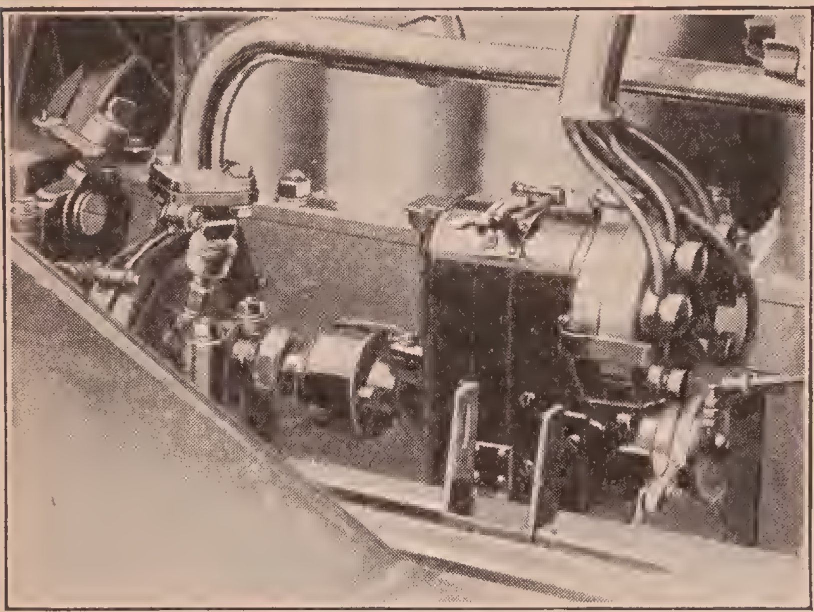


Fig. 111. Mounting of Magneto on Lozier Car

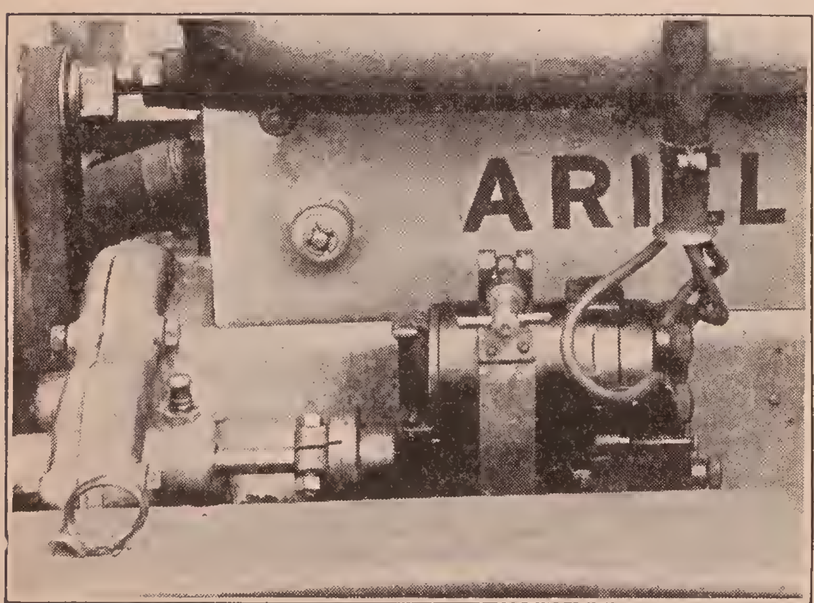


Fig. 112. Magneto Mounting on Ariel Car (British)

in this country for the purpose, being shown on the Lozier, and an equally simple type on the Ariel. On the Pierce-Arrow a leather disk universal drives the magneto and also cushions the armature.

MODERN BATTERY IGNITION SYSTEMS

Effect of Starting and Lighting Developments on Ignition. Prior to the advent of the electrical starting and lighting systems, the magneto had reached a degree of development that appeared to leave not the slightest doubt as to its representing the ultimate type of ignition current generator. With the installation of a direct-current generator capable of supplying more than enough current for lighting and starting the car and charging a storage battery of high capacity, however, it appeared that there was a duplication of electrical apparatus for which there was no good economic reason. In other words, with such an ample and reliable source of current on the car as that presented by the charging generator and storage battery, why continue the magneto? There is no sound reason why one electrical system should not combine all three functions of ignition, lighting, and starting, and this has been successfully carried out on the Cadillac for several years past, while the Reo and other makes have more recently followed suit. There is accordingly considerable doubt as to whether the magneto will not eventually be displaced altogether by combining the ignition with the lighting and starting system.

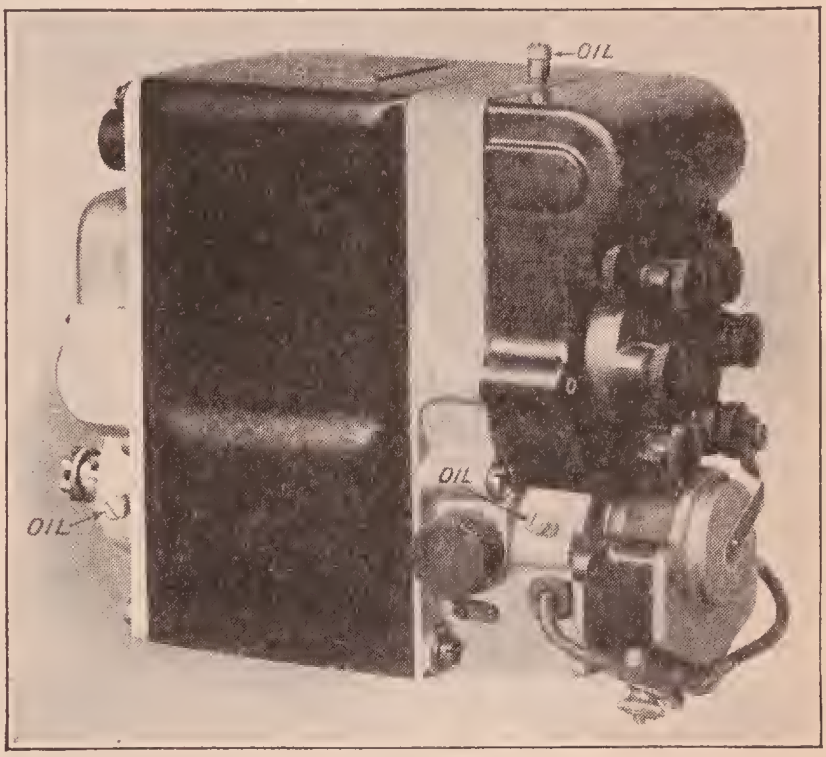


Fig. 113. Westinghouse Generator with Ignition Distributor

Generator Design Follows Magneto Precedent. Several generator designs have been developed, and it is noteworthy that their appearance is quite that of a magneto. In the Westinghouse combination lighting and ignition generator, Fig. 113, and the Remy,

Fig. 114, their contact breakers are of the magneto type, as will be plain from the Remy, Fig. 61, and the Westinghouse, Fig. 115, to cite but two examples of a number. In the case of the Westinghouse, the objection previously held against battery ignition—that it

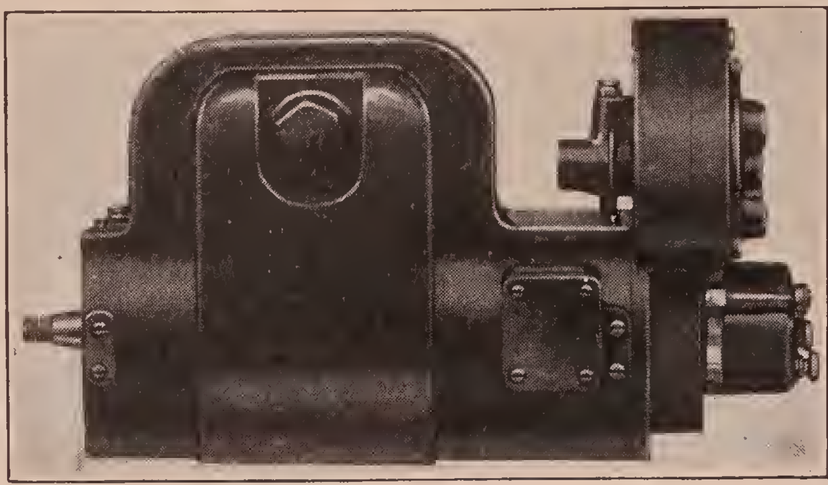


Fig. 114. Remy Combination Lighting and Ignition Generator

required much more manipulation of the spark advance lever to obtain efficient motor running—has been overcome by the provision of a centrifugally operated automatic advance device, Fig. 115, similar in principle and results to the Eisemann and Herz devices, Figs.

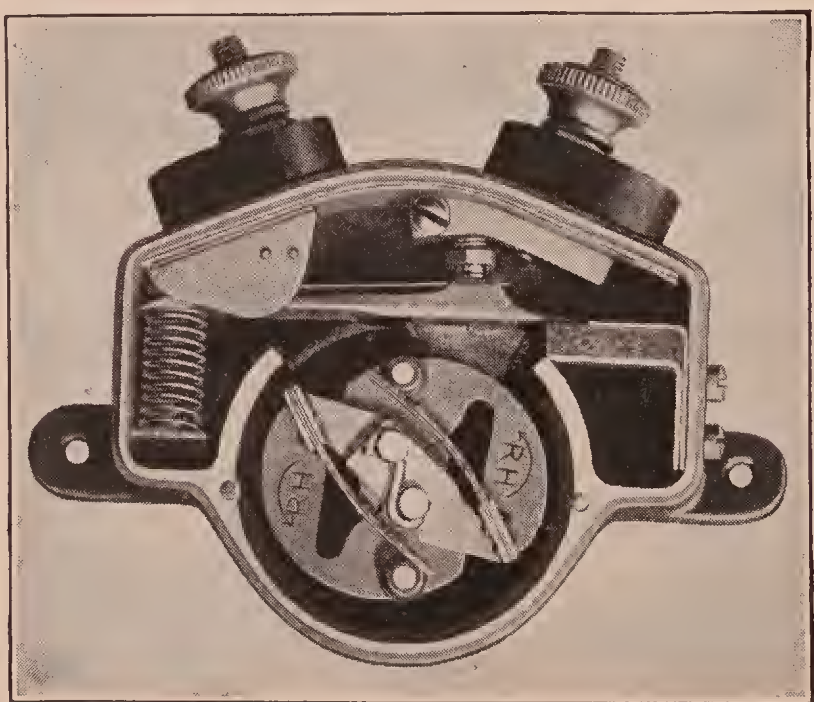


Fig. 115. Westinghouse Contact Breaker with Automatic Spark Advance

98 and 101, though differing from them in construction. The distributors employed are practically identical with those used on magnetos, but all resemblance disappears when the machine is dismantled, Fig. 116, revealing a compact direct-current generator.

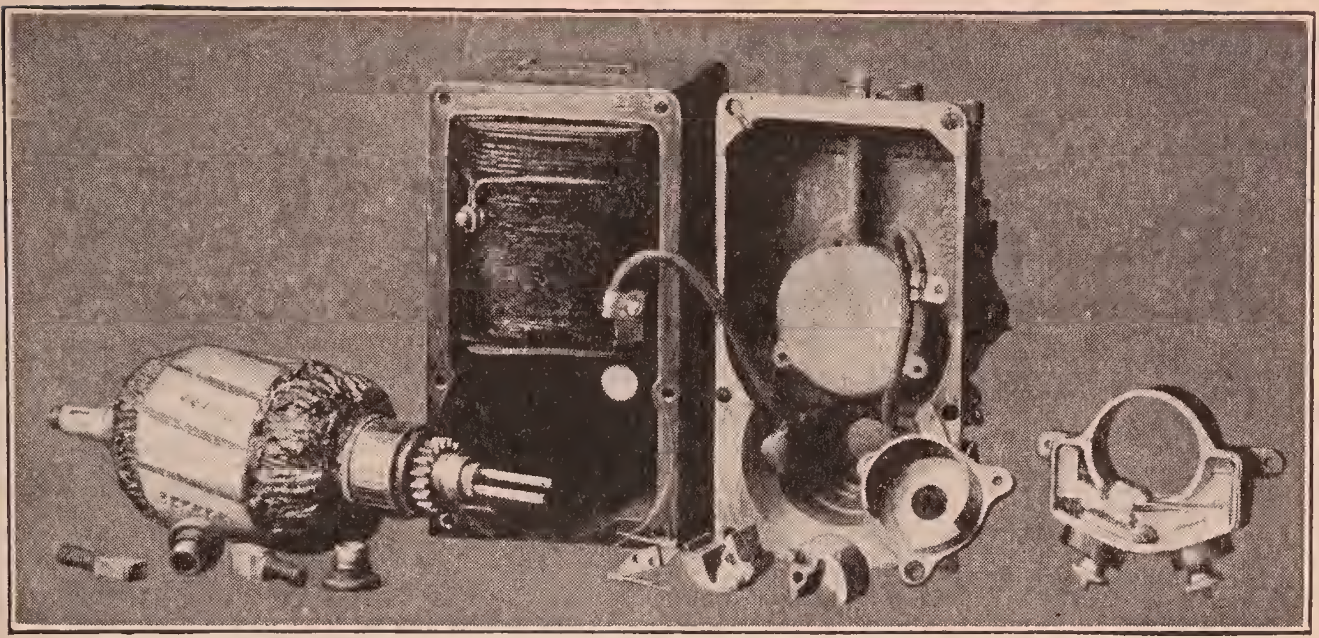


Fig. 116. Details Westinghouse Lighting and Ignition Generator

TYPICAL ARRANGEMENTS

Westinghouse Ignition Unit. This is a combination of all the essentials of magnetic ignition, i.e., the interrupter, distributor, induction coil, and condenser, brought together in a compact unit adapted for mounting either on the lighting generator itself or directly on the engine. It supersedes the type of ignition and lighting generator previously described and which now will be found only on cars of earlier models. As will be noted in Fig. 117, its components are the counterparts of the same essentials on the magneto, except that the interrupter cam has four lobes, so that no further description is necessary.

Fig. 118 is a wiring diagram of the connections. The interrupter and condenser are located at the bottom of the housing with the

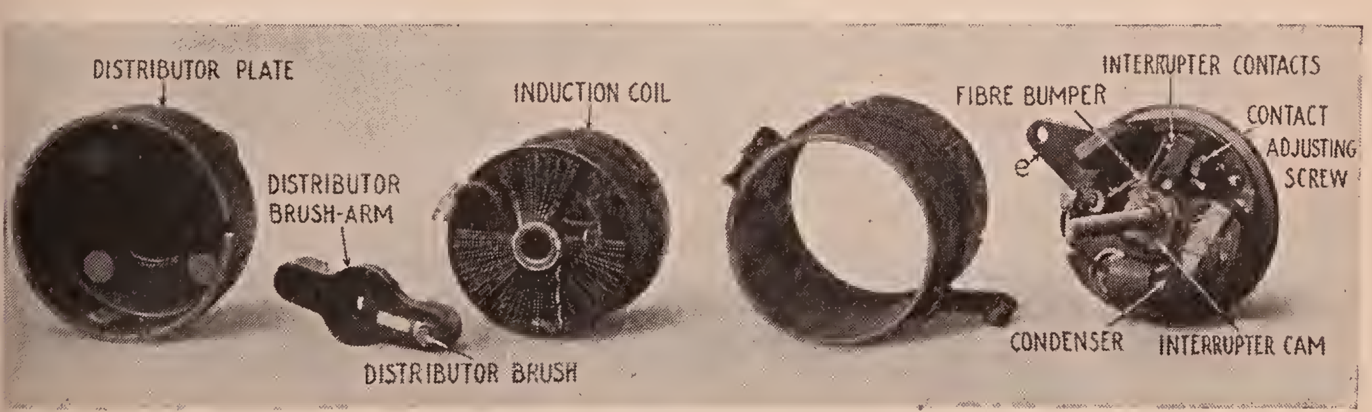


Fig. 117. Details of Westinghouse Ignition Unit
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

induction coil above and the distributor at the top. To prevent an excessive amount of current passing through the ignition unit, a "ballast resistor" is connected in series with it. This is a resistance unit which, in the various models, is combined either with the switch or with the fuse box, or may be mounted independently. In case this resistance unit should become inoperative for any reason, the car may be run by replacing it with a standard 5-ampere fuse cartridge. A fuse of larger capacity than this should not be used and the car should not be run any longer than absolutely necessary with the fuse in place, as the interrupter contacts would be badly burned. The working of the interrupter contacts may be inspected by loosening the set screw at the bottom of the housing and lifting the distributor an inch or so, Fig. 119.

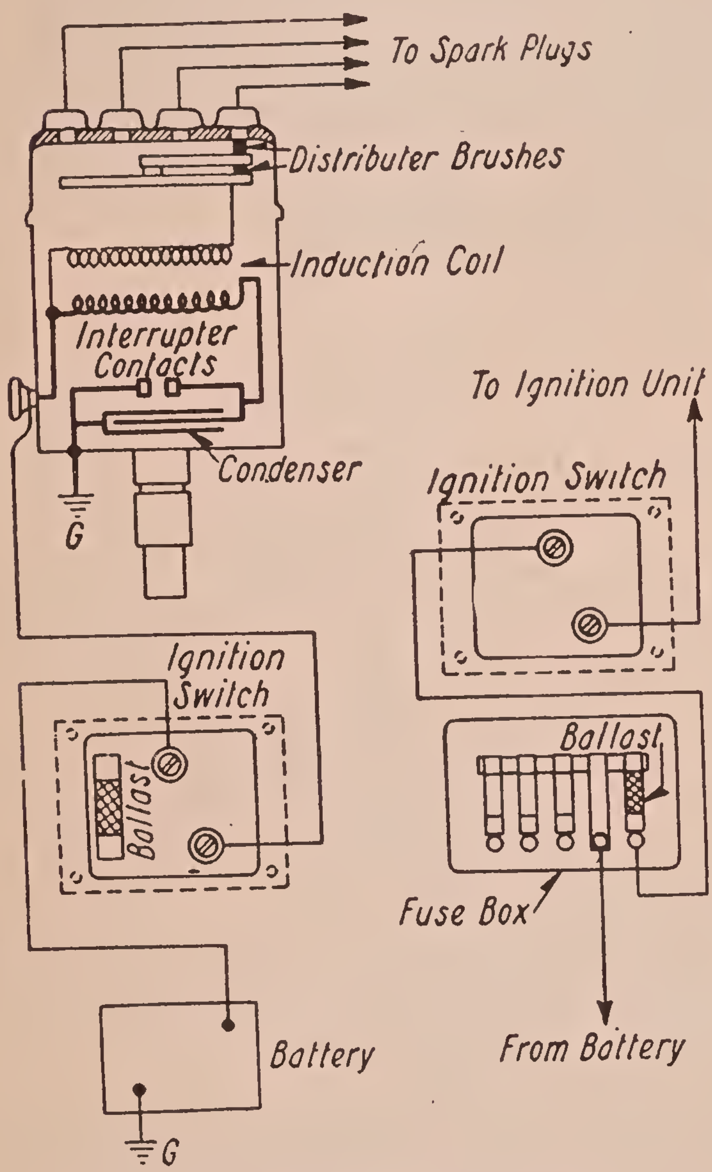


Fig. 118. Wiring Diagram for Vertical Ignition Unit. Left—with Ballast on Rear of Ignition Switch; Right—with Ballast in Fuse Box

Atwater-Kent System. The Atwater-Kent system is based on a "single spark" interrupter and was the pioneer in making battery ignition successful on the modern automobile before the advent of the perfected lighting generator, the current source usually being a dry-cell battery. It was considered an advantage in earlier years to produce a series of high-tension sparks in the cylinder on the theory that, if the first failed to explode the charge, it would be fired by the subsequent sparks. The fallacy of this long since became apparent and the reason therefor has been dwelt upon already. The Atwater-Kent interrupter is typical of devices of this class which have been developed since and as it is fitted on thousands of cars which come to the repair man's attention at one time or another, a detailed description of its working is given here.

Operation of "Unisparker". The ratchet *A*, Fig. 120, has as many notches as there are cylinders to be fired. It is mounted on the central vertical shaft of the device which also carries a distributor, and in this combined form is known as a "Unisparker". On four-cycle engines it is driven at half crankshaft speed, and at crankshaft speed on two-cycle engines (motor boats). The ratchet *A* engages the lifter *B*, and, as *A* rotates, its teeth or notches successively tend to draw *B* with them, against the tension of the spring *C*. In doing

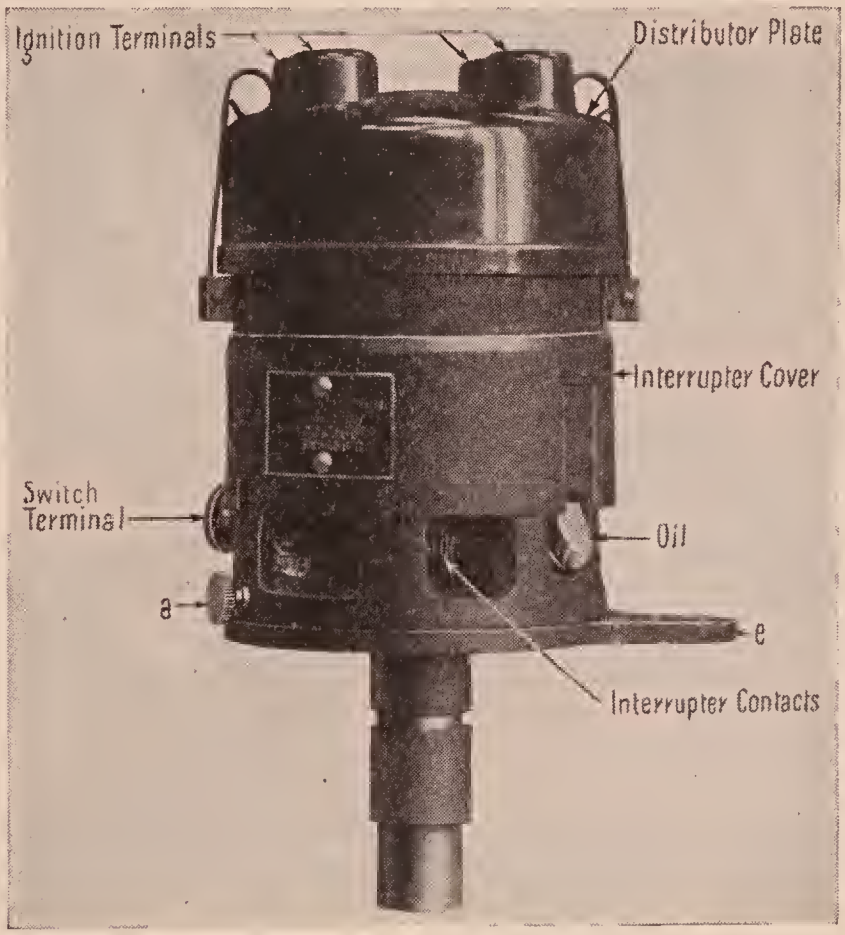


Fig. 119. Westinghouse Ignition Unit with Interrupter Cover Raised Showing Interrupter Contacts
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

so, the head of *B* strikes the swinging lever or "hammer" *D*, whose motion in both directions is limited as shown, and the hammer communicates the blow to the contact spring *E*, bringing the contact points together momentarily. *E* is a compound spring, the straight member of which carries the movable contact, while the stationary contact *F* is mounted opposite it. The second member of this compound spring is curved at its end to engage the straight member. Ordinarily the straight spring blade is held under the tension of the curved blade and the contact points are held apart.

When the curved blade is struck by the hammer *D* the points contact. The curved blade, however, is thrown over farther by the impact and its hook leaves the straight blade. Upon reaching the

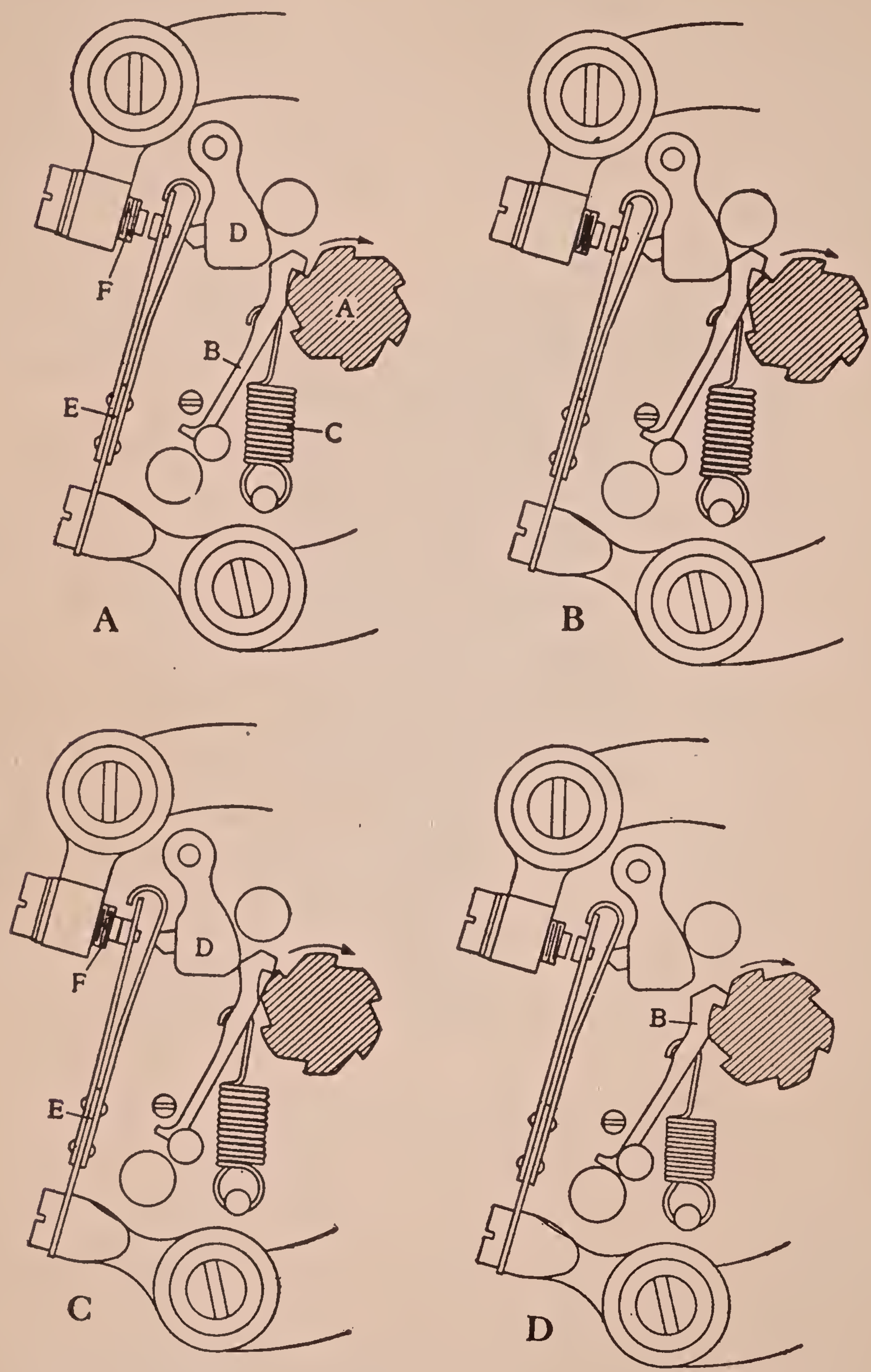


Fig. 120. Diagram Showing Operation of Atwater-Kent Interrupter
Courtesy of "The Horseless Age"

limit of its movement it flies back and strikes the end of the straight blade a blow causing a very sharp break of the circuit. This movement is so extremely rapid that it cannot be detected by the unaided eye, so that its working cannot be tested simply by watching the operation of the contacts as in the case of a magneto interrupter. *B*, *C*, and *D*, of Fig. 120, show the successive movements of the parts during a single phase. In *A*, a notch of the ratchet has engaged *B* and is drawing it against the tension of the spring *C*. In the second sketch *B*, the hook is released. In *C*, the lifter is riding back over the rounded portion of the ratchet and striking the hammer *D*, which in turn pushes *E* for a brief instant against *F*. The return of *B* to the position shown in sketch *D* is so rapid that the eye cannot follow the movement of the parts *D* and *E*, which to all appearances remain stationary.

Adjustment of the contact points is made by removing one of the thin washers from under the head of the contact screw *F*, and the gap should be .010 to .012 inch, never exceeding the latter. Where more accurate means of determining this distance are not available, it may be gaged with a piece of manila wrapping paper which should be perfectly smooth. With the aid of a "mike" (micrometer) a sheet of paper of the proper thickness can be selected. The contacts are of tungsten and as the moving parts are all of glass-hard steel, very accurately machined, the wear is negligible so that adjustment is not required oftener than once in 10,000 miles running and replacement only after 50,000 miles.

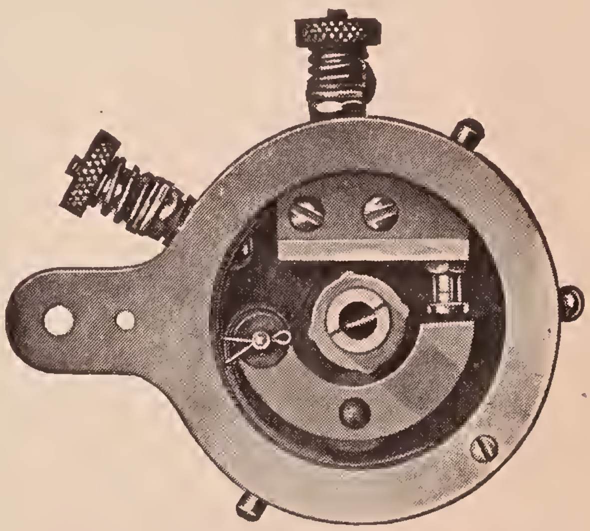


Fig. 121. Connecticut Interrupter

With this interrupter it is impossible to run the battery down by leaving the switch closed inadvertently, as the contacts are never together when the moving parts are idle. The remainder of the system comprises an induction coil (nonvibrator) and a high-tension distributor.

Connecticut Battery System. While this system also employs a single-spark interrupter, it is what is known as a "magneto type", and the similarity to those employed on magnetos for the same purpose will be noted in Fig. 121. A characteristic of this type of interrupter is that its contacts normally remain closed so that if the ignition switch is left on, the battery will be run down. To prevent this in the Connecticut system, an automatic switch acting on the thermoelectric principle is employed. The interrupter consists of a semicircular arm of sheet steel to make it light. This is pivoted at one end, carries a roller at its center and the movable contact at the other end. It is insulated from its pivot and the roller is of fiber. The vertical binding post is electrically connected with the stationary contact and the second one, at an angle, connects with the movable contact.

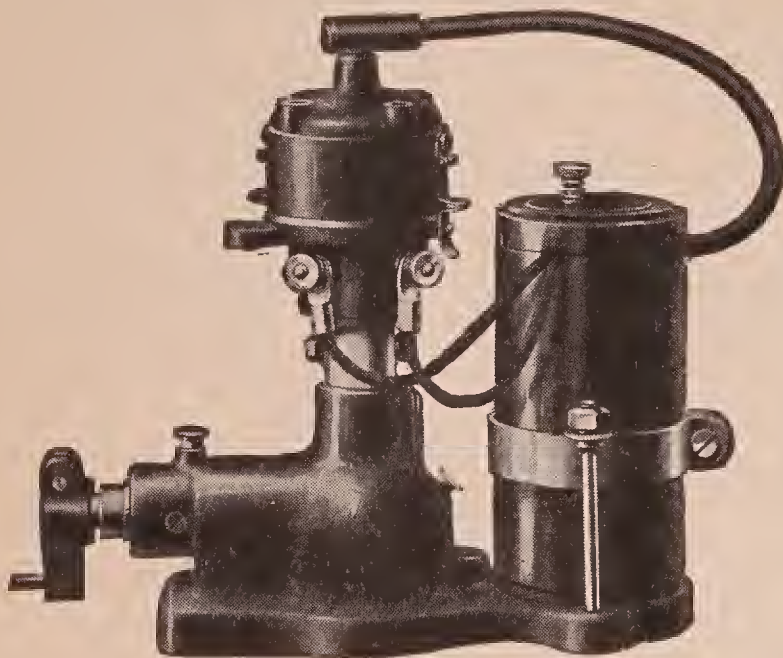


Fig. 122. Connecticut Igniter Complete Except for Switch
Courtesy of Connecticut Telephone and Electric Company, Meriden, Connecticut

While an interrupter of this type has practically no lag, means of advancing the moment of ignition are provided (lever extension at left), as the spark must occur earlier at high engine speeds to permit of propagating the flame throughout the charge in the extremely short time available in the modern high-speed engine. As the contacts are opened only momentarily, the interrupter is in circuit most of the time and accordingly is not economical of current, so that it is designed only for use with the battery and generator of the lighting and starting system.

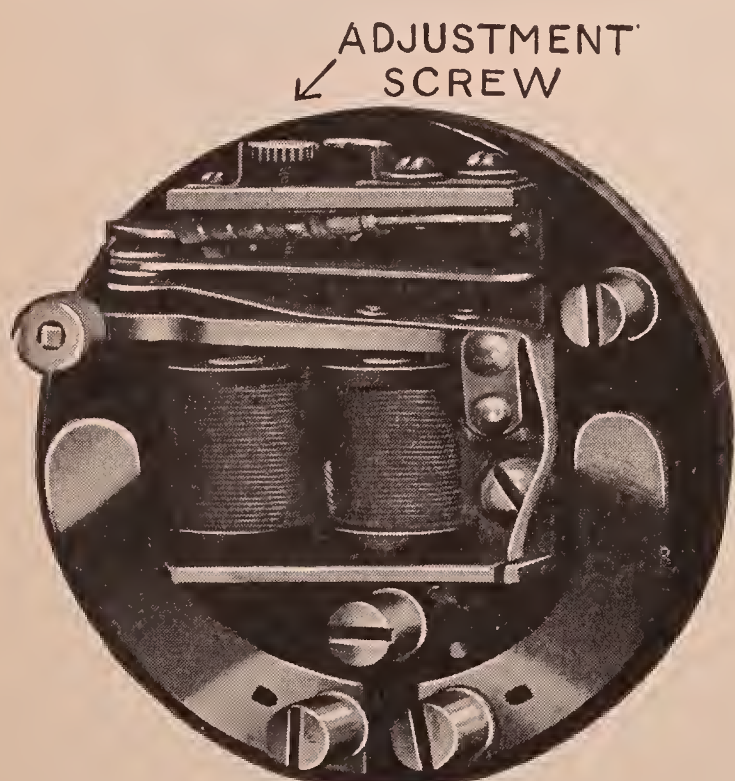


Fig. 123. Connecticut Automatic Switch

Fig. 122, shows the complete Connecticut system (minus the switch) as designed for mounting on a magneto bed plate. The distributor is mounted over the interrupter, while the coil is at the

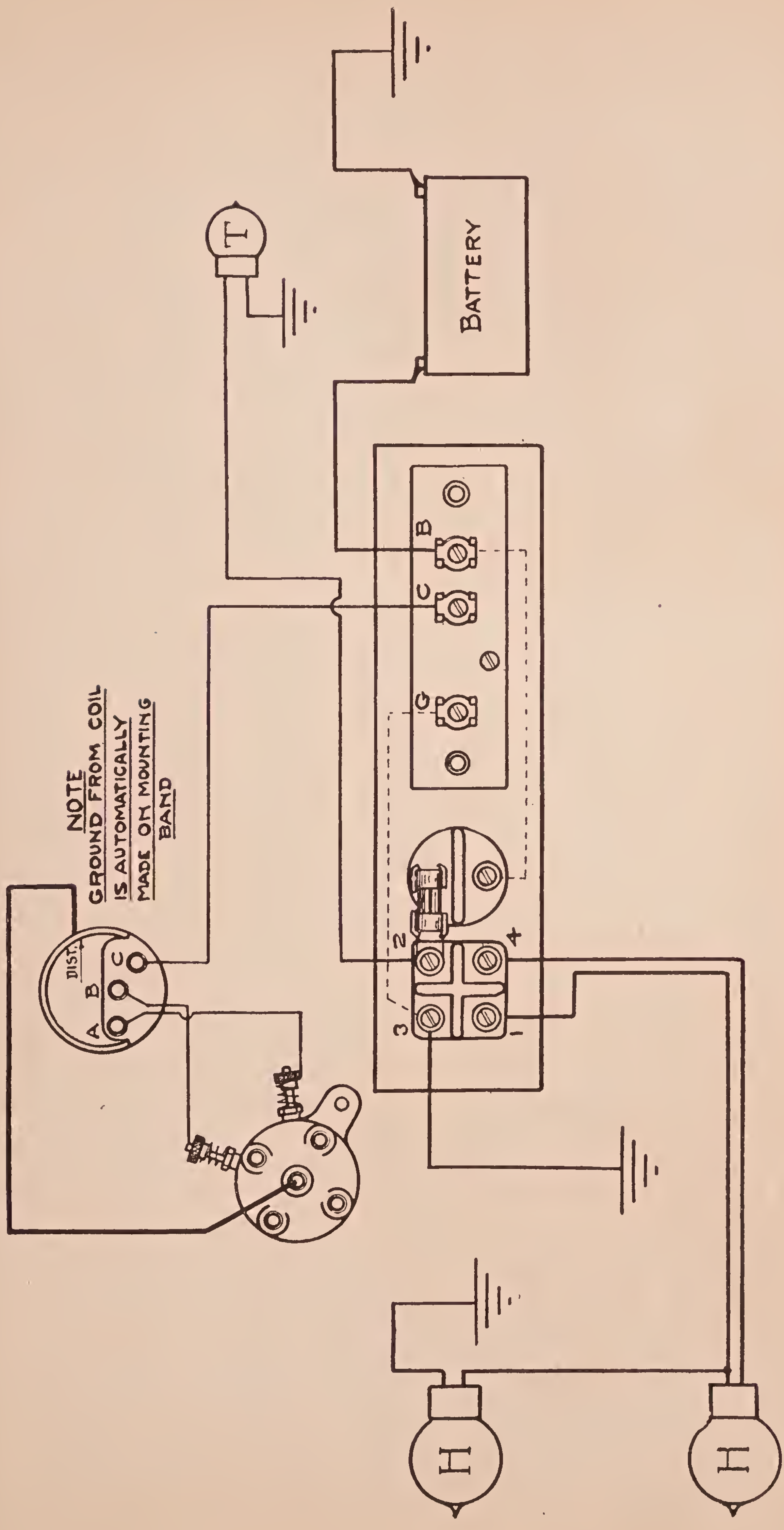


Fig. 124. Wiring Diagram for Connecticut Ignition System

right. The primary of the coil is not grounded, insulated leads being connected to the two binding posts of the interrupter, as shown. The grounding of the secondary winding of the coil is effected through the metal holding band and the bolts fastened to the bed plate. A glass tube is employed to house the safety gap which is mounted under the cover of the coil.

Automatic Switch. The purpose of the automatic switch, Fig. 123, is to open the circuit in case the switch button has been left on with the car stopped. The current passing with the contacts closed, when the engine is idle, is much greater than when it is constantly being interrupted by the rapid-fire action of the cam, but unlike a circuit breaker the device is not designed to act instantly upon the passing of an overload current as this would prevent cranking the motor. The device consists of a thermostatic arm regulated by the adjustment screw at the top of the figure, an electromagnetic vibrator the armature of which carries a hammer, and the necessary connections. Current enters at either the right- or left-hand screw at the bottom according to whether the switch is closed at the end of the sectors at the right or left of the figure (*M* or *B* on the switch cover plate) and flows through the heater tape on the arm of the thermostat to the screw at the upper right in the figure. This heater tape is a resistance that becomes warm upon the passage of a certain amount of current for a short time and with an increase in temperature it causes the arm of the thermostat to bend until it makes contact with the upper thermostatic arm. This puts the windings of the magnet in circuit through the post just below the magnet coils and sets the vibrator in motion, causing the hammer on the armature to strike the switch button and open it. Fig. 124 is a typical wiring diagram in connection with the lighting system, the automatic switch being combined with the lighting switch.

Delco System. A magneto-type interrupter, substantially similar to that of the Connecticut system, except that it is provided with an automatic spark advance, is employed, as shown in Fig. 125. The arm *B* carries the movable contact *D* and a fiber striking lug which bears against the four-part cam and is lifted by its revolution against the tension of the leaf spring held against the inner wall of the housing. The stationary contact is at *C* and is adjusted by means of the screw and locked in place by the nut *N*. These contacts should be so adjusted that when the fiber block on *B* is on

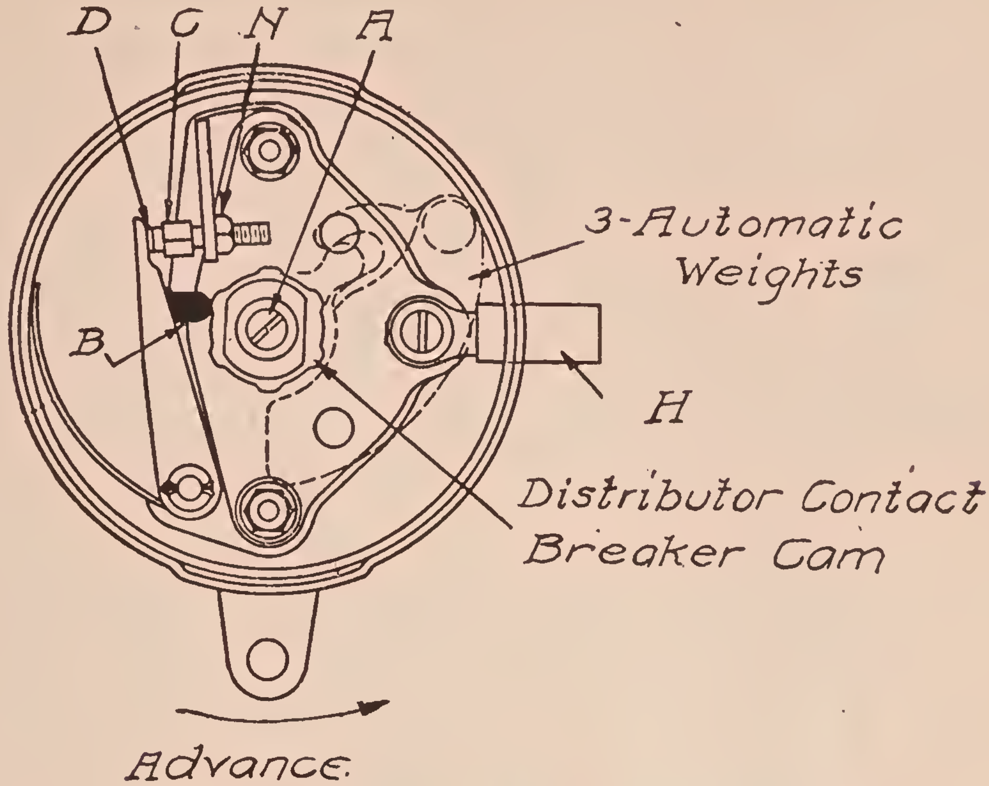


Fig. 125. Delco Magneto Type Interrupter

top of one of the lobes of the cam, the contacts should open sufficiently to allow the gage on the distributor wrench provided with the system to close the gap. As in the Connecticut interrupter, the contacts normally remain closed, being opened momentarily by the cam which has as many projections as there are cylinders to be fired. This is the later model of Delco interrupter (1916).

Earlier Model Interrupter. In an earlier model which will be found on a great many cars, the contacts are normally held open, Fig. 126. The movable contact is carried on a straight spring blade to which is attached a bent spring blade *B* held against the cam by the spring *E*. The latter also places the

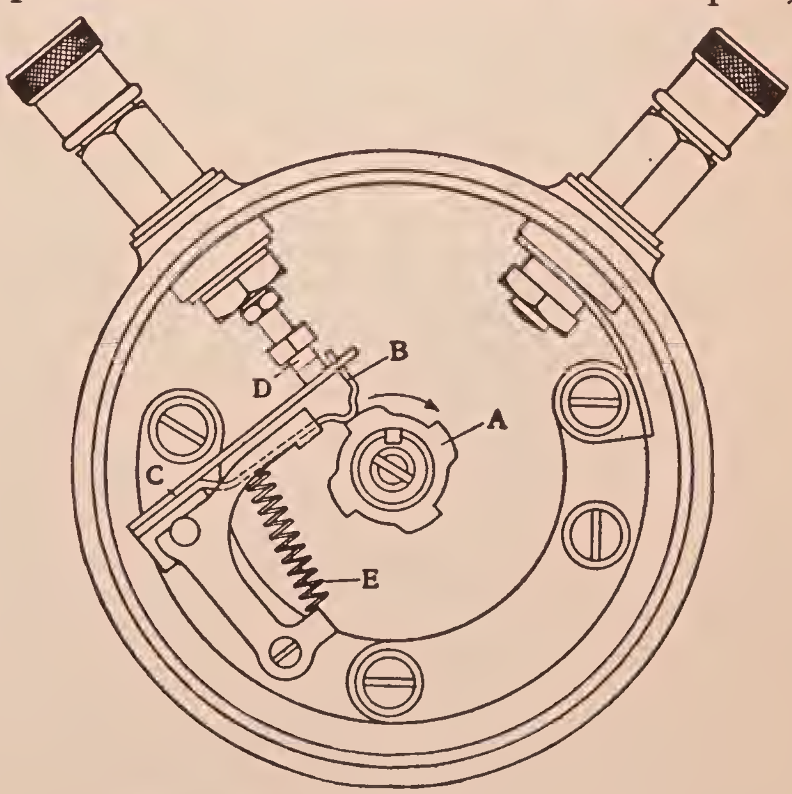


Fig. 126. Diagram of Earlier Model of Delco Interrupter

spring *C* under slight tension and holds the movable contact away from the stationary contact *D*. When the projection of the cam strikes the raised portion of *B*, it deflects the latter and allows the contact points to come together. As it passes the bump on *B*, *E* draws *B* back sharply, its end strikes *C*, and the contacts are suddenly opened, the duration of the contact varying with the speed of the engine.

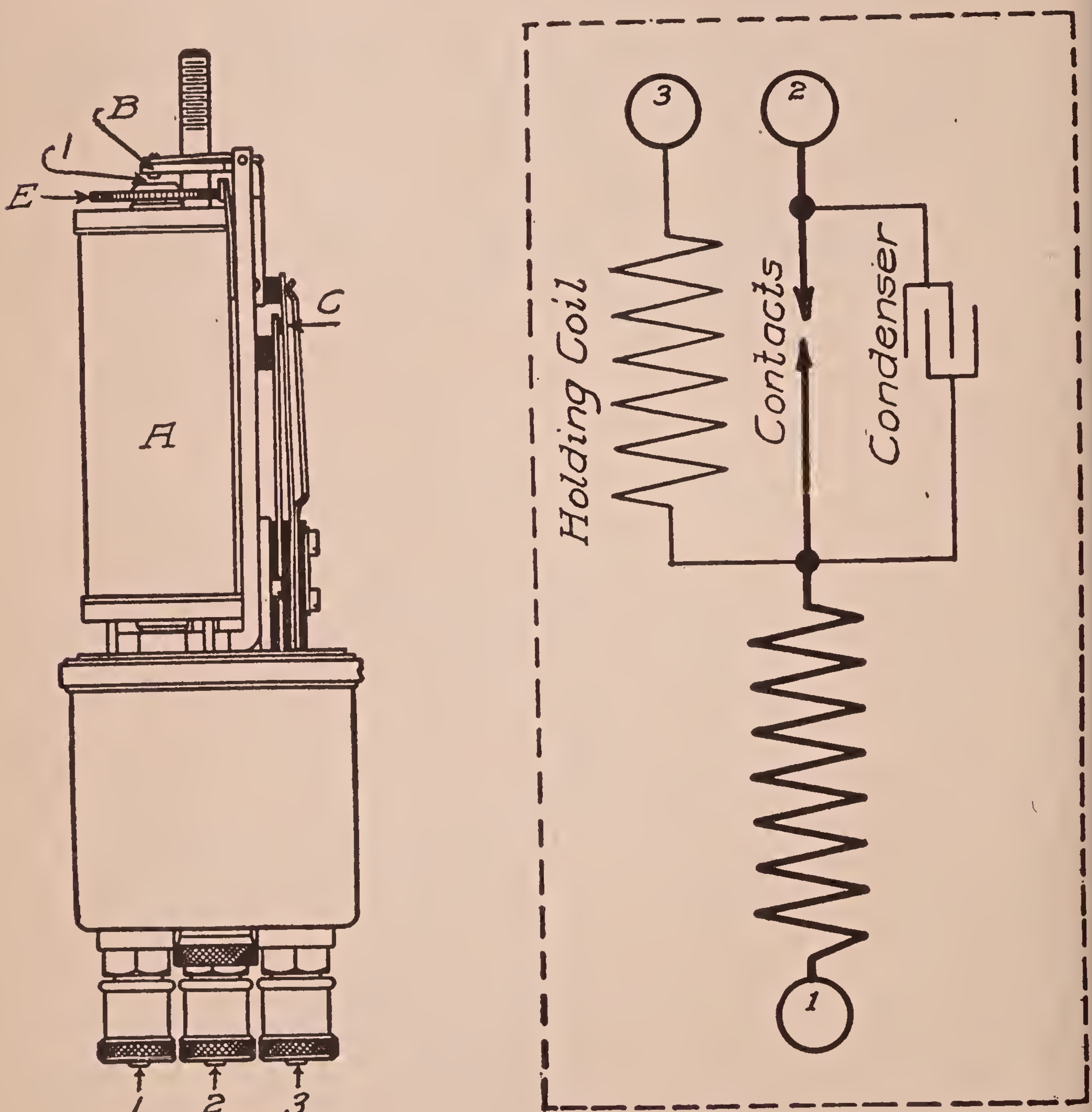


Fig. 127. Diagram of Delco Ignition Relay and Its Internal Connections
Courtesy of Dayton Engineering Laboratories Company, Dayton, Ohio

Delco Ignition Relay. As originally designed, the Delco ignition system was provided with a relay to produce a series of sparks for starting and a single spark when running. While this is no longer a part of the system, it is in use on thousands of cars now in service. The relay itself is shown in Fig. 127, together with a diagram of its connections. It consists of an electromagnet with two windings, one of coarse wire and one of fine wire, similar to a battery cut-out. The coarse winding produces a greater magnetic effect than the fine winding and exerts sufficient pull on the movable armature when at rest to draw it toward the end of the magnet core. It is so connected that the current ceases to flow through it when the contacts C are open. The fine winding is connected to the contacts so that it holds the armature of the relay open after the circuit of the coarse winding is broken at the contacts C, and is known as the "holding coil". Its magnetic pull is not sufficient to draw the armature down from its position of rest, but strong enough to hold it there after it has been pulled down by the other winding.

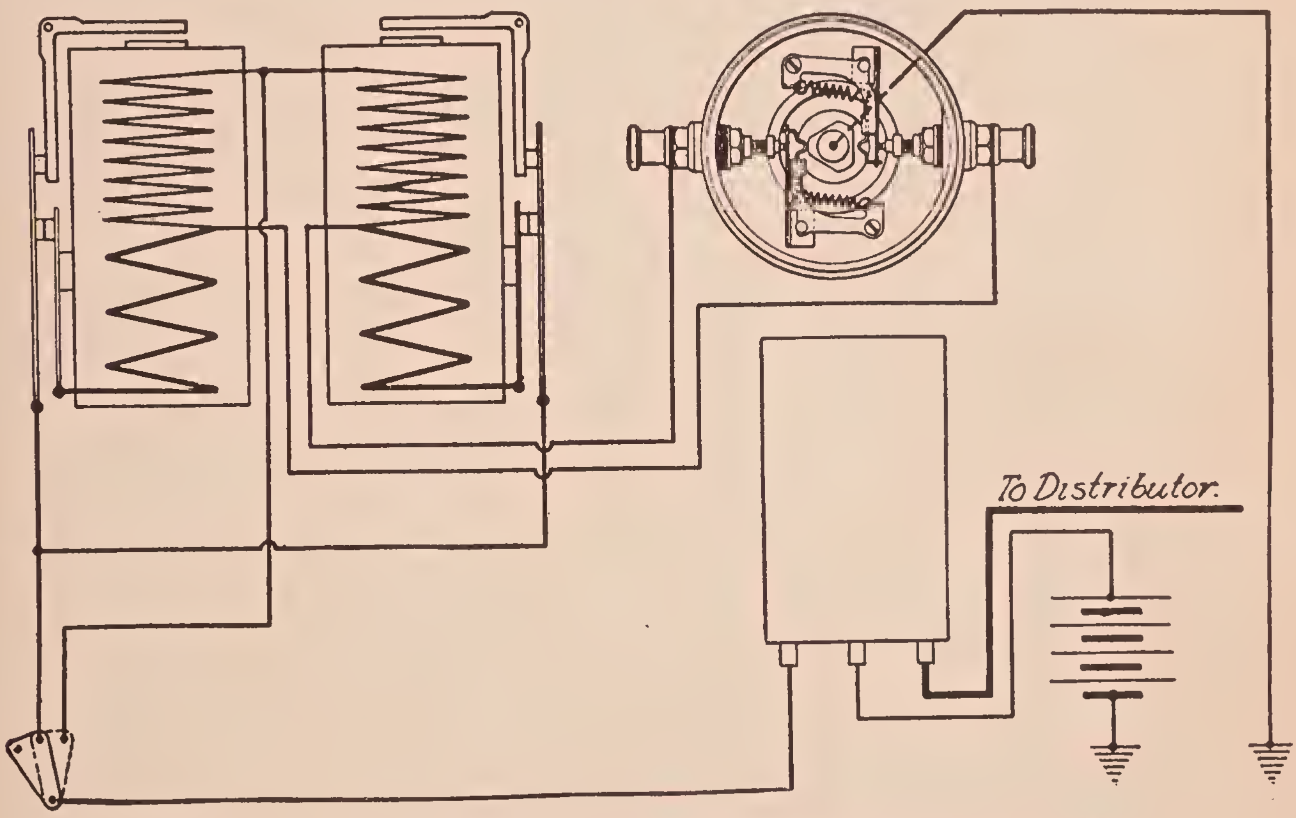


Fig. 128. Diagram of Delco Special Interrupter for High Speed Engines
Courtesy of "The Horseless Age"

A condenser is connected around the contacts C to suppress the arc and increase the speed of working. A three-way switch is provided having a point for "starting", one for "running", and a neutral point. When on the starting point, the relay operates continuously, the same as a vibrator, and produces a series of sparks; on the running point, the fine winding of the coil is energized and the contacts held together, thus producing a single spark.

Interrupter for Higher Speed Engines. For the extremely high-speed engines now coming into general use, a special interrupter having two sets of contact points and a three-part cam is employed (for six-cylinder motors). Each set of contacts is connected to a relay so that the circuit is closed through the two relays alternately, thus giving each magnetic interrupter more time in which to open

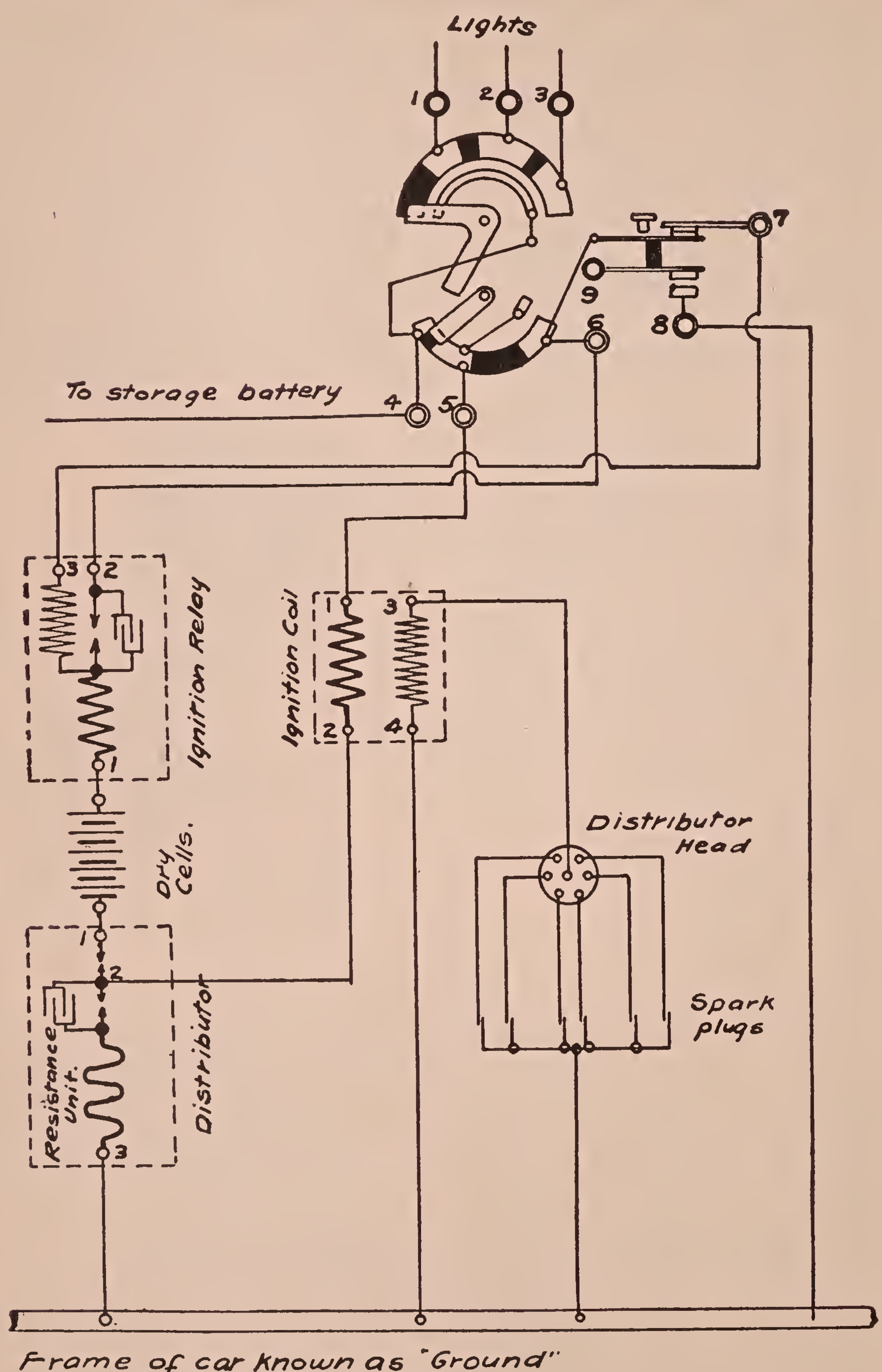


Fig. 129. Wiring Diagram of Delco Ignition System Using Relay

and close the circuit. Fig. 128 illustrates the connections of a system of this type, the interrupter being shown just above the coil, while Fig. 129 shows the complete wiring diagram.

TESTING, ADJUSTMENT, AND MAINTENANCE

Trouble Nearly Eliminated by Efficient Devices. With modern equipment, trouble from electrical sources has been decreased to an almost irreducible minimum and with a knowledge of the rudiments plus consistent observance of a few simple rules, these troubles can usually be remedied without calling in outside assistance. Causes of failure are the most important thing to remember as, with these in mind, it is far easier to trace the trouble logically than where the usual aimless hunt is undertaken on the chance of striking the cause. It must also be borne in mind that all causes of motor stoppage are not electrical. A dry gasoline tank, a plugged-up gasoline feed line or a choked carbureter, failure of a gasoline pressure-feed system, or a stopped-up air vent in a gravity-feed gasoline tank will have the same effect, though one or all of them have not infrequently been attributed to the ignition system.

Causes of Failure. Failures may be generally classed under three heads: short circuits or grounds; failure of current supply; and failure of ignition devices, such as contact breakers, distributors, vibrators, coils, spark plugs, wiring, connections, condensers, etc.

Short Circuits. When a motor that has previously been running normally suddenly stops dead, the indication is almost invariably that of a short circuit or ground. The difference between the two is that a short circuit takes place between two wires or other parts of the system, while a ground is the contact of a chafed wire or other exposed part with some portion of the metal foundation of the car, such as the frame or motor. The effect is the same in either case in that the current takes a shorter path and does not reach the spark plugs. Either may occur in the low- or high-tension wiring, i.e., between the contact breaker and the coil or the battery and the coil; or between the secondary side of the coil and distributor. Owing to the high voltage of the latter, grounding is more apt to result there either from a chafed wire or from a frayed end coming in contact with the motor or other metal. Failure from this cause can frequently be detected by sparking at the point of breakdown. An "open circuit" in one of the main feed cables, such as that connecting the magneto to the primary of the coil in a dual system, or the secondary of the coil to the distributor, or the battery cable in a battery system will naturally have the same effect. The cause is usually a loose connection; sometimes, though rarely, a broken wire. If the connection has not parted entirely, irregular firing will result.

Failure of Current Supply. Failure of current supply will usually result in erratic running as the current weakens until it reaches a point where it is no longer adequate and the motor stops. But the symptoms in this case are the same as in gradual failure of the fuel supply, either through a choked carbureter nozzle, partially obstructed feed line, stopped air vent, lack of pressure, or the emptying of the tank. The motor will run by fits and starts with irregular missing at different cylinders. Defection of the contact breaker or distributor may also manifest itself either by similar erratic operation or by sudden stopping.

Weak Magnets. When the engine fires regularly on the battery but will not do so on the magneto except above a certain speed, it indicates that the magnets are weak and need remagnetizing. Heat and vibration weaken the magnets, so that on some cars it is necessary to overhaul the magneto every five or six thousand miles, whereas, on others, the magnetism shows no appreciable falling off after two or three seasons' use. With a new or recently overhauled magneto it should be easy to start on the magneto by spinning (by hand), but this is not conclusive as some engines will never start on the magneto.

Testing. *Inspection of Wiring.* Examination of the wiring and other parts of the system will usually suffice to reveal short circuits or grounds, or by making emergency connection with extra wire, proper operation through the latter indicating a failure of the parts of the wiring system thus replaced. Extra wire should always be carried on the car for this purpose. With the dual type of ignition system so generally employed, see that the zinc-containing case or the protruding terminals of dry cells are not allowed to come into contact with the metal battery box as this will cause a ground that is difficult to locate. The best preventive is a small wood container to insulate these cells from contact with any metal. Water falling on the high-tension cables will cause serious leaks that will not show in the form of sparks. Above all, every part of the system must be kept dry; sufficient precautions are frequently omitted when washing the car.

Inspection of Current Supply. To make certain that erratic operation is not due to failing current supply, a small testing instrument, such as that shown in Fig. 130, should be carried on the car. This is the Hoyt multimeter, which gives an independent ampere and voltage reading by dials on both sides of the instrument. Either may be used separately or both simultaneously. For dry battery testing an instrument with a high reading ampere scale is necessary, that shown being for the current consumption of a battery-operated vibrator coil where economy is essential. Dry cells should test at least 10 to 12 amperes to give an efficient spark, though they will frequently operate on less. An ammeter should never be employed on a storage battery. For this the voltmeter affords the best test. Full instructions for the care of storage batteries are given in the article on "Electric Vehicles".

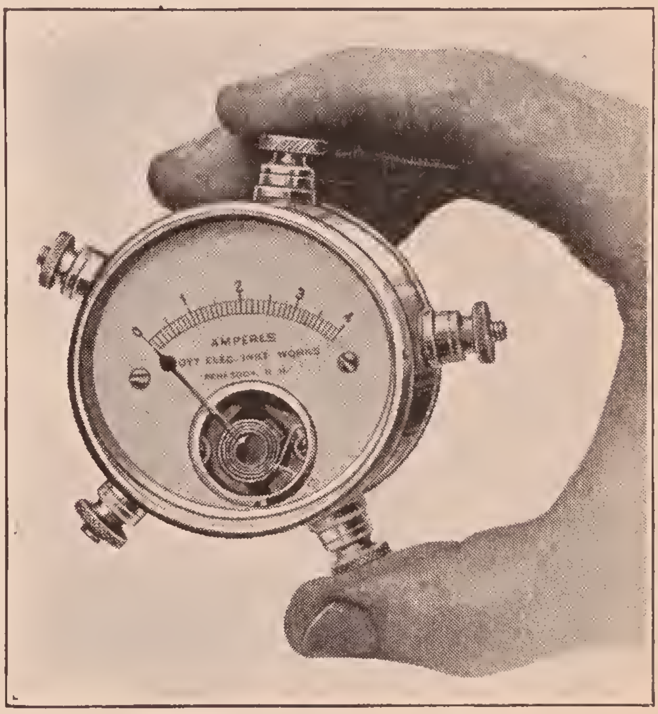


Fig. 130. Hoyt Testing Volt-Ammeter for Automobile Use

Solving Troubles. *Inspection of Contact Breaker.* Derangement of the contact breaker is almost invariably due to wear. In time the contact points will burn away unevenly, this being more rapid in older types not provided with a condenser. If not too far gone, straightening with a very fine file and adjustment will remedy this. Or they may wear down so far that the cam no longer separates them, thus preventing the secondary coil from coming into operation, as the circuit is not opened in the primary and no spark takes place at the plugs. Ample adjustment is provided to take care of this and with a little truing up of the points the trouble will be cured. These contacts will sometimes wear to a point at which the cam will still continue to open them when running at high speed, but fails to do so when the motor is cranked for starting (dual system). This provides the anomalous case of a motor running perfectly the day before and absolutely refusing to start when next cranked. It represents one of the obscure ailments mentioned, as every other part of the system will respond to the usual tests.

Remember Effect of Compression on Spark. The effect of compression on the spark must also be borne in mind, as an apparently efficient spark with the plug out of the cylinder is not equally effective when subjected to the compression. Partial failure of the current supply is the cause in this case, due to weak dry cells or an almost wholly discharged storage battery causing a drop in the voltage. Or it may result from spark plug points that have been burned away until the gap is too great, $\frac{1}{32}$ inch being the maximum distance recommended.

Leakage at Distributor. Leakage may occasionally occur at the distributor due to the use of an excessive amount of lubricating oil which picks up carbon dust, the latter being carried around by the revolving arm until it forms a path for the high-tension current.

Spark Plugs. A broken spark plug porcelain or an internal short circuit of the plug, neither of which may be evidenced externally, will cause missing at that cylinder.

Erratic firing and a very perceptible loss of power will result from the gaps of the spark plugs being too large. With the powerful current supplied by a storage battery or by the modern magneto this takes place by the burning away of the points of the electrodes in a comparatively short time, it being nothing unusual for the $\frac{1}{32}$-inch gap to increase to almost $\frac{1}{8}$ inch in a few weeks' running. This is particularly the case with the cheaper plugs which have iron-wire electrodes; they may be adjusted with the pliers, however, until there is no longer sufficient electrode left to adjust.

Loss of power will also be occasioned by a plug that is not tight in the cylinder or where the plug itself is not tight internally. Squirt a few drops of oil around the base of the plug on the cylinder and also on the porcelain of the plug. When the engine is running bubbles will form at these points: if the plug itself is at fault, a quarter-turn of the nut holding the porcelain in place will usually seat it on the gasket and overcome any leakage at that point; in case of leakage around the thread of the plug, a new asbestos gasket under it or a slight tightening of the plug itself where of the iron-pipe thread class will remedy the trouble. Cleaning at intervals with a stiff brush and gasoline will prevent short-circuiting through an accumulation of carbon on the porcelain and walls of the shell.

Sparking at Safety Gap. In all magnetos of the true high-tension type, the safety gap is incorporated in the magneto itself: in dual-ignition systems it is in the coil, as the latter must be protected from the battery current as well as frcm that of the magneto. Sparking at the safety gap is an indication that there is an opening in the circuit greater than the resistance of the secondary winding of the coil, and unless the spark bridged the safety gap, the insulation of the high-tension winding would be punctured. This opening may be a spark plug whose points are too far apart or a connection that has dropped off either at the plug or at the coil. Owing to its high voltage the current will jump any gap smaller than that of the safety gap with no perceptible difference in the firing, so that loose connections on the high-tension side seldom cause trouble until they actually separate. A piece of metal accidentally falling on it or an accumulation of any conducting material such as dirt or moisture will short-circuit the secondary of the coil through the safety gap and no current will reach the plugs. Frayed terminals in which one or more of the strands of the flexible wire protrude and touch adjacent objects are sometimes responsible for a similar result; the remedy is to wind with friction tape.

Breakdown of Magneto. On cars employing a true high-tension type of magneto, the battery system is entirely independent, as a rule, so that a fault in one never involves the other. Where failure of the magneto is not due to faulty operation of the interrupter, it may be inspected with the aid of the test lamp described in connection with starting and lighting systems. Trace the various circuits of the magneto in question; apply the points to the opposite sides of the condenser. The lamp should not light; if it does, the condenser has broken down and must be replaced. Test the primary and secondary windings of the magneto in the same way; the lamp should light in each case; if it does not, there is a break in that particular winding and a new armature will be required. In the case of the dual-type magneto there is only one winding on the armature, and many of the older makes (1910 or earlier) have no condenser. Many of these older magnetos in the cheaper grades are fitted with plain bearings and the wear of the latter may allow the armature to bind against the pole pieces, or lack of oil may cause the shaft to bind in its bearings.

When a magneto is taken apart for any reason it must always be assembled with the magnets in the same relative position as formerly, otherwise their polarity will be reversed and the magneto will be inoperative. The magnets must never be left off the machine, even temporarily, without placing a bar of iron or steel across their poles to serve as an armature or "keeper"; unless this is done, they will lose their magnetism rapidly. Remagnetizing the magnets of a machine that has become weakened through long use is a simple

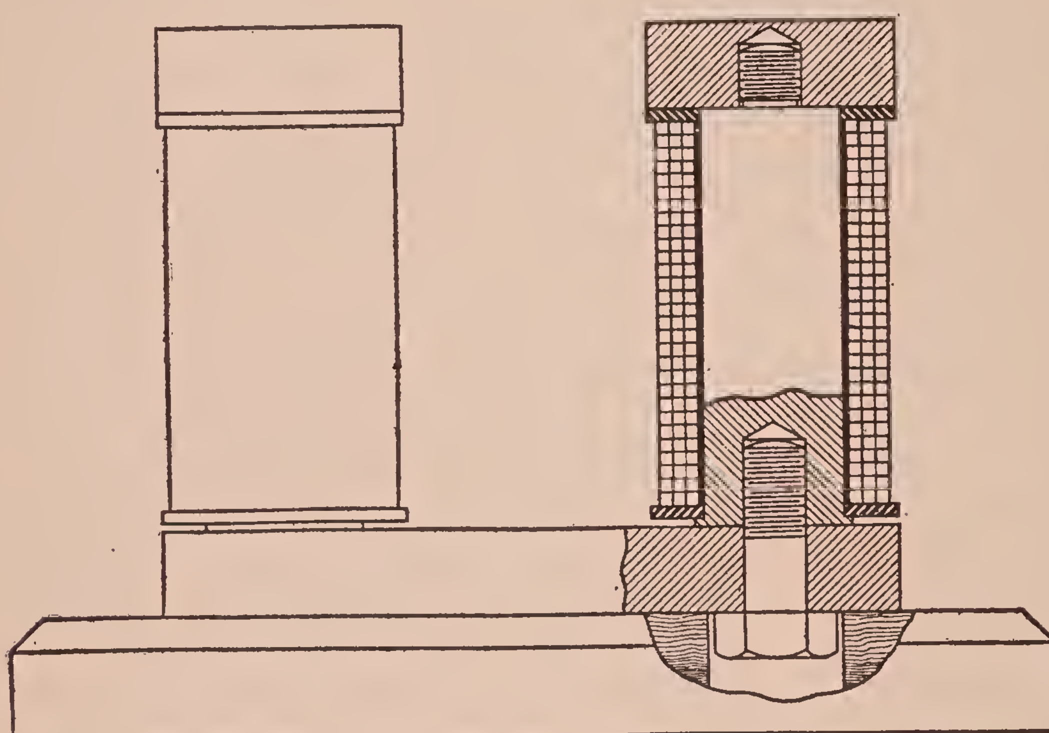


Fig. 131. Design for Magnet Recharger
Courtesy of "The Horseless Age"

process and small electromagnets for this purpose are now to be had for garage use. They will operate, of course, only on direct current.

Remagnetizing. As misfiring at low speeds may be due to causes other than weak magnets on the magneto, the strength of the latter should be tested before deciding that it is necessary to remagnetize them. With the engine running, unclip one of the spark plug leads and hold it close to the terminal. If the magneto is developing a powerful current, it will jump a gap of $\frac{1}{2}$ inch or more; should it not produce a spark at least $\frac{1}{4}$ inch long it needs remagnetizing. In recharging the magnets their original polarity must be preserved, as otherwise it will be necessary to shift their locations in reassembling them. Accordingly, it is important that unlike poles of the permanent magnets and of the electromagnet be brought together; i.e., the north pole of the permanent magnet to the south pole of the recharging magnet and vice versa. To insure this, the current should be turned into the recharging magnet and the other magnet held freely a short distance from its poles. As unlike poles attract and like poles repel, the magnet will find its own proper position, if allowed to do so. If forcibly held against the poles of the recharging magnet regardless of polarity, the strength of the electromagnet is so much greater than that of the weakened permanent magnets that it will reverse their polarity.

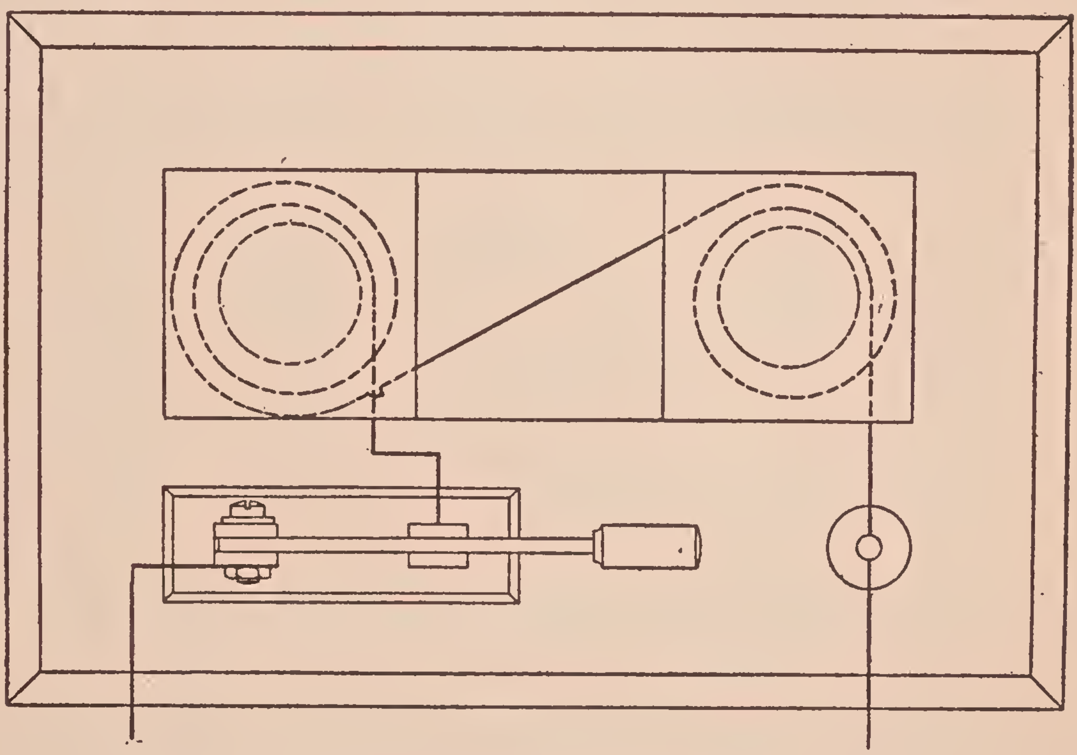


Fig. 132. Diagram of Connections of Magnet Recharger
Courtesy of "The Horseless Age"

In recharging, set the magnet on top of the charger after its polarity has been determined and rock the magnet back and forth on its pole edges a number of times; then lay it on its side with its poles away from you and, extending just beyond the far edges of the recharging magnet poles, apply a keeper to the magnet poles, switch off the current and withdraw the magnet sideways from the recharger. The keeper should remain in place until the magnets are reassembled on the magneto.

Magnet Recharger. Electromagnets designed for this purpose and built specially for garage use are now on the market, or one may be made with little trouble. The following design, Fig. 131, is from *The Horseless Age.* The cores of the magnet are made of soft bar steel 1 inch in diameter and 3 inches long. They are secured to a base measuring $5\frac{1}{4}$ by $1\frac{1}{2}$ by $\frac{5}{8}$ inches and are provided with pole pieces measuring $1\frac{3}{4}$ by $1\frac{3}{4}$ by $\frac{5}{8}$ inches. All contacting surfaces should be absolutely flat and square so that there will be good metallic contact over the entire surfaces. Before the wire is wound on them, the magnets must be insulated. A spool may be formed by placing a fiber ring at each end of the magnet cores, and a better job may be made by turning down a $1\frac{1}{8}$-inch bar, leaving a thin collar of the original diameter at one end. This will support the fiber ring at that end while the other rests against the pole piece. The core between the fiber rings is then insulated by wrapping with several layers of muslin which is given a coat of shellac in alcohol and allowed to dry.

The winding to be applied depends on the voltage to be used. For a 6-volt battery, wind on three layers of No. 12 double cotton-covered magnet wire; for a 110-volt circuit, eight layers of No. 22 double cotton-covered magnet wire. The ends or leads of the wire are then taped and the outer layers of the coils shellaced to make the exposed cotton insulation more enduring. Connect the coils together so that if the current flows through one right-handed, it flows through the other left-handed, when looked at from above, Fig. 132. Mount the completed magnet on a wooden base large enough to carry a single-pole switch and a binding post. The battery or lighting mains are connected to the binding post and the free terminal of the switch; the other terminal of the switch being connected to one end of the magnet coil and the other terminal of the latter to the binding post. Where designed for 110-volt current, it will be preferable to use a double-pole switch mounted on a porcelain base with two screw-plug fuses; 10-ampere fuse plugs being screwed into the sockets. The free ends of the coil are then connected directly to the terminals of the switch at the plugs and the source of current is connected to the other end of the switch. The windings specified will heat up quickly, when connected to current sources of the voltages given, so that the switch should never be left closed more than a few minutes at a time.

Where direct-current mains are accessible, the magnets may be recharged without dismounting them from the magneto. Being flexible and well insulated, lamp cord may be used and must be wound directly on the magnets. The bared ends of the cord should be twisted together so that the two wires form a single conductor. Wrap on about fifty turns and connect this winding to the main switch through a 10-ampere fuse. Particular care must be exercised to make the connections so that the magnets will not have their polarity reversed. A current of high value will flow through the winding during the brief time that it will take to blow the fuse. While this method obviates the necessity of taking the magneto apart, the latter involves so little labor that the use of the magnet recharger usually will be found preferable, particularly where there is any doubt as to the polarity.

Magneto "Don'ts". Care of the magneto in general has been summarized by the makers of the Splitdorf magnetos in a list of "don'ts" that represent valuable advice to the uninitiated. They are as follows:

DON'T attempt to test the magneto unless it is completely assembled, i.e., breaker box in place and distributor cover on, with all wires attached.

DON'T think it necessary when washing the car to flood the magneto with water. All high-tension instruments work better dry. This will be thoroughly appreciated by those who have driven with the old type vibrator coil ignition.

DON'T open the spark plugs nor permit them to burn open more than $\frac{1}{32}$ inch.

DON'T flood the magneto with oil when lubricating the little roller on the breaker bar. The oil should be applied with a toothpick about once a month.

DON'T expect the magneto to operate if you permit the frayed ends of wires to come in contact with each other or with the small parts of the instrument.

DON'T dissect the magneto to see what makes the wheels go around unless you are an expert. We put the right number of wheels inside when we make it.

DON'T drive the motor with the spark retarded, but as far advanced as possible.

DON'T leave the switch turned to "battery" when the car is not in operation.

DON'T try to improve the adjustment of the points in the contact breaker until they stop "breaking".

DON'T lessen the efficiency of the magneto by the use of imitation platinum points.

DON'T disconnect the wires leading from the magneto to the coil unless necessary and be sure to replace them according to the identification letters.

DON'T pull out the carbon brushes in the distributor because you think there is insufficient tension to the springs.

DON'T fail to put back the gauze wire brushes in the breaker box when replacing the latter on the magneto.

DON'T pull out the switch plug until the switch has been placed on the "off" point.

Care of Ford Magneto. Dirt will sometimes accumulate under the collector brush or on the collector ring and reduce the current output. As a guide to the operation of the Ford magneto, the Hoyt magnetometer, Fig. 133, has been devised. The calibration of this is purely arbitrary, the letters representing Poor, Medium, Good, and Excellent. Probably end play in the bearings is the most frequent cause of poor operation of the Ford magneto. This is due to wear of the main crankshaft bearings which permits the magnets to rotate at a greater distance from the coils than originally intended. Taking up this play or replacing the bearings is naturally the remedy. Small particles of metal may sometimes lodge beneath the ribbon terminals of the coils, or the latter may become so thoroughly impregnated with metallic dust as to ground them, making them inoperative. Cleaning and renewal of the oil in the magneto housing will remedy this. To test the coils, four or six dry cells connected in series should be used. Attach one terminal of the battery to the collector brush or insulated plug at the top of the magneto and the other terminal to the connection where the last coil is grounded to the supporting plate. Then with a piece of soft iron touch the iron core of each coil to see if it is strongly magnetized. It should take some effort to pull the iron away. A coil that does not respond properly is probably grounded. Weak magnets are occasionally found to be the trouble, but this is comparatively rare, as well-made permanent magnets are usually good for years of service. When they are found, the best remedy is to replace the entire set, particularly as the cost is low.

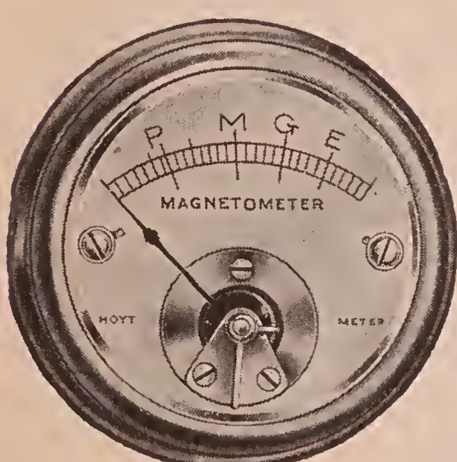


Fig. 133. Hoyt Magnetometer for Ford Cars

SUMMARY OF IGNITION INSTRUCTIONS

DIFFERENT SYSTEMS

Q. How many different systems of ignition are in use on the automobile today?

A. Generally speaking, only one, known as the high-tension system. The low-tension system used in earlier days has been obsolete for a number of years. The single classification, however, may be subdivided into several others which are known by their distinguishing features, the first being determined by the source of current supply, as magneto- and battery-ignition systems. These two classes may be divided further according to the type of magneto employed, such as the duplex, the dual, and the double-spark types. All battery systems are fundamentally the same, only differing in the type of circuit breaker and distributor employed, the mounting of the latter, i.e., whether direct driven from the engine or combined with the lighting generator, and in the type of controlling switches and auxiliary devices.

Q. Why is the system generally used termed a "high-tension" system?

A. Because the current must be passed through a step-up transformer or coil to impress upon it a sufficiently high voltage to cause it to jump the air gap in the spark plug.

Low-Tension Systems

Q. Is the old low-tension make-and-break system entirely obsolete?

A. Since about 1909, it has not been used on the automobile but is still generally employed on small two-cycle marine engines and on stationary engines.

Q. Why is it not suitable for automobile engines?

A. It will not work satisfactorily at high speeds since its time factor is limited by mechanical reasons, i.e., the inertia of the movable electrodes of the low-tension spark plugs, whereas, in the high-tension system, only electrical lag has to be compensated for. It requires a skilled mechanic to time the spark plugs properly and they will not stay in adjustment for very long.

Q. What is the chief attention it needs as employed on marine and stationary engines today?

A. Keeping the electrodes clean; the current burns a film of oxide on the contacts and this insulates them to an extent where the low voltage current will not pass. The timing of the plugs also needs regular attention as the hammering action of their operation tends to throw them out of adjustment. Considerable current is required for the efficient operation of the low-tension plugs, so that where used with batteries as on the motorboat, the cells frequently become exhausted in a comparatively short time.

Q. How can the low-tension plugs be adjusted to give them the proper timing?

A. Turn the engine over slowly by hand and watch the action of the plug. Its contacts should come together when the piston is three-fourths of the way up on the compression stroke; they should snap apart to cause the spark, the advance lever being in the retarded position, when the piston is at upper dead center. Provision is usually made for increasing or decreasing the length of the rod that operates the plug. If the spark is occurring too late, causing a falling off in the power, shorten the rod sufficiently by the adjustment to give the timing suggested above and lock tightly; if too early, lengthen it just enough to overcome any hammering that this would cause.

Q. Why should the plug close the circuit so long before the piston reaches upper center?

A. To give the coil sufficient time to "build up", i.e., for its core to become "saturated", or thoroughly magnetized, as the efficiency of the spark produced depends upon this.

Q. How does the coil of a low-tension system act?

A. It is a single winding of coarse wire on a very heavy core of fine iron wires, i.e., a coil having a high self-inductance. When the circuit has been closed a sufficient length of time to permit this core to become saturated and is then suddenly broken, the current utilized to magnetize the core is redelivered to the coil and causes an arc at the plug as its contacts separate. The current producing this arc is of much greater volume and at considerably higher voltage than could be obtained by making and breaking the battery circuit without a coil in it.

Q. Does the coil ever need attention?

A. Only to see that its connections are clean and tight and that it is kept dry; owing to the solidity of its construction, failure of the coil itself is almost unknown. Test by holding one terminal of a three-cell or four-cell dry battery on one binding post and wiping the other with the wire from the other side of the battery circuit; a bright flash should result. If it does not, see if the wire has broken near one of the binding posts as this may result from vibration.

Q. Is this the only low-tension system used?

A. No. Several makes of magnetic plugs have been used in connection with low-tension systems. Each plug is a solenoid the plunger of which makes and breaks the contact electrically. No mechanism is necessary to operate the plug but a timer must be used in the circuit to close the latter slightly in advance of the time for the spark to occur. This timer is the same as that used in the primary circuit of high-tension systems employing vibrator coils, as on the Ford.

Q. What difficulty is usually encountered with magnetic plugs?

A. They seldom withstand the heat of the engine for any great length of time, so that the insulation fails. Apart from this the troubles encountered are the same as with any other system using movable contacts, i.e., dirt on the contact points, failure to make contact, broken connections, weak battery, etc.

High-Tension Systems

Q. Of what does a high-tension system consist?

A. The essential parts of a high-tension ignition system are: (1) a source of current, such as a dry battery, the storage battery of the lighting and starting system, the direct-current generator of the latter, or a magneto; (2) a step-up transformer or induction coil, the primary winding of which is in circuit with the source of current supply; (3) a contact breaker or interrupter to open this circuit periodically, i.e., once every other revolution for each cylinder of a four-cycle engine; (4) a distributor in circuit with the secondary winding of the coil and provided with as many contacts as there are cylinders; (5) a spark plug for each cylinder; (6) primary and secondary cables for the respective connections, and a controlling switch to open and close the supply circuit or to change from one supply circuit to another, where both a battery and a magneto are employed.

Q. How do these essentials vary in different systems?

A. Where a battery is depended upon for the current supply, the interrupter and the distributor are usually combined in an independent device which is driven from the camshaft of the engine.

In the case of a magneto, both the interrupter and the distributor are integral with it. This does not apply to the Ford magneto which has a separate low-tension timer and uses no distributor, as there is a vibrating coil for each cylinder.

In what are commonly known as modern battery systems, the timer and distributor may be either mounted separately, as first mentioned, or combined with the lighting generator.

CURRENT SUPPLY AND APPLICATION

Magnetos

Q. How many different types of magnetos are there in general use?

A. Two general classes, the low-tension and the high-tension, and various special types, such as the dual, the double spark, the duplex, and the inductor magnetos.

Q. What is the difference between low-tension and the high-tension magnetos?

A. The low-tension magneto has only a single winding on its armature the current being generated at low voltage and transformed by passing through an independent coil, whereas the high-tension magneto generates the current in one winding and steps it up through another, both on the same armature.

Q. What is a dual magneto and why is it so called?

A. It is a low-tension type, the interrupter and distributor of which are also employed in connection with a battery for starting. It is so called because these essentials are common to both the magneto and the battery sides of the system.

Q. What is a double-spark magneto?

A. One provided with two distributors designed to produce two sparks simultaneously at two different plugs in the same cylinder.

Q. What is a duplex magneto?

A. One designed to permit of passing the battery current through the armature of the magneto to facilitate starting, the magneto and battery both acting together to produce the spark at low speeds. To accomplish this a commutator is mounted on the armature shaft and the battery connected to it, the magneto being of the high-tension type. This commutator causes the battery current to alternate in direction with that produced by the magneto so that it is said to be "in phase" with the latter.

Q. What is an inductor magneto and how does it differ?

A. An inductor is employed instead of an armature, the windings being stationary. The inductor is simply a revolving piece of metal which alternately opens and closes the magnetic circuit. In the K-W inductor magneto this winding is of copper ribbon and is placed between the poles of the inductor; in the Dixie magneto it is a conventional induction coil placed in the hollow of the magnets above the inductor.

Q. Why can a magneto not be run in either direction equally well?

A. Owing to the contour of the cam which serves to open the contacts of the interrupter. This must be designed to operate the magneto either as a "right-hand" or a "left-hand" machine.

Q. How is a magneto timed?

A. Disconnect its drive from the engine. Turn engine over by hand until the piston of cylinder No. 1 is exactly at the upper dead center on the firing stroke. Turn the armature shaft of the magneto to a point where the contacts of the interrupter are just beginning to open; the brush of the distributor which is then making contact with the distributor segment should be connected to the spark plug of cylinder No. 1. The next brush should be connected to cylinder No. 2 or No. 3, according to whether the firing order is 1, 2, 4, 3 or 1, 3, 4, 2. The armature of the magneto should be coupled to its driving shaft in the position as determined for the first cylinder.

Q. If after timing a magneto in this manner, it is found that the spark=timing lever does not give sufficient advance or retard, what should be done?

A. Remove the cover from the distributor housing of the magneto, the piston of cylinder No. 1 being at upper dead center of firing stroke and the interrupter contacts just about to open as directed for timing. Note the relative position of the segment and the distributor brush which should be making contact with it. If the segment has already passed the brush, the spark-timing lever being at the maximum advance position, remove the distributor gear from its shaft and from engagement with the pinion on the armature shaft. Move it back one tooth (against the direction of its rotation which is the opposite of that of the armature pinion) and remesh with pinion. If this does not bring it into contact with the brush, move back another tooth. Should the distributor segment not have reached the brush when in the position as given above, move the distributor gear forward or in the direction of its rotation one or two teeth, and remesh.

Q. What is the synchronous operation of the magneto?

A. The distributor segment always passes under one of the brushes connected to a spark plug at the same moment that the cam opens the interrupter contacts.

Q. When a magneto fails to fire the engine regularly below a certain speed, what is the cause?

A. The magnets probably have lost their strength owing to the heat and vibration.

Q. How can it be determined definitely whether irregular firing at low speeds is due to weak magnets or some other cause?

A. With the engine running, loosen one of the spark-plug terminals and hold it close to the plug; the spark should be at least $\frac{1}{4}$ inch long.

Q. When a spark occurs at the safety gap, what does it indicate?

A. That there is an opening in the circuit greater than the length of the safety gap, which is designed to protect the coil.

Q. What is apt to be the cause of such an opening?

A. Spark plug points burned too far apart; a broken or loose connection.

Firing Order

Q. Why do the cylinders of an automobile engine not fire consecutively?

A. Because the pistons are attached to the crankshaft in pairs in the same plane, so that when one piston of a pair is firing the other one is going down on the exhaust stroke.

Q. How can the firing order of a motor be determined?

A. Take out all the plugs and lay them on the cylinders so that the threaded part of the plug makes contact with the cylinder but the terminal does not. Switch battery on and turn engine over slowly, noting the order in which the sparks occur at the plugs. Watch the valve stems; after the inlet valve of cylinder No. 1 has opened and closed, it is ready to fire. The plug at which the spark then occurs is the proper plug for the first cylinder. The next plug to spark belongs to the cylinder whose inlet valve has just closed.

Q. When a motor will not start, but fires once or twice and then stops, the flywheel rocking back and forth, what is the cause?

A. Some of the spark plug leads have been misplaced, so that after one or two explosions, the next one takes place out of sequence.

Spark Plugs

Q. What are the usual causes of failure of the spark plug?

A. An accumulation of carbon on the inner end of the porcelain and the shell, causing a short circuit; broken porcelain; points burned too far apart to permit spark to pass.

Q. When there is a hissing noise at the plug, or when oil squirted on it bubbles violently with the motor running, what does it indicate?

A. Either that the porcelain of the plug is not screwed down tightly on its gasket on the shell, the porcelain is broken, or the plug itself is not tight in the cylinder.

Q. What is the cause of a discharge across the porcelain of the plug?

A. The points are too far apart, or the porcelain is broken; usually the former. This usually will be noted only on plugs having very short porcelains as where the latter are long, the distance is much greater than the maximum to which the points can be separated and any spark that would occur owing to the latter cause would take place at the safety gap.

REGULATING DEVICES

Interrupters and Timers

Q. How does an interrupter operate?

A. It is normally closed, short-circuiting the battery on the primary winding of the coil until just before it is necessary for the spark to occur in the cylinder; a cam then separates the contact points, and the high-tension current induced in the secondary winding of the coil jumps the gap of the plug. In the case of a magneto, the winding of the armature is short-circuited on itself to permit it to "build up", so that when the interrupter contacts are opened by the cam, the peak or highest value of the current wave generated is utilized. The opening of the circuit in either case occurs at the same time the distributor arm is passing one of its contacts.

Q. How does a timer operate?

A. Contacts, insulated from one another, their number corresponding to the number of cylinders, are located at equidistant points on the inner circumference of the timer housing, while the shaft carries a single contact which in its revolution successively touches each one of the stationary contacts. Where separate vibrator coils are used, as on the Ford, each stationary contact corresponds to one of the coils.

Q. Do interrupters and timers fail from the same causes, and what are they?

A. No. The cause of failure in one case is the reverse of that in the other. An interrupter fails when it does not open the circuit, and a timer when it does not close it. Dirt and wear are the usual causes of failure in both cases; moisture is also responsible at times. Test by having an assistant turn the engine over slowly by hand and watch the operation of the interrupter; if the cam fails to separate the contact points, true up their faces with fine sandpaper and test again. (This does not apply to Atwater-Kent interrupters. See description.) Stop with the cam in the opening position and see if a sheet of ordinary paper can be slipped between the contacts. See that there is not an excess of oil in the housing, as oil on the contact points insulates them. In the case of a timer, see that the spring of the movable contact has sufficient tension to keep it pressed firmly against the stationary contacts as it revolves; note whether sufficient wear has occurred to cause poor contact even with sufficient spring pressure.

Q. How far should the contacts of an interrupter separate?

A. This differs somewhat with different systems, but in the case of the interrupters used on battery systems, it is very small, seldom exceeding a few thousandths of an inch. In the case of the Atwater-Kent interrupter, this is 10 to 12 thousandths. (Coated catalogue paper is five to seven thousandths of an inch thick; a thin visiting card is ten to fifteen thousandths thick.)

Q. How does the Atwater-Kent interrupter differ from other battery interrupters?

A. The circuit is normally open and only remains closed momentarily before being opened by the dropping of the lifter into its notch on the shaft.

Q. Can this interrupter be tested in the same way as that just described?

A. No. The movement of the lifter in striking the latch to close the circuit is so rapid that it cannot be detected with the unaided eye, even though the engine be turned over very slowly by hand.

Q. What will cause this interrupter to fail?

A. Wear of the lifter to an extent where it will not engage the notches of the shaft properly, usually caused by lack of oil. Other causes of failure are the same as for other types, generally worn or burned contact points.

Q. When the contact points of an interrupter of any type burn away very rapidly, what is the cause?

A. The condenser has broken down so that it is no longer protecting the points from the full heating effect of the arc formed at the time of breaking the circuit. Use the testing-lamp outfit described in connection with lighting and starting systems. Apply one point to each of the condenser terminals; if the lamp lights, the condenser is short-circuited. The only practical remedy is replacement by the manufacturer, as even the best equipped garage is seldom fitted to take care of such work.

Q. Does discoloration always indicate burned contact points, and how often should these points require cleaning and adjustment?

A. No. According to the particular alloy used in the contacts they will assume a bright purple, an orange, or a gray tinge. The squareness of their surfaces and the contact they make when together are the best indications of whether attention is needed; if pitted or high on one side, truing up will be necessary. Unless the condenser has failed, they should not require attention oftener than once a season, or say six to eight thousand miles' running.

Distributors

Q. What is the function of the distributor and how does it differ from that of the interrupter and timer?

A. At the same moment that the interrupter opens the primary circuit of the coil, or the timer makes it in the case of a vibrating coil, the distributor makes contact with a stationary segment representing a spark-plug terminal. The distributor accordingly is said to run synchronously with the interrupter or timer. It is practically a duplicate of the timer designed to handle a high-tension current, in that it has one revolving contact and a stationary contact for each cylinder.

Q. Does the moving member of a distributor actually make contact with the stationary contacts, as in the timer.

A. No. This is not necessary owing to the high voltage of the current. The moving member passes very close to the face of the stationary contact but does not actually touch it, thus avoiding wear. This applies, however, only to those early-type magnetos or to separate distributors employing a metal moving contact. Where carbon brushes are employed, they are pressed against a fiber disk with a metal segment countersunk flush with its face and this segment passes under each carbon brush in rotation.

Q. What are the usual causes of failure in a distributor?

A. Short circuits, due to moisture, dirt, or carbon dust. Owing to the high voltage of the current it will leak across barely perceptible paths caused by dampness or carbon dust.

Switches

Q. What is a "reversing" switch and why is it employed on ignition systems?

A. It is a double-contact switch which reverses the polarity of the current, i.e., its direction, through the contacts of the interrupter every time the switch is closed. This is done to prevent the burning away of the contact points in one direction which would cause a peak to form on the positive and a crater or depression on the negative. Reversing the direction of the current causes the points to become alternately negative and positive in accordance with the position of the switch.

Q. What is the nature of the trouble ordinarily to be looked for in a switch?

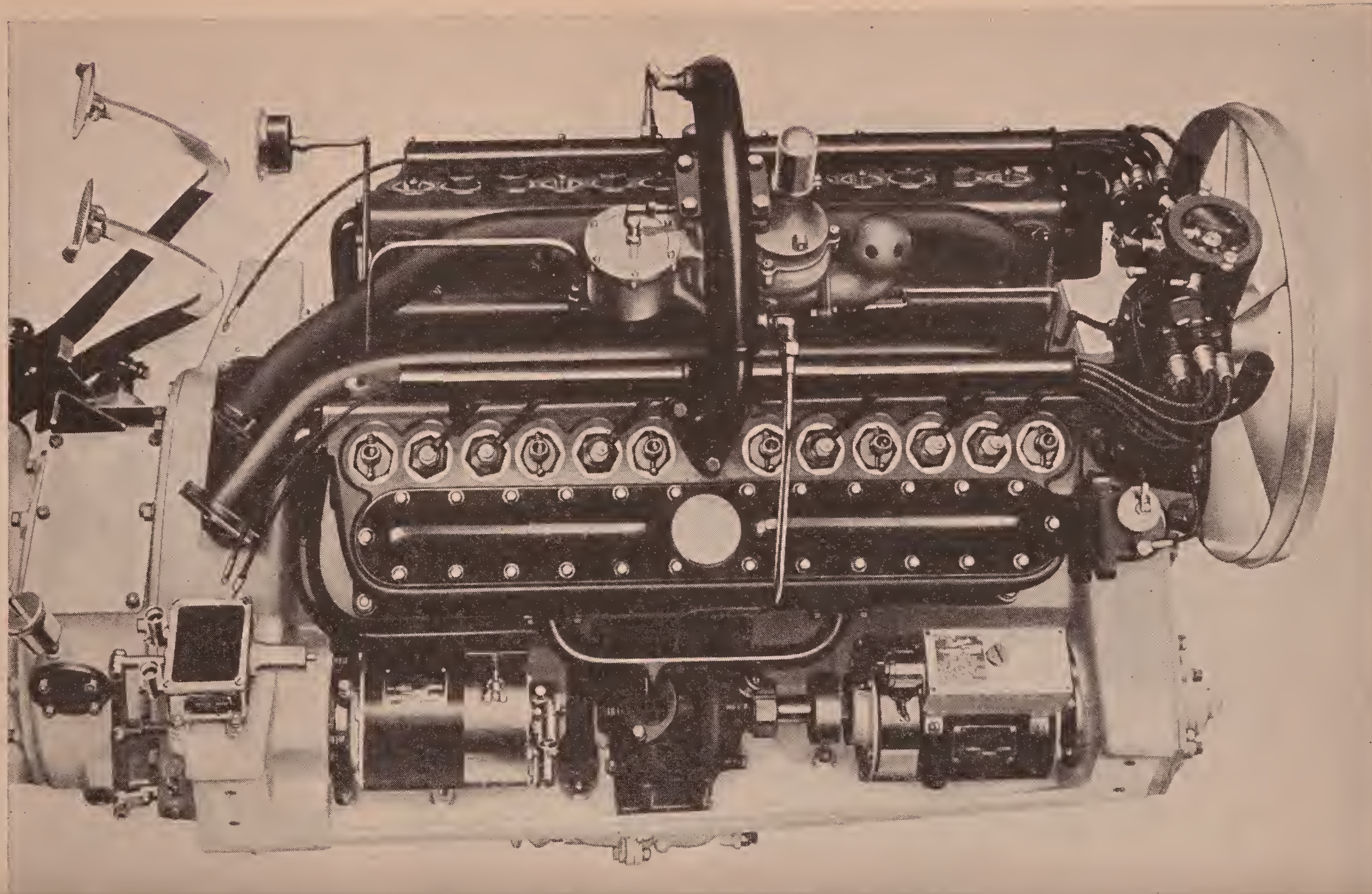
A. Poor contact due to wear or weakening of the spring; broken or frayed connections causing a ground or short circuit.

Q. What is an automatic switch?

A. This term is frequently applied to the battery cut-out of the lighting and starting system. On the Connecticut ignition system, it is a thermally operated switch, designed to open the circuit when the switch has inadvertently been left on after the engine has stopped.

Q. Are there any troubles peculiar to the automatic type of switch?

A. None that is not equally so of any similar device such as the battery cut-out or the circuit breaker.



…MOUNTED ON PACKARD "TWIN SIX"

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART III

ELECTRIC STARTING AND LIGHTING SYSTEMS

GENERAL FEATURES

Fundamental Characteristics. In the introduction to elementary electric principles, no attempt has been made to go beyond simple theory as applied to the generation of electric currents, the operation of electric motors, circuits and the auxiliary devices required by the lighting and starting systems employed on the automobile. A very large part of the theory of electricity and electrical action as given in the majority of textbooks is omitted altogether for the sake of clearness, only that part of it which bears directly on the subject of electrical equipment of the automobile being retained. In the presentation of the latter, a somewhat different method of handling the subject has been followed, particularly with a view to making it appeal to the practical man by citing examples and comparisons, the force of which is at once clear. The man whose time for study is limited has no opportunity to go into all branches of electrical phenomena, so that the subject is presented in the briefest and most practical manner.

Considering that the practical application of electric lighting on the automobile dates back to 1910 only and electric starting to 1912 models, in which year but one make of car was fitted with a complete system as regular equipment, there are a number of different types in use. Each is characterized by varying features of design in the generators, motors, and auxiliary devices. In many instances these are slight, in others they are radical, but in every case they merely represent a different application of the fundamental principles given in the introduction. Since they must first pass the test of practical use before being adopted by the automobile manufacturer, they all operate successfully. But, that they all do not operate equally well, or, to put it better, all do not continue to show the same high degree of efficiency and reliability in service, goes without saying. Owing to the lack of standardization that prevails, it is necessary to become familiar with each system. A brief analysis of each of the systems in general use accordingly is given here, and it will be found valuable for reference.

VARIATIONS OF OPERATING UNITS AND WIRING PLANS

Principal Differences. Before taking up the different systems in detail, an outline of the chief points on which they vary is given as an aid in distinguishing them when found in service on the various makes of automobiles of which they form a part. Electrical systems as a whole may be divided into two general classes. These are the single-unit and the two-unit types.

Single-Unit Type. The first type is characterized by the employment of a *dynamotor*—a single unit with a generator and motor windings on the same armature and fields connected to independent commutators at each end of the armature, as in the Delco, (in some models, two concentric commutators at the same end) or to the same commutator, as in the Dyneto. The single-unit type is greatly in the minority, the two makes cited being the chief exponents of it, though the latter make also is built in the double-unit type as well. When the ignition distributor is incorporated in the generator, as is now very generally the case, the single-unit types incorporate in one machine the three chief electrical functions required on the automobile, viz, charging the storage battery, turning the engine over to start, and distributing the ignition current.

Two-Unit Type. Owing to the difficulty of efficiently combining in one machine two functions so widely separated as the generation of a constant charging current of a value rarely exceeding 20 amperes, and the utilization of currents up to 250 amperes, such as are required for starting, the majority of systems are of the two-unit type. The latter also is generally favored owing to its greater convenience of installation, as the dynamo must run either at motor speed, or at $1\frac{1}{2}$ times that, while it is necessary to gear the starting motor to the engine in the ratio of 30 or 40 to 1. As the term implies, an independent unit is employed for keeping the storage battery charged, lighting the lamps (when running), and distributing the ignition current, while a second unit is installed solely for the purpose of turning the gasoline engine over to start.

Single=Wire and Two=Wire Systems. The difference between these is pointed out in detail in the section on Wiring Diagrams, Part IV. Owing to its greater simplicity of installation, reduced cost for wiring, and the greater ease with which faults may be located, the single-wire system is largely in the majority. In fact, there are only one or two examples of two-wire systems in general use, of which the Bijur, as employed on the Packard, Jeffery, and other cars, may be cited as an instance. In the gradual approach to standardization that is being made each year, the number of cars on which the single-wire system is employed is constantly increasing. But differences will be found in these single-wire systems as well, some employing the frame of the car for the positive side of the circuit, and others for the negative. This must be borne in mind when testing for faults with the volt-ammeter.

Comparison of Systems. While inherently more dangerous, experience has demonstrated that the fire hazard with the single-wire system is more a matter of proper installation than of the comparative merits of the systems themselves, and quite a number of manufacturers who adopted the two-wire system at the outset have later become converts to the single-wire system. In fact, while the Society of Automobile Engineers has not adopted the latter as recommended practice up to the present writing, although the subject has been under investigation for almost two years, the majority of automobile makers have taken it as their standard construction, and it seems more than likely that the others will do so before long. Considerations of economy demand this on the lower-priced machines, as the cables employed are so expensive as to make a substantial difference in the cost per car for the electrical equipment where the single-wire standard is employed. It does not follow from this that where the maximum of safety and efficiency are to be attained regardless of cost, the two-wire system is always employed, as, after experiencing considerable difficulty with it, the makers of the Pierce-Arrow adopted the single-wire system. The Packard, on the other hand, employs the double-wire system, and the advantages in simplicity of the single-wire may be noted by comparing the Packard installation, as shown in Fig. 134, with the Delco single-wire system, Fig. 135, which is employed on a great number of cars. Comparison cannot be made exactly on the

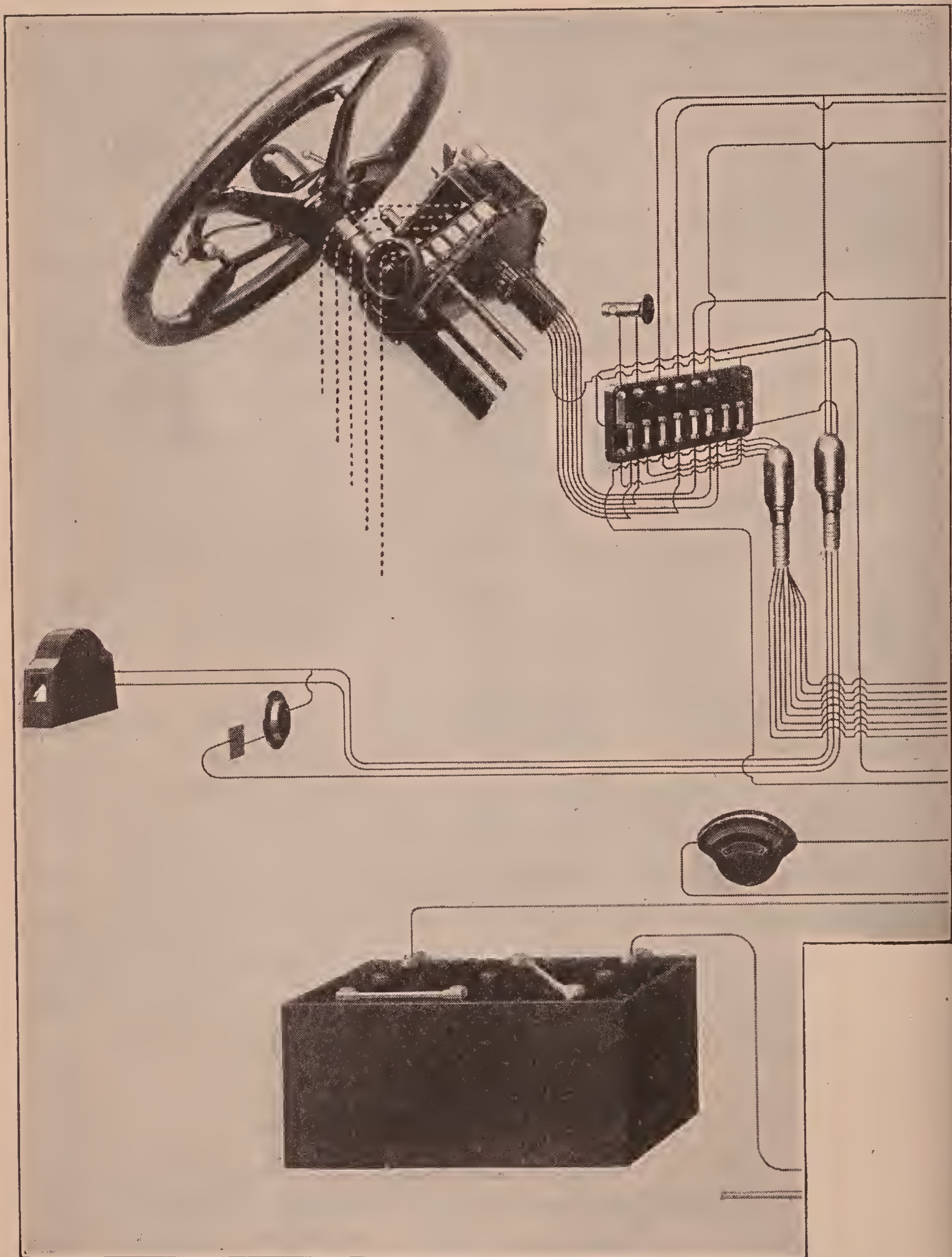
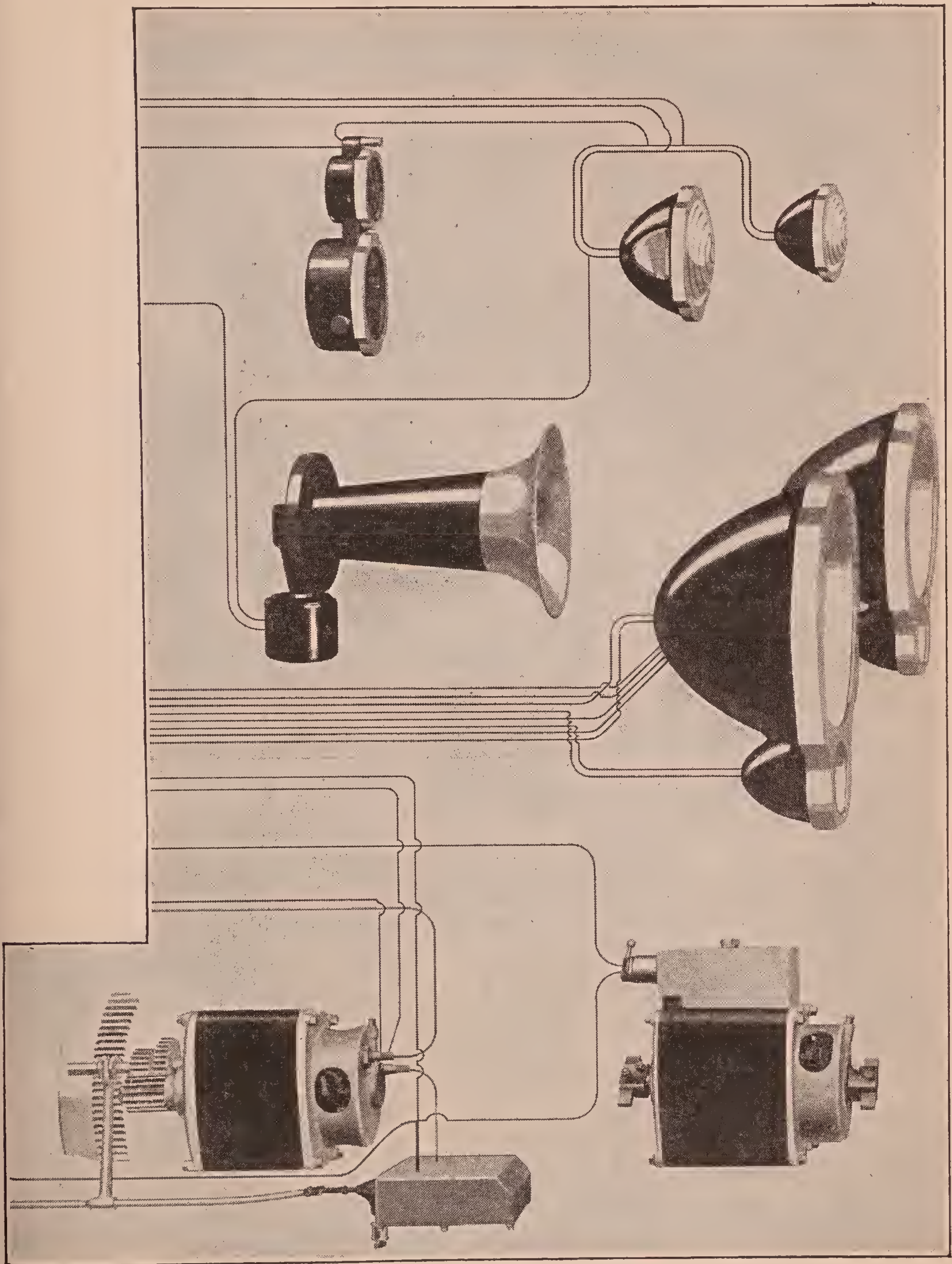


Fig. 134. Wiring of Packard (Bijur) Two-Unit, *Courtesy of Packard Motor Car*

same basis in these two installations, however, as the Packard is what is known as a two-unit system, i.e., the generator and the electric starting-motor are independent, while the Delco is a combination generator, motor, and ignition unit. Moreover, the Packard has several additional lamps, being fitted with double bulb



Two-Wire Starting and Lighting System
Company, Detroit, Michigan

headlights and side lights, which are not present in the Delco installation; but even omitting these considerations, it will be seen that the single-wire system has the advantage of simplicity in a marked degree.

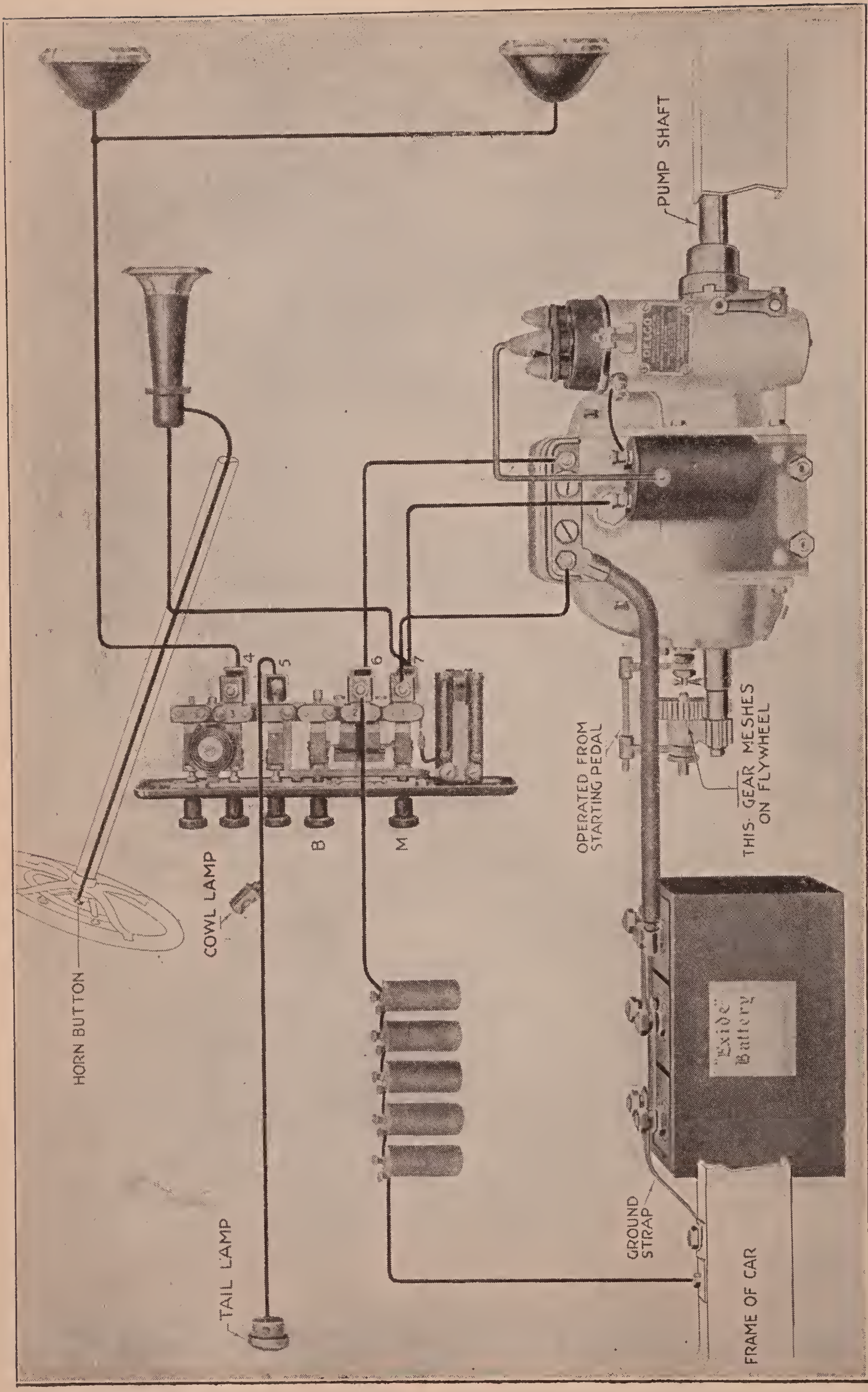


Fig. 135. Wiring of Delco Single-Unit, Single-Wire System
Courtesy of Dayton Electric Laboratories, Inc., Dayton, Ohio

METHODS OF REGULATION

Necessity for Control of Generator Output. In the section on Generator Principles, Part I, mention has been made of the fact that the speed with which the armature coils cut the lines of force of the magnetic field is the chief factor determining the e.m.f. and, in consequence, the current output of the generator. This, in connection with the heating effect of the current due to the resistance of the conductor, limits the amperage that the latter will carry safely. Beyond this point the insulation will take fire and, with a further increase in the temperature due to excessive current, the conductors themselves will fuse. With the extreme variation in speed presented by the operation of the automobile engine, the necessity for regulating the output of the generator will be apparent. There are almost as many methods of regulation as there are systems in use.

As explained in the section on Induction Sources of Ignition Current, Part II, the magneto is an electric generator that requires no current-controlling device, as the magnetic excitation of its fields is permanent. That is, barring gradual exhaustion through age, heat, and vibration, its magnetic field is constant, thus enabling it to generate a current at very low speeds; but the limitations of this type of field are such that electromagnetic fields are employed as in large direct-current generators. These fields depend for their excitation upon the current derived from the armature of the machine itself, and, as the amount developed by the latter increases in direct proportion to its speed, the fields become stronger as the speed increases and correspondingly more current is generated by the armature. As an automobile motor is driven at a great range of speeds, varying from 200 or 300 r.p.m. up to 1500 or 1800 r.p.m., or even higher, and the generator is usually geared in the ratio $1:1\frac{1}{2}$ so as to develop its rated output at the normal speed of the engine—around 1200 r.p.m.—its windings would be quickly burned out unless some provision were made to control the voltage.

Constant-Current Generator. Generators of the so-called constant-current type are frequently regulated by the winding alone. They are usually compound-wound, the series coil being so connected as to oppose the shunt. Assuming the coils to be in equally advantageous positions on the core, the limiting current then is one which gives the same number of ampere turns to the series coil as to the shunt field. Thus, assuming 500 shunt turns in the winding and a shunt current of one ampere, there are 500 ampere turns in the shunt winding. If there are 25 turns in the series winding, the limiting current will be 20 amperes, 500 being the product of 20 by 25. With this winding 20 amperes will be the absolute limit of the current regardless of speed. As a matter of fact, it will be considerably lower than this in practice, owing to the armature reaction or counter e.m.f. generated.

Slipping-Clutch Type. As in every case speed is the direct cause of a rise in the voltage or increase in the current output, one of the methods available for regulating generators is that of mechanically governing the speed at which the generator runs. In the Gray

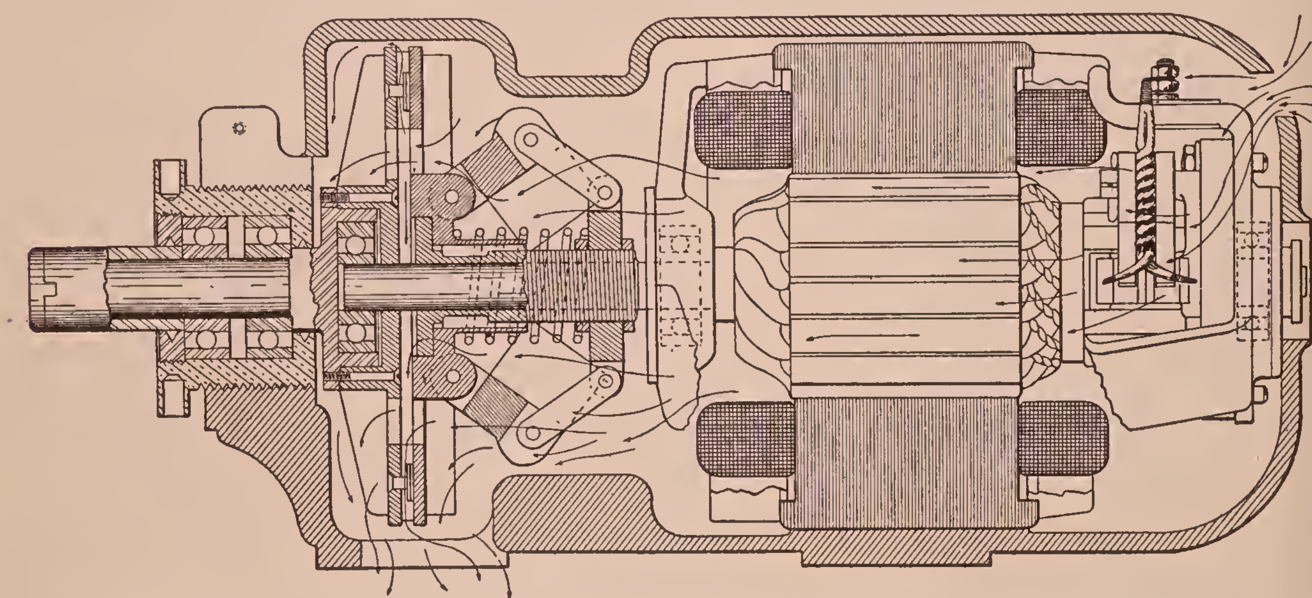


Fig. 136. Section of Gray and Davis Lighting Dynamo (Early Model, Now Obsolete)

and Davis, which is probably the most important representative of this type, a slipping clutch is used for this purpose. A centrifugal governor is employed, as shown in the sectional view, Fig. 136. The drive is through a two-plate friction clutch at the left, the plates of this clutch being normally held in engagement by a spring. The tension of this spring is controlled by the centrifugal governor to which it is attached at the right-hand end, and it may be adjusted to compensate for wear by means of the threaded shaft and nut. This clutch is set to slip at a certain torque and, as soon as the current value corresponding to this torque is attained, the clutch lets go, and the current cannot exceed this limit. Accordingly, one plate of the clutch (the driving side) runs faster than the driven side in proportion to the difference in the speed of the gasoline engine and that at which the generator is designed to run, the *torque* on both sides of the clutch remaining the same regardless of this difference. Ventilation is provided to carry off the heat produced by the slipping clutch, the opening and the arrows shown in the illustration indicating the direction in which air is drawn into and expelled from

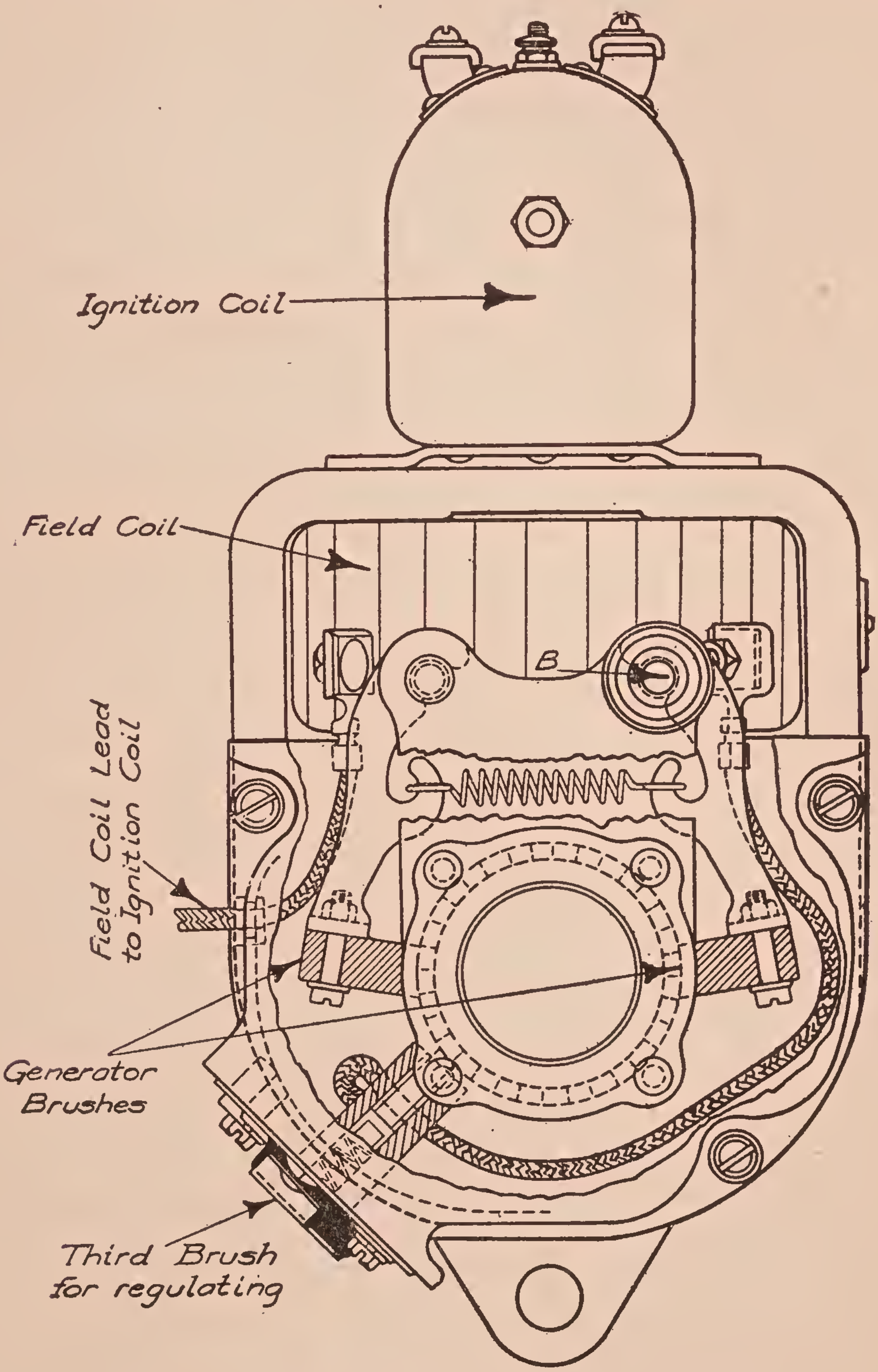


Fig. 137. Delco Third-Brush Method of Regulation

the housing. The generator is of the compound-wound type, and is known as a constant-speed constant-current dynamo. Regulation in this case is by purely mechanical means.

Inherently Controlled Generator. *Westinghouse Type.* A typical example of inherent regulation is represented by the Westinghouse generator. (See Fig. 116, Part II.) When the generator is connected to the battery by the automatic cut-out, the current rises rapidly with the speed until a moderate value is attained. Current in excess of this value passes through a compound series winding, the polarity of which is opposite to that of the shunt winding of the fields. Consequently it acts to oppose the excitation set up in the field magnets by the latter above a certain point. This is known as a "bucking coil" and, while it permits the value of the current generated to increase slightly over the predetermined limit with a further increase in speed, it does not allow it to reach an excessive amount at any speed at which the car can be run. However, current for the lights does not pass through this reversed compound field winding and, when the lights are turned on, the output of the generator increases automatically to supply them. With the usual lamp equipment, this increase in generator capacity is sufficient to operate the lamps without any demand on the battery at ordinary running speeds. At low speeds the battery supplies a certain proportion of the lighting current, and when the engine is not running the battery takes care of the entire demand. When running at night, all current in excess of that required by the lights is utilized to charge the battery, which is thus said to "float" on the line. During the daytime, the entire output of the generator is absorbed in charging the battery.

Delco Third-brush Excitation. Another form of inherent regulation consists of the use of a special brush for taking the current from the armature for the purpose of exciting the field. An instance of this is found in the Delco two-unit system as built for the Oakland cars (1916 models). As the generator is a bipolar type, there are only two brushes for leading the current from the armature to the external circuit, so that the special regulating brush employed, as illustrated in Fig. 137, is commonly referred to as a "third brush". This applies only to this particular type, however, for if the generator were a multipolar type having four brushes, the regulating brush would then be a *fifth* brush. The Delco generator is shunt wound but differs from the standard machine of that type in that the shunt winding is connected to the third brush which bears on the commutator between the other brushes. This method has the advantage of providing a strong shunt field at low speeds so that the generator commences charging while the car is still traveling at a very moderate pace. As the speed increases the voltage applied to the shunt field is decreased, although the total voltage between the main brushes may have increased. This weakens the field and prevents the output of the generator from increasing with the increased speed. At the higher speeds it acts somewhat similarly to the bucking coil previously described, in that it still further weakens the field and causes the generator output to decrease.

Bosch-Rushmore Type. In the Bosch-Rushmore generator, inherent regulation is obtained with a bucking-coil winding used in conjunction with a so-called "ballast" coil, which automatically cuts the bucking coil in or out of the circuit according to its resistance, Fig. 138. Advantage is taken of the fact that the electrical resistance of iron increases enormously after its temperature rises beyond a certain point. This ballast coil accordingly consists of a few turns of fine iron wire on a fluted porcelain rod. The bucking coil, the effect of which is to reduce the field excitation of the dynamo, is connected as a shunt across the iron ballast coil, as shown in Fig. 138. Its resistance is considerably greater than that of the ballast coil when the latter is cold or only warm, so that at low engine speeds practically all of the current generated passes directly to the battery and lamps and the generator acts as a single-shunt dynamo. However, the resistance of the iron wire increases at a constant rate up to about 10 amperes, after which it mounts very suddenly, preventing the passage of any excess current, which, accordingly, must go through the bucking coil. Thus the latter only comes into action at high speeds, so that the output of the dynamo may be adjusted to any value within its capacity simply by employing an iron wire of suitable diameter in the ballast coil.

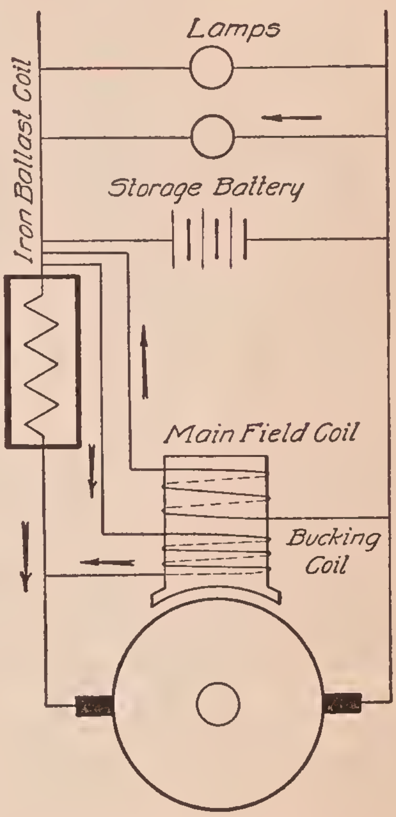


Fig. 138. Connections Bosch-Rushmore Generator

Independent Controllers. The Ward-Leonard controller (constant-current), Fig. 139, is typical of the external or independent controlling devices. In principle, this is the same as the Splitdorf and many others, the chief distinctions between the types usually being found in their construction. Referring to Fig. 139, the coil *F*, on the magnet core *G*, carries the armature current, and when the latter exceeds a certain value—the standard being generally about 10 amperes—the core becomes sufficiently magnetized to attract the finger *H*. This separates the contacts *EE′*, and the resistance *M* is inserted in the field circuit and weakens it. The current then decreases, but when it drops to about 9 amperes, the pull of the magnet is not sufficient to overcome the tension of the spring *J*, and the contacts *EE′* come together again. In actual operation, the finger *H* is kept vibrating at a rapid rate. As a result, the dynamo cannot charge the battery at a rate in excess of 10 amperes, regardless of the speed. At all car speeds above a predetermined limit, usually 15 miles per hour in practice, the dynamo generates a substantially constant current. The regulating device shown at the left of the figure is the automatic cut-out to break the circuit between the battery and the dynamo when the speed of the latter falls below a point at which it is no longer capable of producing the necessary voltage for charging. This is referred to later.

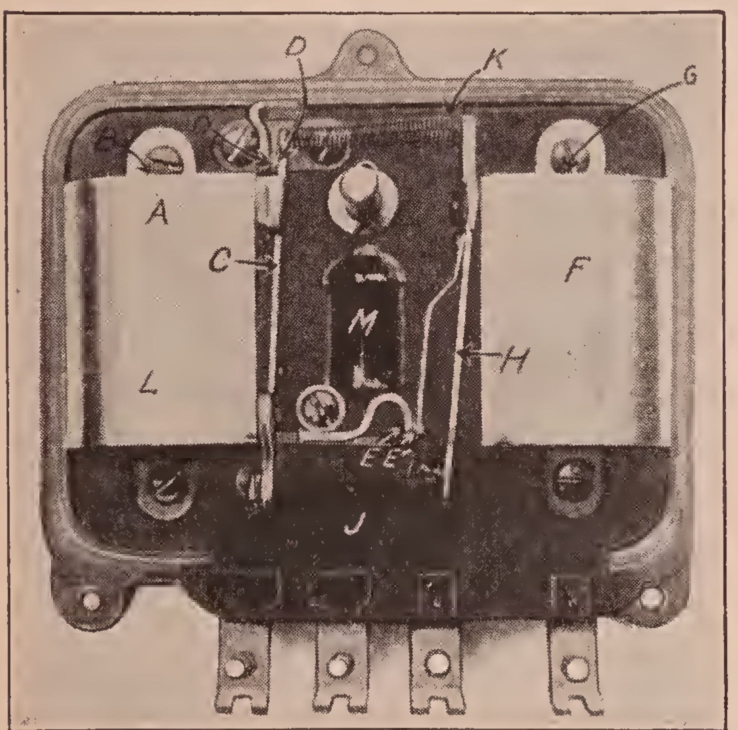


Fig. 139. Ward-Leonard Current Controller and Automatic Cut-Out

All external regulators are not of the constant-current type, however, as some limit the voltage.

Constant-Potential Generators. There is probably a greater variation in the methods employed to control this type than in the constant-current type. This difference is in the method rather than the principle employed, as the majority of such regulating devices act to control the potential by automatically inserting extra resistance in the field circuit or in series with the armature. Quite a number of generators of this type are fitted with a vibrating contact operated by a magnet in much the same manner as a vibrating ignition coil is actuated. The device is either built as a separate unit or is incorporated in the generator itself, as in the Splitdorf.

"Built-In" Regulator Type. In the Splitdorf generator, where the armature is supported by the usual ball bearings, the field poles have extensions which carry windings for the purpose of aiding in the regulation. Extending across these polar projections is a "keeper" (an unwound armature) held by a spring, and in connection with this keeper is a second spring for adjusting the tension of the first spring. The circuit of the battery is closed by the keeper being drawn toward the pole tips under the influence of their magnetism when the machine is running. The coils around these polar extensions are wired in series with the armature of the generator. When the current in the armature reaches a certain predetermined value,

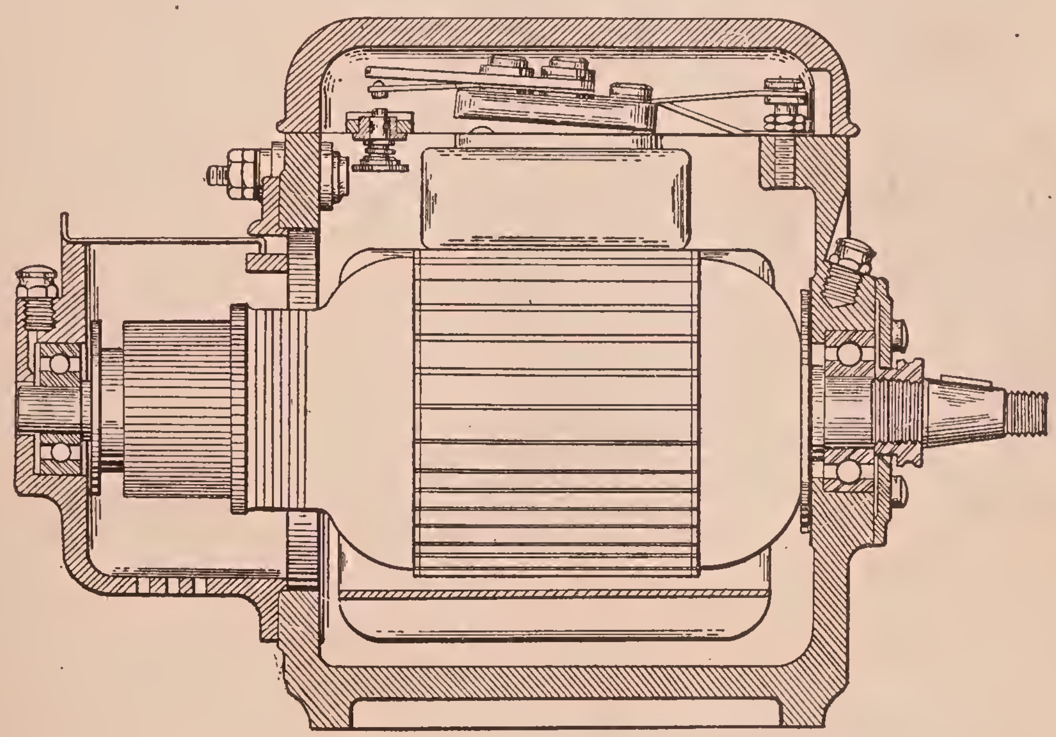


Fig. 140. Section of Splitdorf Generator Showing Controller

the keeper is drawn all the way down and an auxiliary contact is opened which cuts a resistance into the shunt winding of the fields, and thus reduces the magnetic flux due to their action. This, together with the differential action of the series coils on the polar extensions, reduces the magnetic flux through the armature to such a value that the current to the battery does not increase beyond a certain value, no matter how fast the armature is turned. A sectional view of the machine illustrating the details mentioned is shown by Fig. 140. As the speed diminishes the reverse operation of the controller takes place. This generator is driven at twice the crankshaft speed of the motor, and when installed on a car with 34-inch wheels and geared at 3.7 to 1 on direct drive, begins to charge the battery at 7 miles per hour. The high-speed control acts when the car is running between 35 and 40 miles per hour.

External Regulator Type. The Adlake generator is of the constant-potential type governed by an external regulating device, the details of which are shown in Fig. 141. While termed a "regulator", it also incorporates the automatic battery cut-out and the fuses on the same base. This device has been in use on Pullman railroad cars for a number of years, the dynamo in that case being driven from one of the axles of the car. The principle is that of inserting added resistance in the field circuit of the dynamo as its output increases in order to maintain the voltage practically constant. Its operation is made clear by reference to the diagram, Fig. 142. *G* is a solenoid or hollow electromagnet, in the opening of which the plunger *K* may move vertically. The weight of *K* is counterbalanced by *N*, a small piston moving in the cylinder *O*, small shot being put in this piston until both are in equilibrium. They are connected by a chain passing over *M*. An arm *F*, attached to *M*, carries a movable contact designed to make connection with the various contacts of the rheostat *C*, thus putting in circuit a greater or less number of the German-silver-wire resistance coils composing it. These coils are connected in series with the field of the dynamo, which is a plain shunt-wound machine.

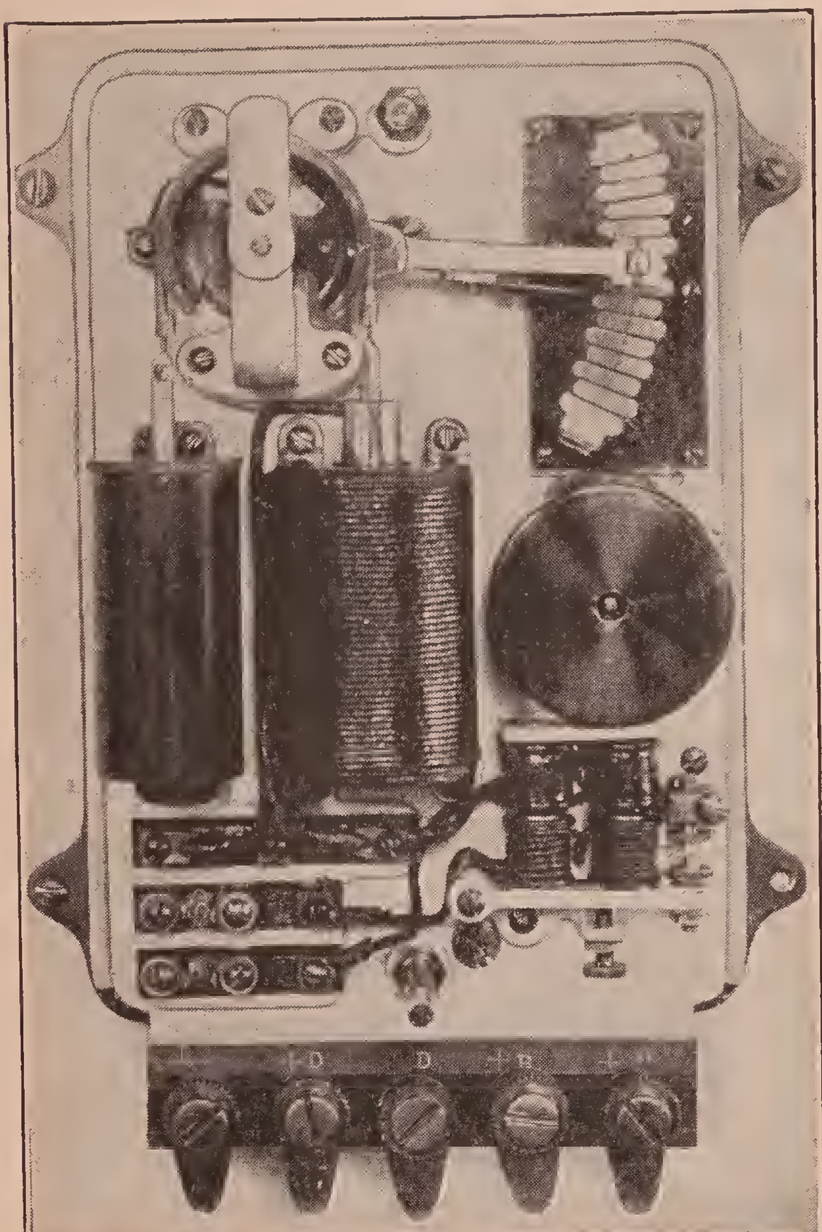


Fig. 141. Adlake "Regulator"

In explanation of the wiring diagram for the Adlake regulator, Fig. 142, start at terminal *A* of the generator; the current flows to A_1 on the regulator and thence to the fuse block *a*. It is here the shunt-field circuit begins. The field current flows from *a* through *b* to the rheostat terminal *c* and through a number of the sections of the latter, depending upon the position of the arm *F*, through this arm and back through *d* to the fuse block *e*, thence through

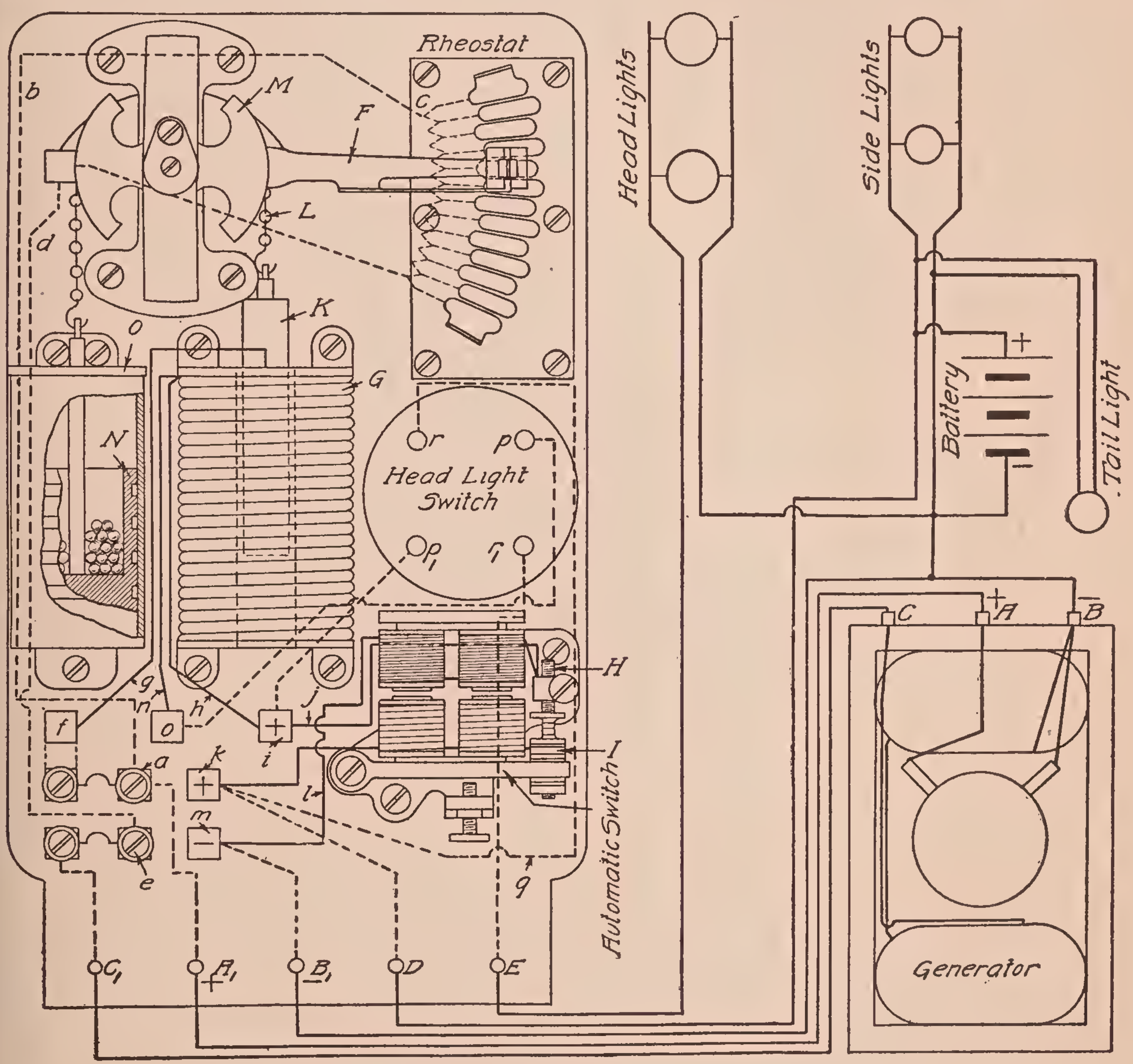


Fig. 142. Connections for Adlake "Regulator" (*Horseless Age*)

the fuse to terminal C_1 and from there to the terminal *C* of the generator, thence through the two shunt-field coils and back to the negative terminal *B* of the generator. From *B* the current flows through the generator armature back to *A*, thus completing the circuit. There being only one field winding, the current always takes the same path, except that it has to flow through more or less of the resistance sections of the rheostat, of which there are fifteen. The path of the main or charging current is from the fuse block *a* to the connector *f*, and through *g* into the solenoid coil *G*. It leaves this coil through *h* and flows to the contact block *i*, which connects by the wire *j* with the stationary contact screw *H* of the automatic battery switch. When the latter is closed for charging, the current flows across to the movable contact point *I* of the switch, and thence through the two lower or series coils of the automatic switch to the connector *K*. From this it flows to the terminal *D* of the regulator, which is directly connected with the positive terminal of the battery, and the current, after flowing through the battery, returns to the negative terminal *B* of the generator through connections clearly indicated.

There are a number of variations in the methods of regulation employed, as well as some that are not given in the foregoing résumé. These are explained in detail in connection with the descriptions of the different systems.

PROTECTIVE DEVICES

Various Forms. When fully charged, the storage battery holds in chemical form the equivalent of two or more horsepower, i.e., 40 to 160 amperes at 6, 12, or 24 volts, according to the system employed and the capacity of the battery furnished. An accidental ground or short circuit in the wiring system would release all of this energy in a flash to the great detriment of the battery itself as well as to any of the apparatus or parts of the car that happened to be included in its path or circuit. To guard against damage from such a cause, various forms of protective devices are employed, and the different systems vary as much in this respect as they do in others. In some instances, a circuit breaker is depended upon to take care of all the circuits. In others, further protection is afforded by the employment of fuses, as well as a circuit breaker. Fuses very generally are employed to protect the lighting circuits as well as some of the other circuits.

Automatic Battery Cut-Out. It will be evident that, if the storage battery were at all times in direct connection with the generator, it would immediately discharge through the latter as soon as the driving speed fell to a point where the dynamo was no longer producing sufficient voltage to charge the battery. If the generator were free to run instead of being positively connected to the engine it would become "motorized" and operate as an electric motor or the battery current. As it is so connected, the battery current would simply burn out its windings, owing to the low resistance of the latter at slow speeds. Consequently it is necessary to insert an automatic switch in the circuit in order to connect the battery with the generator when the speed of the latter reaches a certain point, and to disconnect it as soon as it falls below that value. Such switches are usually termed automatic cut-outs, although sometimes referred to as "reverse-current relays" from the fact that they are designed to prevent the battery current from reversing through the generator. The Ward-Leonard, Fig. 139, is typical in that it clearly illustrates the principles upon which most of these devices are based,

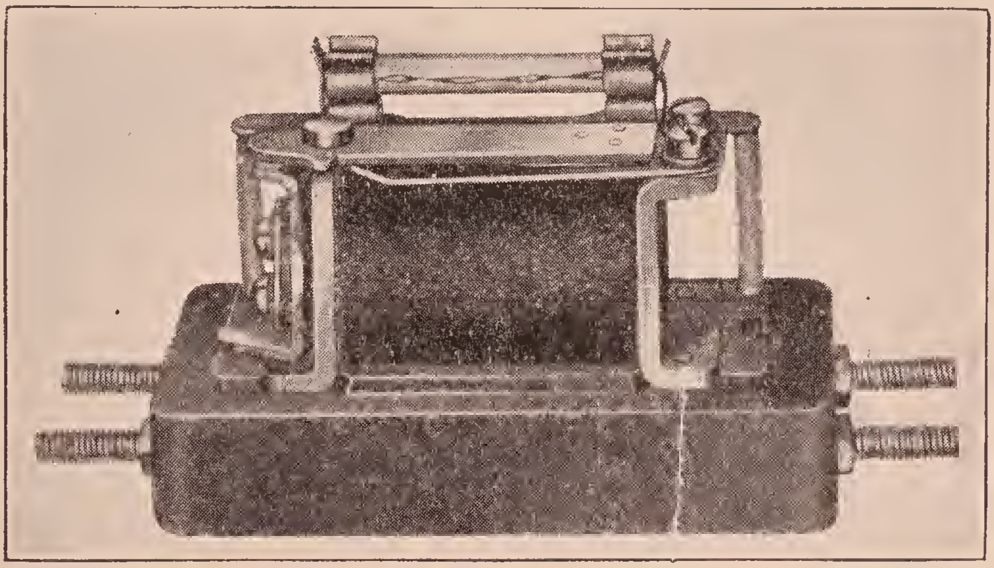


Fig. 143. Remy Reverse-Current Relay

though their construction varies widely, as will be noted by Fig. 143, which shows the Remy reverse-current relay.

Ward-Leonard Type. The switch mechanism is shown at the left of Fig. 139. In this device *A* is the coil, *B* the magnet core, *C* the movable arm, and *DD′* the contacts. The dynamo generates sufficient voltage at a car speed of approximately 7 miles per hour to attract *C* and hold it in position, closing the battery circuit through *DD′*, so that charging proceeds as long as the car is run at anything over a starting speed. Below that point the circuit remains open and the generator simply revolves idly.

Adlake Type. Referring to Fig. 141, Adlake regulator, the automatic cut-out switch will be seen at the lower right-hand corner of the panel. This differs somewhat from the majority of such devices, in that it has two shunt and two series electromagnets, the two latter being carried by the switch, and are therefore movable.

The closing of the switch is effected by the two upper or shunt coils. The current for these coils follows the path of the main charging current as far as the stationary contact screw H of the switch, from which a connection leads to the fine windings of the shunt coils; after passing through these coils, it flows through the wire l to the connector m, which is connected to the terminal B_1. Consequently, as soon as the generator begins to pick up, current flows through the two upper or shunt coils of the switch, and when the magnetism due to this current becomes strong enough the switch closes. Current then flows into the battery for charging, first passing through the two lower or series coils, which greatly increase the pressure at the contact points as long as the charging current is flowing, and insuring a positive interruption of the current when the generator voltage drops below that of the battery. A powerful actuating force is thus obtained with very small magnets.

Circuit Breaker. Circuit breaker, as employed in this connection, must not be confused with "battery cut-out". The cut-out is literally a circuit breaker and is referred to as such by some manufacturers in their instructions, but in electric terminology, as employed in everyday use, the circuit breaker and the cut-out are entirely different things. A circuit breaker is designed to operate only when a current considerably in excess of that for which its circuit is intended passes through it. Whether a protective device is a cut-out or a circuit breaker may be determined by the circuit in which it is placed. The cut-out is never employed in any other circuit than that of the generator and battery. A detailed explanation of the circuit breaker is given in connection with the Delco system.

STANDARDIZATION

Voltage Standards. Weight reduction is a problem of the greatest importance on the automobile and as energy in the form of a lead-plate storage battery is very heavy, the size of the latter is very closely limited. Power, however, depends not so much upon the amount of energy available as it does upon the pressure at which it can be applied. Thus, by doubling the voltage of a storage battery, the capacity needed can be reduced correspondingly. Where only three cells are employed, they must be very much larger than when six are used, and the cells of the latter must be correspondingly larger than those of a 9-cell or a 12-cell battery. While there are a few adherents of the higher voltage battery represented by the systems in use today, the majority favor the 6-volt standard.

Variation by Manufacturers. A final difference to be noted is that systems of totally different characteristics are turned out by the same manufacturer. Automobile motors are still a long way from reaching a degree of standardization that permits them to be classified according to horsepower, dimensions, number of cylinders, or any other easily applied standard so far as their requirements from an electrical point of view are concerned. The manufacturer of electrical apparatus accordingly designs a starting and lighting system to meet the requirements of a certain motor and it will give the most efficient service only when applied to that particular motor. This accounts for the major part of the great variation in electrical systems that exists and particularly for the difference between the equipment of the successive models of the same make of automobile. For that reason, it must never be concluded that a Delco, a Gray & Davis, a Bijur, a Wagner, or any other starting and lighting system is always the same on whatever car it may be found. Automobile manufacturers alter the characteristics of their motors from year to year, and the manufacturer of electrical apparatus not only keeps pace with this by redesigning his system to correspond but also introduces various improvements suggested by experience and the development of the art. In consequence, it would be manifestly impossible to attempt to outline in detail the features of every starting and lighting system to be found on all the cars now running, thousands of which are three to five years old. The following analysis accordingly covers only those of more recent manufacture, but by a study of these it will be easy to become familiar with the general characteristics of all, and to note at a glance where improvements have been made from year to year.

STARTING MOTORS

Speaking broadly, there are three classes of starting devices worthy of mention, viz, the mechanical or spring-actuated devices; the compressed fluid devices; and the electrical starters. While still employed to some extent abroad, compressed air and similar devices are now only of historical interest here as they have been displaced almost entirely by the electric starter.

Modern Electric Starting System Anticipated Sixteen Years. Although it has only come into general use within the last few years, the possibilities of the electric starter on the automobile were foreseen at an early day. Those to whom it has appeared as a novel development of very recent adoption will doubtless be surprised to learn that a car embodying many of the features of present-day electrical systems was built in 1896. Indeed, the following description of it might well apply to the present U.S.L. system, which employs the flywheel type of dynamotor. The machine in question was a Diehl specially wound Gramme-ring type designed to operate at 12 volts. The armature, which weighed 111 pounds, served as the flywheel of a two-cylinder horizontal opposed 6- by 7-inch motor. The system was described as follows:

"The flywheel is constructed as a dynamo, which by rotary motion charges a storage battery carried in the vehicle. At the time of starting the carriage, the motorman turns a switch which discharges the storage battery through the dynamo, converting it for a few seconds into a motor, which, being upon the main crankshaft, gives rotation and does away with the necessity of starting the flywheel by hand. After the motor gives the crankshaft a few turns, the cylinders take up their work and the battery is disconnected from the dynamo, which then acts as a flywheel.

"The flywheel dynamo furnishes the current for the induction coil of the sparking mechanism as well as for the electric lamps at night, thus doing away with the necessity of going to a charging station. Attached to the crankshaft is a device for changing the point of ignition of the spark in the combustion chamber, perfectly controlling the point of ignition, acting as a 'lead' and allowing the motors to be operated at a variable speed, according to the work done."

From this it will be seen that as early as the spring of 1896, the present complete electrical equipment of the automobile, including ignition with automatic spark advance, electric lighting and starting, was fully worked out and applied to an actual machine. It was not until sixteen years later that what had been anticipated at such an early day in the history of the automobile became accepted practice in all the essential points mentioned. In addition, the machine in question was provided with a magnetic clutch which automatically connected and disconnected the engine every time the gear-shifting lever was moved, thus anticipating the present-day electromagnetically operated gearbox.

Requirements in Design. The conditions in applying an electric starting motor to the gasoline engine bear no relation whatever to those of the lighting dynamo, so that the problem is not, as might be supposed, merely a question of reversing the functions of a single unit of the same characteristics. Practically the only requirements of the dynamo that differ from standard practice in other fields are that it shall commence to generate at a comparatively low (car) speed and that its output shall not exceed a safe limit no matter how high the speed at which it is turned over. The problem of the starting motor, on the other hand, involves conditions which have not had to be met in the application of electric motors to other forms of service. For example, a very high torque must be developed to overcome the inertia of the load, and the latter takes the form of intermittent rather than of steady resistance to the driving effort, owing to the alternate compression and expansion in the motor cylinders. The trolley car might be cited as a parallel to the heavy starting torque required, but the intermittent load, as well as the highly important limitations of weight, restricted current supply, voltage, and space considerations, are entirely lacking.

In the last analysis, the electric starter is nothing more nor less than a storage-battery starter, since most of its limitations are centered in that most important essential. The matters of driving mechanism, starting speed, and other equally important details can all be based on what is either accepted practice of long standing in other fields, or on the knowledge of starting requirements gained in the years of experience in applying manual effort to that end, but the storage battery will always constitute the chief limiting factor. This should be borne in mind in considering the forms that various solutions of the problem have taken, and, above all, it must be given first consideration in the successful maintenance of any electric starting system, as the majority of troubles met with have their origin in the neglect of the battery.

Wide Variation in Starting Speeds. In view of the long experience in hand-cranking the motor, it would seem that a definite basis for the starting speed would be an easy thing to establish, but this has not been the case. If "motor" briefly summed up in one word all of the varying characteristics to be found in the great variety of engine designs to which starters must be applied, this might have been easier of accomplishment. What suffices to start one make is, however, frequently found to be totally inadequate for others of apparently identical characteristics, so that in the different makes of starters this essential is found to range all the way from 25 r.p.m. to 200 r.p.m. or over. The necessary speed is largely influenced by the carburetion, as with the stand-by battery ignition almost universally provided, dependence need not be placed on the magneto to start; but to draw a mixture from the carbureter of a cold engine calls for speeds in excess of the lower limit of the range given. The most severe service demanded of the starter and the time when it is most needed are coincident, i.e., in winter use, and the equipment must naturally be designed to meet successfully the most unfavorable conditions. Even with starting speeds of 100 r.p.m. or over, it has been found impossible to start some motors without resort to priming. Some idea of the great variation in the speeds adopted will be evident from the fact that the North East starter, as originally built, was designed to turn the Marmon six-cylinder motor over at only 25 r.p.m.; the Hartford on a similar motor at 70 r.p.m.; the Westinghouse, 80 r.p.m.; Delco, 150 to 175, and the U.S.L. at 200 or over. These speeds are not invariable by any means, as in every case the starting equipment is designed particularly for the motor to which it is to be applied, and will run at different speeds in accordance with the requirements of the engine on which it is installed.

Practice Becoming Standardized. So far as practice may be said to have become standardized at the present writing, speeds of 80 to 100 r.p.m. represent a close approach to the average. One of the reasons for making the speed so much higher than could be effected by hand-cranking is the slowing down of the motor as the pistons reach the maximum compression point in the cylinders, while another is the necessity for drawing a charge of fuel from the carbureter under the most adverse conditions so that starting shall always be accomplished without resort to priming.

Voltage. When an engine has been standing idle for some time at a temperature well below the freezing point, the lubricating oil becomes extremely viscous and the current required for starting at a low voltage is very high. The 6-volt standard inherited from dry-cell-ignition days accordingly appeared to be entirely too low at the outset, and several systems employing 12- and 24-volt batteries were developed. The higher efficiency of the latter in starting is opposed by certain disadvantages inherent in this type of installation. Experience has shown, however, that with proper installation and maintenance the 6-volt system affords advantages which more than offset any increase of efficiency derived from the use of a higher voltage, and the majority of well-known starting systems are now designed to operate on a potential of 6 volts.

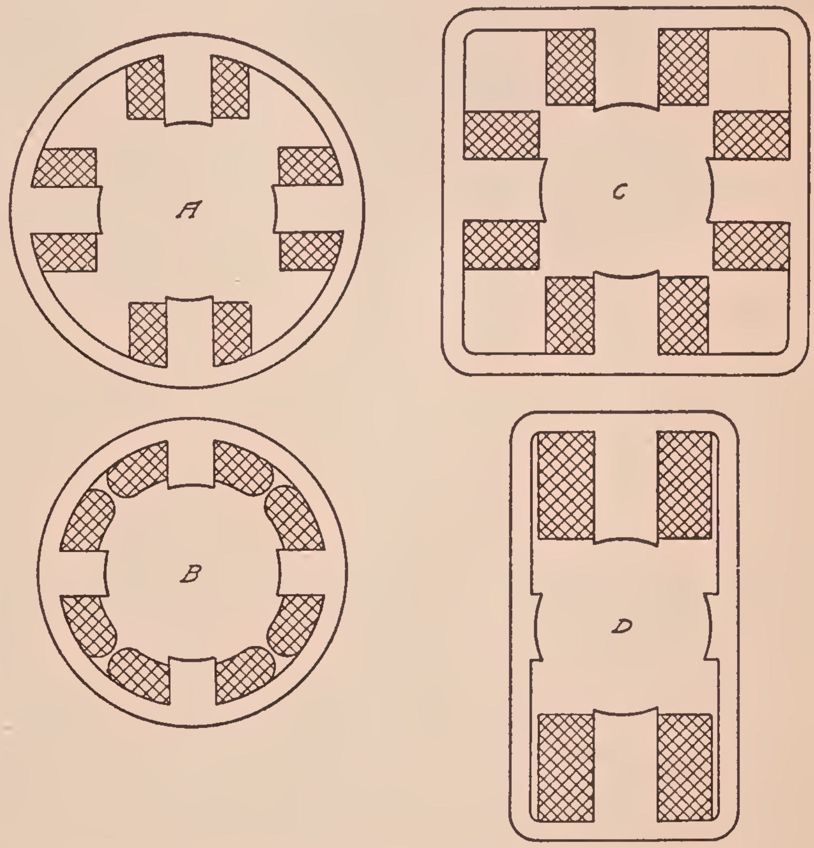


Fig. 144. Cross-Sections Typical Electric Starting Motor
Courtesy The Automobile, New York City

Motor Windings and Poles. The necessity for developing a powerful torque at low speeds naturally calls for a series-wound motor, such as is employed in street-railway and electric-automobile service, and all starting motors are of this type. Motors built to operate at such a low voltage being new to the electrical designer there is more variation in the form and size of starting motors than exists in power units running on current at commercial voltages.

Standard Designs. Briefly stated, the electrical requirements demand a concentrated and correctly proportioned mass of iron and copper in the minimum space. The cross-sections, Fig. 144, show how these requirements have been met in various instances. As the motor is only required to operate for very short periods, both the conductors and insulation can be kept down in size as compared with a motor designed to run constantly under heavy load.

Commercial Forms. The problem is to provide for a certain number of ampere turns around the poles and a magnetic circuit through the latter, as well as steel housing or frame of sufficient cross-section to carry the required degree of magnetization with the

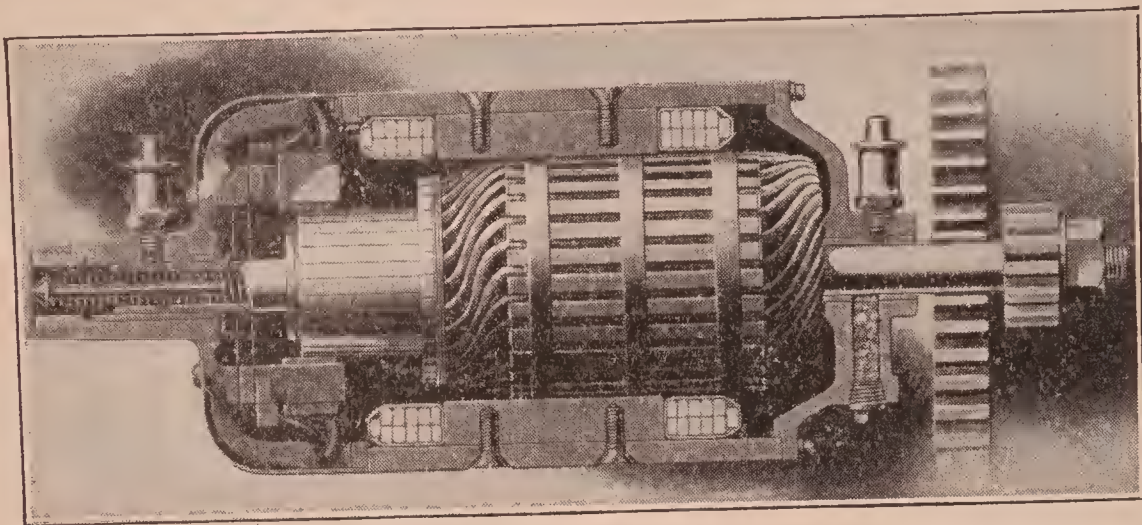


Fig. 145. Section of Bosch-Rushmore Starting Motor

shortest magnetic circuit. Consequently, shallow windings with long flat pole pieces are more efficient than the reverse of this form, particularly as air space in the magnetic field lessens its intensity and calls for a heavier winding to magnetize the extra weight of metal to the same degree. Hence, the type represented by *B*, Fig. 144, is the most efficient, in theory at least, of the four forms illustrated.

Whether the windings be placed on two poles or on four poles is something that each designer decides according to his own preference in the matter. The Bosch-Rushmore starting motor, Fig. 145,

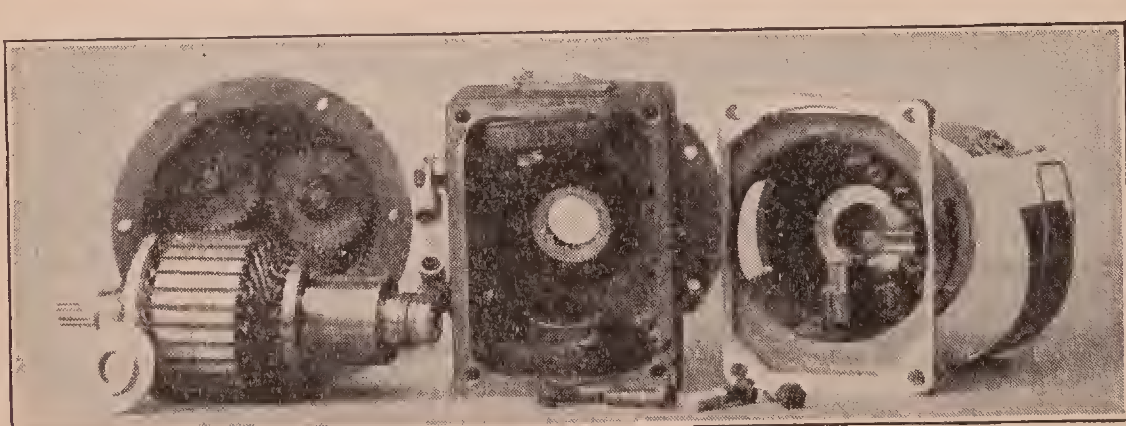


Fig. 146. Westinghouse Starting Motor

exemplifies type *B* referred to above, except that it is bipolar. Windings and pole pieces of the same type are shown in the Westinghouse starting motor, Fig. 146, this being patterned after form *D* in Fig. 144, though it is of somewhat broader section. The auxiliary unwound pole pieces at the sides do not show very clearly in the illustration; they are of substantially the same form, though con-

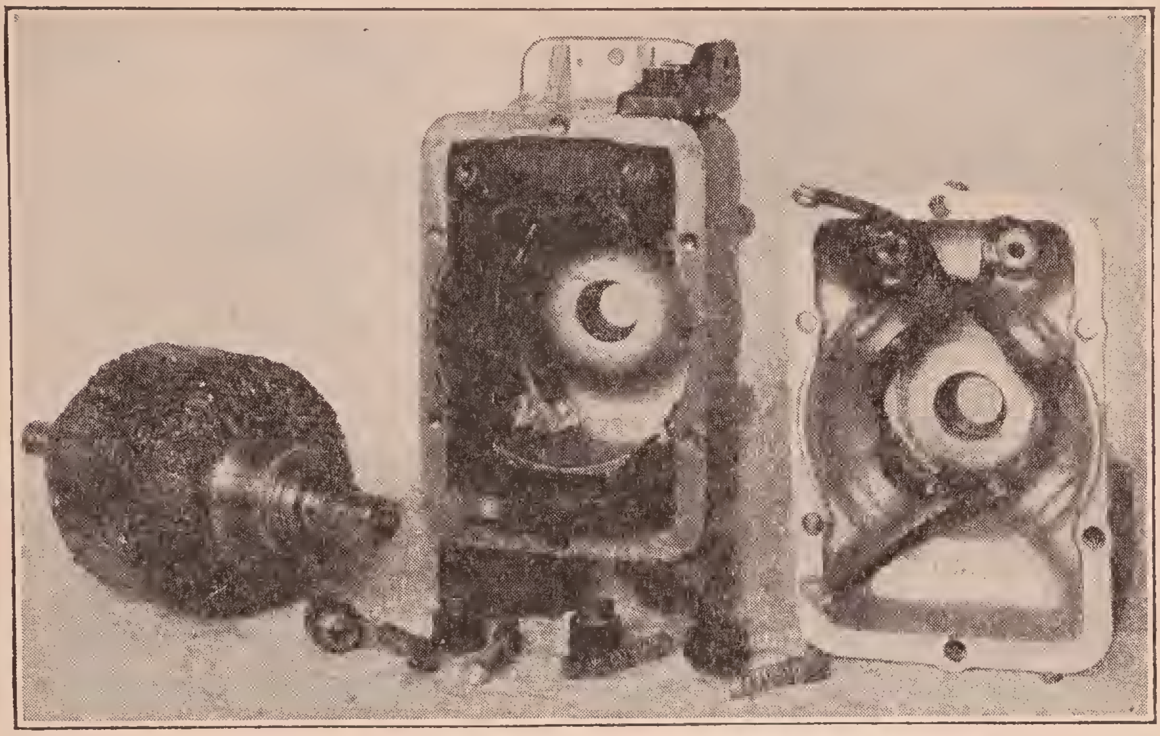


Fig. 147. Bipolar Type Westinghouse Starting Motor

siderably wider than those illustrated in the section in question. For a more restricted space a straight rectangular bipolar type is made, Fig. 147. From the standpoint of both electrical efficiency and space considerations, practice favors the cylindrical rather than the rectangular form.

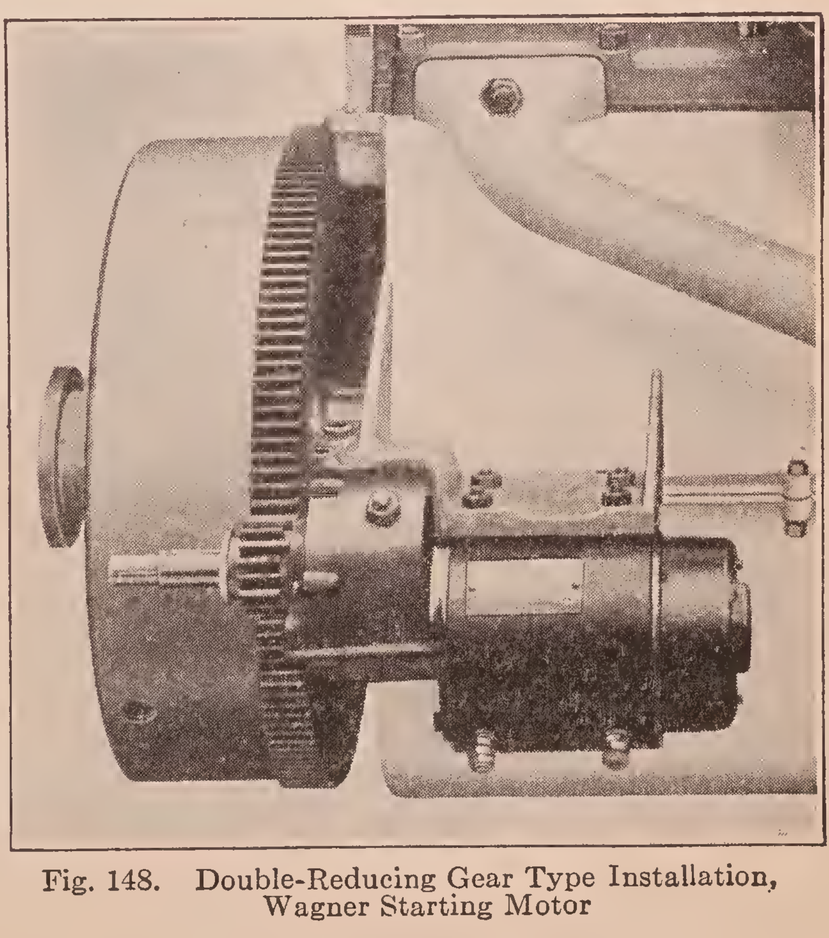


Fig. 148. Double-Reducing Gear Type Installation, Wagner Starting Motor

TRANSMISSION AND REGULATION DEVICES

Installation. As the driving requirements of starting with such a small power unit as space and weight limitations make necessary call for a high-speed motor and a high gear ratio to effect the necessary speed reduction, the mounting of the starting motor is totally different from that of the lighting dynamo. The electric motor runs at 1800 to 3000 r.p.m. or over, according to its design, while, as already mentioned, the engine starting speeds usually average 80 to 100 r.p.m. The great speed reduction required is effected in the majority of instances by utilizing the flywheel as the driven gear, a gear being bolted to it, as shown in Fig. 148, which illustrates the application of a Wagner starter to the Moline-Knight 50 horsepower four-cylinder motor. Or the gear teeth may be cut directly in the periphery of the flywheel itself, as shown by the Delco single-unit

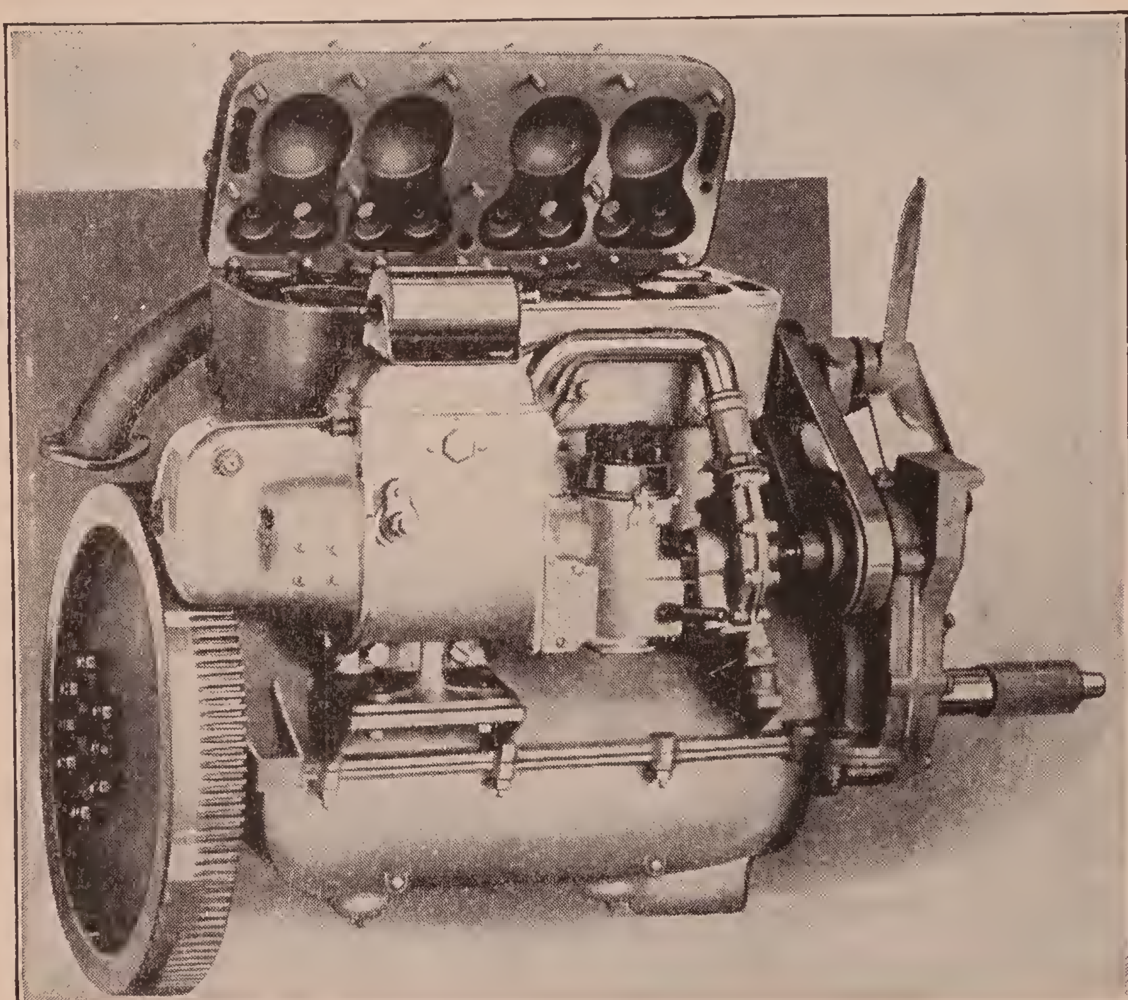


Fig. 149. Mounting of Delco Single-Unit System

system mounted on a Cartercar four-cylinder engine, Fig. 149. In either case, this does not afford sufficient reduction in the speed, and an intermediate set of gears is necessary in installations such as those illustrated. This gearing may be mounted as an attachment to the engine or combined with the starting motor, as shown in Fig. 150, showing a Ward-Leonard starting motor with enclosed gearing. In some instances, a planetary type of gear is employed, an example of which is found in one type of the Westinghouse starting motors, Fig. 151, the gearbox being incorporated in the motor housing and the pinion driving direct. In view of the large reduction available in a planetary gear, a starting motor of this type may be employed to drive through a camshaft or similar location. Planetary gears are also utilized on some of the single-unit systems, such as the Northeast, the gear ratio used being something like 40 to 1 when the dynamotor is used for starting and 1 to $1\frac{1}{2}$ or 2 when running as a generator, Fig. 152. Silent chains are made use of in some cases, but this is done more frequently where a starting and lighting system is applied to an old car rather than to one for which it has been especially designed. Where the starting motor is of a comparatively low-speed type, the single reduction between the motor pinion and the flywheel suffices. Fig. 153 shows a Ward-Leonard starting

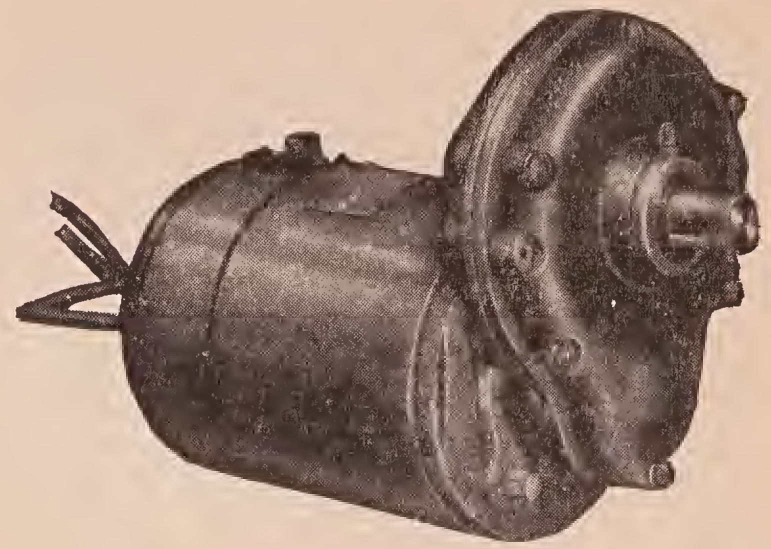


Fig. 150. Reducing Gearing Attached to Ward-Leonard Starting Motor

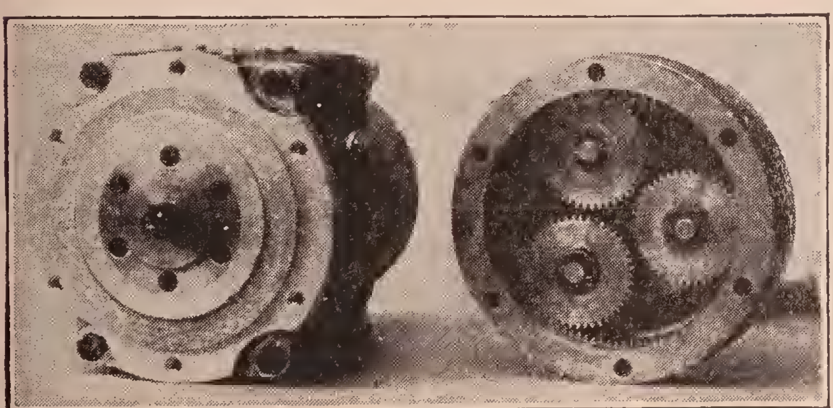


Fig. 151. Westinghouse Starting Motor with Planetary Reduction Gear

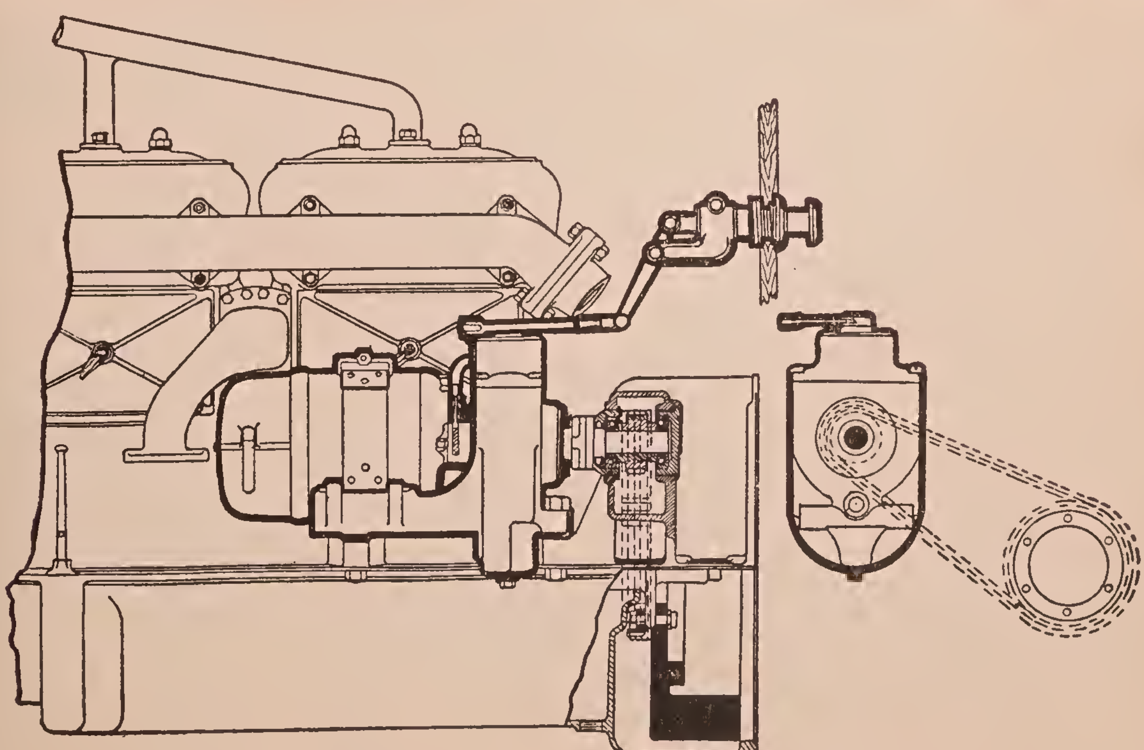


Fig. 152. Mounting and Drive of Northeast Dynamotor

motor designed for direct engagement with the flywheel gear. The purpose of the spring shown on the end of the shaft is to pull the pinion quickly out of engagement when the motor takes up its cycle, as explained in the following sections.

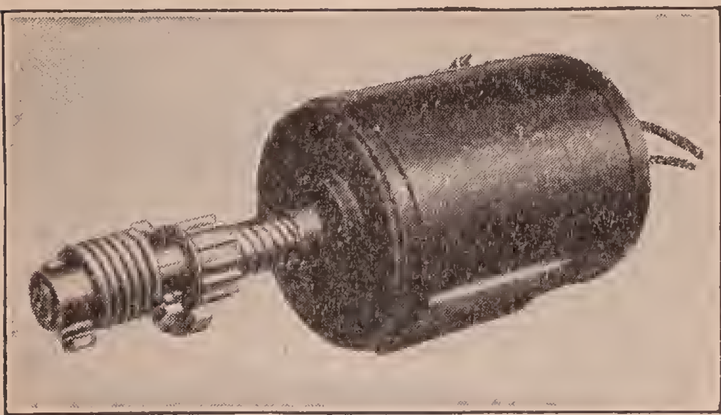


Fig. 153. Ward-Leonard Starting Motor for Direct Engagement

Driving Connections. Except in the case of the single-unit type, which is in a permanent driving relation with the engine, it is necessary to provide some form of driving connection with the latter in order that the electric motor may turn it over to start, and release it the moment the engine fires. The difference between the two types where this essential is concerned will be plain upon comparing Fig. 154, which shows an

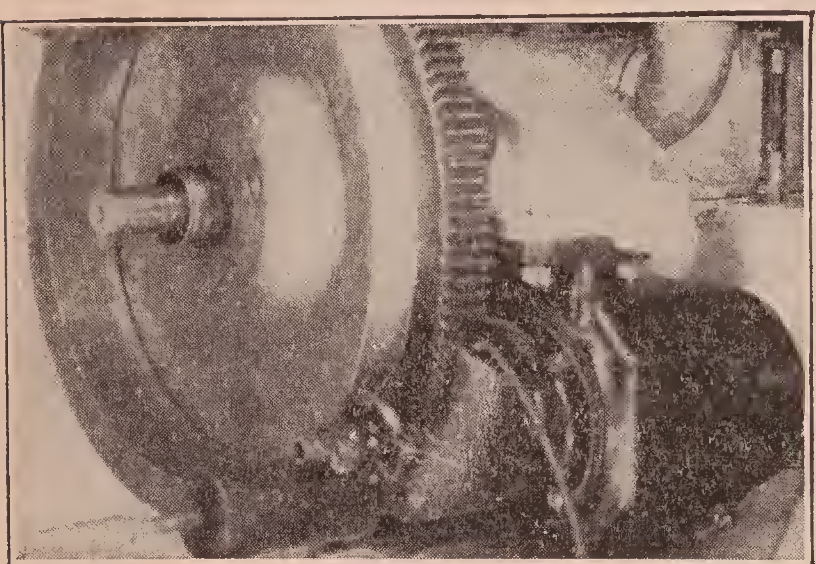


Fig. 154. Autolite Starting Motor on Overland Engine

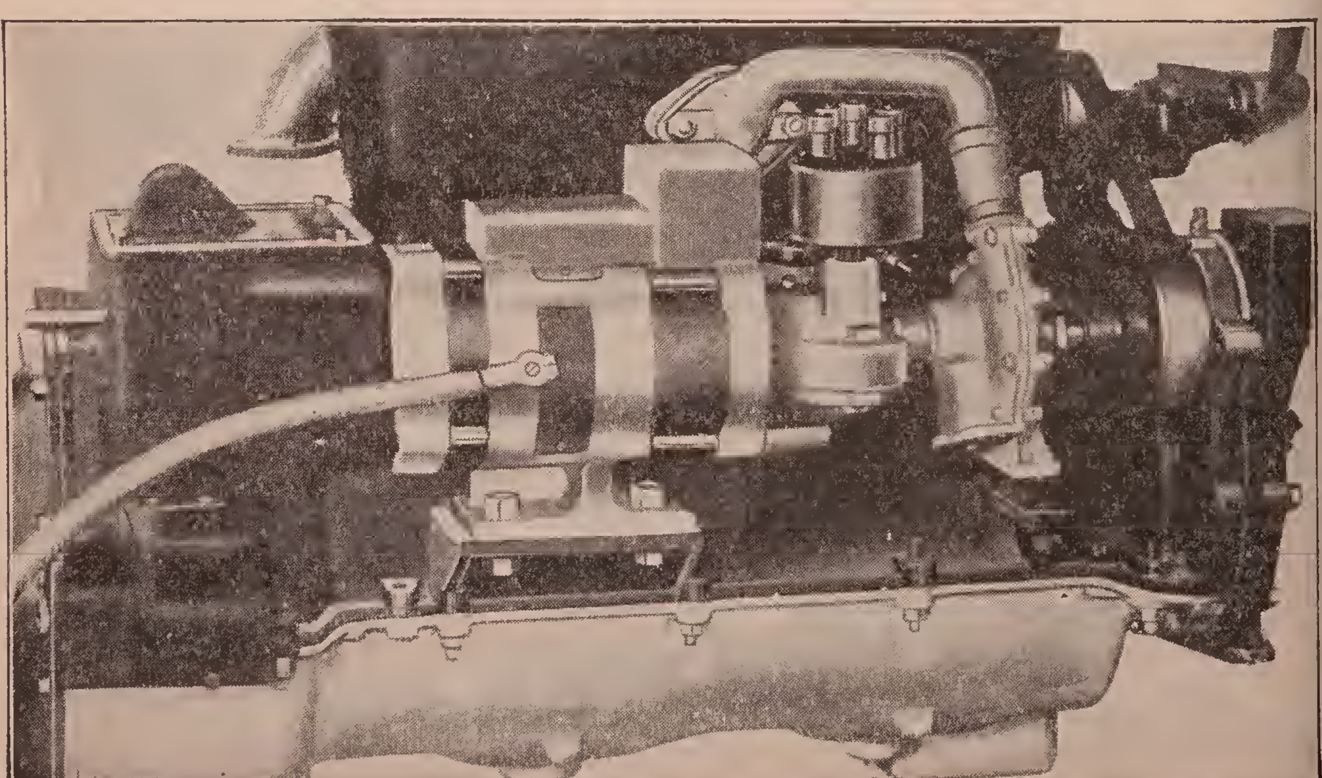


Fig. 155. Drive of Jesco Single-Unit System

Overland four-cylinder motor with an Autolite two-unit system, the starting motor only being shown, and Fig. 155, which illustrates a Jesco single-unit dynamotor. In the former, the control button or starting pedal serves both to connect the motor with the battery and engage the driving pinion with the toothed ring of the flywheel. Typical examples of this form of control are found on the Locomobile and Peerless, which differ only slightly in detail in their methods of installing the Gray and Davis starting motor. The switch is usually located directly beneath the footboards just back of the dash. Depressing the pedal part way makes preliminary contact through a resistance, turning the electric motor over very slowly, and at the same time draws the starter pinion toward the flywheel gear, its slow turning insuring easy engagement. As the pedal is depressed further, it breaks the first contact and closes the main switch, sending the entire battery current through the starting motor and turning the engine over rapidly. Releasing the pedal automatically opens the switch contacts and dis-

Fig. 156. Use of Starting Button, Electric Self-Starter

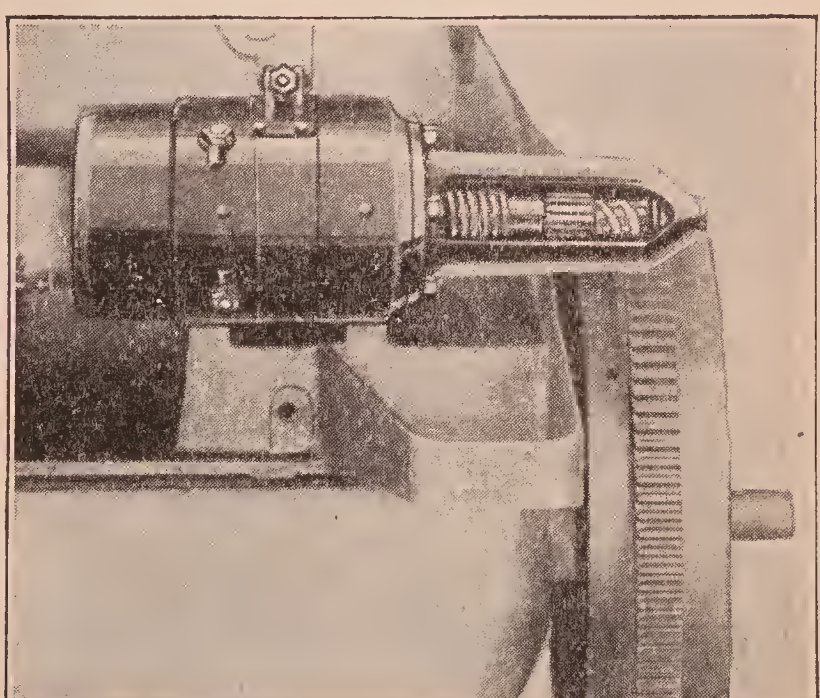


Fig. 157. Automatic Engagement and Release of Starting Motor, Overland Engine

engages the starting motor from the flywheel. Fig. 156 illustrates the use of a starting button of this kind. It is also frequently made in the form of a pedal, and placed on the slope of the footboards under the cowl of the dash, the location in any case being dictated by the necessity of keeping it out of the way of the other controls of the car.

Automatic Engagement. *Auto-Lite Type.* Fig. 157 illustrates an improvement on the foregoing method which eliminates the necessity of mechanically engaging the starting pinion with the flywheel. This is an Autolite generator on an Overland six motor. In starting, the depression of the pedal cuts in a resistance in the same manner at first, as not only would it not be safe to send the full strength of the current through the motor before it picked up the load, but it

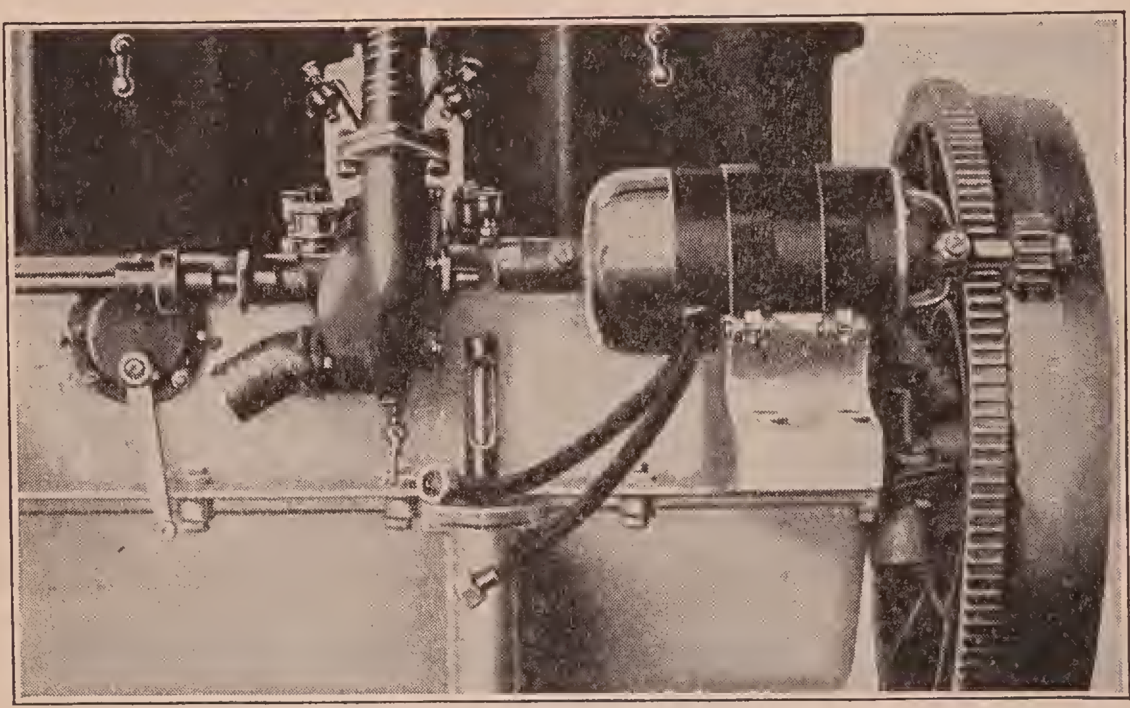


Fig. 158. Mounting of Bosch-Rushmore Starting Motor

would also be impossible to mesh the pinion at full speed. In this starting motor, the pinion is cut on a sleeve surrounding the armature shaft of the motor, and this sleeve is normally held out of engagement by the spring shown. On the armature shaft a thread of coarse pitch is cut which engages the inner surface of the sleeve. When the starting motor begins to turn slowly as the current from the battery enters it through the resistance, centrifugal force moves the sleeve with the pinion along it toward the right until the latter meshes with the flywheel gear. As soon as the current is cut off, the spring draws the pinion out of engagement.

Bosch-Rushmore Type. Another form of automatic engagement, which is electrically operated in this instance, is that of the

Bosch-Rushmore starter. By referring back to Fig. 145, which shows a section of this starting motor, it will be noted that there is a heavy spring on the left-hand end of the armature shaft, and that the armature itself is normally held out of its usual running position by this spring. In other words, it is not centered in the armature tunnel but is two inches or more to the right of the center of the magnetic field. This is just sufficient to keep the pinion out of mesh when the motor is installed as shown in Fig. 158. The first contact of the starting switch sends sufficient current for the field poles to exert enough magnetic drag on the armature to draw it back into its normal centered position, at the same time turning it over slowly, so that engagement is quickly effected automatically. The moment the current is shut off, the spring pushes the armature back and disengages the pinion. Exceptions to the practice reflected by the foregoing examples are to be found on cars like the Reo, in which the Remy starting motor is mounted on the transmission housing and drives to one of its shafts through a worm and worm wheel. The latter lowers the speed sufficiently through a single reduction and the revolution of the armature in starting picks up a clutch which automatically releases as soon as the engine starts.

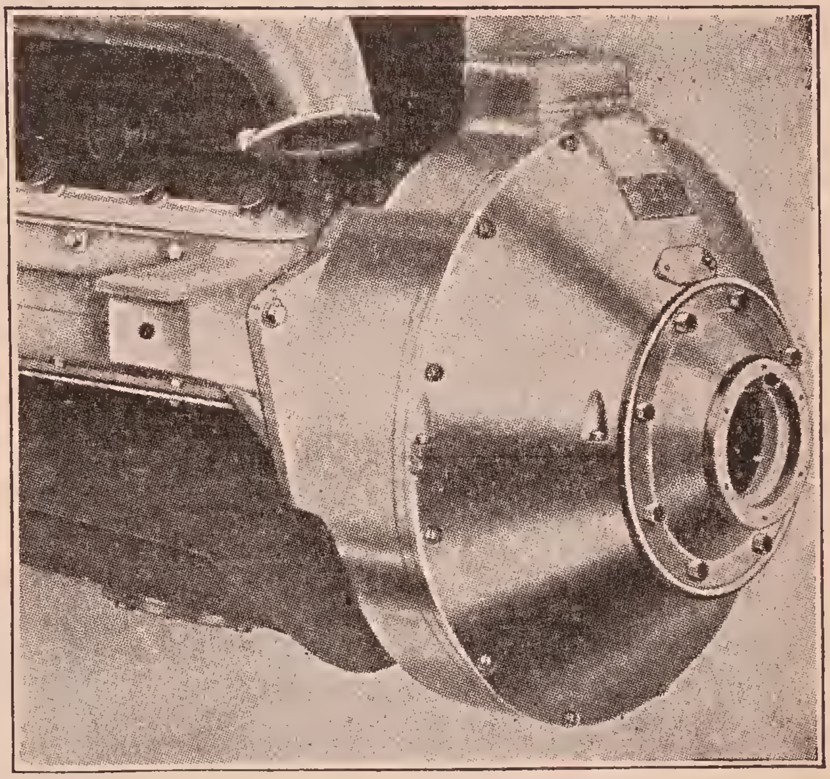


Fig. 159. U.S.L. Dynamo on Sheffield Simplex (British) Engine

Clutches. *Necessity for Disengaging Device.* To prevent the gasoline engine from driving the starting motor when the former takes up its cycle, some form of overrunning clutch must be provided unless the starter is geared directly to the crankshaft or has a mechanical disengaging device, such as the Bendix, or electrical, as the Bosch-Rushmore and Westinghouse. To take care of the speed reduction assume that this gear ratio is 30 to 1, and the throttle is half open when the engine is being cranked. As soon as the explosions begin to take place, the engine will shortly speed up to about 500 r.p.m. Before the gasoline engine is started, however, the electric motor will be running pretty near its maximum rate, say 3000 r.p.m. An electric motor of this type will run as high as 5000 r.p.m. safely, but speeds in excess of this are apt to damage it. If the throttle of the engine should happen to be three-quarters of the way open when started, and it should speed up to 1000 r.p.m. before the starting motor was disengaged, the armature shaft of the latter would attain a speed of 15,000 r.p.m., which is far beyond the safety limit. This makes it necessary to provide some device which, while permitting the starting motor to drive the engine, will prevent the latter from driving the starting motor as soon as the former takes up its regular cycle.

A number of different devices are employed for this purpose, such as the jaw clutch similar to that employed on all hand-cranks, roller clutch, friction clutch, pawl and ratchet, inertia clutch, worm and worm wheel, and others. A description of one or two types will suffice to make clear the principle on which most of the mechanical devices are based. The roller clutch and the overrunning jaw clutch are most frequently used. With starters of the design of the U.S.L., shown on a Sheffield-Simplex (British) six-cylinder motor in Fig. 159, it is obviously unnecessary to provide any form of flexible coupling, as the armature is mounted directly on the crankshaft and accordingly cannot exceed the speed of the latter.

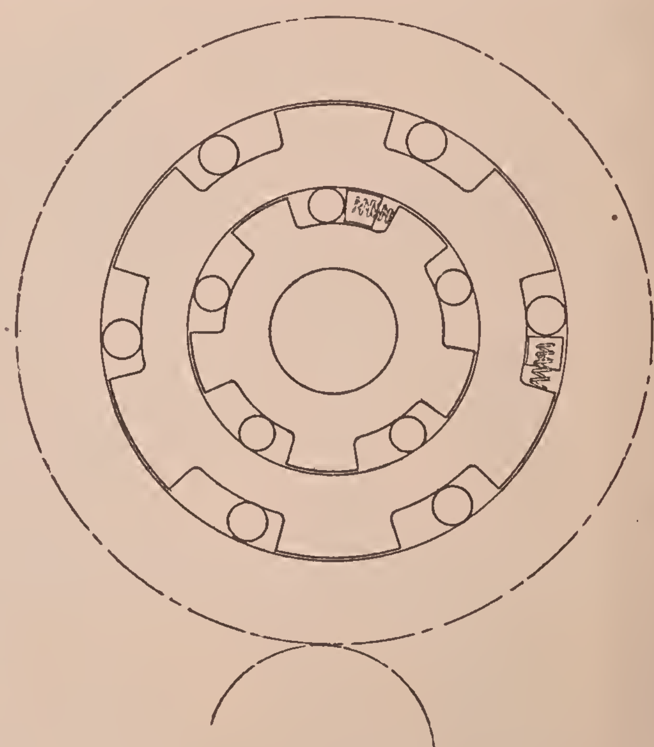


Fig. 160. Northeast Double Roller Overrunning Clutch (*Horseless Age*)

Where the crankshaft is driven direct through a train of gears, or a combination of gears and a silent chain, the clutch is usually placed between the last gear of the train and the crankshaft. None of the gears is then in operation except when starting. On the fly-wheel-gear type of installation used in connection with a second-gear reduction by means of a countershaft (see Fig. 148) the clutch is placed on the latter. Otherwise, it is mounted on the armature shaft. In the case of a worm and worm wheel drive, it is incorporated in the worm wheel.

Overrunning-Jaw Type. The most obvious type of overrunning clutch is one similar to that used between the starting crank and the crankshaft of an ordinary motor, a plain, four-jawed clutch with the backs of the jaws beveled. This was used on quite a number of starters at first and had the advantages of simplicity and positive operation. Owing to the intermittent nature of the load, however, due to the pistons passing the point of maximum compression and then going down with the charge above them expanding rapidly, the engine had a tendency to run away from the starting motor, and this caused a clicking noise, which was considered objectionable in many cases.

Fig. 161. Ratchet and Pawl Type Overrunning Clutch (*Horseless Age*)

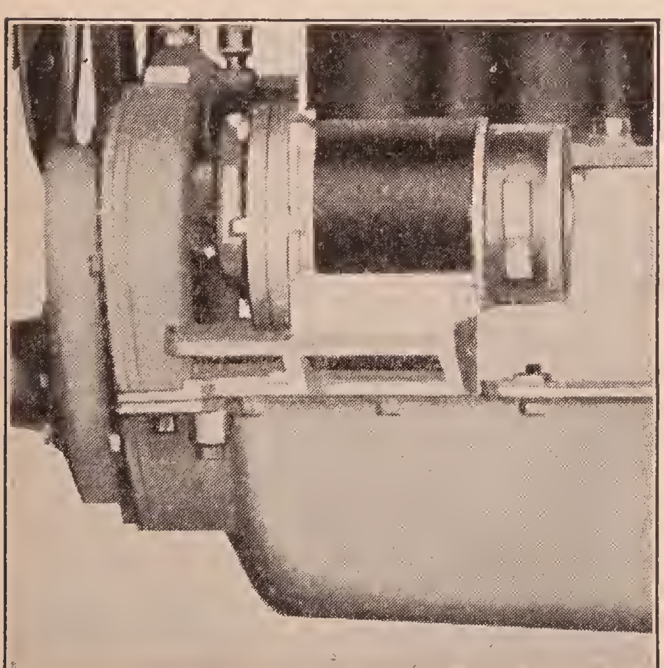


Fig. 162. Leece-Neville Starter Installation, Haynes Motor

Roller Type. The roller type is the most commonly used and, as the various forms in which it is made differ but little, a description of one will suffice to make clear the principle employed. It consists of an inner driving member and an outer driven member, connected by a number of rollers when the driving member is rotated in one direction and disconnected when it is rotated in the opposite direction, i.e., when the driven member tends to run faster than the driver. Fig. 160 shows the double roller overrunning clutch employed on the Northeast dynamotor. A double clutch is employed in this case to permit the dynamotor to be driven at one speed when operating as a dynamo and at another when starting the engine. The ratchet and pawl is such a familiar mechanical device that Fig. 161 will make clear the principle utilized in overrunning clutches of this type. Four pawls are mounted on a plate attached to the crankshaft and engage teeth on the inner periphery of a ring attached to the chain sprocket. At least one, and sometimes two, of these pawls will be in engagement when the engine is at rest owing to their counterweights. A A' are shown in this position. The starter then drives through the chain, sprocket pawls, and plate. As soon as the engine starts and the crankshaft runs faster than the sprocket, the pawls disengage and are held out by centrifugal force. To guard against sudden re-engagement and possible injury to clutch or chain when the engine rocks back and forth in stopping, four auxiliary pawls C C' and D D' are fitted.

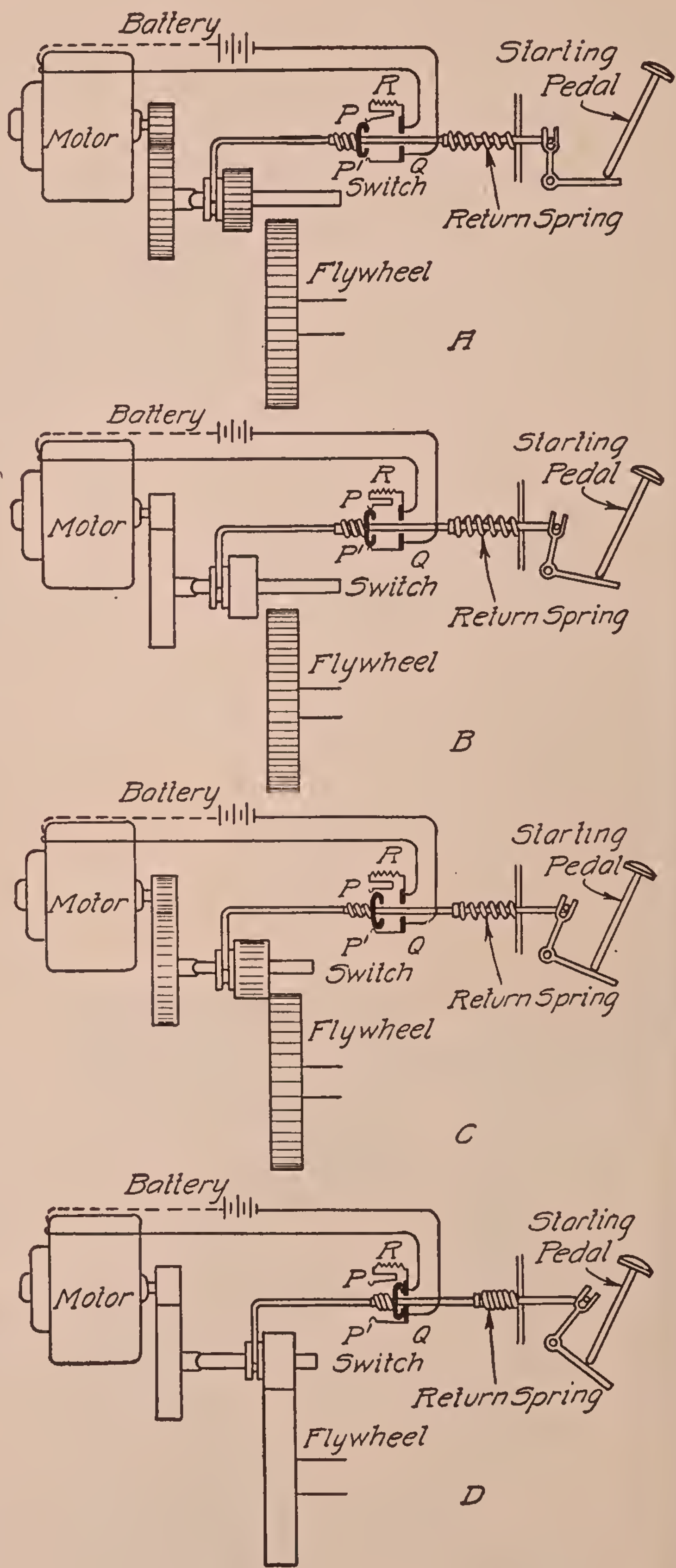


Fig. 163. Diagrams of Electrical and Mechanical Connections of Motor and Switch for Flywheel Drive with Double-Gear Reduction (*Westinghouse*)

When the clutch is idle they fall into the lowest positions possible, but when the pawl plates revolve they fly out to a radial position as shown at *D*. Should the crankshaft start backward, their inertia throws them into the position shown at D', thus preventing the main pawls from engaging the teeth on the sprocket ring. As soon as the crankshaft comes to a complete stop, one of the main pawls falls into position for starting. Fig. 162, which shows the Leece-Neville starter on a Haynes six-cylinder motor, is an example of the use of a roller clutch and chain in place of the gear and pinion connection previously described.

Back-Kick Releases. As the starting motor has more than sufficient power to overcome a back-kick or premature explosion (with the spark timing lever too far advanced) of the engine, and is only slowed down by it, only a few instances of the employment of a back-kick release are found in practice. One of these on the Northeast starter is in the form of a friction clutch held in contact by springs. This clutch will slip under such circumstances. A fric-

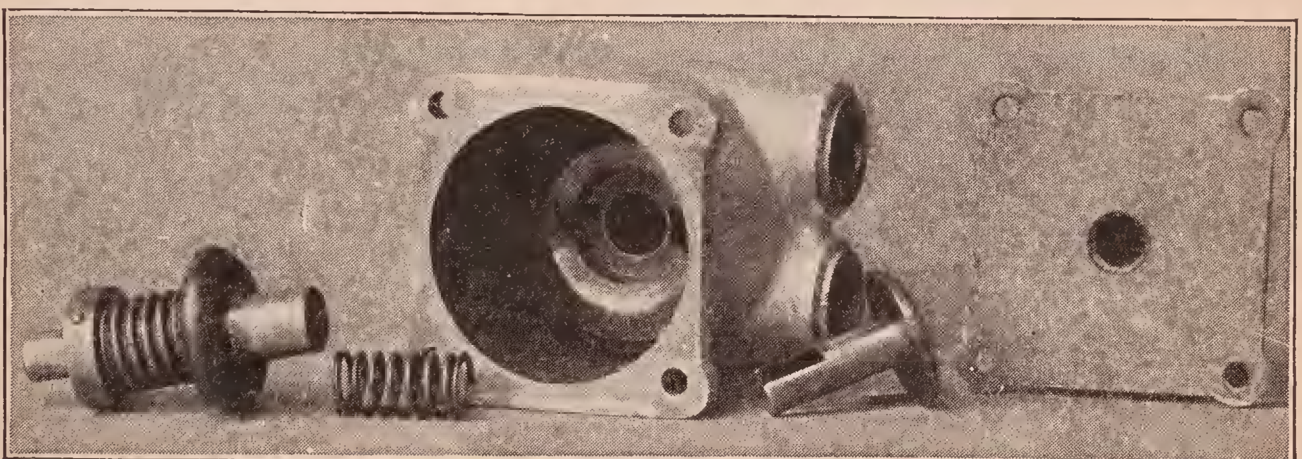


Fig. 164. Details of Westinghouse Switch

tion disk clamped between two steel disks, similar to a shock absorber, is employed on the Hartford starter, this being required because of the irreversible worm and worm wheel drive used, as the teeth of the latter would be injured in case the engine "back-kicked". Another device employs a brake band on the starting gears so designed that it holds in one direction only.

Switches. Two types of switches are employed in connection with starting and lighting systems—those designed to control the lighting circuits to the various lamps, and those employed to connect the battery with the starting motor. As the first type seldom carries more than 5 amperes at 6 volts and proportionately less at higher voltages, it does not differ from the standard forms of switches employed for house lighting, except that it is made much smaller in size. The starting switch, on the other hand, has to carry currents ranging from 50 to 250 amperes or more at voltages varying from 6 to 24, so that such a switch must be well built mechanically and have liberal contact areas. On account of the heavy currents handled by these switches there is a tendency to destructive arcing at the contact points unless provision is made to prevent it.

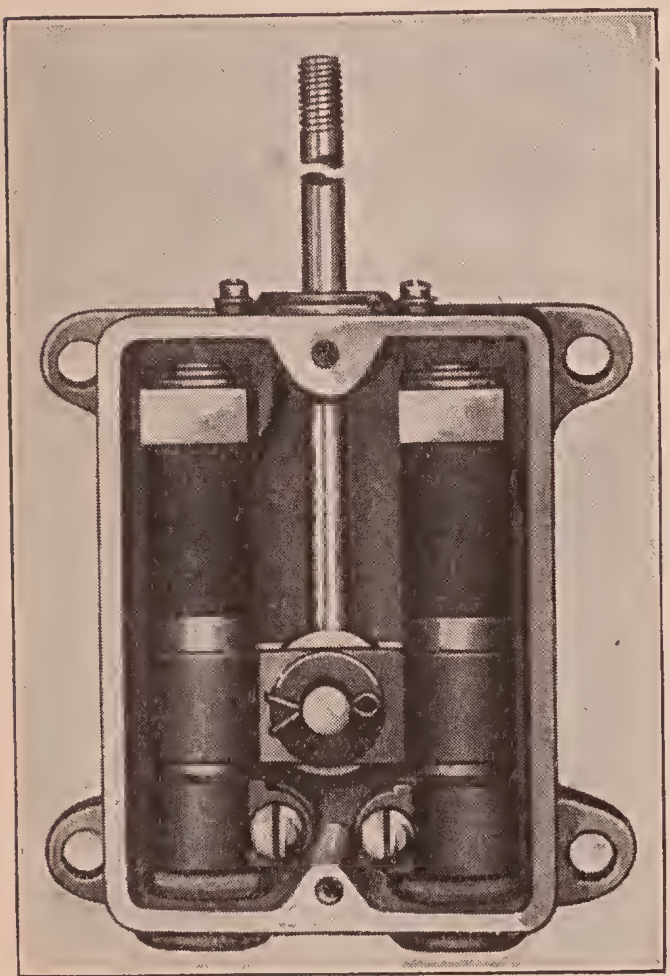


Fig. 165. Remy Starting Switch

Westinghouse Starting Switch. For starting use, two forms of switches are employed according to the method by which the motor starts the engine. Where the motor is connected directly to the battery terminals by the switch, as in the case of single-unit systems such as the Delco, only a single set of contacts is necessary; but in case gears must be engaged before the starting motor can take the full battery current, two progressively operated sets of contacts are used. The first set completes the circuit through a heavy resistance to turn the starting motor over very slowly, and the second set cuts out this resistance, the driving gears then being engaged. The operation of a switch of this type is graphically illustrated by the series of sketches, Fig. 163, showing a Westinghouse starter installation. In sketch *A*, both contacts are open, the return spring holding them apart. When the starting pedal is partly depressed, as in sketch *B*, the first set of contacts *P* come together and current from the battery passes to the starting motor through the resistance *R*.

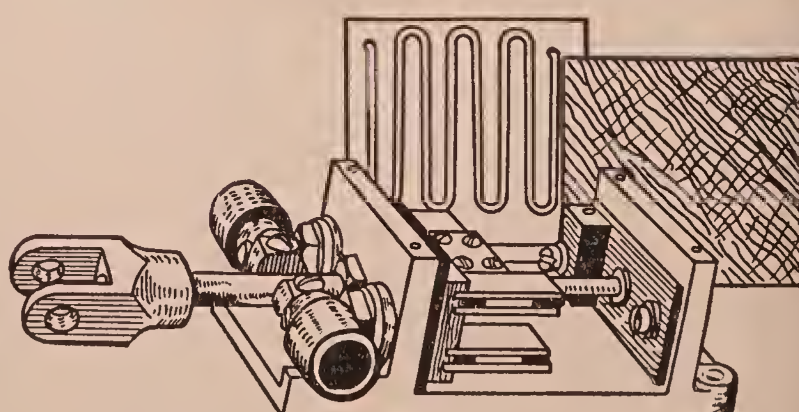


Fig. 166. Dean Knife Starting Switch

This connection continues through the spring fingers P and $P1$ until the sliding member is almost in contact with the main-switch points Q, when it is broken and the circuit is directly closed with the battery by a butt contact. The operation only requires a fraction of the time necessary to describe it. The moment the foot is removed from the starting pedal, the return spring automatically breaks the circuit. The construction of this switch is shown in Fig. 164. Switches of this type are usually mounted directly under the footboards, a slight movement being sufficient to close the contacts. The starting plug may be removed by the driver when leaving the car to prevent tampering, a pin across the tube making it impossible to insert a pencil or stick.

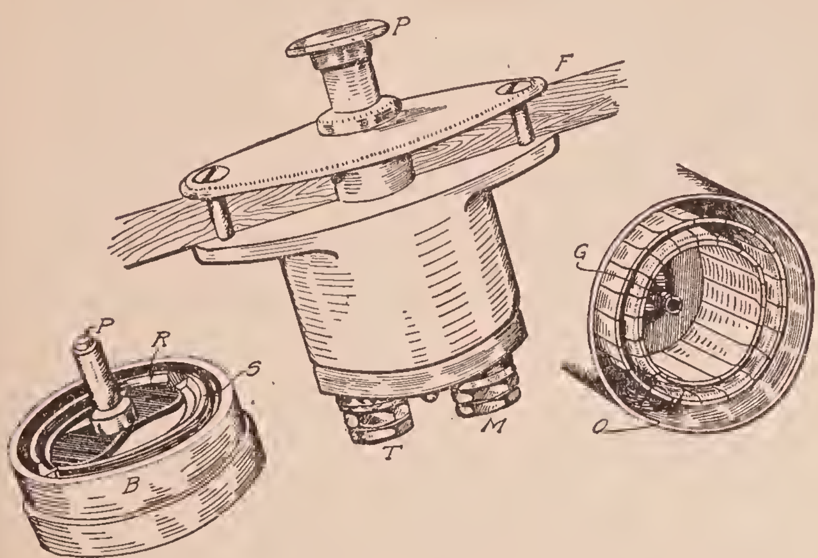


Fig. 167. Gray and Davis Button Starting Switch

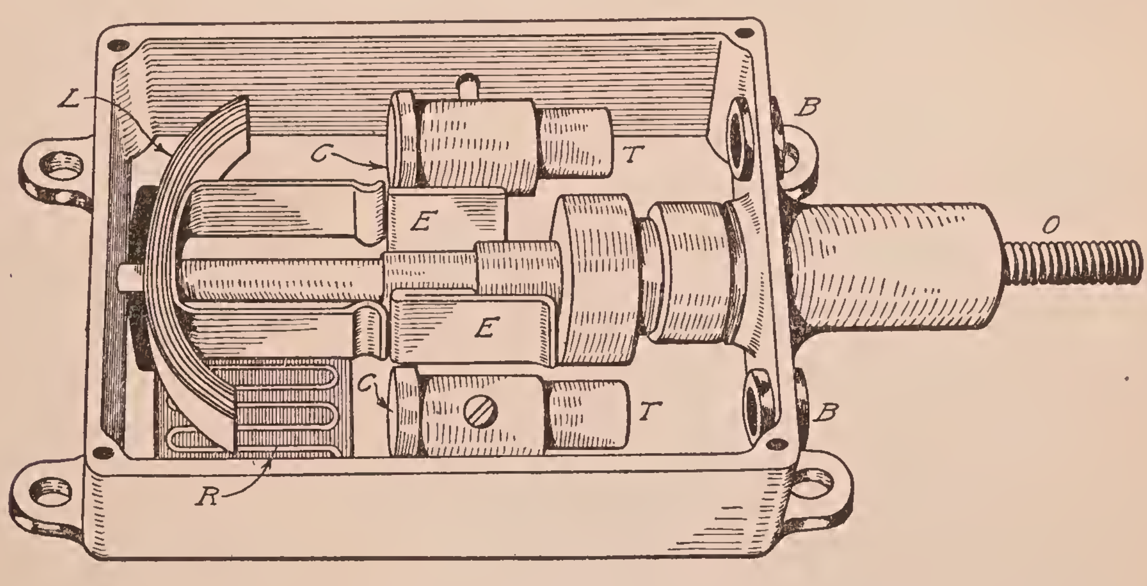


Fig. 168. Gray and Davis Laminated Type of Starting Switch
Courtesy of The Horseless Age

The resistance mentioned is in the form of a ribbon and is incorporated in the switch.

Miscellaneous Starting Switches. The type of switch used in connection with the Remy system is shown in Fig. 165. Both this and the Westinghouse switch described are known as butt-contact switches. The knife-type switch is also employed in several systems, Fig. 166 showing the Dean switch of this class. A somewhat unique form of contact is shown in the Gray and Davis switch, Fig. 167. There being no starting gears to mesh, it is only necessary to turn the current directly from the battery into the motor to start. *P* is the foot button of the starter, *F* the floorboard of the car, and *T* and *M* the terminals of the switch from which cables are led to one side of the battery and to one of the motor brushes, the others being grounded, as this is a single-wire system. Into the cast receptacle of the switch is fitted an insulating disk carrying the contacts *C* and *O* and also serving to insulate the terminals. These contacts are circular in form, and their free ends are turned away from each other so as to slip down over the knives *R* and *S* set in the insulated disk. The contacts are pressed downward by *P*, which is returned by the spring *G* pressing against the spindle *P*. The terminals *T* and *M* are fastened to the semicircular knives *R* and *S* respectively, so that bringing down the contacts *C* and *O* upon these knives completes the circuit from *T* to *M*. Numerous other forms of foot-operated switches are also employed, the Gray and Davis laminated contact switch, Fig. 168, for flywheel-gear installations, and the Ward-Leonard "harpoon" type,

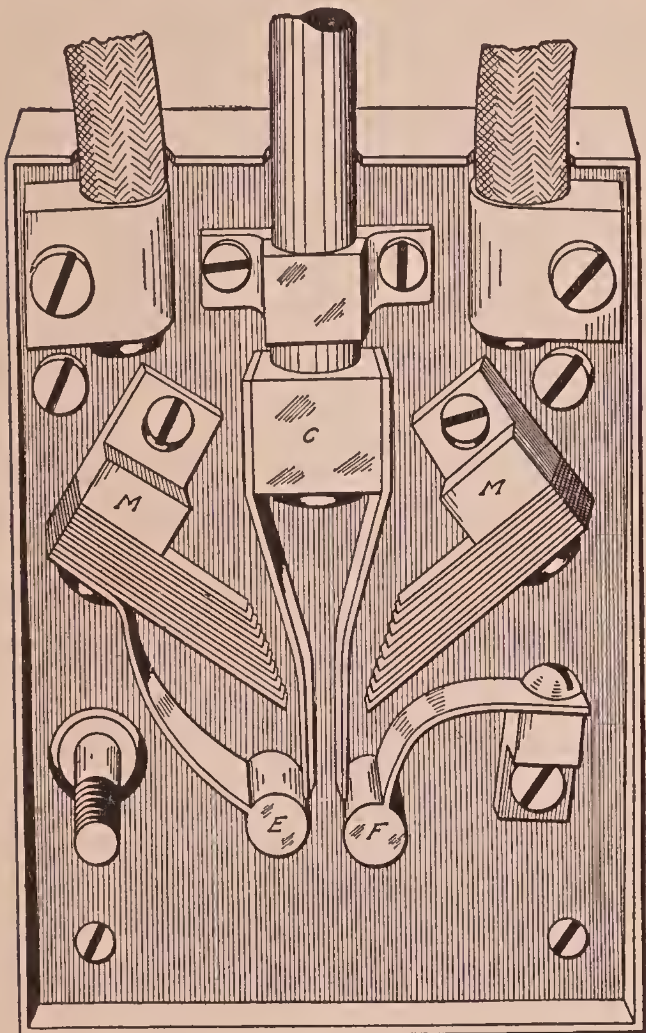


Fig. 169. Ward-Leonard "Harpoon" Starting Switch

Fig. 170. Packard Electrical Control

Fig. 169, being representative examples. Sliding-contact switches are also employed in some instances.

Electrically Operated Switches. In this type a conventional push-button switch, either on the dash or mounted on the steering column, as shown in Figs. 170 and 171, which illustrate the Packard and Overland control, respectively, takes the place of the foot button. This push-button switch, however, only handles a shunt current of low value, which energizes a solenoid to close the contacts of the main switch and also to engage the gears where this is necessary. The Westinghouse magnetically operated switch is explained in detail in connection with the description of that system. This form of control is employed on electric-railway trains and on electric automobiles. In addition to housing the push-button switch of the starting system, the two steering-column-control units mentioned also incorporate all the switches necessary to control the entire electrical equipment of the car, as will be noted by the indications alongside the various buttons on the Overland controller. A complete wiring diagram of the Packard controller is shown in Fig. 134.

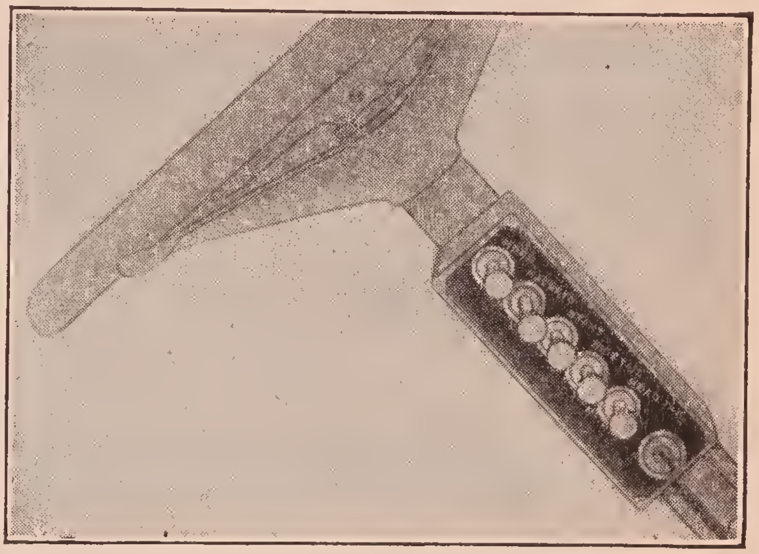


Fig. 171. Overland Electrical Control

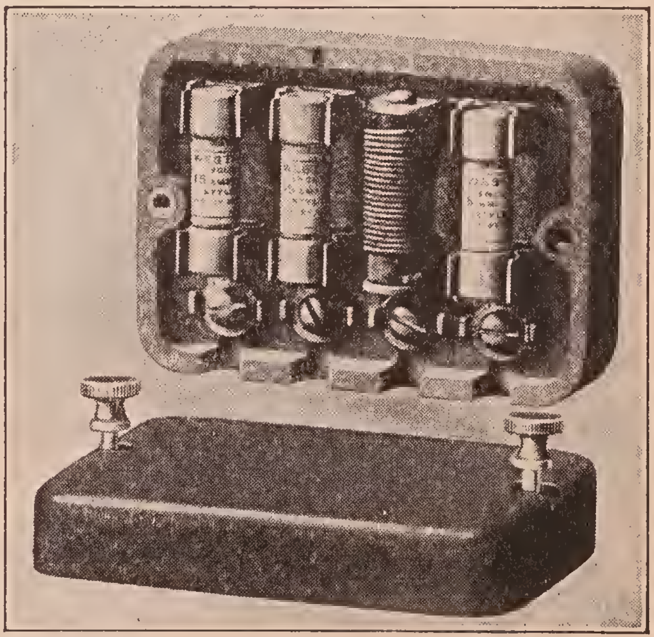


Fig. 172. Type of Fuses Employed on Lighting Circuits

Where a higher potential than the usual 6-volt standard is employed, the switch has another function, which is that of changing the battery connections from the multiple arrangement used for lighting to the series connection necessary to send the full voltage and current of the battery through the starting motor. This is the case with the U.S.L. system, which is made in either 12—6-volt or 24—12-volt forms.

Fuses. Standard practice favors the employment of fuses on all the lighting circuits to protect the battery in case of short circuits in any of the wiring. They were originally considered unnecessary on two-wire systems, but have since been adopted on the latter as well as on the single-wire system. Such fuses are of the cartridge type of miniature size, as shown by Fig. 172, which represents a Westinghouse fuse block, and do not produce a flash when they blow, which is a safety feature of importance in the presence of gasoline. The appearance of a black spot on the label indicates that the fuse has burned out, or these fuses may be had in glass tubes through which the fuse wire is visible.

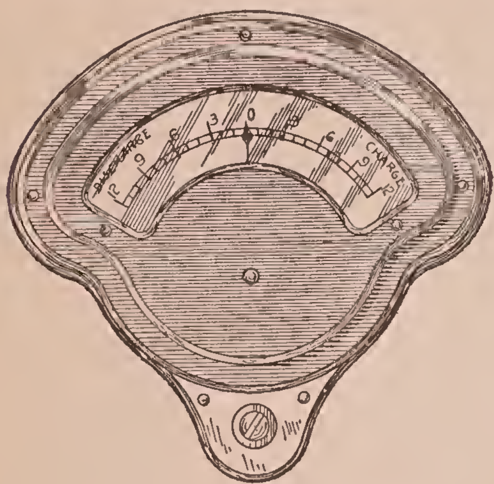


Fig. 173. Gray and Davis Ammeter

A double reading ammeter, mounted on the dash and illuminated at night by a hooded lamp, shows whether current is being sent into the battery or being taken out of it, the needle usually moving over a scale to the right of the neutral line for charging, and to the left for discharging, Fig. 173. This dash lamp is usually connected in series with the tail lamp, so that when it goes out it is an indication that the tail lamp is out as well. A voltmeter sometimes is provided to indicate the condition of the battery. In the Bosch system, this is combined with the lighting switches, as shown by Fig. 174. The use of so much electrical equipment with its numerous controls and indicating instruments has resulted in making the dash of the modern automobile rather a mysterious thing to the layman, though in reality it is not half so complicated as might be judged by looking at a dash such as that illustrated, Fig. 175. It is really only a matter of "pressing the button".

Fig. 174. Bosch Voltmeter and Switches

Electric Horns. The use of a storage battery which is of sufficient capacity for starting purposes, and which is kept constantly charged by the lighting generator, has made it possible to employ numerous auxiliary electrical devices. The electrical horn is the chief of these, and it has to a very large extent displaced warning devices of every other class. Two different types of electric horns are used, in both of which the sound is produced by the vibrations of a sheet-metal diaphragm several inches in diameter. The only difference between the two forms lies in the method of causing this

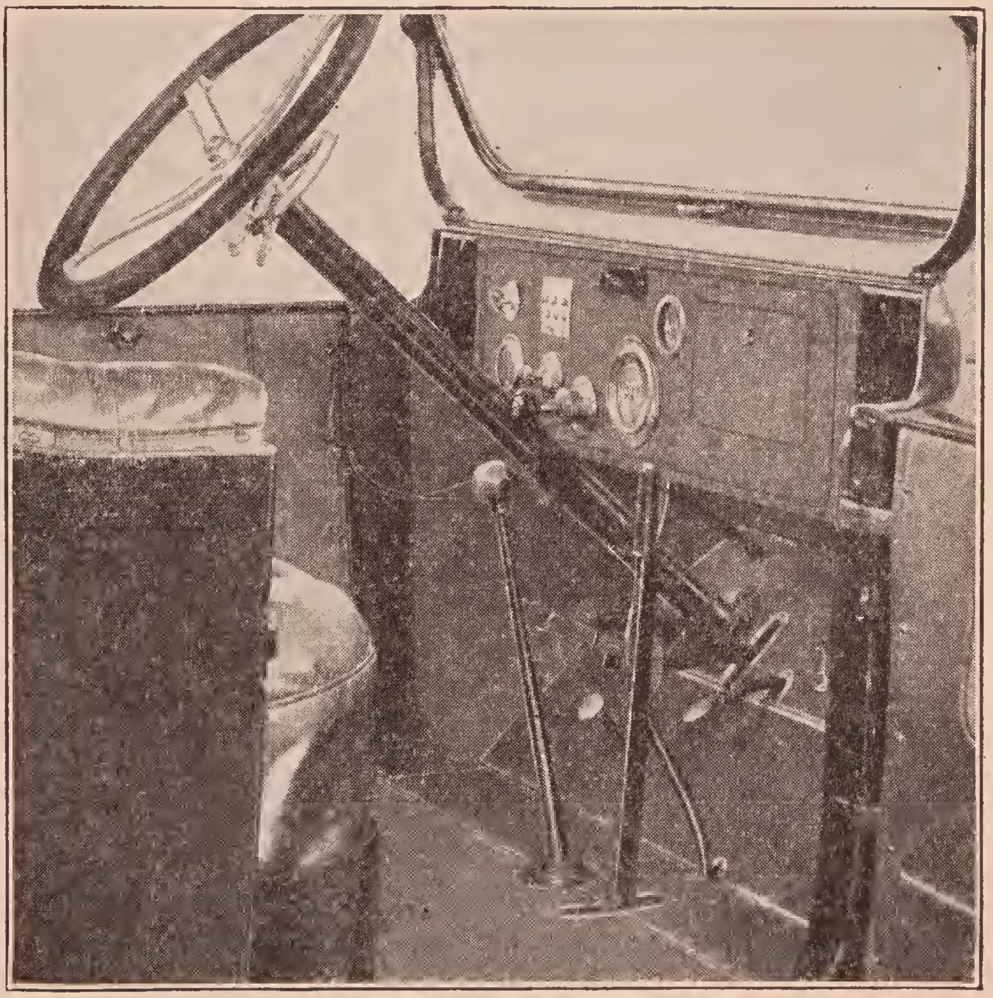


Fig. 175. Typical Dash of Modern Automobile

diaphragm to vibrate, one employing a small electric motor and the other a simple electric magnet. Fig. 176, which is a phantom view of the operating mechanism of a Klaxon horn, shows the first type. On the upper end of the armature shaft of the electric motor is fastened a toothed wheel which strikes the button in the center of the diaphragm and sets it vibrating at the rate of several thousand times per minute, giving rise to the raucous squawk which has come to be identified with automobile warning signals. As shown by Fig. 177, which illustrates a section of the Apollo horn, this type is nothing more nor less than an ordinary buzzer on an enlarged scale. The armature of the electromagnet vibrates at high speed and taps the rod attached to the diaphragm, producing a sound of a lower pitch but of substantially similar character to the motor-driven horn.

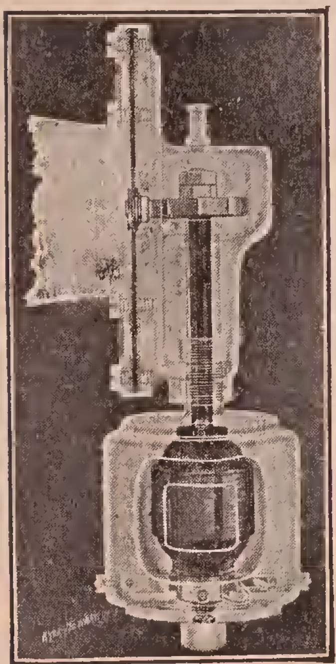


Fig. 176. Phantom View Klaxon Horn

Care of the Electric Horn. As the operation of the electric horn is based upon exactly the same principles as the essentials of the starting and lighting systems, the instructions given for the care and adjustment of the latter will apply to it as well. In the case of the motor-driven type of horn, the commutator and brushes of the motor will require attention from time to time. Failure to operate may be due to a broken connection at the horn, or at the battery, ground in the circuit between it and the battery, brushes not bearing properly on the commutator, or an excess of oil and dirt on the latter. If the motor runs properly but the horn either produces no sound or a very weak sound, the trouble will be due to the poor contact of the toothed wheel with the button on the diaphragm. This button

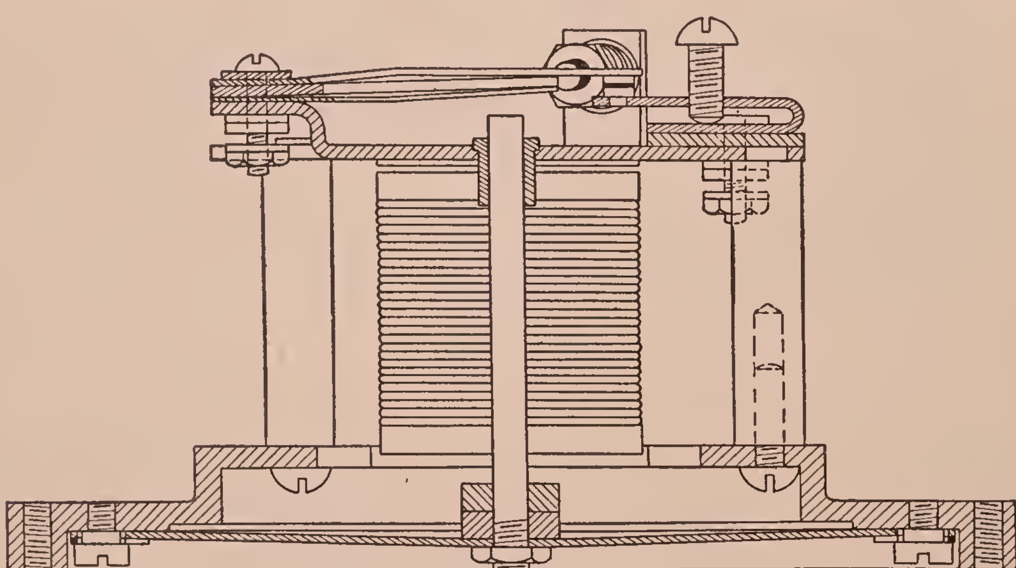


Fig. 177. Mechanism of Apollo Electric Horn (*Horseless Age*)

is made glass hard to obviate wear at that point, but, in time, replacement of either the button or the toothed wheel, or both, may be necessary.

The attention required by the vibrating type of horn, of which there are many thousands in use, is very similar to that described for the battery cut-out and the voltage regulator. The contact points will require cleaning, truing up, and adjustment at intervals, and the spring may also need occasional attention. Failure to operate may be caused by a loose connection or break in the circuit as already mentioned for the motor-driven type or by a lack of adjustment which causes the contacts to be held apart so that no current can pass through the winding of the electromagnet. The latter is not a solenoid, as might appear at first glance from the sketch, the rod passing through the coil being the striker which vibrates against the thin sheet-metal diaphragm. A weak sound from this type of horn will result either from insufficient current, usually from dry cells, or from lack of adjustment of the striker.

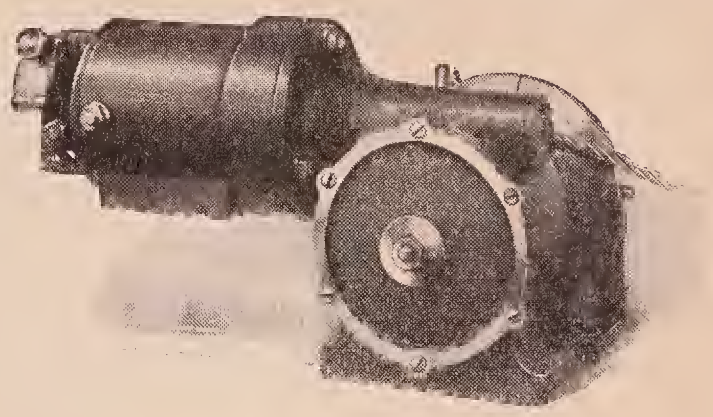


Fig. 178. Hartford Electric Brake

Electric Brake. The development of an electrical method of applying the brakes may be taken as an indication of the extent to which the electrical equipment of the automobile may be carried. In fact, it has been said by the electrical people that the automobile is now an electric power plant with a gasoline engine as an auxiliary. The Hartford electric brake consists of a small high-speed motor and winding drum, Fig. 178. Steel cables connected with the brake bands on the wheels pass around this drum, the motor being designed to take the place of the hand lever for operating the emergency brake, thus leaving the service or running brake to be operated by a pedal as usual. The winding drum is driven by the electric motor through a small worm and worm wheel. Between the worm wheel and the drum is placed a friction clutch adjusted to transmit the maximum power required

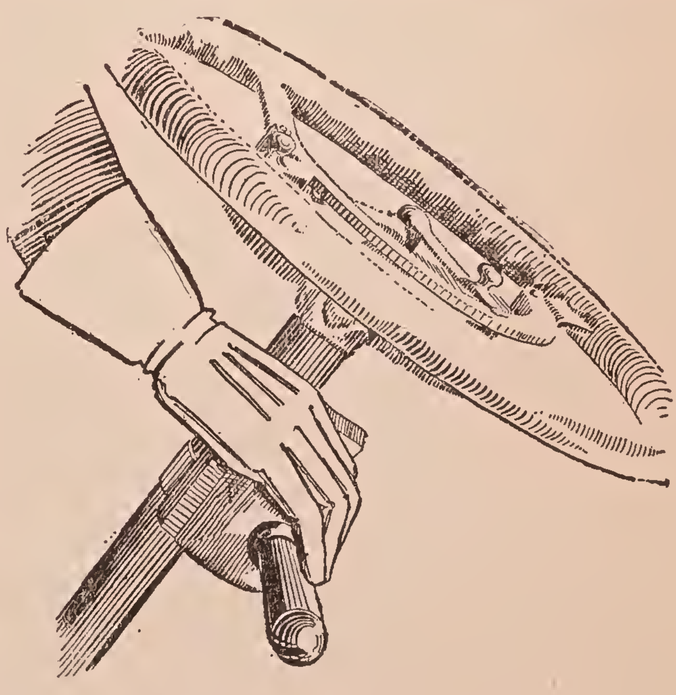


Fig. 179. Controller of Hartford Electric Brake

for efficient braking, but which will slip beyond that point. This avoids trouble from broken cables or other parts.

It has only been through the successful development of a special form of controller that the use of an electric motor for braking has been made possible. As shown in Fig. 179, this controller is located just below the steering wheel, and is so designed that contact at each successive notch gives only a certain amount of movement to the winding drum, making it possible to apply the brakes gradually. For example, a slight movement of the lever forward to a point where a click is heard operates the electric motor for a certain period determined by the length of contact permitted by the automatic controller itself. A further forward movement of the lever repeats this operation, there being two or three contacts for gradual application, while pushing the lever all the way forward connects the battery directly with the motor and gives instantaneous application of the brakes at full power. Fig. 180 is a wiring diagram of the motor connections.

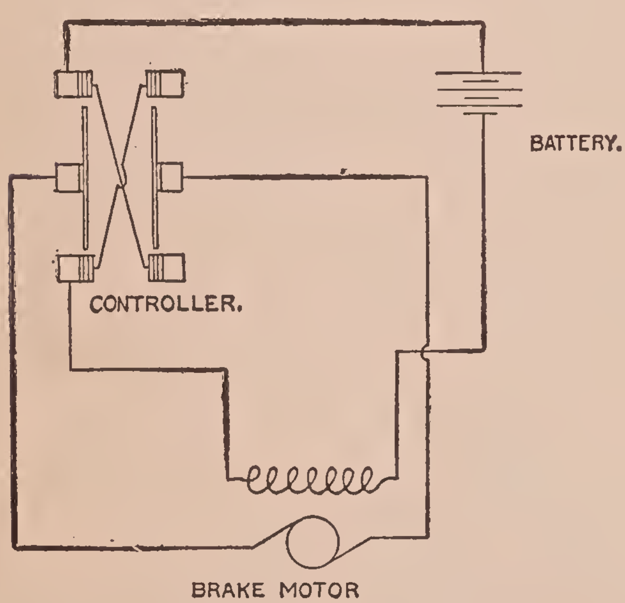


Fig. 180. Wiring Diagram Hartford Electric Brake

LIGHTING

For automobile headlights, side lamps, tail lamps, and general illumination, electric lighting has superseded all other systems. In the best electric lighting systems the current is supplied by a dynamo driven constantly by the engine, with a storage battery auxiliary.

Incandescent Lamps. *Tungsten and Other Filaments.* Incandescent lamps are usually provided with tungsten filaments. These filaments are much shorter and much stronger than in standard lamps, a condition that is further contributed to by the necessities of low voltage and high amperage, which require short and thick rather than long and thin filaments. A good tungsten lamp will afford one candle-power of illumination for each 1.2 watts of current.

Mazda Type. Fig. 181 shows the standard types of lamps generally used. These are Westinghouse Mazda lamps for 6 volts, those at the left being 15 c-p. headlight lamps; the next two, 6 c-p.

side light lamps; and the smallest one is a 2 c.p. size designed for the tail light, meter light, and for interior lighting of closed cars. At 6 volts, the 15 c.p. lamps require 2.5 amperes, the 6 c.p. side lights 1.25 amperes, or where 4 c.p. lamps are employed—a better size for the purpose—.85 ampere; the 2 c.p. lamps take .42 ampere. The larger

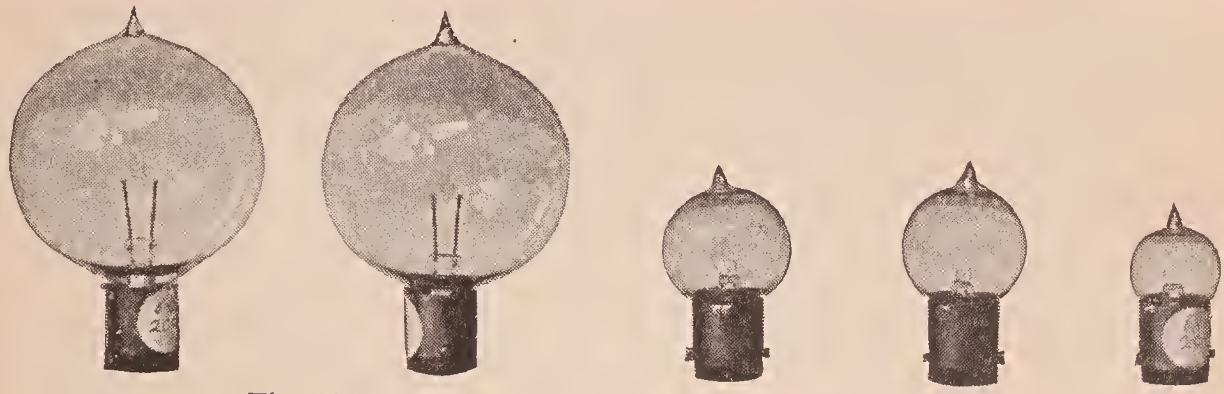


Fig. 181. Westinghouse Lamps—Head, Side, and Tail

lamps have the filament in the form of a spiral coil occupying the minimum space so that the whole source of light can be placed at the exact focus point of the paraboloidal reflector.

Bosch Type. Fig. 182 shows the Bosch lamps, which are of special form. The headlight lamp at the right is of 25 c.p. and has the filament stretched horizontally across wire supports, while the side lamps of 8 c.p. have a loop of corrugated wire, and the tail lamp,

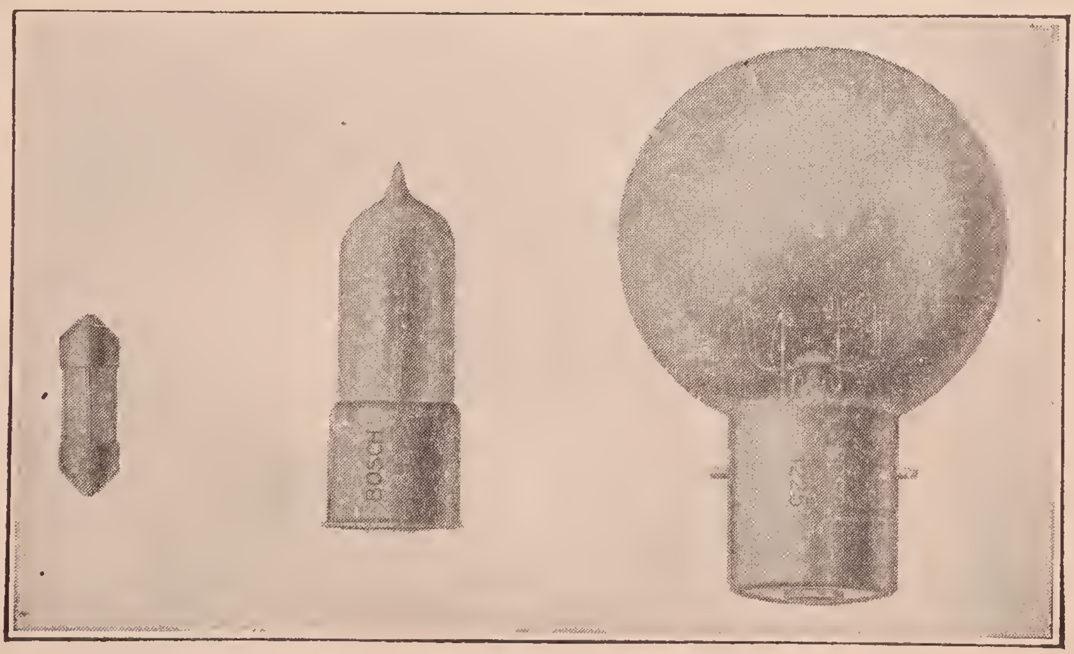


Fig. 182. Bosch Type Automobile Incandescent Bulbs

of tubular form, a single filament running straight across it, the contacts being at either end. Tail lamps are usually wired in series with the instrument lamp so that failure of the latter to light also indicates a failure of the tail lamp.

Lamp Voltages. When Edison was asked how he came to hit upon 110 volts as the standard for incandescent lighting, he said he "just guessed at it". Evidently the six-volt standard in general use on automobiles came about in pretty much the same way. When everything went right with the ignition system, four or five dry cells were found to work satisfactorily, and that number came to be generally used. Such a battery had a voltage range of 6 to 7½ volts when new, dropping off to 5 or 6 volts as the cells became exhausted, so that when the storage battery came into use, three cells giving an average of 6 volts were adopted. It is not practicable to operate small lamps at a high voltage as the lamp of that type requires a long slender filament. Many manufacturers of starting apparatus have deemed it necessary to employ a higher voltage, but the lamps are usually run at 6 volts, so that the batteries employed are accordingly some multiple of 3, as 6, 9, or 12 cells, giving 6, 12, 18, or 24 volts. Where more than three cells are used, this necessitates operating the lamps from a part of the battery, which is not advantageous as it involves discharging the battery unevenly. As a battery capable of delivering current at 12 volts weighs and costs about 35 per cent more than one giving current at 6 volts and the attention required is greater, the lower voltage is generally favored.

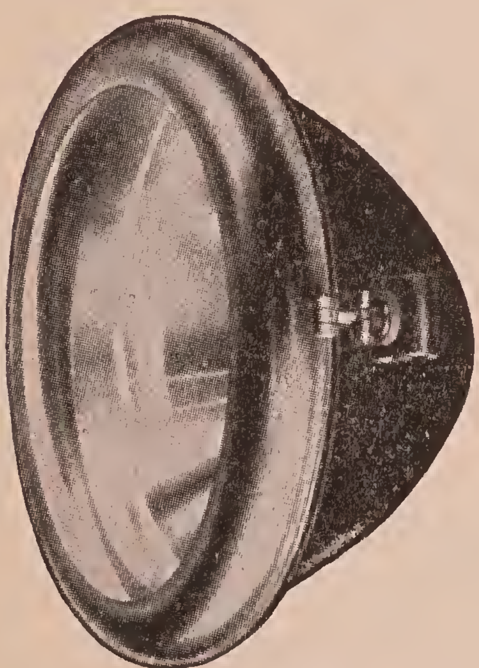


Fig. 183. Typical Electric Automobile Headlight

Lighting Batteries. The only type of batteries suitable for electric lighting—except for very small tail lamps, which can be successfully kept in operation by dry cells—are storage batteries of the lead or Edison types. Typical lighting batteries are illustrated in the article on "Electric Automobiles", pages 8 to 40, where the two types mentioned are fully described.

Reflectors. Much attention has been directed to the problem of defining the best type of reflectors for automobile headlights, and the conditions of lighting by acetylene gas have been determined to be very different from those involved when electric lighting is used.

Parabolic Type. A typical electric headlight for automobile use is that illustrated in Fig. 183, in which the construction is seen to be of the utmost simplicity. The plain form affords a minimum tendency to catch dirt and mud and greatly simplifies cleaning. A finish of black enamel over most of the lamp, with simply a nickel-plated rim holding the front glass, makes a very neat appearance and avoids the necessity for frequent polishing. Means are provided for adjusting the position of the lamp to give correct focus as this is essential to give a properly projected beam of light ahead on the road.

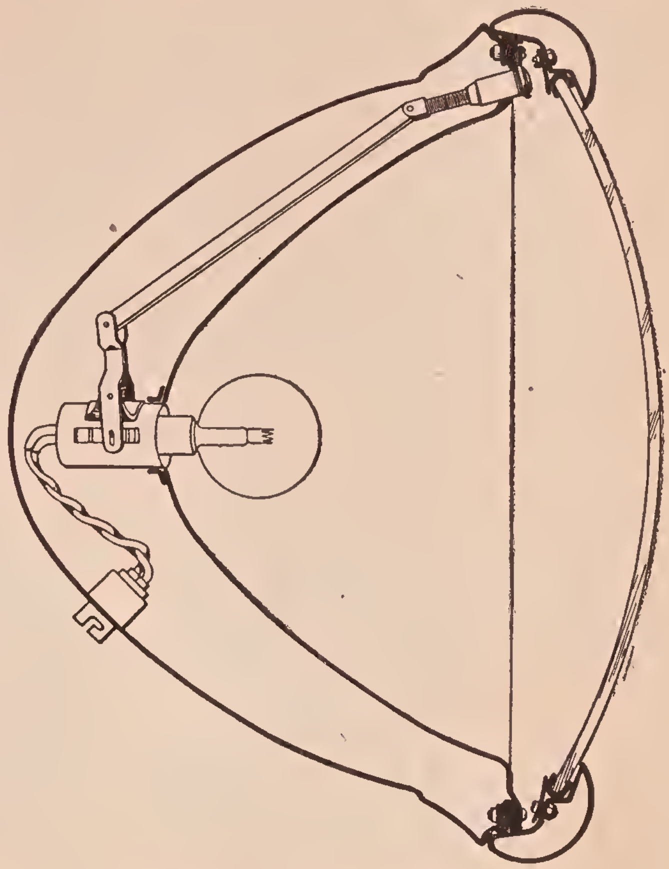


Fig. 184. Section of Fig. 183

Comparison of Parabolic with Lens Type. The reflector in the foregoing lamp is of the deeply parabolic metal type, illustrated in Fig. 184. The advantage of this type of reflector is that it intercepts a much larger proportion of the light rays from the lamp than the lens-mirror type of reflector shown in Fig. 185. Thus, while the mirror type of reflector—made of a glass lens of considerable thickness, silvered on the back—has a higher reflecting efficiency than metal reflectors, except when the latter are freshly polished, the fact that it intercepts so little of the total light available results in its projecting in the beam a correspondingly small proportion of the total light available.

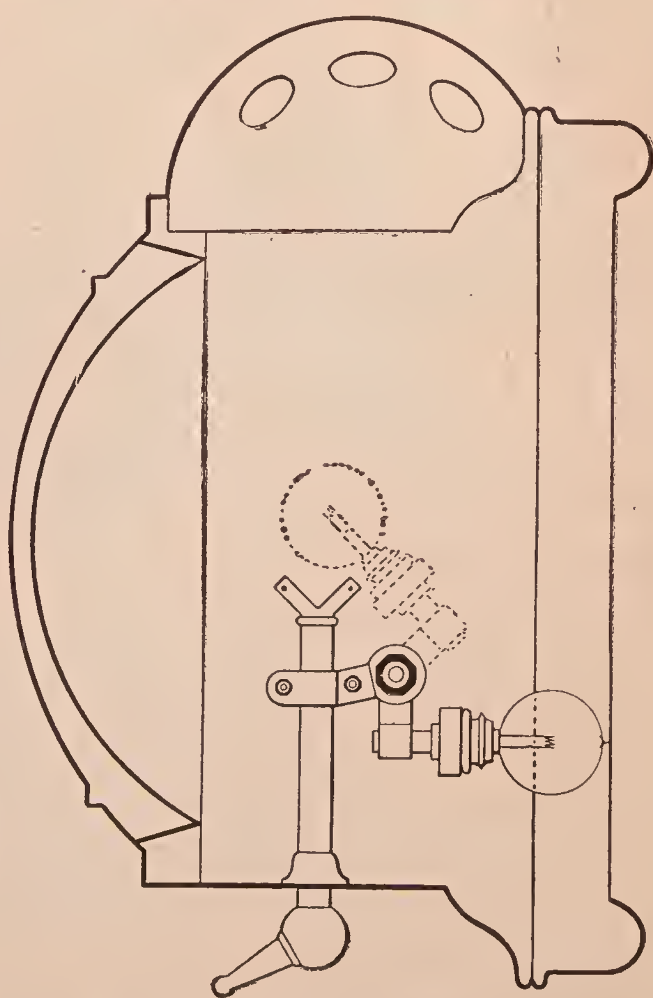


Fig. 185. Mangin Lens Reflector

Furthermore, the difficulty of tarnishing, which rapidly occurs with metal reflectors when gas flames are used, is largely avoided with electric lights, because with electric lamps placed in the reflector cavity the whole can be so closely sealed that tarnishing progresses at a very slow rate. But even with its reflecting surface at less than its full efficiency, the manner in which the deep metal reflector extends forward over the light source causes it to intercept so much higher a proportion of the light rays that the total amount of light projected will average far greater than with the gas flame and a lens mirror.

Comparison of Projected Beam from Electric Lamp and Gas Flame. The reason that electric lights of 8 candle-power can be made to afford as concentrated and powerful a beam as a 16 or 25 candle-power acetylene flame is that the filament of the electric light, from which all of the illumination proceeds, can be coiled in much smaller space, and thus located closer to the focus of the reflector than is possible with an acetylene flame, the great area of which tends to produce a more diffused light because by far the greater proportion of the flame is out of the focus of the reflector, wherefore its light is not projected

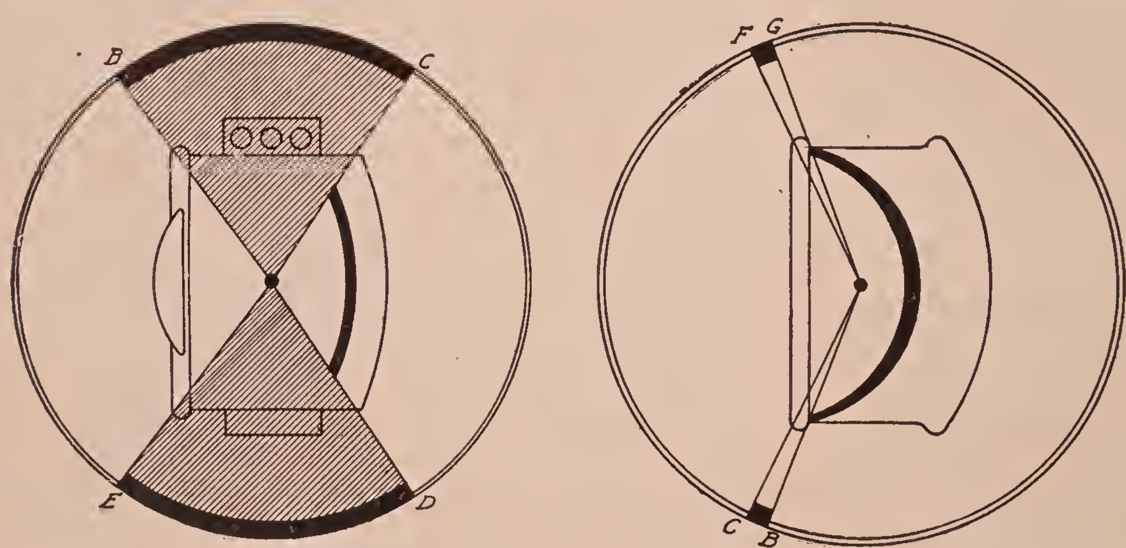


Fig. 186. Diagrams Showing Efficiency of Gas and Electric Lamps (*Horseless Age*)

as a concentrated beam. Fig. 186 shows the relative efficiency of the two. The illumination of the road ahead varies inversely as the square of the distance.

Types for Various Locations. Fig. 187-*a*, -*b*, -*c*, -*d*, and -*e* show the usual types of lamps employed. These are, in the order given, an outside side lamp, flush-type side lamp, two types of electric tail lamps, and a cowl or dash lamp for illuminating the instruments, such as the ammeter, oil telltale, and the like. Fig. 187-*f*, shows a magnetic trouble hunting lamp, the base of which attaches itself to any metal part of the chassis.

Headlight Glare. The greatly increased efficiency of electric headlights has brought with it in far more aggravated degree the disadvantage first experienced with the acetylene lamps. This is the blinding glare created. Glare may be defined as light radiation of such intensity as to be annoying to the eye. It has also been defined as "any light which interferes with the acuteness of vision of other objects". In any case glare is misplaced light and with the aid of electricity there is so much of it that the problem of eliminating it has become serious. Originally, the objection to glaring headlights came chiefly from pedestrians; but since the introduction of electric lighting, it has been objected to most strongly by automobilists them-

Fig. 187. Types of Side, Dash, Tail, and Trouble Hunting Lamps

selves, because to the driver of an automobile, the blinding glare from the headlights of an approaching car means not only annoyance, but danger. Acuteness of vision is wholly destroyed for a period of thirty seconds or more during which only a slow-down to a walking pace will insure absolute safety, as a pedestrian or the usual black and lightless buggy are practically invisible.

Regulating Legislation. The danger has become such that lights producing an annoying glare have been wholly prohibited in cities. An ordinance of this nature was passed in New York several years ago, but it was very indefinite in its scope and just what constituted "glare" was left entirely to the discretion of the traffic policeman. Chicago was the first city to pass a definite ordinance of this kind, the section covering automobiles being appended.

Section 1.—It shall be unlawful for any person operating any automobile, motorcycle, or other vehicle, while operating the same upon the public streets and highways within the city, to use acetylene, electric, or other bright headlight, or any headlight the rays from which shall be intensified by any parabolic or condensing lens in front of the light, unless such headlight shall be properly shaded so as not to blind or dazzle other users of the highway or make it difficult or unsafe for them to ride, drive, or walk thereon.

Several others have adopted this or some slight modification of it, though the restrictions in different cities still vary widely and are based upon common sense in many instances.

Dimming Devices. Owing to the fact that glare and illumination are so closely related and that there is no objection to glare on deserted country roads where the necessity for road illumination is greatest, a permanent dimming of the lights is naturally not practicable. What is required is a device under the control of the driver so that either the full illuminating power of the head lamps or a subdued or dispersed light free from glare may be had as required.

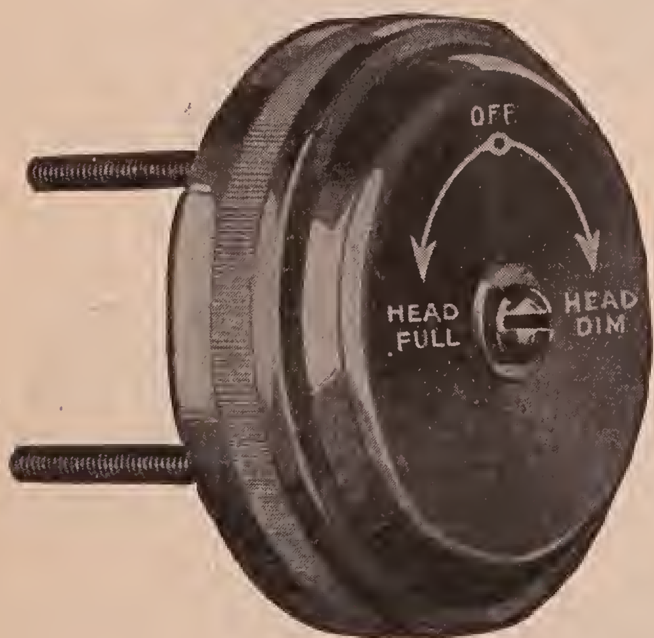


Fig. 188. Type of Headlight Dimming Switch

A great many fundamentally different devices have been offered as a solution of the problem. While differing radically, practically all of them may be classed under two heads, i.e., electrical and mechanical.

Electrical Devices. One of the simplest of this class that has met with considerable favor is nothing more or less than a *resistance* that may be inserted in the circuit of the headlights by turning a small switch either mounted on the steering wheel or in some other easily accessible location. This cuts the voltage down and causes the lamps to burn a dull red instead of the filaments being the dazzling white reached at full incandescence. A dimmer of this type is shown in Fig. 188. An equally simple and practical device is a switch to throw the headlights into series for a dim light and back into parallel again when full illumination is desired. With the series connection, the current must pass through both lamps successively and each bulb thus receives but half the voltage and, as even a comparatively slight drop in voltage causes the efficiency of an incandescent lamp to

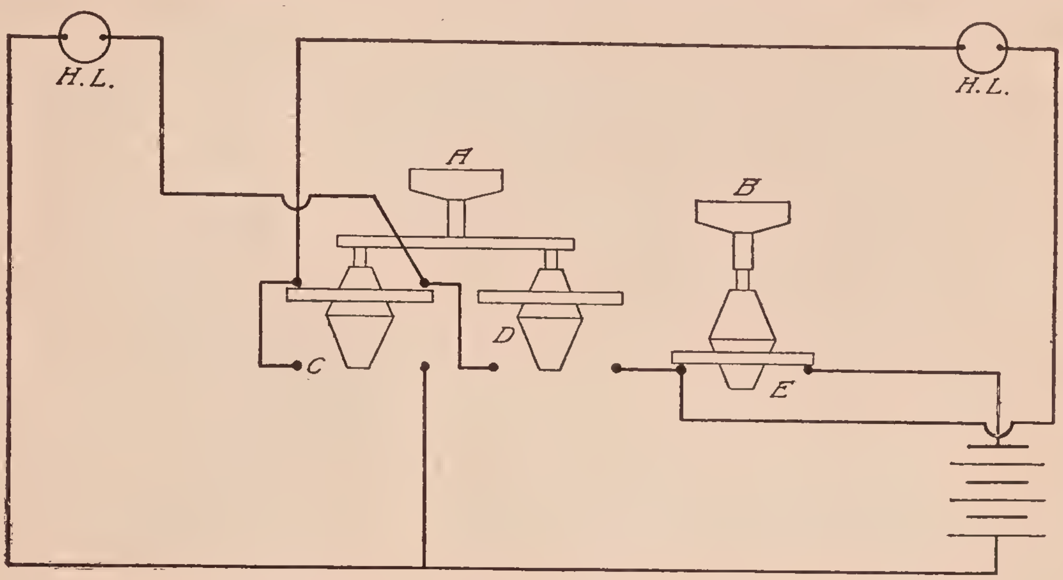


Fig. 189. Wiring Diagram of Parallel Control for Dimming Headlights
Courtesy of Horseless Age, New York City

fall off very markedly, the same result is attained. It is equivalent to burning a six-volt lamp on a three-volt current. With the normal or parallel connection, the current flows through each lamp separately and both receive the full voltage of the battery so that they burn at

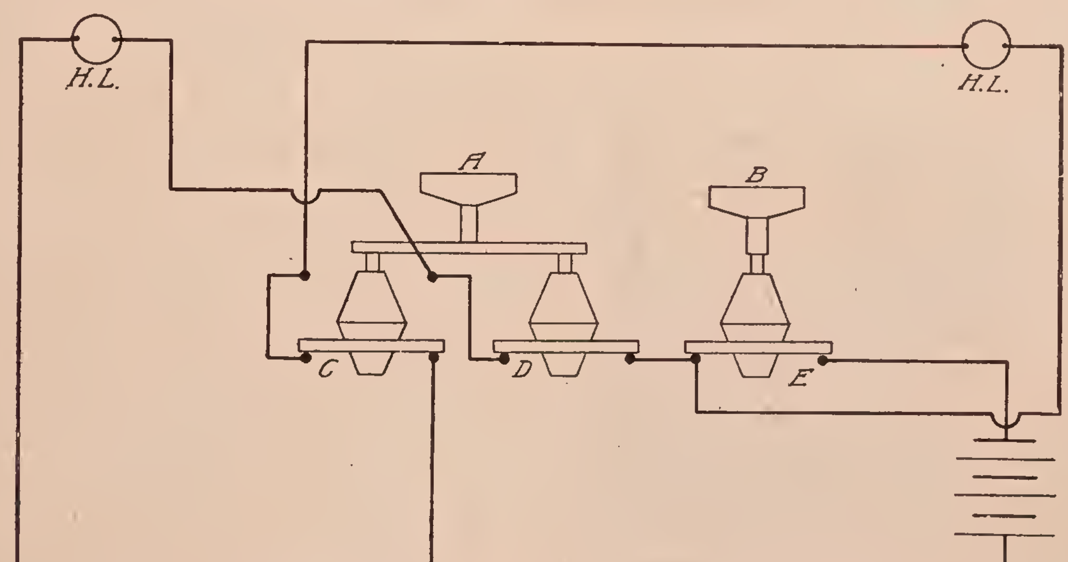


Fig. 190. Wiring Diagram of Series Control for Dimming Headlights
Courtesy of Horseless Age, New York City

full brilliance. A switch of this kind is marketed by the Cutler-Hammer Company. Fig. 189 illustrates the connections for parallel arrangement or full illumination, switches *D* and *B* being closed and the button *A* pulled out to make *C* contact with its lower set of connections. Fig. 190 shows the connections for series burning, effected by pulling out button *B* and pushing in *A*, this closing switch *E*, opening *D*, and putting *C* in contact with the upper connections.

The use of *two bulbs in each headlight* is also commonly resorted to, the method of effecting this being shown by Fig. 191. The second bulb is of the size ordinarily employed for side lights and is, moreover, entirely out of the focus of the reflector, so that the diminished light produced is entirely without glare and is mostly diverted downward.

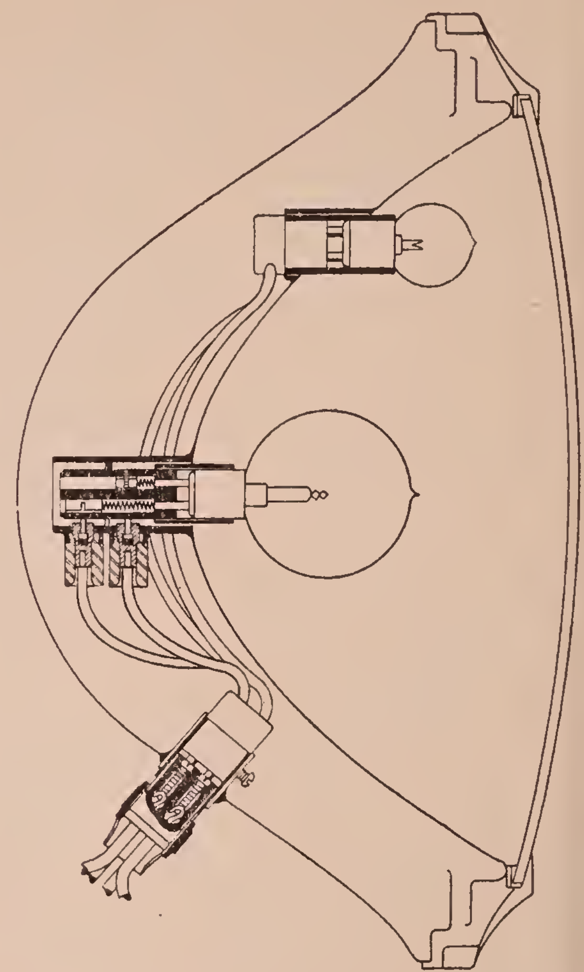


Fig. 191. Section of Hall Double Headlight

A similar end is attained by the use of *two filaments in the same bulb*, as shown in Fig. 192, this being used on the Jeffery cars. The lower filament in this case is employed for full illumination, and the upper, which is out of focus, for the dimmed light. This has the disadvantage that the burning out of either one of the filaments makes it necessary to replace the lamp, while both filaments also require the same amount of current.

Fig. 192. Jeffery Double Filament Lamp

Mechanical Devices. These usually take the form of a shade or shutter of some kind, sometimes controlled from the driver's seat, or a method of turning the lamp so as to divert its rays upward or downward, out of the line of vision of pedestrians or drivers of approaching cars. Devices of the last-named variety, however, do

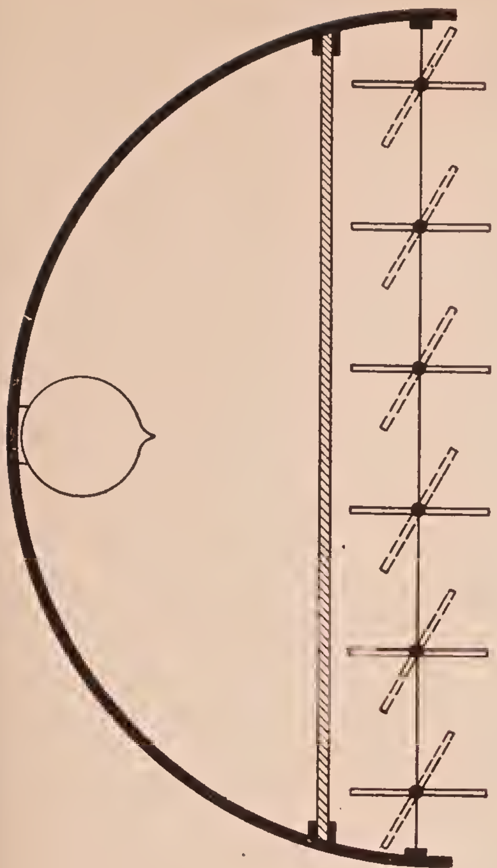


Fig. 193. Sketch of No-Daz Dimmer

not meet the legal requirements in most cases as there is no actual dimming of the light. The "Chicago Dimmer", which is said to conform to the regulations in that city, consists of a simple shutter device made of translucent material and easily attached by inserting between the reflector and the lamp door. A small handle permits of opening or closing it by a slight movement and when closed it gives a well-diffused light.

In another type, the reflector is made in two halves, the division being in a horizontal plane, and each half being hinged at the central point of the arc of the circumference. By means of a cable or other connection leading to the dash, the two parts may be moved so that the reflector is distorted and the focus entirely destroyed. The lower half of the reflector then sends its rays sharply upward, and the upper half downward, so that the direction of the light is not only changed but the actual illumination reduced. The "No-Daz" dimmer utilizes a series of translucent screens, normally standing parallel to the axis of the beam of light, but which may be placed at right angles to it, as shown in Fig. 193. This is effected by a small electromagnet in the lamp and controlled by a button on the dash.

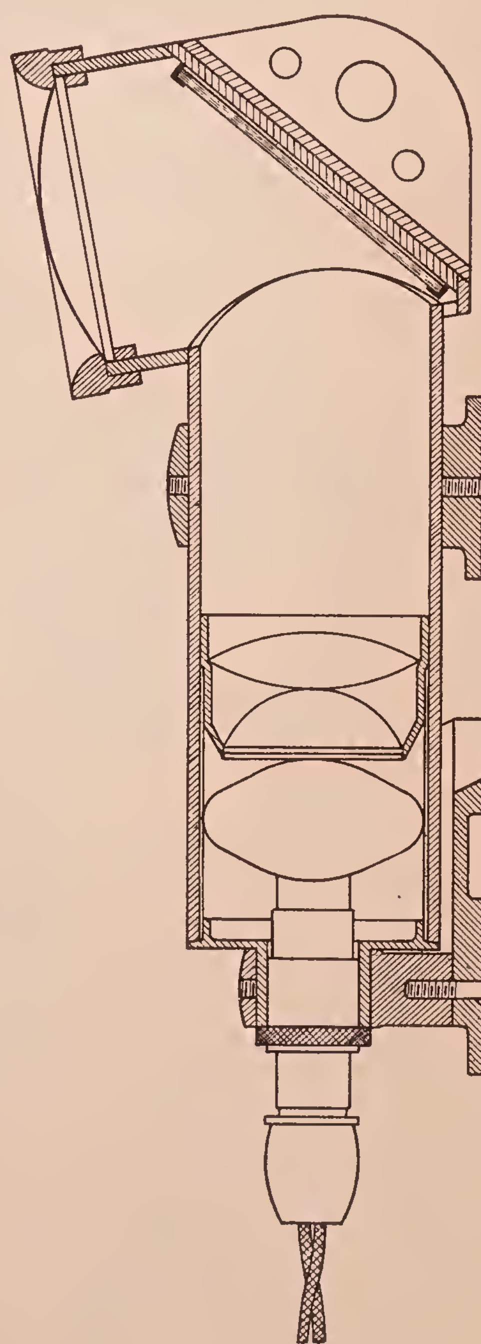


Fig. 194. Roffy-Grace Glareless Headlight

In some cities, such as Cleveland, the "no-glare" ordinance simply provides that at a distance of 75 feet in front of the

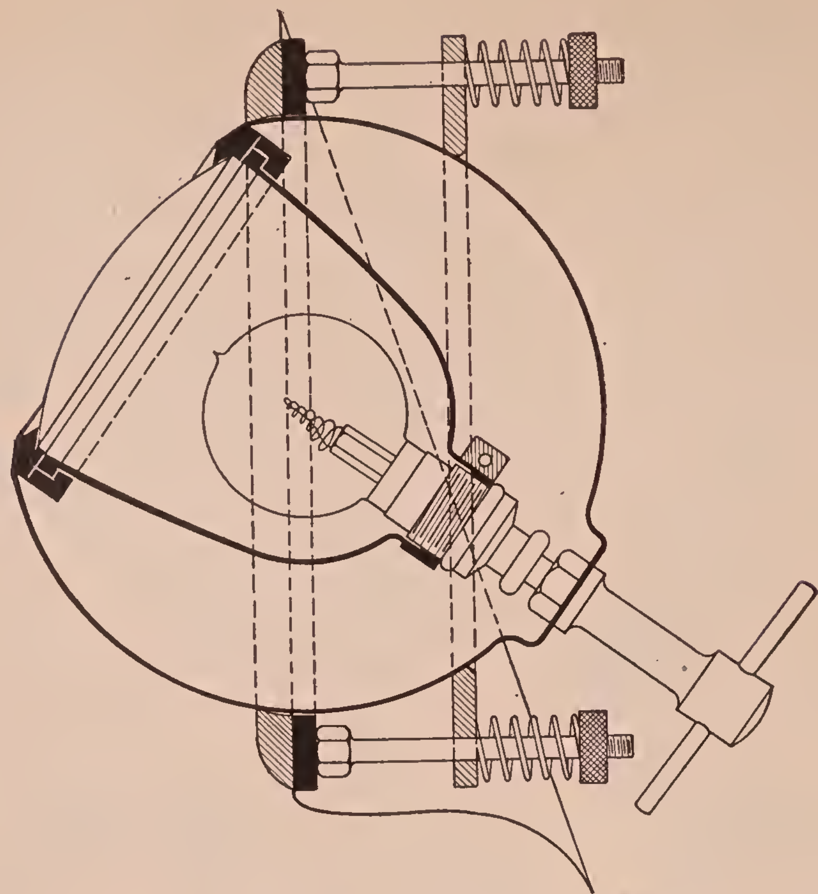


Fig. 195. Constructional Details of New Adjustable Lamp of French Origin

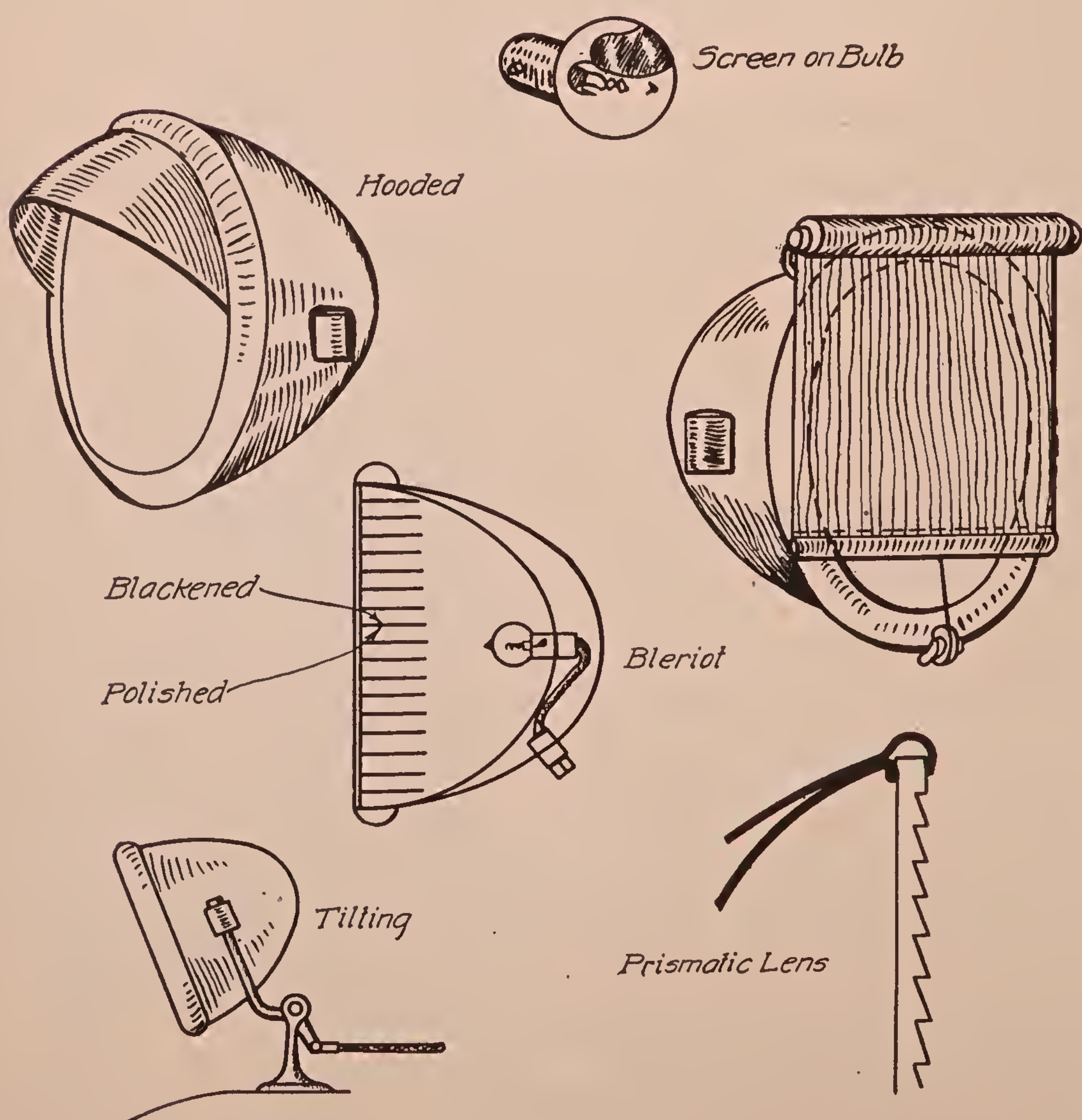
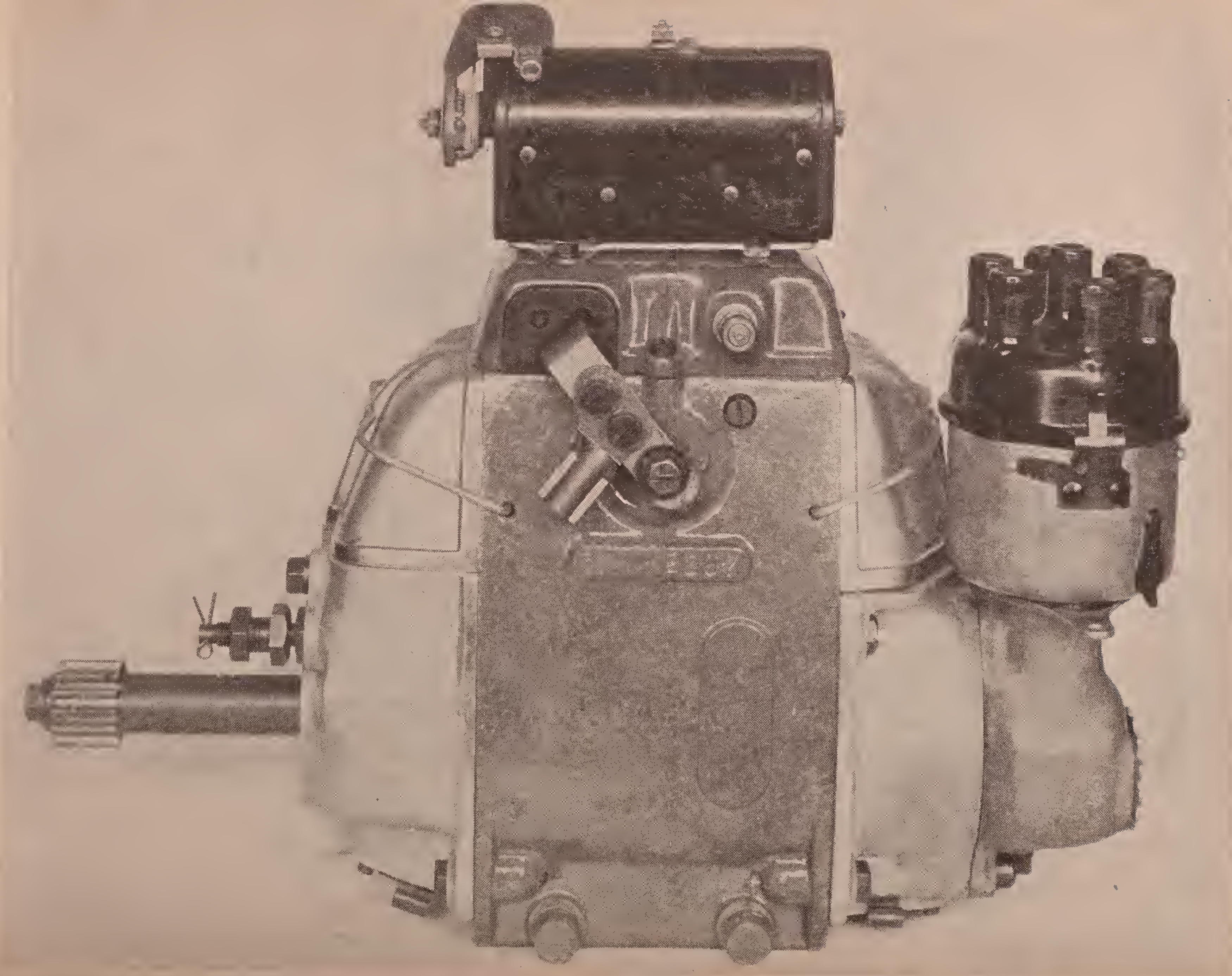


Fig. 196. Anti-Glare Devices

vehicle no part of the reflected beam of light must be visible more than three feet above the ground. The Roffy-Grace lamp, Fig. 194, is a type designed especially to accomplish this. It consists of a vertical tube at the bottom of which is fitted an incandescent lamp, its light being transmitted through two condensing lenses and thrown into a French mirror located in the top, making an angle with the horizontal of about 45 degrees. This mirror throws the rays forward and slightly downward, and they again pass through a condensing lens before leaving the lamp. No portion of the light beam rises higher than the top of the lamp, while the principle involved is that of indirect lighting, now coming into common use for interior illumination. A French lamp has been developed very much on the same principle as the eyeball. It is shown in section in Fig. 195, and as will be noted, it may be turned in any direction.

Special Lenses. Still another method takes the form of special lenses on the lamps themselves. The Hupmobile lamps, for example, have the upper half of the lens of corrugated glass, which disperses the rays falling upon it so that the top half of the projected beam is practically cut off. A similar effect is obtained by making slightly more than half of the upper area of the lens of ground or frosted glass. The J-M lens is of specially curved glass frosted over its entire inner surface with the exception of a carefully designed central transparent portion. Through the latter a beam of light is projected to a distance and slightly downward, while through the frosted portion a diffused light is radiated. Colored glass is also resorted to in some cases. A number of various devices for accomplishing this are shown in Fig. 196.



MOTOR-GENERATOR USED ON DELCO STARTING AND LIGHTING SYSTEM
Courtesy of The Dayton Engineering Laboratories Company, Dayton, Ohio

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART IV

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

PRACTICAL ANALYSIS OF TYPES

EXPLANATION OF WIRING DIAGRAMS

Significance of Symbols. To be successful in running down the cause of defection in a starting and lighting system on a car involves first of all a knowledge of the most likely places to seek the trouble. Unless the trouble is very apparent or becomes so upon making the simplest tests, a process of elimination must be carried out and to do this with any degree of system the trouble hunter must be perfectly familiar with wiring systems in general. To the uninitiated, wiring diagrams are nothing more than a jumble of lines, queer figures, and confusing signs. Familiarity with these signs in consequence is the first thing to achieve. Their direct bearing upon the varying relation of the essentials described in the introductory on Electrical Principles, Part I, will at once be apparent. There are a score or more of these signs, but only the ones generally employed in the wiring diagrams of starting and lighting systems on automobiles are given here.

Current Direction. The plus and minus, or positive and negative signs, + positive, − negative, scarcely call for any extended explanation. They indicate the direction in which the current flows. It is of the utmost importance, where the manufacturers' directions are to connect certain apparatus with a given wire to the plus or positive side, and another wire to the negative, that these instructions be followed explicitly. Otherwise, the apparatus either will refuse to work or it may be damaged, as in the case of a storage battery on which the connections have been reversed. Wherever

+ Positive

— Negative

Fig. 197. Battery, Either Storage or Dry Cells

Fig. 198. Generator, Commutator, and Brushes

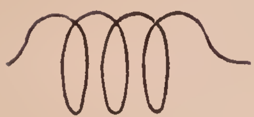


Fig. 199. The Proper Method of Showing a Coil Which Surrounds an Iron Core but Very Seldom Used on Delco Drawings

Fig. 200. The Method Used in Showing a Coil Where There Is No Chance of Confusion—Used in Field Coils, Ignition Coils, Etc.

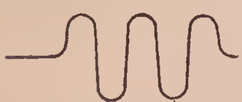


Fig. 201. The Method Used to Show Resistance Such as a Resistance Unit and Charging Resistances

Fig. 202. Ground Connection Where the Wire Is Connected to the Chassis, Engine, or Generator

Fig. 203. Contact Points Such as in Switches, Distributors, Etc.

Fig. 204. Method Used to Show Lighting Switches

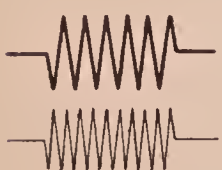


Fig. 205. Primary and Secondary Windings of an Ignition Coil

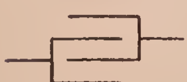


Fig. 206. Condenser

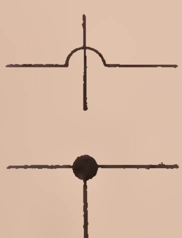


Fig. 207. Upper Showing Crossed Wires not Connected. Lower Showing Connection in the Wiring

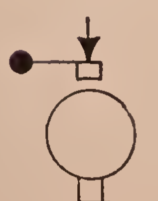


Fig. 208. Motor Commutator and Brushes with Brush Lifting Switch

it is necessary that the current flow through a piece of apparatus in a certain direction, the manufacturer stamps plus and minus signs at the terminals.

Battery; Generator. A battery, regardless of its type, is always shown by alternate heavy and light lines, as indicated in Fig. 197, each pair of lines representing a cell, so that the number of cells in the battery may be told at a glance. Other sources of current, such as generators, are indicated by a conventional sign consisting of a circle with two short heavy lines tangent to its circumference at opposite points and usually at an angle to the horizontal, as shown in Fig. 198. The origin of this sign will be apparent in its resemblance to the end view of a commutator with a pair of brushes bearing on it. This sign is also used to indicate a motor, in which case the letter **M** is inserted in the circle.

Coils. Coils which are wound on an iron core are generally indicated by a conventional sign consisting of a few loops of wire, as in Fig. 199, but this is only the case where such a coil occurs at a place in the circuit where there might be a chance of confusion in identifying it. Where there is no possibility of confusion—as in the case of the windings of a generator or motor, ignition coils, and the like—the sign shown in Fig. 200 is often used. Where the lines are heavy, a coarse wire, such as is employed for series windings of generators or motors, or the primary winding of an ignition coil, is intended.

Resistance. Resistance in a circuit is usually shown by an arbitrary sign, Fig. 201, similar in outline to a piece of the cast-iron grid frequently used in charging resistances, though sometimes shown as a coil and marked "resistance".

Grounds. The sign of a ground connection is the inverted pyramid of short lines, Fig. 202, and indicates that the circuit is grounded. This may be either by a wire directly connected at some point with the frame, as in the case of the storage battery, or it may be through an internal ground connection in the apparatus itself, as in the lamps and sometimes the generator or motor, the connection being made simply by fastening them in place. In any case, the sign indicates that the circuit is completed through a ground.

Contacts. There are a number of signs employed to indicate contact points, switches, and the like, and, where they are not of an arbitrary character, such as Fig. 203, which shows contact such as used in switches, distributors, etc., and Fig. 204, which indicates a lighting switch (Delco diagrams); they usually will be found to bear sufficient resemblance to the apparatus itself to make their identification easy.

Induction Coil. Fine lines indicate a generator shunt winding, the secondary of an ignition coil, or the coil of a relay or cut-out. The primary and secondary windings of an induction coil as used for ignition are indicated by a fine and a coarse coil sign, as in Fig. 205.

Condenser. A condenser with its overlapping plates is shown in Fig. 206.

Crossed Wires. To show wires that cross one another without making connection, a half loop is made at that point to show that the wires do not touch, as in Fig. 207, while wires that are connected are shown by a black dot at the junction.

General and Special Usage. While these signs are not universally used in exactly the form shown here, their employment is very general and in the majority of cases, such as the positive and negative, battery, ground, generator, induction-coil windings, and coil signs, they are never changed. In some instances special signs are employed, such as that shown in Fig. 208, which indicates the motor commutator of the Delco single-unit machine or *dynamotor*, and shows the special brush lifting switch. Incandescent lamps are almost always indicated by small circles, though the lamp itself is sometimes drawn in. As a matter of fact, very little system is followed by different makers in making these wiring diagrams. In an effort to simplify its reading to the uninitiated, a diagram will sometimes picture most of the apparatus in such form that it will be recognized from its resemblance to the original, including the battery, generator, lamps, and the like, using only signs for showing coils and ground connections; others go to the opposite extreme and show nothing but signs.

Diagrams for Single-Wire System

Buick-Delco Type. For purposes of illustration a very simple diagram is selected, Fig. 209. This is the Delco single-unit system as employed on an earlier model of the Buick. Starting at the left side of the diagram, the generator is shown with its shunt-field winding, one brush of the generator and the shunt coil being grounded. This is a complete circuit, but, as the shunt coil has a high resistance, only a very small part of the current flows through it. The series winding of the generator is shown at the top and the explanation that this is a "reverse" series coil means that it is wound to have a polarity opposite to that of the shunt coil. It accordingly opposes the shunt coil at the higher speeds and serves to regulate the output of the generator. This is the familiar bucking coil or "reversed compound winding".

To reach the battery, the current from the generator must pass through the automatic cut-out, the two windings and the contact points of which are shown a little

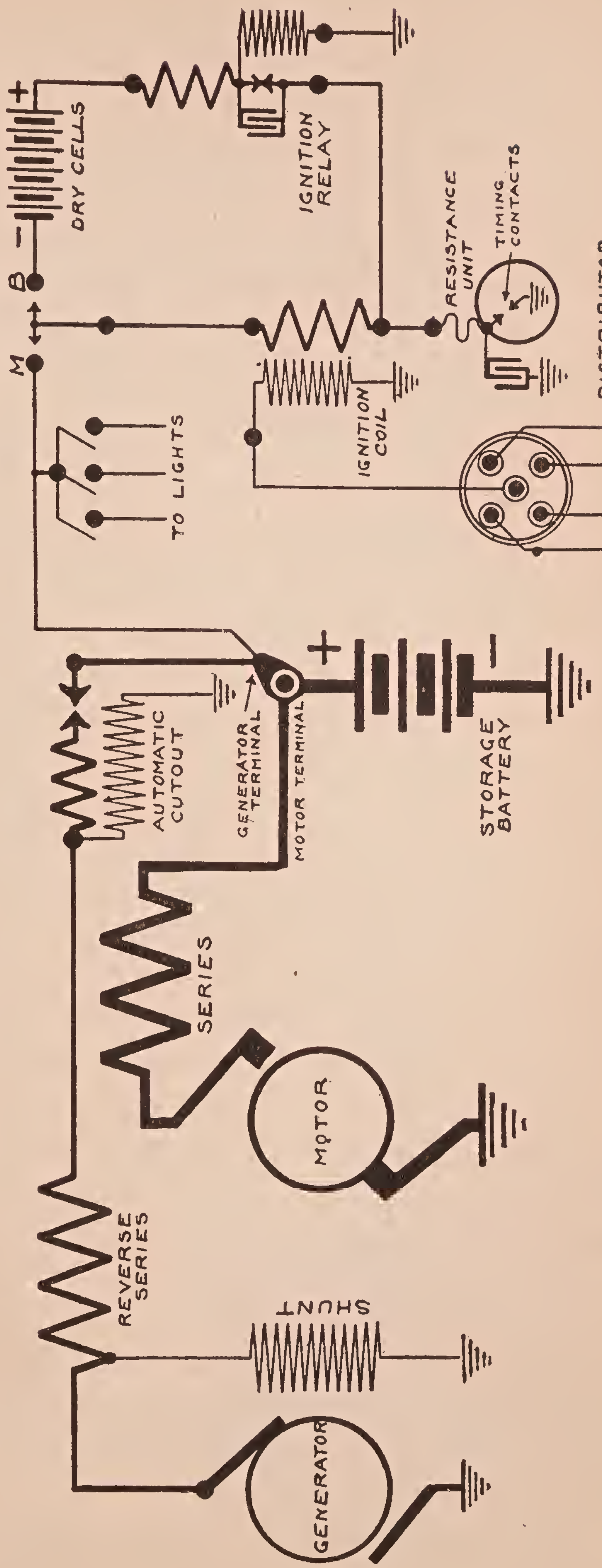


Fig. 209. Wiring Diagram for Delco Single-Unit Single-Wire System

further to the right along the top line. If the ammeter on the dash fails to register any charging current when the engine is running at a speed equivalent to 10 miles an hour or more, the automatic cut-out would be the first place to seek a break in the system. Under normal conditions of working, the cut-out closes the circuit as soon as the generator reaches a certain speed and the 3-cell storage battery, one side of which is grounded, is then being charged, the current entering at the plus or positive terminal and returning by way of the minus terminal or pole through the ground connection. (In some systems, such as the Gray & Davis, the frame of the car is the positive side of the circuit.)

Between the generator and battery circuits is shown the starting-motor circuit. The width of the lines employed indicates that very heavy conductors are used in this circuit and they are necessary owing to the extremely heavy currents handled. The series winding of the motor field is also short and of heavy wire. The upper brush of the motor being in a raised position indicates that the motor is brought into operation through a switching brush, and when this switch is closed to start, one of the generator brushes is raised from the commutator. This completes the generating, starting, and controlling circuits, all of which are shown to the left of the battery. The relative difference in thickness between the wires of these circuits at the left and those at the right for the lighting and ignition show the difference in the amount of current handled by the two. The double set of contact points at the center along the top line indicate the dash switch—turning this to the left giving the magneto connection *M*, while throwing it to the right *B* puts in the battery of six cells shown just a bit further to the right in the ignition circuit. To the left of this dash switch a tap has been made for the lights, the three circuits of which, head, side, and tail are indicated but not completed, the draftsman often taking it for granted that complete detail connections are unnecessary. Another instance of this will be seen just below the lighting switch, the leads from the high tension distributor (four indicating a 4-cylinder motor) ending up a short distance from it, as it is obvious that they lead direct to the spark plugs.

The primary and secondary windings of the induction coil (ignition)—the former of which is grounded through a resistance

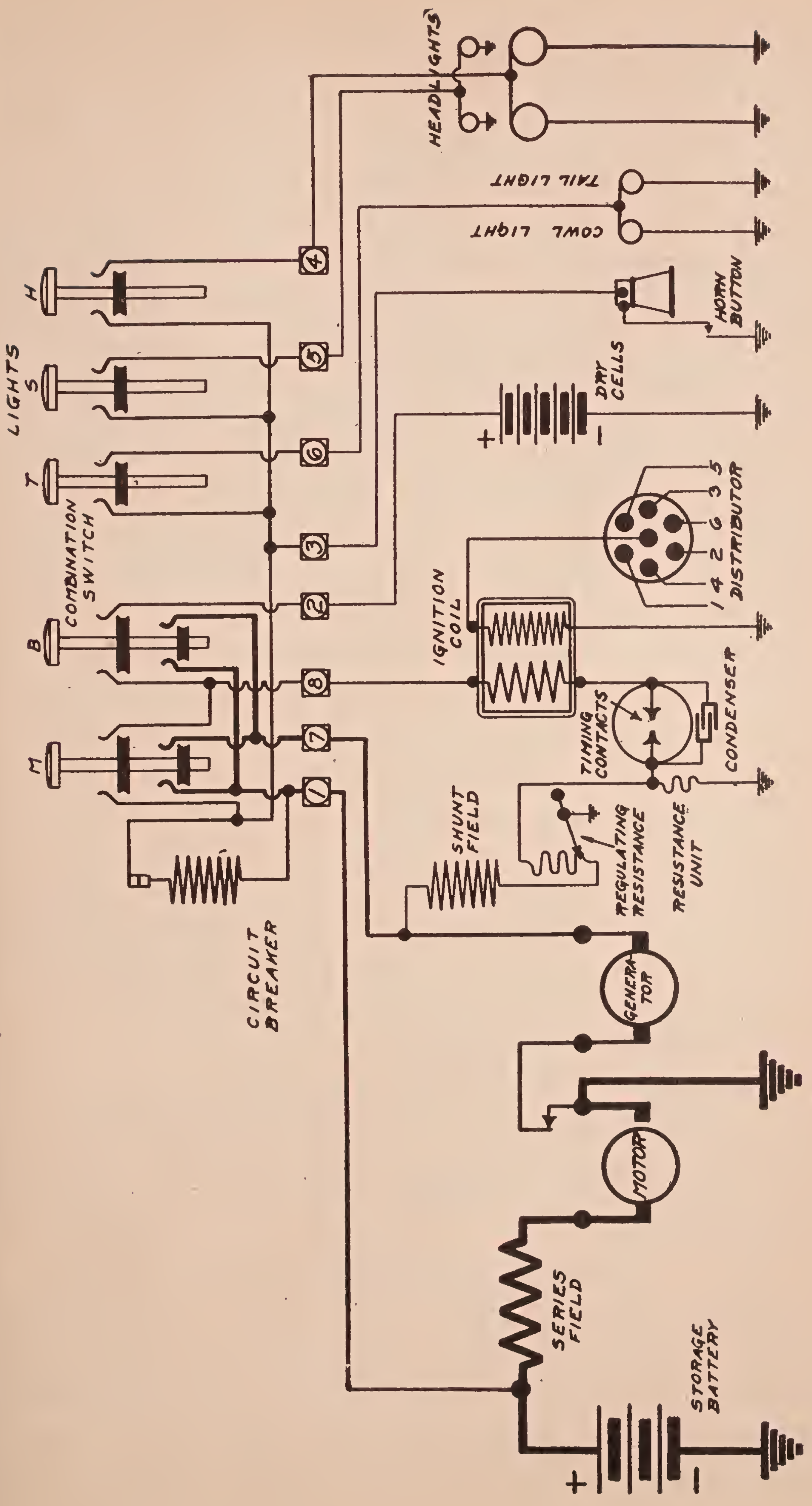


Fig. 210. Wiring Diagram for Delco Single-Unit System on the Auburn Six-40

unit and the timer, and the latter directly—are plain. But it also will be noted that a condenser is shunted around the sparking contacts of the timer, one side being connected to the contact terminating the positive side of the circuit, while the other is grounded. The function of a condenser here is to absorb the charge or surge of current due to the sudden opening of the contacts (breaking of the circuit) and to prevent the formation of an arc which would burn the contact points away rapidly. Badly pitted or burned contact points accordingly are an indication that the condenser has broken down or become disconnected from the circuit. This also will be evident from the excessive sparking at these contacts when the engine is running. The secondary winding of the coil is grounded directly. At the right-hand end of the diagram is seen the independent circuit of the dry-cell battery for emergency use in starting. The current from this battery passes through a relay coil the contact points of which are also provided with a condenser for the purpose already explained.

Auburn-Delco Type. The wiring diagram of the Delco lighting, starting, and ignition system of the Auburn, Model 6-40, Fig. 210, is more completely shown than the one to which reference was made above, in that all the switching connections are indicated and the lamp circuits have been carried out. Examination will also show that it differs in other respects as well. For example, instead of a bucking-coil type of regulator winding, the generator output is controlled through a variable resistance in the shunt-field circuit, the amount of resistance increasing with the speed. As the current through the shunt coil decreases with the increase in resistance, the fields are weakened and the generator output falls off.

Instead of the usual magneto-and-battery switch a special form of combination switch is shown in this wiring diagram which controls two circuits simultaneously, the generator-battery circuit and the circuit breaker-ignition coil circuit. These are discussed further on page 258.

Diagram for Two-Wire System

Chevrolet-Auto-Lite Type. The wiring diagrams already explained are what are known as "single-wire" or grounded systems, there being but a single wire connecting any piece of apparatus to the source of current supply, the return side of the circuit being through the frame of the car. While usually referred to as the "return" side of the circuit, the steel sections forming the frame of the car may be utilized for either the positive or negative side.

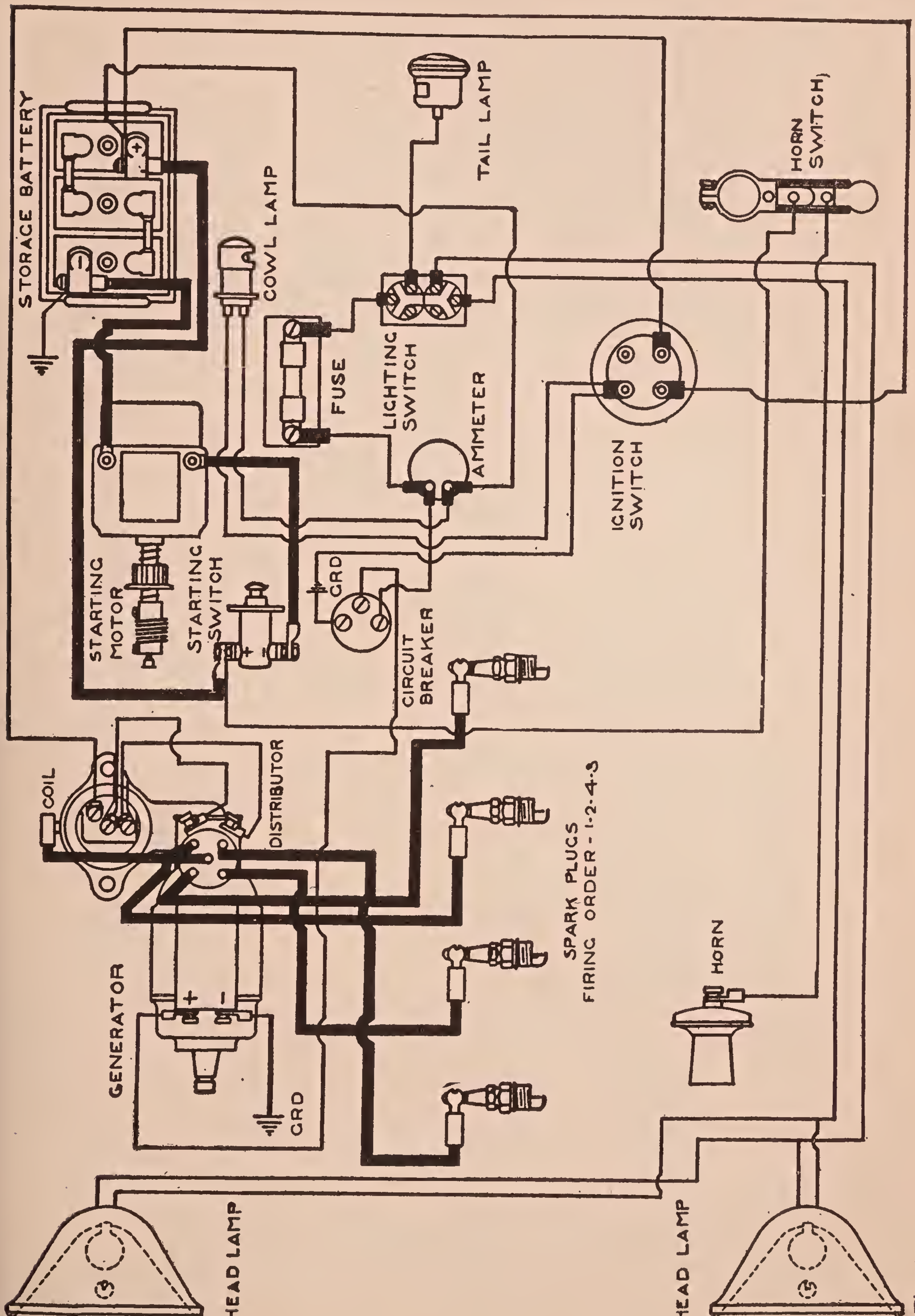


Fig. 211. Wiring Diagram for Auto-Lite System on Chevrolet (Royal Mail and Baby Grand Models) Showing Two-Wire Connections

The wiring diagram, Fig. 211, which is that of the Auto-Lite system as applied to the Chevrolet is of the two-wire type. With

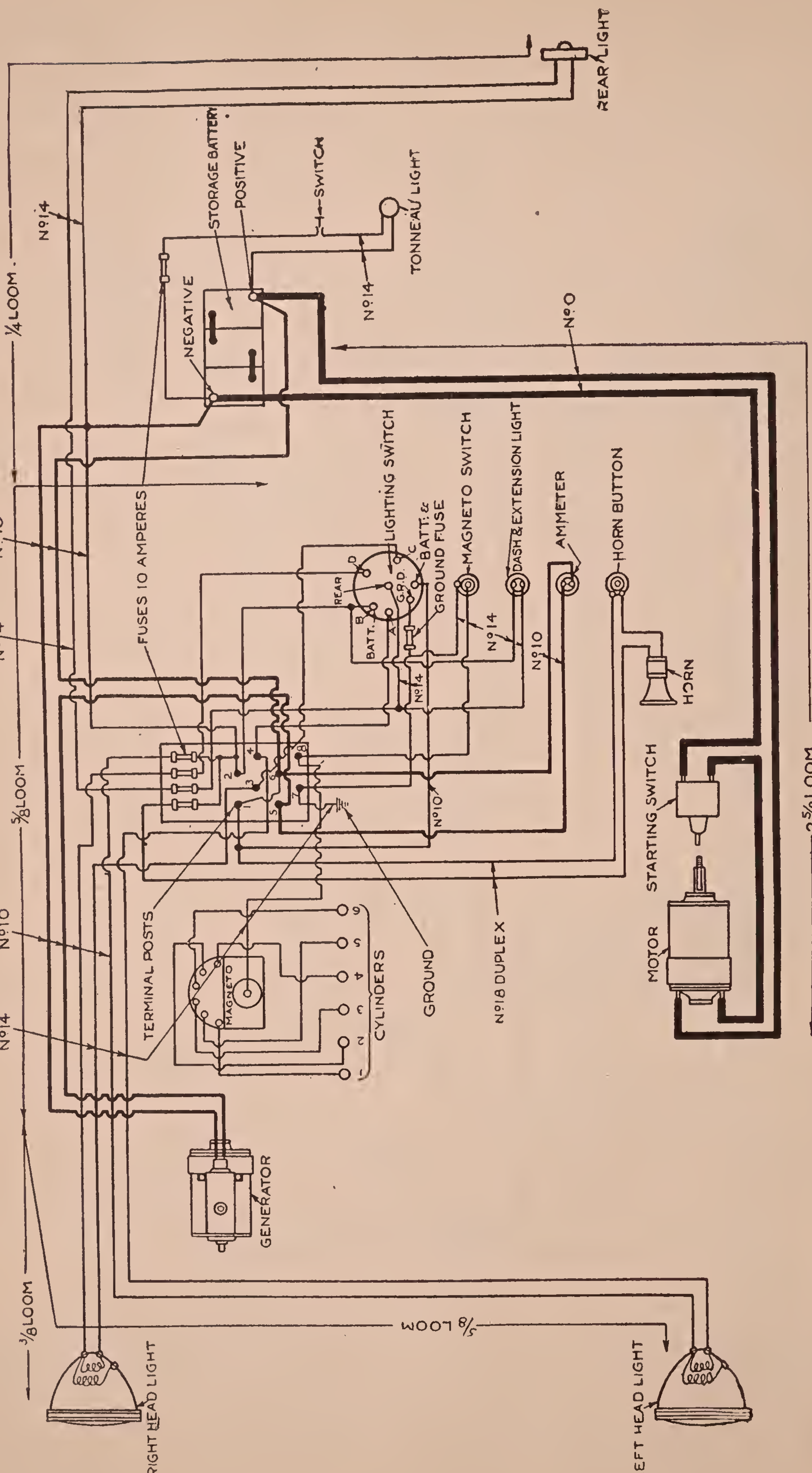


Fig. 212. Wiring Diagram for Bijur Two-Wire System on the Jeffery Chesterfield Six

the exception of the ignition circuit, which is always grounded owing to the spark plugs completing the circuit by being screwed into the cylinder heads, it will be noted that two-wire connections are made. The ignition circuits are completed by a ground at the battery for the starting current, and by another at the generator for the current when running. The circuit breaker is also grounded.

Jeffery-Bijur Type. The two-wire system of the Bijur as installed on the Jeffery Chesterfield Six is shown in Fig. 212. All lighting circuits are fused and there is also a fuse in the ground connection for the ignition. The numbers referring to the various circuits indicate the proper size of wire used in each circuit. This is an important item in every starting and lighting system, as, where any wires have to be replaced owing to mechanical or electrical injury, they must always be replaced with wire of the same size and character of insulation, as otherwise, further and more serious trouble is apt to follow. Thus, for the starting circuit No. 0 (Brown & Sharpe gage) cable is employed; for the charging circuit between the generator and battery No. 10; for the lighting circuits No. 14, which is the size ordinarily employed for incandescent-lamp circuits in house wiring; and for the horn No. 18. "Duplex" in this connection means that both wires of the circuit are enclosed in the same braided insulation. "Loom" is tubular fireproof insulation through which the wires are passed to afford further protection, and the sizes vary in accordance with the size of the wires.

USE OF PROTECTIVE AND TESTING DEVICES

Circuit Breaker. This is a protective device, the theory of which will be clear at once upon referring back to the explanation of an electromagnet in the introductory chapter. It consists of an electromagnet with a movable armature adapted to open the circuit by its movement, the latter being controlled in turn by the amount of current flowing in the circuit.

By referring back to the diagram, Fig. 210, and noting the particular function of the circuit breaker, an excellent example of the value of ability to trace wiring diagrams at a glance can be shown. Assume that when the button *M* of the combination switch, Fig. 210, is pulled out, the ignition fails to work. An examination of the diagram shows that when *M* is pulled out, its lower contact bridges the wires No. 1 and No. 7 connecting the generator with the battery. At the same time its upper contact bridges a pair of terminals which insert the circuit breaker and the ignition coil on cable No. 8 in the circuit. Further examination of the ignition or lighting circuits shows that throwing on any one of these circuits includes the circuit breaker. The function of the latter is to prevent the discharge of the battery when the generator is standing idle or running too slowly to generate the necessary voltage to charge the battery. It also serves to protect the lamps, ignition coil, and horn from damage, in case any of the wires leading to these essentials should become grounded, and in this rôle takes the place of fuses and fuse block. As it requires 25 amperes to operate the circuit breaker in this particular instance, it is not affected by the normal operation of the lamps, ignition, or electric horn. But in the case of a short circuit or ground, the whole output of the battery would pass through the circuit breaker, moving its armature and breaking the contacts, which open the circuit. This cuts off the current and a spring brings the contacts together again, when the operation is repeated, causing the circuit breaker to vibrate and pass an intermittent current of comparatively small value. While it will not break the circuit on less than 25 amperes, it will continue to vibrate on a current of 3 to 4 amperes. Its continued vibration is an indication that there is a ground in one of its circuits. Hence, no attempt should be made to stop this action by tightening the spring of the circuit breaker, but by locating the ground.

Tracing for Grounds. This can best be done by a process of elimination in which a knowledge of the wiring diagram will come handy. Referring again to Fig. 210, if the circuit breaker operates when switch *M* of the combination is pulled out, it will be apparent that the ground is located in either the main generator-battery circuit, or the ignition-coil circuit, as it will be seen that the lower contact member of the switch throws the former in the circuit and the upper contact member throws the latter in the same circuit with the circuit breaker. If pulling out *M* does not set the circuit breaker operating, but pulling out *T* does, this would indicate a ground in the circuit of the tail and cowl lights, while the operation of the circuit breaker on pulling out either *S* or *H*, would indicate that the ground was located in the wiring of either the side lights or the headlights depending on which switch caused the circuit breaker to respond. The combination switch *B* serves to connect the generator and storage battery in the circuit, the same as *M*, but it also includes the 5-cell dry battery in the ignition circuit. It will be noted that the distributor has six spark plug leads, indicating a 6-cylinder engine, also that the connection of the ignition timer in the circuit is somewhat different from the previous diagram, Fig. 209, in which it is on a branch circuit of the storage battery, whereas in this instance it is also in the generator circuit.

Having determined the particular circuit in which the fault lies it is next necessary to narrow it down to exactly the defection that is causing the ground. For work of this nature nothing handier can be devised than the simple testing set which is described later and which may be assembled at nominal expense.

Fuses. The lighting circuits of many cars are provided with fuses, designed to protect the battery. These fuses are usually of the enclosed type, consisting of a glass tube with brass caps at each end to which the fusible wire is connected, as shown in Fig. 213. Usually when a fuse "blows", due to excessive current caused by a ground or "short", the wire melts entirely and this will be visible. But at times it will simply melt at the soldered connection and not show any fault. In beginning a test it is well to go over the fuses first, holding one of the test points of the lamp circuit on one end of the fuse and touching the opposite end of the fuse with the second test point. Failure of the lamp to light will indicate the defective fuse. On systems employing a circuit breaker as shown in the wiring diagram, Fig. 210, no fuses are necessary as the circuit breaker serves the same purpose and also gives an audible signal of trouble by its buzzing. Upon finding an open circuit where one is supposed to exist as shown on the wiring diagram, it is always well to verify this by again testing the trouble lamp itself before beginning to tear anything out. The rough handling to which such a lamp is subjected frequently causes the filament to break.

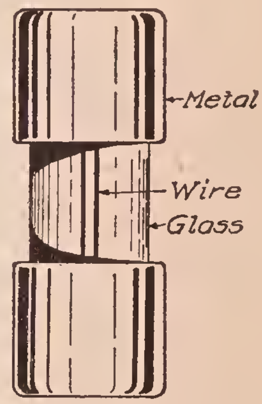


Fig. 213. Typical Fuse

If immediately upon being replaced, a fuse again blows, it may indicate that one of the lamp circuits of the car is short-circuited or the lamp on that circuit is defective, having become short-circuited, the remedy being a new bulb. In some systems, fuses are used in other circuits, as in the case of the Bosch-Rushmore in which there is a fuse on the switch block to protect the main shunt winding of the generator. The blowing of this fuse indicates a broken battery connection, such as a loose or broken terminal or a corroded battery connection on the cells themselves.

Handy Test Set. Take a porcelain base socket, screw it to a piece of board to form a base. Connect one side of this lamp socket

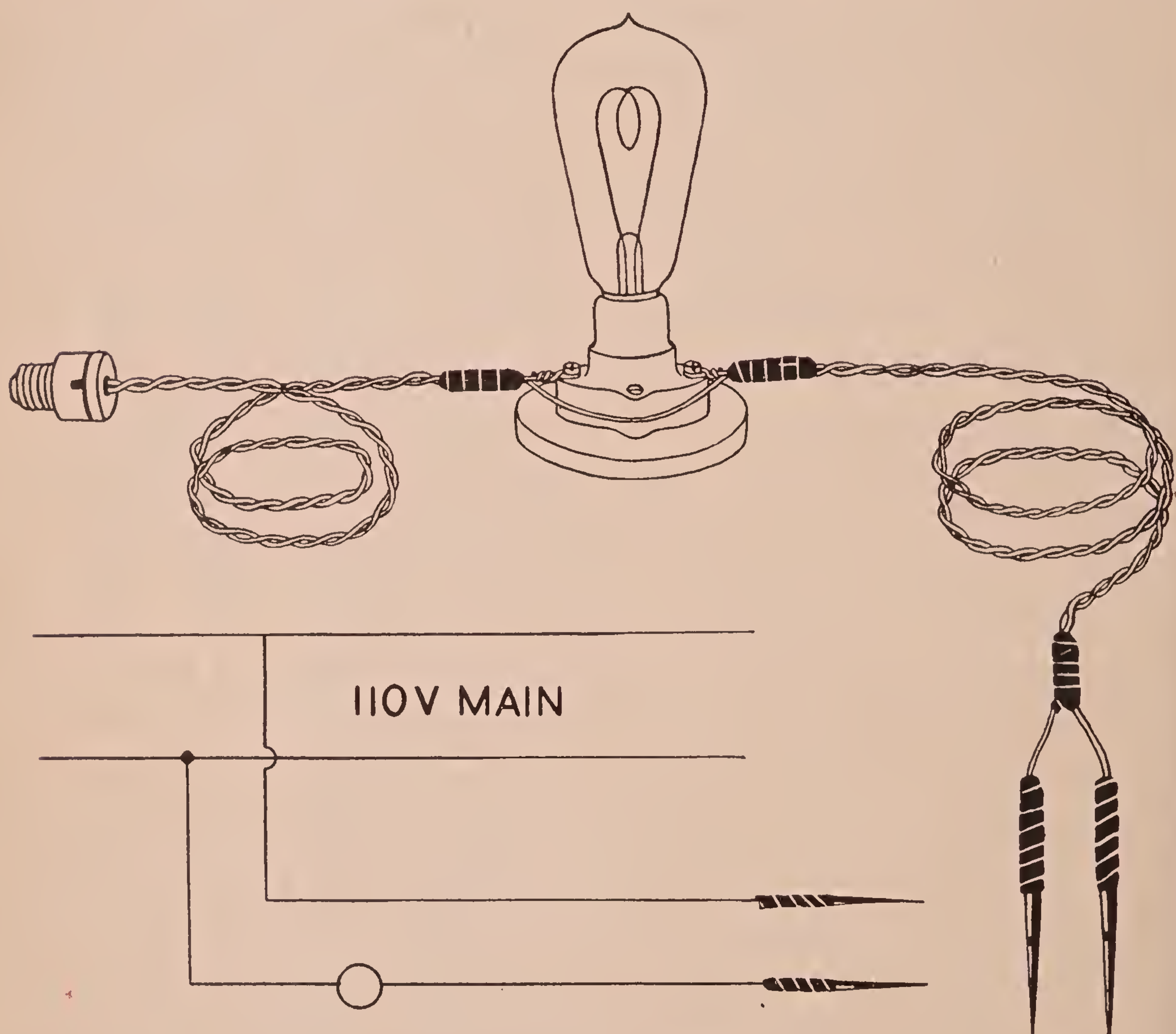


Fig. 214. Handy Testing Set

to a standard screw plug. Procure two pieces of brass or steel rod and file or grind them to a long tapering point. These rods should be about 6 inches long and tapering half their length to a sharp point. Connect the other side of the lamp socket to one of these points and connect the second point to the other terminal of the screw plug. Ordinary lamp cord can be used for the connections. For fastening to the test points it should be bared for several inches, wrapped solidly around the metal rods at their blunt ends, and soldered fast in place. The joints should be heavily wrapped with tape or covered with other insulating material to form a handle, as shown in the illustration, Fig. 214. As shown by the diagram forming part of this illustration, it will be seen that the lamp is in series with one of the points, but that when the circuit is closed by bringing the two points together, the lamp is in multiple with the main circuit. The lamp should be of the carbon-filament type owing to its greater durability. As a lamp of this type of 16 c-p. only consumes a little over 50 watts at 110 volts, or approximately half an ampere of current, there is no danger of injuring any of the apparatus on the automobile through its use. Sufficient cord should be allowed on either side of the lamp to permit of connecting it up with the outlet conveniently.

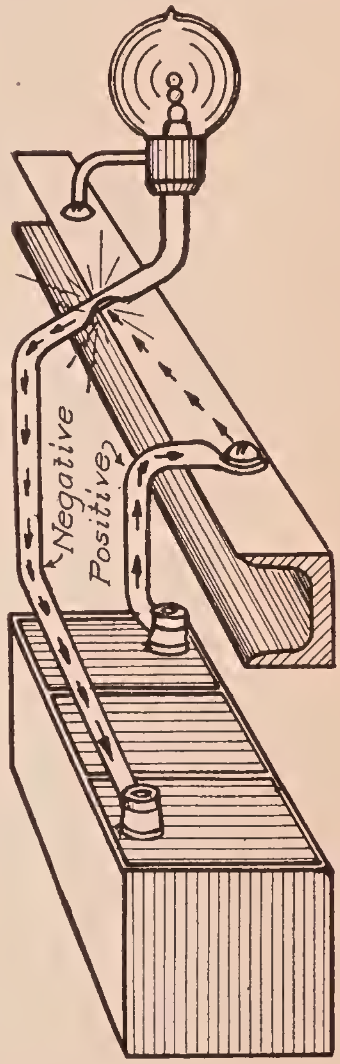


Fig. 215. Diagram of Ground or Short Circuit
Courtesy of Gray and Davis Company

In using this test outfit, the two test points are pressed on places between which no current should pass, and if the lamp lights it indicates that there is a ground between those points. For example, in Fig. 210, if there were a ground between the generator and the switch so that no current reached the latter, the lamp would not light when the test points were placed on terminals 1 and 7 of the diagram, the generator then being in operation. But a little searching along this circuit would soon show where it was grounded, thus making it easy to locate the break or ground. Fig. 215 is a graphic illustration of a ground causing a short circuit, due to worn insulation. Much more satisfactory results can be obtained with a test set of this nature than with either an expensive hand ringing magneto test set, or with a set consisting of a bell or buzzer and a few dry cells. The former is unnecessarily expensive for the purpose while the latter has not sufficient potential to force the current through grounds or breaks that present too great a resistance, whereas the higher voltage of the lamp test set will cause it to give an indication where the battery set would not. With the aid of such a set, every circuit shown on even the most complicated of wiring diagrams can be tested in fifteen to twenty minutes, maybe less, depending upon how accessible the connections of the various circuits happen to be.

If preferred, owing to greater convenience, a 6-volt lamp can be used in the socket of the test set and current from the car battery can be utilized for testing. In case the car happens to have either a 12-volt or a 24-volt system, connect lamp terminals to but three of the cells. Should the lamp not light to full incandescence it

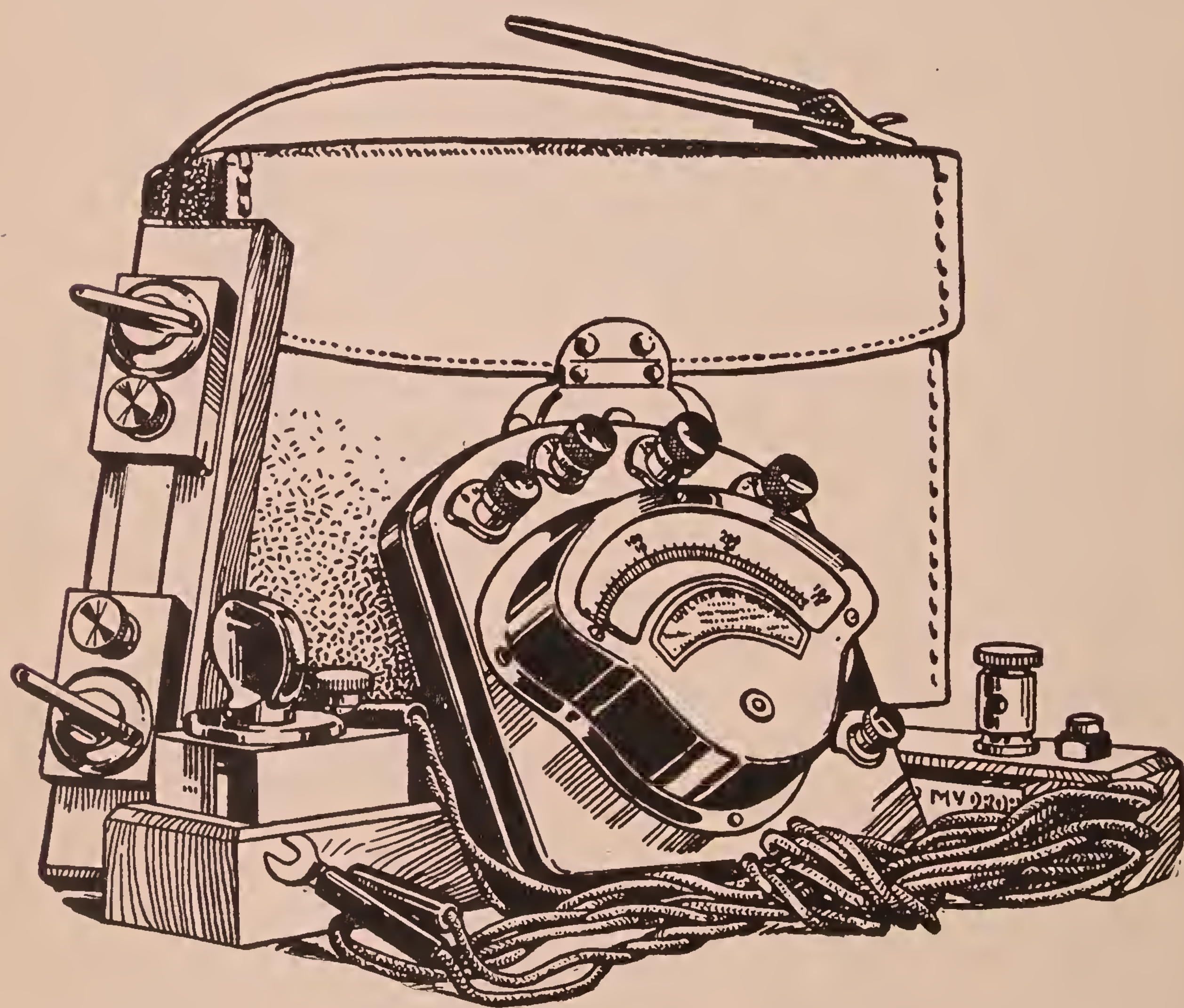


Fig. 216. Portable Combination Volt-Ammeter for Testing

will indicate a weak battery. Full directions for the care of storage batteries are given in the résumé in Questions and Answers, and also in the article on Electric Automobiles. In case the battery does not respond to any of the ordinary methods of treatment given there, it will usually be found preferable to refer it to the nearest service station of the battery manufacturer. This is particularly the case where after refilling with distilled water to the proper level and slowly recharging, the battery does not increase in voltage and specific gravity reading with the hydrometer.

Always Test the Lamp. Whether a standard 110-volt lamp or one of the 6-volt type (for which an adapter may be necessary to fit the standard socket) is used, it is a good precaution always to test the lamp itself before going over the wiring on the car. This will avoid the necessity for blaming things generally after failing to find any circuit at all—after fifteen miutes of trying everything on the car—due to the lamp having a broken filament or one of its connections having loosened up.

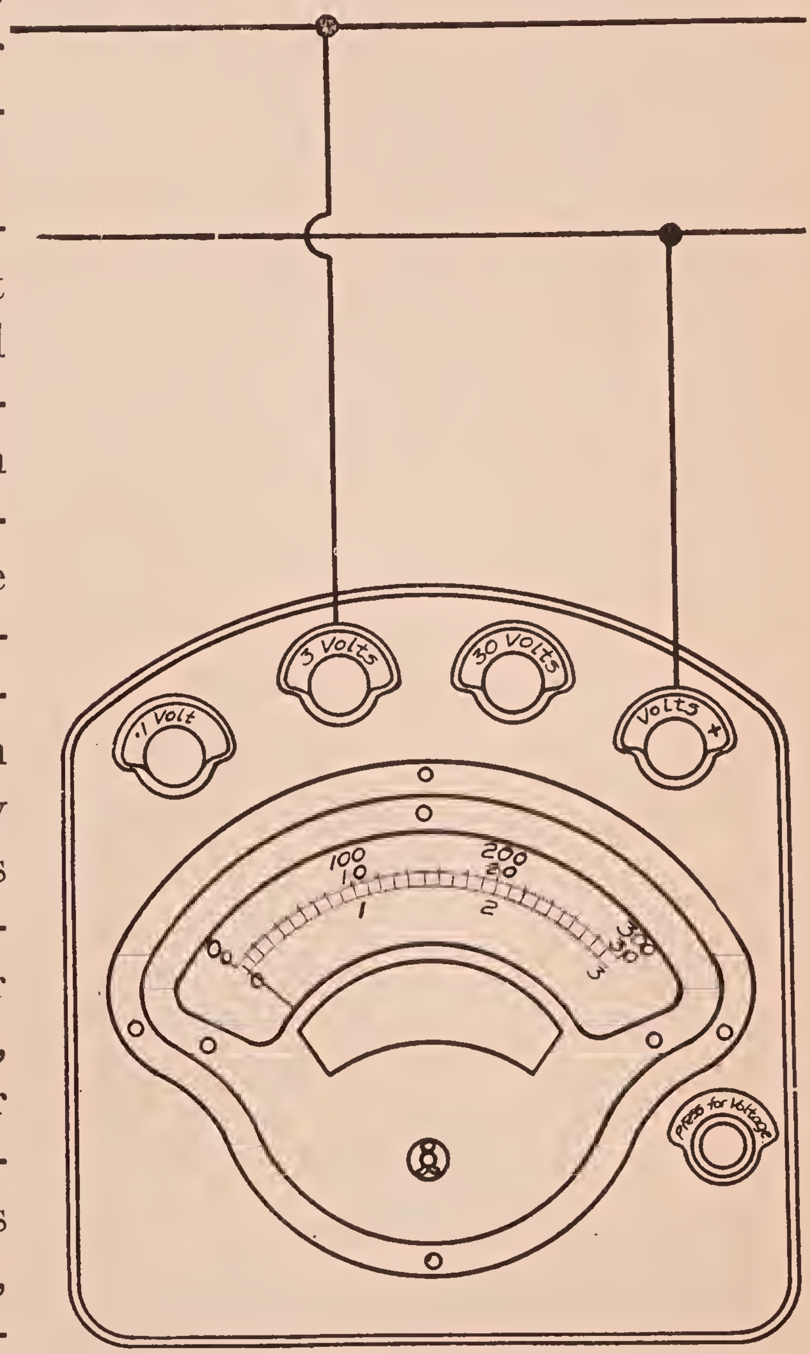


Fig. 217. Diagram Showing 3-Volt Scale Connected across a Circuit

Special Testing Instruments. For the garage that claims to be fully equipped to give all necessary attention to the electrical system of the modern car, something more than the simple lamp testing outfit is necessary. Portable volt-ammeters such as shown in Fig. 216 are made specially for this purpose. This is a Weston combination volt-ammeter, the voltmeter being provided with a 0–30, 0–3, and 0 to $\frac{1}{10}$ scales for making voltage tests, together with three shunts having a capacity of 0–300, 0–30, and 0–3 amperes, respectively, which are used in connection with the $\frac{1}{10}$-volt scale for making current measurements. A special set of calibrated leads for use with these shunts is also provided. With the aid of such an outfit, accurate tests can be made covering the condition and performance of every part of a starting-lighting and ignition installation. For example, a starting system may be otherwise in perfect working condition, but its operation causes such an excessive demand on the storage battery that the generator is not capable of keeping the latter sufficiently charged. Generator tests, which are described later, having failed to show anything wrong with the dynamo, a test of the starting motor, using the 0–300-ampere shunt of the instrument would doubtless show that an unnecessarily large amount of current was being demanded by the motor for its operation, and indicate a fault in the latter.

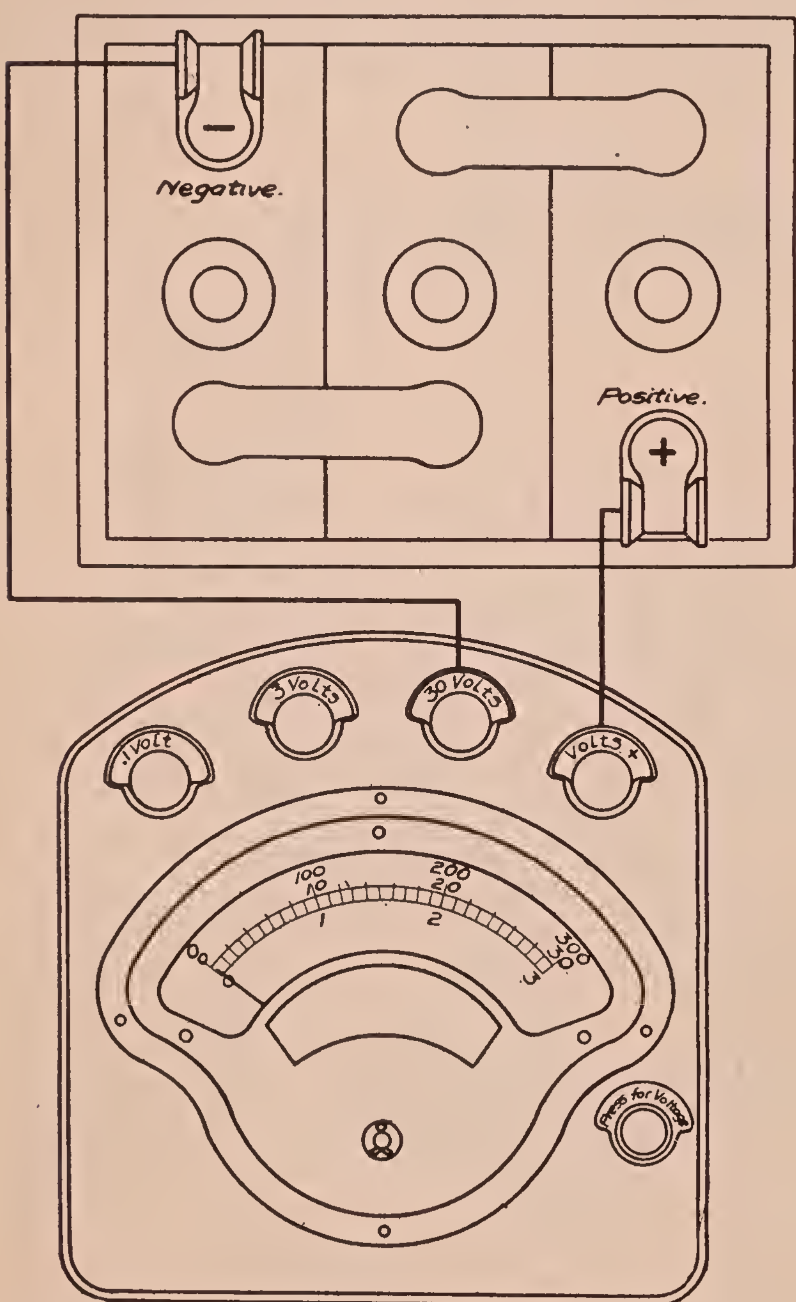


Fig. 218. Diagram Showing 30-Volt Scale Connected across Storage Battery Terminals

Voltage Tests. When the instrument is used as a voltmeter it is necessary to select the proper scale for the circuit, and if there is any doubt it is well to start with the 30-volt scale. For testing individual cells of the storage battery the 3-volt scale would naturally be used, while for testing the entire battery, the 30-volt scale would be the proper one to apply. The proper method of connecting the voltmeter to the circuit is shown by the diagrams, Figs. 217 and 218. It is necessary to connect the positive side of the meter to the positive side of the circuit and the other terminal to the negative. Where the polarity of the circuit is not known, this can be readily determined by a trial reading. If the pointer moves to the right, the connections are properly made; in case it moves to the left, it will be necessary to reverse the connections, which should be done at the circuit terminals and not at the meter, to avoid any accidental short circuits.

Ammeter Readings. When using the ammeter to determine the amount of current consumed by any of the apparatus, such as the starting motor or the lamps, it is necessary to first select the proper shunt. Should the value of the current to be measured be unknown, it is well always to start with the 300-ampere shunt

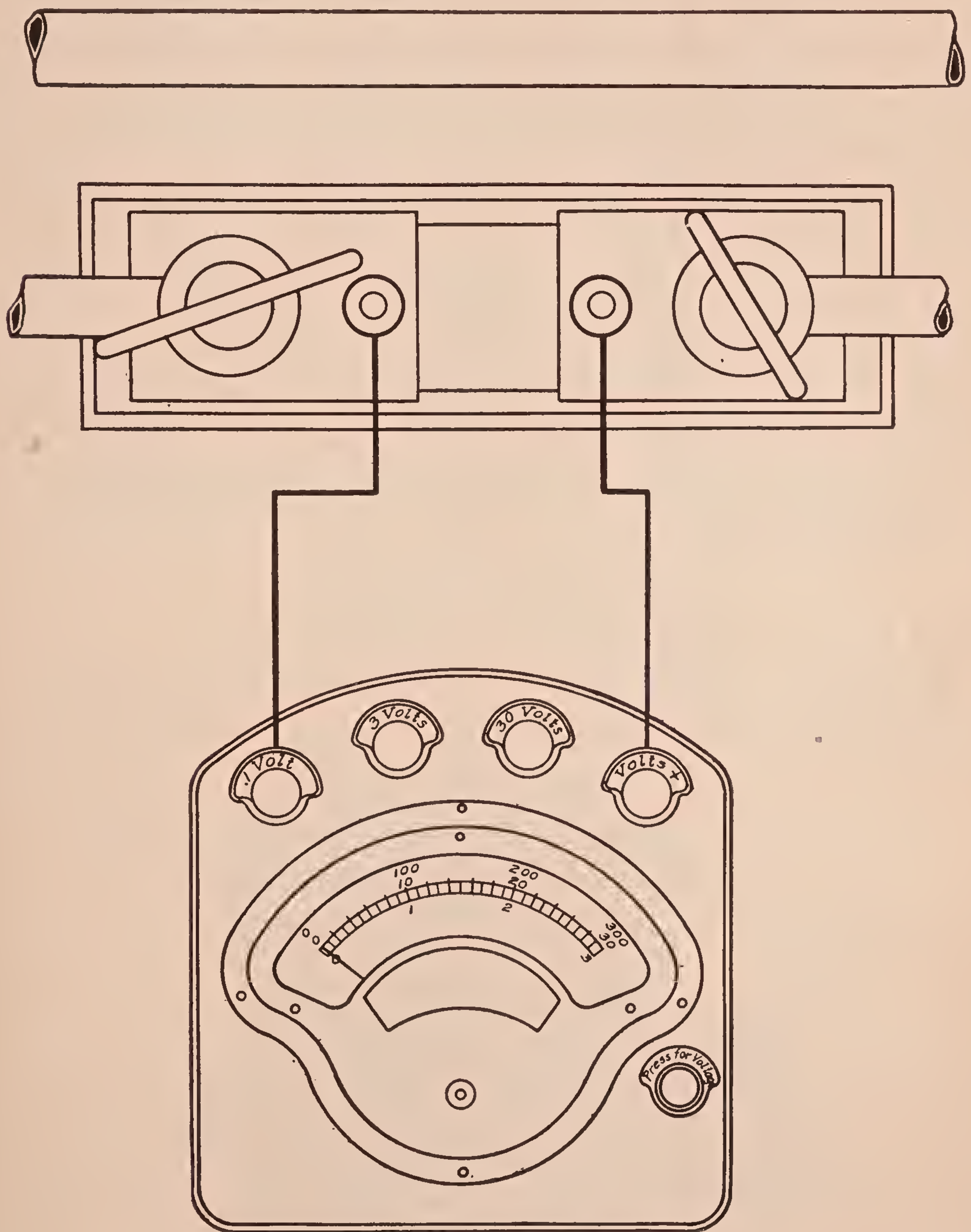


Fig. 219. Diagram Showing Method of Connecting Ammeter to 300-Ampere Shunt

and then insert the 30-ampere shunt in case the reading shows the current to be less than 30 amperes. These shunts are connected in the manner shown by Fig. 219, and as will be plain from this diagram, all shunts are connected in the circuit in a similar manner. The connections always remaining the same, it is only necessary to substitute the different shunts as required by the circuit to be measured. If the polarity be reversed, it is only necessary to shift the connections from the ammeter to the shunt which should be done at the latter, there being no necessity to change the connections of the shunt itself to the circuit. The 300-ampere shunt must always be used for measuring the starting current, as the latter will rarely have a value of less than 200 amperes when the switch is first closed owing to the necessity of exerting great power at first to overcome the inertia of the gasoline engine, particularly at a low temperature when the lubricating oil has become gummed. Cables of the same size as those employed on the starting-motor circuit of the car should be provided for connecting up the shunt to make the tests. The 30-ampere shunt is employed for measuring the charging current to the battery, while the 3-ampere shunt is used for the individual lighting circuits or for the primary ignition current.

In the following section, the various systems in general use are described in detail.

AUTO-LITE SYSTEM

Six-Volt; Two-Unit; Single Wire

Generator. Three types of generators are furnished. One has a permanent magnetic field and resembles a magneto but can

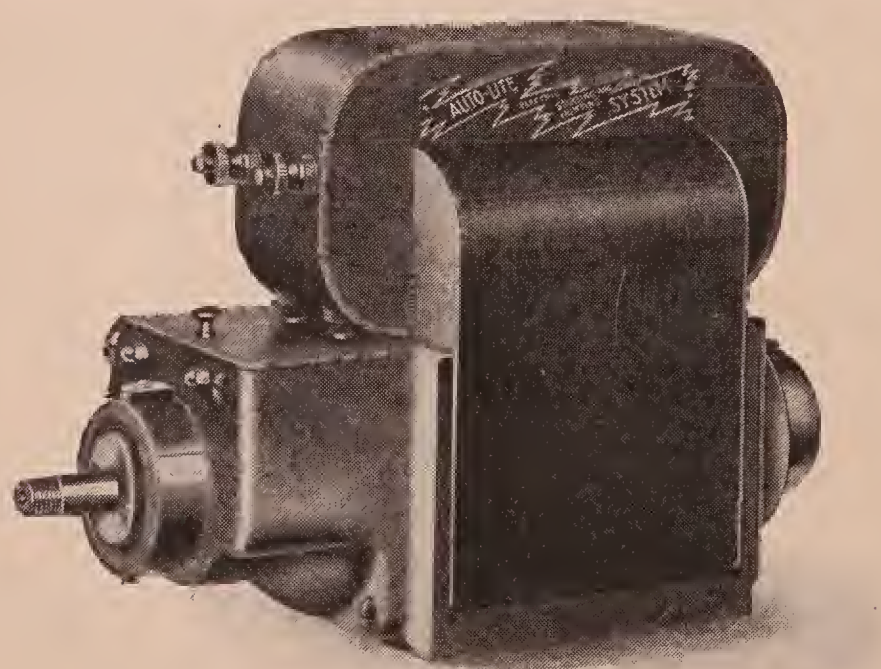


Fig. 220. Auto-Lite Generator of the Bipolar Type
Courtesy of Electric Auto-Lite Company, Toledo, Ohio

be distinguished by its drive and governor, as well as the fact that it is fitted with a commutator and brushes instead of a contact breaker and distributor. It has been supplied chiefly for installation on cars which were not originally fitted with electric lighting and starting systems. The second is somewhat similar in design but has an excited field, the field magnets being of U-form and laminated; this type of generator is used on the Overland Model 82. There is a single field winding, as shown in Fig. 220. The third is a four-pole machine having two wound poles, usually termed *salient* poles and two *consequent* poles, which carry no windings. A diagrammatic section of this generator is shown in Fig. 221. The salient poles are those in the vertical plane while the consequent poles

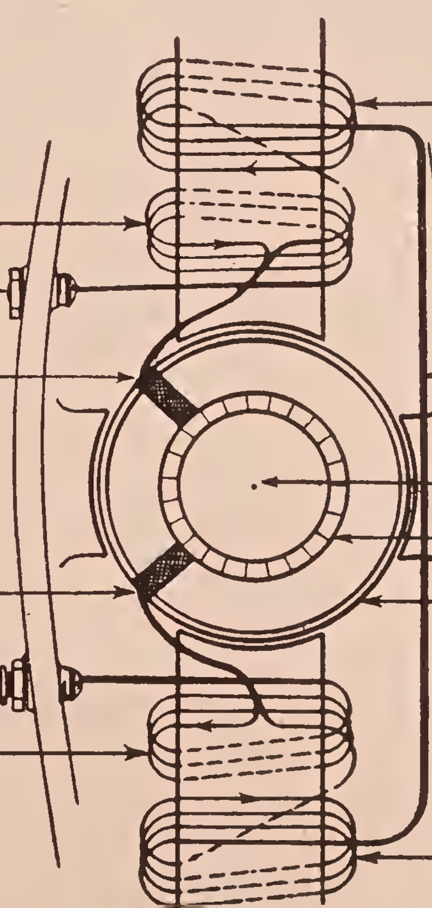


Fig. 221. Diagrammatic Section of Four-Pole Auto-Lite Generator

are horizontal. The diagram also shows the commutator, brushes, and the compound winding of the generator.

Regulation. The current output of the permanent-field type is regulated by a centrifugal governor; it should not drop below 10 amperes, nor exceed 12 amperes. Any falling off can be remedied frequently, simply by cleaning the governor out thoroughly with gasoline, allowing it to dry, and giving it a drop or two of light oil; if this does not increase the output sufficiently, the weights can be moved inward an eighth of an inch or more to decrease the pressure on the springs mounted in the governor arms, Fig. 222. This permits the generator to run at a higher speed. The regulation of the other type is *inherent* and is due to the series windings of the field being made in the reverse direction to that of the shunt windings, so that their polarity is reversed. This is commonly referred to as a *bucking coil,* also as a differential winding. As the speed increases, the magnetizing effect of the shunt coils is opposed by this bucking winding and thus kept within safe limits. This type of generator is used on the Overland Model 80 and Model 81, besides other cars.

Fig. 222. Governor of Auto-Lite Permanent-Magnet Type Generator

Starting Motor. The starting motor is a series-wound multipolar type having four salient poles, Fig. 223 (used on Overland Model 80 and Model 81). In this type the switch is combined directly with the motor, being mounted in a housing at the left end as shown in Fig. 223. It is also fitted with a special locking device, the details of which are illustrated in the sectional view, Fig. 224. One of the buttons on the control board on the steering column closes the circuit of the solenoid shown in this illustration; this causes the plunger to lift and release what is known as the *gear-latch.* The shaft carrying the switch also serves to shift the pinion on the end of the starting-motor shaft into mesh with the flywheel gear. A later and more widely employed type of Auto-Lite starting motor is shown in Fig. 225; this is installed on the Overland Model

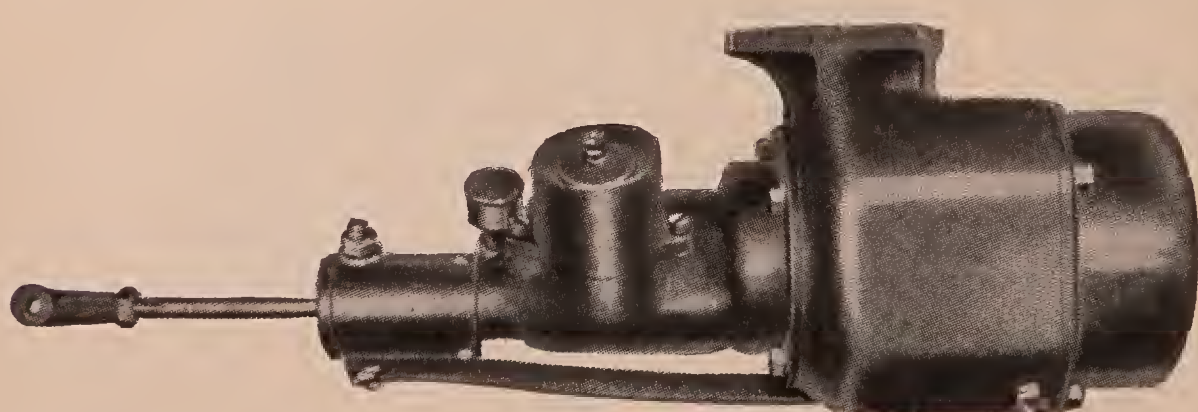


Fig. 223. Auto-Lite Starting Motor Used on Overland Models 80 and 81

82 besides a number of other cars. It is known as the *Bendix drive* and is coming into very general use owing to its simplicity and its

automatic operation which eliminates the necessity for gear-shifting devices actuated by the switch, when operating the starting motor.

The armature shaft has a threaded extension provided with an

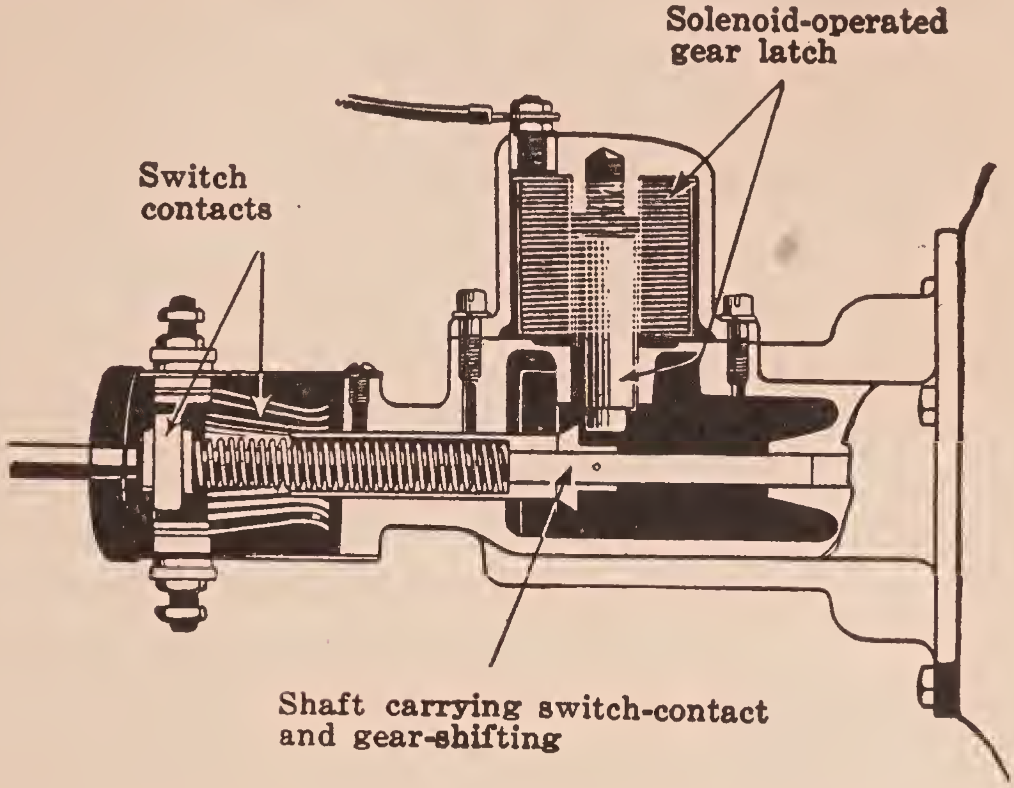


Fig. 224. Sectional View of Auto-Lite Starting Switch and Gear Release

outer bearing and carries a pinion. A weight is solidly attached to this pinion and the latter is loose enough on the shaft always to

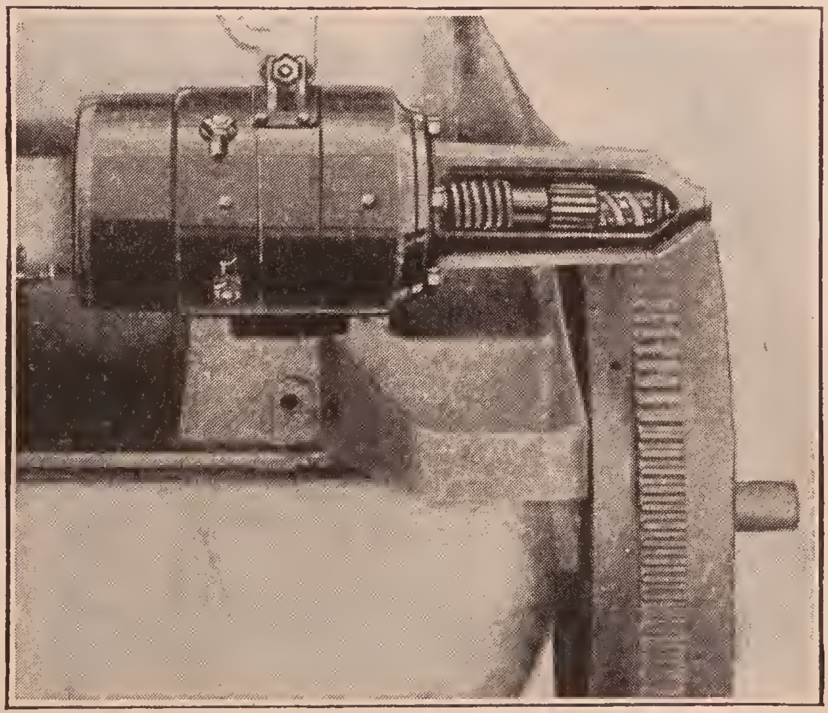


Fig. 225. Auto-Lite Starting Motor with Bendix Drive

occupy the position shown with the weight underneath when the shaft is idle. The leading screw has a triple thread. On starting the electric motor the inertia of the weight causes it and the pinion to be carried along the shaft and into mesh with the gear on the flywheel in which relation it remains until the engine begins to run under its own power. This reverses the relation, the flywheel then driving instead of being driven, which automatically throws the pinion out of mesh. The coil spring shown is simply to take up the shock of starting and permits a slight play between the motor shaft and the threaded extension. Before the switch which is located on the footboards can be operated, a button on the control board must be pushed. This actuates a solenoid the plunger of which raises a latch, releasing the starting switch.

Battery Cut-out. The battery cut-out is shown in Fig. 226. As already explained, the majority of electric systems on the automobile must be provided with a cut-out to protect the battery when the generator speed falls below a certain point. It is frequently referred to as a *circuit breaker,* which it is in fact, though the circuit breaker is a protective device used for another purpose, as has been mentioned. The cut-out may be compared to a check valve in a water supply line between a pump and a tank; the pump can force water into the tank against its pressure but, regardless of how great this pressure becomes owing to the filling of the tank, the water cannot run back through the pump when the latter is idle.

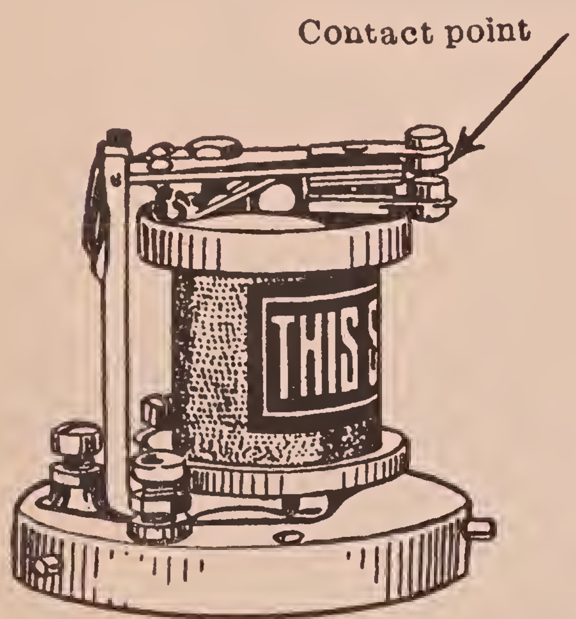


Fig. 226. Auto-Lite Battery Cut-Out (Circuit Breaker)

In principle, the battery cut-out is simply a magnetically operated switch. When the current passes through its winding the armature is attracted and brings a pair of contact points together. These will be seen at the upper right hand at the point of the arrow. In the best-grade apparatus, these points are of platinum or platinum and iridium as the latter is proof against oxidation as well as corrosion and resists pitting under the electrical current better than any other metal. As it costs more than gold, silver, which is next best for the purpose, is frequently employed. The cut-out in this case is set to close the circuit and allow the generator to charge the battery when the engine is driving the car at $7\frac{1}{2}$ miles per hour, but when the speed is dropping it does not open the circuit until it falls to 6 miles per hour. This is to prevent the cut-out from operating continuously when the car is running at its opening speed of $7\frac{1}{2}$ miles. The battery, however, governs to a large extent the running speed at which the cut-out will operate. When fully charged, owing to the higher resistance thus presented, the cut-out does not close the circuit until the car is running at 10 to 12 miles per hour. In case the cut-out is removed from the car for any reason, the latter must not be operated until a short piece of bare copper wire is securely connected from the wire terminal post of the generator to one of the brass screws in the name plate.

Instruments. The instrument regularly supplied is a double-reading ammeter showing *charge* and *discharge* from 0 to 15 amperes. When lamps are off with car running at 10 miles per hour or over, it should indicate *charge*.

Wiring Diagram. The connections are practically the same, regardless of the type of starting motor installed, so that the following description will cover all three of the Overland models mentioned, Fig. 227. The ignition system is entirely independent of the starting and lighting system, although it appears on the diagram. The connections are as follows: Cable 12072, battery negative to motor terminal; cable 12073, battery positive to starting switch; wire 12236, starting switch to fuse block; wire 12066, fuse to positive ammeter terminal; wire 12066, negative ammeter terminal through fuse; wire 12069, to battery cut-out; wire 12068, generator positive terminal to cut-out. The battery negative is grounded at the end of cable 12072, while the cut-out is grounded to the frame through the wire 12906 and the generator is grounded at its negative terminal. This is an example of the frame of the car being employed for the negative side of the circuit, as compared with the Gray & Davis in which it is utilized for the positive side. While the ground connections of the lamps and horn are indicated as separate wires, in the case of the lamps the socket itself forms the ground connection. The location of the various fuses and the relation of the various essentials of the system will be clear upon tracing the diagram.

Instructions. While a car never comes into the shop to have its electrical equipment examined until some fault develops, and the man who has to locate the trouble seldom has occasion to run the car in ordinary service, still it is important that he should famil-

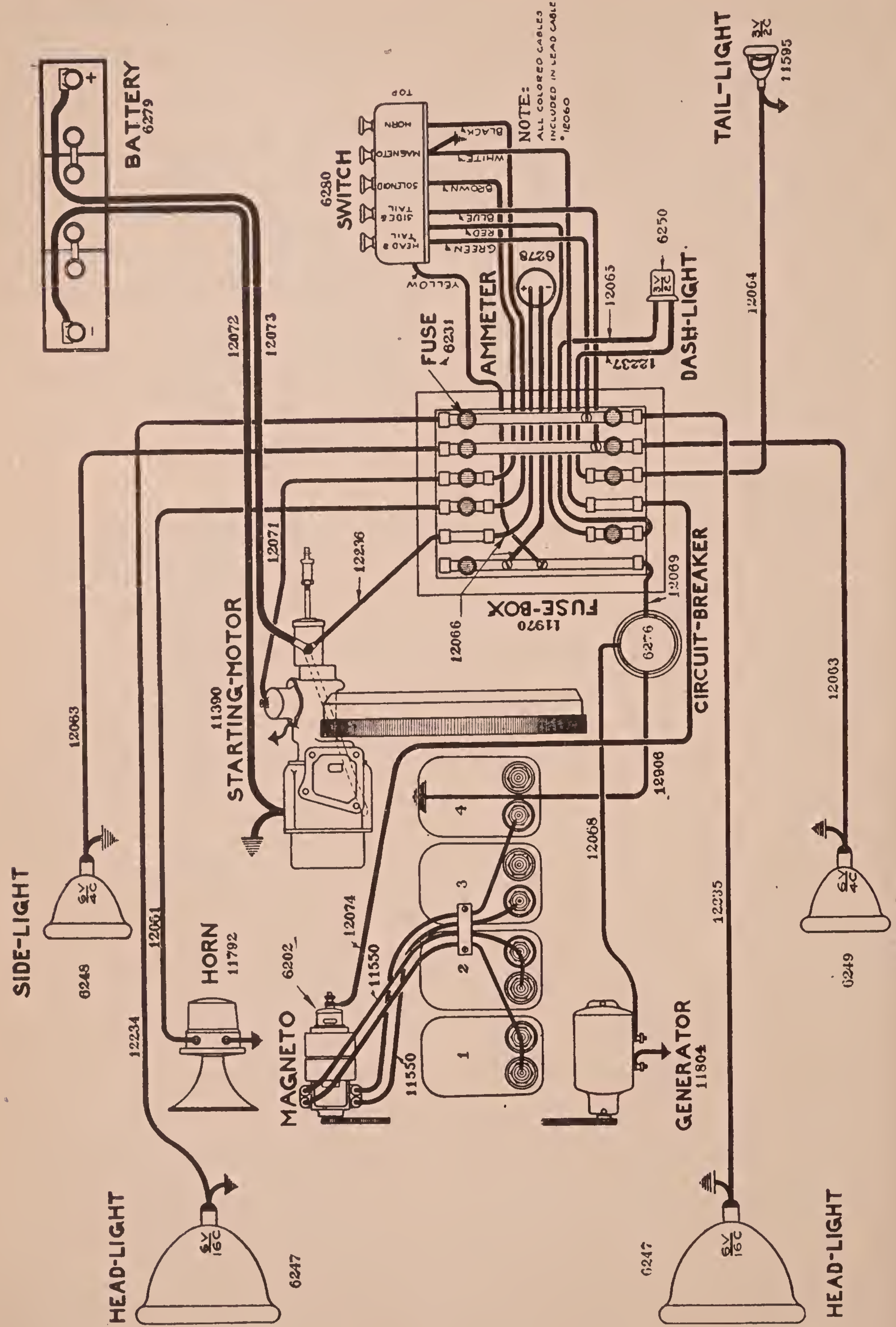


Fig. 227. Auto-Lite Wiring Diagram for Overland Cars

iarize himself with the instructions issued to the owner, in order that he may know at a glance whether these instructions have been carried out or not. It is safe to say that more than half the troubles that arise with this equipment are due to failure to follow instructions in its use. The average motorist ordinarily pays little attention to the workings of the apparatus until it goes wrong and then he is helpless. There is, however, another type—the man who is given to tinkering. He is responsible for not a few of the problems that come into the garage, and familiarity with the manufacturer's instructions will assist in tracing the result of his efforts.

Chain Drive. The silent-chain drive of the generator should be inspected occasionally and any slack taken up by loosening the screw which holds the generator on its bracket, and moving the generator over by means of the adjusting screw. The chain should be just slack enough to have no strain on its links when the engine is not running. Although the initial stretch of the chain is taken out at the factory by running it under load, these chains will continue to stretch slightly in service. After making the adjustment the holding screws should be re-tightened.

Commutator and Brushes. The commutator is the most vulnerable part of a direct-current machine. It should be examined first whenever there is any trouble with the generator, such as insufficient output of charging current, or with the starting motor, such as loss of power, the battery being in good condition. (No mention is made of battery instructions in this connection as the subject is fully dealt with in another volume, and in the summary following this section. The battery is, however, the cause of fully 80 per cent of all electrical-system troubles and neglect is at the root of most of these.)

The commutator is made accessible by the removal of a small plate—in this case, the name plate. If it is blackened and rough, the brushes first should be examined and trued up and the commutator should be smoothed down with fine sandpaper (never use emery cloth as it is metallic and will short-circuit the segments). The mica insulation should be carefully examined; if it is flush with the copper segments this is the cause of the roughened up brushes, and the mica should be undercut. Detailed instructions for smoothing the commutator, truing up the brushes and undercutting the mica insulation are given in connection with the Delco system. Any carbon dust from the brushes should be carefully blown out as this will tend to short-circuit the armature and field windings. See that the brush holders swing easily on the studs and that there is just enough spring tension on the brushes to make good contact on the commutator. Too much tension will cause unnecessary heating and wear of the commutator and brushes. Keep the commutator and brush chamber free from dirt and grease. Never replace brushes with any but those supplied by the manufacturer. See that the brush holders are well insulated from their supports, replacing any of the insulating plates, bushings, or washers that may have become damaged. Should the battery or generator be disconnected do not run the engine until they are again connected. Should it be necessary to do so, connect a short piece of bare copper wire from the terminal of the generator to one of the brass screws in the name plate.

Generator Tests. The following tests will be found an aid in locating failure of the generator.

Field. To test the field coils, lift the brushes off the commutator and insert a piece of fiber or clean dry wood. Close the battery cut-out by pressing the finger on the contacts. The ammeter should then register about one ampere if the coils are all right.

Armature. To test the armature, remove the driving chain and close the cut-out as before. This will *motorize* the generator and it should then run at 650 to 750 r.p.m., drawing 3 to $3\frac{1}{2}$ amperes, if its windings are in good condition. This refers to the generator on Overland Model 80 and Model 81. The Model 82 generator should run at 275 r.p.m. on a current of 2 to $2\frac{1}{2}$ amperes.

Grounds. Tests for grounded windings in either the field or armature coils can be carried out with the aid of the testing-lamp outfit described. Remove the brushes, place one test point on a commutator segment and the other point on the armature shaft; if the coil is all right the lamp will not light. Each coil can be tested in succession in the same way. To test the field coils, lift one brush from the commutator and place the test points one on each brush holder; the lamp should light as this places the field coil in series with the lamp.

In case any faults are located in the windings it will usually be found advisable to consult the manufacturer's service station or the factory direct, as either armature or field winding is something that is beyond even the best equipped of garages.

Battery Cut-Out Tests. Failure of the battery cut-out to operate will most frequently result from pitted or blackened contact points. Clean and true up with fine sandpaper which should be drawn back and forth between them while slight pressure is applied to the upper one, taking care to keep the sandpaper at right angles to the vertical plane of the points, as otherwise they will be put out of true. See that the faces of both points come together over their entire surface when pressed together with the finger.

Operation. Test for operation by sending the current from five dry cells in series through the coil of the cut-out. The points should come together with a snap as soon as the circuit is completed and should hold fast as long as the current is on. This test should not be continued too long, however, as the dry cells will weaken. In case the armature is not attracted, leaving the points in the open position when the battery current is sent through it, inspect the connections from the binding posts to the coil. The wire is small and may have broken from vibration.

Should no circuit be found through the coil with the dry battery, try the test-lamp outfit on the 110-volt circuit, holding one point down on a binding post and just touching the other momentarily with the second point. If the lamp fails to light, there is a break in the coil and the cut-out should be returned to the manufacturer.

BIJUR SYSTEM

6-Volt; Two-Unit; Single- or Double-Wire, According to Make of Car. Also 12-Volt Single-Unit;

Generator. The generator is a special reversible type. Due to the reversible characteristics of the machine it may be connected in either direction and it will assume the proper polarity for charging the storage battery.

Regulation. This is the constant-voltage type, the regulator and battery cut-out being mounted directly on the generator. The principle of this method of regulation is to maintain the voltage of the generator constant, the current output depending on the resistance of the circuit and varying with the state of charge of the battery. This is accomplished by the use of a magnetic vibrator similar in principle to the ordinary electric bell, or buzzer, though it takes a different form, Fig. 228. *H* is the magnet winding, *A* the soft-iron core of the magnet, and *G* the vibrating armature. To prevent *G* from coming directly in contact with the pole piece on the upper end of *A*, a stop pin *I* is provided. *C* and *F* are the contacts, *C* being held away from *F* by the spring *E*. These contacts are mounted on vibrating reeds (thin strips of spring brass) placed at right angles to each other. Contact *C* and its reed are attached to the armature *G*, and stop pins *B* limit the lateral movement of this contact. *F* and its reed are also mounted on an arm as shown.

When a current flows through the magnet coil the armature *G* is attracted, automatically released by the breaking of the circuit, and again attracted so that it vibrates, the rate of vibration depending upon the amount of current. As the vibrator is included in the field circuit the current in the latter is accordingly pulsating, and as a field circuit, owing to its heavy iron core has considerable self-induction, the amount of current flowing through it will decrease in proportion to the rapidity of the vibration or pulsations. To prevent the field losing its excitation altogether every time the vibrator opens the circuit, the latter is not connected directly in circuit with the shunt winding of the generator, but is placed across the terminals of a resistance unit in series with the shunt field. This also prevents the arcing or heavy sparking that otherwise would result from the breaking of a circuit having so much inductance. Failure of a vibrating regulator is usually caused by the contact points sticking or fusing together owing to the heat. Mounting the points on reeds is designed to prevent this as the vibration due to the operation of the car keeps them moving laterally, thus overcoming the formation of a cone of metal on the negative contact point at one spot caused by the small particles constantly transferred by the current from the positive to the negative.

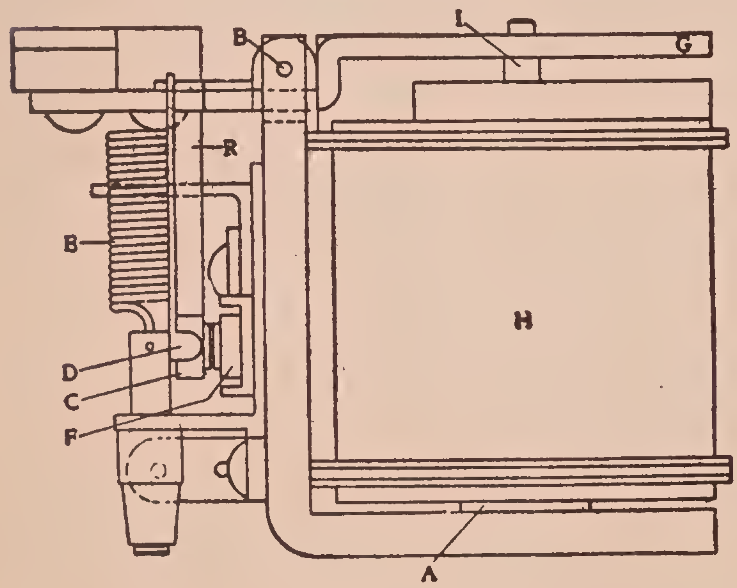


Fig. 228. Bijur Vibrator Voltage Regulator
Courtesy of "The Horseless Age"

Starting Motor. This is of the series-wound bipolar type. The installation of motor and starting switch as mounted on Hupp cars is shown in Fig. 229.

Instruments. A dash ammeter is supplied. With constant voltage control the amount of current delivered to the battery by the generator depends upon the condition of the former. With battery almost discharged, its voltage is lowered and the current reading may then be as high as 15 to 20 amperes. With battery fully charged and no lights on, the reading will decrease to 5 amperes or less, the charging current at all times depending upon the state of charge of the battery.

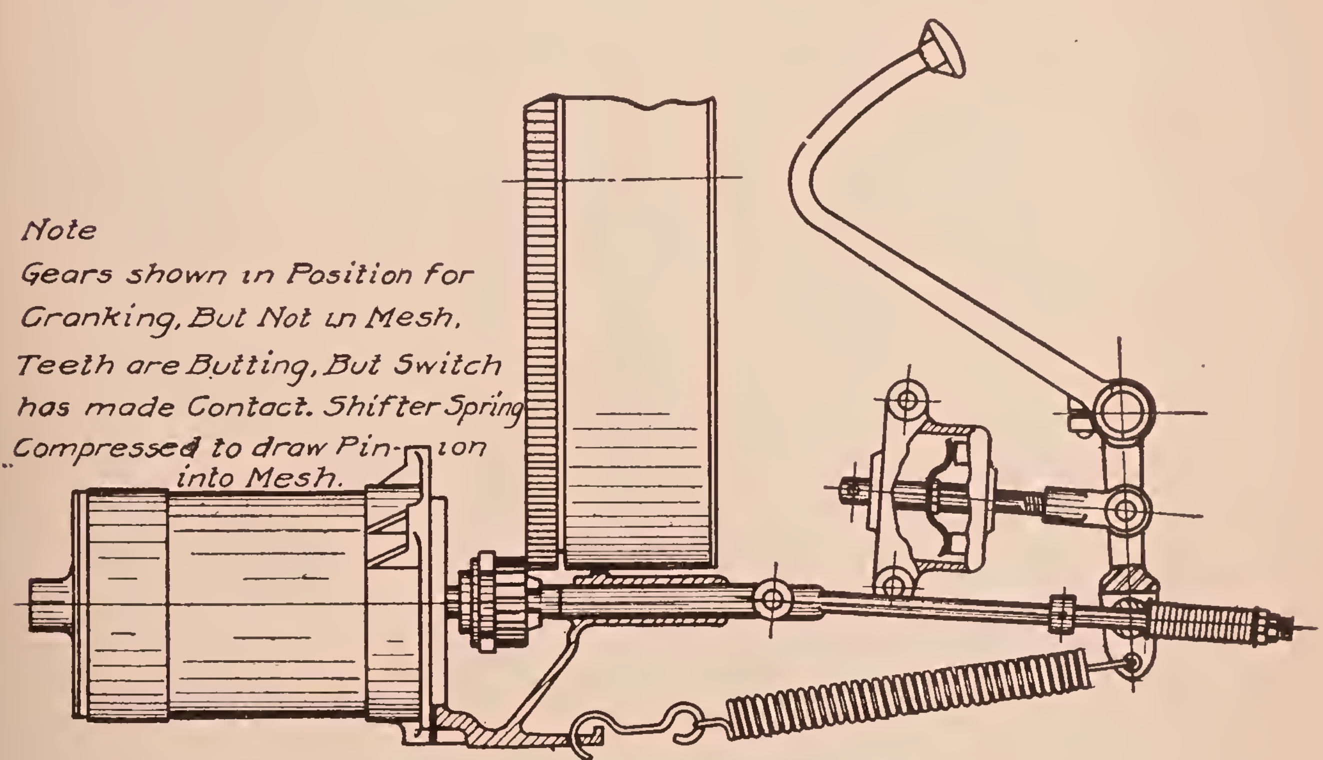


Fig. 229. Bijur Starting Motor as Installed on the Hupp

Wiring Diagrams. *Winton.* This, as shown in Fig. 230, is a single-wire system. The generator is located alongside the transmission case and is belt-driven, provision for belt adjustment being made by swinging generator to tighten belt. The numbers on the wires indicate the sizes of wire used for connecting the various apparatus. Ground connections are on engine and transmission case. In this installation the starting switch is mounted directly on the starting motor. A spare lamp circuit is provided on which a portable, trouble-hunting lamp may be connected. Fuses are provided on all lamp circuits.

Jeffery. Fig. 231 illustrates the six-volt two-wire system used on the Chesterfield Six Model. With the exception of the out-of-

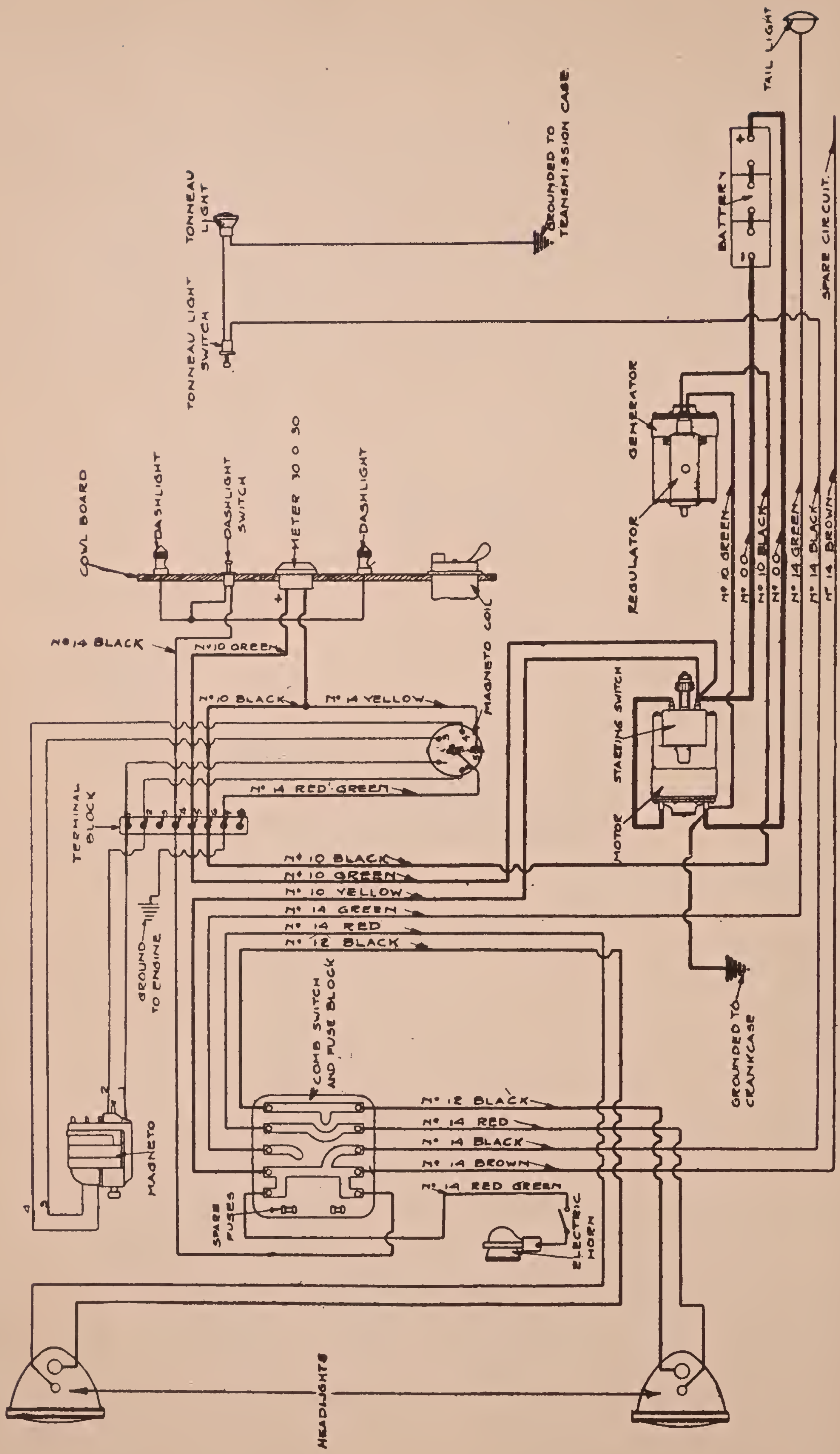


Fig. 230. Bijur System as Installed on the Winton

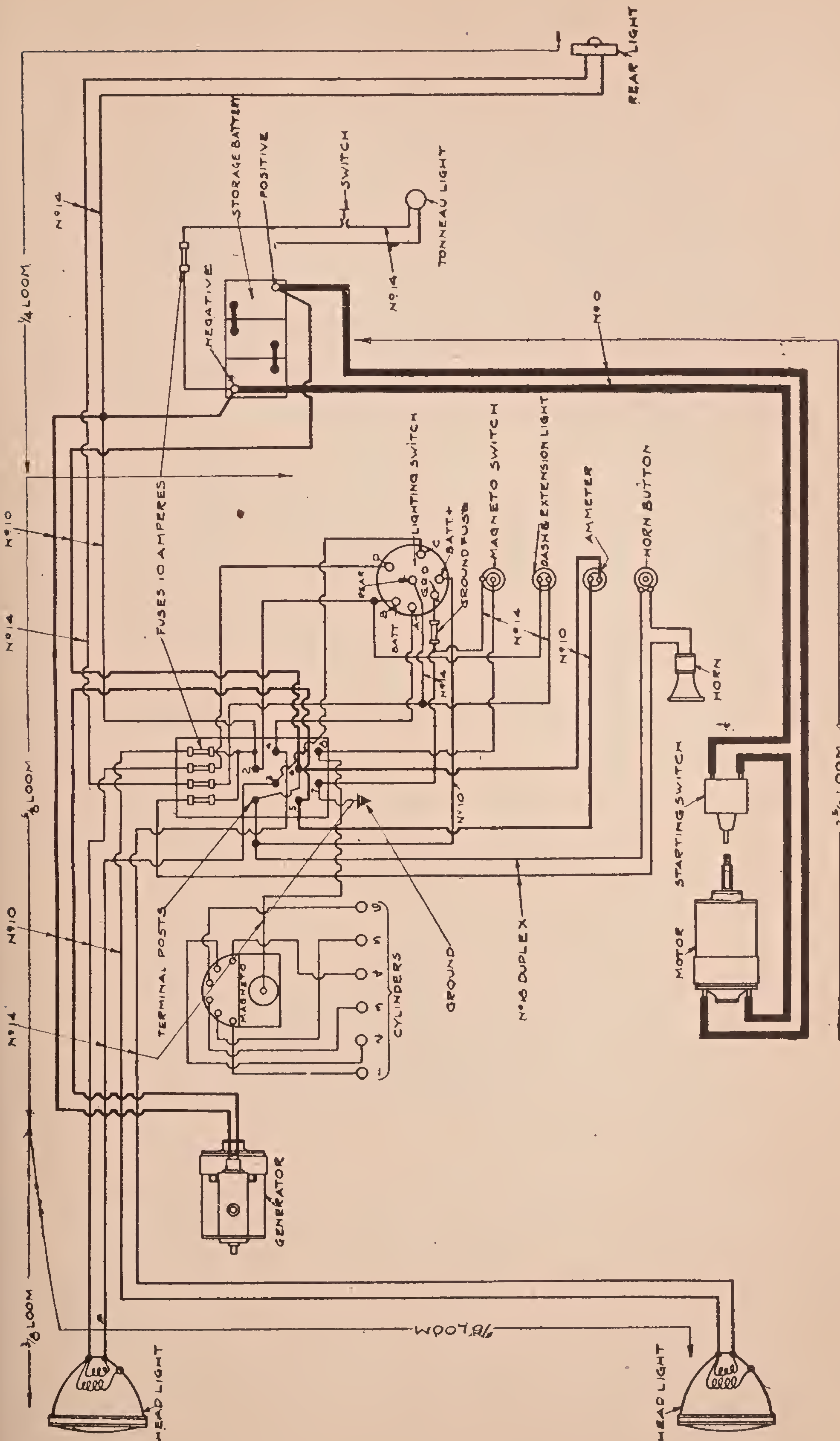


Fig. 231. Bijur System (Two-Wire) Installed on the Jeffery Chesterfield Six

focus lamps in the headlights for city running which are on the three-wire plan, one side being grounded, all apparatus is connected with two wires. In addition to lamp fuses, the ground connection is also fused. The blowing of any of these fuses does not affect the ignition circuits. The generator is mounted on the right side of the motor and is driven through a flexible coupling from the timing-gear shaft. At its rear end, the generator is connected through a jaw coupling to the water pump, this shaft also serving to drive the magneto. The starting switch is mounted on a housing covering the motor pinion, the starting motor being mounted on the left side of the engine. A five-way switch is provided for lamp control.

Hupp. Fig. 232 shows the six-volt single-wire system. This diagram is simplified by the omission of the magneto, current from the battery being supplied to a single coil and distributor system for this purpose. The generator is bolted to an extension on the right side forward of the engine and is driven by silent chain from the crankshaft. The cut-out and regulator are mounted inside the generator. The field windings are protected by a 6-ampere fuse. There is a four-way switch for lighting circuits.

Apperson. The six-volt two-wire system is shown in Fig. 233. The cut-out and regulator are mounted inside the generator. A "charge indicator" is fitted instead of an ammeter, having three readings—*charge, floating,* and *discharge. Floating* is the neutral position and the indicator should show this when engine is stopped and no lights are on, and may show either *charge* or *floating* at car speeds in excess of 12 miles per hour with lights on, according to the condition of the battery. Generator fields are protected by a 6-ampere fuse.

Scripps-Booth. In this connection is used the twelve-volt single-wire system employing a single unit or dynamotor for charging and starting. The dynamotor is driven by silent chain from the crankshaft. At speeds above 6 miles per hour, it acts as a generator to charge the battery; at speeds below this point, it automatically acts as a motor to drive the engine. Control is by three-way switch, having *on, off,* and *idle* positions. In the *on* position, the dynamotor is connected to the battery, the generator field circuit is closed, and the ignition circuit is closed. This is the normal operating position. In the *off* position, all circuits are opened and the car cannot be run. Shifting the switch to the

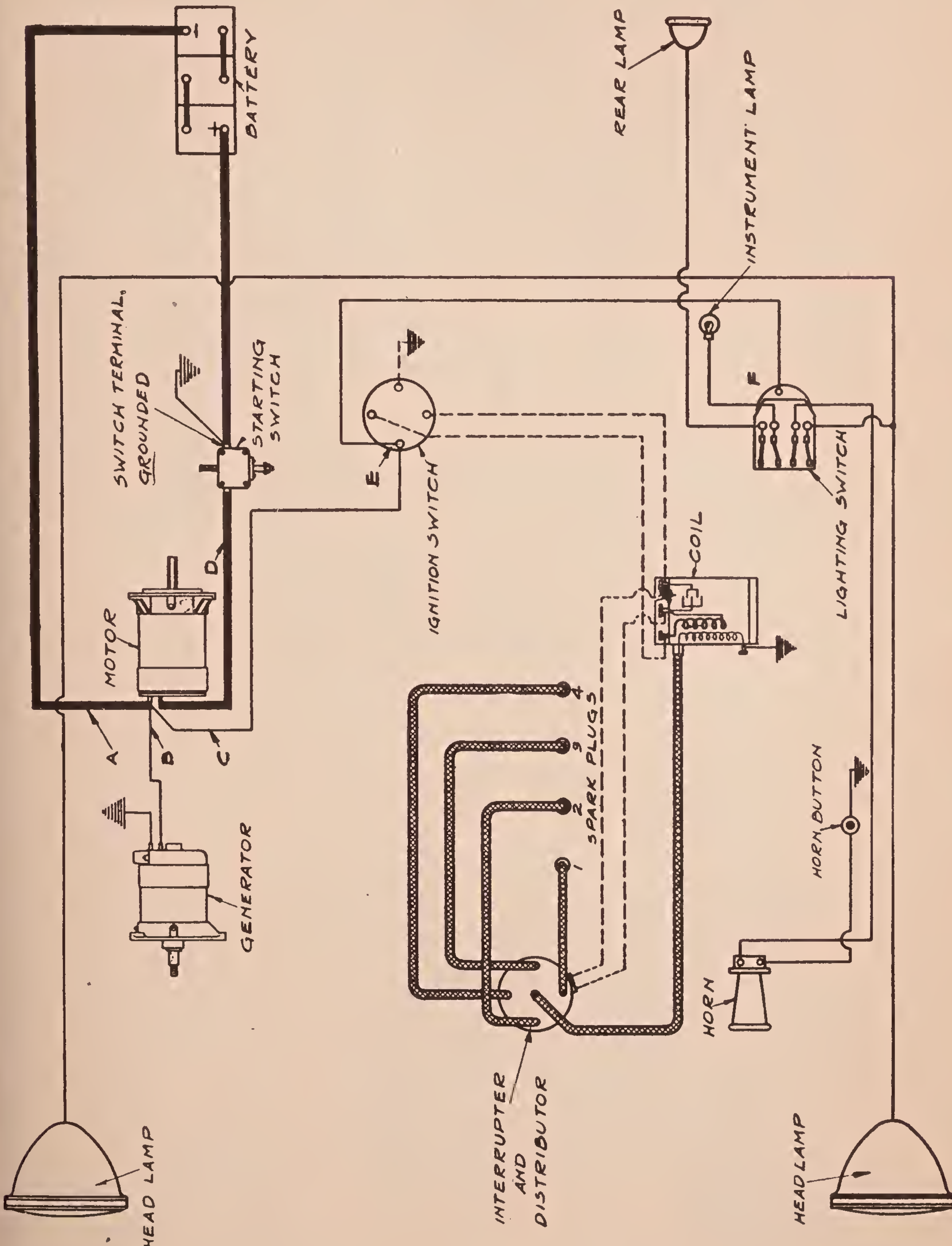


Fig. 232. Wiring Diagram for the Bijur System on the Hupmobile

idle position closes the ignition circuit so that the engine can be operated, but the dynamotor is disconnected from the battery and its field circuit is opened so that it generates no current.

Fig. 234 shows the wiring diagram as used on the earlier models of the Scripps-Booth, while Fig. 235 is the diagram of later models

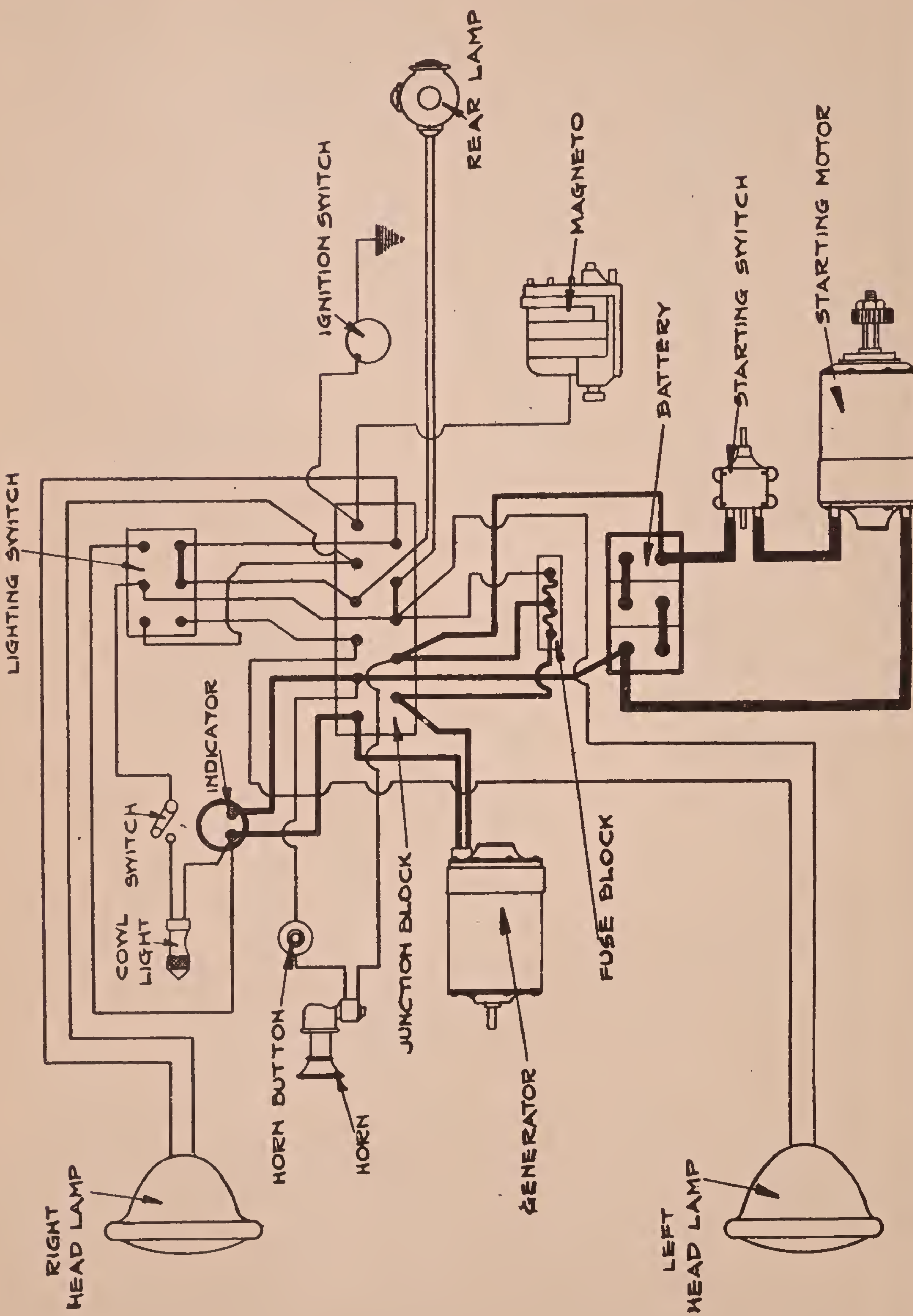


Fig. 233. Wiring Diagram for the Bijur System on the Apperson Car

of the same make. A current indicator shows the operation of the system and a four-way lighting switch is employed. The generator produces current at 12 volts and charges the storage battery cells in series. Twelve-volt tungsten lamps are used.

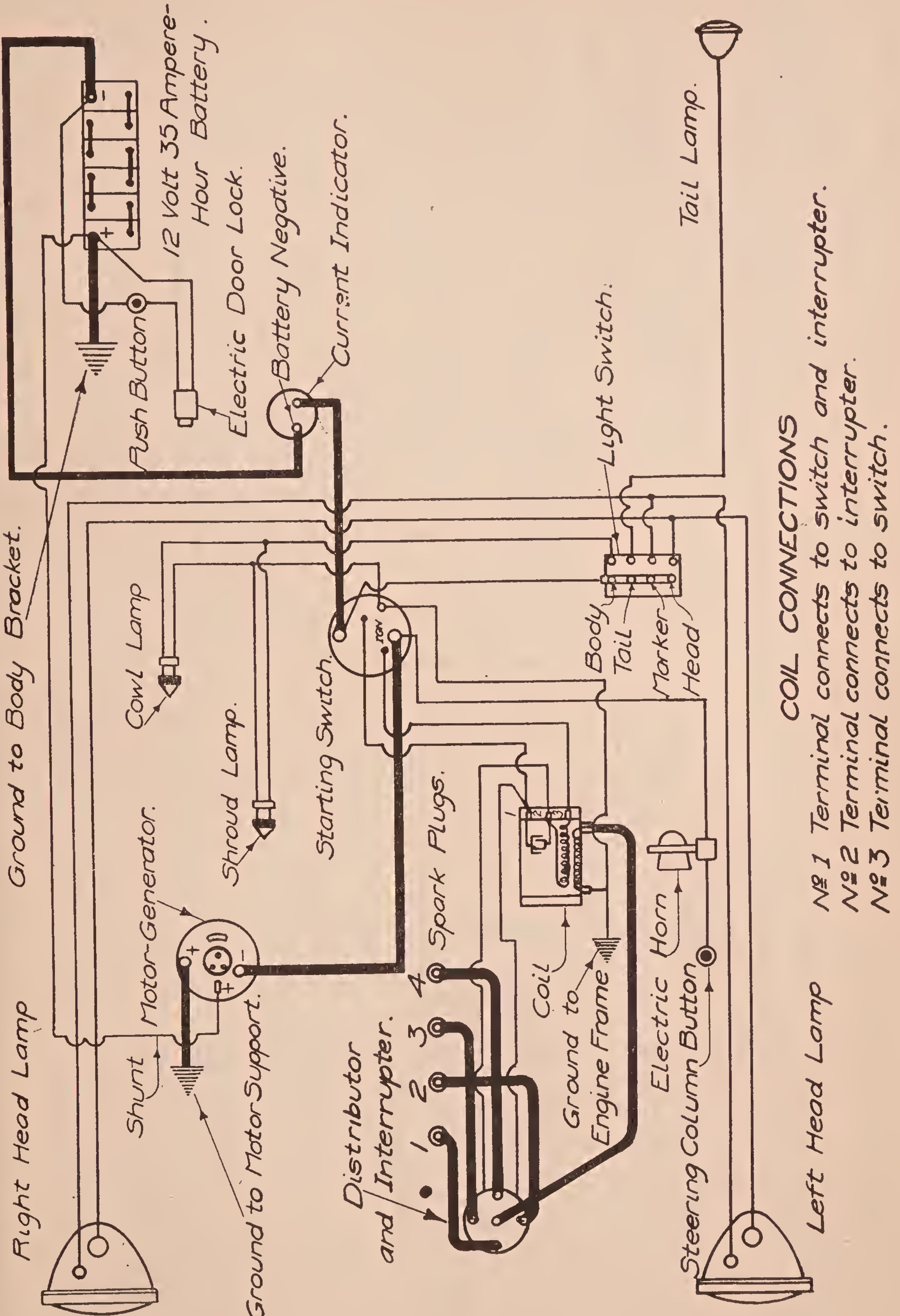


Fig. 234. Bijur System as Installed on Earlier Models of Scripps-Booth Cars

Instructions. *Winton.* No *charge* reading will be indicated on the ammeter when the engine is running (on high gear or direct

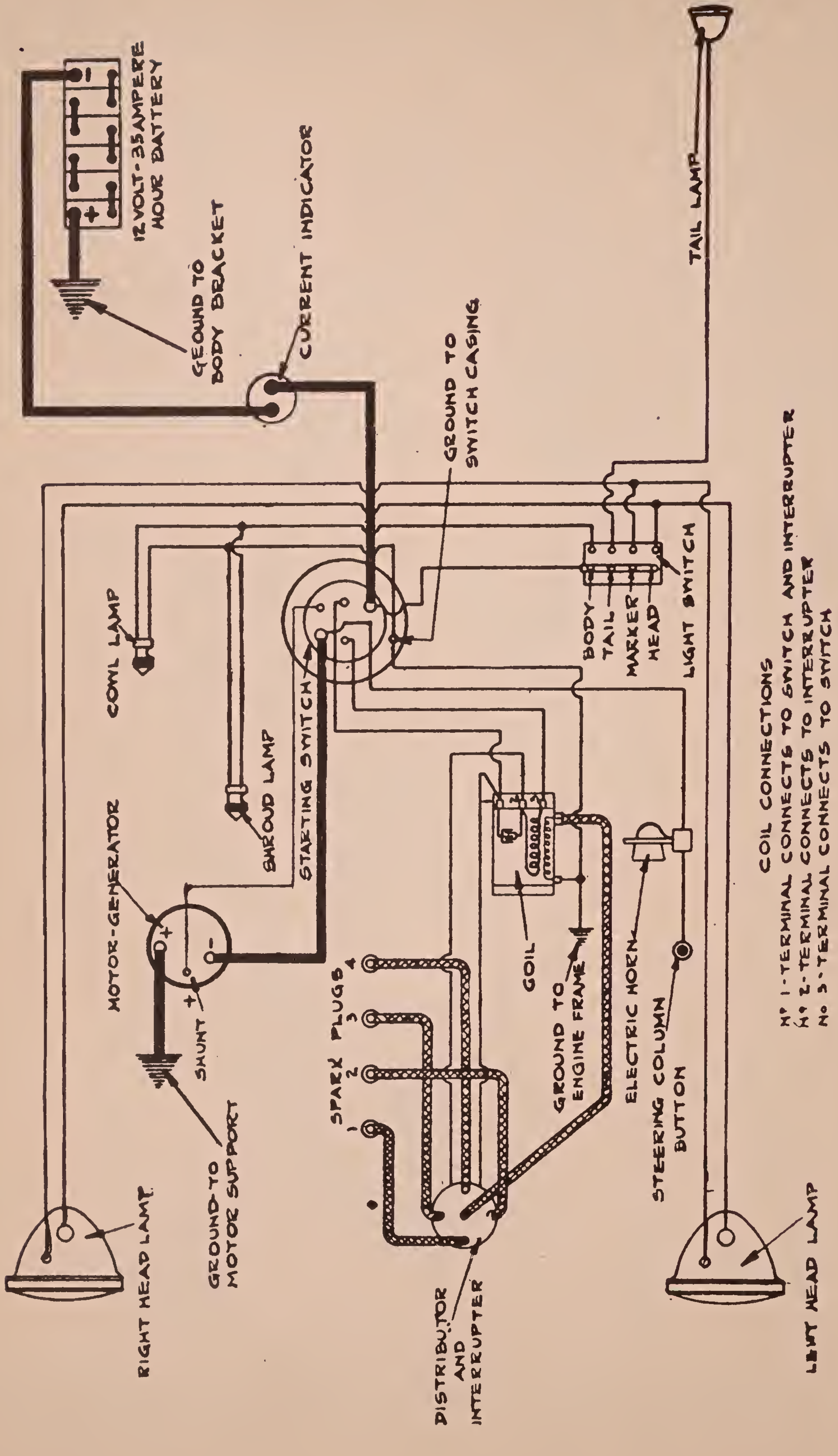


Fig. 235. Bijur System as Installed on Later Models of Scripps-Booth Cars

drive) at a car speed of less than 10 miles per hour. Failure to indicate a charge at speeds higher than this is a sign that the generator belt is too loose or that the generator itself is inoperative. To determine this, remove No. 10 black wire, Fig. 230, connected to No. 6 post on the terminal block, which goes into the aluminum box above it. Connect a voltmeter between this wire and the chassis and run the engine at a speed corresponding to a travel of 15 miles per hour on high gear. The voltmeter should indicate 7.3 to 7.4 volts. Instructions regarding brushes, commutator, and tests of armature- and field-winding circuits with the aid of testing lamp as given in connection with the Auto-Lite system apply to determine the nature of the fault in the generator. A special disconnecting plug is incorporated in the regulator box on top of the generator. This plug has two flat parallel faces and should never rest in its receptacle so that these flat faces stand in a vertical position, but should be pushed in and turned in either direction past its central position until it locks. When making tests for generator faults see that this plug is in the proper position to close the generator circuit.

To remove the regulator box from the generator, the disconnecting plug should be pushed in and turned to its central position when the plug may be withdrawn from its socket. After removing the plug, the knurled screw on top of the regulator box should be loosened and the box lifted by grasping it and the plug receptacle at the same time. Do not hammer the receptacle in order to release the box. If the disconnecting plug is round and knurled on the portion extending from the receptacle, the plug may be withdrawn when the V-groove extending horizontally on the plug matches with the slot at the top of the receptacle. The plug should never be left in this position, but should be turned in either direction until it springs forward and locks. Every five hundred miles, this disconnecting plug should be pushed inwardly to unlock it, and turned past its vertical position until it springs forward and locks. In carrying out any repairs or tests involving the disconnection of any of the wires which might cause a short circuit by coming in contact with metal parts of the car, the cable connected to the positive terminal of the battery should be disconnected and its bare end taped. This naturally applies to all grounded electrical systems and not merely to the car under consideration.

Jeffery (*Chesterfield Six*). Instructions for failure of generator, starting motor, lamp circuits, etc., are the same as those given in connection with other installations, except that in making tests the fact that two-wire circuits are employed must be borne in mind and connections made accordingly. The headlights supplied are special double-filament lamps, one of the filaments being out of focus to provide a non-glaring light for city driving. Where emergency replacements are made with standard single-filament lamps (double-contact type), the lamp controller should be turned to the *in focus bright* position when the head lamps are to be used. It is not possible to dim the lights under these conditions. In making a head-lamp double-filament bulb replacement, the lamp controller should be turned to the *out of focus dim* position. The new bulb should then be inserted in its socket. The out-of-focus filament in each headlight should then burn dimly. If they do not, the last bulb inserted in its socket should be removed, reversed, and replaced. When bulbs are correctly inserted, the two out-of-focus filaments will burn dimly when the lamp controller is turned to the *out of focus dim* position. Instructions for the use of the disconnecting plug are the same as for the Winton.

To determine whether generator is inoperative remove wire leading from the ammeter to No. 5 post of the junction and fuse block, Fig. 231, then connect voltmeter to terminals 2 and 5 and run engine as previously directed. A fuse is in the ground circuit between the magneto tap and the lamp controller and this fuse will blow if an accidental ground is made on either side of the system. The blowing of this fuse when the lamp controller is in the *off* position, shows that the accidental ground causing it is on the positive side of the system. Should the ground fuse blow when the lamp controller is in the *all bright* or *out of focus bright* positions, it shows that the accidental ground is on the negative side of the system. In testing the wiring to locate grounds, the headlight bulbs should be removed and the ground wire leading to connecting post No. 7 of the fuse and terminal block should be disconnected, and the magneto switch should be placed in the running position. With the ground fuse blown, the following lighting conditions obtain. Controller at *in focus bright* position, lamps will burn normally. At *out of focus bright* position lamps will not light; at *all bright* position only the in-focus filaments will light. At the *out of focus dim* position all the lamps will light.

Hupp. General instructions covering failure of generator, starter, or lamp circuits apply as already given. If the starting motor is damaged so that its removal is necessary, it should be removed by disconnecting one of the battery terminals and the two small wires *B* and *C* as shown on the diagram, Fig. 232. Next remove the heavy cable *D* from the starting motor. The holding nuts on the motor can then be loosened to permit its removal. In replacing a starting motor, the pinion riding on the square shaft of the motor should be tested to see that it has a free sliding fit on the shaft. Do not use a file but see that all surfaces are perfectly clean and well oiled. The pinion must be guided over the shaft before the motor is pushed into place. Connect the new motor in accordance with the wiring diagram. Do not make storage-battery connections until all other connections have been made and while repairs are being carried out battery terminals should be protected so that no metal, such as tools, can accidentally drop on them, as this will ruin the battery by putting it on dead short circuit.

In case an inoperative starting motor is removed and a new one is not immediately available for installation, the car may be run with the hand-starting crank by proceeding as follows: Terminals on the end of cable *A* and the wires *B* and *C* must be connected together by binding tightly with bare copper wire and then thoroughly taping so as to form a good electrical joint that is well insulated. Secure the cables and wires to adjacent parts of the car with the aid of cord or insulating tape (not with wire) so that they cannot be chafed or otherwise injured by moving about while the car is running. The heavy cable *D* must be similarly taped and secured. The lighting system is then independent of the starting system. By making a study of the wiring diagram and carefully noting the different circuits, the starting circuit may be isolated from the lighting circuits on any car having a two-unit system. Before replacing a blown fuse always examine for grounds, short circuits, or defective bulbs. Never replace a blown fuse with anything but another of the same capacity. If it is necessary to use the car before the trouble can be located, the grounded circuit can be left open by omitting its fuse. When all lights fail this is due to an open circuit between the battery and the fuse block. Examine the battery connections and connections of the cable *A* and wire *C* at the starting motor, connections *E* at the lighting switch, *F* at the ignition switch, and fuse block at *G* at the starting switch and the ground connection from the switch. If all of these connections are clean and tight, making good electrical contact, there is a broken wire between these points and the various circuits should be tried with the testing lamp.

Before making the usual tests for an inoperative generator see that the fuse protecting the field windings is intact. If this fuse has not blown and all connections are tight and properly made, remove wire from *B* which connects the generator to one terminal of the starting motor, and connect an ammeter in this circuit. Run the engine at a good speed, equivalent to 15 miles per hour or more. If the ammeter shows no current, while the commutator is bright, brushes bearing on it properly, and the battery connections are all right, test the armature and field windings with a lamp outfit to locate short-circuited windings. Do not remove the generator unless another is available for immediate installation. If it is necessary to run the car with the generator inoperative, the field fuse should be removed as a precaution against damage. To take the generator off, remove the circular cover plate from the front end of the chain case and take out the three bolts holding the generator to the rear side of the chain case. The driving chain should be supported through the opening at the front to prevent it from falling to the bottom of the chain case. It is not necessary to remove a pin connecting the links together. The chain may be tightened by loosening the three bolts mentioned and swinging the generator outward until the slack is taken up and then retightening the bolts.

Apperson. The generator on the Apperson system has a fuse protecting the field circuit, Fig. 233. Open connections between the generator and the battery will blow this fuse. It is located on the end of the generator adjacent to the terminals and is protected by an aluminum housing. To examine, remove the latter by taking out its two holding screws. The fuse is of the standard glass-tube type and may be lifted out of its clips with the thumb and finger. Do not attempt to pry a fuse out of its clips with a screwdriver or other tool. Before replacing a blown fuse examine all connections and wiring to see that they are in good condition. The engine must never be run with the battery disconnected, as this will blow the generator-field fuse. These instructions apply to all generators equipped with field fuses, although the placing of the latter will naturally differ in other systems. Instructions for testing circuits are the same as those for other two-wire systems. There are no grounds except in the ignition system. Tests for inoperative generator or starting motor and instructions for the removal of either of these units are the same as already given.

Scripps-Booth. With the higher voltage battery supplied (12-volt) in the single-unit system employed on this car, the cells are of considerably smaller capacity (35-ampere-hour as compared with 80-ampere-hour on the Apperson and 120-ampere-hour on the Winton), so that if the car has been left standing for long periods with the lamps on, or is only run for short periods during the daytime, thus giving the battery no opportunity to become fully charged, it will not have sufficient capacity to start the engine. As the motor-generator (dynamotor) automatically reverses its functions in accordance with the speed at which it is being driven by the engine, the latter should not be run with the switch in the *on* position at speeds corresponding to a travel of less than 6 miles per hour. Under such conditions, as when the car is left standing with the motor idling slowly, or when driving at a very slow pace as in congested traffic, the switch should be placed at the *idle* position. Should the engine stall when the switch is at the *idle* position, it should be shifted immediately to the *on* position. For failure of the current indicator to work see instructions on this point on page 237. The indicator should never show *discharge* when the car is running above 12 miles per hour.

If necessity requires the operation of the car with the battery disconnected, disconnect the wires from the generator at the machine, as otherwise it is liable to injury. On the earlier Scripps-Booth models, Fig. 234, the engine should not be used as a brake in running down hill except in emergencies, but on later models, Fig. 235, this may be done without injury to the dynamotor by throwing the switch to the *off* position. By referring to the wiring diagram it will be noted that the shroud-lamp and cowl-lamp bulbs are of the double-contact type; all others are of the single-contact type. All must be 14-volt lamps, 15 c-p. and 4 c-p. in the headlights and 2 c-p. for the others.

BOSCH-RUSHMORE SYSTEM

Twelve-Volt; Two-Unit; Single-Wire

Generator. The bipolar shunt-wound type of generator is made in two sizes, one for driving from pump shaft, and the other for silent-chain or belt drive.

Regulation. *Ballast Coil Employed.* The regulation is the inherent type, using a bucking-coil winding in conjunction with a so-called "ballast coil" which automatically cuts the bucking coil in or out of the circuit, according to the resistance of the ballast coil. Mention has been made in Elementary Electrical Principles, Part I, that the resistance of certain metals increases greatly with an increase in their temperature. This is particularly the case with iron, and advantage has been taken of this fact in the Bosch-Rushmore generator. The ballast coil consists of a few turns of fine iron wire on a fluted porcelain rod. The bucking coil, which is simply a *reversed* field winding, has a polarity opposite to that of the winding employed to excite the field magnets. Consequently, when a current passes through it, the effect is to oppose the excitation of the field magnets. The bucking coil is connected as a shunt across the iron ballast coil, Fig. 138, Part III. The resistance of the bucking coil is considerably greater than that of the ballast coil when the iron wire is cold or only warm, so that at low engine speeds practically all the current generated passes through the shunt-winding of the dynamo. However, the resistance of the wire increases at a constant rate with the current up to 10 amperes, after which it increases very suddenly owing to the heating effect of the current in the iron. Any current in excess of 10 amperes accordingly must pass through the bucking coil, which consequently tends to limit the output of the generator to that amount of current.

Starting Motor. *Method of Operation.* This is the series-wound bipolar type, as illustrated in section, Fig. 145, Part III, which shows the field windings as cut in half. As the illustration is to scale, the large size of the conductors in a series-wound field will be noted, this being necessary owing to the heavy current required to operate a starting motor. The starter pinion is mounted directly on the armature shaft without any intermediate gearing and the engagement of this pinion with the flywheel gear is automatic, as will be made clear by referring to Fig. 145, and to Fig. 157, Part III, showing the mounting of the Bosch starter on an automobile motor.

Refer back for a moment to the description of magnetic fields under Electrical Principles, Part I. See also the description of the action of a solenoid. It will be noted that every magnet has a magnetic circuit and that the lines of force comprising it are most numerous in close proximity to the poles of the magnet. In other words, the magnetic attraction is most intense at those points. The magnetic poles of the field of the Bosch starter are the metal projections each of which is held in place by two machine screws, top and bottom, as will be seen in the sectional view. It will also be plain that the armature of the starting motor is not directly in the magnetic field of these poles, and that it is held in this off-center position by the spring pressing against its shaft as seen at the left. The moment the switch is closed, however, and the field magnets are excited, the whole motor acts as a solenoid and forcibly pulls its armature into a central position against the spring, at the same time as it begins to revolve. This gives ideal conditions for meshing the starter pinion with the flywheel gear, as it is pulled against the latter and at the same time revolved, so that the moment its teeth correspond with spaces in the flywheel gear, it slips into engagement and begins to turn the engine over. As soon as the current is cut off by opening the switch, the spring returns the armature to its normal inoperative position and disengages the gears.

Starting Switch. There are two contacts on the starting switch, the first sending only a small amount of current through the starting motor, this being just sufficient to pull the armature into center and engage the gears, when a further movement of the switch sends the full current from the battery through the starting motor. This progressive movement of the switch and the two circuits between the battery and starting motor are shown in Figs. 236 and 237. It will be noted that the first movement of the switch throws the field of the starter in shunt with its armature, thus causing it to revolve slowly, while the further movement of the switch places the field in series. Fig. 238 shows the actual wiring diagram of the starting-motor circuit. In actual operation, the movement of the

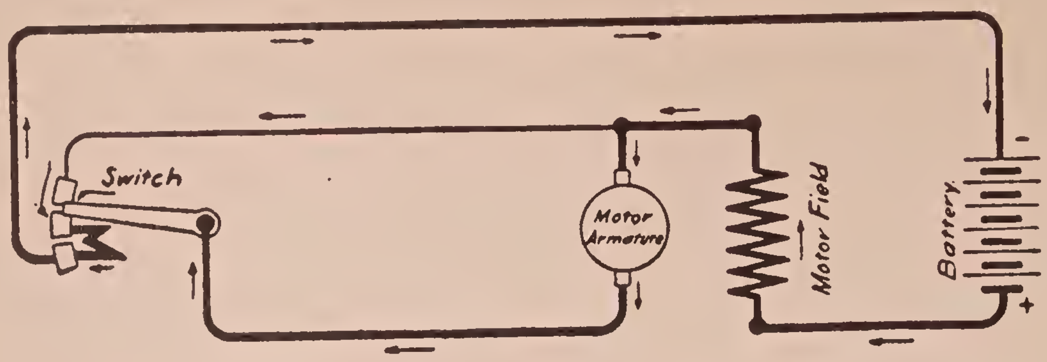


Fig. 236. Wiring Diagram for First Part of Downward Movement of Bosch Switch Pedal

switch is practically instantaneous. No damage will result in case the switch is held down after the engine starts, as the moment the latter begins to fire, the load on the starting motor is greatly reduced and the current consumption decreases to a point where the field coils no longer have sufficient pull to overcome the spring on the armature. The pinion on the shaft of the latter is automatically disengaged from the flywheel gear and the motor will only idle slowly, owing to the armature being off center.

Instruments and Protective Devices. A standard double-reading ammeter is supplied. The normal charging rate is approximately 20 amperes with the car running 20 to 25 miles an hour or over.

In addition to the usual battery cut-out which is an essential feature of most electric lighting and starting systems and will be found on most cars so equipped, whether it is specifically mentioned in the description of the various systems or not, a ballast coil is inserted in the charging circuit. This is similar to the ballast coil used in the regulation of the generator. This ballast coil is controlled

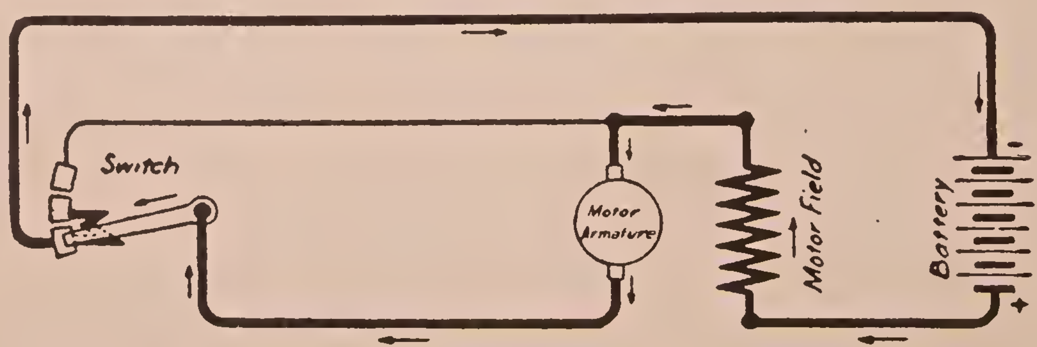


Fig. 237. Wiring Diagram for Circuit When Switch Pedal Has Completed Downward Movement

by the left-hand button of the switch (installation on Mercer cars), and its function is to prevent overcharging of the battery. By

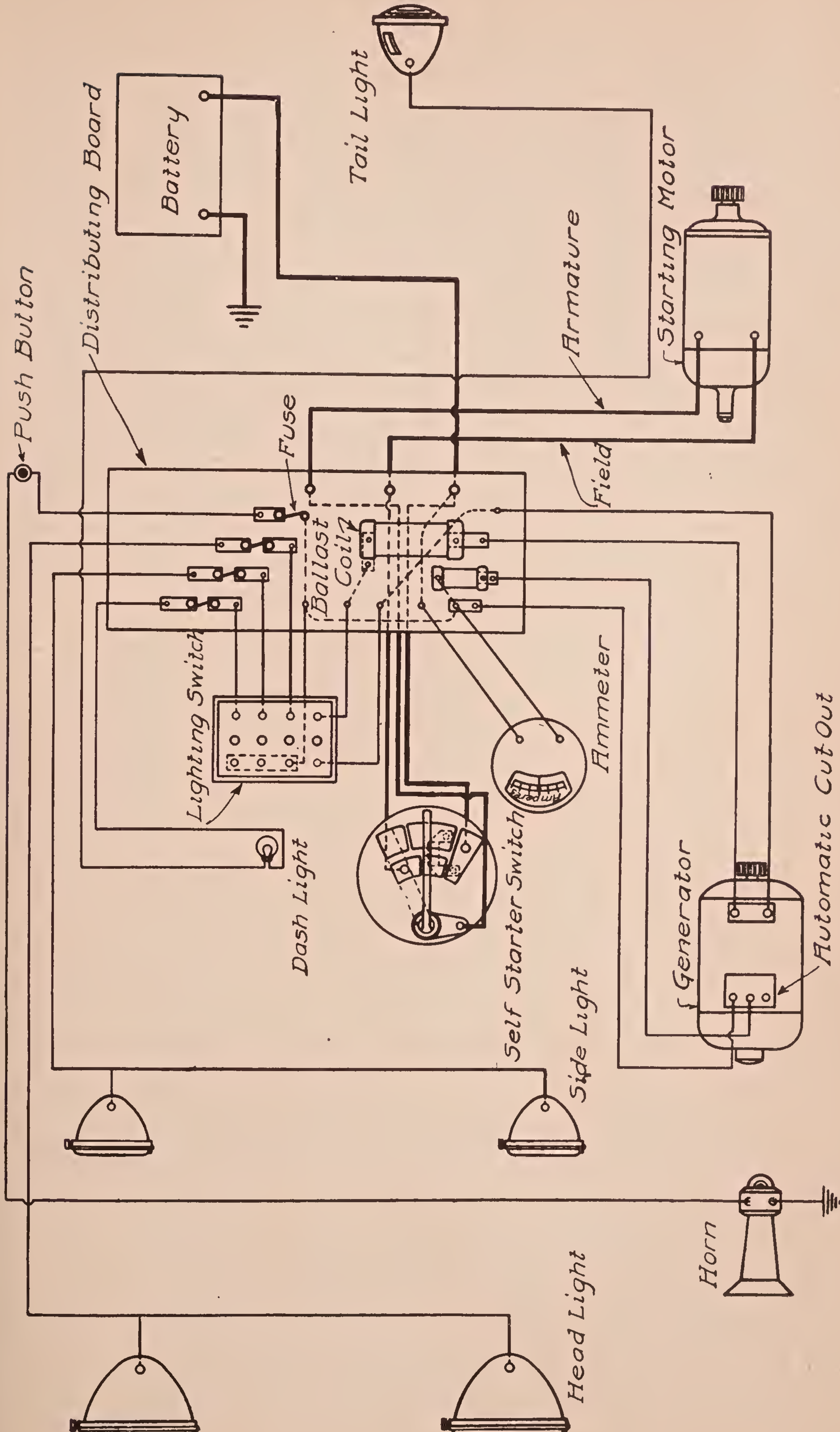


Fig. 238. Wiring Diagram for Bosch-Rushmore Starting System on a Mercer Car

putting it in the circuit the charging rate is reduced to 5 amperes. Where a great amount of day running is done, it is recommended that the ballast coil be left in circuit. All circuits, except starting motor, but including field coil of generator, are fused.

Wiring Diagram. The various circuits of the single-wire system, as employed in the Mercer installation, are shown in Fig. 238. The automatic cut-out for the battery circuit is mounted on the generator. Ground connections are not indicated in every instance, as in the case of the generator and the starter they are made within the apparatus itself, and this is also the case with the lamps, which are known as the single-contact type. The latter are employed in all single-wire systems. In this case, they must be 12-volt bulbs as six cells of battery are employed. In making lamp replacements, only bulbs of the proper type, i.e., single or double contact, depending on whether the system is one- or two-wire, and of the proper voltage must be used. This, of course, applies to all electric systems, as, where a 6-volt bulb is placed on a 12-volt system, it will be burned out immediately. A 12-volt bulb on a 6-volt circuit will burn very dimly, so that when only one headlight burns brightly the voltage of the dim burning bulb should be ascertained before looking for trouble elsewhere. If the manufacturer's label has disappeared from the bulb, it can be tested with dry cells, starting with four in series which should make a 6-volt bulb burn brightly, and increasing to eight in series for a 12-volt bulb.

Instructions. *Battery Charging.* With all lamps on, the lighting equipment consumes about 12 amperes; the side and tail lamps together take about 3 amperes, so that when the ammeter reading shows a consumption in excess of these figures for the conditions given, the usual tests should be made for short circuits or grounds. The latter will be the case also when the ammeter shows any *discharge* reading with all lamps off. Any discharge under such conditions is *leakage.* However small it may be, it should be investigated at once, as it will run the battery down. The trouble may consist of a short circuit in one of the lighting circuits or it may be due to current flowing back through the generator caused by the failure of the cut-out to work properly. In case the lamps burn dimly when the generator is at rest, it indicates that the charging rate is not sufficient to keep the battery up. This may be caused by a great deal of night running with the ballast coil in the charging circuit, as the charging rate is then only about 5 amperes. In the majority of instances, however, it will be found, probably, that the battery itself is responsible. For instructions on battery maintenance, see the article on Electric Automobiles.

The battery furnished on the Mercer has a capacity of 120 ampere-hours. The starting motor takes approximately 200 amperes for its operation which, with the engine in good condition, should not consume more than 10 seconds for each start. To replenish the current consumed by starting twelve times in a day, or say a total of two minutes' operation of the starting motor at the 200-ampere rate, the engine would have to run only about half an hour at the average charging rate of 15 amperes. With the current consumed by the lamps, based upon their use for 5 hours per night, plus the natural deterioration losses of the battery, drop in efficiency through switches, contacts, and wiring, approximately two hours of daylight running would be required to keep the battery fully charged. Night running can be disregarded where battery charging is concerned, as the total consumption of the lamps is practically the equivalent of the average charging rate. An undue brilliancy of the lamps would indicate a battery wire off or loose and should be investigated.

Fuses. When ammeter shows no reading of charging current with the engine running, the most likely place to look for the trouble is the fuse protecting the generator field circuit. (This applies to all generators so equipped.) The field fuse of the Bosch-Rushmore generator is located on the distributing board, and it may be tested by short-circuiting the ends of the fuse cartridge with a pair of pliers, a screw driver, or other piece of metal. In case the ammeter then registers a charging current, the fuse has been blown out and should be replaced with another of the same type and capacity. As all circuits, except the starting motor, are fused, a similar test can be carried out in case of the failure of any of them. The blowing of a fuse is usually due to a short circuit, and before replacing it, the reading on the ammeter should be noted when the fuse terminals are short-circuited with the pliers, the generator being idle. A short circuit will be indicated by the needle of the ammeter moving sharply to the limit of its travel on the scale. The use of the testing lamp for finding short circuits is given in connection with the instructions under Auto-Lite, Delco, Gray & Davis, and other systems.

Gear Meshing. Faliure of the starting motor to operate will be due to an exhausted battery in the majority of instances, but on cars that have seen considerable service, it may be caused by a settling or distortion of the frame resulting in binding of the gear teeth too tightly. This may be corrected by readjusting the mounting of the starting motor in its supporting cradle so that the gears mesh quite loosely. It should always be possible to push the gears into mesh by hand without any effort. Unusually slow operation of the starting switch may also cause failure of the starting motor to operate properly. The first contact of the switch places a small resistance in the circuit and too long a delay may overheat this resistance to such an extent as to burn it out. Over-rapid operation of the switch may also cause failure to start as no opportunity is allowed the gears to mesh. This will be indicated by their clashing and by the spinning of the starting motor. The switch should be given a comparatively slow but steady movement from the first contact to the second.

DELCO SYSTEM

Six-Volt; Single-Unit; Single-Wire

Variations. On cars of models prior to 1914, a 6—24-volt system is employed, the battery being charged in series-multiple, i.e., connected for charging so that it consists of four units of three cells each, while for starting, all twelve cells are in series to supply the motor windings of the single unit with current at 24 volts. The system is also arranged at 12 volts to meet special requirements as for fire-engine starting equipment. In general, however, the 6—24-volt Delco system will be found on pleasure cars prior to 1914 and the straight 6-volt system on all cars of this type subsequent to that date.

Dynamotor. Usually referred to as a motor-generator, though it is actually a generator-motor, i.e., a dynamo-motor which has been shortened to dynamotor, this term having been adopted by the Society of Automobile Engineers to designate the combination unit in question. A motor-generator as employed for transforming alternating current to direct current consists of two separate units, —a motor driven by alternating current, and a dynamo generating

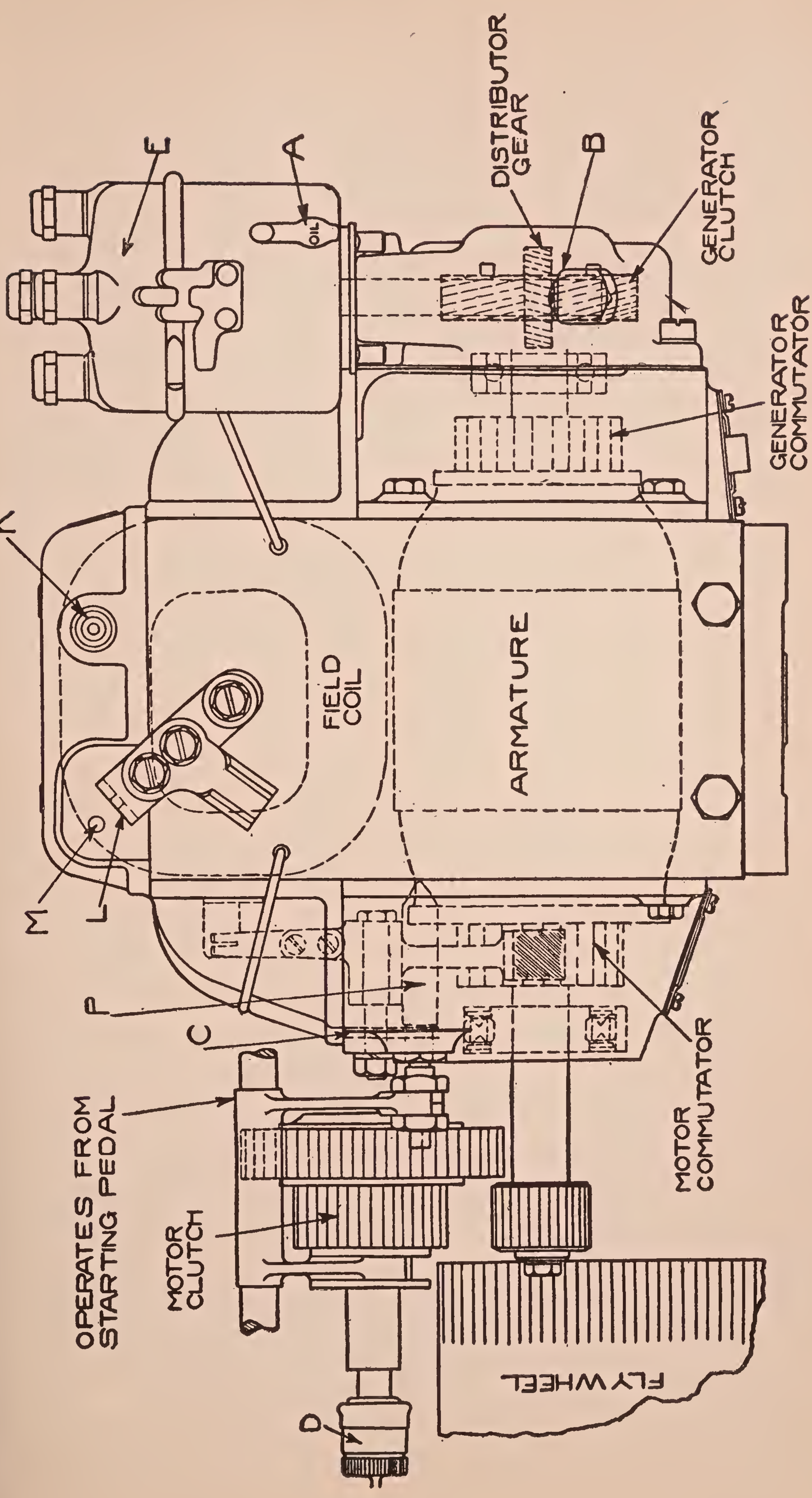


Fig. 239. Diagram of Delco Dynamotor for Single-Unit System

direct current, mounted on the same bed, and with their armature shafts directly coupled.

The Delco single-unit machine consists of two separate field windings and two independent armature windings, the latter being connected to separate commutators at either end of the shaft. In combination with this is an ignition timer and distributor mounted at the generator end and driven from the armature shaft through spiral gears. The generator is driven from the pump shaft of the engine through an overrunning clutch which permits the armature to run free when the unit is operating as a starting motor. At the starter end, the armature shaft carries a small pinion meshing with the larger unit of a pair of sliding gears, the smaller of which is adapted to slide into engagement with the gear ring of the flywheel. This arrangement is shown clearly in Fig. 239; it provides a double gear reduction between the starting motor and the engine. In the smaller of the two sliding gears is incorporated an overrunning clutch which releases the starting motor from the engine in case the latter should be speeded up without disengaging the starting gears, thus preventing damage to the starting motor by running it at an excessive speed.

Control. The necessary switches for putting the generator in circuit to charge the battery, and to cut it out of this circuit and put the starting motor in circuit with the battery to turn the engine over, are built into the machine and take the form of lifting brushes. Their operation is as follows:

To start, the ignition button on the switch panel on the dash is first pulled out. This connects the storage battery with the ignition circuit and with the armature of the dynamotor through a resistance which permits only a current of small value to pass. This current *motorizes* the generator and causes its armature to rotate slowly, giving it just enough speed to facilitate the meshing of the starting gears. The starting pedal is then depressed and during the first part of its travel it serves to engage the gears, Fig. 239. Then it withdraws the pin *P*, Fig. 240, allowing the motor brush switch to make contact with the motor commutator. At the same time it causes the generator switch to open, thus cutting out the generator during the cranking operation. As soon as the motor brush makes contact, the full current from the battery passes through the series-field winding of the motor element and through the corresponding armature windings, and sets the armature rotating at full speed.

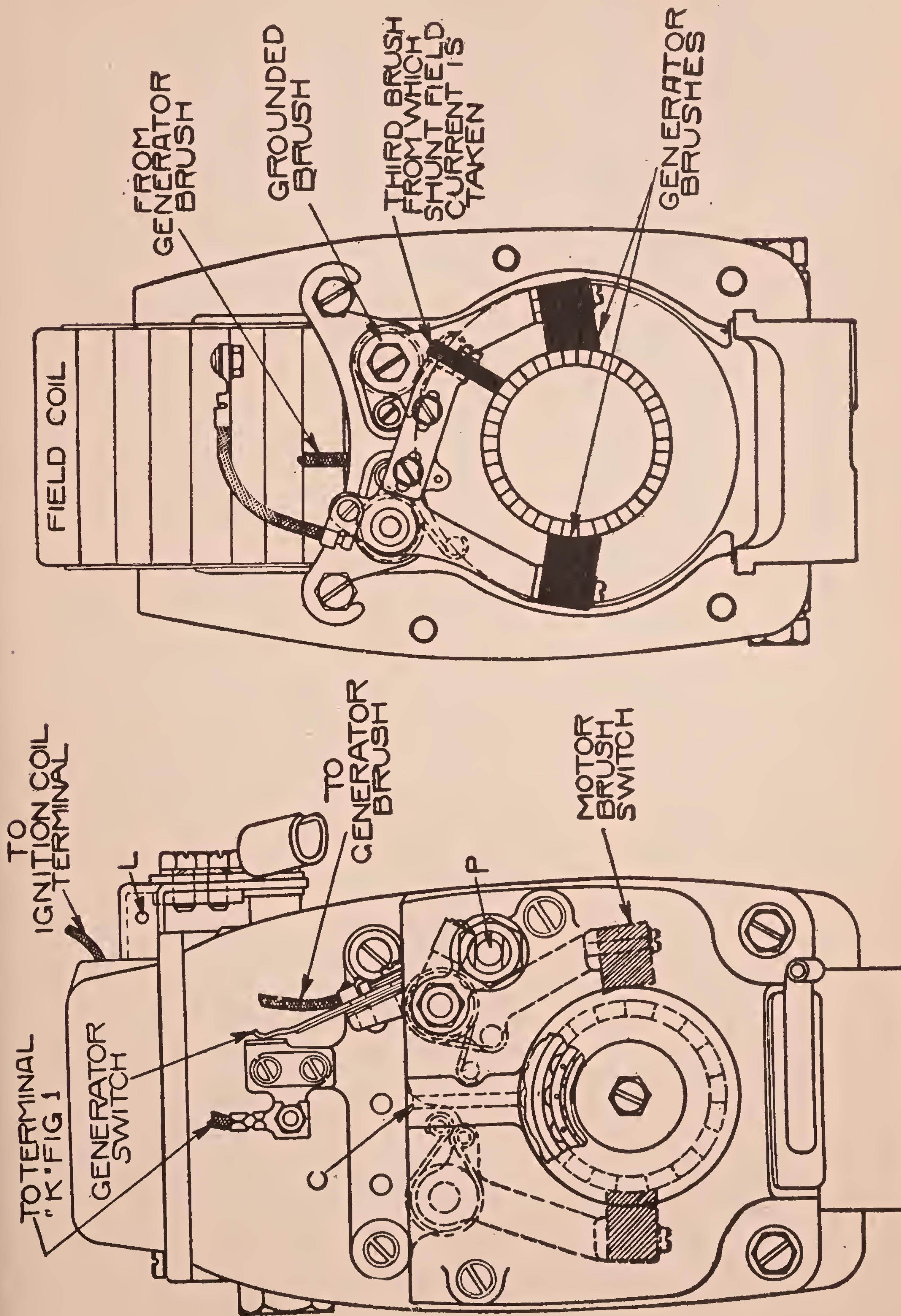


Fig. 240. Details of Brushes and Brush Switches, Delco Single-Unit System

The starter pedal is returned to the open position by a spring and as soon as it is released, the motor brush is lifted from its commutator and the generator switch is closed, thus cutting out the motor windings and connecting the unit to the storage battery as a generator. Charging begins when the engine reaches a speed corresponding to 7 miles per hour.

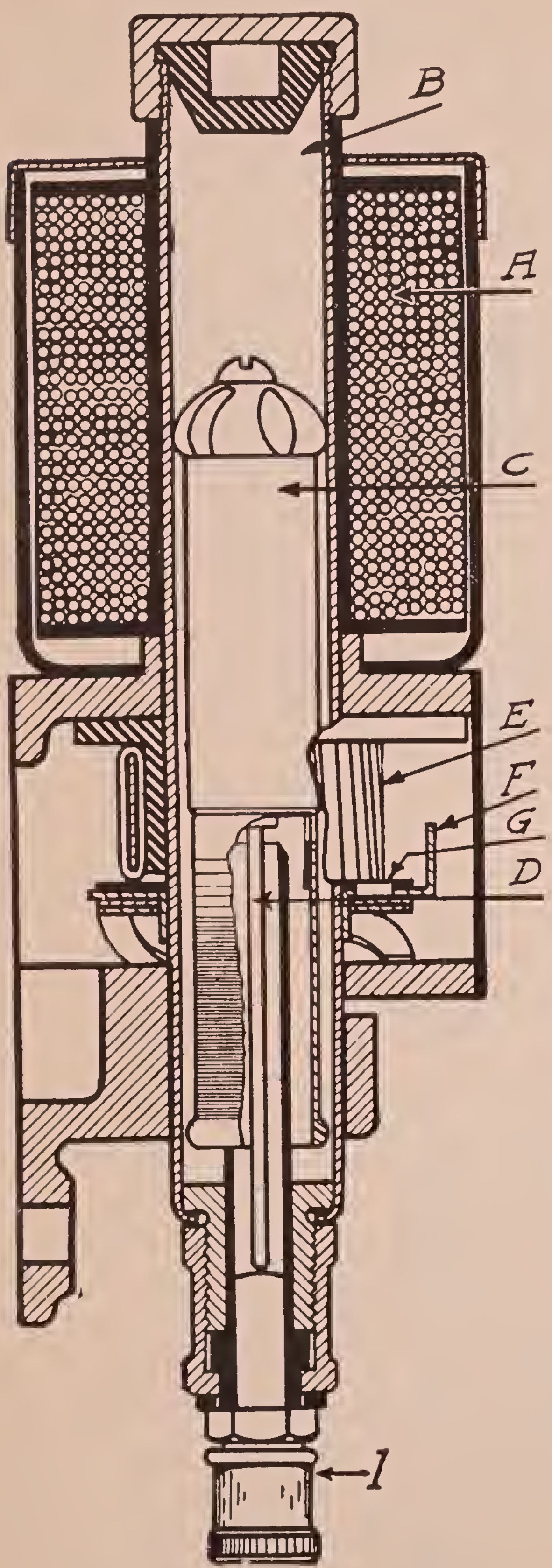


Fig. 241. Section Showing Delco Mercury-Bath Voltage Regulator

Regulation. *Constant-Voltage Control Type.* Of the four types produced the first employs a resistance variable in accordance with the speed. The regulator consists of a solenoid the core of which has a spool of resistance wire wound on its lower end, Fig. 241. This core or plunger *C* floats in a bath of mercury, and, in accordance with the depth to which it sinks in the mercury, more or less of the resistance wire is short-circuited by the mercury. The solenoid winding *A* is connected in shunt across the generator terminals so the current flowing through it and the magnetic effect exerted by it are always proportional to the voltage at the generator terminals. The resistance wire on the plunger of the solenoid is in series with the shunt-field winding of the generator. If there were no other forces than the buoyancy of the mercury and that of gravity acting upon the plunger it would remain at approximately the same height, but as the plunger is iron it is acted upon by the solenoid winding, the effect being to withdraw it from the mercury as the current through the winding of the solenoid increases, thus putting more and more of the turns of resistance wire on the spool in circuit. Hence, the greater the current flowing through the solenoid the greater will be the resistance in circuit with the shunt-field winding of the generator. To overcome the effect of temperature variation on its operation which would cause the charging rate to be higher than intended at high temperatures, and *vice versa*, the solenoid is wound and connected in series with a resistance wire of special material having a negative temperature coefficient (i.e., whose electrical resistance decreases with an increase in temperature), so that the total resistance of the solenoid circuit remains the same regardless of temperature changes. With a few exceptions, such as the Olds 1915 Model 55, this method of voltage regulation is not employed on cars subsequent to 1914.

Bucking-Coil Type. This is the type of regulation usually referred to as *inherent* in that it is accomplished by the windings of the generator itself. The latter is compound wound but the series field has a reversed polarity, so that its effect is to oppose that of the shunt winding.

Mechanically Varied Resistance. In this type the same principle as that employed in the first type described is used, i.e., that of weakening the generator field by increasing the amount of resistance in circuit with it in accordance with the speed, except that it is varied by mechanical means instead of electrical. The regulator resistance is in the form of a rheostat, the arm of which is controlled by a centrifugal governor driven from the shaft of the ignition distributor. As the weighted element of the governor expands under the influence of the increasing speed, it moves the arm of the rheostat over the contacts each of which represents an added resistance to the circuit.

Both the bucking-coil type and the mechanically varied type of regulation are employed in Delco systems installed on 1915 and subsequent cars, different models of the same make and the same year having different systems, so that instructions for their maintenance depend upon the system employed.

Third-Brush Method. As the voltage generated varies directly with the speed, it is evident that to maintain a nearly constant voltage with a variable speed, it becomes necessary to decrease the magnetic field as the speed increases. Since the magnetic field of the generator is produced by the current in the shunt-field winding, a decrease in this current as the speed increases will regulate the output. Bearing in mind that a current always produces a magnetic field, whether the latter is desired or not, the theory of this method of regulation will be clear from the following reference to Fig. 242. The full voltage of the generator is obtained from the brushes *C* and *D*. When the magnetic field from the pole pieces *N* and *S* is not disturbed by any other influence, each coil is generating uniformly as it passes under the pole pieces; the voltage from one commutator bar to the next is practically uniform all around the commutator. Therefore, the voltage from brush *C* to brush *E* is about 5 volts, when the total voltage between the main brushes *C* and *D* is $6\frac{1}{2}$ volts and current at 5 volts' pressure is supplied to the shunt-field winding. This voltage is sufficient to cause approximately $1\frac{1}{4}$ amperes to flow through that winding.

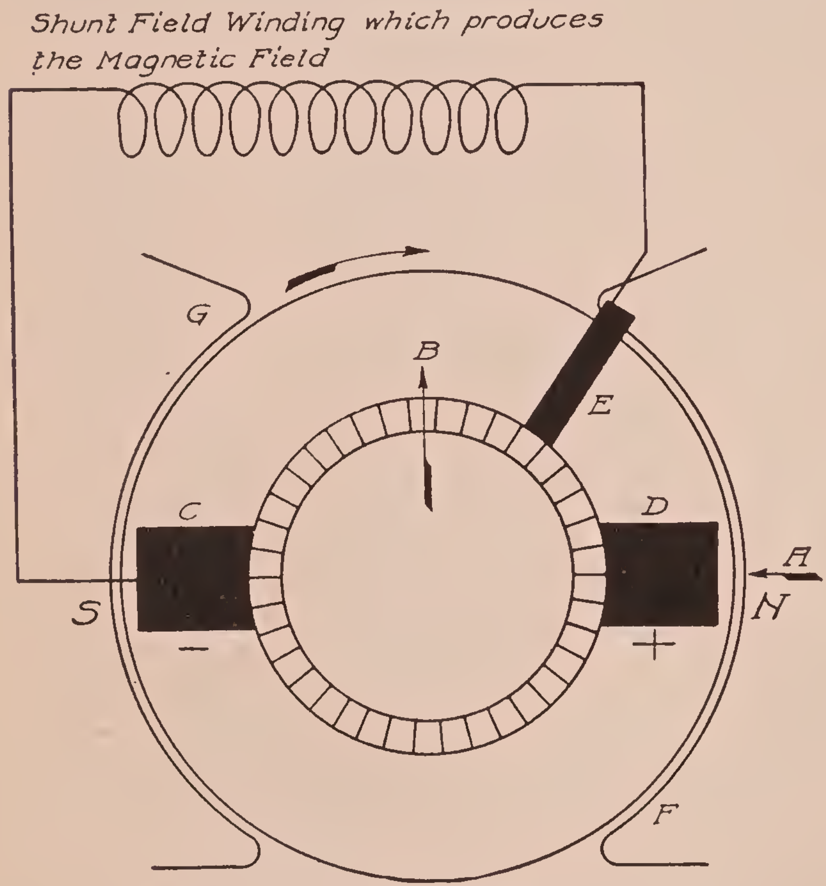


Fig. 242. Delco Third-Brush Regulator

As the speed increases, the voltage does likewise, charging the battery. This charging current flows through the armature winding causing a magnetic effect in the direction of the arrow *B* and the latter acts upon the main magnetic field, which is in the direction of *A*, with the result that the latter is twisted or distorted out of its original position, in much the same manner as two streams of water meeting are deflected from their original directions. This deflection causes the magnetic field to be strong at the pole tips *G* and *F*, and weak at the opposite tips, with the result that the coils generate a very low voltage while passing from brush *C* to brush *E* (the coils at this time are under the pole tips having a weak field) and produce the greater part of their voltage while passing from brush *E* to brush *D*. The amount of this variation depends upon the speed at which the generator is driven, thus decreasing the current supplied to the shunt field as the speed increases.

Protective Devices. *Battery Cut-Out.* In connection with Delco systems using the voltage regulator of the mercury type already described, a battery cut-out or a *cut-out relay,* as it is sometimes termed, is employed. Fig. 243 shows this cut-out together with a diagram of its windings. It consists essentially of a compound-wound electromagnet and a set of contacts designed to be closed by the movement of the pivoted armature of the magnet, and to be opened by a spring when the magnet is not excited. The compound winding consists of a voltage coil of a great many turns

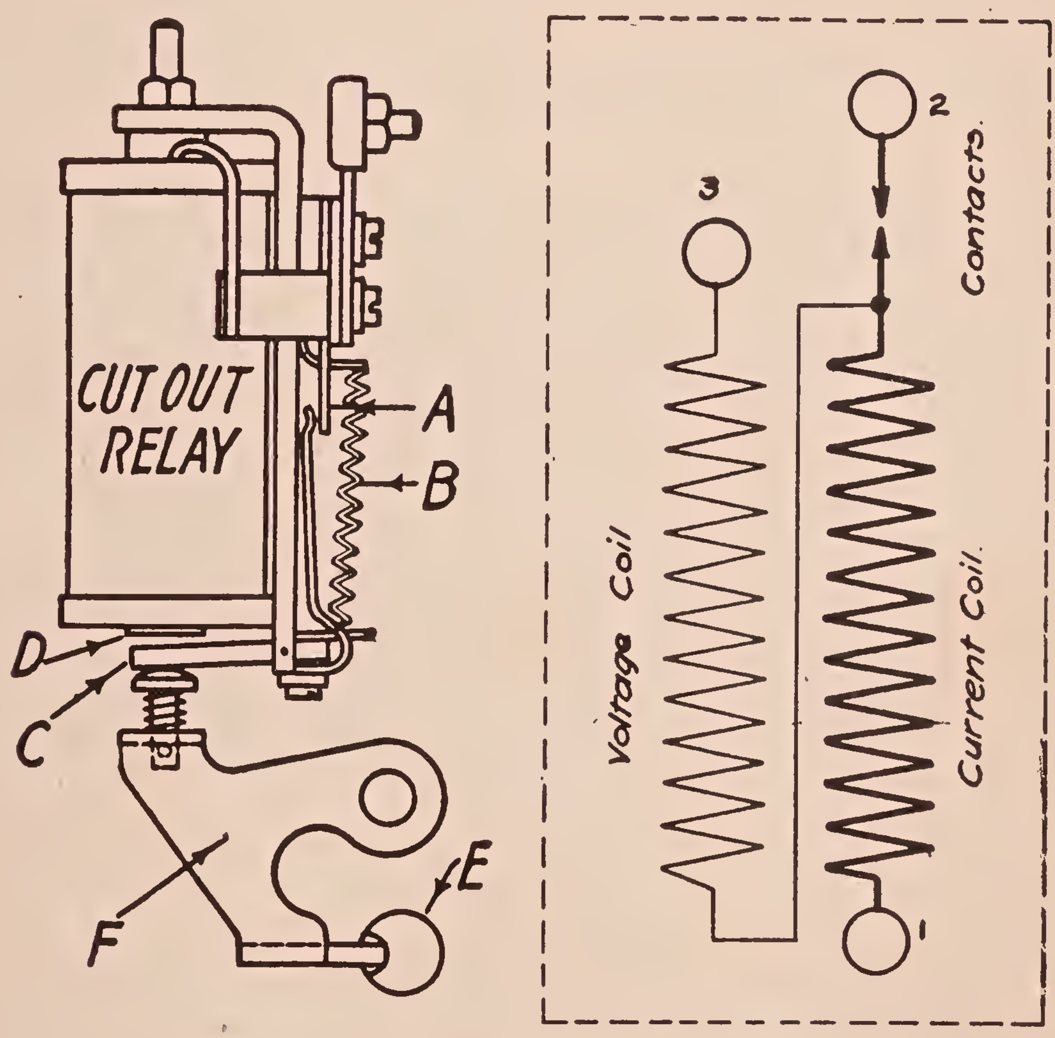


Fig. 243. Sketch and Diagram for Delco Cut-Out Relay

of fine wire, as shown at the left of the wiring diagram, and a current coil of a comparatively few turns of heavier wire. As soon as the engine begins to drive the generator the voltage of the latter "builds up" and when it reaches a value between $6\frac{1}{2}$ and $7\frac{3}{4}$ volts, the current passes through the voltage winding of the electromagnet and produces sufficient magnetism to overcome the tension of the spring *B*, attracting the armature *C* to the core *D* which closes the contacts at *A*. These contacts close the circuit between the generator and the storage battery and the whole output of the generator then flows through the current coil, greatly increasing the magnetism in the core in the same direction thus strengthening the pull on the armature *C* and holding the contacts tightly closed. When the generator slows down and the voltage drops below that of the battery, current flows from the latter to the generator through the current coil in the reverse direction. But, as the voltage coil is directly in circuit with the generator, the flow of current through it continues in the same direction, so that the magnetizing effect of the battery current through the current coil opposes that produced by the voltage coil and the latter is not sufficient to hold the armature against the spring. This causes the contacts to open and prevents any further flow from the battery through the generator. The relay is designed

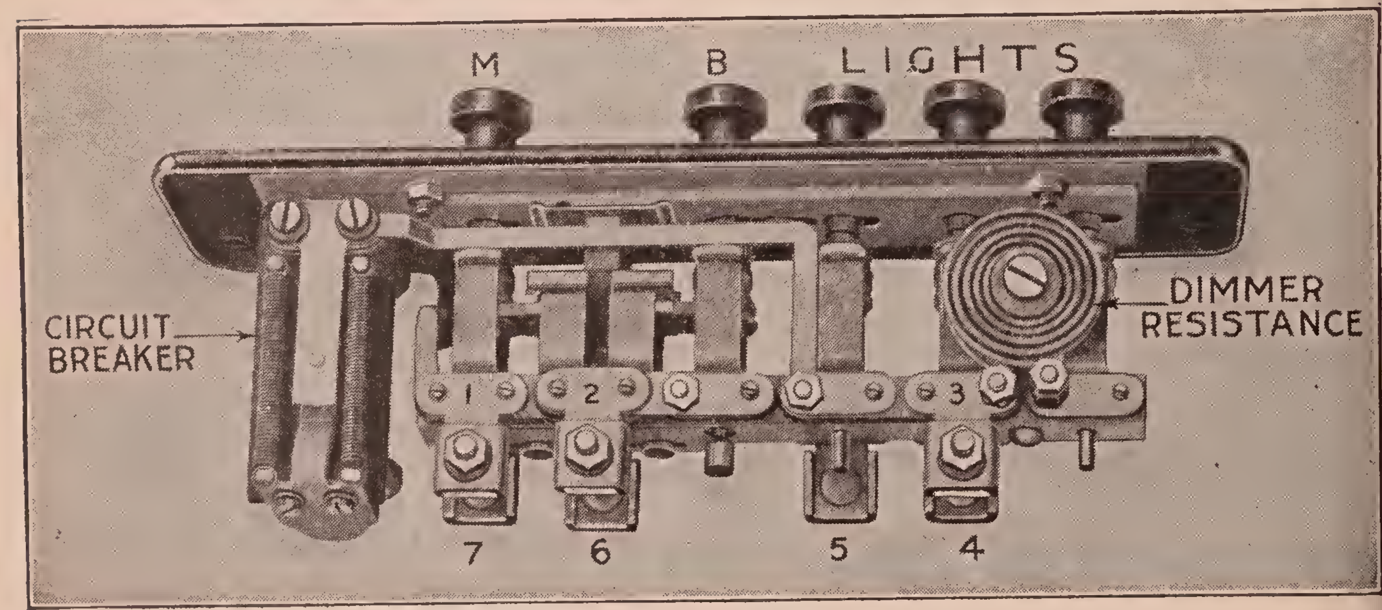


Fig. 244. Delco Combination Switch
Courtesy of Dayton Electrical Engineering Laboratories Company, Dayton, Ohio

to cut out the battery before the discharge current reaches a value of 1 ampere. As mentioned previously, but few cars subsequent to 1914 are fitted with systems using the mercury voltage regulator and only these systems are equipped with a battery cut-out.

Circuit Breaker. Delco systems fitted to cars subsequent to 1914 are protected by a circuit breaker. This takes the place of the fuse block and fuses employed in most other systems. It is mounted on the combination switch controlling the ignition, generator, and lights, as shown by Fig. 244. The button *M* controls the magneto ignition circuit, and the button *B* the dry-battery circuit for the same purpose. In addition both these buttons control the circuit between the battery and the generator for the purpose of *motorizing* the latter to start. When the circuit is closed by either button M or button B, current flows from the battery to the generator, when the engine is not running and when it is running at speeds below 300 r.p.m., but the amount of current flowing at the lowest engine speeds possible is so small as to be negligible. With the engine stopped, pulling out the button M sends sufficient current through the generator armature to run it slowly as a motor so that the gears may be meshed for starting. The amount of current thus employed is limited by a resistance unit in series with the shunt field of the generator.

In principle the circuit breaker is the same as an ordinary electric bell or buzzer, but its winding and the spring controlling its armature are such that it comes into action only when a heavy current passes through it. It is included in every circuit of the electrical system, including the ignition, with the exception of the starting-motor circuit, so that all the current used for every purpose except starting passes through it. But as long as the lamps, ignition, and horn are consuming the normal amount of current, it is not affected. In case any of the wires of these circuits becomes grounded, however, a heavy current passes through the circuit breaker, thus producing a strong magnetic pull which attracts the armature and breaks the circuit. This cuts off the flow of current and the spring again closes the contacts, causing the circuit breaker to pass an intermittent current by vibrating its armature. A current of 25 amperes is required to operate the circuit breaker, but once started it will continue to vibrate on a current as low as 3 to 5 amperes.

Wiring Diagrams. The Delco system is applied to such a number of different makes of cars, frequently varying in detail not only with each succeeding year's models of the same make, but also on different models of the same make and same year of production, that space would not permit of reproducing them all here. While these wiring diagrams differ in detail, they may, however, be divided into three general classes based upon the type of regulation used with the generator. At least one of each of these classes of wiring diagrams is reproduced here and familiarity with them will make it easy to trace the wiring of any system of this make.

Cadillac. Wiring diagram of the 1912 model is given in Fig. 245. Reference to a model as early as this is made to show the pro-

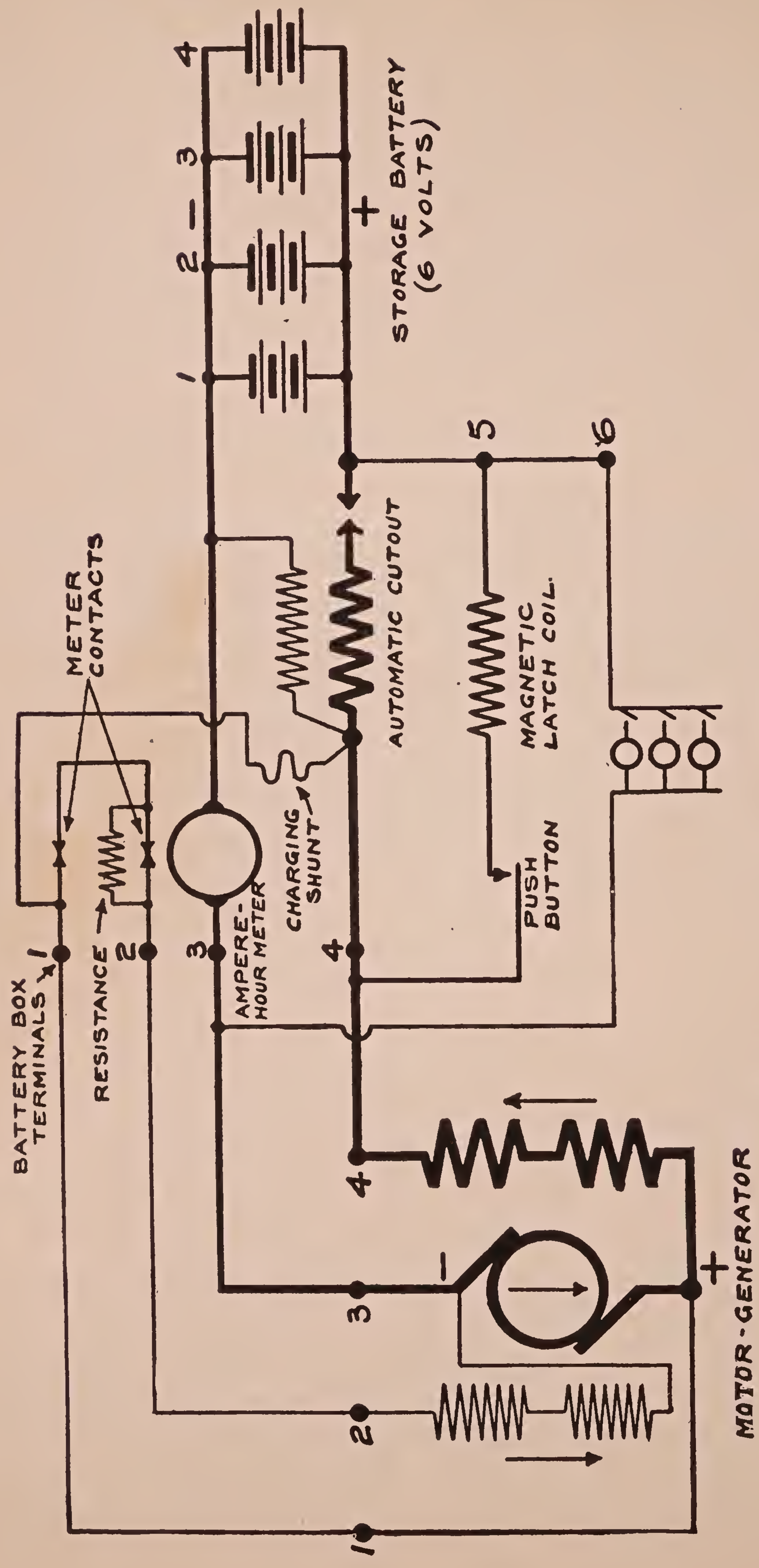


Fig. 245. Wiring Diagram for Generator Circuits of Delco Installation on Cadillac 1912 Models

gressive steps represented by each succeeding year; also because there are a great many of these cars still in use. Twelve cells of battery were employed though the dynamo generated current at 7 to 8 volts (nominally a 6-volt system), and as shown by the diagram which illustrates the connections of the generator circuit, the battery was divided into four groups of three cells each in series-multiple for charging. An ampere-hour meter showed the state of charge of the battery and also indicated how much current was consumed by the various circuits, including the starting motor. Regulation was by means of extra resistance inserted in the field circuit of the generator and an automatic battery cut-out was employed. The diagram shown in Fig. 245 is applicable to the connections of all the Delco 6—24-volt systems in use, when the machine

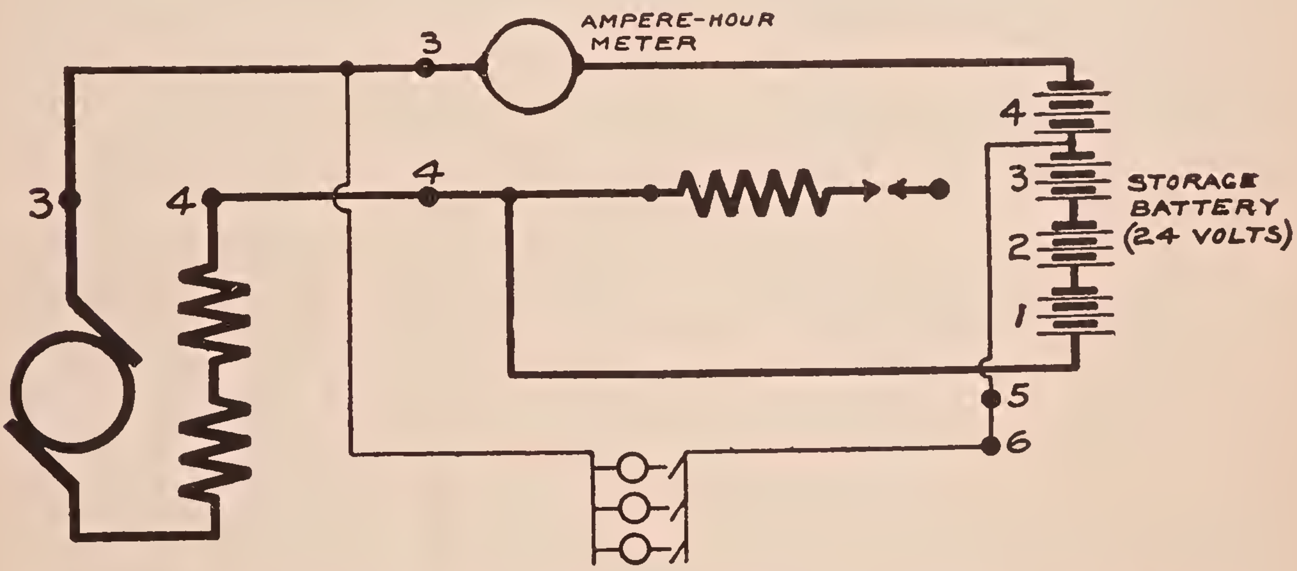


Fig. 246. Wiring Diagram of Starting Motor Circuit for All Delco 6—24-Volt Systems

is operating as a generator. The heavy lines indicate the main charging circuit. Fig. 246 shows the starting motor circuit of all the Delco 6—24-volt systems, and it will be noted that the cells of the battery are all in series to supply current at 24 volts, group No. 4 being utilized to supply current to the lamps at 6 volts.

Fig. 247 shows the wiring diagram of the Cadillac 1914 model. This is a straight 6-volt system, the generator being provided with the mercury type of voltage regulator previously described and an automatic battery cut-out. The starting-motor circuit is controlled by an external switch and the lighting circuits are protected by fuses. The earlier form of the combination switch controlling the ignition and the preliminary motorizing of the generator for starting, is seen at the right. The 1914 diagram is essentially the same, the chief

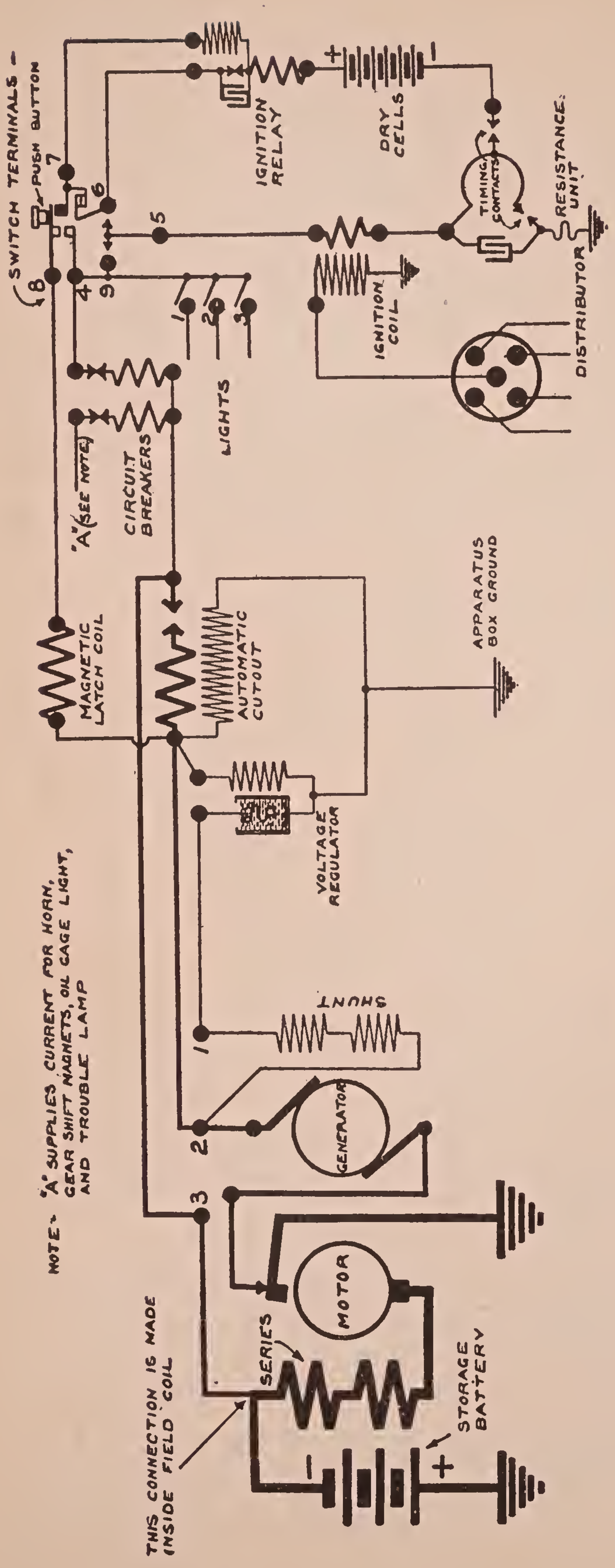


Fig. 247. Wiring Diagram for Delco System on Cadillac 1914 Models

difference being the substitution of the motor brush switch for the external switch controlling the starting motor. The fuses were also replaced by two circuit breakers, one for the main lighting circuits and ignition, and the other for the auxiliary lamps, horn, and the gear-changing solenoids, the model of that year being equipped with an electric magnetic gear shift in the transmission.

In the 1915 wiring diagram, Fig. 248, the method of regulating the generator has been changed to the mechanically varied resistance already described. One circuit breaker protects all fuses and a rotary form of combination switch controls all the circuits.

Buick. Two different types are employed on the 1915 models, the only distinction, however, being in the method of

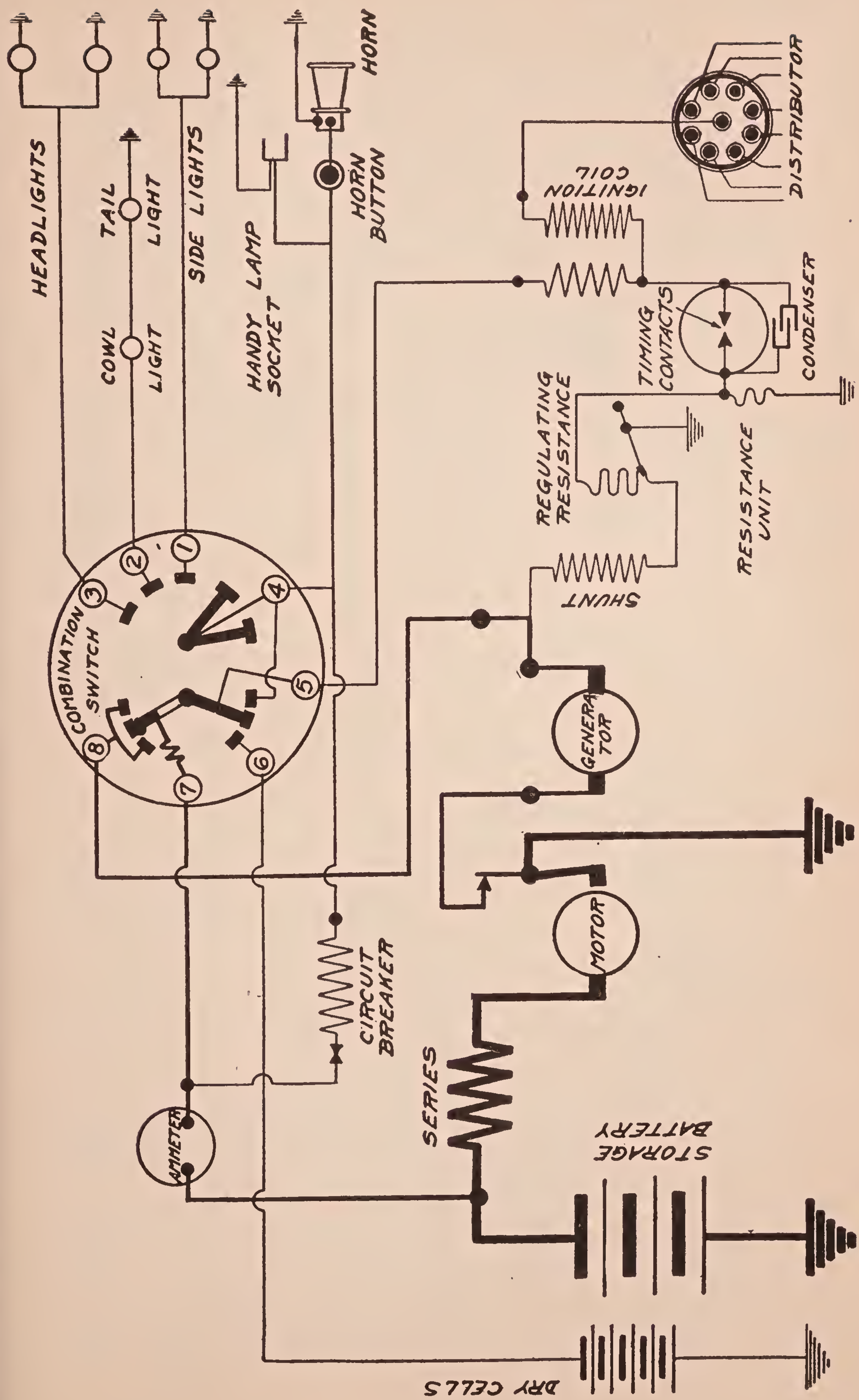


Fig. 248. Wiring Diagram for Delco System on Cadillac 1915 Models

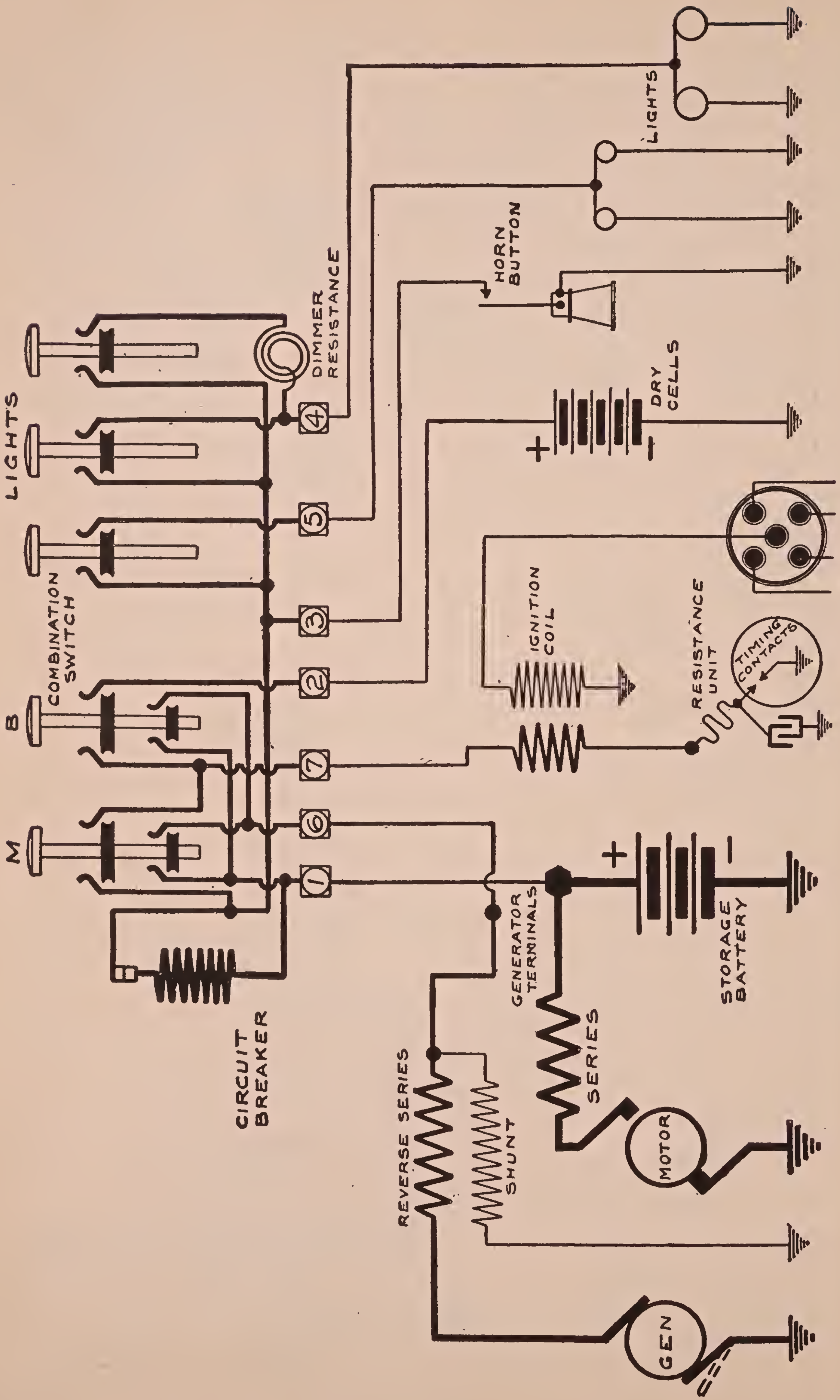


Fig. 249. Wiring Diagram for Delco Installation on the Buick Models C24 and C25

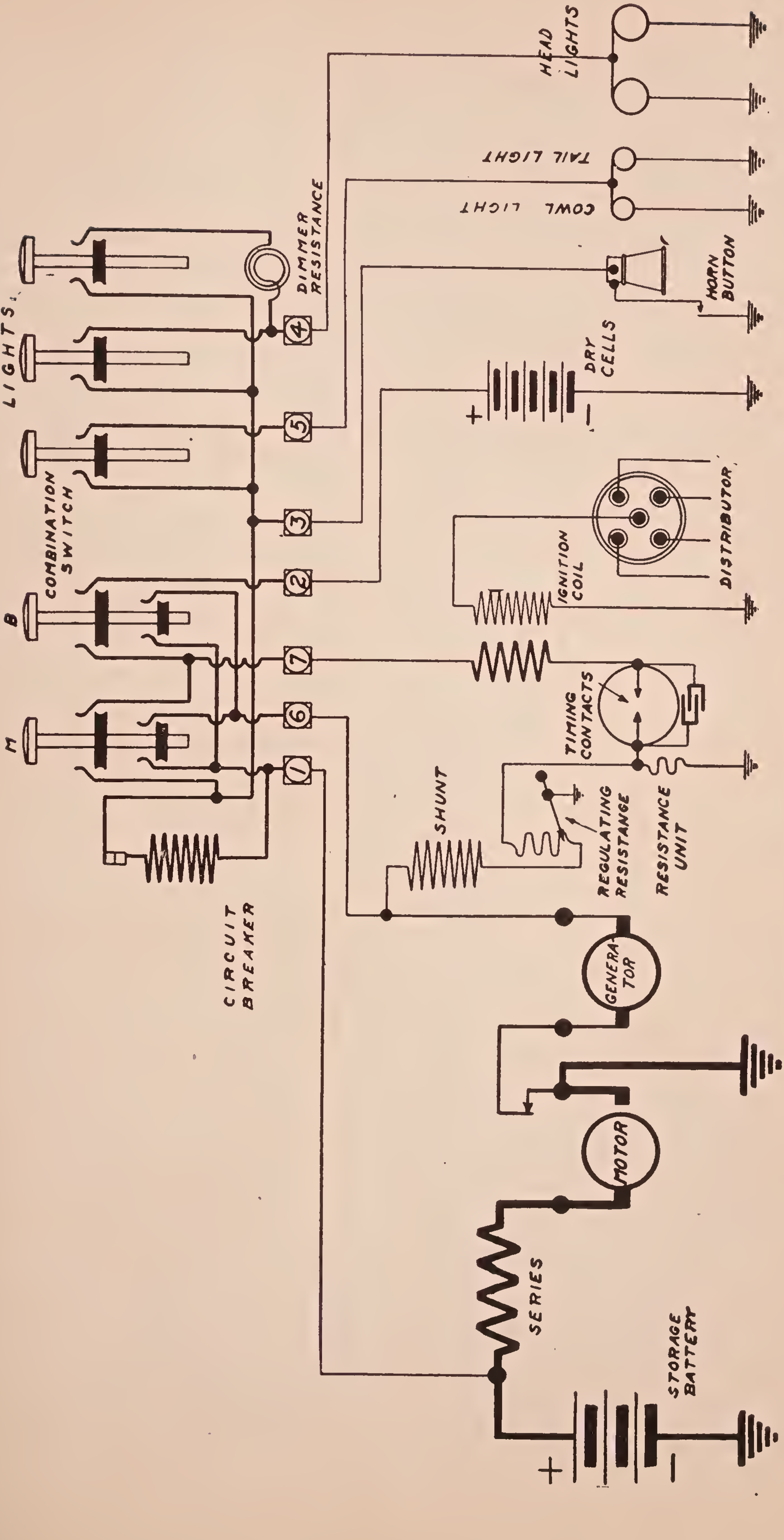


Fig. 250. Wiring Diagram for Delco Installation on Buick Models C36 and C37

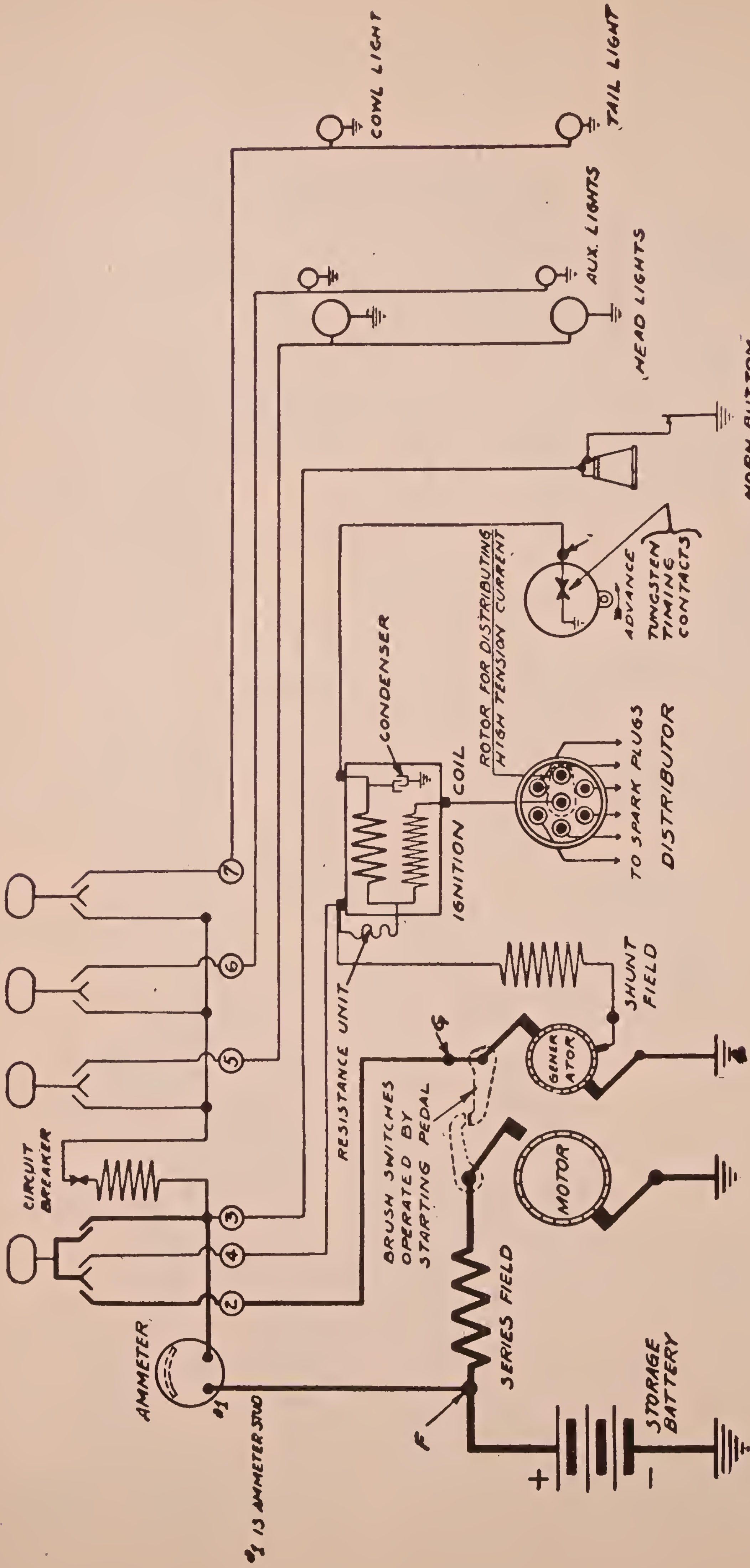


Fig. 251. Wiring Diagram for Delco Installations on Buick 1916 Models

generator regulation. That of Models C24 and C25 is by means of the reversed series-field winding or bucking coil, while that of Models C36 and C37 utilizes the mechanically varied resistance or rheostat operated by a centrifugal governor, as shown in Fig. 250. The buttons *M* and *B*, in each instance, control the ignition circuit, depending upon whether the storage or the dry battery is called upon for the ignition current as well as for the current to motorize the generator preliminary to starting. The remaining three buttons of the combination switch control the lights and dimming resistance and it will be noted that the circuit breaker forms a part of every one of the circuits except that of the starting motor.

On the 1916 Buick models, the generator is regulated by the third-brush method; the brush switches are operated by the starting pedal; only the lighting circuits are protected by the circuit breaker, and an ammeter is inserted in the circuit with the latter, Fig. 251. No mention is made of the details of any of the ignition circuits in these diagrams as that is taken up in the section on Ignition. Apart from the fact that the Oakland Model 50 has a 4-pole motor winding instead of the bipolar type shown in all the previous diagrams, the wiring diagrams of the Oakland models for 1916 are the same as those shown for the Buick. On the two 1915 models of the Cole, the distinction between the wiring diagrams is the same as that mentioned for the two classes of Buick models of the same year, i.e., one having the reversed series field, and the other the variable resistance controlled by the governor—the combination switch, circuit breaker, and other connections of the diagrams being essentially the same.

Instructions. If the starter, lights, and horn all fail, the trouble is in the storage battery or its connections, one of the latter being loose or corroded, or one of the battery jars being broken. When the lights, ignition, and horn all work normally but the starter fails to operate, the trouble is in the motor-generator or dynamotor and may be caused by the motor brush switch not dropping on the commutator, or by dirt or grease on the latter. Owing to the heavy current required by the motor in starting, if the lights are on at the time they will become dim when the starting circuit is closed but remain so only momentarily. In case they go out or become very dim when the starting-motor circuit is closed, it indicates that the battery is practically depleted. When the motor fires properly on the *M* button of the combination switch, but not on the *B* button, the wiring between the dry cells or the connection from the dry cells to the combination switch must be at fault. When the ignition works all right on button *B*, but not on *M*, the trouble must be in the leads running from the storage battery to the generator, or in the lead running from the small terminal on the generator to the combination switch, or in the battery connections, either of the cells themselves or the ground connections. If the supply of current from both the dry cells and the storage battery is ample, yet both ignition systems fail, trouble should be sought first at the timer contacts, then the coil, resistance unit, and the condenser. An examination of the timer contacts will show whether they are clean, square, and in good working condition; if badly burned and pitted, true them up square with a strip of fine emery cloth or a very fine flat file. The coil, resistance unit, and condenser may be tried out with the test-lamp outfit. If the lamp lights when circuit is made through the terminals of the coil or the resistance unit, it indicates that nothing is wrong with them, but if it lights on the condenser it shows that the insulation of the latter has broken down, as there should be no circuit through the condenser. The only remedy is to replace it. All of the units mentioned work in the same capacity for each system of ignition.

If, for purposes of making tests, it becomes necessary to remove any of the electrical apparatus from the car, or to make any adjustments, the storage battery should first be disconnected. This can be done most conveniently by removing the ground connection and winding the bare terminal with electrician's tape so that it cannot come in contact with anything that would cause a short circuit. The car should not be run with the storage battery disconnected from the generator or with the battery off the car unless the generator is short-circuited, as otherwise serious damage may result, as the generator is likely to be burned out.

Testing Cut-Out. If the battery is not charging properly, the generator being in good condition, or it is discharging too much current through the cut-out, the latter should be tested and adjusted to remedy the trouble. The cut-out is designed to close when the voltage across the terminals of the voltage coil is $6\frac{1}{2}$ to $7\frac{3}{4}$ volts.

To check this a voltmeter should be connected across the terminals, noting the reading at the point that the contacts close. It is designed to break the circuit when the discharge current is less than 1 ampere, preferably as close to the zero mark as possible to reduce the arc on breaking the contacts. This can be checked by placing an ammeter in the circuit in series with the current coil of the cut-out, noting the value of the current at the moment that the contacts separate. When properly adjusted the air gap should be $\frac{1}{32}$ inch.

To adjust the cut-out, the influence of both the air gap and of the spring tension must be taken into consideration. The air gap has little or no effect upon the point of cut-out, this being governed almost entirely by the spring tension, whereas the point of cutting in is governed by both the air gap and the spring tension. The following examples will illustrate the adjustments necessary in cases of excess voltage and current, excess voltage alone, insufficient voltage and excess current, and insufficient voltage alone.

Where the relay cuts in at 8 volts and cuts out when the discharge current is 2 amperes: Decrease the air gap, as this will lower the voltage of the cut-in point, but it will also increase the discharge current on cutting out. To overcome the latter, increase the spring tension slightly, noting the effect on the ammeter until the latter registers less than 1 ampere on cutting out.

Where the relay cuts in at 8 volts and cuts out at one ampere: Decrease the spring tension as this will cause the relay to cut in at a lower voltage and also to cut out after the current starts to discharge through it.

Where the relay cuts in at 6 volts and cuts out at 2 amperes: Increase the spring tension, causing the relay to cut in at a higher voltage and also to cut out at a discharge-current value of less than 2 amperes.

Where the relay cuts in at 6 volts and cuts out with a discharge current of 1 ampere: Increase the air gap slightly and also increase the spring tension so as to cause the relay to cut in at a higher voltage and also cut out at a discharge current of less than 1 ampere.

In this connection *cut in* signifies the closing of the contacts when the voltage coil becomes energized as the generator starts up; *cut out* indicates the opening of the generator-battery circuit when the current from the battery reverses the polarity of the current coil of the relay, thus opening the circuit and cutting out the generator from the battery circuit when the generator slows down and there is insufficient voltage for charging the battery. While these instructions apply particularly to the Delco relay or cut-out, all devices of this nature operate on the same principles.

Before making any adjustments, the contact points should be examined. If they are blackened or pitted, take two narrow strips of emery cloth about $\frac{3}{8}$-inch wide and both the same length. Place them together, emery sides out, insert between the contacts and while an assistant holds the points together, draw back and forth. If no assistance be obtainable, use a single strip and apply alternately to each contact point until its face is bright all over and true so that when the two points come together they touch evenly all over their surfaces. Do not take off any more than is necessary for this purpose, particularly where the contacts are platinum, as this simply wears them away uselessly and they are very expensive to replace. After cleaning, test for cutting in voltage and cutting out current and it frequently will be found that no adjustment is necessary.

These instructions regarding the cleaning of contact points apply with equal force to all instruments having contacts by means of which the circuit is frequently made and broken, for even platinum is burned away by the electrical action of the current which tends to carry the metal of the positive contact over to the negative in finely divided form, thus making a hole or crater on the positive and a cone or peak on the negative.

If the contacts are too badly burned to permit of their being put in good condition in this way, it will be necessary to replace them. After the relay has been reassembled with the new contacts, it should be adjusted in accordance with the instructions already given. When the contacts are correctly adjusted, both pairs will make contact at the same instant and clear across the line of contact so that when the relay is held up to the light, it is impossible to see light passing through any portion of the line of contact. When adjusting the relay make sure that all insulating bushings are in good condition and that the connections and coil terminals are free from breaks or grounds, as these would cause uncertainty in its operation.

Testing Circuit Breaker. In case the circuit breaker vibrates constantly, it indicates a ground in one of the circuits. Should it continue to vibrate when all of the buttons of the combination switch have been pushed in, the ground will almost invariably be found in the horn or its connections. In case no ground can be found in any of the circuits with the aid of the testing lamp, and the circuit breaker still continues to vibrate, connect the portable testing ammeter in the circuit, using the 30-ampere shunt. Then hold the circuit breaker closed and note the ammeter reading when it opens. This must be done quickly as the current necessary to keep it operating is small so that the ammeter reading will quickly drop to a value of 3 to 5 amperes. However, the circuit breaker should not open on a current of less than 25 amperes. If the ammeter reading indicates that it does so, increase the tension of the spring until the current necessary to operate it shows that it is properly adjusted. In case the instrument shows that the circuit breaker is opening at the proper point but still continues to vibrate, another series of tests for a ground must be made as the latter is the cause of the trouble.

Seating the Brushes. To insure proper operation of the machine either as a generator or as a motor, it is necessary that the brushes fit the commutator exactly and that they make good contact over their entire surface. If they do not, sparking will occur and the commutator will become burned and blackened, cutting down the efficiency of the machine. The brushes are the only wearing parts of a direct-current generator or motor, and, as this wear on them is constant, they will require attention at intervals to keep them in good condition. Whenever sufficient wear has taken place to make the contact uneven, the brushes must be fitted to the commutator or *sanded in.* Cut a sheet of No. 00 sandpaper in strips slightly wider than the brush. Emery cloth must *never* be used for this purpose. It is metallic and will tend to cause short circuits in the commutator. The strip of sandpaper is wrapped around the commutator so as to make contact with at least half of its circumference in the manner illustrated in (*a*) and (*c*) of Fig. 252. The smooth side of the paper is laid on the commutator so that the sanded side rubs the brush. By drawing the sandpaper back and forth, it is possible to fit the brush very accurately to the commutator. It will be obvious that if the sandpaper be applied to the commutator as shown in (*b*) and (*d*) of the same illustration that the brush will only touch at its center and there will be excessive sparking between the gaps thus formed.

A high squeaking note caused by the operation of either the generator or motor is an indication that either the brushes or the

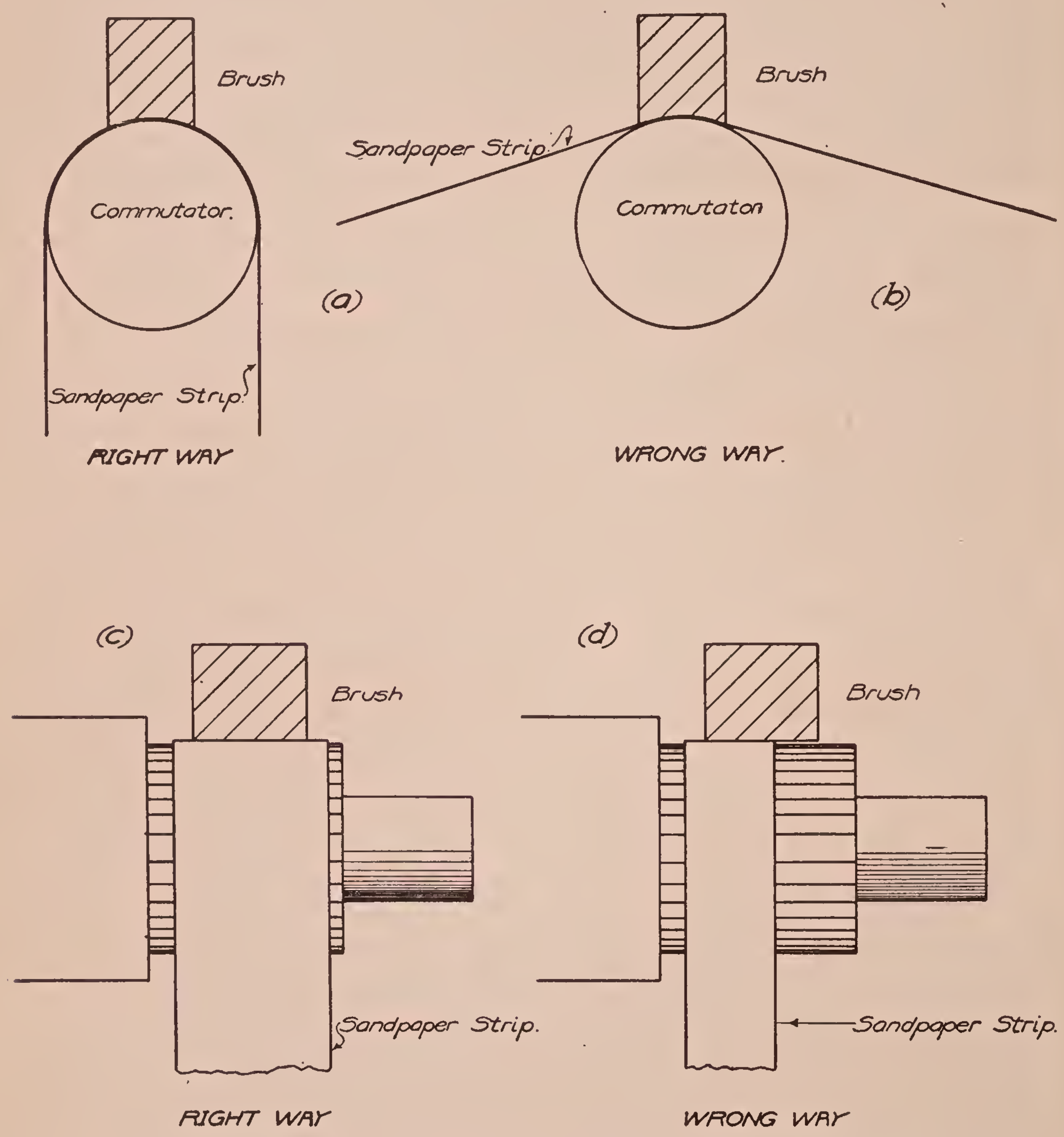


Fig. 252. Method of Sanding-In Brushes

commutator need sanding in as the latter will become roughened from the wear. It should be smoothed up by taking strips of the same grade of sandpaper sufficiently wide to cover the commutator, applying them by wrapping in the same manner but with the sanded surface on the commutator bars. This can be done most effectively by running the machine through its other commutator for a few moments while holding the sandpaper strip in place on the first. If, after this smoothing up, the mica insulation between the bars of the commutator is flush with the surface of the copper bars, it must be undercut as directed in the following section. On most of the Delco machines it will be found possible to sand in the upper and lower brushes separately by this method, but in a number of cases on account of the construction of the machine, it will be found advisable to sand in both motor brushes, as well as both generator brushes at the same time. It is unnecessary to lubricate either the motor or the generator brushes or commutators, as this simply results in gumming them and causes

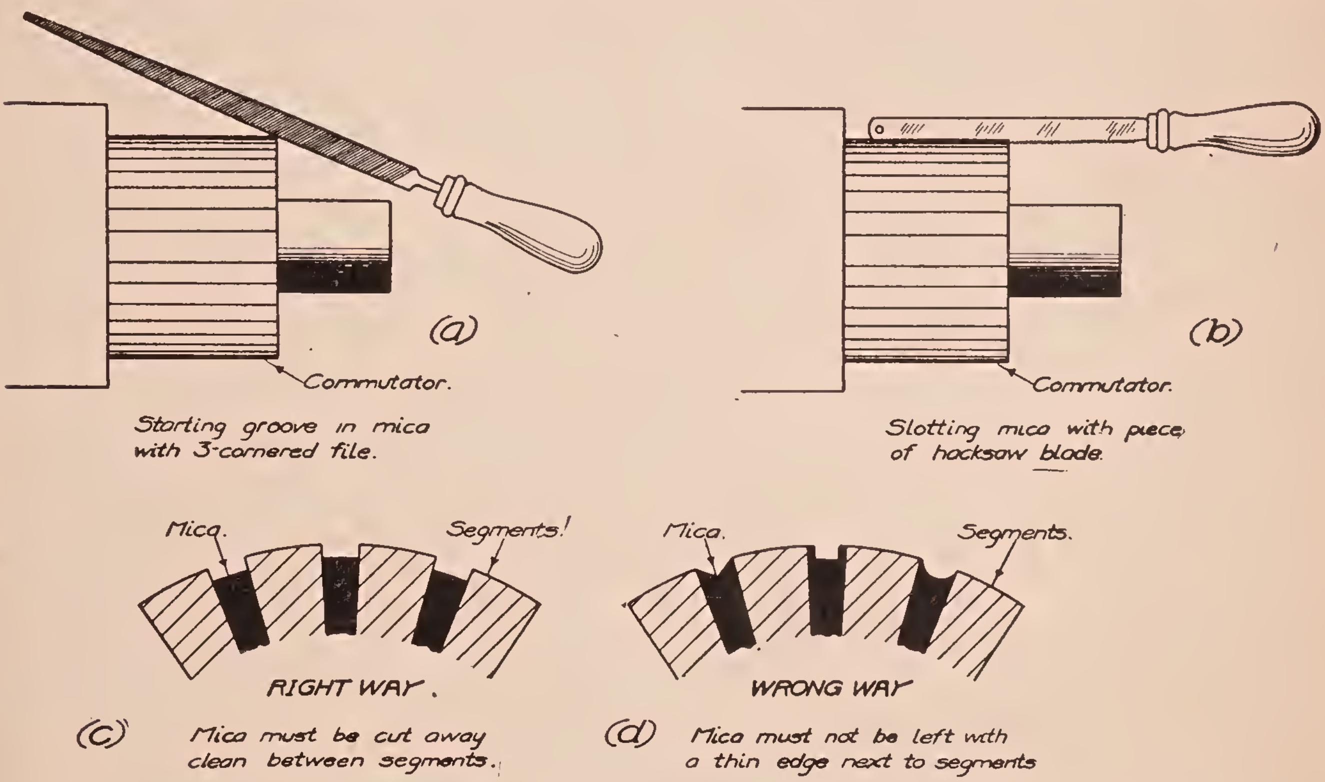


Fig. 253. Method of Undercutting Mica Insulation on Commutator

grit and dirt to collect on the commutator and cut grooves in both it and the brushes.

Commutator Maintenance. In the course of time, the commutator bars of the generator will wear down until they are flush with the mica insulation separating them. When this occurs there will be excessive arcing at the brushes which in turn will cause the copper to be burned away until it is level with or below the surface of the mica. This condition will be indicated by a rusty black color on the commutator bars. To prevent this condition progressing too far, the commutator should be inspected at intervals and cleaned occasionally with sandpaper as directed. Should this cleaning show that the mica is *high*, it should be undercut as follows:

The armature is removed from the machine and placed in a lathe, truing up both commutators until they are perfectly concentric. This should be done carefully and then as fine a cut as possible taken to avoid wasting the copper needlessly. When the commutators have been trued up in the lathe, cut out mica between the commutator bars of the generator only. For this purpose a piece of hacksaw blade should be fixed in a handle, as shown in Fig. 253, and its teeth ground off until they will cut a slot that is just slightly wider than the mica insulation. The cut need not be more than $\frac{1}{32}$ inch deep. In this way a rectangular slot, free from mica, will be obtained between each two adjacent commutator bars. After undercutting the mica, the edges of these slots should be beveled very slightly with a three-cornered file in order to remove any burrs which would cause excessive wear of the brushes.

It is unnecessary to undercut the mica on the motor commutator, as, wherever metal or metallic brushes are used on Delco machines, they are sufficiently hard to keep the mica flush with the surface of the copper as it wears down without any undue arcing at the brushes, whereas in the case of generators provided with carbon brushes, the carbon is not hard enough to do this. After completing the undercutting, the commutator when viewed from the end should show clean-cut rectangular slots between the bars, as in the left-hand view, Fig. 253. The machine should then be reassembled and the brushes sanded in to the commutator, as previously described. This operation of fitting the brushes to the commutator will be necessary whenever anything has been done to the commutator, when new brushes are installed, or when the third-brush location is readjusted to vary the output of the machine on generators having this type of regulation.

These instructions for fitting the brushes, cleaning the commutator, and undercutting the mica of the commutator of any machine equipped with soft carbon brushes, apply with equal force to all makes of generators and starting motors employed on automobiles. Next to the battery the brushes and commutators will be found to demand most attention—or to put it another way, they will be found to constitute a cause of trouble only second in importance to the battery. It must not be assumed, however, that all blackening of the commutator is caused always by high mica. Any one of the following conditions may cause the commutator to assume an appearance similar to that produced by high mica: Generator brushes of improper size or material, as where replacements other than those supplied by the manufacturer of the machine have been installed. Insufficient spring tension on brushes—all springs slacken up in time and they should be examined at intervals to see that the brushes are being held against the commutator firmly. Overloading of the generator caused by partial failure of the regulating device or other cause. An open or short circuit in the generator windings, or a short circuit between generator and motor windings in a single-unit machine like the Delco.

DISCO SYSTEM

Single-Unit Twelve-Volt Type

Dynamotor. The dynamotor is bipolar with both windings connected to the same commutator.

Regulation: Operating Devices. Constant current-control regulation by means of a vibrating regulator is employed. (See description of the Ward-Leonard regulator, Fig. 139, Part III.)

Battery Cut-Out. The cut-out is of the conventional type, combined with the current-control regulator.

Switch. The switch is the spring-controlled type which is only closed for starting.

Disco Two-Unit Six-Volt Type

Units. Both the generator and the starting motor are of the bipolar type, the motor being designed to operate through a Bendix drive.

Instructions. As both types of the system are characterized by standard features throughout, instructions given in connection with other systems apply here.

DYNETO SYSTEM

Single-Unit Twelve-Volt Single-Wire Type

Dynamotor. *Nonstalling Feature.* Both windings are connected to the same commutator. No battery cut-out is employed, control being by means of a single-pole knife-blade switch which is closed for starting and left closed as long as the engine is running. This switch also controls the ignition circuit. Upon closing the switch, the dynamotor acts as a starter and turns the engine over; as soon as the engine takes up its cycle and drives the dynamotor above a certain speed, the latter automatically assumes its functions as a generator and begins to charge the battery. Whenever the speed drops below that point, the dynamotor again acts as a motor to turn the engine over, this characteristic being termed the "non-stalling" feature of the system. Provided the battery is sufficiently charged, the dynamotor will always act as a starter (the switch being closed) whenever the engine is inadvertently stalled or its speed drops below the generating point of the machine.

Instructions. The switch must never be left closed with the engine stopped, and, when the car is stopped, the engine must not be allowed to idle at a very low speed, as in either case the battery will be run down. Instructions for lack of generator capacity, the location of ground or short circuits, and the like are the same for other systems.

Dyneto Two-Unit Six-Volt Type

New Features. This six-volt type, with multipolar generator and starting motor, was not placed on the market until the beginning of the present year (1916), so that details are not available.

FORD STARTERS

Special Models of Standard Makes. Thousands of Ford cars are being equipped annually with electric lighting and starting systems, and many of these machines will come to the repair man's attention, both for the installation of the system in the first place and for aid in maintaining it in good operating order subsequently. Several manufacturers of this class of equipment include a model specially designed for installation on the Ford. Some of the more prominent are the Disco, Genemotor (G. E. Co.), Gray & Davis, North East, Splitdorf, and Westinghouse. It naturally follows that the same general principles of operation and practically the same features of design are carried out in these special models as are to be found on the apparatus of the same make designed for larger cars. Likewise the general principles already outlined, and which apply to all of the larger models, apply to the Ford type equally well. Consequently, it is hardly necessary to describe each of the makes in question, so that only a general reference is made to them.

Genemotor for Ford Only. Of those mentioned, the only one that is made specially for the Ford without reference to any other models of the same manufacture is the Genemotor, built by the General Electric Company. In the model built for 1915, the first year it was put out, it was designed for silent-chain drive, but the subsequent model is driven by a shaft. The silent-chain drive is a feature common to all of the others mentioned. Likewise all are of the single-unit type. The dynamotor is hung on a special bracket provided for the purpose and which is attached at the forward left-hand side of the motor to two of the cylinder-head studs, special studs being supplied for the purpose. In some instances, such as Gray & Davis, one of the holding bolts of the cold-water pipe (the lower pipe of the thermo circulating system) is also utilized as a support.

Drives. *Installation.* All drives are the same in principle, though practically every one differs somewhat in detail. The fan-belt pulley on the crankshaft is replaced by a sprocket. The old fan bracket is discarded and replaced by one specially designed for the purpose. This carries a pair of sprockets, or a single sprocket, depending on whether the drive is first to the fan bracket and then to the dynamotor, or direct to the latter from the crankshaft and then back to the fan. As full instructions for installation accompany each particular outfit, it is hardly necessary to go further into detail on this point. Regardless of the make, however, it is absolutely essential in every case that the sprockets be accurately lined up and that they be maintained in this condition if the system is to operate satisfactorily. Lack of alignment will cause rapid and uneven wear on the sprockets and chain and will also exert a harmful strain on the armature shaft of the dynamotor and on the crankshaft of the engine.

Adjustment. Proper tension of the chain is also an important factor. The amount of slack should be just perceptible when the chain is idle, so that when it is running, one side will be taut and there will be a perceptible sag in the other. Anything tighter than this will put an unnecessary strain on the sprockets, shafts, and the mounting of the machine. As the silent chain will stretch slightly in service, simple means of taking up this extra slack are provided in every instance. In the case of the Westinghouse, there is incorporated in the sprocket a cushioned drive in the starting direction and a friction drive in the generating direction, the friction engage-

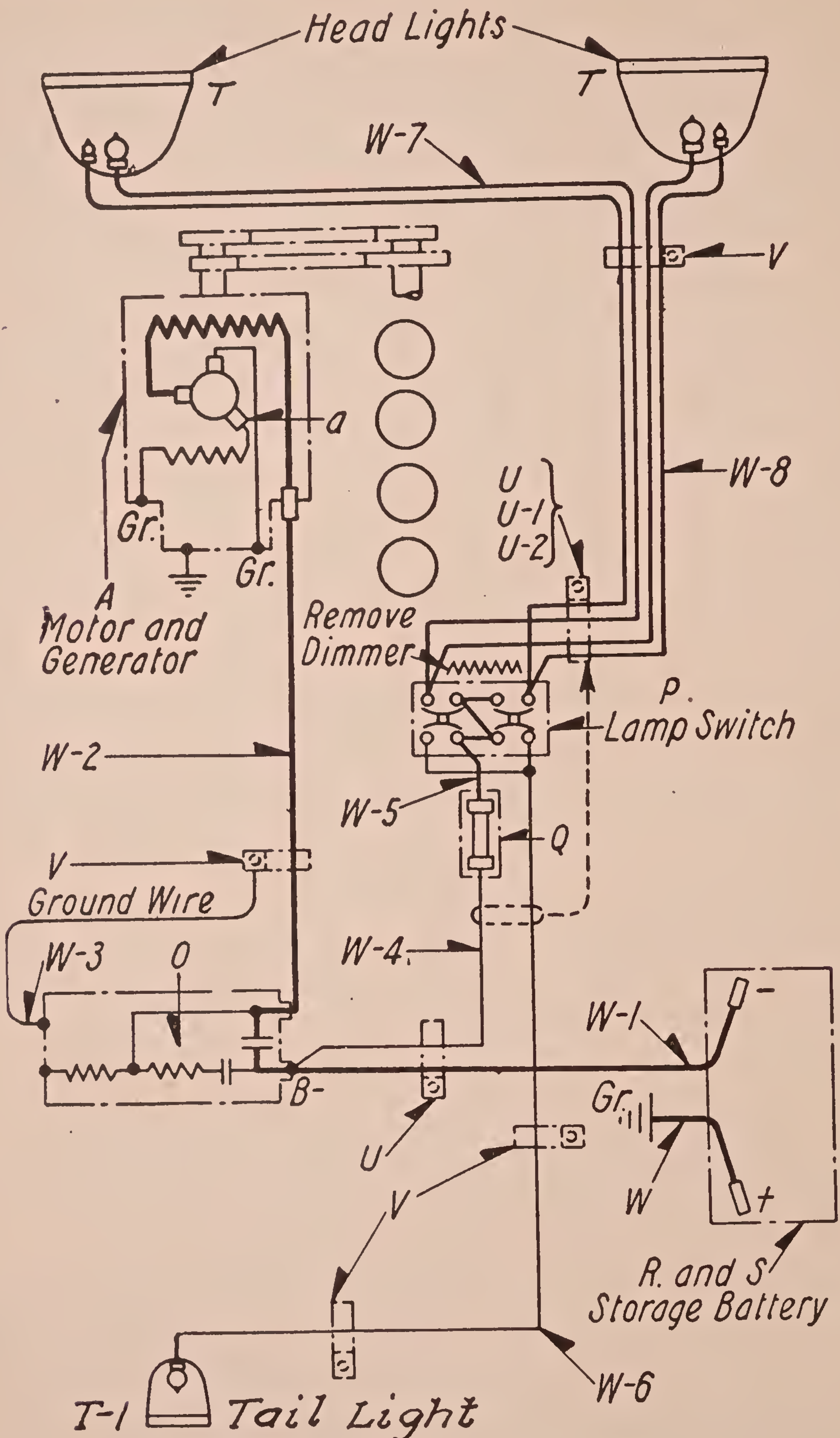


Fig. 254. Wiring Diagram for Westinghouse-Ford Installation Using Two-Bulb Headlights

ment being adjustable for wear. With the exception of the later model of the Genemotor, the unit is mounted in every case at the forward upper left hand of the motor. The Genemotor is mounted at the rear on the same side and is placed at an angle so that its shaft runs down at a slant to the level of the crankshaft, from which it is driven through gears.

Regulation. The regulation is either identical with that of the larger models of the same make of equipment or it may be slightly modified to conform with the special design of the unit. For example, the regulation of the Gray & Davis is by means of the same type of regulator employed on the other models; and the North East is of the inherent type, as in its larger models.

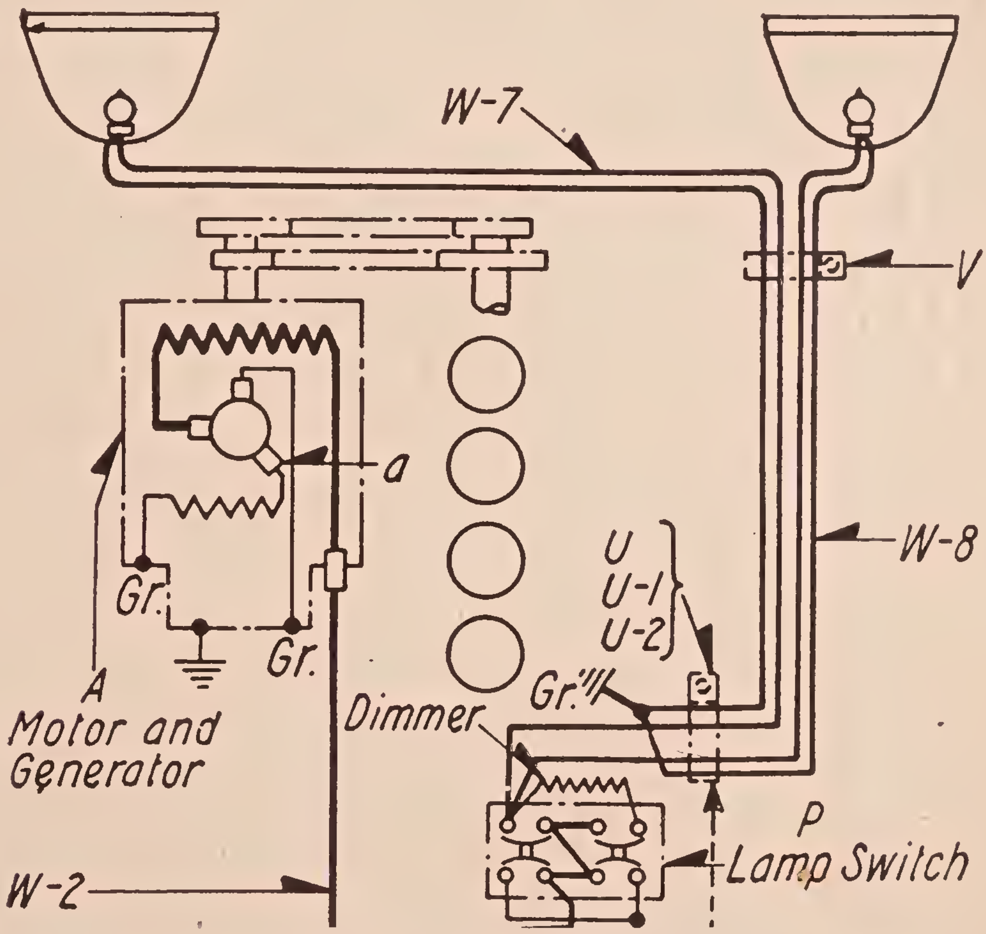


Fig. 255. Upper Portion of Westinghouse-Ford Installation Using Ford Lamps and Dimmer

Voltage. The majority of makes of starting systems designed for installation on the Ford employ a 6-cell or 12-volt storage battery. The Gray & Davis 6-volt system is an exception to this.

Wiring Diagrams. *Variations Same as in Large Cars.* The same variations are to be found as on larger cars, some systems employing the single-wire and others the two-wire type.

The Westinghouse is an example of the single-wire type, as shown in Fig. 254 and Fig. 255. The two diagrams are given, as in some cases it is desired to retain the electric lights provided with the

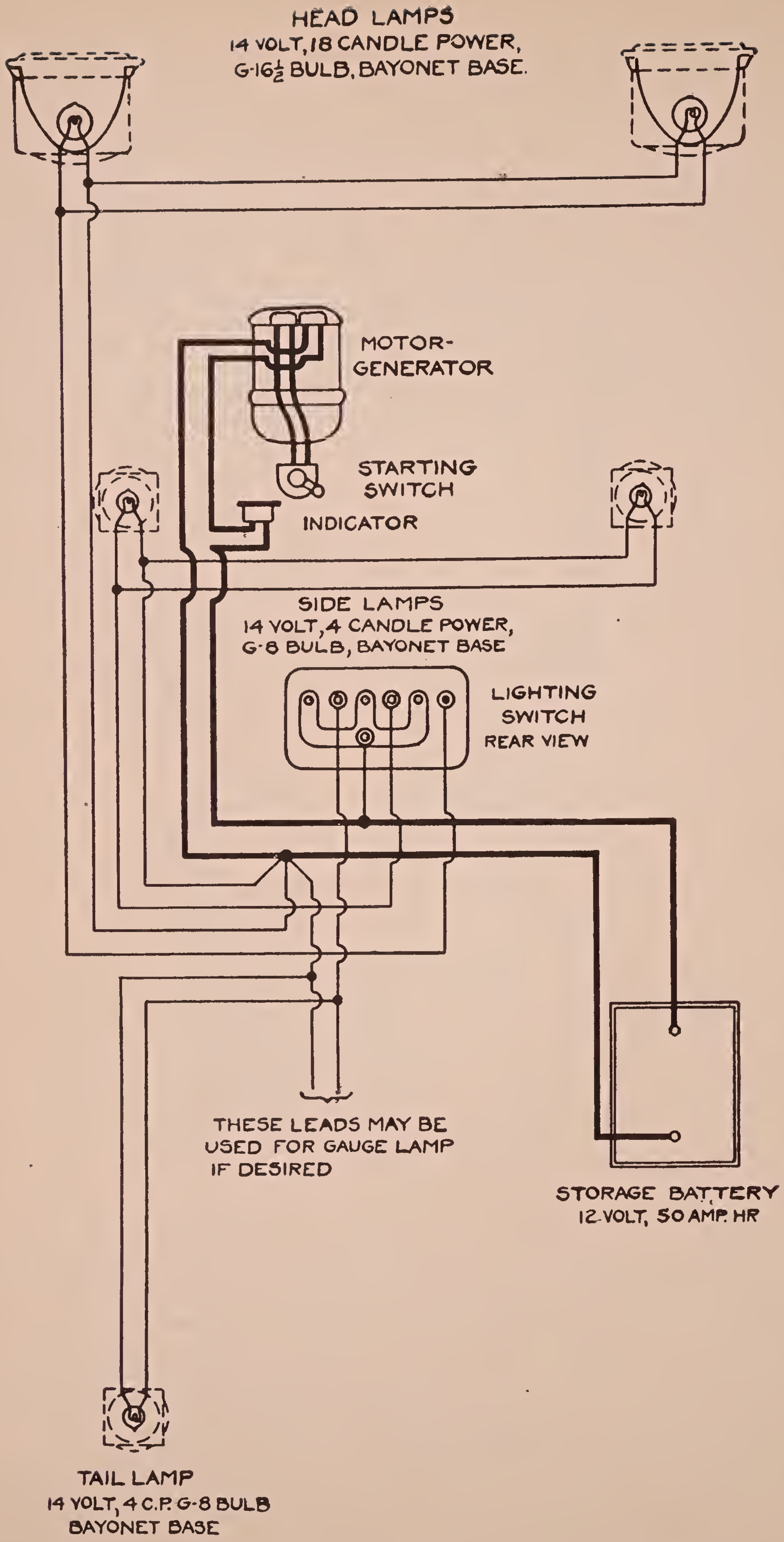


Fig. 256. Wiring Diagram for North East Installation on Ford Cars

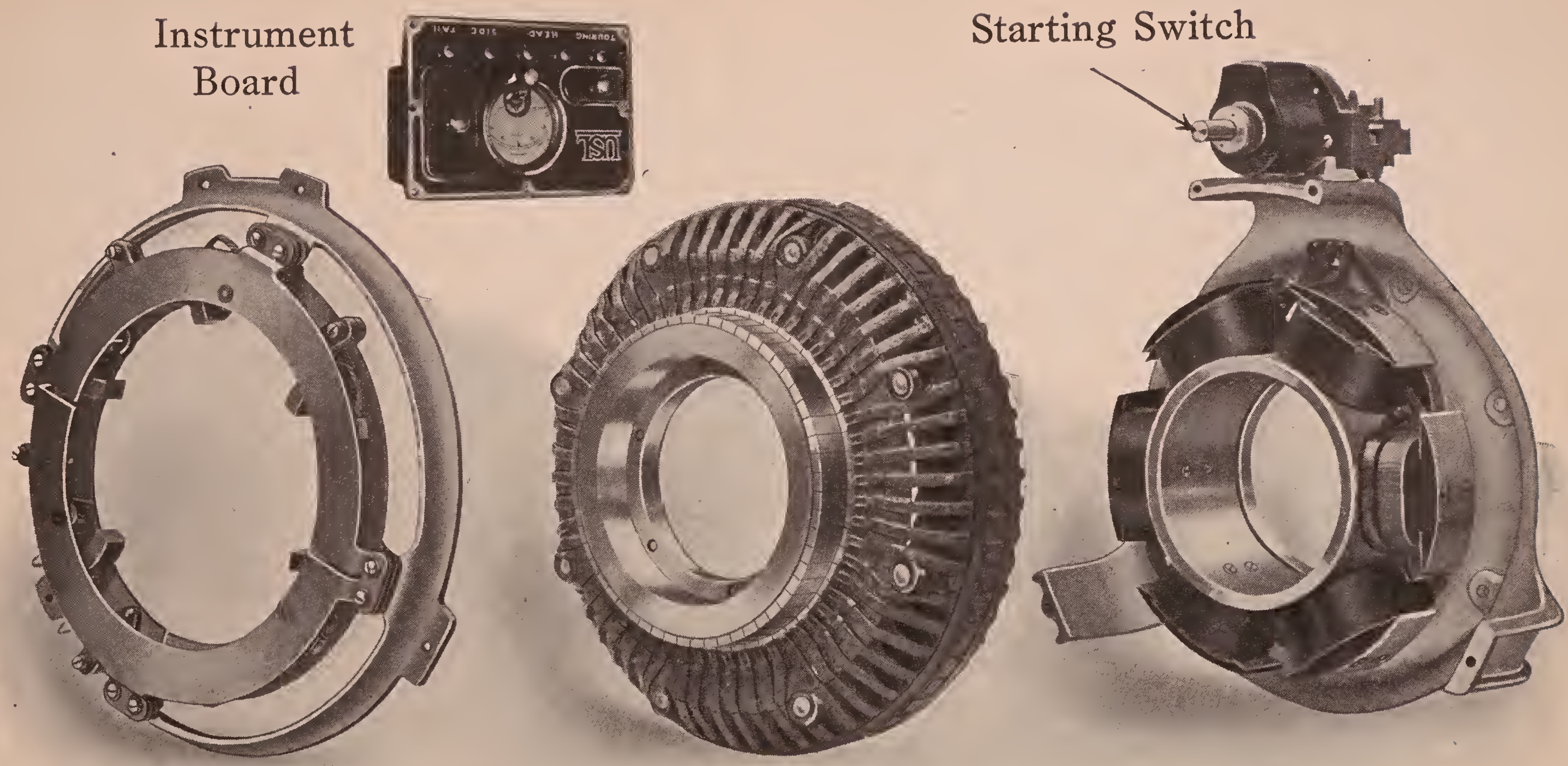
car, while in many instances special lamps which are provided with the outfit at extra cost, are installed. In Fig. 254 are shown the connections used with special two-bulb headlights. In this case no dimmer is necessary. In Fig. 255 the upper half of the wiring diagram is shown with the original lamps and a dimming resistance is included to permit lowering them for city use. The lower half of the diagram coincides with that of Fig. 254.

Fig. 256 illustrates the two-wire system of installation used in connection with the North East, and it will be noted that it does not differ in any essential from the method of wiring other models of the same make using the two-wire system.

Ford Magneto System Distinct. Regardless of whether the single-wire or the two-wire system is employed, it will be apparent that no connection whatever is made with either the ignition or electric lighting system of the car when being supplied direct from the Ford magneto which replaces the flywheel. Upon installing a lighting and starting system, the old lighting wires are removed and the same lamps connected to the new system as shown in Fig. 255, or new lamps are substituted as in Fig. 254.

In some systems, such as the Westinghouse, ignition also may be supplied by the generator and storage battery. To effect this, the Westinghouse combination ignition unit (see Part II on Ignition) is substituted for the Ford timer and vibrator coils, which are removed from the car; or, if desired, they may be retained as an emergency system, there being no interconnection between the two. When discarded, the old connections are removed and the magneto is allowed to run idle.

Instructions. So far as the installation is concerned, detailed instructions are provided by the manufacturer in every case, as every system differs more or less in detail. Apart from the necessity of maintaining the silent-chain drive in accurate alignment and keeping the chain at the proper tension, any instructions regarding the maintenance of the dynamotor, switches, controls, and wiring are the same in both principle and practice as those given in connection with the other models of the same makes, and this is likewise the case with regard to failure of any parts of the apparatus to operate properly.



U-S-L-MOTOR-GENERATOR DISASSEMBLED WITH INSTRUMENT BOARD ABOVE
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, New York

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART V

ELECTRIC STARTING AND LIGHTING SYSTEMS—(Continued)

PRACTICAL ANALYSIS OF TYPES—(Continued)

GRAY AND DAVIS SYSTEM

Six-Volt; Two-Unit; Single-Wire

Generator. The bipolar generator is designed for drive by silent chain, as shown in Fig. 257, or when combined with ignition distributor, from the pump shaft, Fig. 258.

Regulation. Earlier types, including the original lighting generator were of the constant-speed type regulated by a governor and

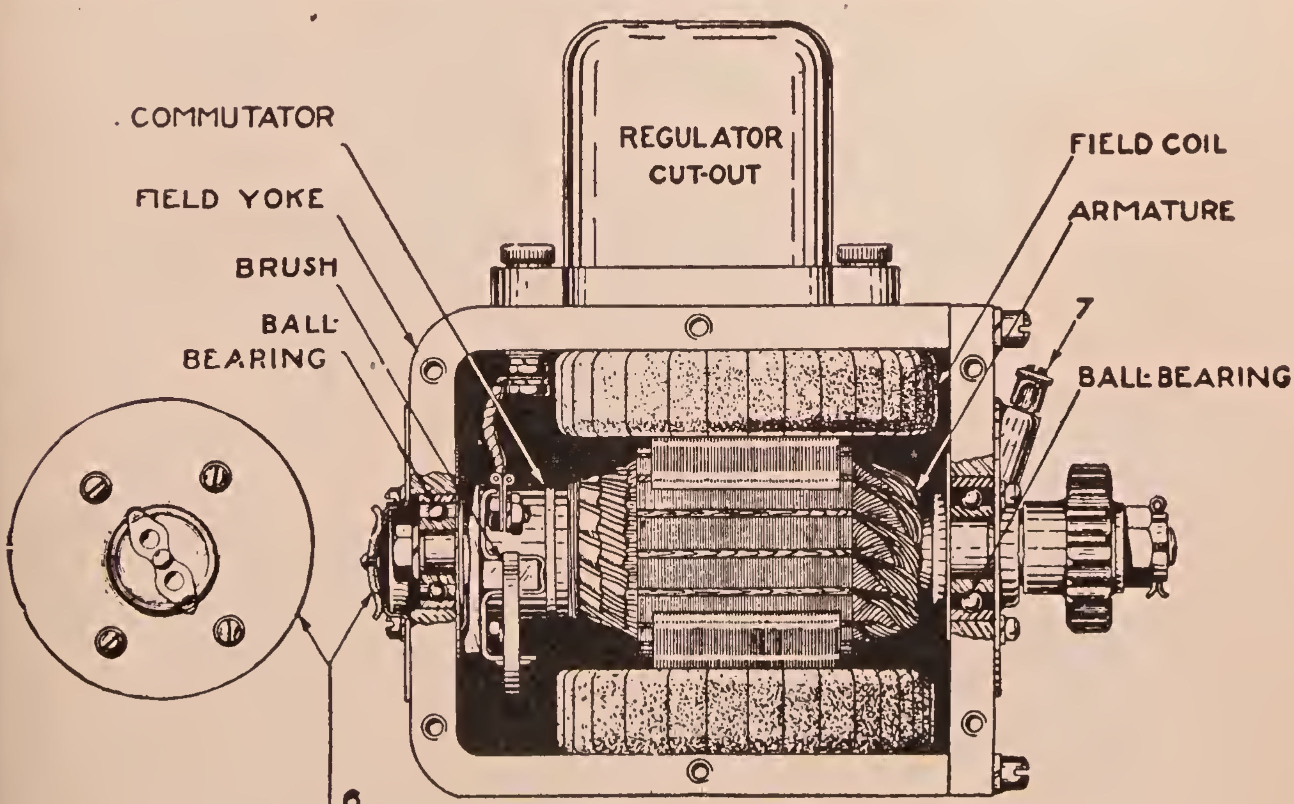


Fig. 257. Section of Gray and Davis Generator for Silent-Chain Drive

slipping clutch which maintained the speed of the generator constant. The 1914 and subsequent models are controlled by a combination regulator cut-out, usually mounted directly on the generator itself. The regulator increases the resistance of the

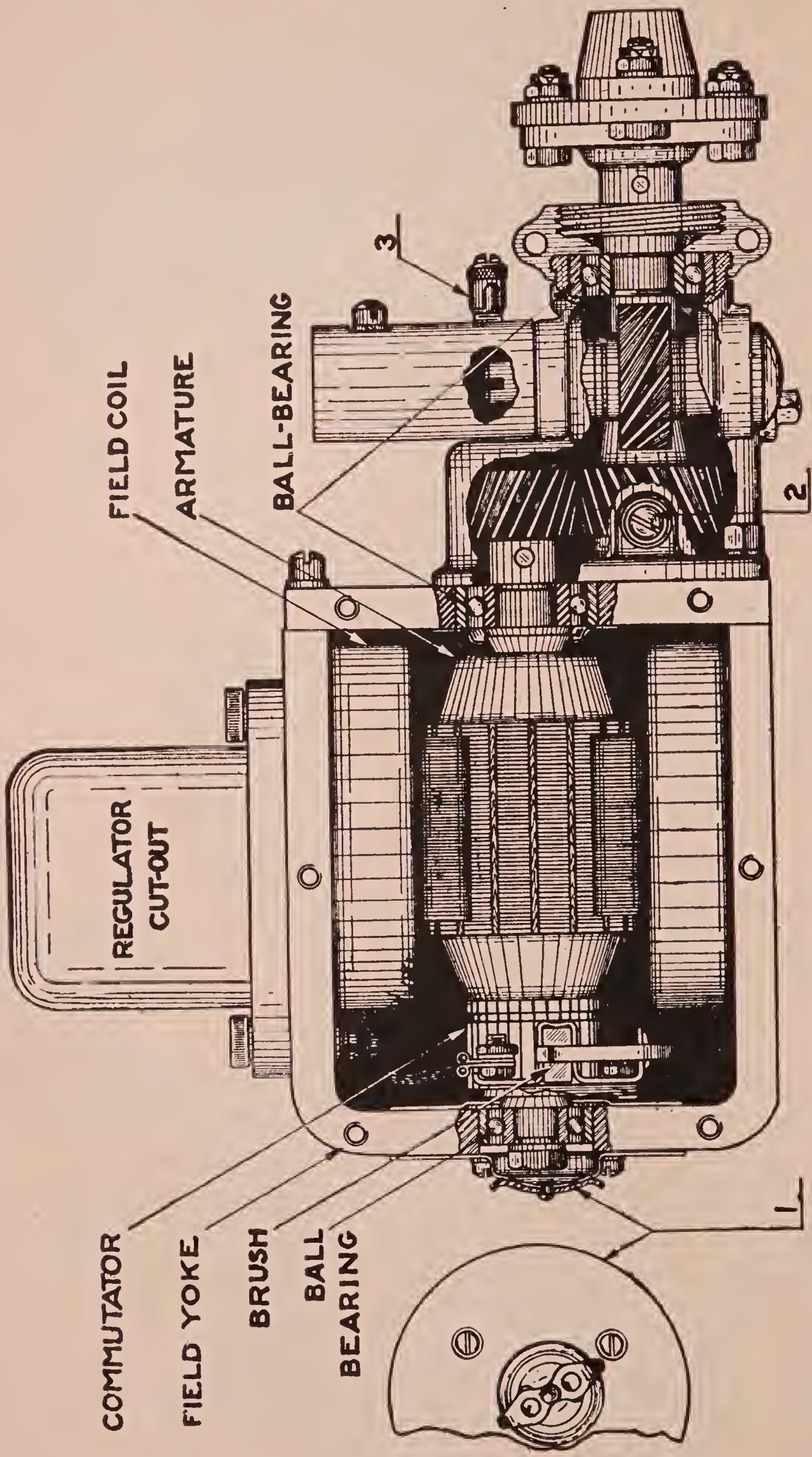


Fig. 258. Section of Gray and Davis Generator with Ignition Distributor Gearing (Shaft Drive)
Courtesy of Gray and Davis Company, Boston, Massachusetts

generator-field windings in proportion to the increase in speed, thus maintaining the output steady.

Starting Motor. The series-wound bipolar motor is made for either open- or enclosed-flywheel drive, according to the type of

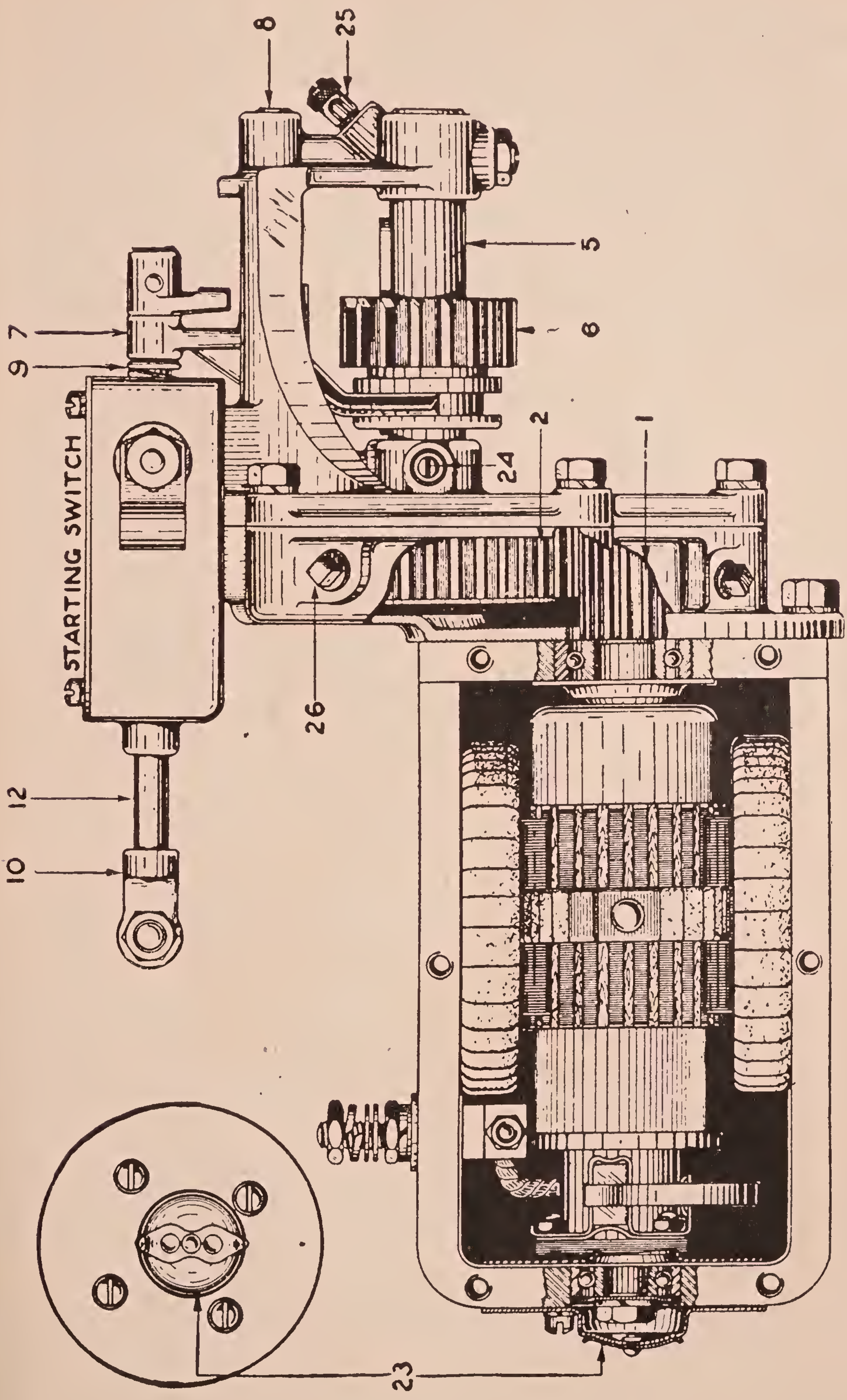


Fig. 259. Gray and Davis Starting Motor with Reduction Gearing for Open Flywheel. 1—Motor Pinion; 2—Intermediate Gear; 5—Intermediate Shaft; 6—Sliding Pinion; 7—Shifter Fork; 8—Shifter Rod; 10—Clevis; 12—Switch Rod; 23, 24, and 25—Oilers; 26—Oil Plug

car. Fig. 259 shows the open-flywheel type. The illustrations of both the generator and motor show them with the side plate removed for inspection. The type of starting switch employed on later models is shown in Fig. 260. The rod passing through it leads to the pedal on the footboards for operating it.

Instruments. Either an indicator showing whether the battery is charging or discharging or is neutral, or an ammeter serving the same purpose, is supplied. The ammeter is provided with a graduated scale and its normal readings should be as follows: Standing, no lights on, *zero;* with lights on, *discharge* 5 to 7½ amperes. Car running 6 to 8 miles per hour, lights on, *discharge* same rate. Above 8 miles per hour, lights off, *charge* 5 to 9 amperes; above 10 miles per hour, lights on, *charge* ½ to 3 amperes. Under the last-named

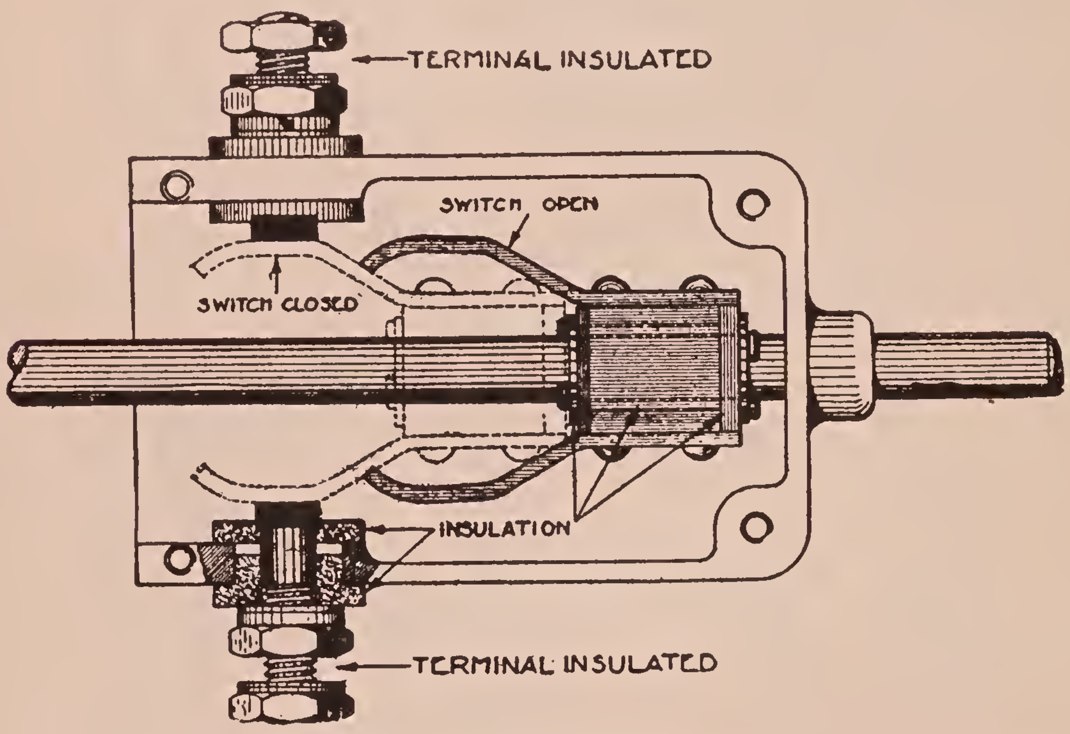


Fig. 260. Gray and Davis Starting Switch with Both Terminals Insulated

condition the lights are being supplied directly by the generator and only the excess current is charging the battery. Whenever the generator output drops below a point where it is supplying sufficient current to light all the lamps that are on, the battery supplies the balance. The battery is thus said to be *floated on the line.* It charges or discharges according to the current supply and the demand upon the latter.

Wiring Diagrams. Single-wire system is standard, but in some cases the motor is grounded, and in others the switch. Among others, the Gray & Davis system with grounded motor is installed on the Peerless, Chandler, Stearns, and Winton; with grounded switch, it is installed on the Chalmers, Paige, and Maxwell. It is

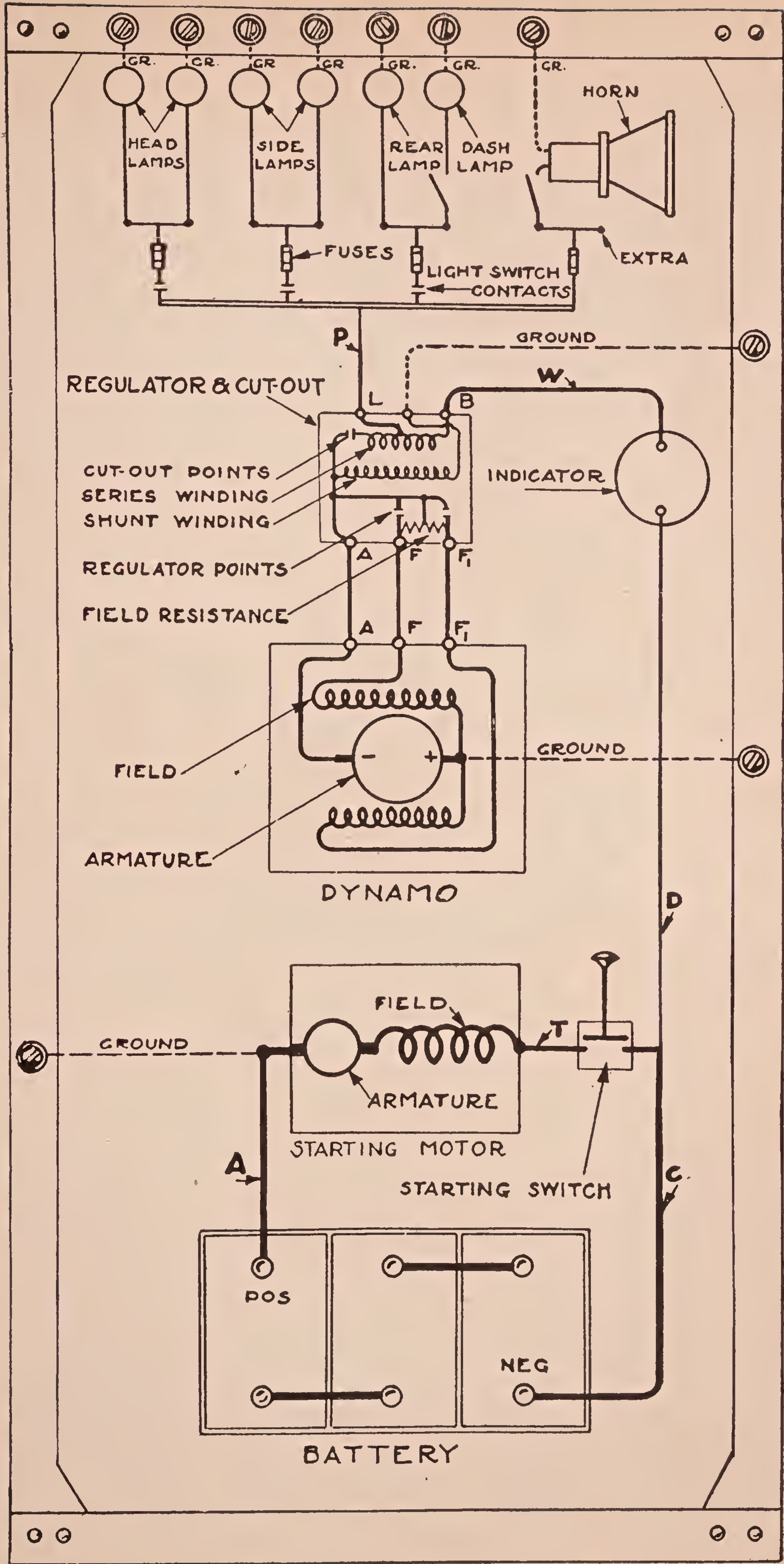


Fig. 261. Wiring Diagram for Gray and Davis Single-Wire System with Grounded Motor

naturally impossible to give complete lists of installations in any case, so that only one or two representative makes are mentioned to enable certain systems to be identified in the garage when desired.

Grounded-Motor Arrangement. Fig. 261 shows the Gray & Davis wiring diagram with grounded motor. Cable *A*, from the battery positive terminal, connects to grounded terminal of starting motor. Cable *T* connects an insulated terminal on the starting motor to one of the starting-switch terminals. Cable *C*, from the starting-switch terminal, connects to the battery negative terminal, thus completing the circuit. On some makes of cars, cable *A*, instead of connecting directly to the starting motor, is connected to the frame

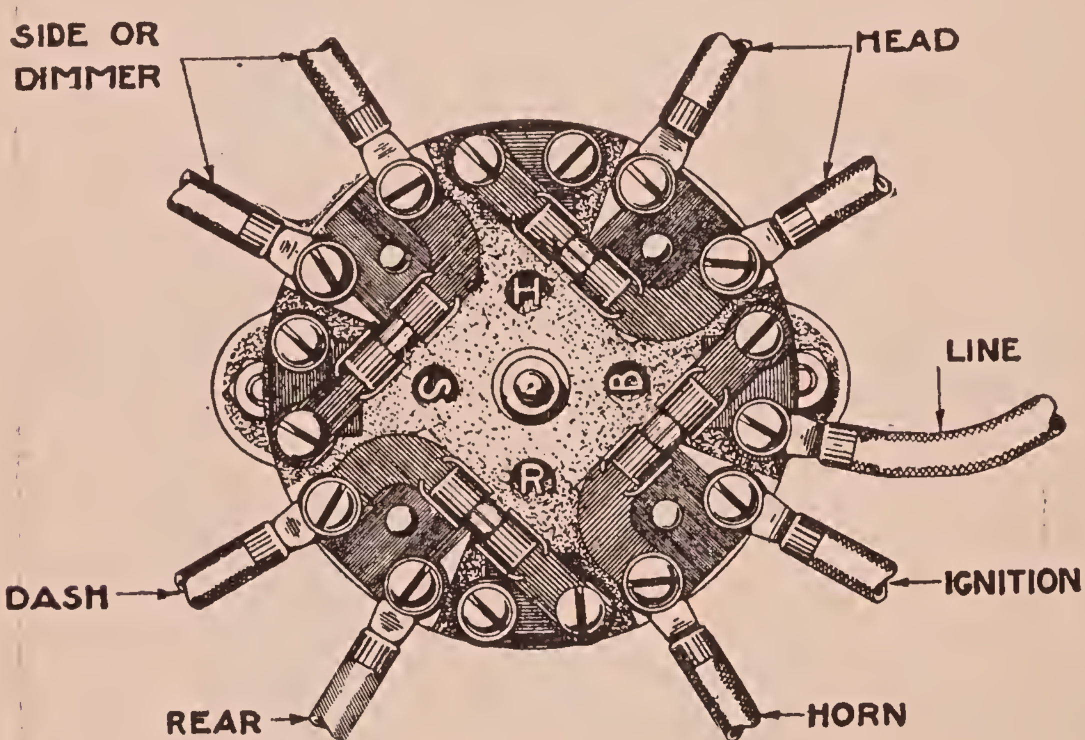


Fig. 262. Gray and Davis Lighting Switch, Rear View

of the car or *grounded.* The car frame carries the current to the grounded terminal of the starting motor. Wire *D*, from the end of cable *C* at the starting switch, connects to the lower terminal of the indicator (or ammeter). Wire *P* connects dynamo terminal *L* at regulator to lower terminal of block *B* at lighting switch—Fig. 262 showing rear view of lighting switch. From terminals at fused side of *H* at the lighting switch, two wires connect to the right-hand and left-hand head lamps, while from the terminals at the fused side of *S* on the lighting switch corresponding wires connect to the two small lamps in the headlights. The tail lamp is connected from the fused side of *R* on the lighting switch and in some cases to the dash lamp while the electric horn and ignition are

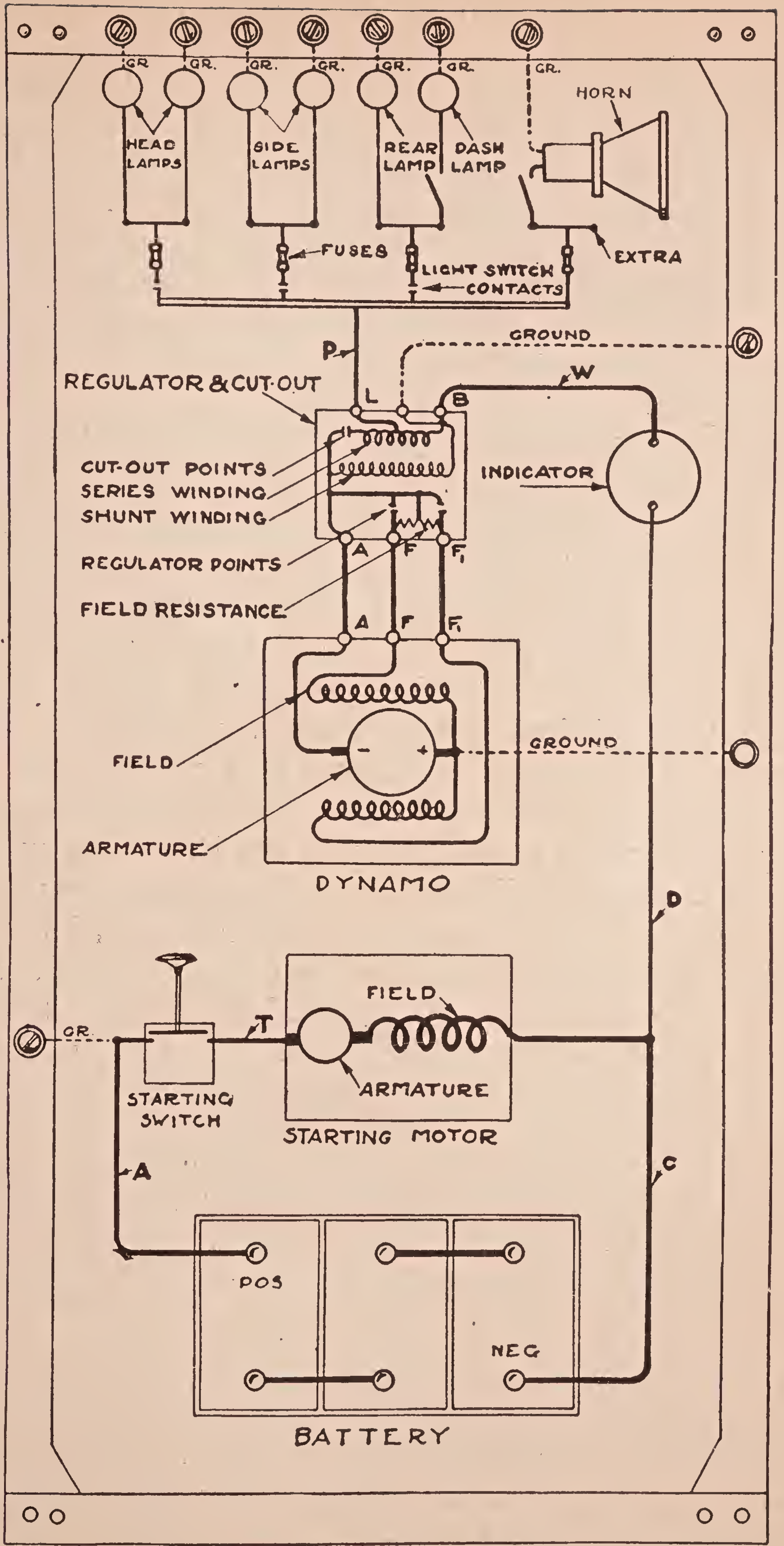


Fig. 263. Wiring Diagram for Gray and Davis Single-Wire System with Grounded Switch

connected to the fused side of *B*. The various ground connections are as follows: battery positive by cable *A* to frame at grounded terminal of starting motor; generator positive terminal to the frame of the dynamo itself; one side of all lamps to frame of car.

Grounded-Switch Arrangement. Fig. 263 is the Gray & Davis wiring diagram of the grounded-switch type. The only difference between this and the other diagram is that the ground connection is taken from the terminal of the cable *A* to the switch, instead of from the motor.

Single-Unit Ford Set. A Gray & Davis single-unit system is made specially for installation on Ford cars. The dynamotor has a single commutator and is driven from the crankshaft of the engine through a silent chain which also serves to turn the engine over when the unit is operating as a motor. Regulation is by means of a combined variable field resistance and battery cut-out termed the *regulator*, which is mounted directly on the dynamotor. A 6-volt storage battery and single-wire connections are employed.

Instructions. When the indicator does not indicate *charge* though the engine is speeded up, but indicates *discharge* with the engine stopped, the dynamo or regulator may not be working properly. To verify this, turn on all lights, run engine at speed equivalent to 10 miles per hour, disconnect wire from terminal *B*, Fig. 261, at regulator cut-out; if lights fail, either the dynamo or regulator is at fault. Reconnect wire to terminal *B* and remove side plate from dynamo to examine brushes. Slide brushes in and out, see that they slide freely in brush holders and make good contact with commutator and that wires from brush holders and fields to dynamo terminals are firmly connected. If dynamo is belt driven, the belt may not be tight enough to rotate dynamo at sufficient speed to charge battery. The commutator, if coated or dirty, may be cleaned while rotating by holding a cloth slightly moistened with oil against it.

Should these tests fail to remedy trouble, connect a wire at regulator cut-out from terminal *A* to terminal *B*. With lights off speed engine to equivalent of 10 miles per hour. If indicator then shows *charge*, the regulator cut-out is at fault. Note whether any connections on it are loose or broken from vibration; see that contacts are clean and come together properly. Take a match stick or small piece of clean wood and press them together; if this remedies trouble, the contact points are at fault. Clean with a strip of fine emery cloth or with a very small fine flat file, not taking off any more than is necessary to clean and true up the points. In case this treatment does not put the cut-out in working condition again, the manufacturer's service department should be called on for assistance.

But if, under conditions just given, the indicator or ammeter shows neither *charge* nor *discharge*, the dynamo circuit is open. This may be from poor brush contact or from a loose or broken connection at some other point. If the indicator shows *discharge*, reduce engine speed to equivalent of 8 or 9 miles an hour; then while engine is running, connect another wire from dynamo terminals *F* and *F*1 to terminal *A*. If indicator then shows *charge* the regulator is at fault as this wire cuts the regulator out of the charging circuit. While making this test, care must be taken not to run the engine any faster than mentioned as the dynamo is not protected by the regulator. If in this test, the indicator still shows *discharge*, it signifies that the dynamo field circuit is open or the armature is short-circuited.

Loose Connections. If, with the engine speeded up, the indicator does not show *charge*, nor with the engine stopped and the lights turned on does indicate *discharge*, there is an open or loose connection in the battery circuit. See that all wires are firmly connected and that contact faces are clean. Or the indicator itself may be at fault. Verify by disconnecting one wire from it and if it then returns to neutral it indicates that some part of the wiring is grounded on the frame of the car and is causing a short circuit which is discharging the battery. But if, after disconnecting this wire, the indicator shows *discharge*, it is at fault. See if pointer is bent. This probably will be the case, if it indicates *charge* with the engine stopped.

Short Circuits. If the ammeter discharge reading is above normal, it may indicate that higher candle-power lamps have been substituted for the standard bulbs, or that some of the lamp wires are short-circuited. Intermittent jerking of the pointer from *charge* to *neutral* while engine is being speeded up also indicates a short circuit. Repeated blowing of fuses indicates short-circuited lamp wires or defective lamps. Trace wires along their entire length and try new bulbs.

Starting-Motor Faults. If motor does not rotate, battery may be discharged. In case engine has been overhauled just before, main bearings may have been put up so tightly that starting motor has not sufficient power to turn it over. Starting switch may not be making good contact, or the motor brushes may not be bearing properly on the commutator; battery terminals may not be tight. If the starting motor rotates but does not crank engine, the over-running clutch may not be running properly or the engaging gears do not mesh. When the starting motor cranks the engine a few turns and stops, the battery is almost discharged. Unless the engine starts after the first few revolutions, do not continue to run the starting motor, as it will exhaust the battery very quickly. Look for causes of engine trouble—lack of gasoline, ignition circuit open, or the like.

HEINZE-SPRINGFIELD SYSTEM

Six-Volt; Two-Unit

Generator. The generator is the four-pole type, combined with the ignition service, and with the regulator and cut-out in one.

Regulation; Control. Regulation is accomplished by means of a vibrating regulator giving voltage control.

Switch. A combination switch is employed giving control of the ignition, lighting, and starting through a single lever.

Starting Motor. The motor is the four-pole type, and designed for Bendix drive.

This system was only placed on the market at the beginning of the present year (1916), so that installation details were not available.

LEECE-NEVILLE SYSTEM

Six-Volt; Two-Unit; Two-Wire

Generator. Standard shunt-wound bipolar type, combined with ignition timer and distributor driven by a worm gear on the armature shaft. The generator is mounted on the left side of the engine and is driven by the pump shaft (Haynes installation 1913, and subsequent models to date).

Regulation. Generators of the 1915 and 1916 models are controlled by armature reaction through a third brush, the field coils receiving their exciting current from the armature through this brush. The position of the latter on the commutator is shown at *B*, Fig. 264. A slight rotation of this brush relative to the commutator changes the electrical output of the machine. As adjusted at the factory this brush is set to give a maximum output of 15 amperes at $7\frac{1}{2}$ volts. (All generators for 6-volt systems are wound to produce an e.m.f. of $7\frac{1}{2}$ volts, or thereabout, in order that the voltage of the generator may exceed that of the battery when the latter is fully charged. The e.m.f. of generators for 12-volt and 24-volt systems also exceeds that of their batteries in about the same proportion. Otherwise the generator would not be able to force current through the battery.)

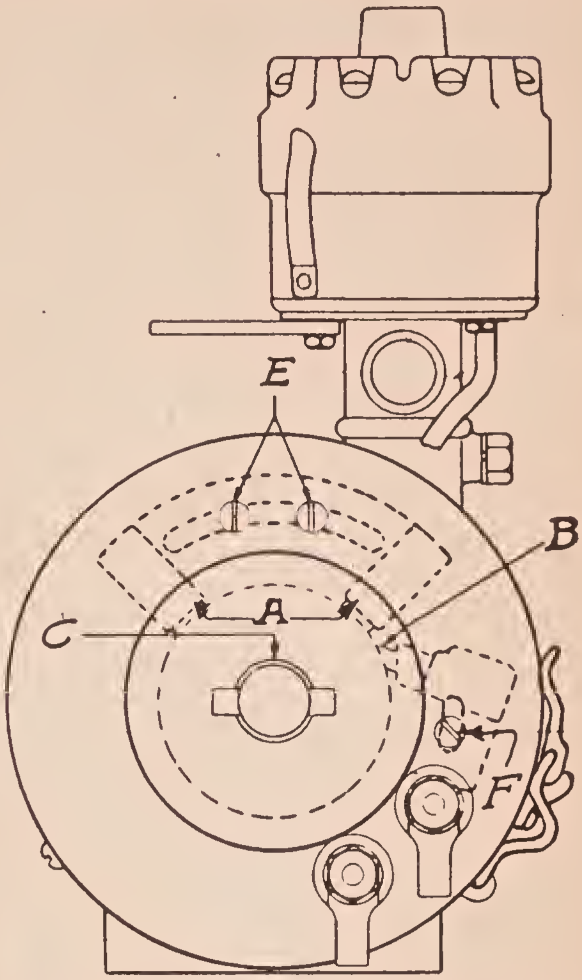


Fig. 264. Diagram of Arrangement of Brushes on Leece-Neville Six-Volt Generator

Starting Motor. The motor is the bipolar series-wound type driving the engine through a roller chain and an over-running clutch.

Fig. 265. Details of Leece-Neville Indicator

Instruments. An indicating type of battery cut-out is employed, thus combining the functions of the cut-out and ammeter in one device. The details of this device are shown in Fig. 265. *O* is the winding or coil of the electromagnet of which the U-shaped bar *8* forms the magnetic circuit. *4* is the pivoted armature, normally held in the *OFF* position as shown by a spring, when no current is passing, and adapted to be drawn against the pole pieces

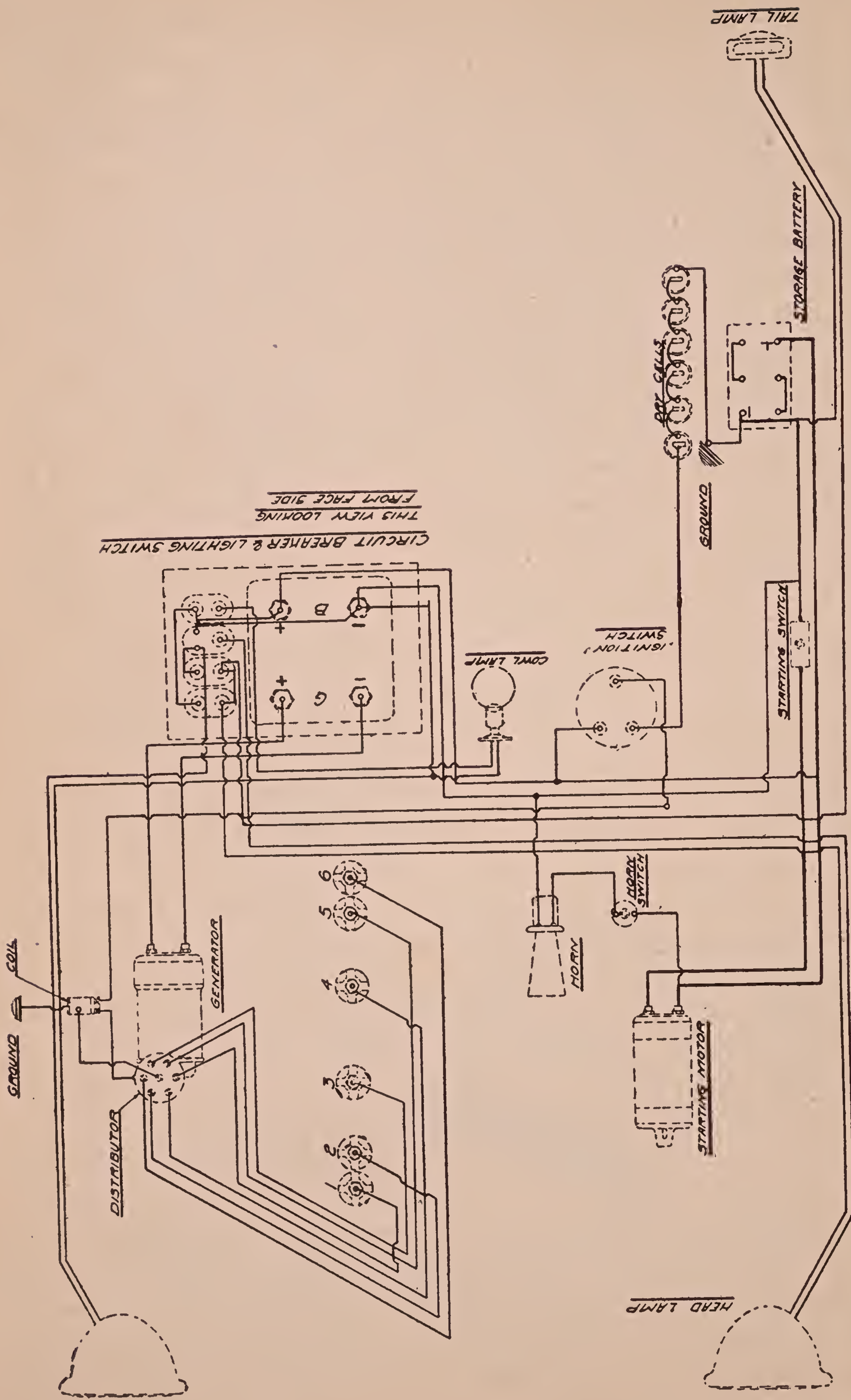


Fig. 266. Wiring Diagram for Leece-Neville System on Haynes Light Six

of the magnet when the latter is excited by the charging current. As the two-wire system is employed, the cut-out breaks both sides of the battery-charging circuit and it is provided with six current-carrying contacts on each of the sides of the circuit. Four of these which carry most of the current are *copper* to bronze, while those that take the spark in breaking the circuit are *cophite* to iron and are actuated by a spring. The indicating target *16* is held in the *OFF* position by the spring *19* when no current is passing and this reading appears in the opening of the panel on the cover. When the generator starts and the cut-out closes, the target is moved to bring the word *CHARGING* in the opening. The same panel also carries the three-way lighting switch controlled by buttons. The central button closes the circuit to the headlights and tail lights in the usual manner, while the upper button throws the headlights in series-parallel connection. As this doubles the resistance (See Resistance, Introductory), it halves the voltage passing through the lamps and they accordingly burn dimly. The lower button controls the cowl light over the instruments on the dash.

Wiring Diagram. Fig. 266 illustrates the Haynes 1915 installation. While two wires are employed for connecting all the apparatus, it will be noted that the storage battery and the dry-cell battery are grounded by a common ground connection. This is to permit using current from the storage battery for ignition, the corresponding ground to complete the circuit being noted at the ignition coil, close to the distributor. The connections *G* and *B* on the panel board are those of the generator and the battery to the indicating battery cut-out, the connections of three lighting switches being shown just to the right.

Instructions. Never run the engine when the generator is disconnected from the battery unless the generator is short-circuited, as otherwise it will be burned out in a very short time. This applies to all lighting generators except those protected by a fuse in the field circuit, in which case the fuse will be blown. The Leece-Neville generator can be short-circuited by taking a small piece of bare copper wire and connecting the two brush holders together with it. Instructions for short-circuiting other makes are given in connection with the corresponding descriptions.

Regulating Brush. In case the generator output falls off as shown by its inability to keep the battery properly charged, the battery itself and all connections being in good condition and a proper amount of day running being done to provide the necessary charging current, the trouble may be in the regulating brush of the generator. Test by inserting an ammeter, such as the Weston portable or any other good instrument with a scale reading to 30 amperés, in the line between the generator and the battery. Run the engine at a speed corresponding to 20 miles per hour, at which rate the ammeter should record a current of approximately 15 amperes. If the ammeter needle butts against the controlling pin at the left end of the scale instead of showing a reading, it indicates that the polarity is wrong and the connections should be reversed. Should there be no current whatever, the needle will stay perfectly stationary except as influenced by vibration. If the ammeter shows a reading of less than 15 amperes, the current output of the generator may be increased by loosening the set screw holding the third brush and rotating the brush slightly in the same direction as the rotation of the armature. This should be done with the generator running and the ammeter in circuit, noting the effect on the reading as the brush is moved. To decrease the output, it should be moved in the opposite direction until the proper reading is obtained, after which the brush must be sanded-in to a good fit on the commutator. It may sometimes occur that sufficient movement cannot be given the third brush without bringing it into contact with one of the main brushes. This must be avoided by loosening the two set screws marked *E*, Fig. 264, and moving the main brush holder away from the third brush until there is no danger of their touching. After securing the desired adjustment, fasten the third brush in place again, stop the engine, and then reconnect the generator to the battery. Do not cut the ammeter out of the circuit while the generator is running.

Brush Replacements. Never replace any of the brushes on either the generator or starting motor with any but those supplied by the manufacturer of the system for this purpose. Motors and generators adapted for use on electric-lighting circuits are usually fitted with plain carbon brushes. These are not suitable for use on automobile generators or starting motors owing to their resistance being much higher. Due to the low voltage of electric apparatus on the automobile, special brushes of carbon combined with soft copper are usually employed. Brushes also differ greatly in hardness and a harder brush than that for which the commutator is designed will be apt to score it badly besides producing a great deal of carbon dust which is dangerous to the windings. This, of course, applies to all makes of apparatus and not merely to that under consideration.

Generator or Motor Failure. For failure of the generator or of the starting motor, see instructions under Auto-Lite, Delco, and Gray & Davis, bearing in mind, however, that the system under consideration is of the two-wire type, so that in using the test lamp to locate short circuits a connection to the frame or ground is not always necessary. The short circuit may be between two adjacent wires of different circuits. Given properly installed wires and cables there is less likelihood of short circuits in the wiring of a two-wire system. Defective lamps will not infrequently prove to be the cause, as, in burning out, a lamp often becomes short-circuited.

NORTH EAST SYSTEM*

Twelve-Volt, Sixteen-Volt, or Twenty-Four-Volt; Single-Unit; Single-Wire or Two-Wire, According to the Installation

Dynamotor. The dynamotor is of the four-pole type, with both windings connected to the same commutator. It is designed for installation either with silent-chain drive—as on the Dodge, Fig. 267, in which case the drive is direct either as a generator or as a motor—or with a special reducing gear and clutch for driving from the pump or magneto shaft of the engine. In the latter type, the starting switch is mounted on the gear housing which is integral with the bed plate of the dynamotor. In this case the drive as a generator is $1\frac{1}{2}$ times engine speed, while as a starting motor the reduction through the gear is approximately 40 : 1.

Regulation. The regulation is by means of a differential winding or bucking coil, in connection with an external resistance automatically cut into the shunt-field circuit by a relay in series with the battery cut-out. See "Limiting Relay", Fig. 268. The "Master

* (The voltage of any system may be determined by counting the number of cells in the storage battery, and multiplying by 2 in the case of a lead battery, or multiplying by $1\frac{1}{4}$ where an Edison battery is used.)

Relay" in this diagram is the battery cut-out. The condenser indicated on the diagram is to reduce sparking at the contacts of these relays.

Protective Devices. There is a fuse in the field circuit of the generator as shown in the diagram. No fuses are employed on the lighting circuits.

Wiring Diagrams. A graphic diagram of the North East installation on the Dodge is shown in Fig. 269. This is a 6-cell or 12-volt system. The sprocket on the forward end of the machine drives from a similar but much larger sprocket on the forward end of the crankshaft of the engine through a silent chain. Fig. 270 shows the wiring diagram of an 8-cell or 16-volt system, but the

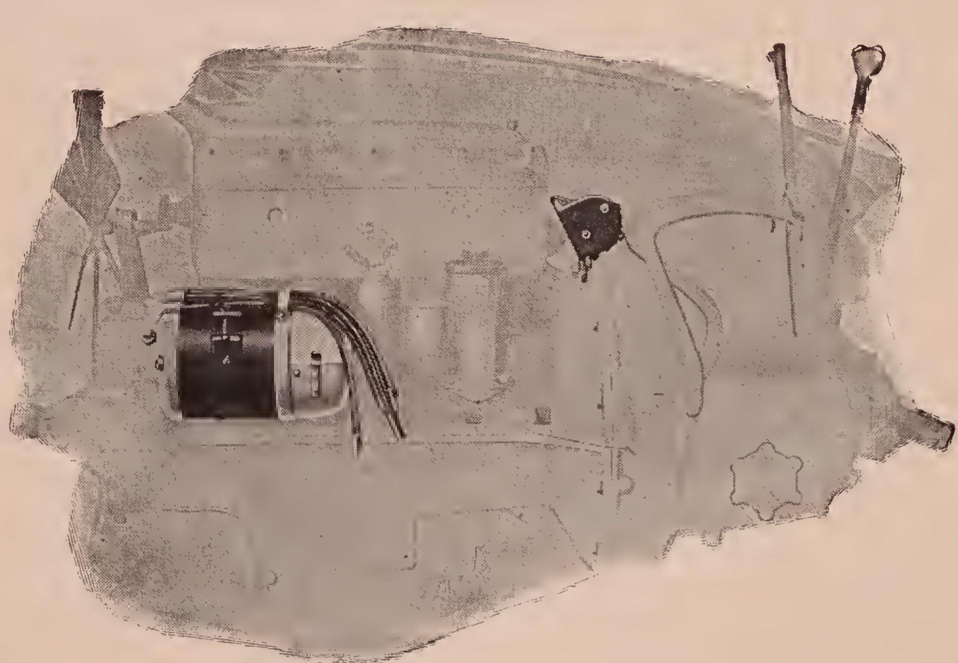


Fig. 267. North East Dynamotor with Silent-Chain Drive. Starting Switch Shown at the Right
Courtesy of North East Electric Company, Rochester, New York

battery is divided for the lighting circuits so that $8\frac{1}{2}$—9-volt bulbs are used, whereas 14-volt bulbs are necessary on the Dodge installation as the entire battery is used in series for lighting. The wiring of the 12-cell or 24-volt system is shown in Fig. 271. In this case the battery is divided for lighting so that 7-volt lamps are employed. Such a system is usually designated as 24—6-volt, while the previous one would be a 16—8-volt. The North East installation for Ford cars is 24—14-volts. With the exception of the Dodge, the two-wire system is employed on the installations mentioned.

Instructions. The indicator shows when the battery is charging or discharging and accordingly should indicate *OFF* when the

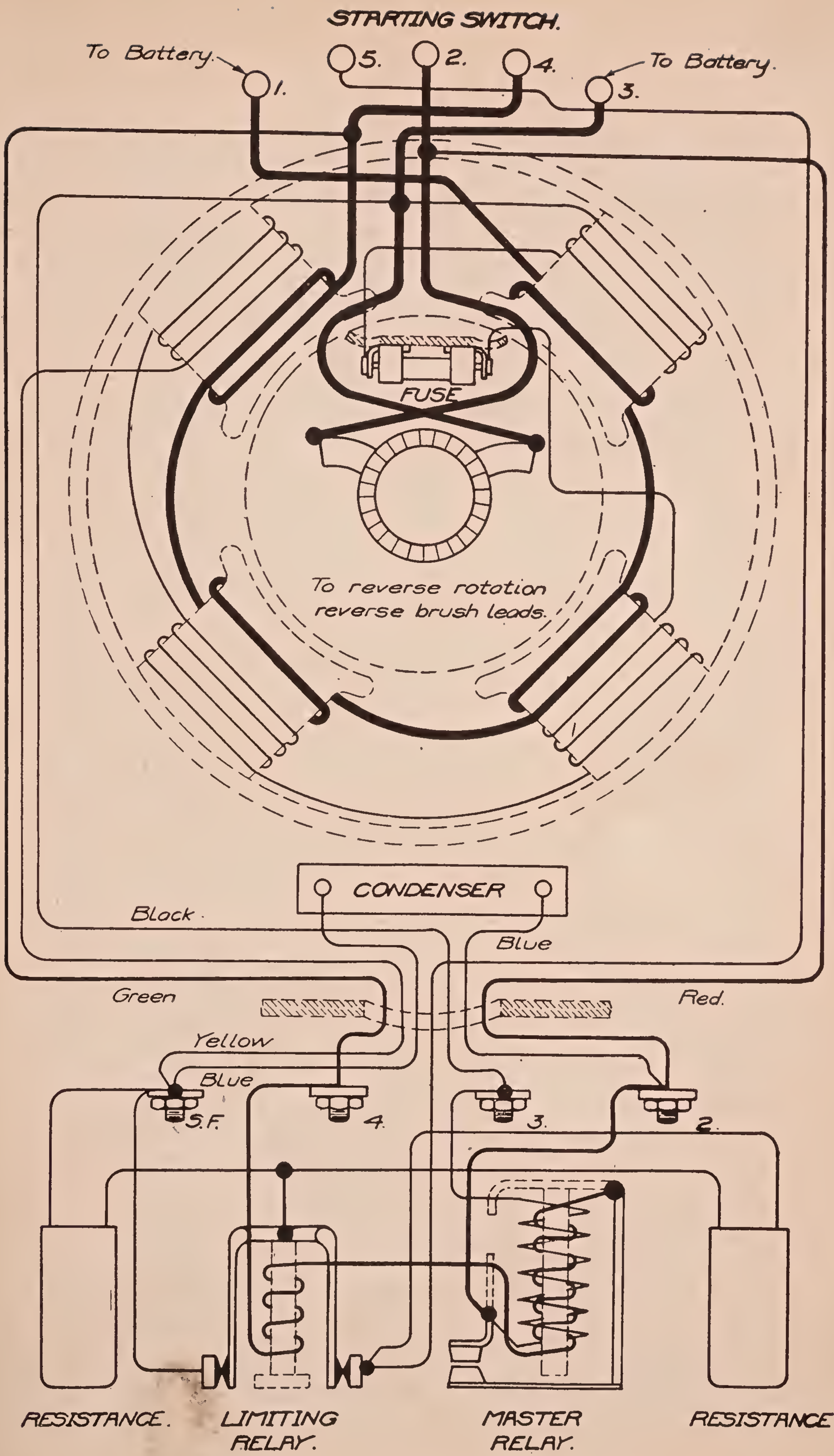


Fig. 268. Diagrammatic Section of North East Dynamotor Showing Regulator (Limiting Relay) and Cut-Out (Master Relay)

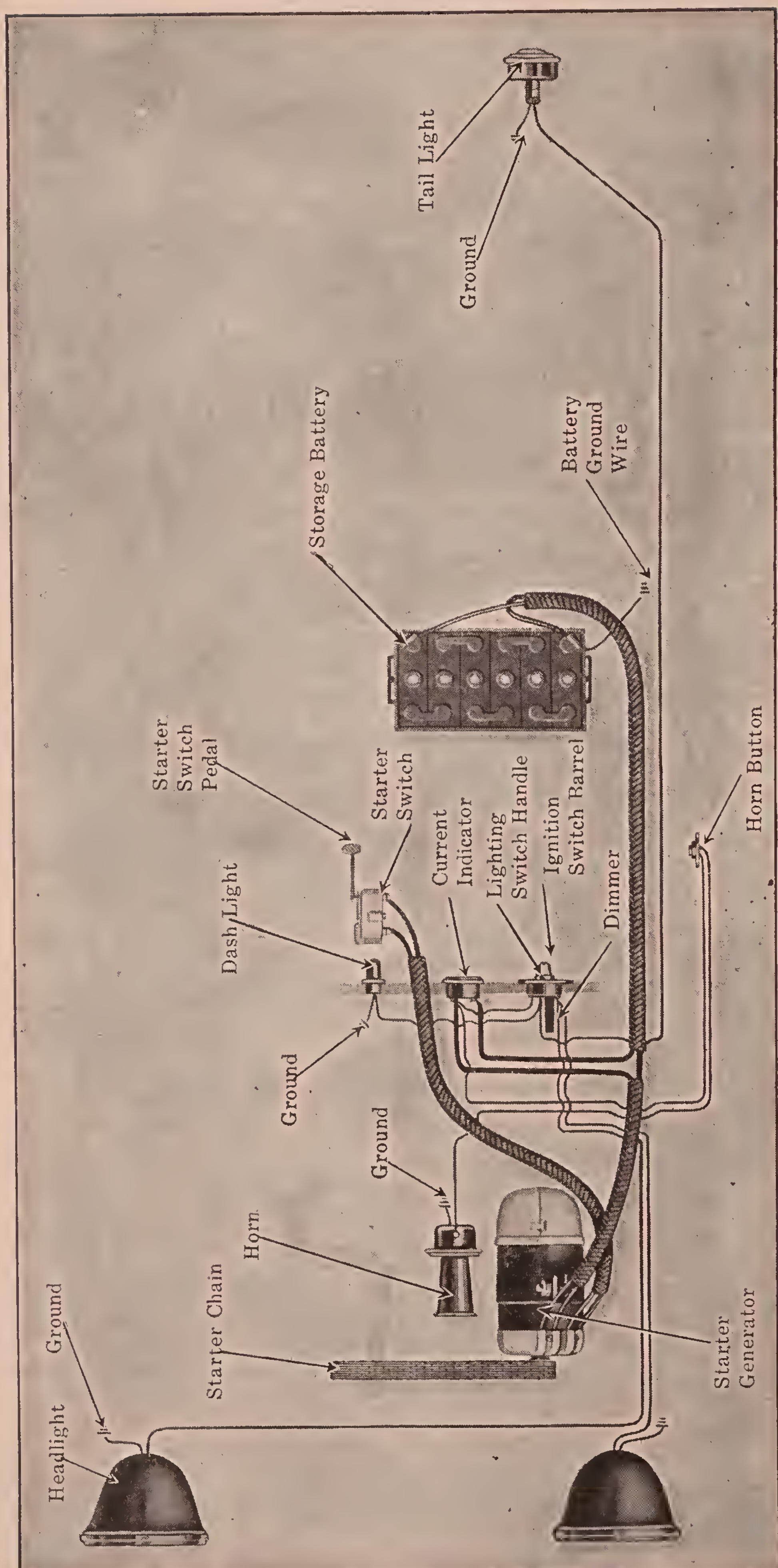


Fig. 269. Diagrammatic Lay-Out of North East Installation on the Dodge Car
Courtesy of North East Electric Company, Rochester, New York

engine is idle and no lamps are lighted. A discharge reading under such conditions would indicate the presence of a ground, short circuit, or failure of the battery cut-out to release. Should the generator fail to charge the battery, note whether the field fuse has been blown by short-circuiting the fuse clips with the pliers or a piece of wire while the engine is running at a moderate speed. Look for cause of failure before replacing the fuse. If the fuse has not blown, see whether battery cut-out is operating; look for loose connections at generator, cut-out, and battery. If the battery is properly charged, loose connections are also most apt to be the cause of failure of the starting motor; or, any of the instructions covering brushes, commutator, etc., as given previously may apply.

Instructions already given covering the care of contact points in the cut-out and limiting relay, wiring, switches, indicator, and driving chain (where used) apply here as well. If for any reason the storage battery is removed or disconnected from the generator, the engine must

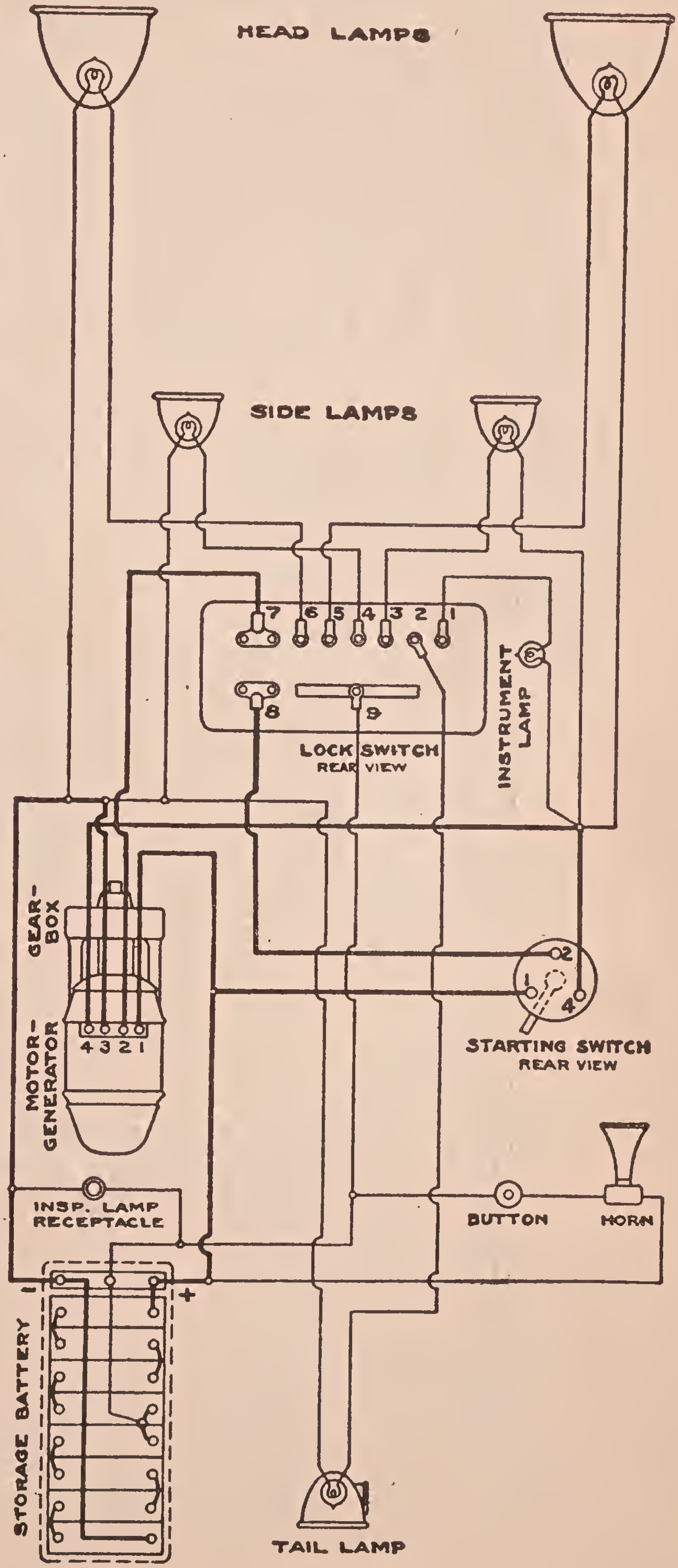


Fig. 270. Wiring Diagram for 16-Volt North East System Using 8½- to 9-Volt Lamps

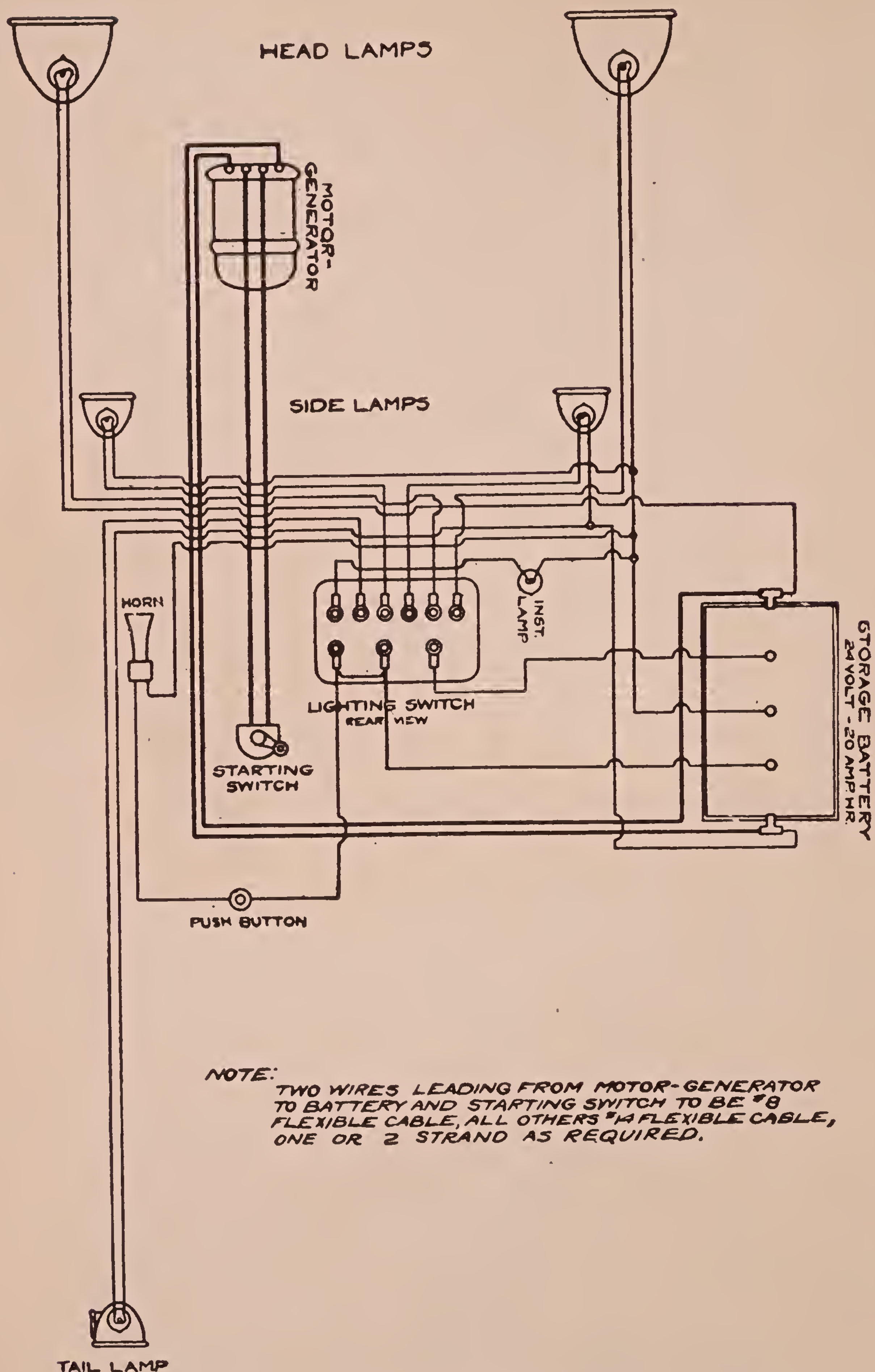


Fig. 271. Wiring Diagram for 24-Volt North East System Using 7-Volt Lamps

not be run unless two brushes on one side of the commutator are removed.

REMY SYSTEM

Six-Volt Two-Unit Single-Wire Type

Generator. Of the multipolar (four-pole) shunt-wound type of generator combined with ignition timer and distributor, and designed to be driven at $1\frac{1}{2}$ times crankshaft speed, several models are made, of which one is shown in Fig. 272. In this case, both the regulator for the generator and the battery cut-out are mounted directly on the generator. On some of the models only the regulator is so mounted, the cut-out being placed on the dash of the car, while on others no independent regulating device is required as the third-brush type of regulation is employed (on bipolar generator).

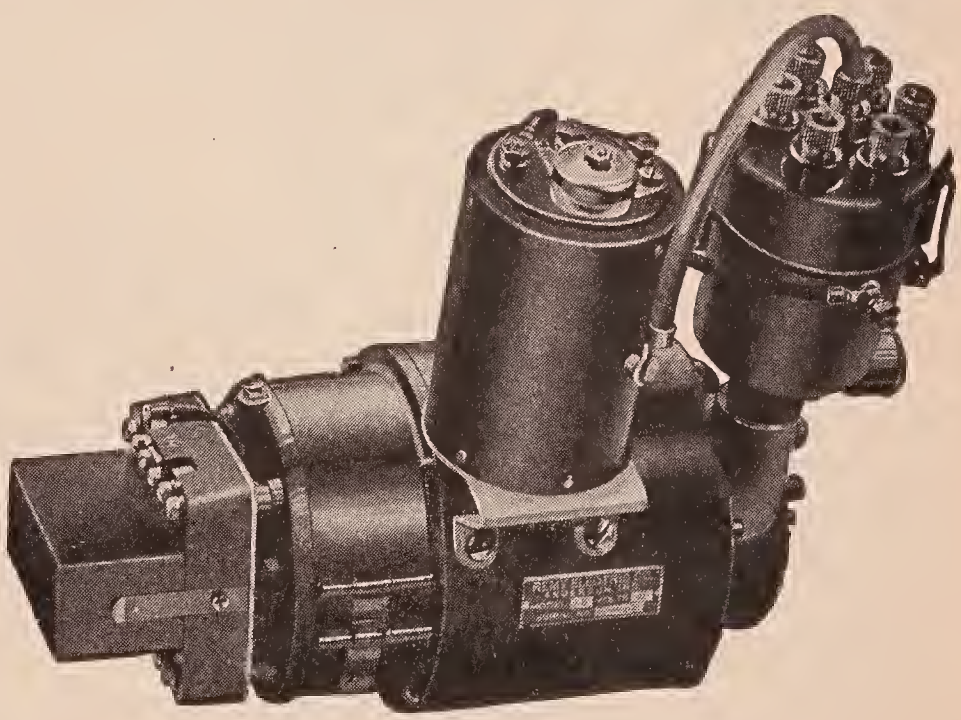


Fig. 272. Remy Ignition Generator and Distributor
Courtesy of Remy Electric Company, Anderson, Indiana

Regulation. In accordance with the model of generator and the requirements of the engine to which it is to be fitted, either the constant-voltage method of regulation using a vibrating regulator mounted on the generator, or the third-brush method, is employed.

Constant-Voltage Method. The regulator for the generator is similar in principle to that described in connection with the Bijur system. It consists of an electromagnet, two sets of contact points, two of which are mounted on springs, a pivoted armature which may move to make or break the circuit and a resistance unit. When running at too slow a speed to produce its maximum output, the generator field is supplied with current passing directly through the regulator contact points which are held together by a spring. As soon, however, as the speed of the generator increases to a point where it tends to cause its output to exceed the predetermined maximum, the charging current which is flowing through the coil of the electromagnet, energizes it to such an extent as to cause it to pull the armature down. This separates the contacts and causes the field current to pass through the resistance unit, thus decreasing the field current and in turning decreasing the generator output which reduces the exciting effect on the electromagnet and causes it to release its armature cutting the resistance out of the field circuit. The latter immediately builds up again and the operation is repeated as long as the speed remains excessive for the generator, which is thus supplied with a pulsating current to excite its fields, and its output is held at a practically constant value.

Third-Brush Method. The third-brush method of regulation is based upon the distortion of the magnetic field of a generator at

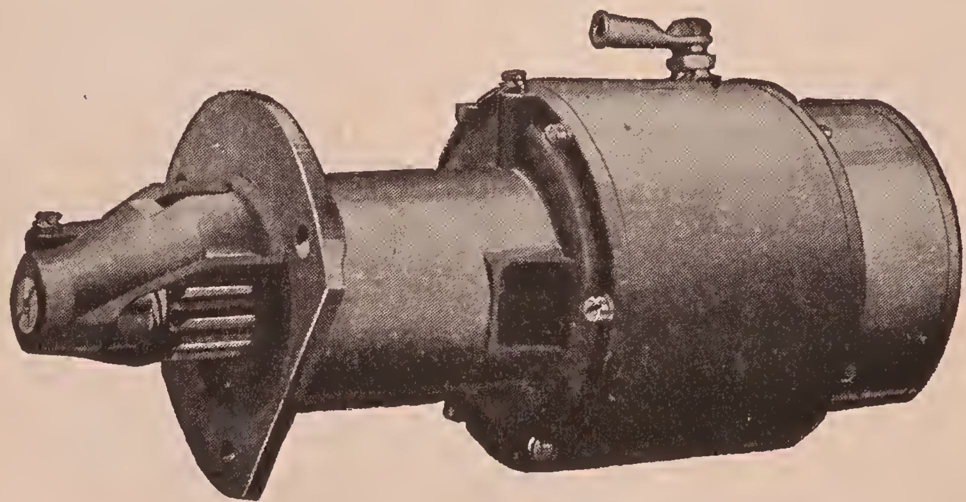


Fig. 273. Remy Starting Motor with Outboard-Type Bendix Pinion

high speeds. When running at low speeds, the magnetic flux of a generator is evenly distributed along the faces of its field pole pieces, but at high speeds there is a tendency to drag it out of line in the direction of the rotation of the armature. It is then said to be distorted. The third brush, which supplies the exciting current to the field winding is so located with relation to the main-line brush of opposite polarity that this distortion of the magnetic flux reduces the current which it supplies to the fields. This decrease in the exciting current of the field causes a corresponding decrease in the output of the generator, and as the distortion of the magnetic flux is proportional to the increase in speed, the generator output falls off rapidly the faster it is driven above a certain point so that it is not damaged when the automobile engine is raced.

Starting Motor. The motor is the six-volt four-pole series-wound type illustrated in Fig. 273. Mounted either with gear reduction and overrunning clutch, or with automatically engaging pinion for direct engagement with flywheel gear, as described in connection with the Auto-Lite. The latter is known as the Bendix gear. The control is by independent switch.

Instruments and Protective Devices. An indicator or *telltale* shows when the battery is charging or discharging, and also serves to indicate any discharge in all except the starting-motor circuit due to grounds or short circuits. All lamp circuits are fused and a fuse is inserted in the regulator circuit.

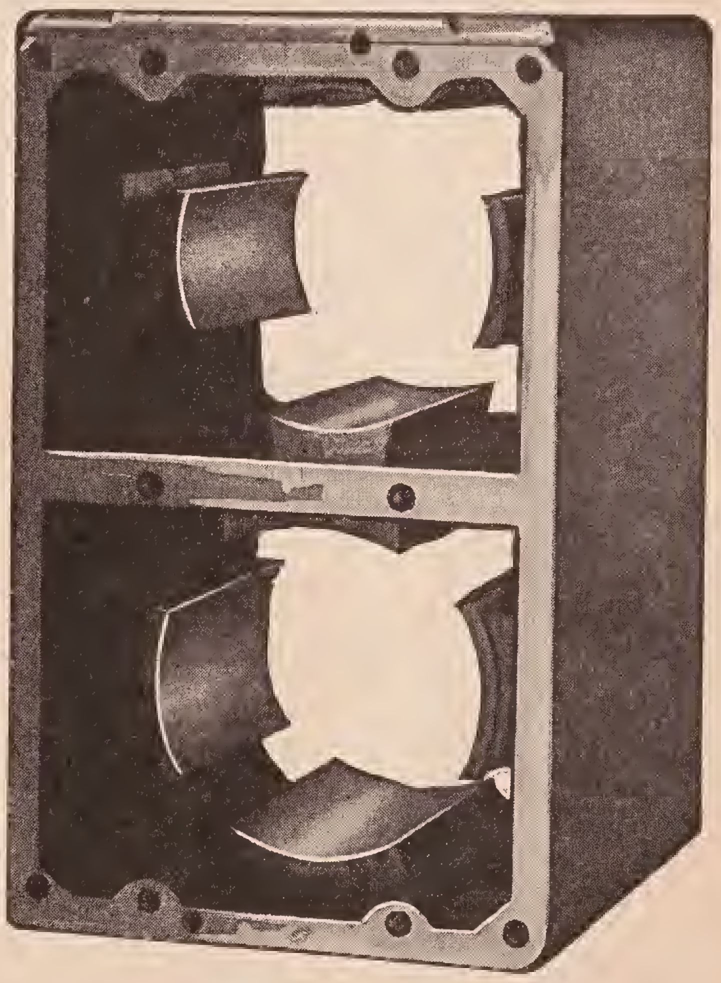


Fig. 274. Combined Field Frame of Generator and Motor for Remy Single-Unit System

Remy Single-Unit Type

A Mechanical Combination. While termed a single-unit type, this is actually two independent units combined *mechanically* and *not electrically,* so that it bears no resemblance to the single unit on which both field and armature windings are carried on the same pole pieces and armature core. The field frame for the two units is a single casting, Fig. 274, but the magnetic circuits of both the generator and the motor are entirely independent and each is a separate unit. They are combined in this manner solely for convenience in mounting where space is limited. The vibrating type of voltage regulator is employed in connection with the generator while the starting motor operates through a train of reducing gears and an overrunning clutch. Apart from the combination of the two units and the method of starting drive which this entails, the system is the same in its essentials as where the units are mounted independently.

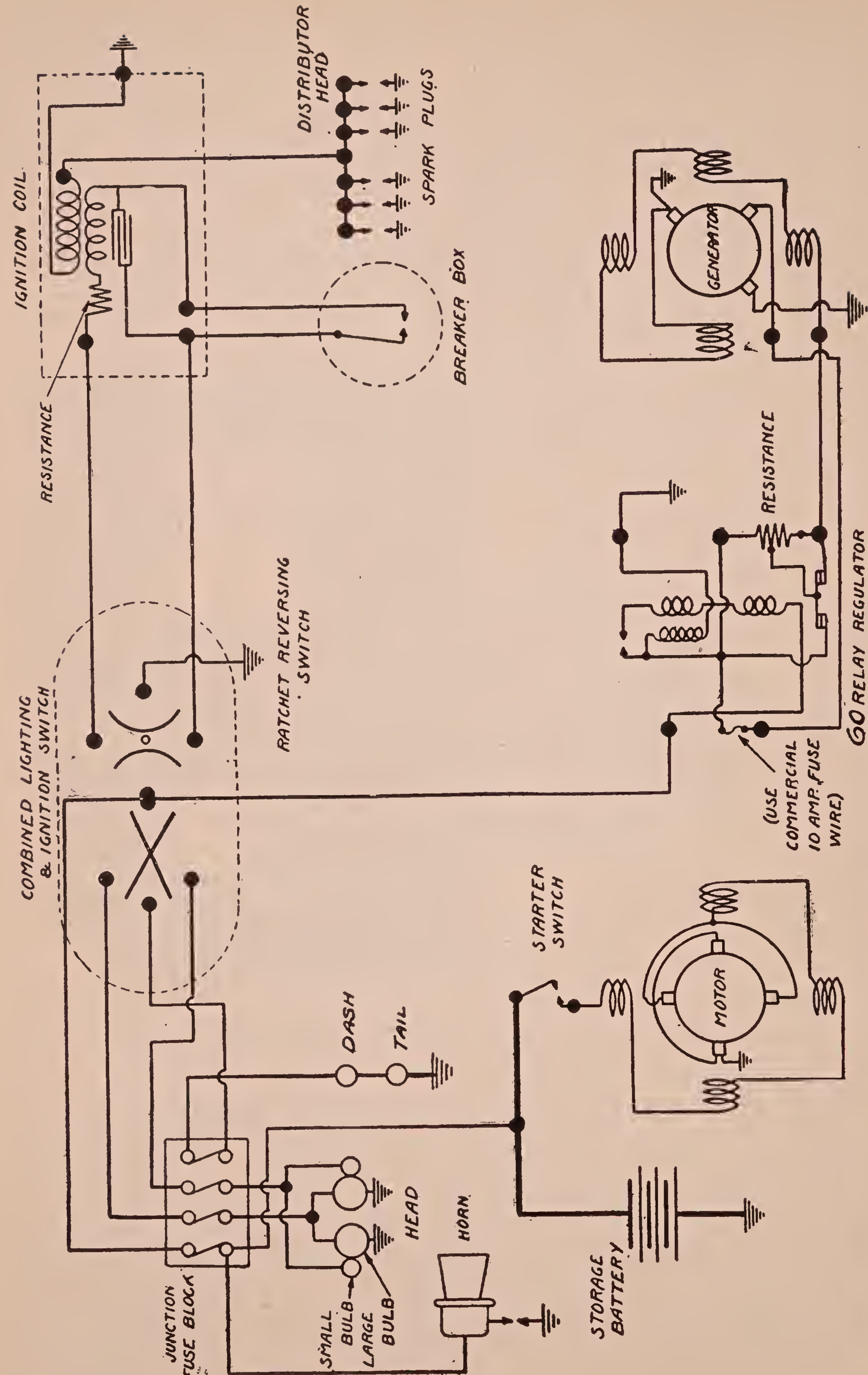


Fig. 275. Wiring Diagram for Remy Installation on the Velie, Model 22

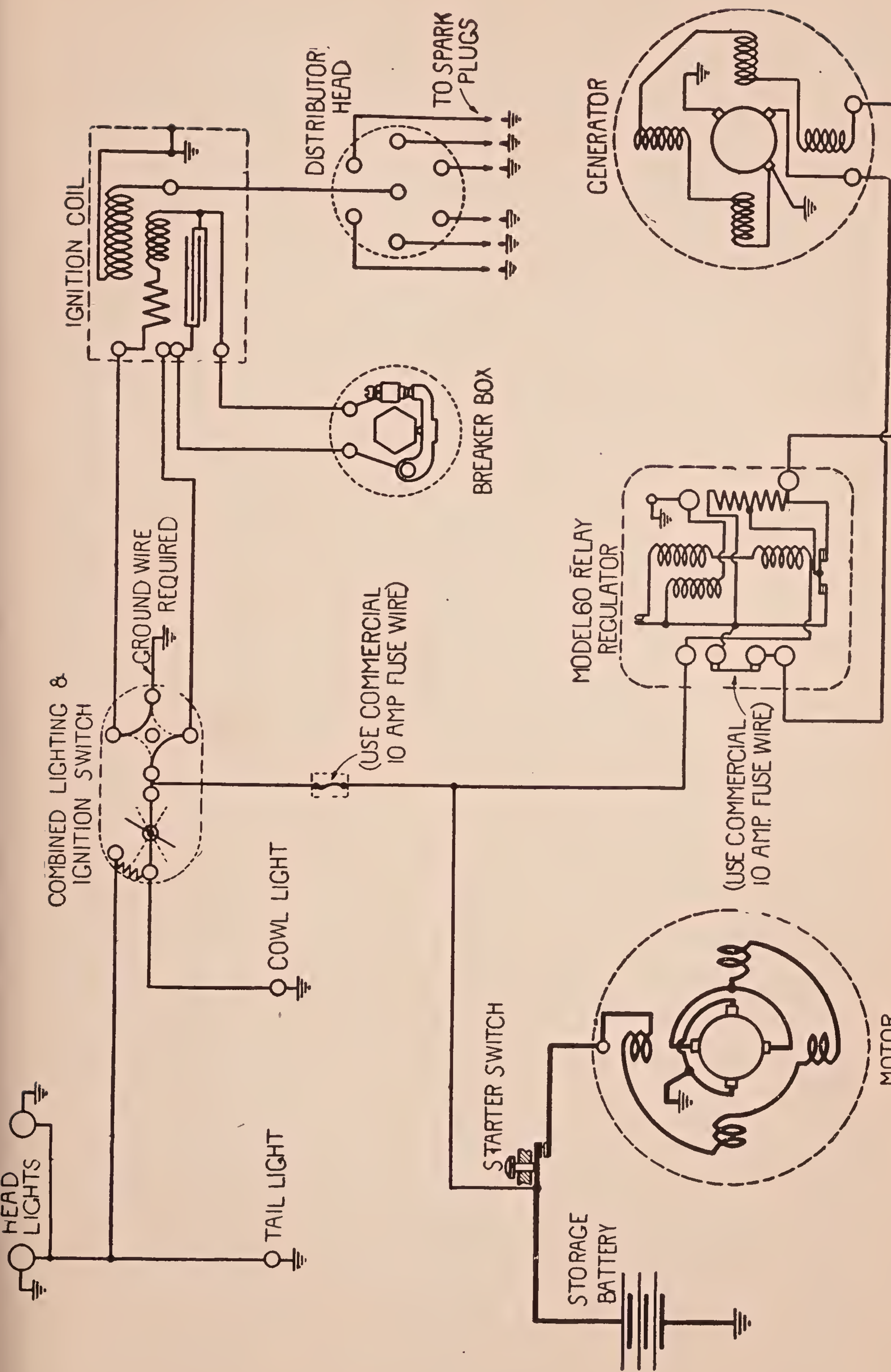


Fig. 276. Wiring Diagram of Remy Installation on the Oakland, Model 32

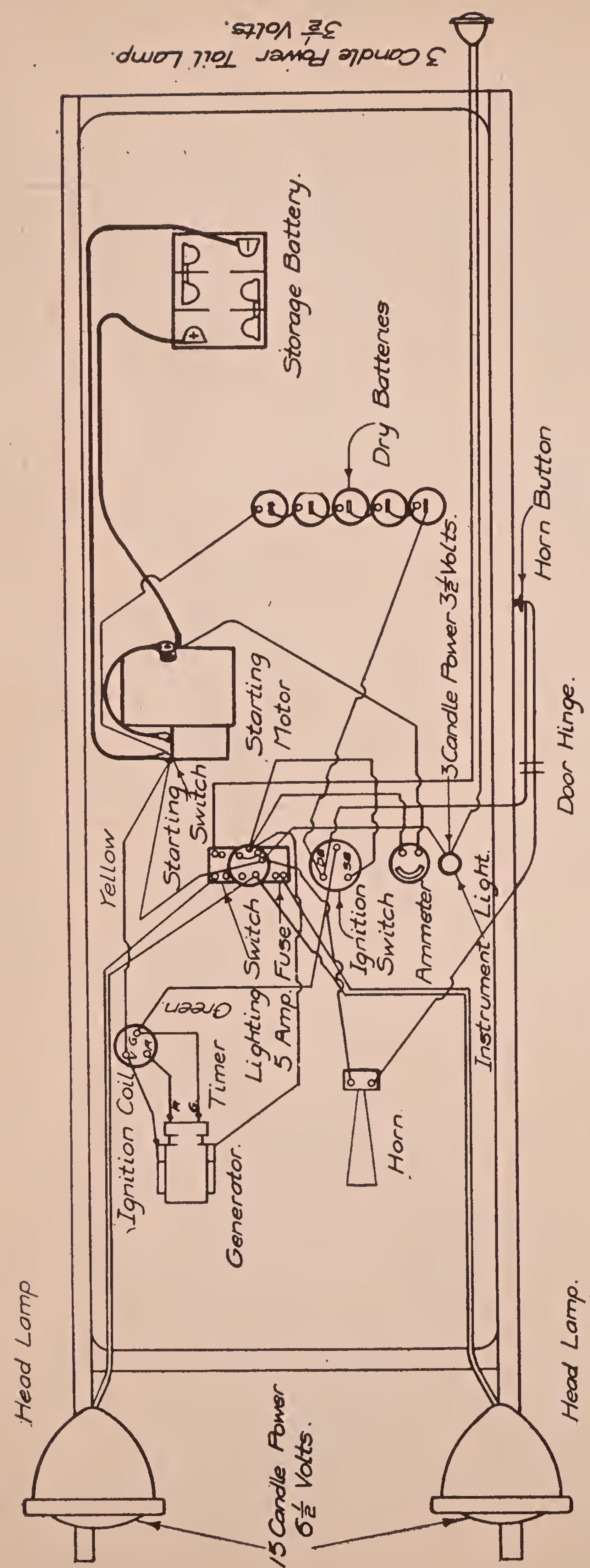


Fig. 277. Wiring Diagram for Remy Installation on the "Reo the Fifth"

Wiring Diagrams. Velie. Fig. 275 shows the installation on Velie, Model 22, and the details will be plain with further explanation. The "ratchet reversing switch" mentioned on the diagram is for controlling the ignition current and it is designed to reverse the direction of this current each time the switch is turned on in order to prevent the formation of a crater and cone on the ignition interrupter contacts, as previously described, thus keeping the points in good working order for a much longer period. The dash and tail light are 3½-volt lamps wired in series so that the failure of one puts the other out, thus giving an indication of the failure of the tail light at the dash.

Oakland. The Remy installation on Oakland Model 32 is

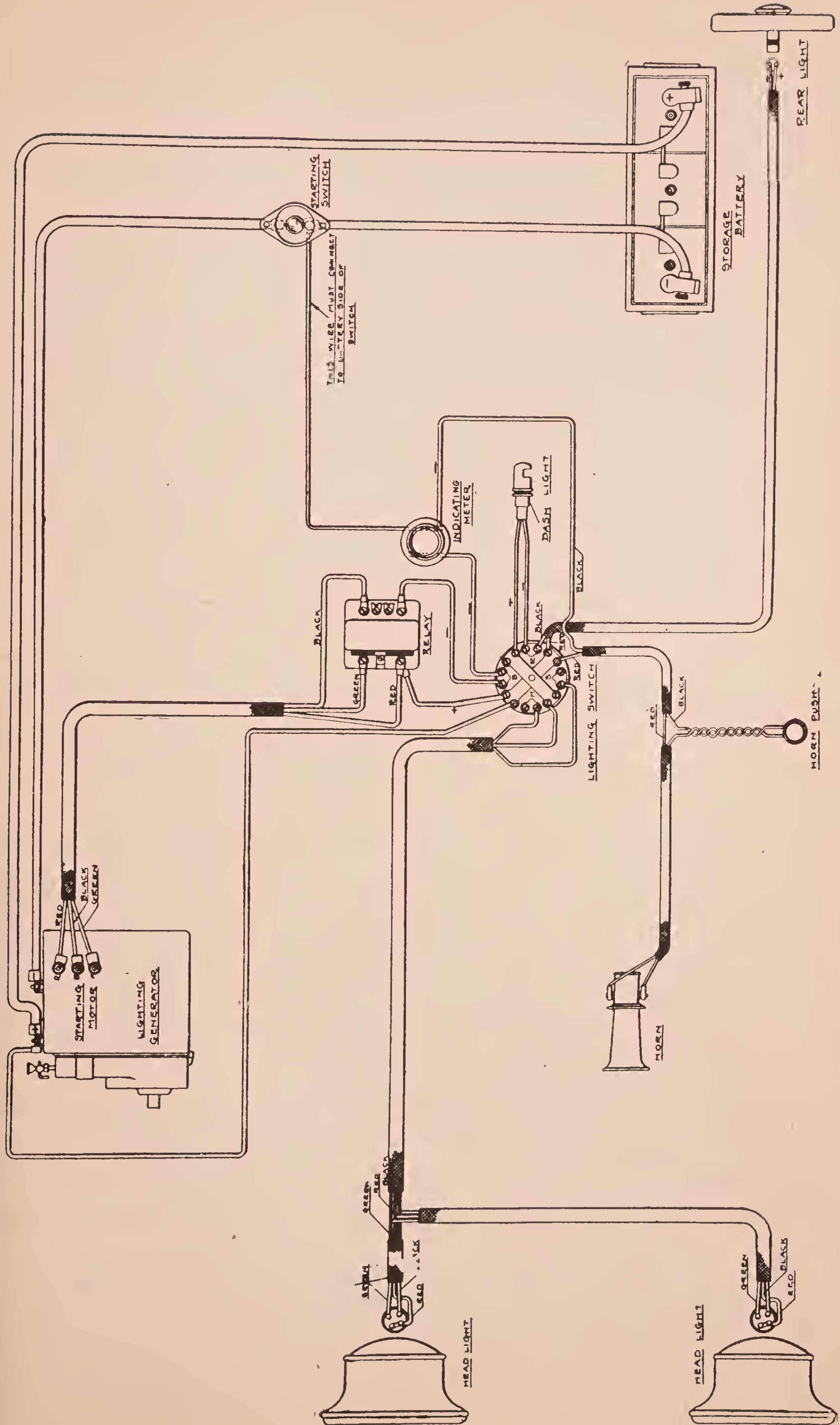


Fig. 278. Wiring Diagram for the Remy Double-Deck Unit on the National Six

shown in Fig. 276. The chief distinction between this and the previous diagram is the employment of a single 10-ampere fuse on the lighting circuits instead of independent fuses on each circuit. "Breaker box" refers to the ignition-circuit contact breaker or interrupter, as it is variously termed. The starting motor in this case is fitted with the Bendix drive.

Reo. On the Reo installation, Fig. 277, the starting motor is mounted on the transmission housing and drives to a shaft of the latter through a worm gear. In this case the starting switch is mounted directly on the starting motor, and an ammeter is supplied on the charging circuit instead of a telltale or indicator.

National. A typical installation of the single unit, or so-called double-deck unit is shown in Fig. 278. This is on the National six-cylinder model and is a two-wire system. It is not interconnected with the ignition system so there are no ground connections and no fuses are employed.

Instructions. These instructions cover the systems which include the ignition. For instructions applying to the double-wire system on cars having an entirely independent ignition system, like the National, see instructions under Auto-Lite, Delco, Gray & Davis, and others for failure of generator or motor, short circuits, and the like.

Battery Discharge. In systems of this type, discharge of the battery may be due to failure to open the ignition switch after stopping the car. The amount of current consumed is small but in time it will run the battery down. The indicator or the ammeter, according to which is fitted, will show a discharge. An entire failure of the current may indicate: a loose connection at battery terminals, at battery side of starting switch in connection with a blown main fuse (Oakland), or a loose battery ground connection; a loose connection at motor side of starting switch or at starting motor, and a broken wire between the switches. (See previous instructions on other makes for testing for broken or grounded circuits with lamp set.)

Failure of Lighting, Ignition, Starting. When the lights and ignition fail but the starting motor operates, it indicates a short or open circuit between the starting switch and the main fuse (Oakland). This fuse should first be examined and, if blown, a search should be made for the ground or short circuit causing it before putting in a new fuse. The fault will be in the wiring between the switch, lights, and ignition distributor. See that all connections including those on fuse block are tight. When the lights fail but the ignition and starting motor operate, the trouble will be found either in the circuits between the lighting switch and lamps, in the lamps themselves, as a burned-out bulb causing a short circuit, or from loose connections in these circuits. Failure of the ignition with the remainder of the system operating may be traced to loose connections at the ignition switch, coil, or distributor, poor grounding of the ignition switch on the speedometer support screw, or to open or short circuits between the ignition switch and the distributor. Further detail instructions on ignition are given in Part II, Ignition.

Dim Lights. When all the lights burn dimly, the most probable cause is the battery, but if a test shows this to be properly charged, a ground between the battery and the starting switch or between the latter and the generator may be responsible for leakage. Other causes are the use of higher candle-power lamps than those specified, the use of low efficiency carbon-filament bulbs, or failure of the generator to charge properly.

Examine generator-field fuse and if blown, look for short circuits before replacing as previously instructed. A simple test of the generator may be made by switching on all lights with the engine standing. Start the engine and run at a speed equivalent to 15 miles per hour or over. If the lights then brighten perceptibly the generator is operating properly. This test must be made in the garage or preferably at night, as the difference would not be sufficiently noticeable in daylight.

If the generator fuse is intact, examine the regulator relay contacts. If the points are stuck together, open by releasing the relay blade with the finger. Clean and true up points as previously instructed and clean out all dust or dirt from relay before replacing cover. Particles of dirt lodged between the points will prevent generator charging properly.

The failure, flickering, or dim burning of any single lamp will be due to a burned-out bulb, to loose or frayed connections at lamp or switch, to a bulb loose in its socket, or to an intermittent ground or short circuit in the wiring of that particular lamp, or to the frame of the lamp not being grounded properly. Where dash and tail lamps are in series, examine both bulbs and replace the one that has burned out. Test with two dry cells connected in series.

Ammeter. When the indicator or ammeter does not register a charge with the engine running and all lights out, stop the engine and switch on the lights. If the instrument gives no discharge reading, it is faulty. If it shows a discharge, the trouble is in the generator or connections. In case the ammeter registers a discharge with all lights off, ignition switch open, and engine idle, examine relay contacts to see if they remain closed. If not, disconnect the battery. This should cause the ammeter hand to return to zero; if it does not, the instrument is out of adjustment. With the ammeter or indicator working properly and the relay contacts in good condition, a discharge then indicates a ground or short circuit. When examining the relay for trouble, do not change the adjustment of the relay blade.

SIMMS-HUFF SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The dynamotor is of the multipolar type having six poles, as illustrated in Fig. 279, which shows the field frame, coils, and poles. Fig. 280 shows the complete unit with the commutator-housing plates removed, while Fig. 281 illustrates the complete brush rigging.

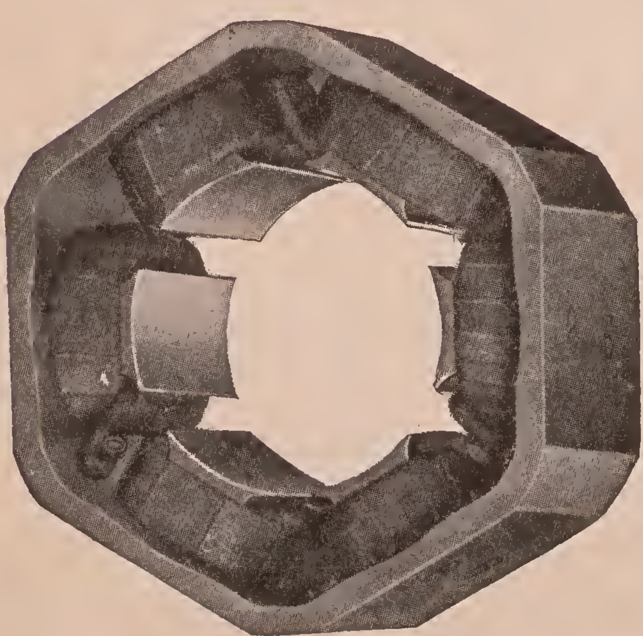


Fig. 279. Field Frame, Poles, and Windings for Simms-Huff Dynamotor
Courtesy of Simms Magneto Company, East Orange, N. J.

Regulation. Regulation is by reversed series field, in connection with a combination cutout and regulator.

Instruments. An ammeter is supplied showing *charge* and *discharge.*

Wiring Diagram. The dynamotor has two connections, one at the bottom of the forward end plate, marked "*DYN+*", and the other on top of the field yoke designated as "*FILED*". As the system is a single-wire type the opposite sides of both circuits are grounded within the machine itself. The terminals on the cut-out are marked "BAT+", "DYN+" and "DYN−", "BAT−", and "FLD". BAT+ connects through a 12-gage wire to the negative side of the ammeter and thence to a terminal

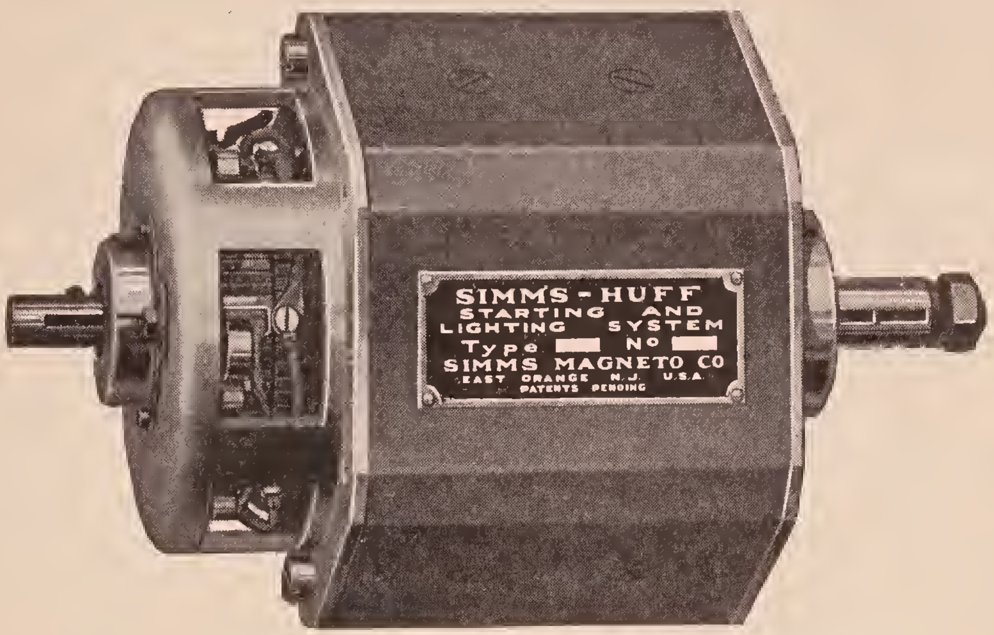


Fig. 280. Simms-Huff Dynamotor with Commutator Housing Plates Removed

on the starting switch. This connects it permanently to +R of the battery through the ammeter. This wire supplies the current to the distributing panel from which current is supplied to the lamps and horn. DYN+ connects through a similar wire to the plus terminal of the dynamo, while DYN− and BAT− connect with the −L terminal of the storage battery through a wire of the same size.

Change of Voltage. The system is known as 6—12-volt type, signifying that the current is generated at 6 volts, but is employed for starting at 12 volts. There are accordingly six cells in the storage battery and the latter is charged by placing the two halves of it consisting of two 3-cell units in parallel. This is indicated in the upper diagram, Fig. 282, also in the middle diagram which shows the connections for charging. In the lower diagram of the figure are shown the starting connections, the switch being connected to throw the six cells of the battery in series so that the unit receives current at 12 volts for starting, thus doubling its power. Six-volt lamps are

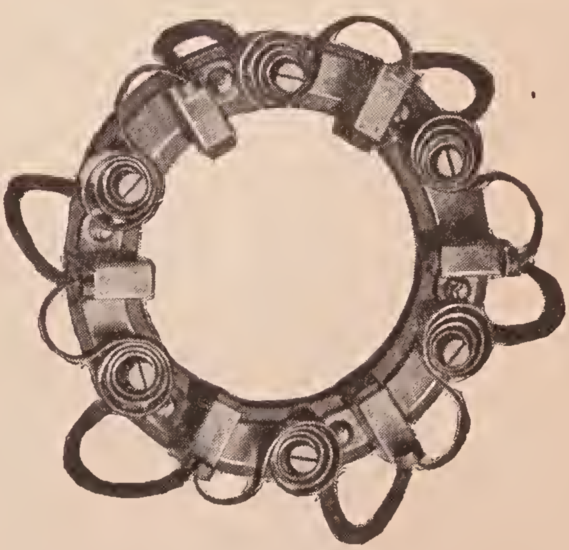


Fig. 281. Brush Rigging for Simms-Huff Dynamotor

employed and are supplied with current from the left-hand section of the battery, marked *1*, as shown in the upper part of the diagram.

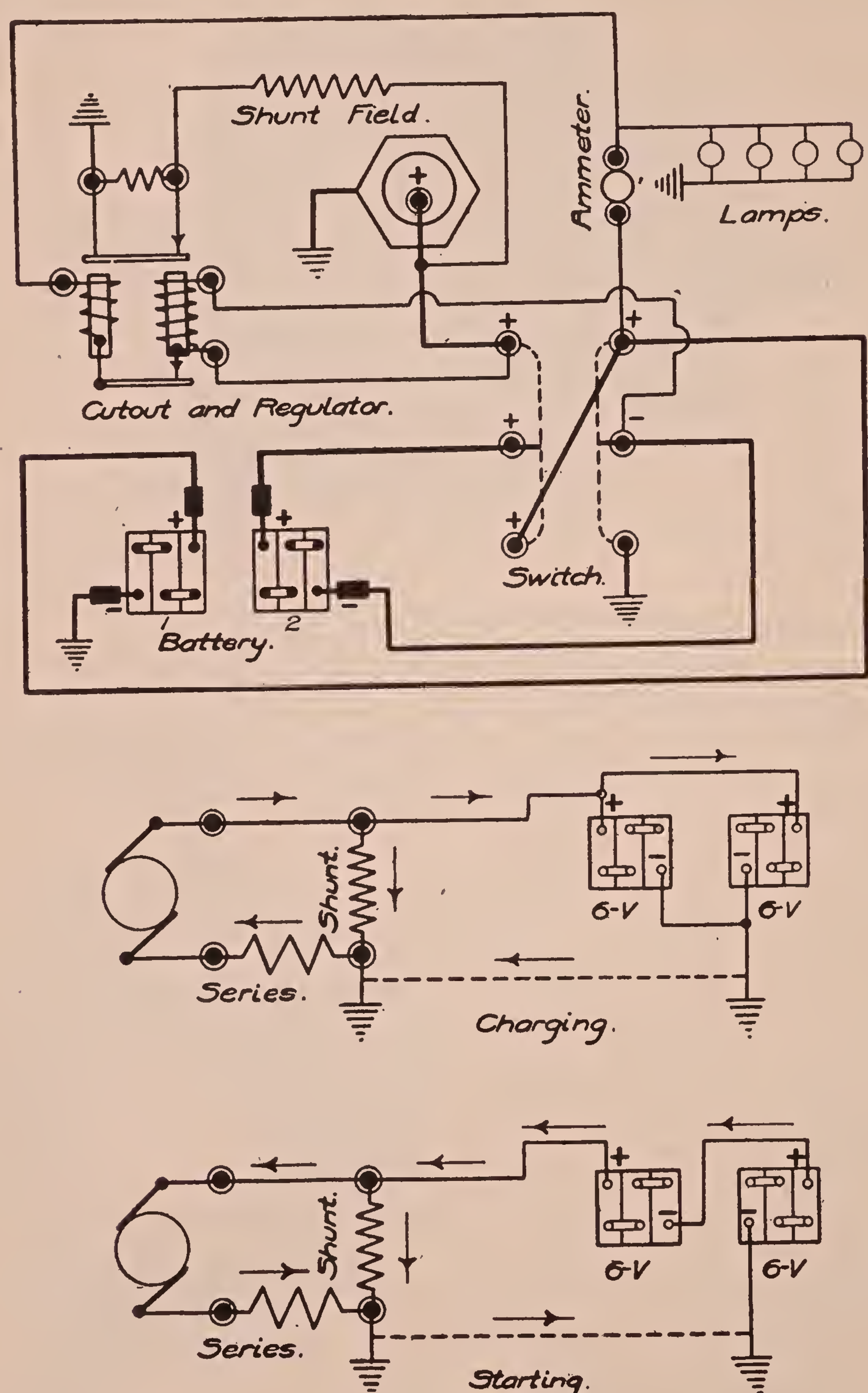


Fig. 282. Wiring Diagram for Simms-Huff Starting and Lighting System

Instructions. The Simms-Huff system as above described is standard equipment on the Maxwell cars. The combination cut-out and regulator is mounted on the rear of the dash panel carrying the ammeter and switch. It consists of two distinct devices, the cut-out serving the usual purpose of protecting the battery when the generator voltage drops, and the regulator limiting the current output of the dynamo as the engine speed increases. In connection with it a special regulator switch is provided. This is located on the right side of the dash panel and has two positions, HIGH, and LOW, the latter inserting additional resistance in the field circuit of the dynamo to further limit its output when the car is driven steadily at high speed on long runs. This switch is kept in the HIGH position for all ordinary driving and only shifted to LOW as above mentioned.

Failure of Cut-Out or of Regulator. Should the ammeter pointer go to the limit of its travel on the *discharge* side, this indicates that the cut-out contact points have failed to release on the slowing down of the generator. The latter also will continue to run as a motor after the engine is stopped. Disconnect the two wires from the terminals on the generator and wrap them with friction tape to prevent their coming in contact with any metal parts of the car. Clean and true up contact points as outlined in previous instructions. An unusually high reading on the *charge* side of the ammeter will indicate a failure of the regulator to work. If an inspection shows no sign of broken or crossed wires, loose connections, or other obvious trouble, the manufacturers recommend that the unit be sent to them. In the case of the owner, it is recommended that no attempt be made to correct faults in the cut-out or regulator, but that it be referred to the maker or the nearest service station.

SPLITDORF SYSTEM

Single=Unit Twelve—Six=Volt Two=Wire Type

Dynamotor. Both windings are connected to the same commutator on the dynamotor which is the bipolar type.

Regulation. The inherent type of regulation using a bucking-coil winding is employed.

Wiring Diagram. As the lamps are run on 6 volts, the 6-cell battery is connected as two units of 3 cells each for lighting, and these units are connected in series-parallel for charging, as the dynamotor produces current at 6 volts. The remaining details of the connections will be clear in the wiring diagram, Fig. 283.

Splitdorf Two-Unit Six-Volt Type

Control. *Switch.* The starting switch is mounted on the starting motor. This switch automatically breaks the circuit as soon as the engine starts. The starting gear slides on spiral splines on the armature shaft, so that when the engine gear overruns it, the starting gear is forced out of engagement. This gear is connected to a drive rod which also engages a switch rod, so that when the

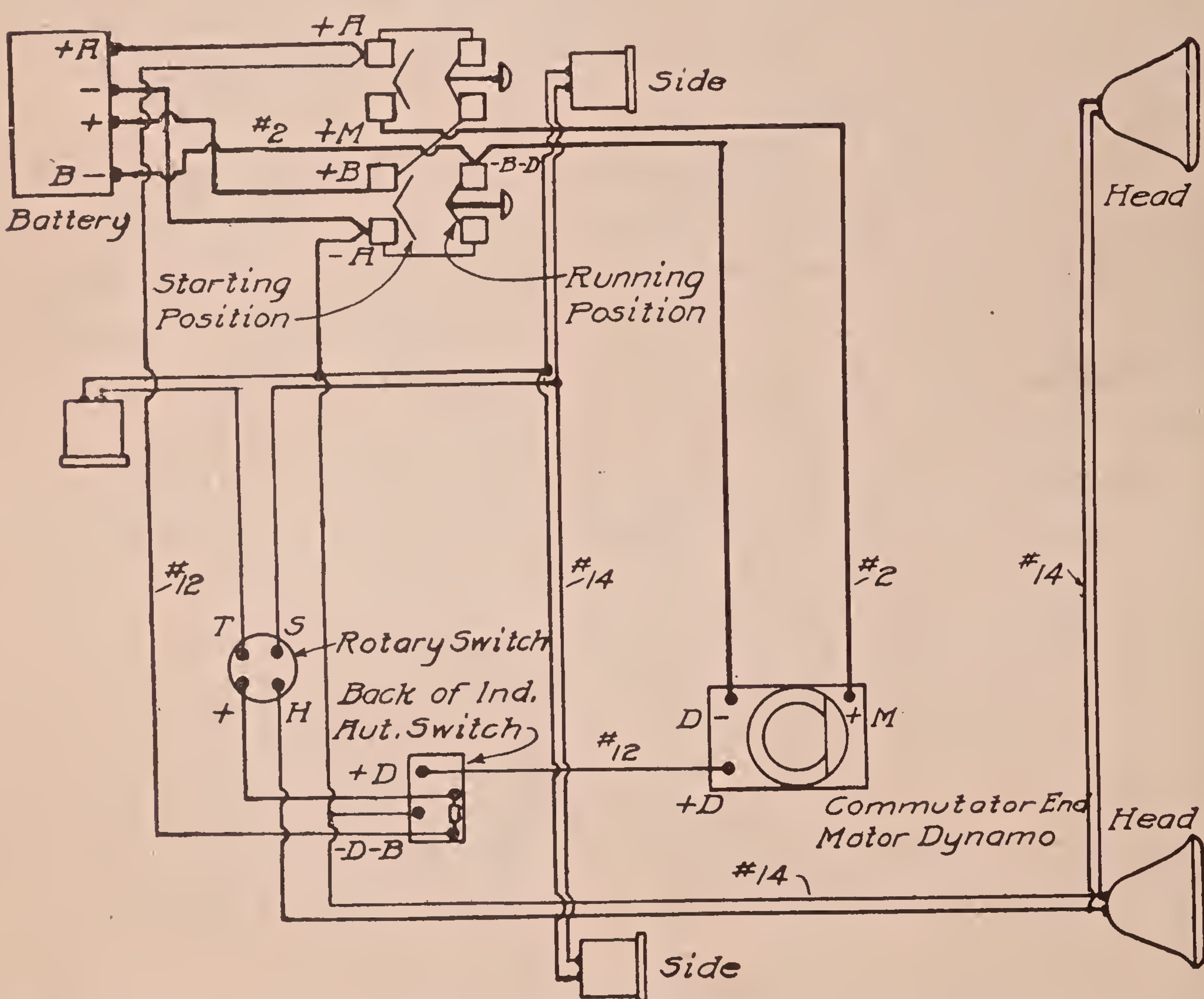


Fig. 283. Wiring Diagram of Splitdorf-Apelco Single-Unit Twelve- to Six-Volt Two-Wire System

gear is forced out of mesh with the flywheel, it carries the switch rod with it and automatically opens the circuit. The switch contacts cannot stick and no damage can result from holding down the switch pedal after the engine has started.

Regulation. A vibrating type of regulator built into the generator is employed. (See the description under Methods of Regulation, Part III.) This system otherwise is along standard lines, and instructions given in connection with other two-unit systems of similar type apply to it.

U. S. L. SYSTEM

Twenty-Four—Twelve-Volt, and Twelve—Six-Volt; Single-Unit; Two-Wire

Variations. The 24—12-volt signifies that the starting voltage is 24 and the generating voltage 12, the battery of twelve cells being

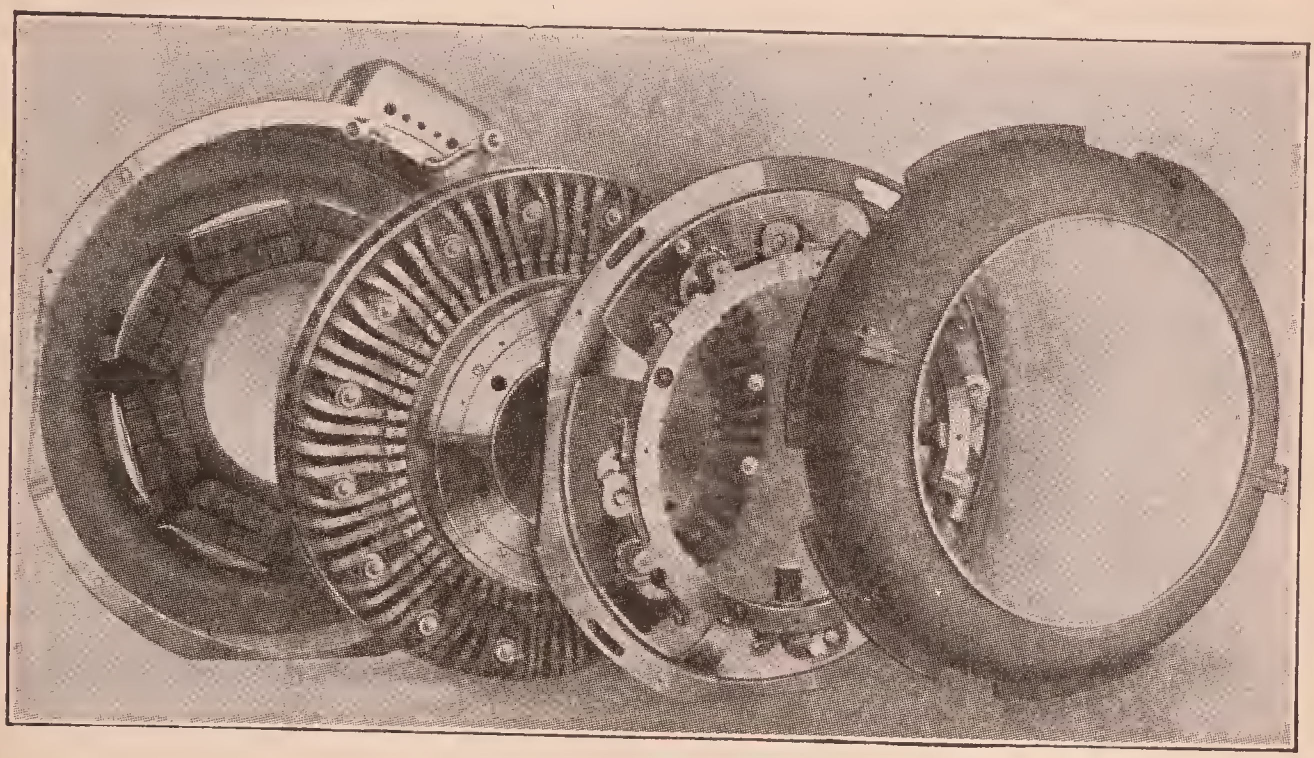


Fig. 284. Details of U. S. L. Flywheel Type Dynamotor with Outside Armature
Courtesy of U. S. Light and Heat Corporation, Niagara Falls, N.Y.

divided into two groups of six each in series-parallel for charging, while 12—6 signifies that the starting voltage is 12 and the generating voltage 6, the six-cell battery being divided in the same manner.

Generator-Starting Motor. The machine is multipolar (eight poles) and is designed to take the place of the flywheel of the engine: the 24—12-volt being made with an "outside" armature, Fig. 284, i.e., the armature revolving outside of the field poles which it encloses; and the 12—6-volt with an inside armature, Fig. 285. As the armature is mounted directly on the end of the crankshaft, the drive is direct at engine speed whether charging or starting.

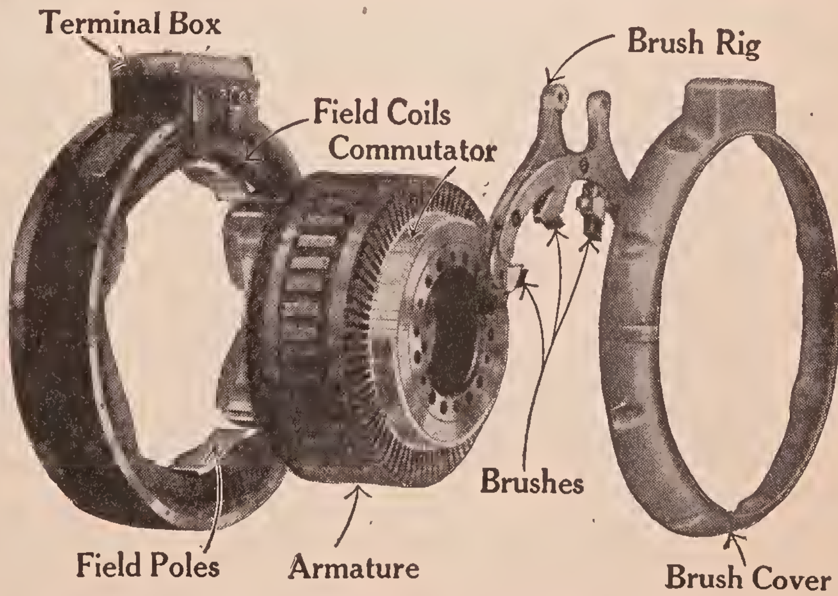


Fig. 285. U. S. L. Inside Armature Type Dynamotor (External Regulator)

As a machine of this size would generate an amount of current far in excess of that required for the charging of the largest practicable battery that could be employed, only three of the brushes are used when the unit is running as a generator, Fig. 286, while all of the brushes are employed when it operates as a starting motor.

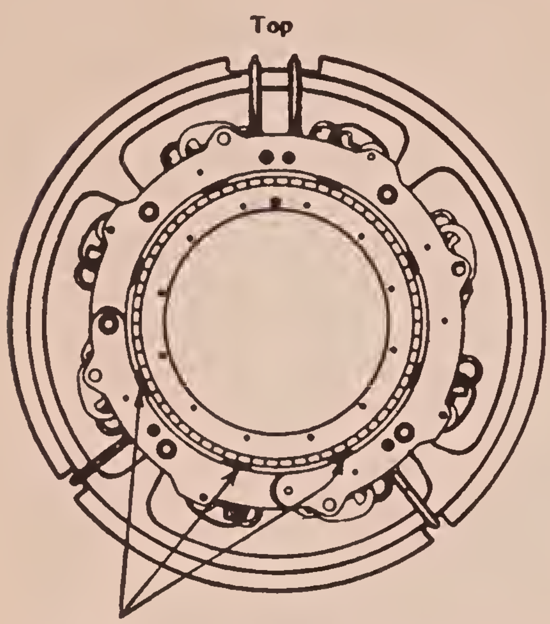


Fig. 286. Location of Generating Brushes in U.S.L. Dynamotor

Regulation. The 24—12-volt unit is made with two types of regulation, one using an external regulator, usually mounted on the dash, and the other of the inherent type employing a differential winding or bucking coil. The 12—6-volt type has the external regulator. They may be distinguished by the presence of the regulator in the charging circuit. This regulator, however, must not be confused with the automatic switch or battery cut-out which is only employed on the inherently regulated type.

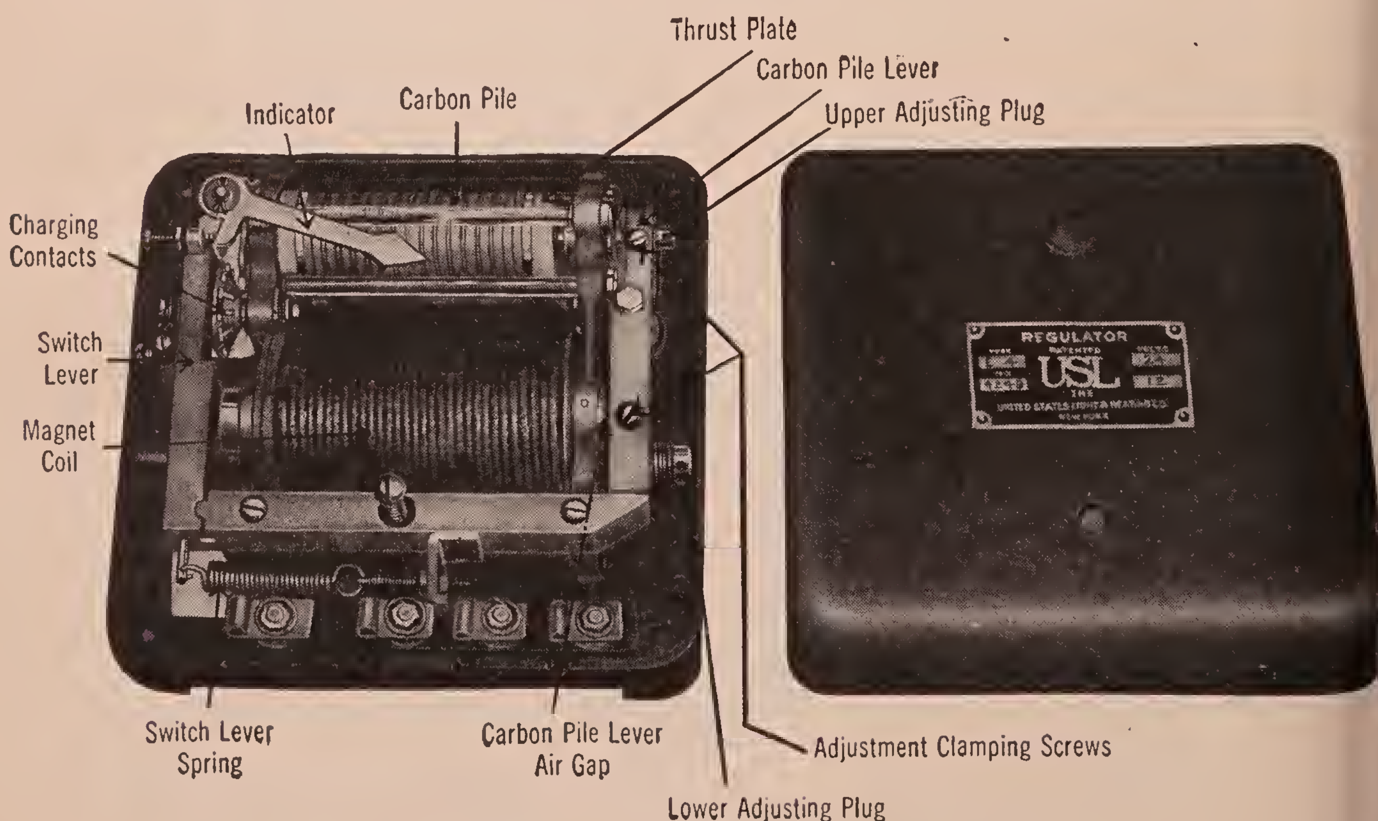


Fig. 287. External Regulator of the U.S.L. System
Courtesy of U.S. Light and Heat Corporation, Niagara Falls, N. Y.

The details of the regulator are shown in Fig. 287, and it will be noted that it also incorporates the battery cut-out as well as an indicating

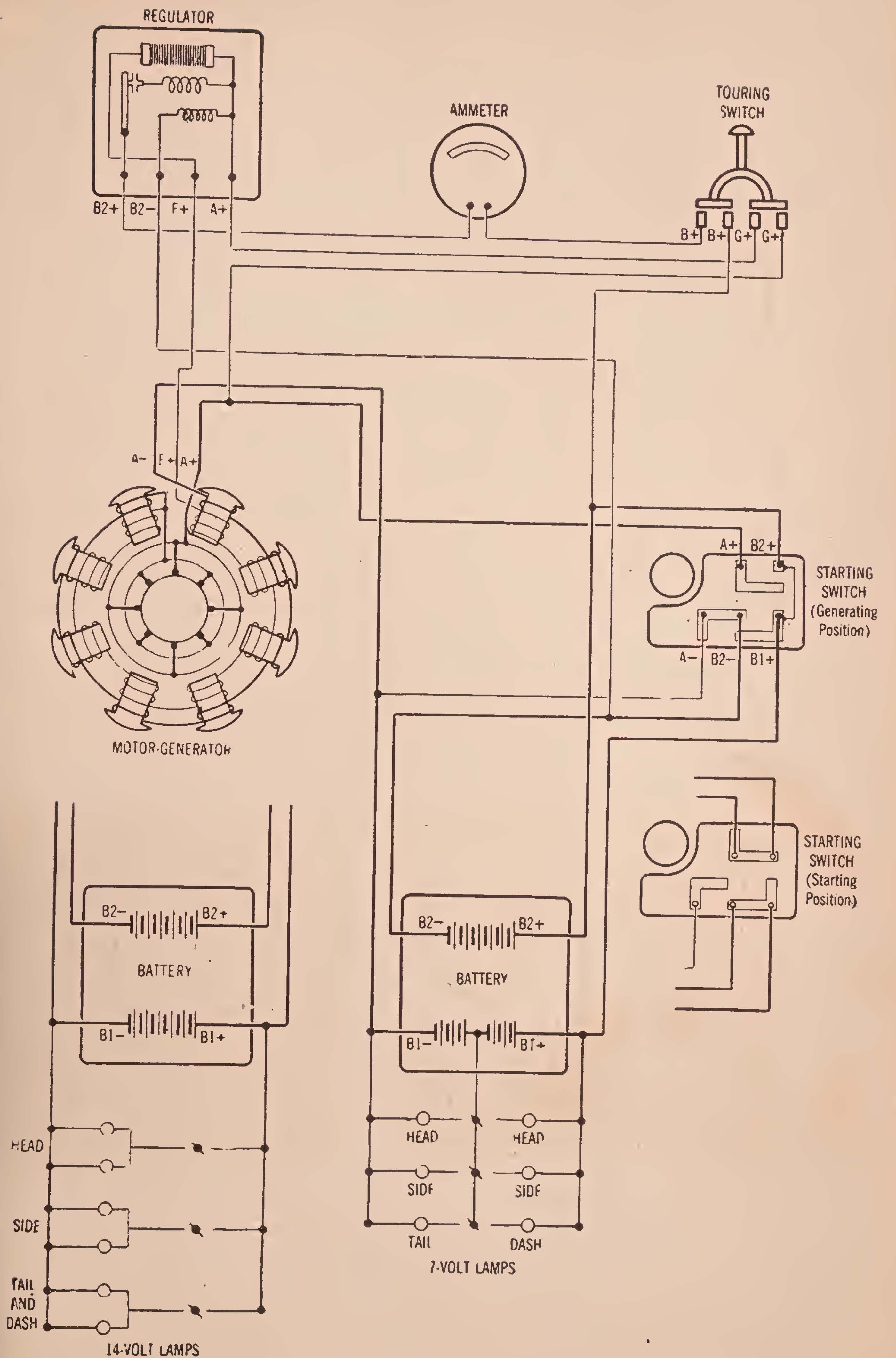


Fig. 288. Wiring Diagram for 24- to 12-Volt External Regulator Type, U.S.L. System

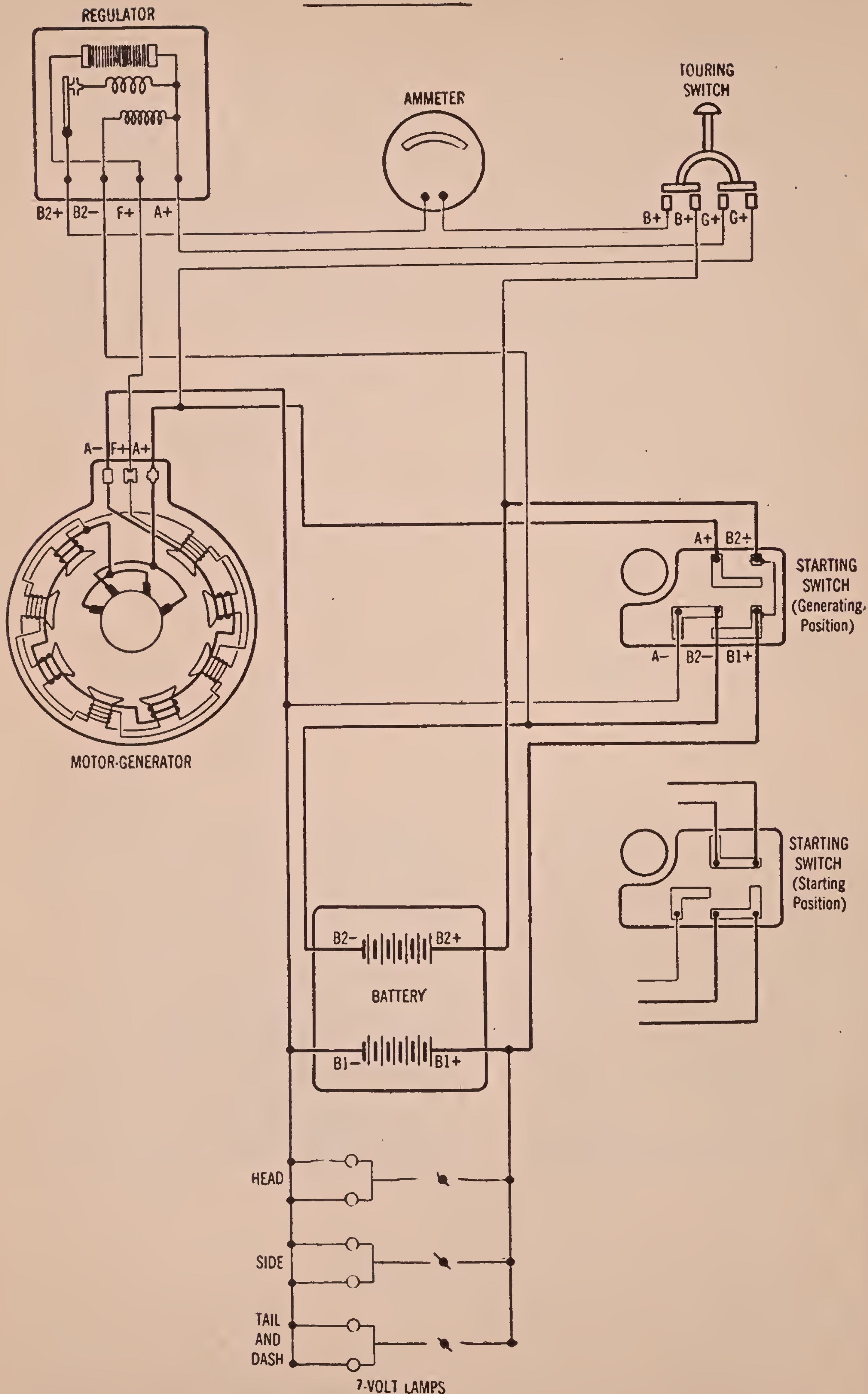


Fig. 289. Wiring Diagram for 12- to 6-Volt External Regulator Type, U.S.L. System

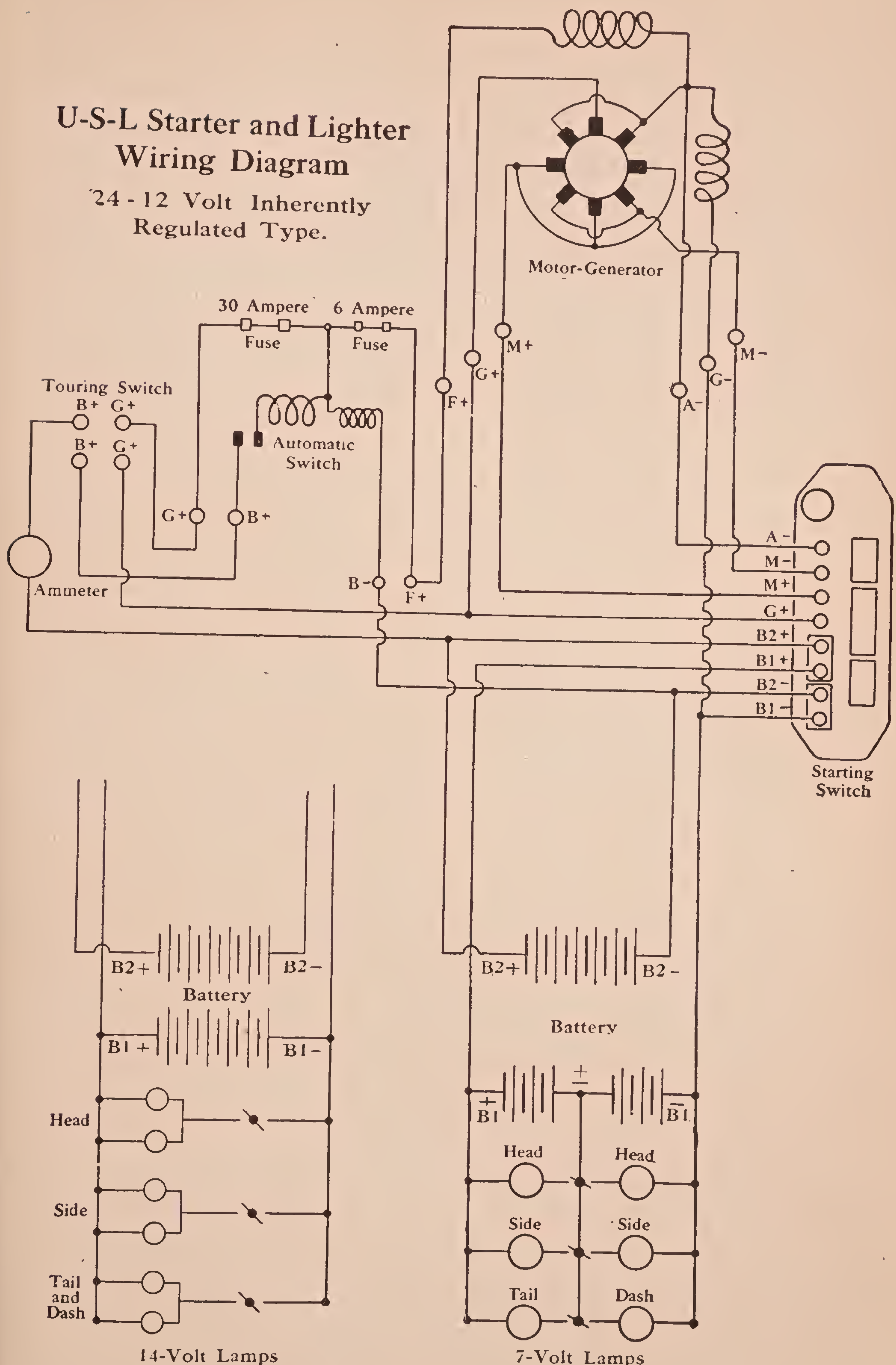


Fig. 290. Wiring Diagram for 24- to 12-Volt Inherently Regulated Type, U.S.L System

pointer which shows whether the regulator is working properly or not. In operation, the regulator cuts into the generator-field circuit a variable resistance consisting of an adjustable carbon pile. The connections of the regulator are shown in the wiring diagrams.

Instruments and Protective Devices. In addition to the indicator which is combined with the external regulator in that type, an ammeter is also employed to show the rate of charge and discharge.

Two fuses, mounted in clips on the base which holds the battery cut-out or automatic switch, protect all the circuits. The smaller of these is a 6-ampere fuse and is in the field circuit of the generator, while the larger is a 30-ampere switch and is in the generator charging circuit.

Wiring Diagrams. Figs. 288, 289, and 290 show the standard wiring diagrams of the three types mentioned, being, respectively, the 24—12-volt externally regulated type, the 12—6-volt external regulator and internal-armature type, and the 24—12-volt inherently regulated type. In the diagram proper of each of the 24—12-volt types is indicated the layout for using 7-volt lamps, while the extra diagram at the side shows the method of connecting for 14-volt lamps. The "touring switch" shown on the first two diagrams is a hand operated switch in the charging circuit and is designed to prevent overcharging of the battery when on long day runs. This is not employed on the inherently regulated type (24—12-volt) in which the reversed series-field winding of the generator itself takes the place of the external regulator, and the battery cut-out is an independent instrument, also serving to carry the fuses.

Instructions. *Touring Switch.* On the types equipped with the touring switch, this enables the driver to control the charge. Pulling out the button closes the switch and permits the generator to charge the battery when the engine reaches the proper speed; pushing it in opens the circuit. This switch must always be closed before starting the engine, and it must be kept closed whenever the lights are on and also under average city driving conditions where stops are frequent and but little driving is done at speed. When touring, the switch should be closed for an hour or two and then allowed to remain open during the remainder of the day, as this is sufficient to keep the battery charged and there is no need for further charging until the lamps are lighted. This switch should be inspected at least once a season. Push in button to open circuits, remove screw at back and take off cover. The switch fingers should be bright and make good contact with the contact block; if they do not do so, remove and clean them as well as the contact pieces on the block. Do not allow tools or other metal to come in contact with switch parts during the operation, for even though the switch is open, a short circuit may result and one of the fuses will blow. In replacing the fingers, bend sufficiently to make good firm contact. Some of the first cars put out are equipped with a touring switch of the push-button type like a lighting switch. This switch is entirely sealed and cannot be inspected except to see that the connections are tight.

Starting Switch. The starting switch is filled with oil and this should be renewed once a year. To do this, the switch must be disconnected and the screws *A*, Fig. 291, removed; in case the box sticks, insert a screwdriver point between the top of the box and the bottom of the frame and pry loose. To guard against the switch dropping when these screws are removed, hold the hand beneath it while taking them out. Before attempting to remove the switch, the positive battery connections, B1+ and B2+ (see diagram, Fig. 290), must be taken off and the terminals taped to prevent accidental short circuits. Pour out the old oil, clean out thoroughly with gasoline, allow to dry, and refill with the best grade of transformer oil to the proper level with the switch box standing plumb. The proper height on the Type E-2 or E-3 box is $1\frac{5}{8}$ inches, on E-4 box $2\frac{3}{4}$ inches. Before putting in the new oil, however, the drum and finger contacts should be examined, and, if pitted or dirty, should be cleaned with a fine file. Make sure that all fingers bear firmly against the drum so as to make good contact; if they do not, remove and bend them slightly to insure this. If the starting switch is abused in operation, or if improper oil containing water or other impurities be used, the contacts will burn and fail to make good electrical connection. The switch box is the only place in the system requiring oil.

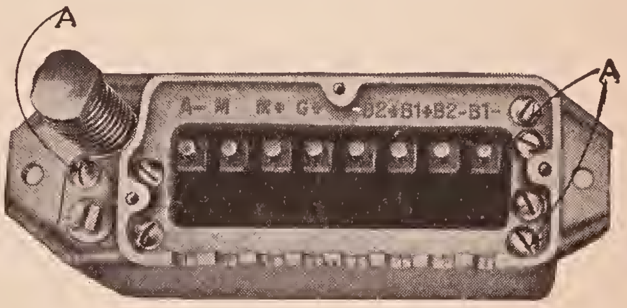


Fig. 291. U.S.L. Oil-Filled Starting Switch

Brush Pressures. There is only one adjustment on the generator, viz, the tension of the brush fingers. The brushes should fit freely in their holders so as to transmit the full pressure due to spring tension against the commutator. The adjustment as made at the factory should not need correction under one or two years of service. Pressures required on the various machines are as follows: for Type E-12 external regulator, $1\frac{3}{4}$ pounds on each brush; $1\frac{1}{4}$ pounds on brushes of all other external-regulator machines; $1\frac{3}{4}$ pounds on each of the three lowest brushes on the inherently regulated type, these being the only brushes used in generating the charging current; $1\frac{1}{4}$ pounds on each of the remaining brushes of the inherently regulated generator. Keep commutator clean as the chief cause of failure of the inherently regulated type is an excess of oil or dirt or both accumulating on it.

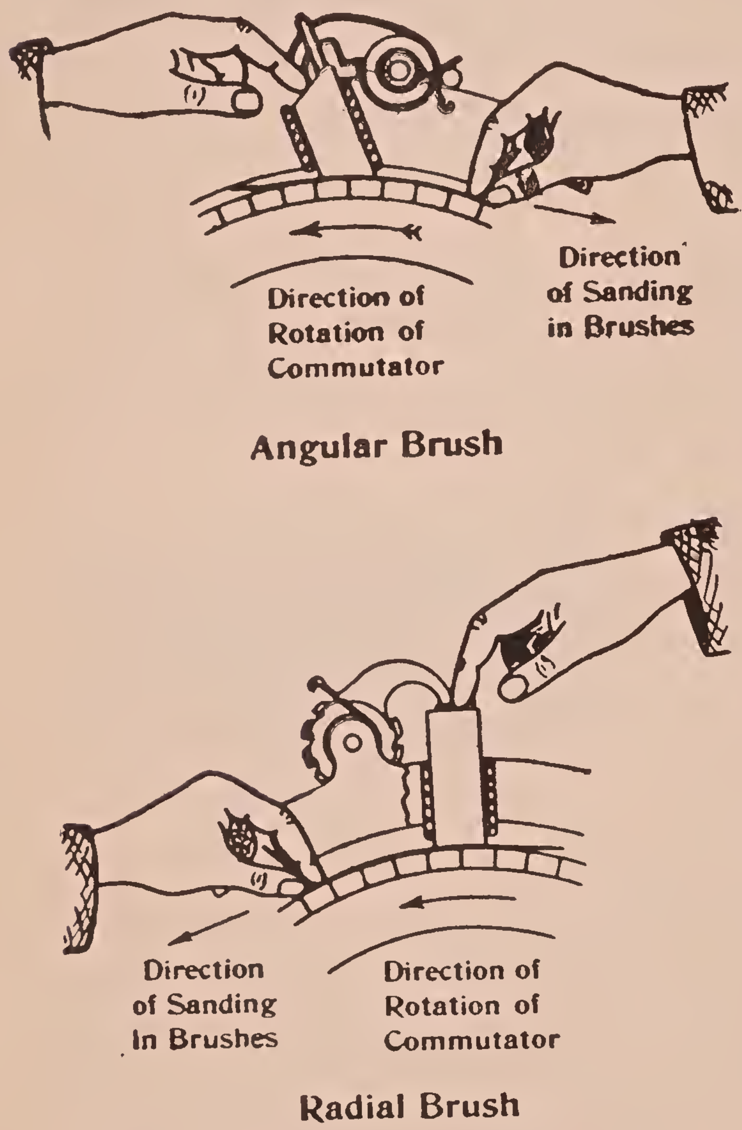


Fig. 292. Methods of Sanding-in Brushes on Dynamotor

Radial and Angular Brushes. The brushes employed are of two types—radial and angular. Radial brushes are used on external-regulator type generators other than those having "Type No. E-49" on the name plate; angular brushes are used on Type E-49 and all inherently regulated generators. Each radial brush should bear squarely against that side of its holder *toward which the commutator rotates.* Each angular brush should bear squarely against that side of its pocket *away from which the commutator rotates.* To sand-in old brushes or fit new brushes properly, insert a strip of No. 00 sandpaper (never emery), preferably worn, between the commutator and brush, press down on top of brush and draw sandpaper under it, Fig. 292. If the brush is *radial*, draw the sandpaper in the direction of commutator rotation; if *angular*, draw the sandpaper in the direction opposite to that of commutator rotation. No oil is needed on the commutator as the brushes themselves contain all the lubricant necessary. Fine sandpaper as mentioned above may be used for cleaning the commutator when necessary, the engine being allowed to turn over slowly during the operation.

External Regulator. Should the automatic switch (cut-out) member of the regulator remain closed with the engine stopped, start the engine at once, and the switch lever should open. If it does not, remove the regulator cover (with the engine running) and pull the lever open by hand. When the switch lever is correctly set, a slight discharge will be noted on the ammeter the moment the switch lever opens. This discharge reading should not exceed 4 amperes; if in excess of this, increase the tension of the switch-lever spring by releasing the lock nut on the left side of the plate and turning up on the nut at the right until the proper adjustment is secured, then retighten the lock nut. The indicating pointer is moved by the switch lever in closing and when it appears in its upper position through the sight glass on the cover, the battery is charging; when the switch lever opens the pointer drops against its stop by gravity.

When the battery shows a lack of capacity, the battery itself and all connections and fuses being in good condition, note the amount of charging current indicated by the ammeter. If the maximum current (external-regulator type) shown by the ammeter does not exceed 10 to 12 amperes at full engine speed after the engine has been running for fifteen minutes, see that the brushes and commutator are in good condition—wipe off the commutator with a dry cloth and if necessary sand the brushes in to a good seat. If this does not increase the generator output as shown by the ammeter, test the latter as already noted, i.e., see whether the pointer is binding and, if not, check with the portable testing instrument or another ammeter of the dash type. Should none of these remedies correct the fault, *screw in* the lower adjusting plug of the carbon-pile lever slowly, noting the effect on the ammeter reading as the adjustment is made.

With the external regulator, the charging current should not exceed 18 amperes at the highest engine speed. If at any time, the ammeter shows a higher reading than this, *screw out* the lower adjusting plug of the carbon-pile lever slowly to decrease the current, stopping when the indication does not go above 18 amperes at full speed.

After making this adjustment of the lower plug, make sure that the carbon-pile lever air gap does not exceed $\frac{1}{8}$ inch, nor is less than $\frac{3}{32}$ inch when the engine is stopped. If the gap is too small the switch lever will vibrate rapidly at high engine speeds. When necessary to adjust this gap, screw the upper adjusting plug in or out, but after doing so the current output must be checked and adjusted by means of the lower adjusting plug. Always tighten the adjustment clamping screws after setting either of the adjusting plugs.

Testing Carbon Pile. If the automatic-switch unit of the regulator does not cut in with the engine running at speed equivalent to 10 to 14 miles per hour, test the carbon pile by short-circuiting the terminals F+ and A+ of the regulator with the blade of a screwdriver. Speed up engine slowly and note whether the regulator cuts in much sooner than when the terminals are not short-circuited. Do not run the engine at high speed, nor for any length of time with the terminals short-circuited, as an excessive amount of current would be generated. If the regulator does cut in much earlier with the terminals short-circuited than without this, the carbon pile needs cleaning. Should the regulator not cut in earlier when short-circuited, or fail to operate altogether, examine the brushes of the generator. If they are in good condition, clean the carbon pile.

Unscrew the plug at the upper end of the glass rod and remove the rod; if any of the discs are pitted or burned, rub them together or against a smooth board to make them smooth and flat. Remove the end carbons and clean the brass plates with fine sandpaper, if necessary. In replacing end carbons make sure that they fit firmly against the brass end plates and that the screw heads do not project beyond the faces of the carbon discs. After reassembling the carbon pile, the regulator will need adjustment for current output, as previously noted.

If for any reason it becomes necessary to disconnect the battery, either open the touring switch and block it open so that it cannot be closed accidentally if car is to be run, or disconnect and tape the right-hand regulator terminal, A+. Otherwise, the machine will be damaged by operating.

Battery Cut-Out. Should either of the fuses mounted on the automatic switch of the inherently regulated type blow, immediately open the touring switch. A loose connection or a short circuit is probably the cause and the touring switch should not be closed again until it has been located.

Ammeter. This should be checked at least once a year by comparing it with a standard instrument such as the portable outfit mentioned previously, or any other suitable low-reading ammeter of known accuracy. To do this, disconnect the positive wire from the ammeter on the dash and connect it to the positive terminal of the standard ammeter used for testing; then connect a wire between the negative terminal of the standard ammeter and the positive terminal of the dash ammeter. With the engine running at various speeds, take simultaneous readings of both instruments; any difference between the two should be taken into consideration thereafter when reading the dash ammeter. Unless a test of this kind is carried out, the battery may be receiving either an insufficient or an excessive charge while the ammeter indicates the proper amount.

WAGNER SYSTEM

Single-Unit Twelve-Volt Two-Wire Type (Early Model)

Dynamotor. The bipolar-type dynamotor has both the series and the shunt-windings, i.e., of generator and motor, connected to the same commutator. It is driven direct as a generator, and through a special planetary gear when operating as a starting motor.

Regulation. The regulation is of the inherent type, utilizing the generator winding to weaken the field with increase in speed, i.e., a bucking coil.

Wiring Diagram. (*Single-Unit Type.*) The left side of the lower half of the diagram, Fig. 293, illustrates the connections when the unit is being used as a starter, as indicated by the arrow showing the direction of rotation of the armature. Those at the right are the running connections, the armature then rotating in the reverse direction and generating current to charge the battery.

Control; Transmission. *Switch.* This is a special type of drum switch mounted directly on the dynamotor on the same base with the battery cut-out. As shown in Fig. 294, when the lever *Q* is thrown to the left for starting, it also serves to tighten the brake band on the planetary gear. When moved in the opposite direction, it releases this brake, and another set of contacts on the drum of the switch connect the generator for charging. Fig. 295 shows the

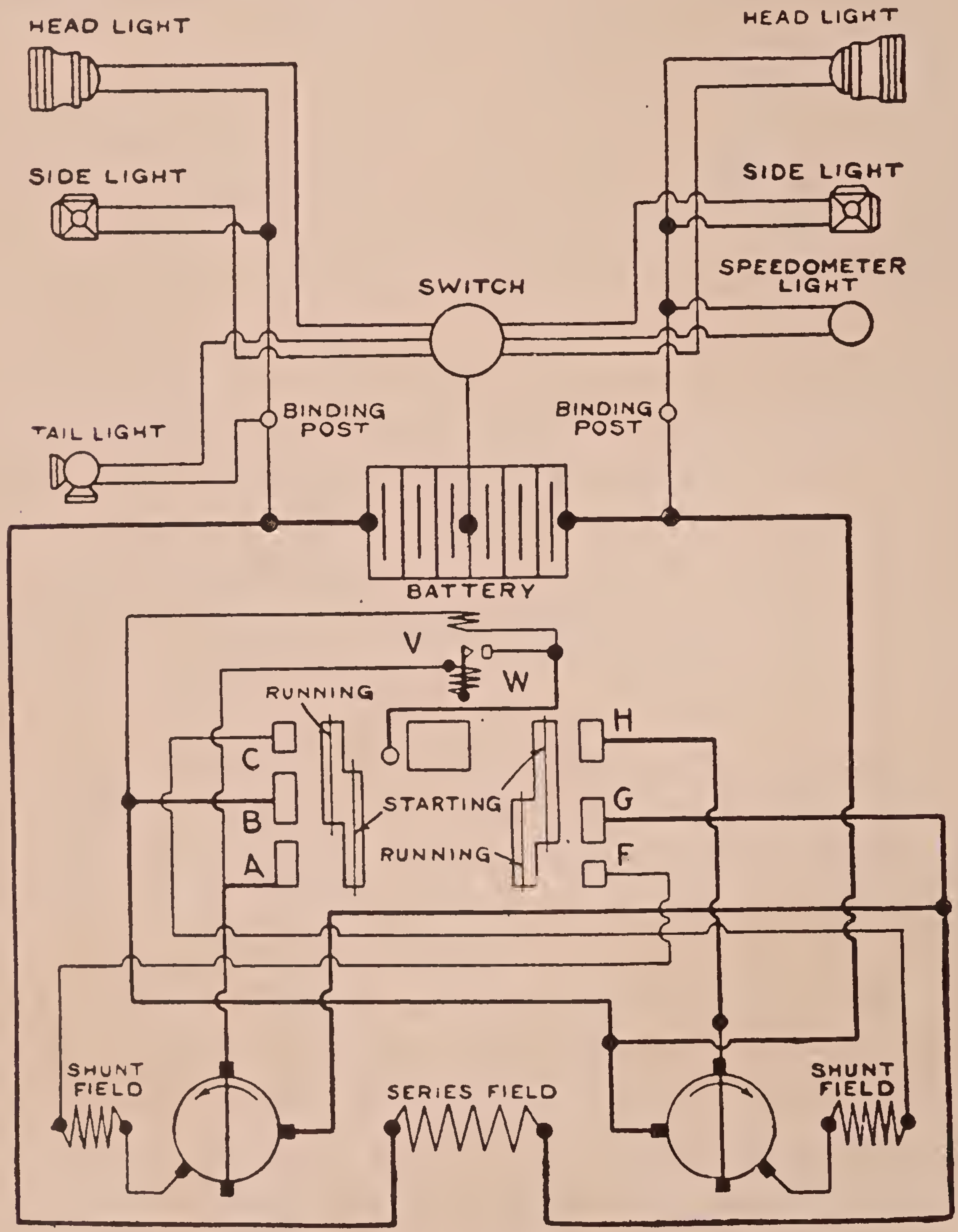


Fig. 293. Wiring Diagram for Wagner Single-Unit 12-Volt Two-Wire System (Early Model)

details of this switch: *A*, *B*, and *C* are the contacts on the starting side, while *H*, *G*, and *F* are the running-position contacts (see wiring diagram, Fig. 293). The segments *E* and *L* on the drum contact with the fingers mentioned when the drum is revolved part way in either direction by the lever shown at the right which engages the shaft *M*.

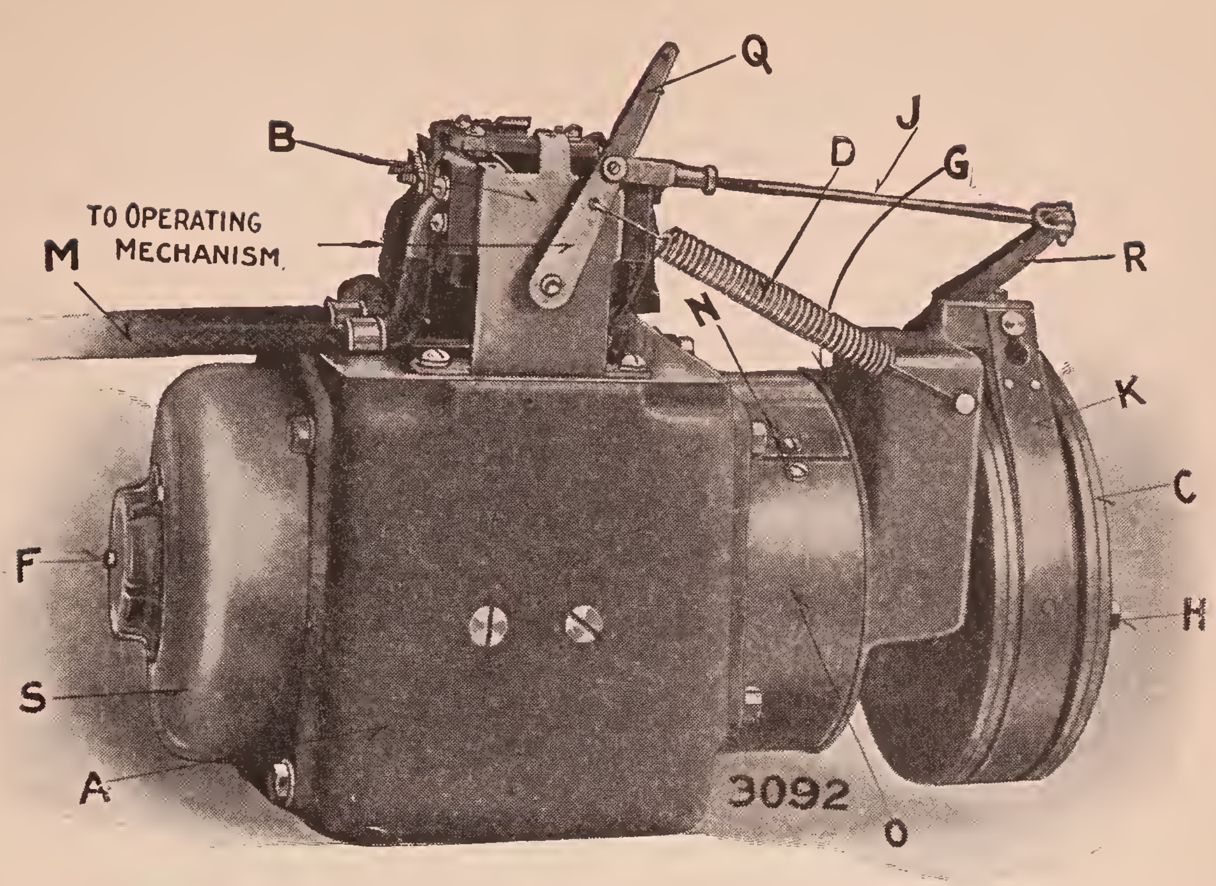


Fig. 294. Wagner Control Switch of Drum Type. A—Starter Frame; B—Switch Support; C—Outside End Plate Gear Box; D—Return Spring; F—Oil Hole Screw; G—Self-Closing Oiler; H—Oil Plug; J—Connecting Rod; K—Brake Band; M—Battery Leads; N—End Plate Screws; O—Back End Plate Shield; Q—Starting Switch Lever; R—Brake Band Lever; S—Front End Plate Shield

Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

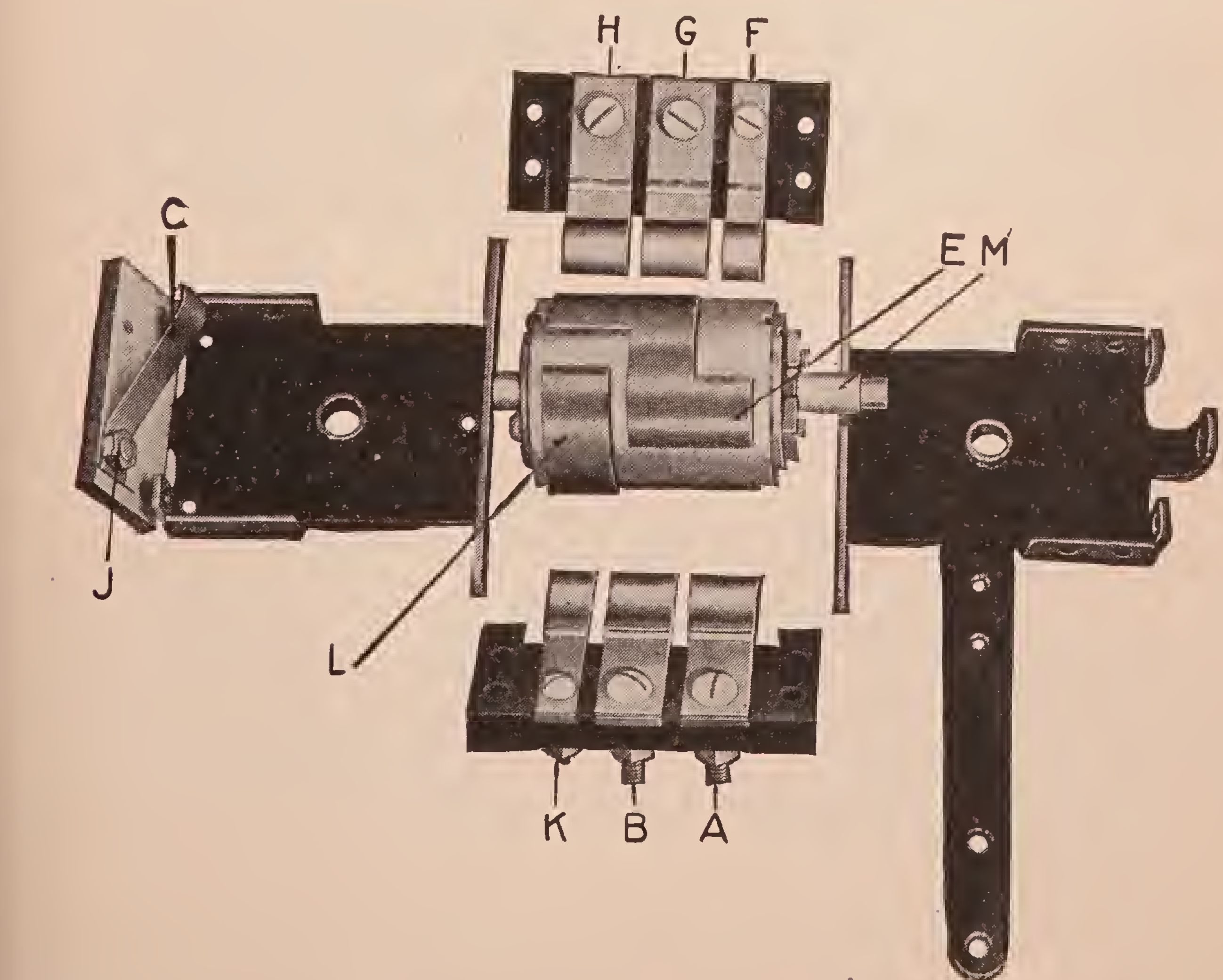


Fig. 295. Exploded View of Drum Switch. A, B, F, G, H, and K—Contact Screws to Contact; C—Auxiliary Contact Finger; E—Drum Contact; J—Screw Holding C; L—Auxiliary Drum Contact; M—Shaft

Battery Cut-Out. This is of conventional design: for description and explanation of operation see previous systems in which a battery cut-out or "automatic switch" is employed. Methods of locating trouble are given in connection with instructions farther along.

Planetary Gear. The external form of the different gear boxes used on the early-model single-unit Wagner starter is the same, but their internal construction differs somewhat. The details of the two types employed are shown in Fig. 296 and Fig. 297. The principle employed is that of the planetary gear as used to obtain first, or low, and high speeds on early-model light cars. The unit consists

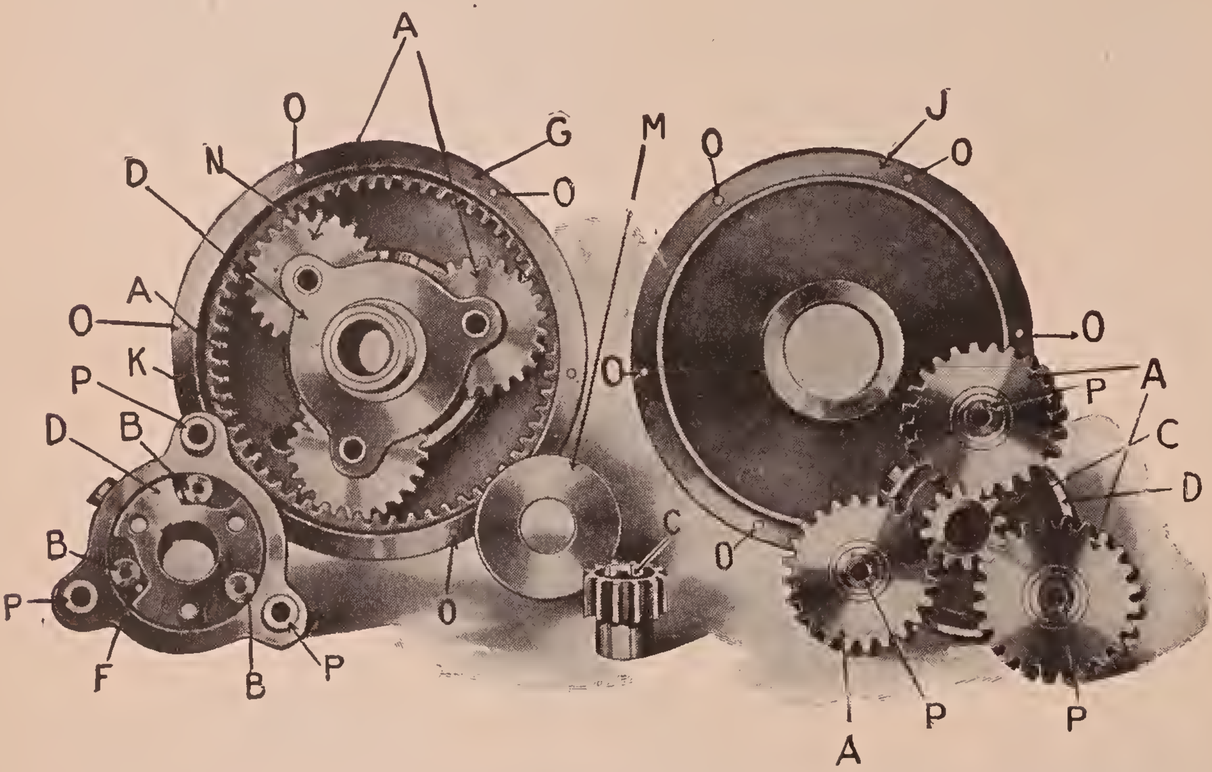


Fig. 296. Exploded View of Planetary Gear Transmission. A—Planetary Pinion; B—Rolling Pawl; C—Center Pinion; D—Planetary Hub; E—Pawl Seat; F—Pawl Plunger; G—Internal Gear; H—Inside End Plate; J—Outside End Plate; K—Oil Plug; M—Sheet Steel Disc

of a central or sun gear *C*, Fig. 297, and three planet pinions *A*, meshing with the central gear and also with the internal gear ring *G*. For starting, the tightening of the brake band on the outer groove of the internal gear holds it fast, so that the drive is through the central gear and the reducing pinions in engagement with it and the gear ring, while, for running, the rollers *B* in the clutch *D* lock the gears together so that, when generating, the gear revolves idly as a unit.

Instructions. The instructions previously given in connection with other systems apply here. For failure to generate, lack of capacity, grounds, or short circuits in windings, and keeping the commutator and brushes in condition, see instructions already given, as well as Summary of Instructions at the end of Part V.

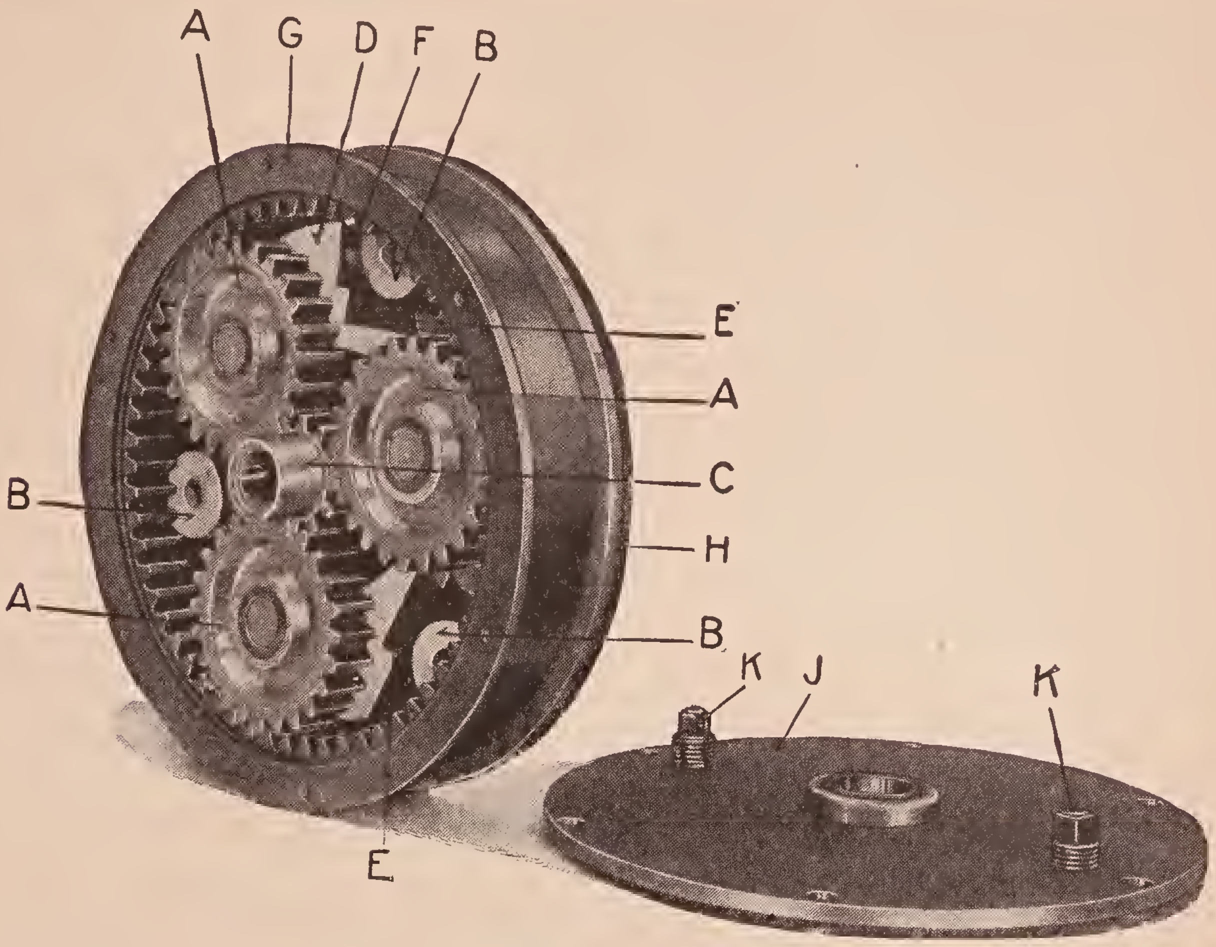


Fig. 297. Assembled Planetary Gear. Letters same as Fig. 296

Method of Tooling Commutator. A different method of undercutting the mica of the commutator is recommended from that already described in connection with the Delco system. This is

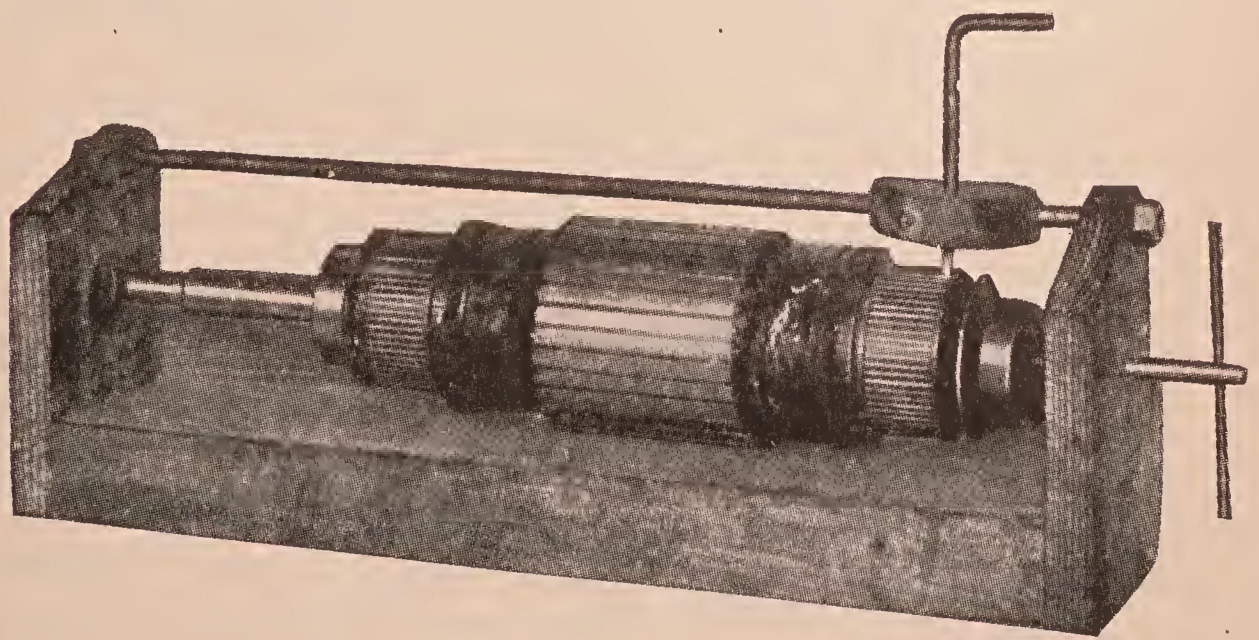


Fig. 298. Jig for Holding Armature and Tooling Commutator

illustrated in Fig. 298. The armature is removed from the generator and mounted in a simple jig, as shown. It is made of 1-inch oak, while ordinary machine screws held in place by lock nuts are utilized as the centers. The bar or guide, on which the cutter operates, can be made of ½-inch rolled-steel rod, while the cutter itself should be made of ¼-inch drill rod. The point of this cutter is ground sharp, like the parting tool used on a lathe or planer, to the thickness of the mica between the commutator bars. The cutter is moved backward and forward on its guide in the same manner as a planer or shaper tool, and the armature is rotated one segment at a time to bring the mica sections under the tool successively. Where there is not sufficient work of this nature to make it worth while to build the jig, a simple hand tool, Fig. 299, may be used. This can be made of a discarded hacksaw blade or a new one, about 8 inches long. One of the ends is ground similarly to the cutter described for the jig, while the other should be shaped like a hook, having the same kind of point as the cutter end. Around the center of this tool should be folded a piece of heavy tin (sheet iron) and the whole wrapped with electric tape. This will prevent the brittle saw blade from breaking, and make it much easier to handle. The mica is removed by forcing the sharp end of the tool from the outer edge of the commutator surface to the inner edge, and the rough cut thus made is finished by drawing the hooked end of the tool back through the groove in the opposite direction. To do the job properly, the armature should be held in a vise, otherwise it is apt to move, or the tool is apt to slip, and the copper will be cut away with very poor results. Fig. 300 shows the commutator before and after undercutting the mica.

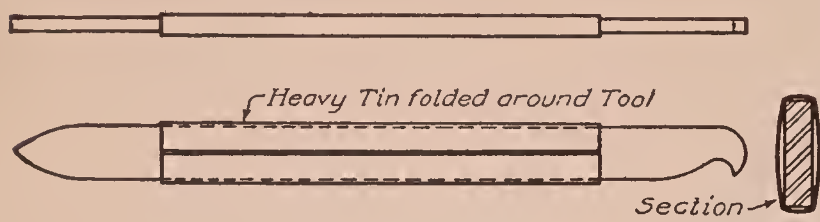


Fig. 299. Diagram of Simple Hand Device for Tooling Commutator

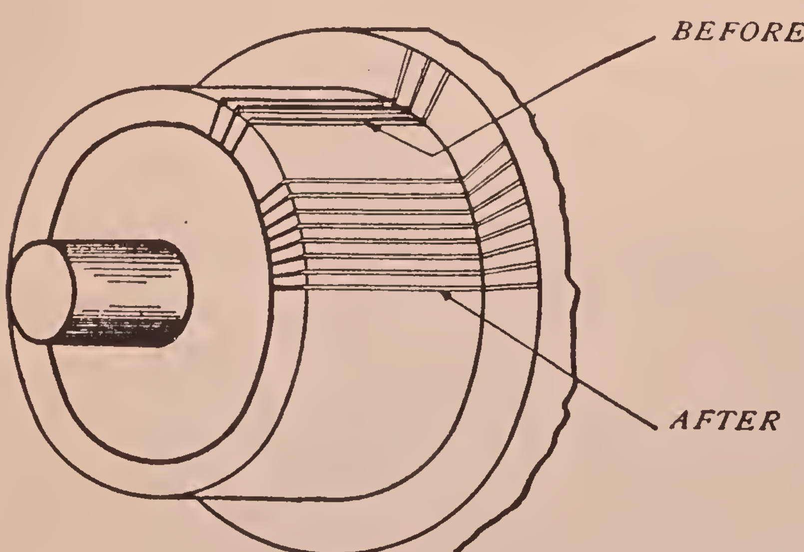


Fig. 300. Diagram Showing Commutator Sections before and after Tooling

A needle-pointed tool should never be used as it will simply make a V-shaped cut in the mica, removing too much in depth and not enough in width. The mica must be cut out clean and square and a small magnifying glass should be used to see that all of the pieces adjacent to the bars have been removed. After removing the mica, the armature should be placed in a lathe and a light cut taken from the commutators, i.e., just enough to remove all roughness and flat spots. The cutting tool employed should be very sharp, so that the soft copper will not be dragged from one segment to another. After turning, fine sandpaper should be used to smooth the commutator. Whether the brushes are replaced with new ones or the old ones retained, they must be sanded in to the commutator (see Delco

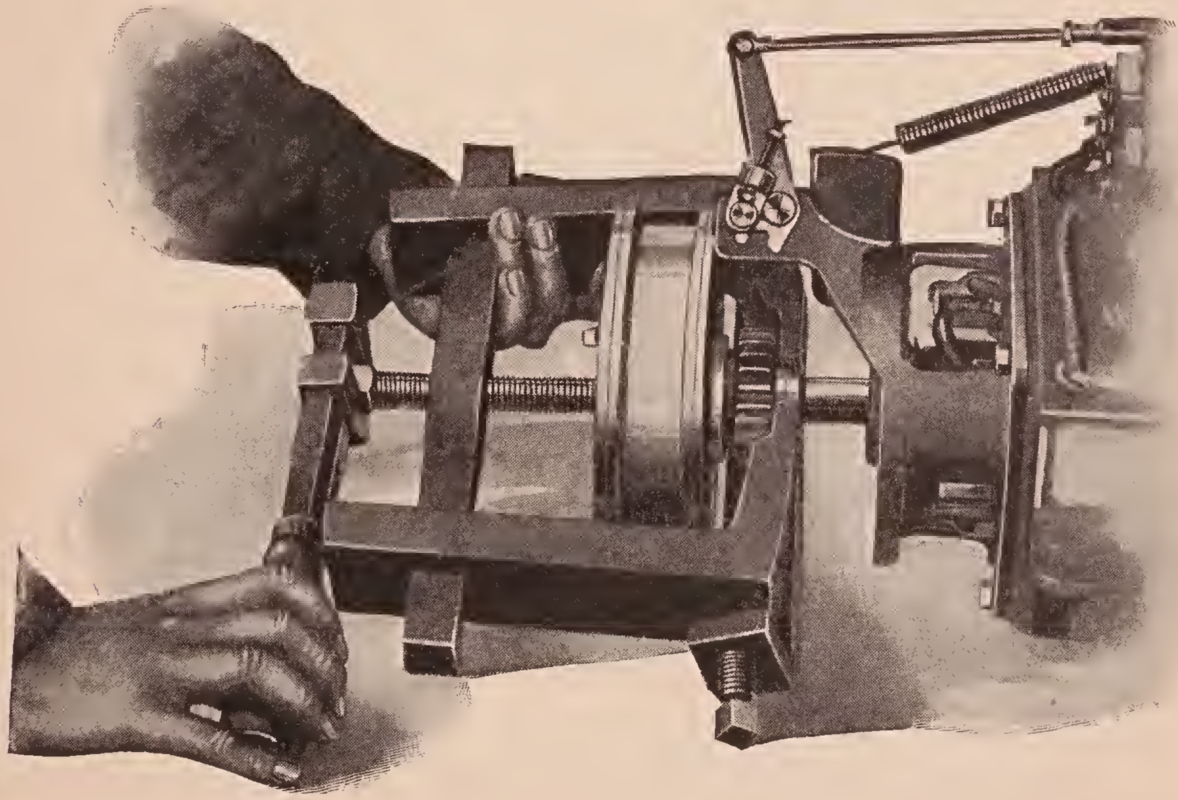


Fig. 301. Method of Pulling Wagner Gear Box with a "Come Along"
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

instructions). The springs also should be tested for tension; they must never be allowed to become loose enough to permit the brushes to chatter when the generator is running, as this would interfere seriously with its output.

Lack of Capacity through Faulty Gear Box. Should the battery not charge properly, note whether in starting the lights brighten perceptibly with the car running below 5 miles per hour, while at high speed they remain dim. This indicates that the brake band of the gear box does not release, due either to improper adjustment of the tightening screw or to something getting between the band and drum. To remedy, the band adjusting screw should be turned until the band feels free when the starting lever is in the running position. If something has caught between the band and the drum, its removal usually will be the only remedy necessary.

Should the battery show signs of exhaustion and if there is no noticeable increase in the brightness of the lamps when the car reaches a speed of 10 miles per hour or its equivalent, the trouble probably is in the gear box. Remove the front end plate and note if the commutator is rotating. If not, and the reason therefor is not apparent on an inspection of the gears, it may be necessary to remove the gear box. A "come along", such as is employed for taking off Ford wheels, is necessary for this, Fig. 301. It may be found that some of the parts need replacement, or that an entirely new gear box is necessary.

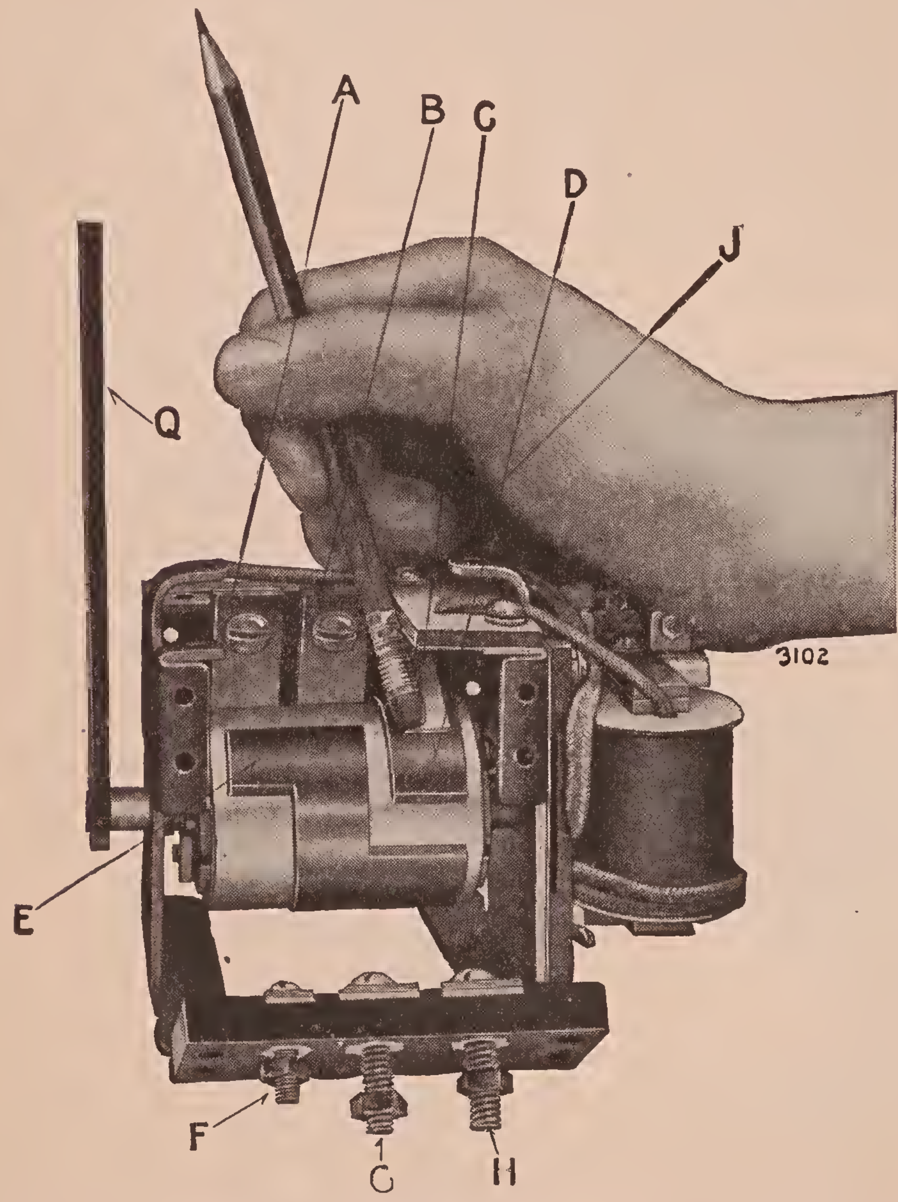


Fig. 302. Details of Wagner Starting Switch. A and B—Large Contact Finger; C—Auxiliary Contact Finger; D—Auxiliary Contact; E—Drum Switch; F, G, and H—Drum Switch Studs; J—Screw Leading to C; Q—Starting Switch Lever

Failure Due to Battery Cut-Out. If the failure to charge the battery be not due to the gear box, remove the cover of the cut-out and see if it is operating properly. When the engine is running at a speed equivalent to 15 miles per hour, the contact should spring away from the adjusting screw. If it does not, connect a voltmeter across the terminals *B* and *H* of the switch, Fig. 302. Should the voltmeter needle not move, examine the contact fingers connected to the studs *C* and *F* and see that they make firm contact with the drum of the switch. Place the end of a pencil on the contact finger D and bear down lightly; if the main contact maker then springs away from the adjusting screw, the cause of the trouble is an open circuit at this contact. Bend D so that it bears down on the drum segments; should the contacts not close on making this test, the trouble will be an open connection, either in the generator itself or in the connections between the generator and the cut-out (switch).

Should the voltmeter give a reading of 6 volts while the contacts do not close, it shows that the shunt coil of the cut-out is open and indicates that its connections are broken or that the trouble is in the coil itself. This may be confirmed by operating the contacts by hand—pushing the contact away from the adjusting screw until it touches the stationary contact. If it remains in that position, the generator is charging the battery but the shunt coil of the cut-out is out of action and the cut-out will function automatically as it should.

If, under the conditions mentioned in the first paragraph under this heading, the cut-out closes, connect the voltmeter as described and accelerate the engine to a speed corresponding to 25 miles per hour. If the reading is then 15 to 20 volts, the trouble may be looked for in a break in the generator connection to the cut-out. Should it not be possible to locate any break, it may be in the series coil of the cut-out, in which case a new cut-out will be necessary.

Switch or Generator Parts to Be Adjusted. If the starting lever of the switch is not returning to the proper position for running after starting the engine, it will be indicated by a low battery and dim lights. Adjust so that the lever will go to correct position for running and see that the contact fingers of the switch are making proper contact with the drum.

In case the battery does not get sufficient charge, connect an ammeter to the terminal D of the switch and to W of the cut-out. At a speed equivalent to 15 miles per hour, the ammeter should read 7 to 9 amperes, if the generator is working properly. If it does not, examine the commutator, brushes, and wiring, as previously described.

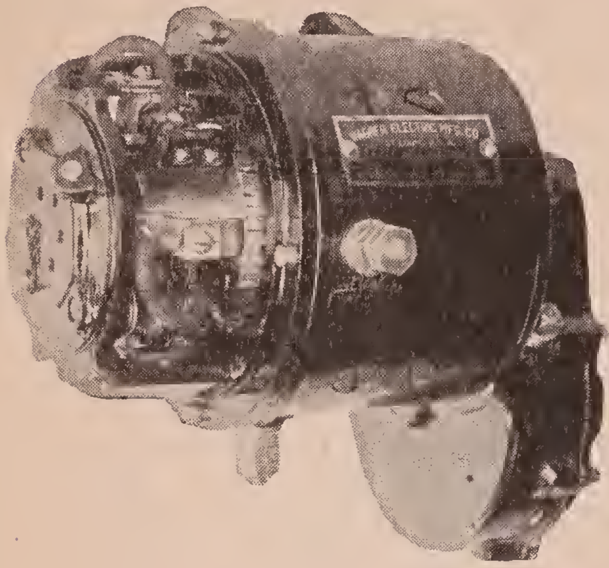
Wagner Two-Unit Six-Volt Type

General Characteristics. This type is similar in characteristics to most of the other makes of this class already described.

Generator. The generator is the multipolar (four-pole) shunt-wound type.

Regulation. The regulation is of the inherent or bucking-coil type, integral with the field windings of the generator.

Starting Motor. The motor is four-pole and series-wound, driving through a reducing gear mounted on the motor housing, Fig. 303.



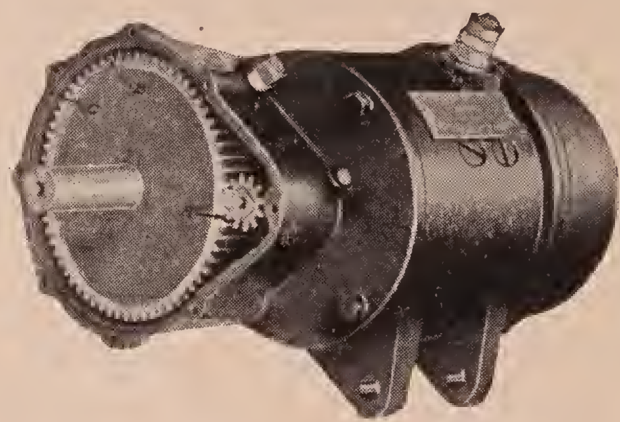


Fig. 303. Wagner Two-Unit Six-Volt Type Starting Motor. Left—Commutator End; Right—Gear End

Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

Control. *Battery Cut-Out.* The complete instrument, minus its cover, is shown in Fig. 304. It is of standard design and is intended to be mounted in the tool box under the driver's seat. As shown in the photograph, the upper binding post is the series-coil connection, the central binding post just below it is the shunt-coil connection, while the lowest binding post is a connection completing the circuit through both coils to the battery.

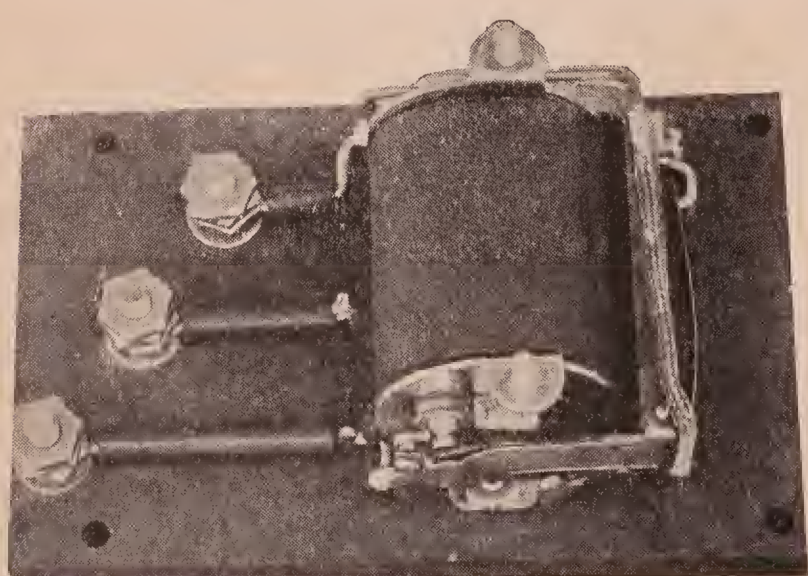


Fig. 304. Wagner Cut-Out

Switch. The switch is of the circular knife-blade type, two sets of spring contacts close together being pressed down over the stationary contact against the spring, as shown in Fig. 305, which illustrates the parts of the switch.

Instructions. *Ground in Starting or in Lighting Circuits.* When the blowing of a fuse on one of the lighting circuits is due to a ground, or a similar fault is suspected in the starting system, it may be tested for either with the lamp outfit already described, or with the low-reading voltmeter, as follows:

Disconnect one battery terminal, taping the bare end to prevent contact with any metal parts of the car, and connect one side of the voltmeter to this terminal. Attach a length of wire having a bared

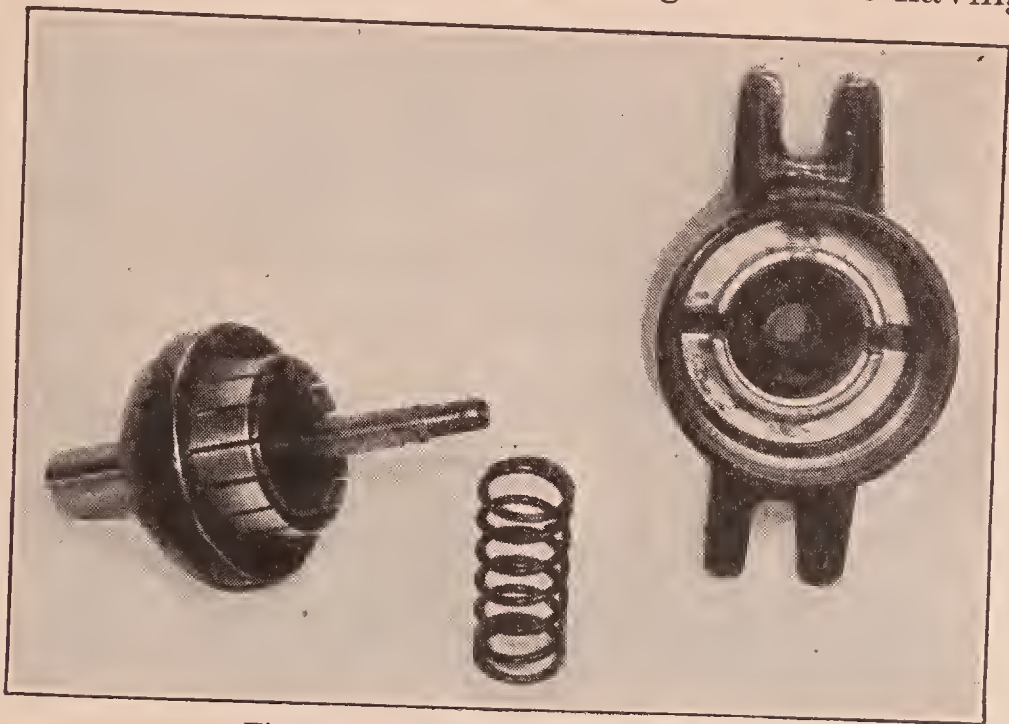


Fig. 305. Details of Wagner Switch
Courtesy of Wagner Electric Manufacturing Company, St. Louis, Missouri

end to the other terminal of the voltmeter, as shown in Fig. 306. Connect the bared end of the free wire to some part of the car frame; making certain that good electrical contact is made. Disconnect the generator and starting motor completely, open all lighting switches, and be sure that ignition switch is off. If there is no ground in the circuit, the voltmeter will give no indication. Be sure that none of the disconnected terminals is touching the engine or frame; to insure this, tape them.

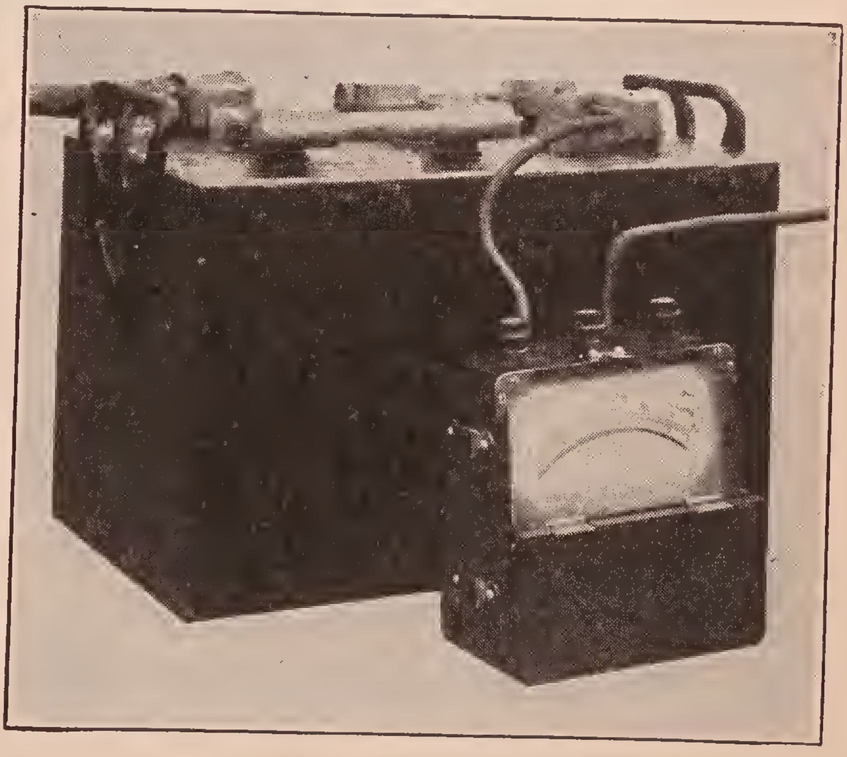


Fig. 306. Testing for Grounds with Voltmeter in Two-Wire System

Should the voltmeter give a reading of 4 volts or more, it indicates that there is a ground in the wiring between the battery and the junction box, or in the wiring between the junction box and the generator or the starting motor. If the voltmeter reads less than 4 volts but more than $\frac{1}{2}$ volt, all wiring and connections should be carefully inspected for faults. This test should be repeated by reversing the connections, i.e., by reconnecting the side of the battery circuit that has been opened and disconnecting the other side.

Localizing Any Ground. To localize any fault that the reading of the voltmeter may show, reconnect the wires to the starting motor and close the starting switch; any reading of the voltmeter with such connections will indicate that the ground is in this circuit.

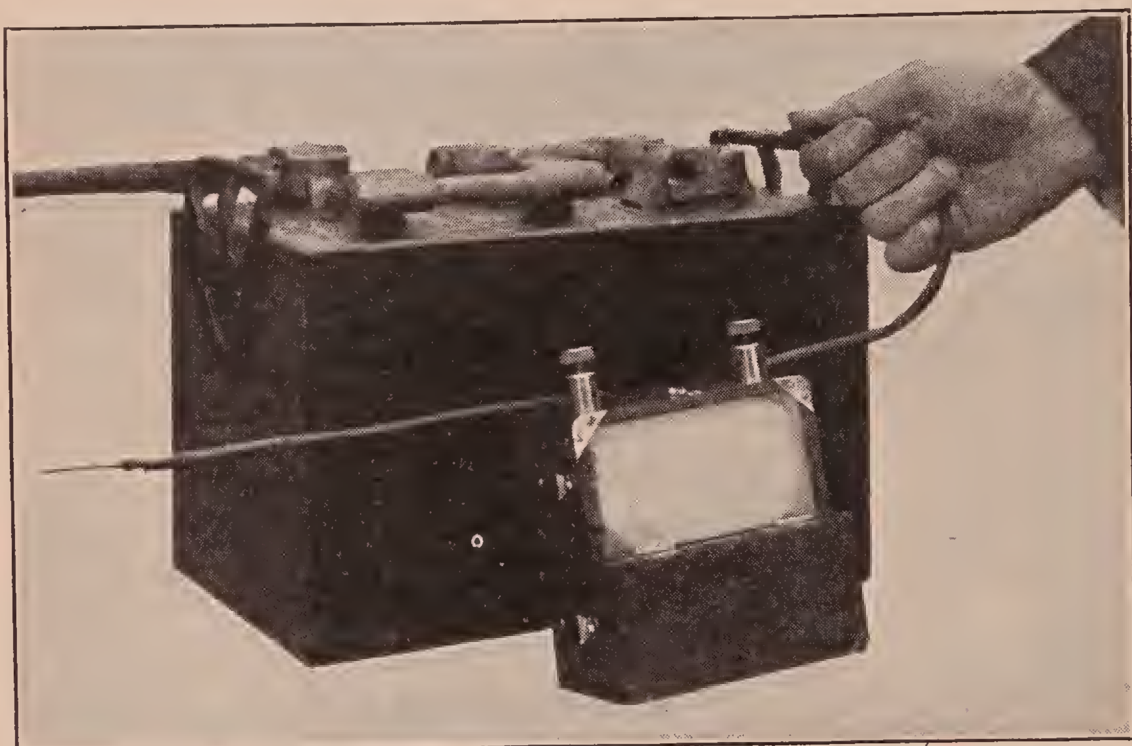


Fig. 307. Testing for Short Circuits with Ammeter in Two-Wire System

Should no ground be indicated with these connections, disconnect the starter again and reconnect the generator; if the voltmeter records any voltage, the ground is in the generator circuit. With both starter and generator disconnected, the voltmeter being connected first to one side of the battery and then to the other, operate the lighting switches, the ignition switch, and the horn, one at a time, and note whether the voltmeter needle moves upon closing any of these switches. A voltage reading upon closing any of these switches will indicate a ground in that particular circuit.

Short-Circuit Tests. To test for short circuits, substitute the ammeter for the voltmeter, but do not connect the instrument to the battery. The shunt reading to 20 amperes should be employed, one side of the ammeter being grounded on the frame as previously described, and the other being connected with a short wire that can be touched to the open side of the battery, see Fig. 307. Disconnect the starter and the generator, and open all switches, then touch the bare end of the wire to the battery terminal on the open side as shown. Any reading, no matter how small, will indicate a short circuit (two-wire system) in the wiring between the battery and junction box or between the latter and the starter or generator. If the ammeter reading shows a heavy current, there is a severe short circuit.

Localizing a Short Circuit. The short circuit may be localized in the same manner as described for the voltmeter test, i.e., connect the starter and test; disconnect starter, connect generator and test. A reading on the generator test may be due to the contacts of the cut-out sticking together. If the cut-out contacts are open and the ammeter registers, there is a short circuit in the generator windings.

Disconnect generator again, remove all lamps from sockets, and turn on lighting-circuit switches one at a time, touching wire to battery terminal after closing each switch. A reading with any particular switch on indicates a short circuit in the wiring of the lamps controlled by that switch. Only one switch should be closed at a time, all others then being open. This test should be made also with the ignition switch on but with the engine idle. The ammeter then should register the ignition current, which should not exceed 4 to 5 amperes. If greater than this, the ignition circuit should be examined.

Cautions. Do not attempt to test the starter circuit with the ammeter as it will damage the instrument. To test the starter circuit, reconnect as for operating, removing the ammeter. Close the starting switch; a short circuit in the wiring will result either in failure to operate or in slow turning over of the engine. See that the switch parts are clean and making good contact. If the short circuit is in the winding of the starter, there will be an odor of burning insulation, or smoke.

The battery must be fully charged for making any of these tests. While the effect of either a ground or a short circuit will be substantially the same, it will simplify its location and remedy to determine by testing whether it is one or the other.

WESTINGHOUSE SYSTEM

Twelve-Volt; Single-Unit; Single-Wire

Dynamotor. The single unit of the 12-volt system, or the "motor-and-generator" as the manufacturers term it, is a bipolar machine, both the generator and starting-motor windings of which are connected to the same commutator. Installation is usually by means of a silent chain as on the Hupp (1915 and earlier). The characteristics of this type of machine are such that when running at a speed equivalent to 9 miles per hour or less, it acts as a motor, and when the speed increases it automatically becomes a generator and begins to charge the battery.

Regulation. The third-brush method of regulation is employed, the amount of current supplied to the shunt fields by this brush decreasing as the magnetic field of the generator becomes distorted due to increased speed.

Control. The switch employed with this type of combined unit is the regular single-throw single-pole switch as used on lighting-plant switchboards. This switch controls both the ignition and

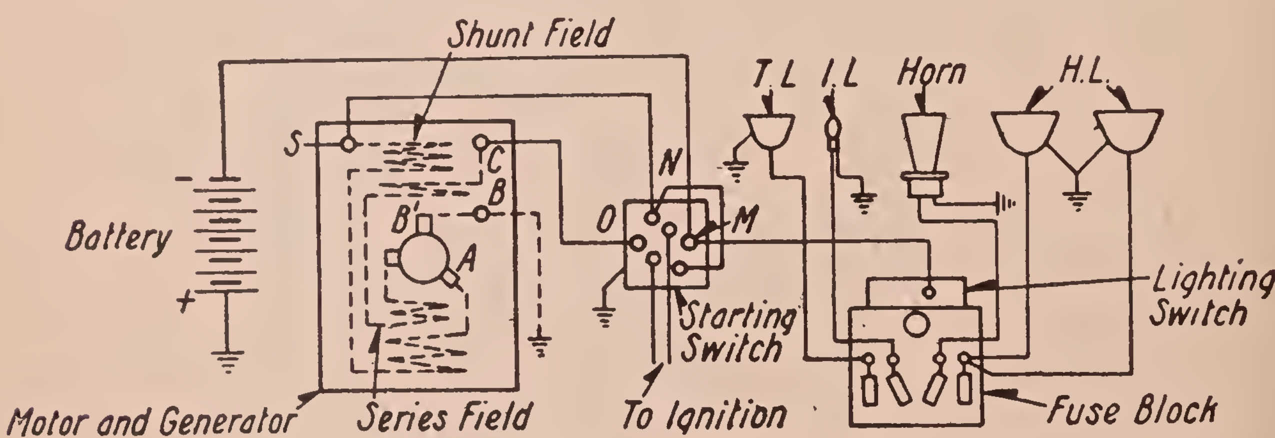


Fig. 308. Wiring Diagram for Westinghouse Single-Unit System on Hupmobile

the starting-motor circuits and at starting is thrown on and left closed as long as the car is running.

Wiring Diagram. The connections of the Hupp installation are shown in Fig. 308.

Instructions. *Battery Charging.* As the unit acts as a motor to drive the engine when the latter is running at a speed of less than the equivalent of 9 miles per hour on high gear, slow driving or permitting the engine to idle at a very low speed when the car is standing will discharge the battery. Where no fault in the wiring or connections exists and the battery will not stay charged (the generator, of course, working properly), this practice may be the cause of the trouble. If the voltage drops to 10 or 11 volts, with the headlights on but with the engine stopped, it indicates that the battery is practically discharged. This voltage reading will be somewhat higher in summer than in winter. The remedy is to run with fewer lights at night or to run the engine for longer periods in the daytime, or at higher speeds. Running solely at night will not keep the battery sufficiently charged, as most of the generator output is consumed by the lamps. Should the battery become discharged to a point where it cannot operate the starting motor, disconnect the wires *C* and *S* at the dynamotor, taping their terminals to prevent contact with any part of the engine or chassis. Start the engine by hand and, when running at a speed of about 500 r.p.m., reconnect these wires, *being sure to connect wire S first*, when the battery will begin to charge.

Fire Prevention. Gasoline or kerosene is frequently employed to wash automobile engines. Before doing so, be sure that the starting switch is open, and disconnect the negative or – terminal of the battery, taking care that it does not come in contact with any metal parts of the car. To make certain of this, it is better to tape the metal terminal. Allow the gasoline to evaporate entirely before reconnecting the battery, as a flash or spark would be apt to ignite the vapor. This naturally applies to all cars, although only such as are equipped with the Westinghouse single-unit or the Dyneto single-unit have starting switches which remain closed all the time the engine is running.

Weak Current. If the dynamotor fails to operate when the starting switch is closed, open the switch and test with the portable voltmeter. If it indicates less than 11 volts, the battery is run down; if it indicates 12 volts or over, look for a loose connection or an open circuit (broken wire) either in the connection from the battery to the starting switch, from the switch to the dynamotor, from the latter to the ground, or from the battery to the ground, in the order named. Dim burning of the lamps when the engine is stopped also indicates a discharged battery. When this is the case it is advisable to recharge at once from an outside source, if possible.

A quick method of determining whether there is a ground in the wiring is to disconnect the battery wire and, the engine being stopped and all lights turned off, to touch the disconnected wire to the terminal lightly. A spark when this contact is made will indicate a ground between the battery and the dynamotor or the switch. The testing lamp should then be used to locate the circuit in which the ground exists.

Failure to charge properly may be due also to imperfect contact at the brushes or to a break in the shunt-field circuit of the generator, as explained in previous instructions. If the shunt-field circuit is found open, the trouble doubtless will have been caused either by a ground between the battery and generator or by running the latter when the generator was disconnected.

To remove the brushes, lift the spring that holds the brush in the guide and take out screw holding the brush shunt, when the brush can be slipped out. Care should be taken to replace brushes in the same position, and if they do not bear evenly over their entire surface on the commutator, they should be *sanded in* as described in the Delco instructions. The latter suggestion also applies to new brushes, when necessary.

Six=Volt; Double=Unit; Single=Wire

Generators. Three types of generators are made as shown in Fig. 116, Part II, in Fig. 147, Part III, and Fig. 309, herewith.

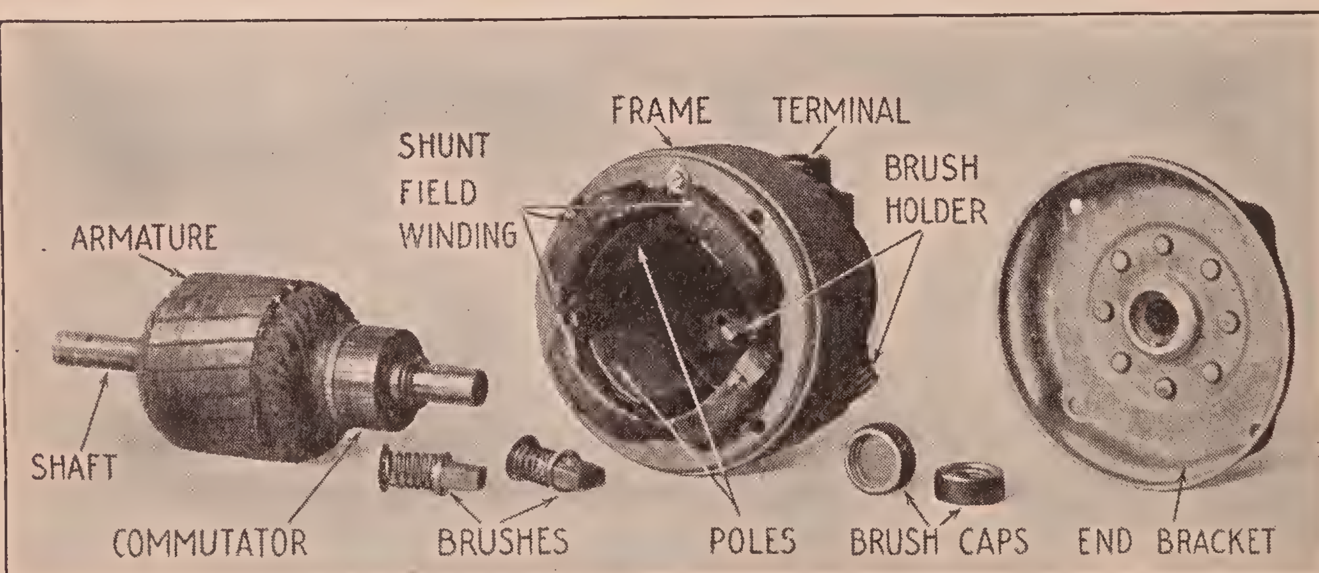


Fig. 309. Westinghouse Bipolar Generator for Six-Volt Double-Unit Single-Wire System
Courtesy of Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

Regulation. The reverse series-field winding or bucking-coil method is used in the first two types of generator, while a voltage regulator combined with the battery cut-out is employed on the third. This regulator is either self-contained, i.e., built in the generator, or is mounted independently. The connections of the built-in regulator are shown in Fig. 310. The open and closed positions of the contacts of the external cut-out are shown in Fig. 311.

Wiring Diagram. Fig. 312 shows the connections of the separately mounted regulator together with the charging and lighting circuits.

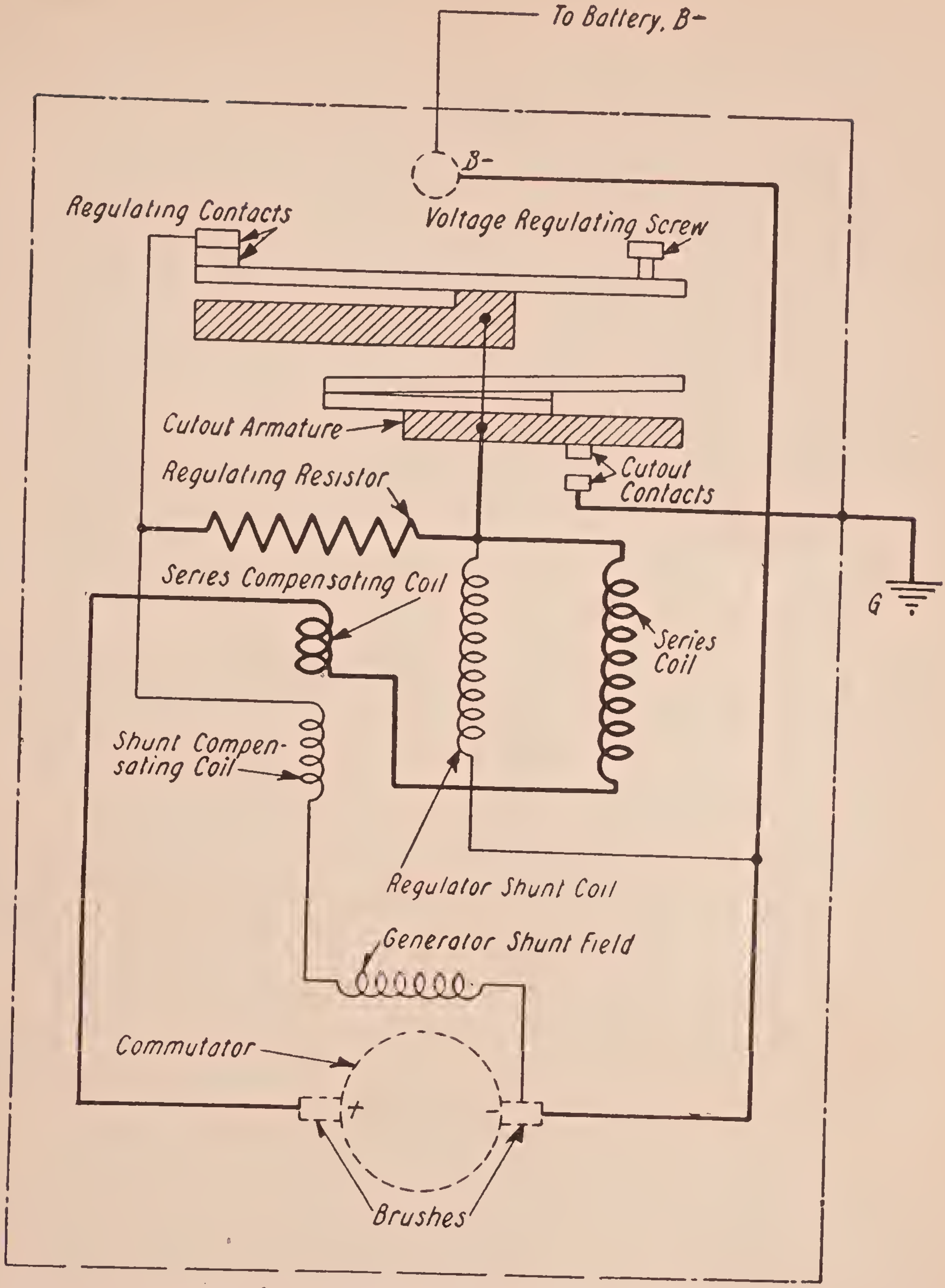


Fig. 310. Wiring Diagram for Westinghouse Generator with Self-Contained Regulator

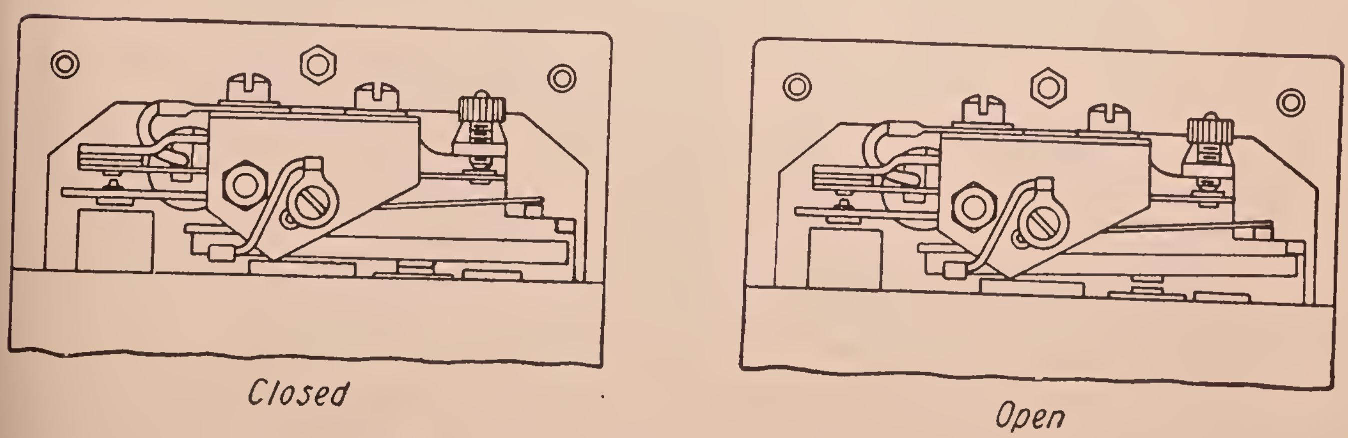


Fig. 311. Closed and Open Position of Westinghouse Cut-Out Switch

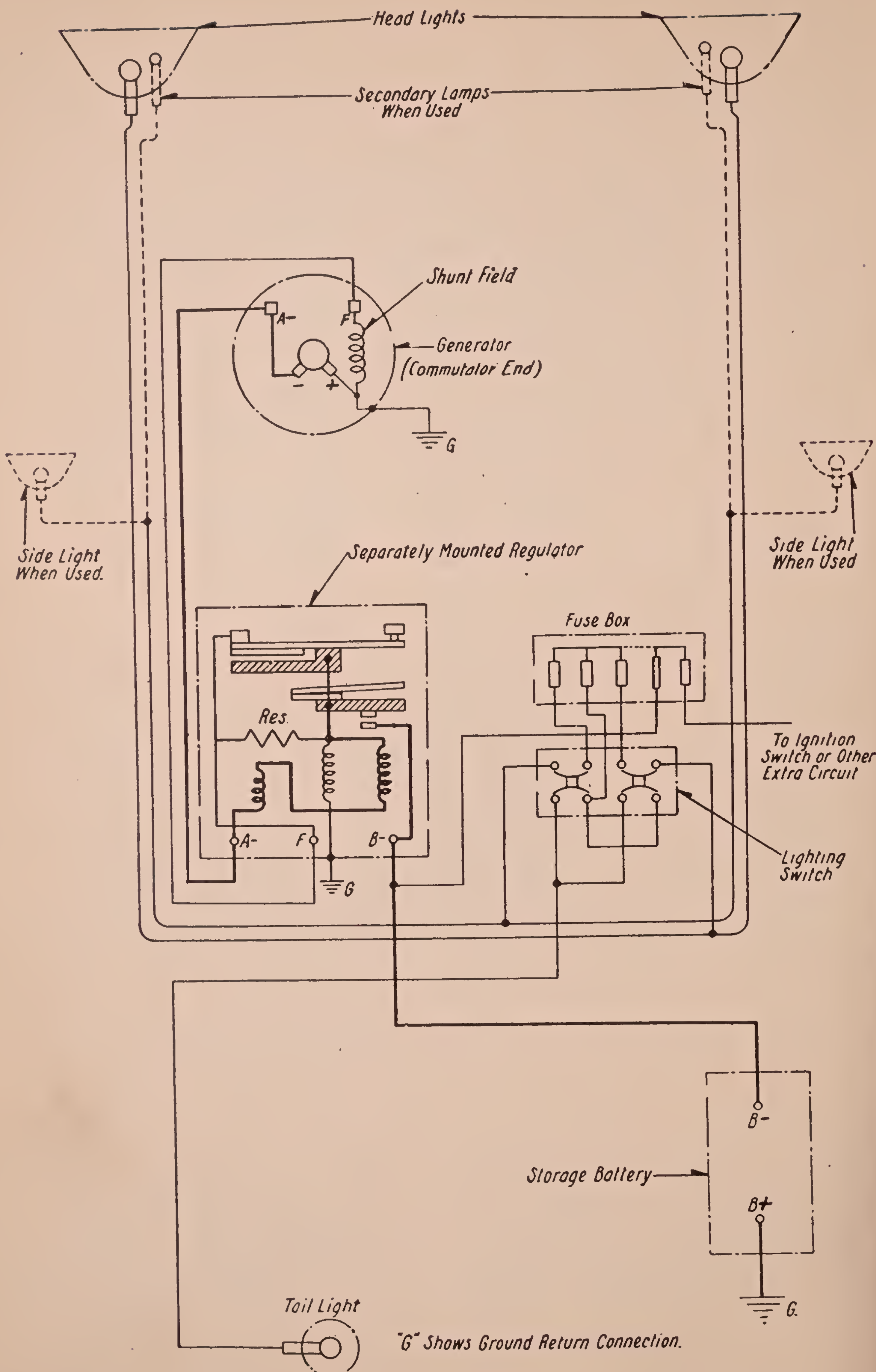


Fig. 312. Wiring Diagram for Westinghouse System with External Regulator

Starting Motors. *Variations.* Several types are built to meet varying requirements; i.e., with self-contained reduction gearing, with single-reduction automatic screw pinion shift (Bendix drive), and with automatic electromagnet pinion shift. The first two will be familiar from the descriptions already given of other makes. The third is similar in principle to the Bosch-Rushmore but an independent magnet is employed instead of utilizing the armature of the motor itself for this purpose.

Magnetic Engaging Type. This, as well as the other types of starting motors mentioned, may be operated either by a foot controlled switch or by a magnetically controlled switch put in action by a push button. The wiring diagrams, Fig. 313, show the circuits of both installations and also make clear the operation of the auto-

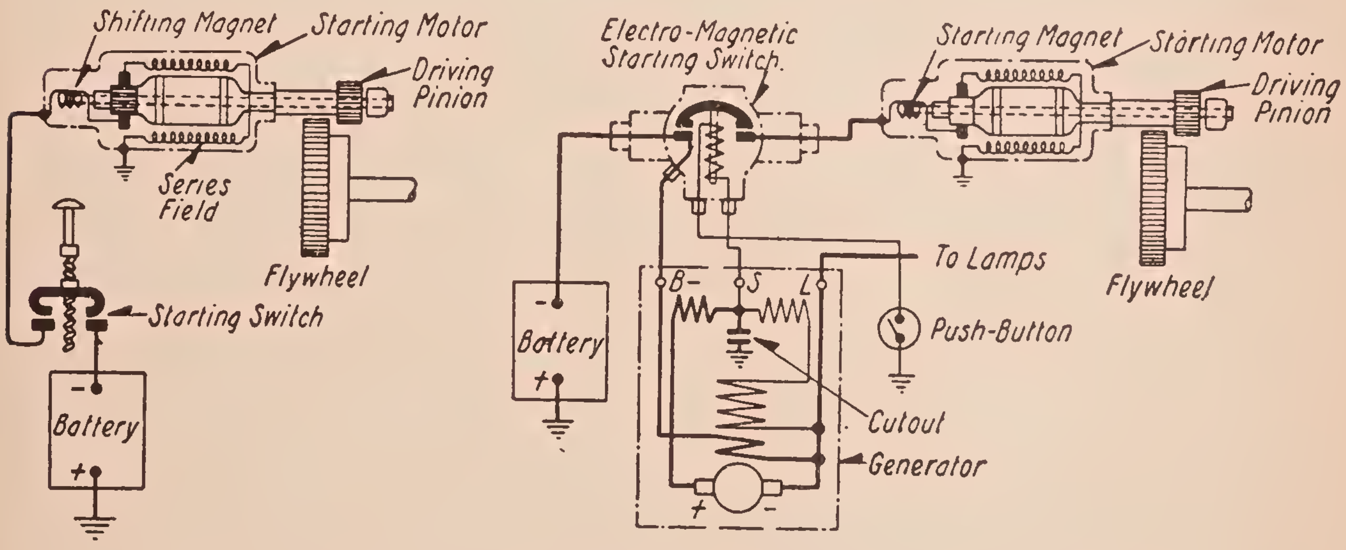


Fig. 313. Wiring Diagram of Motor Connections for Automatic Electromagnetic Pinion Shift

matic engagement. The armature is mounted on a hollow shaft; and on the end of this shaft there is carried a splined pinion designed to engage the flywheel gear. This pinion is caused to slide along the shaft by a shifting rod which is attached to the pinion and passes through the hollow shaft. The other end of this shifting rod acts as the core of the shifting magnet and will be recognized as the plunger of a solenoid. When the motor is idle a spring holds the pinion at the right-hand end of the shaft and clear of the flywheel gear.

As shown diagrammatically in Fig. 313, when the starting switch is closed, the circuit is completed from the negative terminal of the battery, through the switch, the shifting solenoid, the armature, and the series field of the motor, to the frame of the car on which the positive side of the battery is grounded. The large amount of current necessary for starting energizes the shifting solenoid sufficiently to overcome the force of the spring and it draws the shifting rod to the right through the hollow shaft, meshing the pinion with the flywheel gear. When the engine speeds up to the no-load speed of the starting motor, the current in the latter falls off so that the pull of the solenoid is less than that of the spring and the pinion is automatically disengaged, though the motor will continue to revolve until the starting switch is opened.

Electromagnetic Switch. In principle, the electromagnetic switch is the same as that of the automatic engaging device for the pinion. The movable double-pole contact, instead of being attached to a rod for foot operation, is mounted on the plunger of a solenoid and normally is held open by a spring. This solenoid requires but a small amount of current for its operation and is connected on an independent circuit with the battery. It is controlled by a push button and when the circuit is closed by means of the latter, the plunger of the solenoid is drawn into the coil against the pull of the spring, thus bringing the contacts together and holding them there as long as the solenoid is energized.

Instructions. *Regulator.* When the generator of the voltage-regulator type fails to charge the battery properly, all parts of the circuits and connections having been examined to determine that they are in proper condition, the regulator may be tested for faults. With the aid of the portable voltmeter, note at what voltage the contacts of the cut-out close or *cut in*, and at what voltage they *cut out* or open. See that the contact points are clean and square so that they make good contact over their entire surfaces when pressed together with the hand. Insufficient charging may be due to the voltage regulator keeping the voltage of the generator below the proper point for this purpose. A voltage adjusting screw is provided to compensate for this. With the voltmeter in circuit and the engine running, turn the screw very slowly and note the effect on the reading. For proper charging the latter should be approximately 7½ to 8 volts, and the screw should be adjusted very gradually to bring the voltmeter reading to this value. This screw is properly set at the factory and is unlikely to need adjustment so that all other possible causes should be investigated before changing it. The instructions for the 12-volt system also apply here, except that for voltage tests remember that the system operates on 6 volts.

SUMMARY OF INSTRUCTIONS ON ELECTRIC STARTING AND LIGHTING

It will be apparent from the foregoing description of the various systems that, while the majority differ more or less in detail, all are based on a comparatively small number of well-defined principles, and that once these are mastered, their application in any system under consideration will be clear. To avoid unnecessary duplication in the instructions covering points that are common to all, general instructions have been given only in connection with one or two systems, and it will be understood that descriptions of the methods of locating short circuits or grounds, of caring for brushes and commutator, and of testing with a portable lamp or with the volt-ammeter are equally applicable to all. The instructions given with other systems accordingly are limited to special references to the details of installation that will make it easier to locate faults in that particular system.

In order to bring the two together in such form that the particular information desired may be found instantly, a summary of all the instructions given in the preceding sections is outlined here in questions and answers. While the storage battery is treated at length in connection with Electric Automobiles in Part III, a brief résumé bearing particularly on the starting and lighting battery is given here also for more convenient reference, as the battery, or rather its abuse, is the source of a very large part of all the troubles experienced with electric lighting and starting systems.

BATTERY

Electrolyte

Q. Why is it necessary to refill the battery jars at regular intervals?

A. Because the heat generated in the cells evaporates the water from the electrolyte, and, if the latter is permitted to fall below the tops of the plates, they will dry out where they are exposed, and the heat of charging will then cause them to disintegrate, ruining the battery.

Q. Why should this be done at intervals of not less than two weeks?

A Because the limited amount of electrolyte permitted by the restricted size of the cells over the plates—usually half an inch—will be evaporated in that period by a battery that is in more or less constant use.

Q. Why should water alone and never acid or electrolyte be used to make up this loss?

A. Only the water evaporates, so that if either acid or fresh electrolyte is added, it will disturb the specific gravity of the solution in the cells and totally alter their condition.

Q. What is the reason that battery manufacturers insist that only distilled water or its nearest equivalent, rain water or melted artificial ice, be used for this purpose?

A. Because ordinary water contains impurities that are apt to harm the plates, such as iron salts, or alkaline salts that will affect both the plates and the electrolyte.

Q. What should be done to a battery that has had its efficiency impaired by being filled with impure water?

A. The cells should be taken apart, the separators discarded, the plates thoroughly washed for hours in clean running water without exposing them to the air where they would dry, the jars washed out, the plates reassembled with new separators, the jars filled with fresh electrolyte of the proper specific gravity, and the battery put on a long slow charge from an outside charging source, i.e., not on the car itself. Unless there are proper facilities for carrying this out, it will be preferable to ship the battery back to the maker so that it can be given proper treatment, particularly as it is necessary to reseal the cells.

Q. How is electrolyte prepared?

A. By adding pure sulphuric acid a very little at a time to distilled water until the proper specific gravity is reached, and then permitting the solution to cool before using. The mixture must always be made in a porcelain, hard-rubber, or glass jar; never in a metal vessel. Commercial sulphuric acid or vitriol should not be employed, as it is far from pure. Never add ~~acid~~ to ~~water~~. water to acid The chemical combination of the two evolves a great amount of heat and the acid will be violently spattered about.

Hydrometer Tests

Q. Why should the battery be tested with the hydrometer at regular intervals of a week or so?

A. Because the specific gravity of the electrolyte is the most certain indication of the battery's condition.

Q. What should the hydrometer read when the battery is fully charged?

A. 1.280 to 1.300.

Q. What point is it dangerous to permit the specific gravity of the electrolyte to fall below, and why?

A. 1.250; because below this point, the acid begins to attack the plates and the battery plates sulphate. The lower the specific gravity, the faster sulphating takes place.

Q. What should be done when the hydrometer reading is 1.250 or lower?

A. The battery should be put on charge immediately, either by running the engine or by charging from an outside source of current, until the gravity reading becomes normal.

Q. If the hydrometer reading of one cell is lower than that of the others, what should be done?

A. Inspect the cell to see if the jar is leaking; note whether electrolyte is over the plates to the depth of $\frac{1}{2}$ inch; and whether the electrolyte is dirty. If none of these causes is apparent, the cell will have to be opened and inspected for short circuits due to an accumulation of sediment or buckling of the plates.

Gassing

Q. Why should the cell tops be wiped dry from time to time and the latter as well as the terminals be washed with a weak solution of ammonia and water?

A. As the charge approaches completion, the cells "gas"; when overcharged they "gas" very freely. This gas carries with it in the form of a fine spray some of the electrolyte, and the acid of the latter will attack the terminals and corrode them. Wiping clean does not remove this acid entirely, so the ammonia solution is necessary to counteract its effect, the ammonia being strongly alkaline.

Q. Why should an unprotected light, i.e., any flame or spark, not be allowed close to a storage battery?

A. Because the gas emitted by the battery on charge is hydrogen, which is not only highly inflammable but, when mixed in certain proportions with air, forms a powerful explosive mixture.

Q. What is the cause of "gassing"?

A. When a battery is charged, the water of the electrolyte is decomposed by the current into gases. During the early part of the charge these gases unite with the active material of the plates, but, as the charge proceeds, more gas is evolved than the plates can take care of and it bubbles up through the electrolyte. This is known as the gassing point, and the temperature of the cell also begins to rise at that point.

Q. Is "gassing" harmful to the battery?

A. The greatest wear on the positive plates takes place during the gassing period, and, if carried too far, they may be injured by reaching a dangerous temperature (105° F., or over) which will tend to loosen the active material.

Q. How can "gassing" be checked?

A. By cutting down the charge. In some systems this can be effected by the insertion of extra resistance provided for the purpose. Where this cannot be done and it is necessary to keep the car running, turn on all the lamps or start the engine once or twice to reduce the charge in the battery. As the lamps usually consume 80 to 95 per cent of the generator output, they should be sufficient to prevent a further overcharge.

Q. Can the generator be disconnected from the battery to prevent overcharge?

A. Not unless it is short-circuited as directed in the instructions covering different systems. Otherwise, it will blow its field fuse, or, where one is not provided, burn out its windings, except in cases where special provision is made to guard against this.

Sulphating

Q. Why must a battery never be allowed to stand in a fully discharged state?

A. Because the acid of the electrolyte then attacks the plates and converts the lead into white lead sulphate which is deposited on them in the form of a hard coating that is impenetrable to the electrolyte, so that the plates are no longer active. The battery then is said to be *sulphated.*

Q. Can a sulphated battery be put in good condition, and what treatment must be given it to do so?

A. If the sulphating has not gone too far, the battery may be brought back to approximately normal condition by a long heavy charge at a higher voltage than ordinary. Where the battery has become badly sulphated, it is preferable to remove it from the car and charge from an outside source of current, as it may require several days to complete the process. (Note instructions regarding the running of the generator when disconnected from the battery, as otherwise it may be damaged.) If avoidable, the car should not run with the battery removed. If the battery has not stood discharged for any length of time, the charge may be given on the car by running steadily for 8 to 10 hours with all lights off. No lamps must be turned on, as the increased voltage is apt to burn them out.

Sediment

Q. What is the cause of sediment or "mud" accumulating in the jars, and why must it be removed before it reaches the bottoms of the plates?

A. This sediment consists of the active material of the plates that has been shaken out, due to the loosening caused by the charging and discharging, and aggravated by the constant vibration. It must never be allowed to reach the plates, as it is a conductor and will short-circuit them, ruining the battery.

Q. How long will a battery stay in service before this occurs?

A. This depends on the type of jar employed and the treatment that the battery has received. If it has been kept constantly overcharged, or if discharged to exhaustion in a very short period as by abuse of the starting motor when the engine is not in good starting condition, or if it has been subjected to short circuits by grounding or by dropping tools on its terminals, the plates will disintegrate much quicker than where proper treatment has been given it. With the old-style jar, only an inch or so is allowed to hold this accumulation of sediment below the plates, while in later types fully 3 inches or more are allowed in the depth of the cell for this purpose. A battery with jars of the latter type and that has been cared for properly should not require washing out under two years. The proceedure is the same as that given for removing the effects of impure water. The plates must never be allowed to dry.

Washing the Battery

Q. What is meant by "washing" the battery, and why is it necessary?

A. Washing a battery involves cutting the cells apart, washing the elements and the jars, and reassembling with new separators and new electrolyte. It is necessary to prevent the accumulation of sediment, consisting of active material shaken from the plates, to a point where it will touch them and thus cause a short circuit.

Q. How often is it necessary to wash a battery?

A. This will depend on the type of cell in the battery and the age of the latter. If the battery has the modern-style jar with extra deep "mud space" it probably will not be necessary to wash it until it has seen two to three seasons' use. With the older form of cell in which the space allowed for sediment is much less, washing doubtless will be necessary at least once a season. As the battery ages it will be necessary to wash it oftener.

Q. What other causes besides the type of jar and the age of the battery influence the frequency with which it is necessary to wash the battery?

A. The treatment the battery has received. If it has been abused by overcharging and permitting the cells to get too hot, the active material will be forced out of the grids much sooner.

Q. How can the necessity for washing be determined?

A. The presence of one or more short-circuited cells in a battery that has not been washed for some time will indicate the necessity for it. Each cell should be tested separately with the low-reading voltmeter; a short-circuited cell will either give no voltage reading or one much below that of the others. Cut such a cell out and open it; if the short circuit has been caused by an accumulation of sediment, the others most likely are approaching the same condition.

Q. How is a battery washed?

A. By cutting the cells apart, unsealing them, and lifting out the elements which should be immersed immediately in a wooden tub of clean pure water. The separators then are lifted out and the positive and negative groups of plates separated, but they must be marked so that the same groups may go back in the right cells. Before disposing of the old electrolyte, its specific gravity should be noted, as new electrolyte of the same density must be used. The plates should be washed in copious running water for several hours, but their surfaces must never be exposed to the air. Reassemble with new separators, fill the jars with fresh electrolyte of the same specific gravity as that discarded, and keep the elements under water until ready to place in the jars, which then should be sealed and the lead connectors burned together again.

Give a long slow charge after reassembling. The battery will not regain its normal capacity until it has been charged and discharged several times.

Connectors

Q. Why should lead connectors be employed, and why is it necessary to burn them together?

A. Any other metal will corrode quickly. Burning is necessary to make good electrical connection, except where bolted connectors are employed.

Q. When connections have become badly corroded or broken what should be done with them?

A. They should be replaced with new lead-strap connectors supplied by the makers. If they are not obtainable and the battery must be in service meanwhile, the old ones can be cleaned by cutting away the corroded parts and "burning" new lead on them to bring them to normal size. If broken, "burn" together with lead in the same way. Heavy copper cable can be used temporarily but must be removed as soon as possible, as it will corrode quickly. Never use any other metal except lead or copper and never use light copper wire. It will either be burned up in a flash or it will cut down the amount of current from the battery, thus causing unsatisfactory operation.

Buckled Plates

Q. What is the cause of badly disintegrated or buckled plates?

A. Sudden discharge due to a short circuit or to constant abuse of the starting motor on an insufficiently charged battery.

Q. Is there any remedy for such a condition?

A. If the plates are not badly buckled and have not lost much of their active material, the cells may be put in service again by washing and reassembling as described, but if there is any considerable loss of active material, new plates will be necessary.

Low Battery

Q. What are the indications of a "low" battery?

A. The starting motor fails to turn the engine over, or does so very slowly, or only a part of a revolution. The lights burn very dimly. The hydrometer shows a specific-gravity reading of 1.250 or less. Voltmeter test shows less than 5 volts for a 3-cell battery (for greater number of cells, in proportion), or 1.75 volts or less for each cell.

Q. What are the causes of a low battery?

A. The electrolyte's not covering the plates, or being too weak or dirty. A short circuit in the battery due to the accumulation of sediment reaching the bottom of the plates. An excessive lamp load, all lights being burned constantly with but little daylight running the car. Generator not charging properly.

Specific Gravity; Voltage

Q. What are the specific gravity and voltage of fully discharged and fully charged cells?

A. Total discharge: 1.140 to 1.170 on the hydrometer; and 1.70 to 1.85 volts on the voltmeter. Fully charged: 1.276 to 1.300 specific gravity; 2.35 to 2.55 volts.

Q. Are these readings always constant for the same conditions?

A. No. The charging voltage readings will vary with the temperature and the age of the cell; the higher the temperature and the older the cell, the lower the voltage will be. Hydrometer readings also depend on the temperature to some extent. For every ten degrees Fahrenheit rise in temperature, the specific gravity reading will drop .003 or three points, and *vice versa*.

Q. Under what conditions should voltage tests be made?

A. Only when the battery is either charging or discharging. Readings taken when the battery is idle are of no value.

Q. Under what conditions should hydrometer tests be made?

A. The electrolyte must be half an inch over the plates and it must have been thoroughly mixed by being subjected to a charge. Hydrometer readings taken just after adding water to the cells are not dependable.

Q. When should acid be added to the electrolyte?

A. As the acid in a battery cannot evaporate, the electrolyte should need no addition of acid during the entire life of the battery under normal conditions. Therefore, if no acid has leaked or splashed out and the specific gravity is low, the acid must be in the plates in the form of sulphate and the proper specific gravity must be restored by giving the battery an overcharge at a low charging rate.

Q. What does a lower specific gravity in some cells than others indicate?

A. Abnormal conditions, such as a leaky jar, loss of acid through slopping, impurities in the electrolyte, or a short circuit.

Q. How can it be remedied?

A. Correct the abnormal conditions, and then overcharge the cells at a low rate for a long period, or until the specific gravity has reached a maximum and shows no further increase for 8 or 10 hours. If, at the end of such an overcharge, the specific gravity is still below 1.270, add some specially prepared electrolyte of 1.300 specific gravity. Electrolyte should not be added to the cells under any other conditions.

Q. Is an overcharge beneficial to a battery?

A. The cells will be kept in better condition, if a periodical overcharge is given; say once a month. This overcharge should be at a low rate and should be continued until the specific gravity in each cell has reached its maximum and comparative readings show that all are alike. To carry this out properly will require at least 4 hours longer than ordinarily would be necessary for a full charge. If the plates have become sulphated due to insufficient charging, it may be necessary to continue the overcharge for 10 to 15 hours longer. Should the specific gravity exceed 1.300 at the end of the charge, draw off a small amount of electrolyte with the syringe from each cell, and replace with distilled water. If below 1.270, proceed as mentioned above for addition of acid.

Charging from Outside Source

Q. What is meant by charging from an outside source?

A. A source of direct current other than the generator on the car.

Q. Why is it necessary to charge the battery from an outside source?

A. When the battery has become sulphated, has been standing idle for any length of time, or has been run down from any other cause so that it is out of condition, a long charge at a uniform rate is necessary and it would seldom be convenient to run the car for 8 or 10 hours steadily simply to charge the battery; frequently a longer charging period than this is necessary.

Q. How is charging from an outside source effected?

A. This will depend on the equipment at hand, and the nature of the supply, i.e., whether alternating or direct current. If the current is alternating, a means of converting it to direct current is necessary, such as a motor-generator, a mercury arc rectifier, chemical or vibrating type of rectifier. These are mentioned about in the order of the investment involved. In addition, a charging panel is needed to complete the equipment, this panel being fitted with switches, voltmeter and ammeter, and a variable resistance for regulating the charge. Where direct-current service is obtainable at 110 or 220 volts, the rectifier is unnecessary.

Q. How can a battery be charged from direct=current service mains without a special charging panel?

A. By inserting a double-pole single-throw switch and 10- or 15-ampere fuses on taps from the mains, and ordinary incandescent lamps in series with the battery to reduce the voltage, Fig. 314.

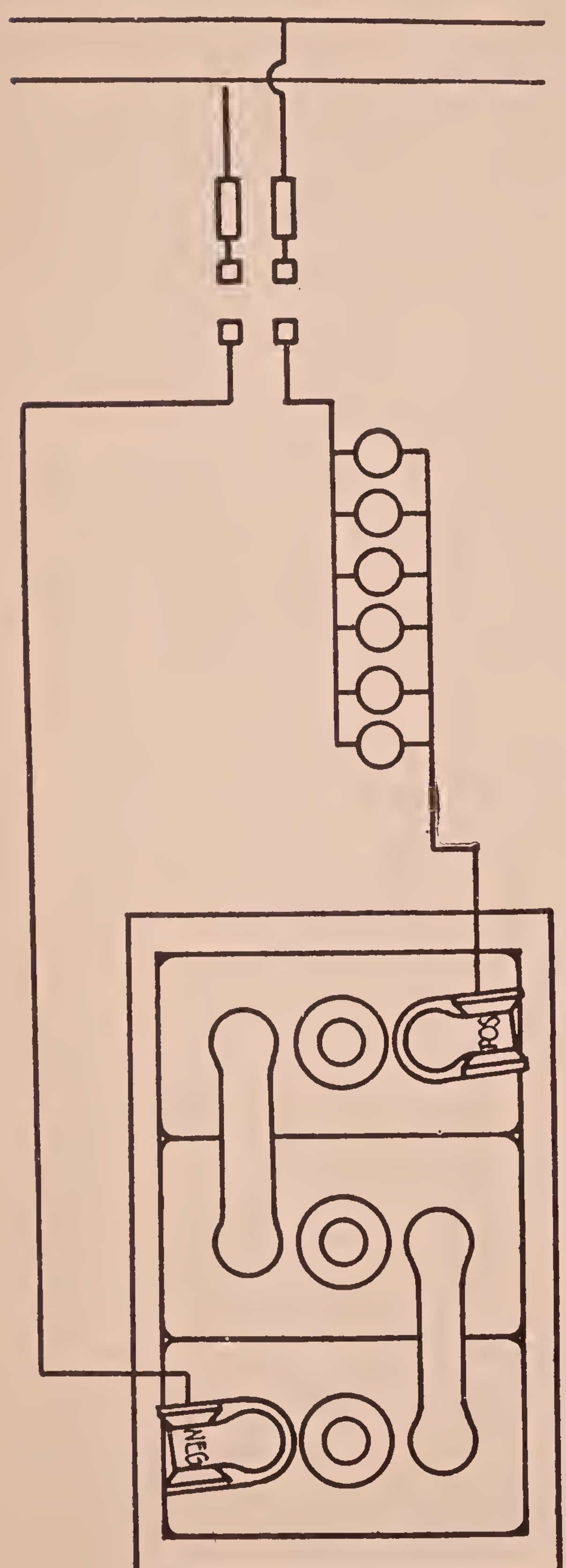


Fig. 314. Diagram of Connections for Charging Six-Volt Storage Battery from Lighting Circuit

Q. How many lamps will be needed?

A. This will depend upon their character and size, as well as upon the amount of charging current necessary. For a 10-ampere charge for a 6-volt storage battery, seven 110-volt 100-watt (32 c-p.) carbon-filament lamps or their equivalent, will be needed; i.e., fourteen 110-volt 50-watt (16 c-p.) carbon-filament lamps; eighteen 110-volt 40-watt tungsten lamps, or twenty-eight 110-volt 25-watt tungsten lamps. For a 12-volt or 24-volt battery the number of lamps will have to be decreased in proportion, in order not to cut the voltage of the supply current below that of the battery. For 220-volt d-c. supply mains, if a three-wire system is employed, the taps should be taken from the center wire and one outside wire; this will give 110 volts. If the service is 220-volt two-wire, more lamps will be needed to reduce the voltage, which should exceed that of the battery by only 1½ to 2 volts, except where a high voltage charge to overcome sulphating is being given, in which case it may be slightly higher.

Q. Where no outside source of current is available, or where no rectifier is at hand to convert alternating current, how can the battery be given the long charge necessary?

A. Run the engine. Supply it with plenty of oil and provide hose connections from the water supply to the filler cap on the radiator and a drain from the lower petcock. Open the latter and turn on just sufficient water to keep the engine reasonably cool; increase if necessary as it runs hotter.

Q. What precaution must be taken always before putting the battery on charge from an outside source?

A. The polarity of the circuit must be tested in order to make certain that the battery will be charged in the proper direction.

Q. How can this be done?

A. If a suitable voltmeter is at hand, i.e., one of the proper voltage for the 110-volt current, connect to the mains. If the needle does not move over the scale but shows a tendency to butt against the stop pin at the left, reverse the connections. The needle will then give a proper reading and the positive connection to the meter must be used for the positive side of the battery. Should no voltmeter of the right voltage be available, connect two short wires with bared ends to the fused end of the switch. Dip the bared ends in a glass of water, being careful to keep them at least an inch apart. When the switch is closed, fine bubbles will be given off the wire connected to the negative side. The battery terminals are stamped *Pos.* and *Neg.*, and the connections should be made accordingly.

Intermittent and Winter Use

Q. What should be done with an "idle" battery?

A. If it is to be idle for any length of time, as where the car is to be stored, it should be given a long overcharge as described above before putting out of service. Fill the cells right to the top with distilled water to allow for evaporation and absorption of acid by the plates. Give the battery a freshening charge at a low rate once a month. Discharge the battery and recharge before putting into service again. If it has stood out of service for a long period, the battery will not reach its maximum capacity again until it has had several charges and discharges.

Q. Does cold weather have any effect on the storage battery?

A. It causes a falling off in its efficiency. If not kept charged, the electrolyte will freeze under the following conditions: battery fully discharged, sp. gr. 1.120, 20° Fahrenheit; battery three quarters discharged, sp. gr. 1.160, temperature zero; half discharged, sp. gr. 1.210, 20 degrees below zero; one quarter discharged, sp. gr. 1.260, 60 degrees below zero. When storing away for the winter, the battery must either be kept charged or put where the temperature does not go lower than 20 degrees above zero.

Edison Battery

Q. Is it ever necessary to wash out an Edison battery?

A. No. The cells are permanently sealed, as the active material cannot escape from its containers.

Q. Do all of the foregoing instructions apply to the Edison as well as to the lead-plate battery?

A. No. The Edison requires very little attention, practically the only care necessary being to keep the cans replenished with distilled water at intervals.

Charging rates for Edison cells are given on pages 113 and 114—Electric Automobiles. S. A. E.-standard instructions for lead-plate cells on pages 132–134.

GENERATOR

Loss of Capacity

Q. What are the chief causes for the falling off in output of the generator?

A. In about the order of the frequency of their occurrence, these are as follows: dirty or worn commutator; worn brushes making poor contact; dirty or loose connections causing extra resistance at generator, regulator, cut-out, ground, or battery terminals; failure of cut-out to operate at proper voltage; worn or pitted contacts in regulator or cut-out; loose connections at brush holders; short-circuited coils in the armature; some of the armature-coil connections broken away from the commutator; short-circuited bars in the cummutator.

Q. How can the generator output be tested?

A. The simplest method is to switch on all the lamps with the engine idle. Start the engine and speed up to equivalent of 15 miles per hour. The lights should brighten very perceptibly, the test being made indoors in the daytime with the lights directed against a dark wall, or preferably at night. A more accurate test can be made with the portable volt-ammeter, using the 30-ampere shunt. Most generators have an average current output of 10 to 12 amperes, but the normal output as given by the maker should be checked before making the test. Generators having a constant-voltage control will show a greatly increased output if the battery charge is low, running up to 20 amperes or over. On such machines, the condition of the battery should be checked either with the hydrometer or with the voltmeter before making the test. The charging current should be 10 to 12 amperes with a fully charged battery, and more in proportion when only partly charged.

Q. What other simple method is there of determining quickly whether the generator is producing its normal output or not?

A. On generators having an accessibly located field fuse (there are several makes) lift this fuse out and, with the engine running at a speed equivalent to 10 miles per hour or more, touch the fuse terminals lightly to the clips. If the machine is generating properly, there will be a bright hot spark. Should no spark appear, replace the fuse and bridge the terminals with a pair of pliers by touching the jaws to the fuse clips; if a spark appears, the fuse has blown. Before replacing with a new fuse, find the short circuit or other cause.

Q. Granting that the fuse has not blown, that the cut-out, regulator, and wiring are all in good condition, and still the generator does not produce any current, what is apt to be the cause?

A. One of the brushes may not be touching the commutator, a brush connection may have broken or carbon dust may have short-circuited the armature or field windings. Test for short circuits with the lamp.

Q. If the machine is generating current, and the auxiliary devices and wiring are in good condition, but the battery does not charge, what is the cause?

A. Short circuit in the battery due to active material having been forced out of the plates, or accumulation of sediment touching plates at their lower ends. See Battery instructions.

Q. Is the regulator ever responsible for a falling off in the current or for generation of excessive current?

A. Yes. Any irregularity in the operation of the regulator will affect the output of the generator.

Q. How can this be overcome?

A. This will depend upon the type of regulation employed (see Regulation). Where the method of regulation is inherent, i.e., forming part of the construction of the generator itself, such as the third-brush method, or a bucking coil; it may be remedied by cleaning and seating the brush properly or by testing the bucking-coil winding to see if its connections are tight and clean, or if it is short-circuited (see Windings). If cleaning and sanding-in the brush do not cause the generator to produce its normal output, the brush itself may be adjusted by shifting its location. Moving it backward or against the direction of rotation of the commutator will reduce the output; moving it forward or in the direction of rotation will increase the output. This refers specifically to the Delco regulation already described. To adjust properly, the portable ammeter should be put in circuit and the effect on the reading noted as the brush is moved, clamping it back in place when the proper point is found. The brush should then be sanded-in to the commutator, as it will not have a good bearing if its original location has been disturbed.

Regulation

Q. Why is regulation of the output of the generator necessary?

A. Because of the great variation in speed at which it is driven. Below a certain speed, the armature coils do not cut the lines of force of the magnetic field with sufficient rapidity to generate sufficient e.m.f. to overcome that of the battery. Above this speed they generate so much that excessive current is produced, and, unless some method is provided for preventing it, this strengthens the magnetic field to such an extent that the current will burn up the windings.

Q. What is the principle of regulation usually employed?

A. Weakening the magnetic field of the generator as the speed increases, so that above a certain speed, the faster it runs the less current is generated.

Q. How is this usually accomplished?

A. There are several methods in general use, such as constant-current or constant-voltage control by means of vibrating regulators (Gray & Davis, Bijur, Delco, and Splitdorf); exciting the shunt-field windings by means of a third brush which depends upon the distortion of the magnetic field for the amount of current it sends through the field windings (Delco); a bucking-coil or reversed-series winding on the fields (Auto-Lite, Westinghouse) which counteracts the magnetizing effect of the shunt winding above a certain speed; bucking coil in connection with a thermo-controlled resistance or iron-wire resistance known as a ballast coil (Bosch-Rushmore) which, when hot, increases its resistance to such an extent that all excess current is shunted through the bucking coil; variable resistance controlled by a centrifugal governor (Delco), or by a solenoid (Adlake); speed control of the generator by a centrifugal governor (Gray & Davis early models); permanent-magnet fields, the excitation of which is the same at all speeds (Auto-Lite early models).

Q. What attention does the regulation require?

A. This will depend upon the method employed, but generally speaking very little is necessary. Some makers seal the regulator to prevent tampering by the owner and state that breaking the seal will invalidate their guarantee. Troubles with the regulation, however, are infrequent in the first year or two of service. Where a governor is employed, the springs will weaken in constant use and should be given a little more tension to compensate for this, as required. With the third-brush type, the brush may wear and make poor contact. (See Commutator and Brushes for remedy, and Loss of Capacity for adjustment of brush.) The variable-resistance contacts and movable switch arm may require cleaning in that type, or the same treatment may be necessary as for the contacts of a vibrating regulator. Resistances or reversed-field windings may become short-circuited. Any serious trouble with the regulator, which does not at the same time short-circuit the generator, will usually result in burning out the generator windings. Resistances may burn out due to excessive current.

Windings

Q. Are faults in the generator windings frequent?

A. They constitute one of the least frequent sources of trouble with the machine.

Q. What is apt to cause them?

A. Dousing the machine with water is apt to be one of the most frequent causes of short circuits or grounds in the generator windings. All electrical machinery is intended to be kept dry. Except where provided with a field fuse, running the generator when disconnected from the battery or with the battery removed from the car is another cause. Excessive speed, in some instances, may generate sufficient centrifugal force to lift the armature coils out of their slots so that the insulation becomes abraded by rubbing against the pole pieces, but this is very unusual. In rare instances, a hard kink left in the wire when winding may crystallize the metal and make it break at that point, due to the vibration. Unless cleaned out at intervals fine carbon dust from the wear of the brushes may accumulate in the interstices of the windings, and, when aggravated by moisture, this is apt to cause short circuits.

Q. What are the usual indications of such faults?

A. With a short-circuited generator coil (armature), all other parts of the apparatus and circuits being in good condition, the charging rate will be lower than normal. The ammeter needle will vibrate violently when the engine is running at low speeds, and two or more adjacent commutator bars will burn and blacken. With an open armature coil (broken wire), the indications will be practically the same and there will be severe sparking at the brushes, causing serious burning of the commutator bar corresponding to the open coil. A grounded armature coil will give the same general indications, and if the machine is a single-unit type, the cranking ability of the starting motor will be seriously impaired. The ammeter, however, will not vibrate as in the former cases. There will be practically no charge from the generator, and the battery will be discharged very rapidly by the starting motor.

In a single-unit machine, when the windings of the generator and the starting motor become interconnected, the indications will be practically the same as those of a grounded armature coil. If the motor windings of a single-unit machine become grounded, there will be an excessive discharge from the battery, while the motor will develop but little power.

Q. How may such faults be located?

A. With the aid of the testing-lamp outfit. Remove the brushes (when replacing them later, be sure to put each brush back in the holder from which it was taken) or the brushes may be insulated from the commutator by placing paper under them. For a grounded coil, place one test point on the commutator and the other on the frame; if grounded the lamp will light. For interconnected motor and generator windings in a single-unit machine having two commutators, insulate the brushes as mentioned and place the test points one on each commutator. The light will burn if the two windings are connected. For a grounded-motor winding, test from the motor commutator to the frame; the light should not burn if the insulation is all right. For a break or open circuit in the field winding, touch the terminals of the latter with the test points, the commutator being insulated or the armature removed. The lamp should light. For a blown field fuse on machines so equipped, place the points on the clips; if the fuse is intact the lamp will light.

Q. Are these tests conclusive?

A. No. They will indicate any of the faults mentioned, but they will not reveal an internal short circuit in the windings which cuts some of the armature or field turns out of action but does not break the circuit as a whole. Such a short circuit reduces the output of the generator and can only be determined definitely by measuring the resistance of the windings. This requires special and expensive testing instruments such as the Wheatstone bridge, so that where all other tests fail to reveal the cause of a falling off in the output of the generator, it should be sent to the maker for inspection.

Commutator and Brushes

Q. What does a blackened and dirty commutator indicate?

A. Sparking at the brushes or an accumulation of carbon dust due to putting lubricant on the commutator.

Q. What is the cause of sparking at the brushes?

A. Poor brush contact, due to worn brushes; brush-holder springs too loose, so that brushes are not held firmly against the commutator; excessive vibration which may be due to a bent shaft, an unbalanced gear pinion, or improper mounting; using too much oil or using grease in the ball bearings—this gets on the commutator and, acting as a solvent for the binder of the carbon, forms a pasty mass which prevents proper brush contact; worn or roughened commutator on which the mica needs undercutting; overload due to failure of regulator, or grounded coils in armature.

Q. What is the remedy for sparking?

A. Clean the commutator with fine sandpaper and sand-in the brushes to a true bearing on the commutator as directed in the Delco instructions. See that the brush springs have sufficient tension to keep the brushes firmly pressed against the commutator when the machine is running. If the mica protrudes above the commutator bars, it must be undercut as directed, and the commutator smoothed down again after the operation to remove any burrs.

Q. Why do some commutators need undercutting and others not?

A. Undercutting is required only on machines equipped with brushes that are softer than the mica. Copper-carbon brushes, as employed on starting motors to reduce the brush resistance, are hard enough to keep the mica worn down with the copper of the commutator itself.

Q. If, after smoothing off and undercutting the mica, the commutator still has an uneven and irregular surface, what is the remedy?

A. The armature should be removed from the machine and the commutator trued up in the lathe, taking as light a cut as possible consistent with obtaining a true round and smooth surface.

Q. How can excessive commutator wear be prevented?

A. Inspect at regular intervals and on the first sign of sparking, smooth up the surface and sand-in the brushes. Keep the commutator clean and do not permit carbon dust or oil to accumulate in the commutator and brush housing. Never replace brushes or brush springs with any but those supplied by the manufacturer for that particular model. The machine will work with any old brush and any old spring that fits, but they will prove detrimental to its operation in a comparatively short time, and its *working* under such conditions will never be satisfactory.

Q. Is discoloration of the commutator ever caused by anything else than sparking?

A. Not actual discoloration which requires cleaning, but the normal operation of the machine produces a purplish blue tinge on the bars which is sometimes mistaken for discoloration by the inexperienced. This color in connection with a high polish of the metal indicates that the commutator is in the best of condition. Once the commutator takes on this high polish, it will operate for long periods without other attention than the removal of dirt by wiping with a clean rag. Sanding to remove this purple tinge is a mistake, as it only destroys the polish without having any other beneficial effect.

STARTING MOTOR

Q. In what way does the starting motor of a two-unit system differ from the generator?

A. It is a simple series-wound machine having but one winding of coarse wire on the fields, and all the current from the battery passes through its armature coils and field windings.

Q. Is it subject to electrical faults other than those already referred to in connection with the generator?

A. No. The care and the nature of the tests required to locate faults are the same. The commutator should be kept clean, brushes bearing firmly on commutator, and all connections kept tight. The same instructions for sanding-in brushes and keeping the commutator in good condition apply as in the case of the generator.

Q. When the starting motor fails to operate, what is apt to be the cause?

A. In the majority of instances, a low state of charge or a wholly discharged battery will be responsible. If the battery is all right, a loose connection at the battery, switch, or motor, or a short circuit in some part of this wiring may be the cause. Should the battery be properly charged, all wiring and connections in good condition, switch contacts clean, etc., the starting gears may be binding, due to dirt or lack of alignment between the motor shaft and the flywheel of the engine. In this case, the motor will attempt to start when the current is first turned on, but will be held fast. Loosen the holding bolts and line up the motor, cleaning the gear teeth if necessary.

Q. What is apt to be the cause of the starting motor running slowly and with very little power?

A. Exhausted battery, poor switch contacts, loose connections, partial ground or short circuit in wiring causing leakage, improperly meshing gears, dirty commutator, brushes making poor contact due to weak springs or worn brushes, or a ground in the motor itself. The remedies for all these faults have been given already.

Q. When the battery, all connections, and wiring are in good condition but the motor fails to crank the engine, what is apt to be the cause?

A. The engine may be too stiff. If it has been overhauled just previously, the main bearings may have been set up too tightly. Test with the starting crank to see if it can be turned over easily by hand. If unusual effort is required, easing off the bearings should remedy the trouble. Should the engine not turn over as soon as the switch is closed, release immediately, as the battery will be damaged otherwise.

WIRING SYSTEMS

Different Plans

Q. What is the difference between the single=wire and the two=wire systems?

A. In the single-wire there is but one connection to the operating circuit by means of a wire or cable, the circuit being completed in every instance by *grounding* the other side of the circuit. For this reason the single-wire is also referred to as a grounded system. In the two-wire system copper wires or cables are employed to complete the circuits between the generator and battery and between the latter and the starting motor as well as to the lamps.

Q. What forms the return circuit of a single-wire system?

A. The steel frame of the chassis.

Q. How are the various circuits grounded?

A. In the case of the battery, a special ground connection is usually made by drilling the frame and fastening a clamp to it. The ground cable from the battery is attached to this clamp. The generator and starting motor are grounded internally, i.e., the end of a winding or of a brush lead that would be taken out to form the return side of a two-wire system, is connected to the frame of the machine and the latter completes the connection to the chassis through its holding bolts or other means of attachment. One side of all lamp sockets is usually grounded, so that the bulb itself completes the connection when fastened in place. Sometimes there is a special ground connection from the battery for the return side of the ignition or lighting circuits and this ground wire is fused.

Q. What are the advantages and disadvantages of the single-wire system?

A. It greatly simplifies the wiring, as but one wire connection is necessary to the apparatus for each circuit, but this advantage renders it more susceptible to derangement through unintentional grounds or short circuits, since the touching of any metal part of the chassis by a bare wire will cause a short circuit. This depends to a very great extent, however, on the thoroughness with which the wiring is protected, and, with the armored cables or loom and the junction boxes used on modern installations, it is reduced to a point where both systems are practically on a par in this respect.

Q. What are the advantages and disadvantages of the two-wire system?

A. Each circuit is complete in itself thus rendering it easier to locate faults, while no one connection coming in contact with a metal part of the chassis will cause a ground. The wiring itself, however, is much more complicated and, with the small space available on the bulb connections, it is more difficult to insulate them properly.

Q. Which system of wiring is favored?

A. The single-wire system will be found on the majority of cars, and the number of makers adopting it is steadily increasing.

Faults in Circuit

Q. What is the difference between a ground and a short circuit?

A. So far as the effect produced is concerned, they are the same; the difference in the terms referring solely to the method of producing it. For example, if the cable of the starting motor circuit becomes abraded and the bare part touches the chassis or some connecting part of metal, this is a *ground*. But it is also a short circuit in that the circuit to the battery is completed through a shorter path than that intended. On the other hand, if, in a two-wire system, the two cables of the same circuit become chafed close together and their bared parts touch, this is a short circuit but it is not a ground. For all practical purposes, however, the two terms are really interchangeable when applied to faults in the circuit. (See Gray & Davis instructions.)

Q. How may grounds be located in a single=wire system?

A. In any of the fused circuits the fuse will immediately blow out. Remove the fuse cartridge and shake it; if it rattles, the fuse wire has melted and the fuse is "blown". If it does not rattle, short-circuit the fuse clips with the pliers or a piece of metal; a spark will indicate the completion of the circuit and will also indicate that the fuse has blown. If, on bridging the fuse clips, the lamp lights, or other apparatus on the circuit operates, the short circuit was only temporary. This does not mean, however, that the fault has been remedied; the vibration of the car may have shaken whatever caused it out of contact and further vibration sooner or later will renew the contact with the same result. Inspect the wiring of that particular circuit and note whether the insulation is intact throughout its length. See that no frayed ends are making contact at any of the connections and that the latter are all tight and clean. In case the lamp does not light on bridging the fuse clips, see if the bulb has blown out; if not, use the test lamp by applying one point to the terminal and the other to various points along the wiring.

Q. Does the blowing of a fuse always indicate a fault in the wiring?

A. No. A bulb, in blowing out, frequently will cause a temporary short circuit that will blow the fuse. To determine this, apply the points of the test-lamp outfit to the bulb contacts; if the test lamp lights, the bulb is short-circuited and a new fuse and bulb may be inserted without further inspection of the circuit. In case the test lamp does not light on this test, it does not necessarily indicate a fault in the wiring of that circuit, though inspection is recommended before putting in new fuse and bulb. The blowing out of the bulb may cause a short circuit which is ruptured by the current burning away the light metal parts that were in contact, such as a small piece of the filament.

Q. Can a short circuit or ground occur without blowing a fuse?

A. Yes. No fuses are employed on starting-motor circuits owing to the very heavy current used and its great variation depending upon the conditions, such as extreme cold gumming the lubricating oil, tight bearings, binding of the pinion and gear, sprung shaft, starting motor out of alignment, or the like. On other circuits, the amount of current leaking through the fault in the circuit may not be sufficient to blow the fuse, as the capacity of the latter is such that it will carry the maximum current to which the apparatus in that circuit can be subjected without damage—usually 5 or 10 amperes on lighting circuits and 10 amperes on generator-field circuits.

Q. How can such faults be noted?

A. The ammeter or indicator will show a discharge reading when the engine is idle and all lamps are switched off.

Q. What is the usual nature of such a fault?

A. The battery cut-out may have failed to open the circuit completely; a frayed end of the stranded wire at one of its connections may be making light contact which will permit a small amount of current to pass; a particle of foreign matter of high resistance may be bridging a gap either at the cut-out or some other part of the circuit; or the ignition switch may have been left on the *battery* contact so that current is flowing through the ignition coil.

Q. How may faults be located in a two-wire system?

A. With the aid of the test lamp, placing the points along the two wires of the circuit at fault from one set of terminal connections to the other, examine all connections in the circuit in question; note whether any wires have frayed ends and, if so, wind them tightly together and dip in molten solder. See whether any moving part is in contact with one or both of the wires and whether the insulation of the latter has been worn off. In some two-wire systems there is a ground connection to the battery for the ignition system, in which case tests for grounds in the circuit in question must also be made. Examine the ignition switch for faults; also the switch of the circuit under test. This applies to single-wire as well as to two-wire systems.

Q. What is one of the most frequent causes of short circuits in a two-wire system?

A. The bulbs and their sockets, owing to the very small amount of space available for the insulation. Dirt or particles of metal may be bridging the small gaps between their insulated contacts. A blown out bulb also may be responsible, as previously mentioned.

Proper Conduction

Q. Why are different sizes of wire employed in the various circuits?

A. To permit the passage of the maximum current necessary in each circuit consistent with the minimum drop in voltage due to the resistance of the wire and its connections. The voltages employed are so low that any substantial drop due to this cause would seriously impair the efficiency of the system and particularly of the starting motor. For the latter the cables employed are not only large, but they are also made as short and direct as possible to save current, as well as expense in the installation.

Q. What is the smallest wire that should be employed in automobile wiring?

A. No. 14 B. & S. gage, and this should be used only for the tail lamp, dash lamp, primary circuit of the ignition, or similar purpose. No. 10 or No. 12 is usually employed for the other lighting circuits.

Q. When, in making alterations on a car, it becomes necessary to extend a circuit, what should be done?

A. The ends of the wires should be scraped clean and bright for at least 2 inches and a "lineman's joint" made with the aid of the pliers to insure having it tight. A lineman's joint is made by crossing the bared ends of the wires at their centers at right angles to each other, then wrapping or coiling each extending end tightly around the opposite wire; the joint then should be soldered and well taped. A circuit should be extended only by using wire of the same size and character of insulation. None of the foregoing applies to the starting-motor circuit. It is inadvisable to lengthen this circuit if avoidable, but in the rare instances when it would be necessary, new cable of the same size or larger and with the same insulation should be cut to the proper length and the old cable discarded. All terminals should be solidly fastened to the new cable by soldering.

Q. Why should connections be inspected frequently?

A. The vibration and jolting to which they are subjected in service is so severe that no mechanical joint can be depended upon to remain tight indefinitely.

Q. What harm does a loose or dirty connection occasion?

A. A loose connection causes the formation of an arc between its contacts whenever vibration causes the parts to separate temporarily. This wastes current and burns the metal away, leaving oxidized surfaces which are partially insulating, thus increasing the resistance at the connection. Dirt getting between the surfaces of the connector has the same effect; the resistance is increased and there is a correspondingly increased drop in the voltage of the circuit which cuts down its efficiency.

Q. Why should all terminals be well taped when the battery, starting motor, generator, or other apparatus is temporarily disconnected for purposes of inspection or test?

A. To prevent accidental short circuits which would be caused by these terminals coming in contact with any metal part of the chassis on a single-wire system. Such a short circuit would ruin the battery and burn out any lamps that happened to be included in the circuit. This precaution applies with equal force to the two-wire systems, as in this case the terminals of the different wires might come together, or there might be a ground connection in the system.

PROTECTIVE AND OPERATIVE DEVICES

Q. What are the protective devices usually employed on electric systems?

A. Fuses in the separate lamp circuits, in the ground connection, and in the field circuit of the generator on some machines; battery cut-out for the charging circuit; circuit breaker which takes the place of the fuses.

Fuses

Q. What is a fuse and what is its function?

A. A fuse consists of a piece of wire of an alloy which melts at a low temperature and which will only carry a certain amount of current without melting, the latter depending upon the diameter of the wire, i.e., cross-section and the nature of the alloy. The fuse is usually in the form of a cartridge, the wire being encased in an insulating tube having brass ends to which the ends of the wire are soldered. These brass ends are pressed into spring clips to put the fuse in circuit. In some cases open fuse blocks are employed, the wire itself simply being clamped under the screw connectors on the porcelain block. The function of the fuse is to protect the battery and the lamps when, by reason of a ground or short circuit in the wiring, an excessive amount of current flows.

Q. When a fuse blows out what should be done?

A. Investigate the cause before replacing it with a new one. (See Wiring Systems.)

Q. Is it permissible to bridge the fuse gap with a piece of copper wire when no replacements are at hand?

A. Only in cases of emergency and after the short circuit which has caused the fuse to blow, has been remedied. The finest size of copper wire at hand, such as a single strand from a piece of lamp cord, should be used. If this burns out, there being no ground or short circuit in the wiring, use two strands. Remove the wire as soon as a new fuse is obtainable.

Q. Why are fuses not employed in the starting-motor circuit?

A. The current necessary is so heavy and varies so widely with the conditions that it would not be practicable.

Circuit Breaker

Q. What is a circuit breaker, and what is its function?

A. The circuit breaker is an electromagnet with a pivoted armature and contacts, similar in principle to the battery cut-out. All the current used in the various circuits, except that of the starting motor, passes through it, and its contacts normally remain closed. The winding of the magnet coil is such that the normal current used by the lamps or ignition does not affect it, but the passage of an excessive amount of current will energize the magnet, attract the armature, and break the circuit. The spring holding the armature away from the magnet will again close the circuit and the circuit breaker will vibrate until the cause has been removed. This is usually a ground or short circuit. The function of the circuit breaker is to protect the battery and lamps in place of the usual fuses.

Q. If the circuit breaker operates when there are no faults in the wiring, what is apt to be the cause?

A. Its spring may have become weakened so that the vibration of the car causes it to operate on less current. The Delco circuit breaker is designed to operate on 25 amperes or more, but, once started, a current of 3 to 5 amperes will keep it vibrating. If tests show that no faults in the wiring or connections exist, increase the spring tension with the ammeter in circuit until the reading of the latter indicates that the circuit breaker is not operating on a current of less value than that intended. See that the contacts are clean and true.

Battery Cut-Out

Q. What is a battery cut-out?

A. It is an automatic double-acting switch which is closed by the voltage of the generator and opened by the current from the battery.

Q. Of what does it consist?

A. It is essentially a double-wound electromagnet with a pivoted armature and a pair of contacts. One winding, known as the *voltage coil*, is of fine wire and is permanently in circuit with the generator. The second winding of coarse wire is termed the *current coil* and is put in circuit by the contacts.

Q. Why is a cut-out necessary?

A. To protect the storage battery. When the generator speed falls below a certain point, it no longer produces sufficient voltage to charge the battery and the latter then would discharge through the generator windings if not prevented. This discharge would always take place when the generator was idle, except for the cut-out.

Q. How does it operate?

A. When the generator voltage approaches the value necessary for charging, it energizes the magnet through the voltage coil and closes the contacts, cutting in the current coil which further excites the magnet and holds the contacts firmly together. The closing of these contacts puts the battery in circuit and it begins to charge. As soon as the generator speed falls below the point necessary for charging, the battery voltage overcomes that of the generator and sends a current in the reverse direction through the current coil, causing the contacts to separate and cutting the battery out of the charging circuit.

Q. If the generator is run for any length of time at or near this critical speed, what is to prevent the cut-out from vibrating constantly instead of working positively one way or the other?

A. The resistance of the windings is so proportioned that there is a difference of 1 to 2 volts between the cutting-in and the cutting-out points.

Q. What is the result when the battery cut-out—which is variously termed a cut-out, a circuit breaker, an automatic switch, and a reverse-current relay or an automatic relay—fails to operate?

A. If it fails to cut in, i.e., the contacts do not come together, the battery does not charge and will quickly show a falling off in capacity, such as inability to operate the starting motor properly or to light the lamps to full brilliance. If it fails to cut out, the battery charge will be wasted through the generator windings with the same indications of lack of capacity.

Q. What is the most frequent cause of trouble?

A. Automatic cut-outs have been perfected to a point where but little trouble occurs. "Freezing" or sticking together of the contacts due to excessive current will most often be found to be the cause of the device failing to cut out when the generator is stopped. The points should be cleaned and trued up as described in previous instructions. Loose or dirty connections making poor contact may insert sufficient extra resistance in the circuit as to prevent the device from cutting in at the proper point. Excessive vibration, particularly when the cut-out is mounted on the dash, may prevent the contacts from staying together as they should when the engine is running at or above the proper speed. See that the cut-out is solidly mounted. Temporary loss of battery capacity may be due to slow driving over rough roads at about the speed at which the cut-out is designed to put the battery in circuit.

Q. None of the above causes existing, what further tests may be made?

A. The windings may be tested as already described for the generator windings, but trouble from this source is equally rare. If the contacts are clean and true and the connections are tight, look for a loose connection elsewhere, as at the generator or battery or the ground on the frame. A loose connection vibrates when the car is moving, constantly opening and closing the circuit and causing the cut-out to do likewise, so that the battery does not charge. A wire from which the insulation has been abraded will also vibrate due to the movement, causing an intermittent short circuit. With all contacts and connections in good condition, failure to cut out indicates a ground or short circuit between the battery and cut-out; failure to cut in indicates similar trouble between the generator and the cut-out.

Q. Is a battery cut-out necessary on every electrical system?

A. No. On single-unit systems of the type of the Dyneto in which the generator becomes *motorized* as soon as its speed, and consequently its voltage, drops below a certain point, the battery is always in circuit. A plain knife-blade switch, which also controls the ignition, is closed to start and left closed as long as the car is running. But the engine must not be allowed to run at a speed below which it generates sufficient voltage to charge the battery, nor must the switch be left closed when the engine is not running; otherwise, the battery will discharge through the generator windings.

Switches

Q. How do switches as employed on the automobile differ in principle and operation?

A. Starting-circuit switches are either of the knife-blade or the flat-contact type, while in the majority of cases the lighting switches are of the push-button type, though knife-blade switches are used for this purpose also. In some instances, one of the brushes of the machine is made to serve as a switch, as in the Delco. Ordinarily, the switch is normally held open by a spring and is closed by foot pressure, the spring returning it to the open position as soon as released. A variation of this is the Westinghouse electromagnetically operated switch in which a solenoid takes the place of foot operation. The circuit of the solenoid is controlled by a spring push button, which is normally held out of contact. Single-unit systems, such as the Dyneto in which the machine automatically becomes motorized when the speed drops below a certain point, are controlled by a standard single-throw single-pole knife-blade switch which is left closed as long as the machine is running.

Q. What faults may be looked for in switches?

A. Loose connections; weakening of the spring; burning of the contact faces in the knife-blade type, due to arcing caused by releasing too slowly; dirt or other insulating substance accumulating on the contact faces of the flat-contact type; failure to release through binding.

Q. Why is it important to keep the switch contact faces clean and bright?

A. Dirt or burned surfaces increase the resistance and cause a drop in the voltage at the starting motor. The energy represented by an electric current is a measure of the volume or amperes times the voltage or pressure under which it flows, and, as such low voltages are used, only a slight falling off represents a serious percentage of the total potential. With a dirty switch or one that makes poor contact, current that should be utilized in the starting motor is wasted in overcoming the resistance of the switch.

Q. Why is it inadvisable to insert an extra switch in the starting circuit, as is done in some cases by owners to insure against theft?

A. Because of the drop in voltage. The loss in switches as designed for lighting circuits is about 1 per cent, or a little over 1 volt. If the same switch is used on the low voltage of the starter system, the loss is then equivalent to about 10 per cent.

LIGHTING AND INDICATORS

Lamps

Q. How many types of bulbs are there in general use on automobiles?

A. Four: miniature and candelabra screw base, and single- and double-contact bayonet-lock base, both of the latter being of the candelabra size.

Q. Are these types equally favored?

A. No. The screw-base type, particularly in the miniature size will be found only on old cars and this type, generally speaking, is practically obsolete on the automobile, as the vibration tends to unscrew the lamp. Of the bayonet-lock type, the single-contact style is steadily gaining favor. Ten million bulbs for automobile lighting were produced in 1915 (S. A. E. report) and of these 67 per cent were of the single-contact type.

Q. In how may different voltages are these bulbs made?

A. Four: a 6—8-volt bulb for a 3-cell or 6-volt system; 12—16-volt bulb for 6-cell or 12-volt systems; and 18—24-volt bulbs for 9-cell systems; 3—4-volt bulbs for tail-light and dash-light use, where these lights are burned in series on a 6-volt system.

Q. Are these the only voltages in which the bulbs are made?

A. No. They are the types that are being standardized to reduce the stock of replacements that it is necessary for a garage to carry. It has been customary for the lamp manufacturer to supply bulbs made exactly for any voltage that the maker of the electric system ordered. Taking into consideration only the standard sizes now listed for use on 3-, 6-, and 9-cell systems, and the different bases regularly used, there are about twenty-four different bulbs that should be stocked by a garage. In addition, about forty other sizes are in general use, and if individual voltages had to be supplied, considering the different standard bases, a stock of over two-hundred different bulb sizes would be required.

Q. Why is the voltage of a bulb expressed as "6—8", "12—16", etc.?

A. Owing to the rise and fall of the battery voltage according to its state of charge, this variation must be provided for or the lamps would be burned out when the battery was fully charged. Headlight bulbs for 3-cell systems are made for $6\frac{1}{2}$ volts, while the side, rear, and speedometer lights are made for $6\frac{3}{4}$ volts, owing to the lesser voltage drop in their circuits, but they will all operate satisfactorily on a potential that does not exceed 8 volts or does not drop below 6 volts.

Q. When all the lamps burn dimly, what is the cause?

A. Battery is nearly exhausted, in which case its voltage will be only 5.2 to 5.5 volts for a 3-cell system. The car should be run with as few lights as necessary to permit the generator to charge the battery quickly.

Q. What is the cause of one light failing?

A. Bulb burned out or its fuse blown; examine the fuse before replacing the bulb and if blown, examine the wiring before putting in a new bulb. Poor contact; see that the lamp is put in properly and turned to lock it in place. A double-contact bulb may have been put in single-contact socket, or *vice versa*.

Q. Why will one lamp burn much brighter than the other?

A. A replacement may have been made with a bulb of higher voltage; a 12-volt bulb will only give a dull red glow on a 3-cell system. Where the difference is not so marked as this, but still very perceptible, it may be due to the difference in the age of the lamps. As a bulb grows old in service, its filament resistance increases, so that it does not take so much current and will not burn as brightly as when new.

Q. Will the failure of a bulb cause its fuse to blow though there is no fault in its circuit?

A. This sometimes happens owing to the breaking down of the filament, causing a short circuit when the lamp fails.

Q. Can the proper voltage bulbs needed for any system always be told simply by taking the total voltage of the battery, i.e., the number of cells times 2?

A. No. Always examine the burned out bulb and replace with one of the same kind. Many 6-cell systems use 6-volt lamps and are known as 12—6-volt systems. The battery is divided into two groups in series parallel for lighting and sometimes for charging, all the cells being in series for starting. Other arbitrary voltages are also adopted; for example, 14-volt bulbs are used on 12-cell systems, the battery being divided in the same manner, so that this would be a 24—12-volt system. The only safe way to order replacements is to give the voltage on the printed label on the old bulb and state the make of the system on which it is to be used.

Q. What type of bulb is used where the current is taken from the magneto, as on the Ford?

A. As supplied by the maker, only the headlights are wired and they are in series and in recent models a 9-volt bulb is used, but the above instructions for replacements will apply here also. Ordinarily, double-contact bulbs are required, unless the fixtures are insulated from one another, in which case the single-contact type can be used.

Q. Why is a bulb of a voltage lower than that of the system itself often employed on 6=, 9=, and 12=cell systems?

A. The lower the voltage, the thicker the filament can be made. A short comparatively thick filament concentrates the light and makes the bulb easier to focus; it is also much more durable than the thin filament required for higher voltages.

Q. Under what conditions will the best results be obtained from the headlamps?

A. When the bulbs are in proper focus with the lamp reflectors. The usual focal length for headlight bulbs is $\frac{13}{16}$ inch, and the focal length of the reflector is made greater than this to permit of adjustment. The center of the filament should be back of the focus of the reflector to spread the beam of light. In this position a greater number of the light rays are utilized and redirected by the reflector, producing a higher beam candle-power. If the center of the filament is forward of the focus, the lower part of the reflector will produce the most glare and throw it into the eyes of pedestrians and approaching drivers.

Q. How can the headlights be focused?

A. Place the car in position where light can be directed against a wall about 100 feet distant. Adjust the bulbs backward or forward until the spotlight on the wall is most brilliant and free from black rings and streaks. When this position is found, lock the bulb securely in place. Focus each headlight separately. See that the lamp brackets are set so that the light is being projected directly ahead.

Q. How can metal headlight reflectors be cleaned when discolored?

A. Wash by directing a gentle stream of cold water against the surfaces and allow to dry without touching them. The reflectors should never be rubbed with cloth or paper as it will scratch the highly polished surfaces. If they become very dull, it will be necessary to have them replated.

Q. What is the meaning of the identification marks usually placed on bulbs, in addition to the voltage, such as "G=6"?

A. This refers to the size and shape of the bulb. The diameter of the glass bulb is expressed in eighths of an inch and its shape by a prefixed letter, *G* for round (globular), *T* for tubular, *S* for straight-side, etc. Thus, G-6 is a round bulb $\frac{6}{8}$ inch or $\frac{3}{4}$ inch in diameter.

Instruments

Q. What instruments ordinarily are employed in connection with electric systems on the automobile?

A. Either a double-reading ammeter, a volt-ammeter, or an indicator, the first-named being employed generally. The ammeter shows whether the battery is charging or discharging or no current is passing; the indicator reads either *Off* or *On;* while the volt-ammeter gives the voltage, usually upon pressing a button to put it into operation, in addition to the readings already mentioned. Volt-ammeters seldom are used.

Q. On what circuits are the indicating instruments placed?

A. The charging circuit from the generator to the battery, and the lamp and ignition circuits.

Q. Why is an ammeter not used for the starting=motor circuit?

A. The current is so heavy and varies so greatly with the conditions that an ammeter designed to give an accurate reading of it would not be sensitive enough to indicate the smaller amounts of current used by the lamps, or produced by the generator for charging. Furthermore, the starting motor is intended only to be used for very short periods, while the other circuits are in constant use.

Q. Do the small ammeters employed fail very often?

A. Considering the unusually severe treatment to which they are subjected by the vibration and jolting of the car, their failure is comparatively rare, but as the conditions are so severe for a sensitive indicating instrument, too much dependence should not be placed on the ammeter reading when making tests.

Q. What are the usual causes of failure?

A. Failure to indicate—the generator, wiring, and other parts of the curcuit being in good operative condition—may be caused by the pointer becoming bent, so as to bind it; the pointer may have been shaken off its base altogether by the jolting, or one of its connections may have sprung loose from the same cause.

Q. How can the ammeter reading be checked?

A. By inserting the portable testing volt-ammeter in circuit with it, using the 30-ampere shunt and comparing the readings. The dash ammeter must not be expected to give as accurate a reading as the finer portable instrument. Failing the latter, a spare dash ammeter may be employed in the same manner and the spare may be tested beforehand by connecting to a battery of 4 dry cells in series; if brand new they should give a reading of 18–20 amperes. Do not keep the ammeter in circuit any longer than necessary to obtain the reading as it only runs the cells down needlessly.

Q. Should an ammeter ever be used in testing the storage battery?

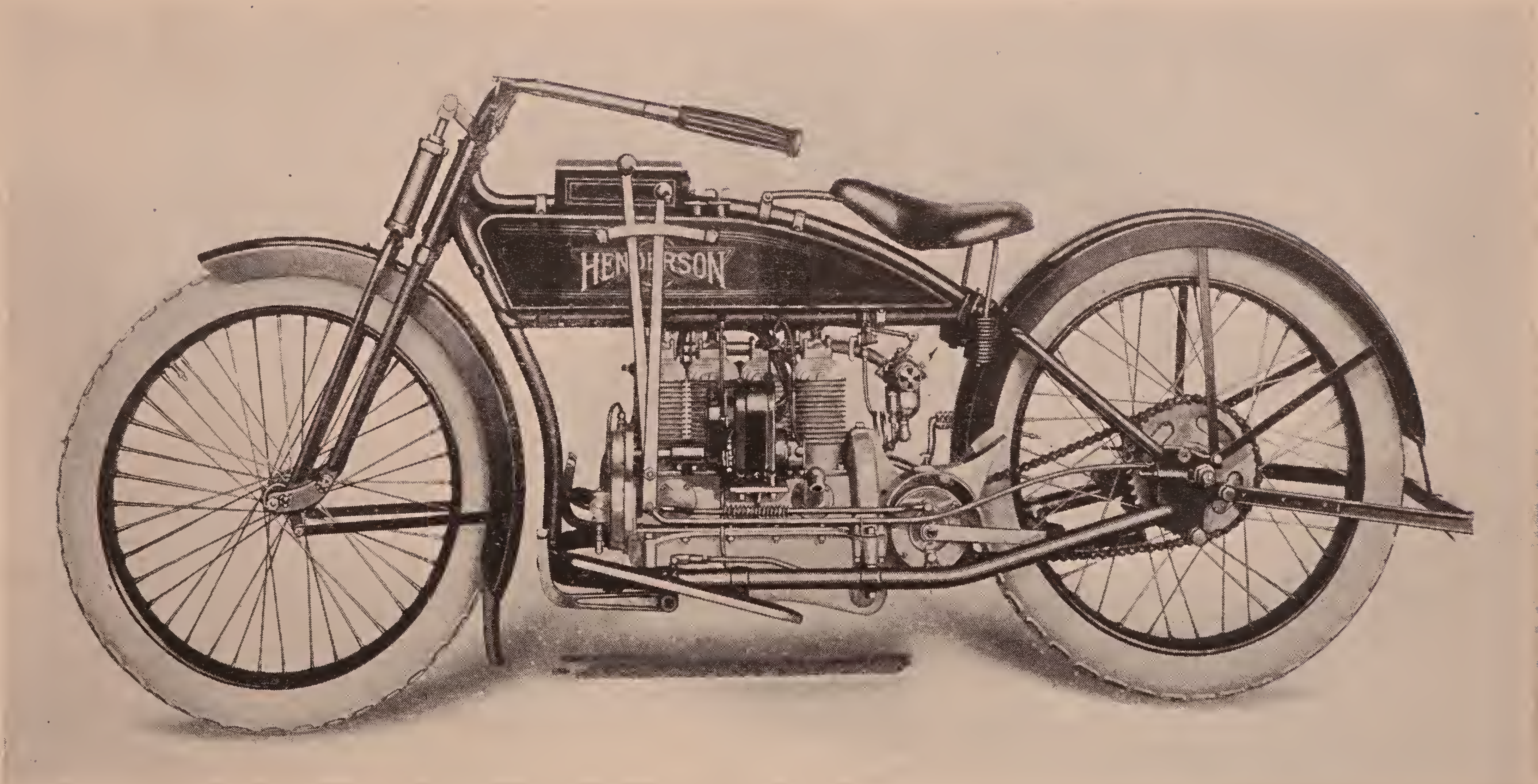
A. No. Because it practically would short-circuit the battery, burn out the instrument, and damage the battery itself. Nothing but a voltmeter should be employed for this purpose, as its high resistance coil permits only a small amount of current to pass. An ammeter reading from a storage battery gives no indication whatever of its condition, whereas the voltage affords a close check on the state of charge, varying from 1.75 for a completely discharged cell to 2.55 volts for a fully charged one, the readings always being taken when the battery is either charging or discharging. The voltage on discharge will not be as high as on charge, the conditions otherwise being the same.

Q. Why are indicators employed on some systems, instead of ammeters?

A. As the indicator is not designed to give a quantitative reading, it need not be so sensitive as an ammeter and accordingly can be made more durable.

Q. What are the most frequent causes of failure of an indicator?

A. Usually of a mechanical nature caused by the jolting, such as the target being shaken off its bearings, broken wire, etc.



FOUR-CYLINDER TWO-SPEED HENDERSON MOTORCYCLE
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

MOTORCYCLES

INTRODUCTION

Evolution of the Motorcycle. The same period which has brought the automobile to its present state of perfection has also witnessed the birth and development of the motorcycle. This two-wheeled motor vehicle was developed from the bicycle, in fact, the first motorcycles were bicycles with motors attached. However, owing to the comparatively high speed attained, the strains put upon the bicycle frame were too great, and extensive modifications were carried out, which resulted in a distinctive design and construction to stand the requirements of the service. It is significant of the general improvement in the construction that several motor bicycles have recently been designed and are giving good service.

The motorcycle started entirely as a pleasure or sporting vehicle, used by a few bicycle enthusiasts who desired greater speed, or by racing men for pacemaking. Gradually, however, the utility of the machine in many directions became established, and now its place in its own field is as surely fixed as that of the automobile itself. For single or tandem road work, for package delivery, messenger service, military duty, and a hundred other important offices, it is unexcelled, and the thousands upon thousands of machines that are sold every year in this country alone bear testimony to its popularity. There are other indications in some recently developed types that the field of usefulness of this flexible machine will be broadened still further.

Standard Specifications. The conventionalized American motorcycle is of two-cylinder construction. The frame is tubular and diamond shaped, with a double crossbar at the top, between which bars are located a gasoline and an oil tank. The frame at its lowest point is in the form of a loop, in which is clamped the aluminum crankcase of a twin-cylinder air-cooled motor with the cylinders set V-shaped and a carbureter fitted between. Separate exhaust pipes lead from each cylinder to a muffler. The motor is of the L-head type, with the cylinders, as a rule, cast in one piece. The exhaust valves are at one side of the motor and are operated by cams on the lower side of the crankcase. The same cam often operates both exhaust valves.

In a removable cage on the roof of the valve pocket, just over the exhaust valve, is located the intake valve, which is operated by a rocker arm above it, controlled by a push rod running up the side of the motor from the cam case. The crankcase contains two flywheels which form also the crank arms of a built-up crank. Both connecting rods are fastened to the same crankpin, and these rods run down between the flywheels.

In the cam case is a small plunger oil pump which pumps oil in small quantities to the forward cylinder, this oil being delivered through the wall of the cylinder directly onto the piston at the lower end of its stroke. From this point the oil drops into the crankcase and is thrown up through the rest of the motor by the splash system. The crankshaft on one side runs into the cam case, from which a train of gears drives a magneto for ignition. The advance and retard of this magneto are controlled by twisting one of the handlebars of the motorcycle, this motion being ordinarily transmitted to the magneto through a series of bell-cranks and rods. The throttle is controlled by twisting the opposite handlebar so that the control of the entire machine is always within the driver's grasp.

The right end of the motor shaft projects beyond the right side of the case and ends in a small roller-chain sprocket, from which a chain runs to a larger sprocket on a countershaft set at the base of —or just back of—the vertical frame tube member. Since change-speed gearsets are becoming common, this shaft is generally located back of the seat-post tube. The large countershaft sprocket connects with a small countershaft sprocket or with a gearset by means of a multiple-disk friction clutch, either of the dry fabric-faced type or of the metal type. This clutch may be operated by a lever in front of the driver's seat or by a foot pedal, or both. From the countershaft a chain runs from a smaller sprocket to a larger sprocket on the rear wheel hub of the motorcycle. In this hub is located a brake or brakes of the expanding or contracting type, or both, operating on a brake drum. The rear end of the frame is often mounted on springs from the seat-post back, the lower frame forks being pivoted and the upper connection sprung. Within this triangle and generally back of the seat post, is fitted a tool box, while over the wheel a luggage carrier forms the stock equipment. A stand is always fitted on the rear wheel to enable one to leave the motorcycle without its falling over.

The saddle is very large, as compared with a bicycle seat, and has sensitive springs, as well as being usually mounted in a spring seat post located in the vertical tube member. This saddle is always placed as low as possible on the frame. The front forks are mounted on some sort of springs—generally of the flat-leaf type—in order to absorb the shocks, and thus avoid metal fatigue in the machine as well as bodily fatigue in the rider. This in outline is the American motorcycle of today.

European Design. European practice is more varied than it is in America, the reasons being entirely manufacturing ones. In Europe, quantity-production is not the rule and hence motors have not become standardized, which fact has allowed more experimenting and greater individuality in design than has been possible in America. Here, quantity-production is the practice and this latter method has restricted the try-out to avoid mistakes, so that only established ideas have been used. The resulting standardization of the general type of American motorcycle has only been disturbed by the four-cylinder motor designs and by small-quantity production of two-cycle motors.

HISTORY

Early Machines. The first motorcycle built was the work of Gottlieb Daimler, who, in 1885 built a two-wheeled vehicle to try-out a gasoline motor with which he was experimenting. This machine was the forerunner not only of the motorcycle but of the automobile as well. De Dion of France, with Karl Benz of Germany, developed along with the automobile the gasoline motor, and the De Dion type was soon applied to a motor-tricycle, followed by a motor-bicycle using the same motor.

This motor was the predecessor of the motorcycle motor of today. The cylinder arrangement and the location of the compression chamber were almost identical. Two flywheels were used with a connecting rod between, and the flywheels were entirely enclosed in the crankcase. Viewed in the light of modern design the motor was very crude but developed horsepower enough to drive this early machine at what was then considered an astonishing speed of 30 miles per hour.

The foreign machines were developed between 1894 and 1898, when an American inventor who had been building racing bicycles, took up the motor-driven tandem as a pacemaking mount for bicycle racing. As the motorcycle is all wheelbase and no tread, it has no difficulty in holding the road at any speed, a fact which made it very adaptable to this kind of service. The transmission of this machine, designed by Oscar Hedstrom, was the basis of the formation of a company for the manufacture of motor-bicycles, with George M. Hendee as the business manager of the concern. At about the same time, the Thomas, Holly, Orient, and Mitchell motorcycles were being developed.

Two-Cylinder Motors. Glenn Curtiss was one of the first to develop a two-cylinder motor. It was in connection with his experiments with motors that he built a motorcycle equipped with an eight-cylinder V-type motor, which, covering a mile in 26.4 seconds—the fastest mile ever covered by man—held the record until recent date.

The first motors built were small-power engines of about the same stroke as bore; they attained surprising speed and cooled very successfully with flanges of small area.

Starting with 2.5-horsepower motors, power and weight were continually added until motors of 12- and even 14-horsepower have become common practice. The latter are for the most part of large bore and of comparatively slow speed, but, through the activity of European developments, light-weight machines with high-speed motors are coming into prominence.

Influence of High-Speed Motors. In the early days, when materials and workmanship were questionable, except at a great expense, high speed in a motor was a disadvantage and tended toward short life. Belt drive from the motor to the rear wheels was common, and hence motors could not be geared below a certain ratio without having the belt pulley too small to transmit the power. Flat belts became very popular in America and were used on such machines as the Excelsior, Harley-Davidson, Yale, etc., while the Reading-Standard and the Indian factories consistently held to chain drive. Within the past few years, with the introduction of change-speed gears and high-speed motors, a positive drive has become a necessity and chain drive with reduction to a countershaft located between the motor and the rear wheel has become almost standard practice.

Foreign designers still favor the belt to transmit the power from the countershaft to the rear wheel, claiming greater flexibility of drive. American makers obtain smoothness of action by incorporating a slipping clutch in the transmission.

Light=Weight Machine. First to bring into prominence the light-weight motorcycle and high-speed motor was the Douglas Company, of England, which built a small horizontal-opposed, two-cylinder, air-cooled motor which, through its almost perfect balance of moving parts, proved successful above 4000 r.p.m. This motor was set fore-and-aft in a light frame with a chain taking the power from the motor to a countershaft at the frame junction below. A V-type pulley was the front member of the belt-driven system and the gear reduction of the first chain drive threw a minimum strain on the belt and hence proved very reliable. This machine weighed, complete, about 183 pounds and yet was capable of the same road performance as the high-powered American machines of greater weight.

Other makers have followed the lead of this firm in developing what are known as light-weight motors, and America has taken up the idea, although road conditions do not allow the extreme lightness which is possible abroad.

Modern Improvements. Single-cylinder motorcycles are very rare in America today, the preference being for high-power, twin-cylinder mounts. The greatest improvements of recent date have been toward making the motorcycle more comfortable, cleaner, easier to operate, more reliable, and more foolproof. This, in nearly every case, has meant increased rather than decreased cost, but buyers prefer a completely equipped machine at higher prices to partially developed mounts at lower figures. Four-cylinder machines are becoming popular with each succeeding year, and the manufacturers are also incorporating three-speed gearsets, self-starting systems, and other automobile features to as great an extent as possible.

With the many improvements in construction, convenience and reliability in the motorcycle has come a broadening of its field of usefulness. Fitted with a side and an extra wheel, it has become the family carryall or has been utilized for city runs and delivery purposes. In the recent wars, motorcycles have played a very important part in the transmission of messages and in the quick dispatch of repair men and scouts for emergency service. A number of the sidecar vehicles have even been fitted with machine guns and very successfully used for rapid reconnoissance work.

TYPES OF MOTORCYCLES

Excelsior. An Excelsior machine, shown in Fig. 1, is equipped with a twin-cylinder V-type 10-horsepower motor, chain drive and two-speed crankshaft gear. The frame has an exceptional amount of drop at the rear, allowing the rider to sit very low—close to the ground. The front forks are fitted with a leaf spring shock-absorbing device, the seat is hung on the usual spring-tube construction and

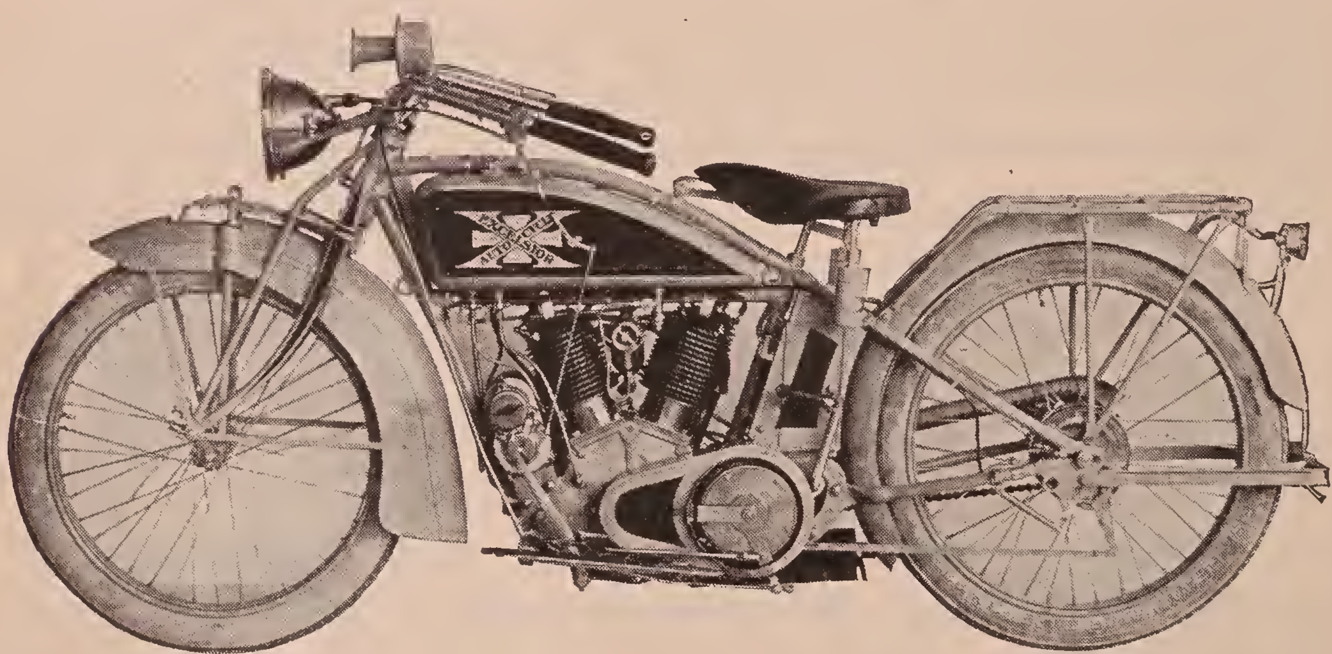


Fig. 1. Excelsior Model 15-3 Motorcycle
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago

the side springs themselves are incased. Contracting- and expanding-band brakes are used on the rear wheel, and no pedals are used on the model shown. This machine is chain-driven, has a gearset on the countershaft giving three speeds, an electric lighting and ignition system, a kick starter, and extra long footboards. The equipment is exceptionally complete. The details of these various mechanisms and those of other motorcycles will be described later.

Indian. The Indian motorcycle, shown in Fig. 2, is driven by a twin-cylinder motor for which a 15-horsepower output is claimed. A feature of this machine is the hanging of the entire mechanism on leaf springs, both front and rear. It is chain-driven, fitted with a dry-disk clutch and is equipped with either two- or three-speed gear. This gear is of the sliding type, and is located in the countershaft.

No pedals are used, the motor being depended upon entirely for power, and starting being obtained by a kick pedal, as described later.

Harley-Davidson. The Harley-Davidson twin-cylinder motorcycle is shown in Fig. 3. It is fitted with an 11-horsepower motor,

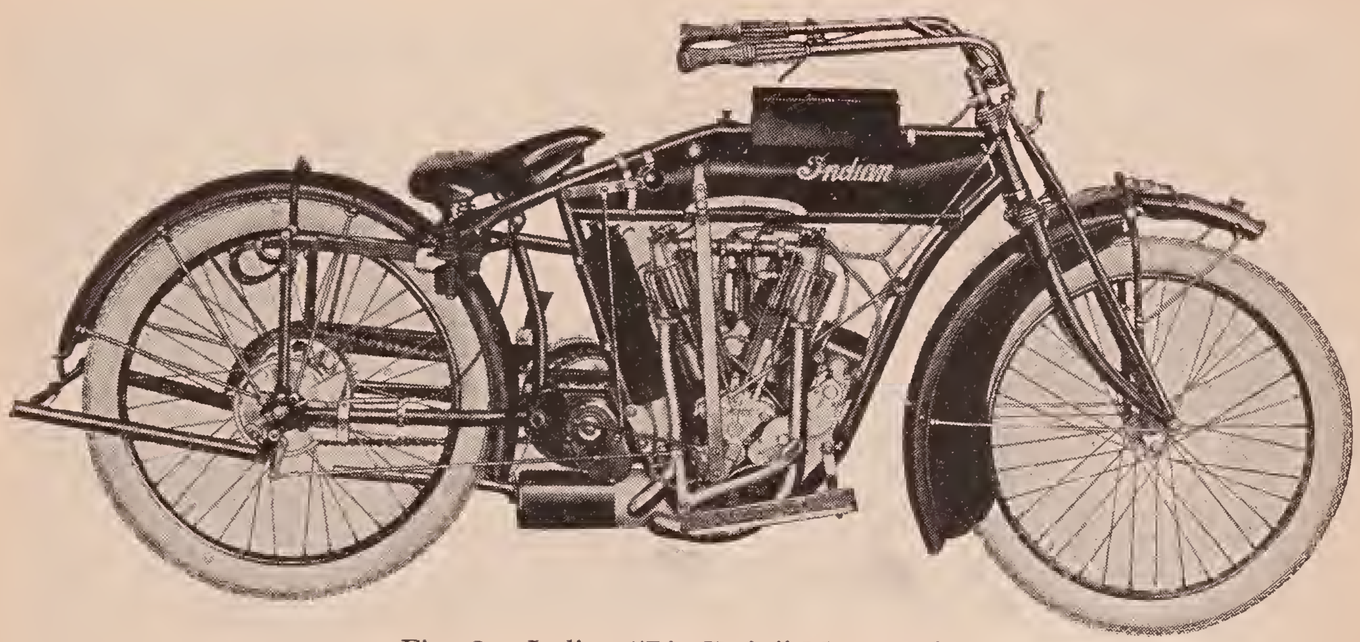


Fig. 2. Indian "Big Twin" Motorcycle
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

chain drive, and a three-speed gearset. It is equipped also with footboard, foot control, luggage carrier, and stand, and has a special type of spring seat for absorbing road shocks. The oil feed for the

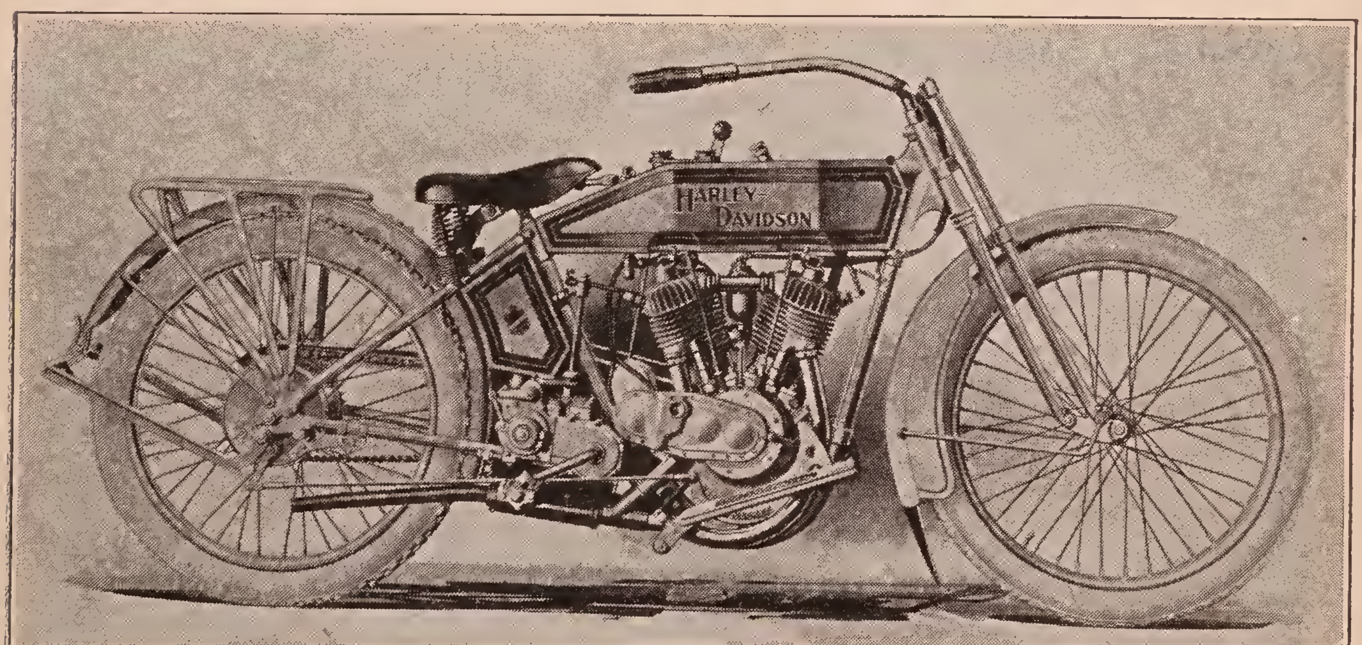


Fig. 3. Harley-Davidson Twin-Cylinder Motorcycle
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

motor is by a special type of plunger pump. Coil spring forks are used instead of leaf springs, as in the models already mentioned.

Dayton. The Dayton motorcycle, shown in Fig. 4, is of conventional design, fitted with a V-type motor, footboards, and clutch and is obtainable also with a two-speed gear. The clutch is of the multiple dry-disk type.

Flying Merkel. The Merkel motorcycle, shown in Fig. 5, obtains the springing effect by a spring plunger located under the saddle at

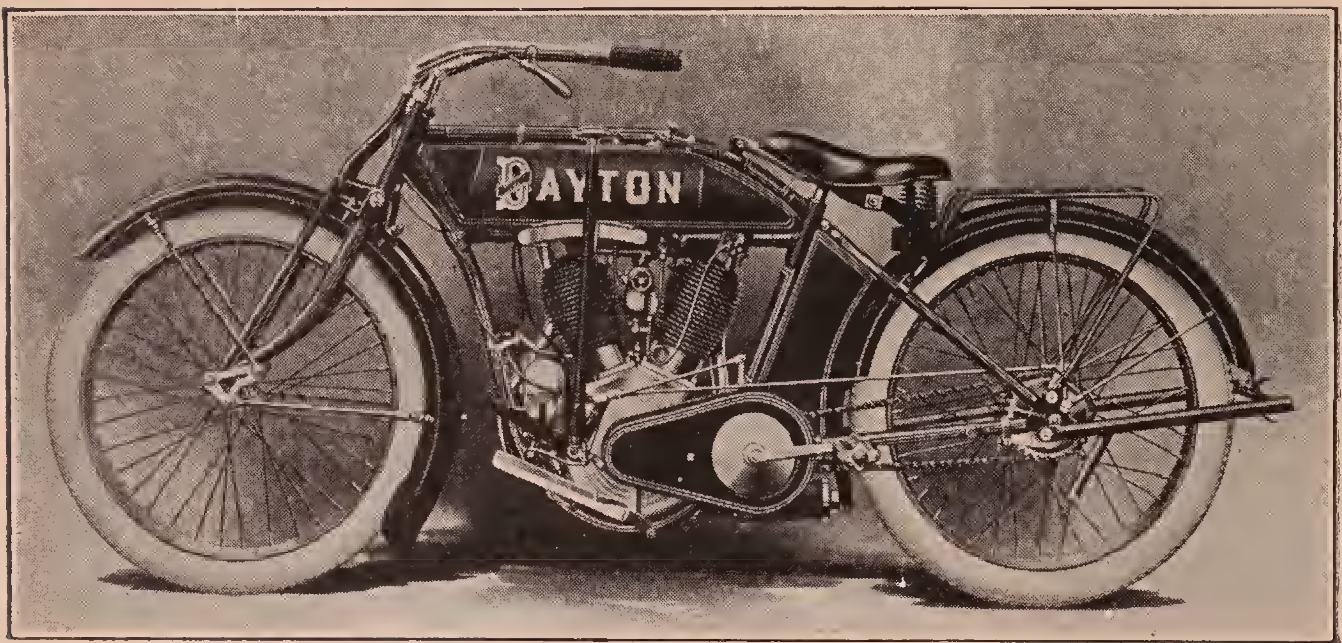


Fig. 4. Dayton Twin-Cylinder Motorcycle
Courtesy of Davis Sewing Machine Company, Dayton, Ohio

the angle of the rear upper forks. The lower forks are pivoted about the pedal shaft, thus springing the whole rear end of the frame on a coil spring, quite unlike the other types using leaf or coiled springs.

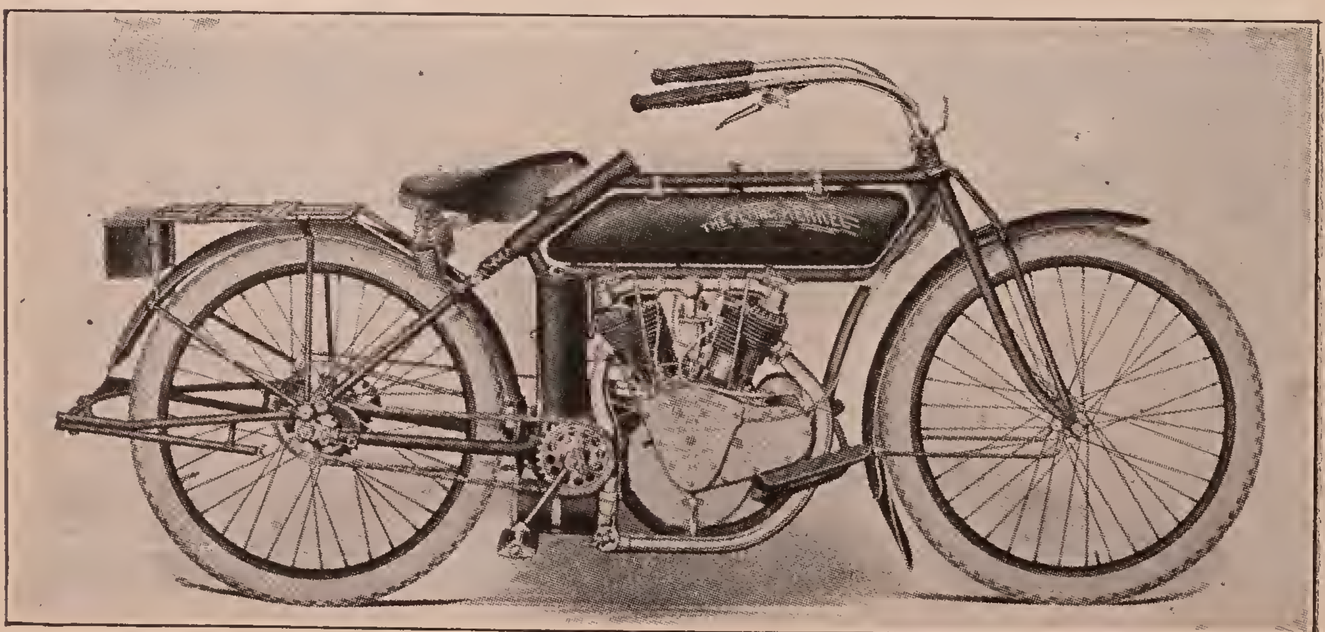


Fig. 5. Flying Merkel Twin-Cylinder Motorcycle
Courtesy of Miami Cycle and Manufacturing Company, Middletown, Ohio

The Merkel is fitted with a 9-horsepower twin motor and chain drive. It is started with a kick starter and may be obtained with a two-speed planetary crankshaft gear. The clutch is of the metal-disk type running in oil.

Pope. All the motorcycles mentioned so far are fitted with L-head V-shaped motors with the inlet valve located over the exhaust and operated by an overhead rocker arm and push rod.

The Pope, illustrated in Fig. 6, departs from this usual practice

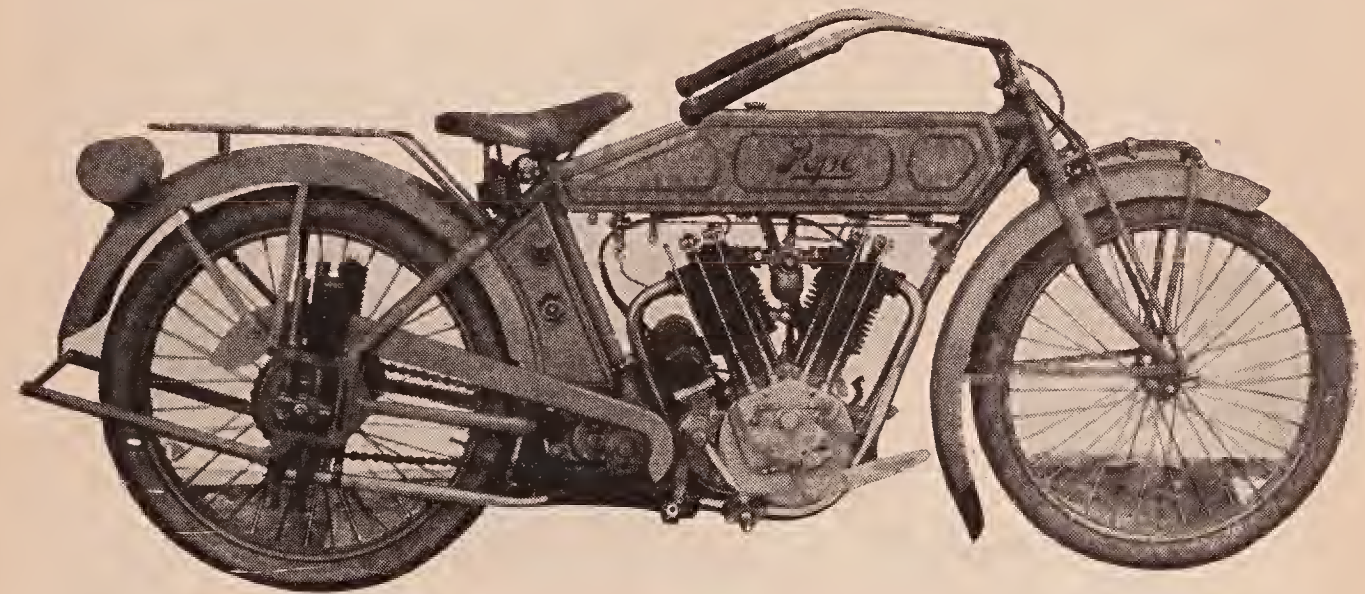


Fig. 6. Pope Twin-Cylinder Motorcycle
Courtesy of Pope Manufacturing Company, Westfield, Massachusetts

by employing an extra-efficient 15-horsepower air-cooled V-type motor with overhead valves. The motorcycle otherwise is standard. The front fork has a leaf spring, while the rear-wheel vibration is

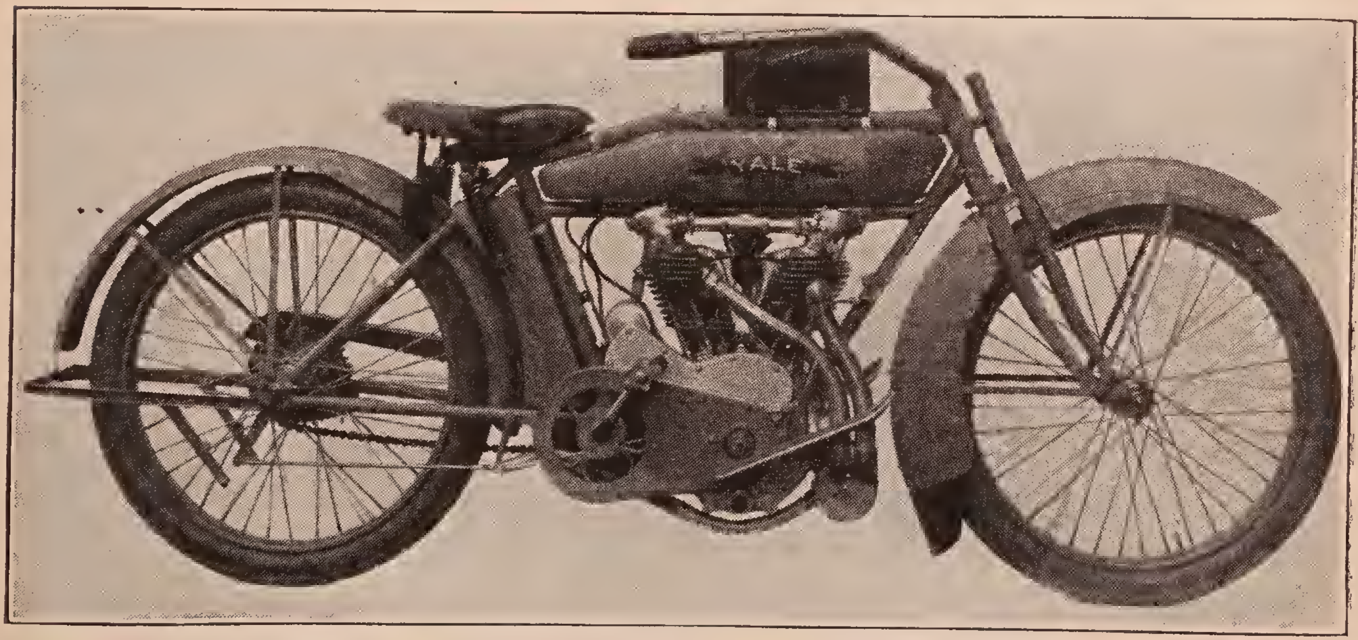


Fig. 7. Yale Twin-Cylinder Motorcycle
Courtesy of Consolidated Manufacturing Company, Toledo, Ohio

absorbed by having the wheel mounted on both sides on plungers which are so connected with coiled springs that they support the whole rear end of the machine. This machine is very fast and is said to be very comfortable.

Yale. The Yale motorcycle, Fig. 7, has as a feature a twin motor with cooling fins on the cylinders cast horizontally, that is, on the line of the air current, with the idea of obtaining a greater amount of cooling. The motor is of the high-speed type, with the valves in the conventional side location. The front fork is of the coil-spring-and-plunger type. The seat is supported on extra springs to add to the rider's comfort. A two-speed gear is provided on the countershaft. Drive from motor to countershaft is by chain, a second chain taking the drive from here to the rear.

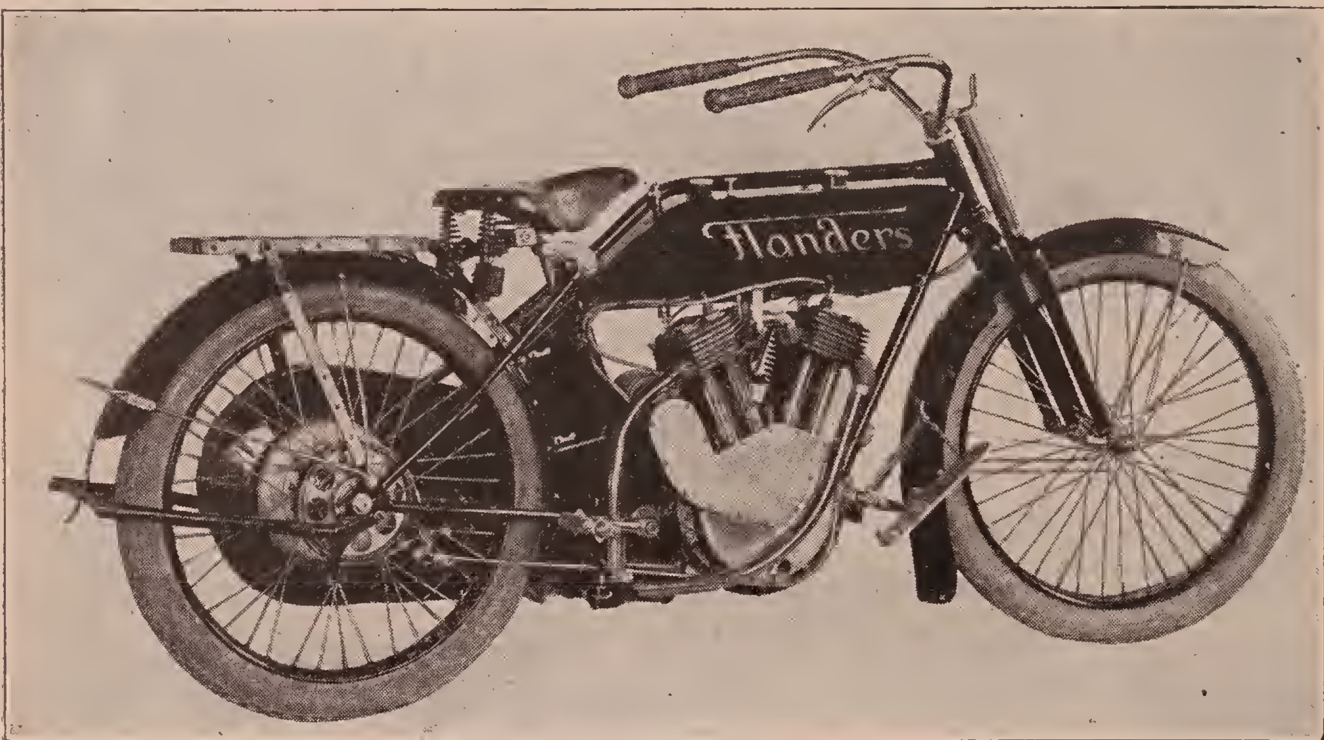


Fig. 8. Flanders Twin Motorcycle
Courtesy of Motor Products Company, Detroit, Michigan

Flanders. The Flanders motorcycle, shown in Fig. 8, is distinguished by its direct drive from the motor to the rear wheel. This is accomplished by the use of a large sprocket at the rear. The driving chain is ordinarily incased in a dustproof covering, and is extra silent. This construction eliminates countershaft troubles and delivers a maximum of power to the rear wheels.

Reading Standard. The Reading Standard motorcycle, Fig. 9, is equipped with three-speed sliding gear, a step starter, and external hand brake. The two-cylinder motor develops 12 h.p.

Shickel. A unique feature of the Shickel motorcycle is the two-stroke, valveless, single-cylinder motor. This has a rating of six horsepower and is a very simple and efficient motor. This motorcycle has an individual feature in the unit tank and frame construction which has proved very satisfactory. A chain drive with one reduction or a direct belt drive, Fig. 10, is provided. This

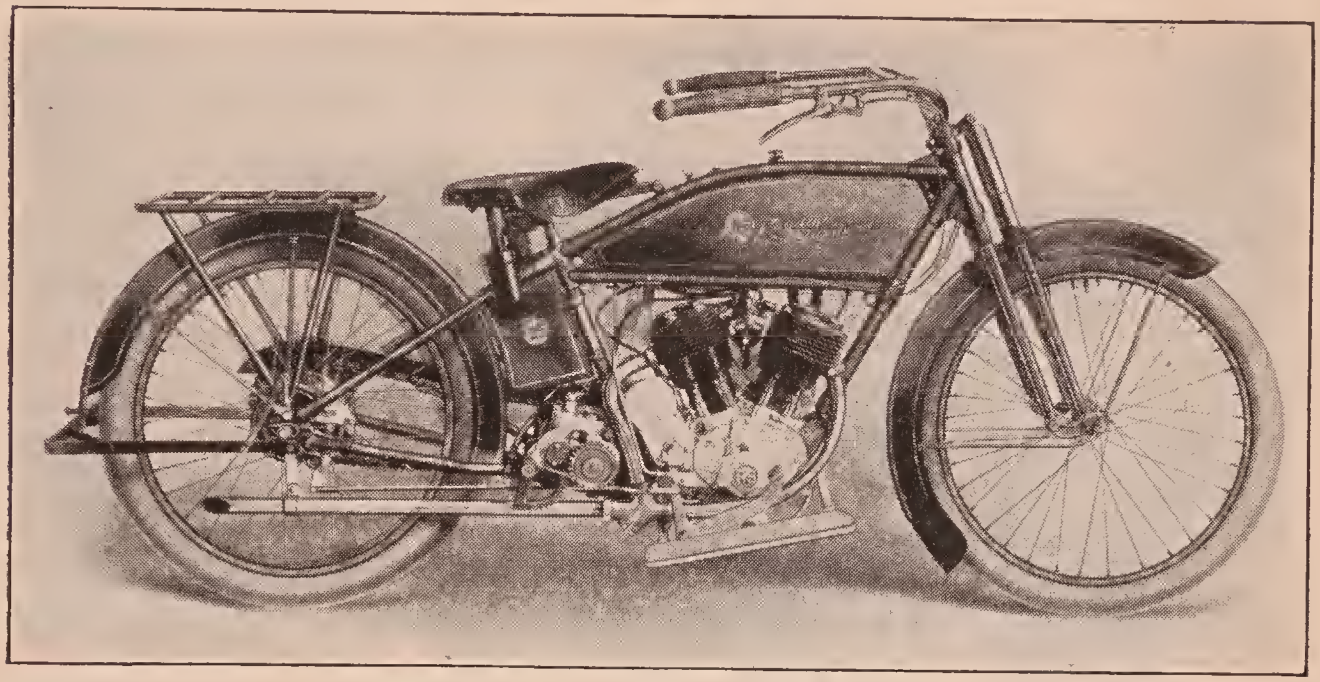


Fig. 9. Reading Standard Two-Cylinder Motorcycle
Courtesy of Reading Standard Company, Reading, Pennsylvania

Company also manufactures a small motorcycle weighing 95 pounds and a motor attachment for a bicycle.

Henderson. The four-cylinder motorcycle is growing in favor in America. One of its chief advantages is its ability to run at

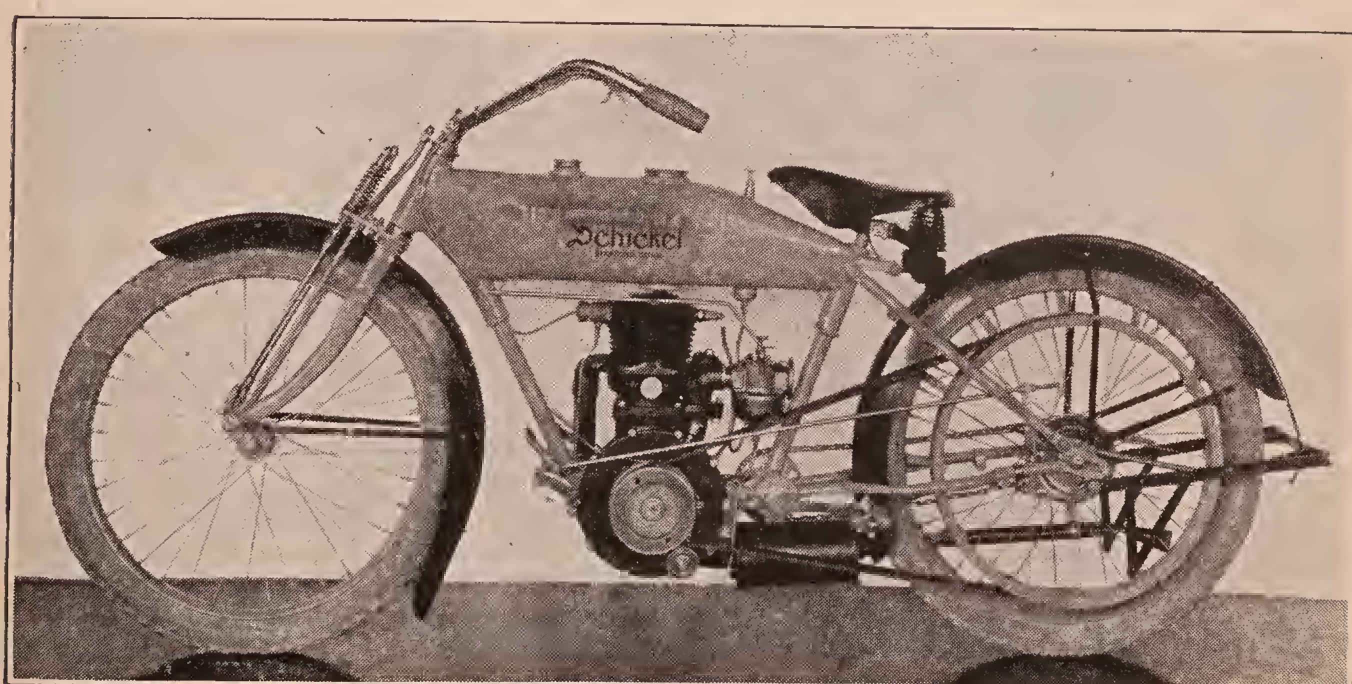


Fig. 10. Schickel Single-Cylinder Motorcycle with Valveless Two-Stroke Motor
Courtesy of The Schickel Motor Company, Stamford, Connecticut

exceptionally low speeds when the traffic is heavy and to accelerate with wonderful rapidity. An example of this type, the Henderson, is shown in Fig. 11. Its construction is especially compact and follows automobile practice largely. It is very low-hung, silent in operation, flexible, and fast. The motor is mounted directly under the driver's seat, leaving space up forward for a large, comfortable foot-board and easy-acting control pedals. The motor is started by a crank fitted at the side of the machine. A contracting-band brake at the rear is operated from one of the foot pedals. A two-speed planetary gearset is obtainable on this machine for an extra charge. The front fork is of the plunger and coil-spring type, but there is no special springing feature at the rear.

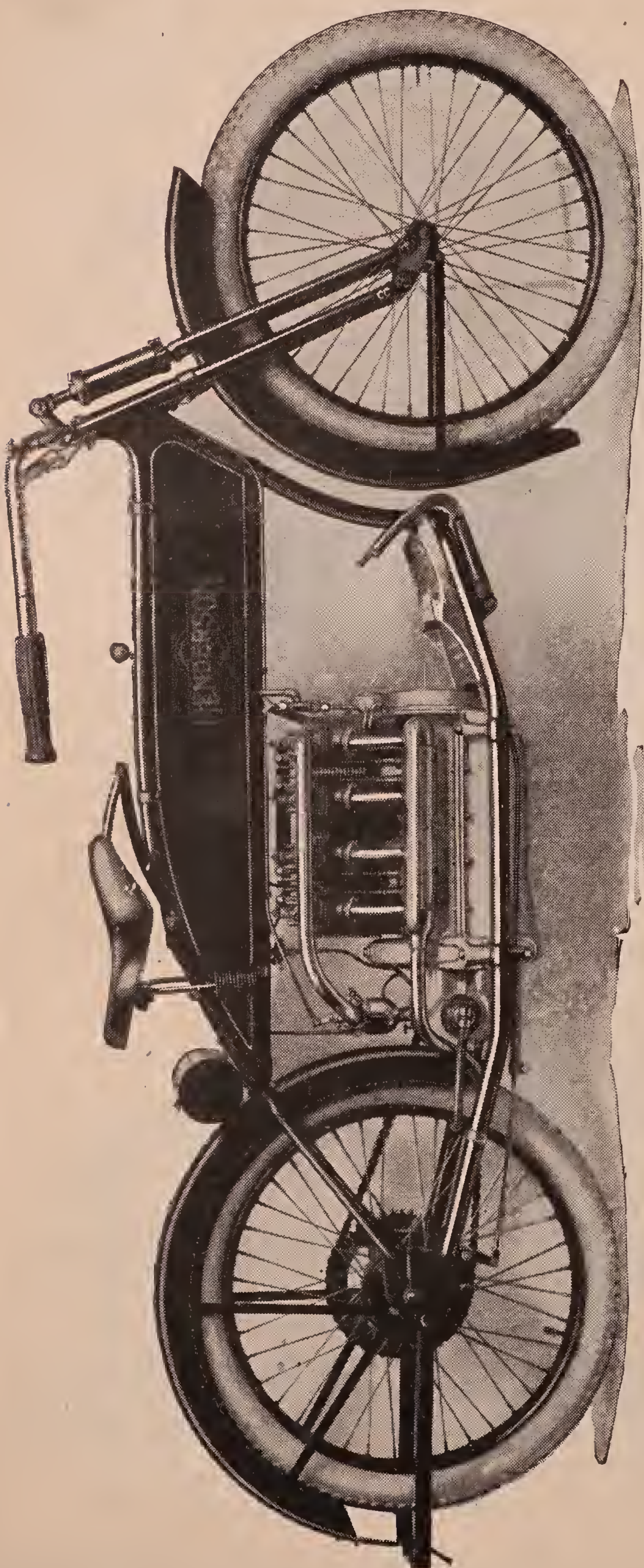


Fig. 11. Henderson Four-Cylinder Motorcycle
Courtesy of Henderson Motorcycle Company, Detroit, Michigan

CONSTRUCTION DETAILS

Spring and Frame Construction. *Seat-Post Springs.* The springs used on a motorcycle to absorb the road shocks or add to the comfort of the rider are usually located on the front forks, in the rear frame, or in the seat post. One of the first firms to adopt a spring seat post was the Harley-Davidson, but the Merkel had used a spring-frame construction some time previous. The more prominent of the modern spring constructions are illustrated below.

The *Merkel* spring-frame construction is shown in Fig. 12, a coil spring being fitted under the saddle and forming a continuation of the upper forks. In action the lower forks are pivoted about the crankshaft of the motor below, this acting as a radius for the rear axle. The upper forks support the entire weight of the motorcycle on the coil spring.

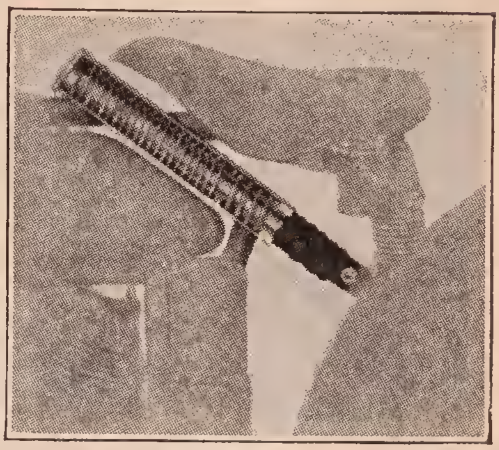


Fig. 12. Flying Merkel Spring Seat Post

The *Harley-Davidson* and the *Dayton* systems, which are very similar, are illustrated in Figs. 13 and 14. In this construction the vertical tube of the frame contains a plunger operated from a fixed center with a coil spring on either side. The saddle fastens to a radius rod at the top of this plunger, the front end of this radius rod being bolted to a clutch on the frame. The entire weight of the rider is supported through the saddle on the coil spring below, allowing a very easy-riding action.

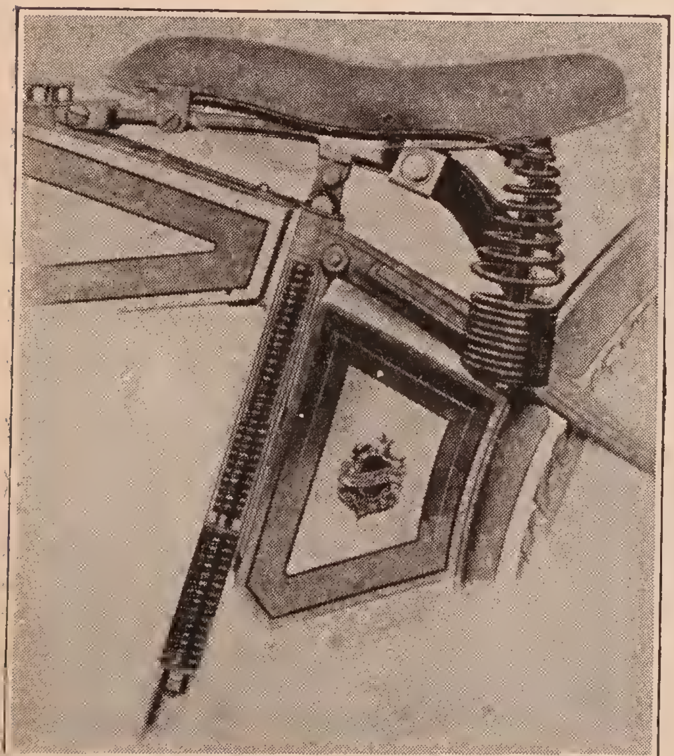


Fig. 13. Harley-Davidson Spring Seat Post

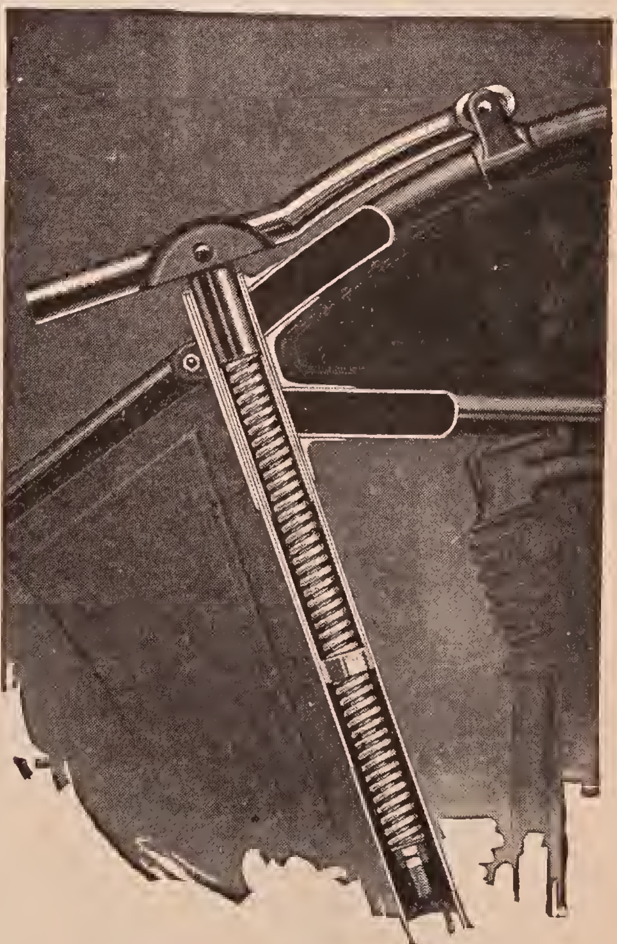


Fig. 14. Dayton Spring Seat Post

Rear and Front Frame Springs. The Pope uses a leaf-spring front fork and a spring type of rear suspension, Fig. 15. The latter consists of a drop-forged bracket on each side brazed to the rear end of the frame with a tension spring fastened to the top surface of the bracket. Double guide rods, as shown in the figure, are used on the model illustrated in Fig. 6, these rods carrying an axle yoke which is free to move between the jaws of the bracket, thus allowing the spring to absorb the rear vibration. Fig. 16 illustrates the *Indian* cradle-spring frame at the rear. This construction has the lower forks pivoted, as on the Merkel, but the weight of machine and rider is supported on the two leaf springs, as shown. The details of the front-fork leaf springs of the Indian are shown in Fig. 17.

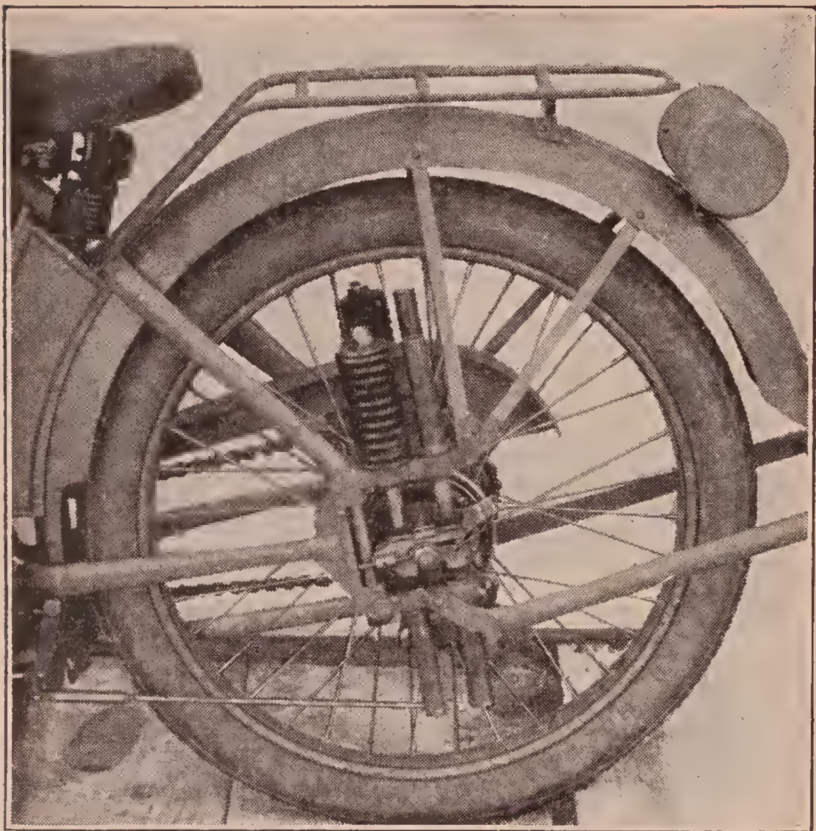


Fig. 15. Pope Rear Frame Spring Arrangement

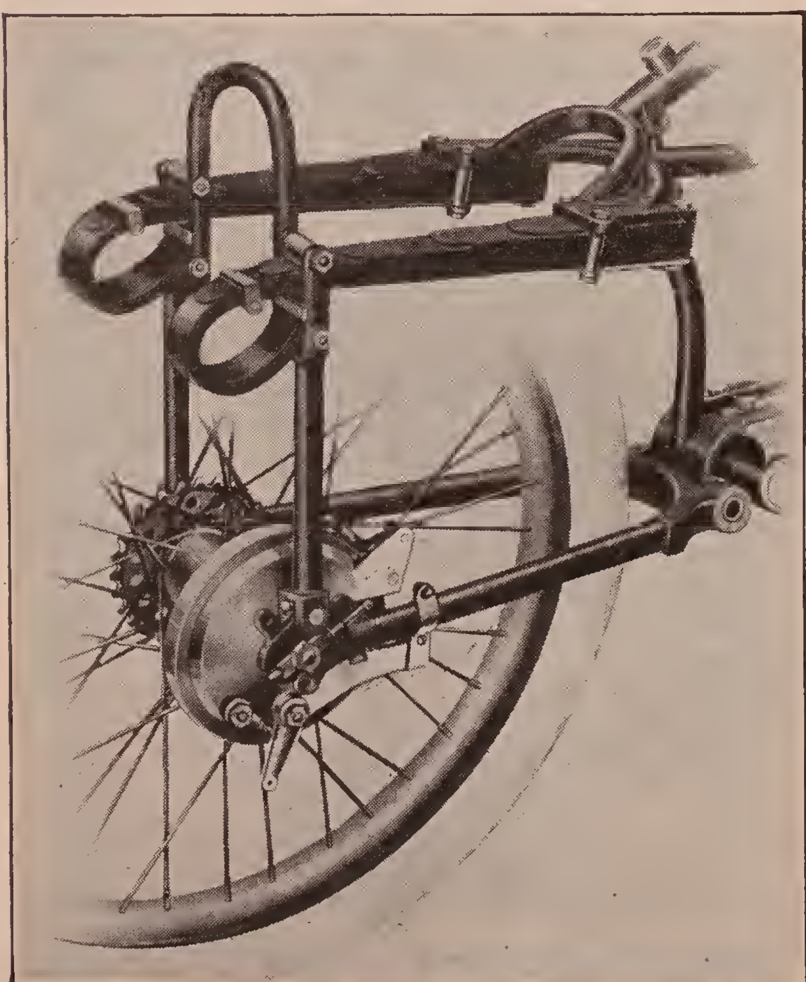


Fig. 16. Indian Rear Cradle-Spring Frame

Types of Frames. There are two types of frames ordinarily used in motorcycle construction. The one is formed with a loop, as shown in Fig. 18, the motor fastening to lugs on either side of the loop. This construction makes the machine very easy to assemble and the frame is equally strong whether the motor is in or out of the frame. The other construction is similar to this, except that the loop

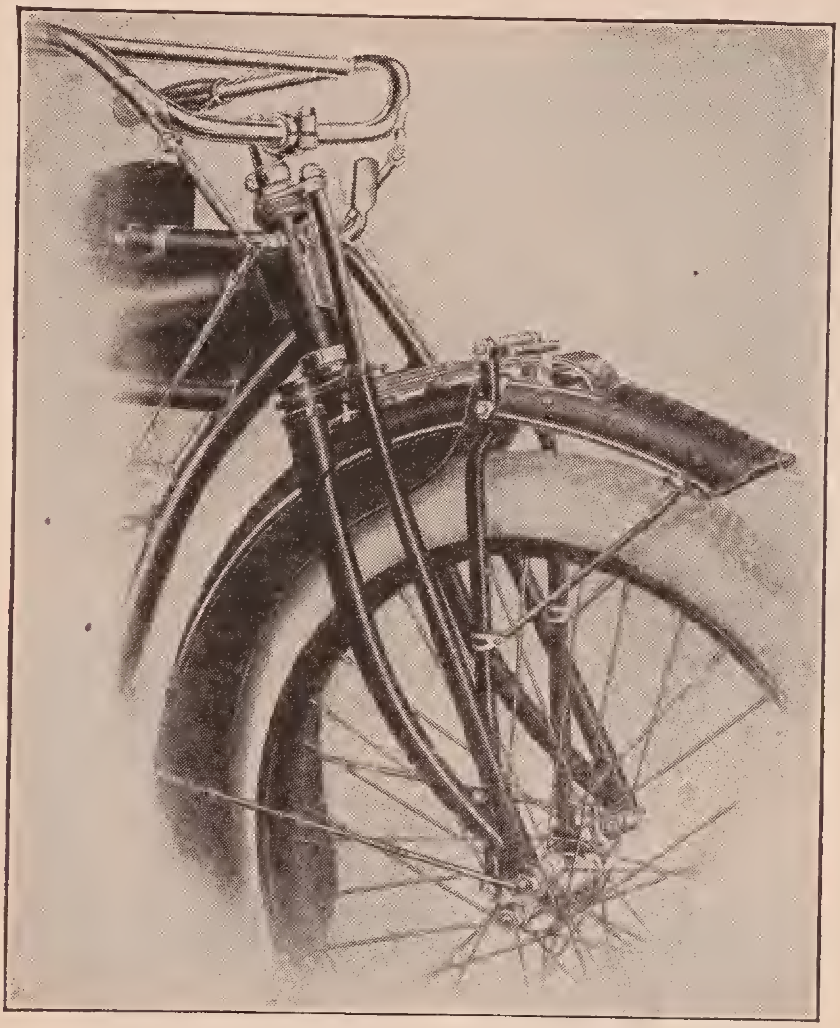


Fig. 17. Indian Front-Leaf Spring

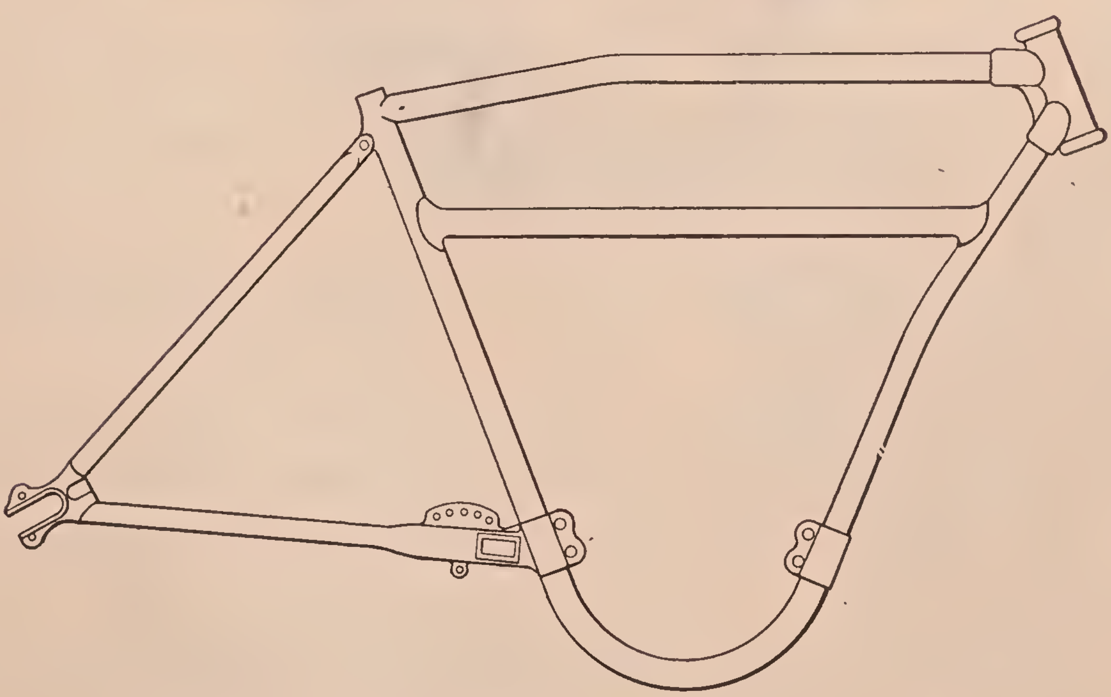


Fig. 18. Loop Frame Showing Lugs for Motor Attachment

below is eliminated, as shown very noticeably in Fig. 7. The lugs fasten directly to the crankcase of the motor, which thus becomes the lower member of the frame.

Motors. Motors for motorcycle use are usually of the four-cycle air-cooled variety. These, as previously described, are now built with one, two, and four cylinders. Water-cooling has been tried abroad on motorcycles with considerable success, but so far has not been applied in America.

Single-Cylinder Type. A single-cylinder type of motor is illustrated in Fig. 19. This is an **L**-head motor with exhaust valve below and the inlet valve above, operated by a long push rod. The car-

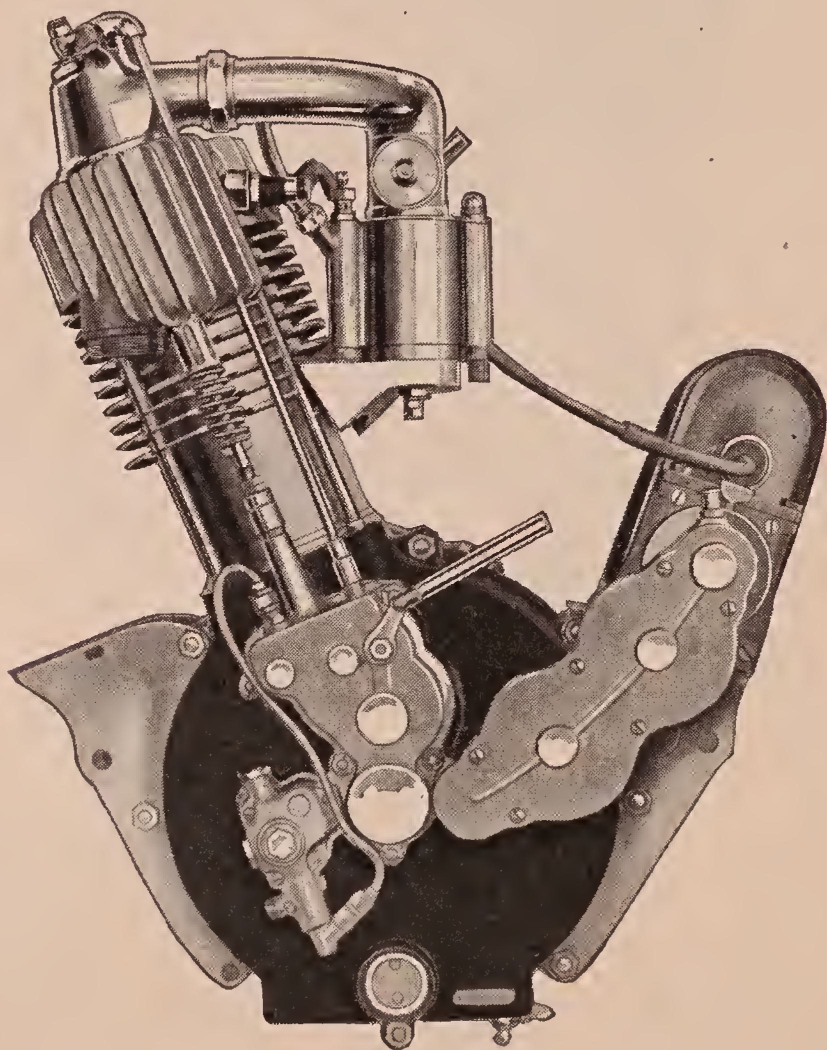


Fig. 19. Single-Cylinder Motor with Mechanical Oiler Shown at Side of Crankcase
Hendee Manufacturing Company, Springfield, Massachusetts

bureter is shown above connected by a pipe to the inlet manifold. The magneto, connected to the motor by a train of gears, is shown at the right. This illustration is of an early type of motor used on the Indian motorcycle.

Two-Cylinder Type. Most motors on the machines of today are of the two-cylinder V-type, a typical example being the Harley-Davidson, shown in Fig. 20. The magneto will be noted on the left, and the carbureter at the top between the cylinders. The cylinders are arranged in a V-shape with their center lines meeting at the center of the crank. Both connecting rods act on one crankpin. The exhaust valves are inclosed in the large tubes to be noted at the side of each cylinder.

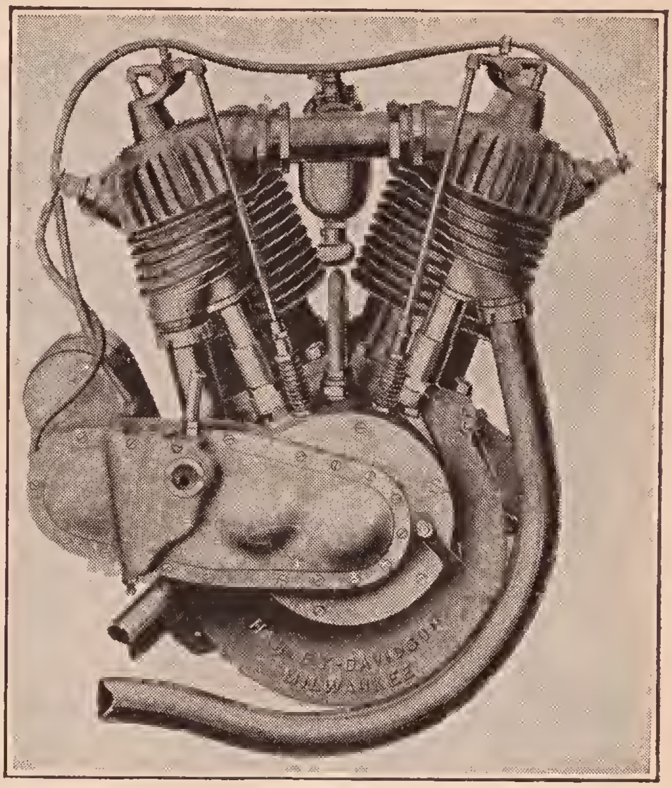


Fig. 20. Harley-Davidson Twin-Cylinder Motor

The overhead inlet valves are operated by long push rods attached to rocker arms on top of each cylinder. The long curved pipe at the right is the exhaust pipe, leading from the forward cylinder. A pipe leads from the rear cylinder, these two pipes remaining separate until they reach the muffler. Other motors of the conventional V-type may be noticed on the cuts of the different motorcycles already illustrated. A V-motor with overhead valves is used on the Pope motorcycle, as shown in Fig. 21. This type of motor is in outline almost the same as the other ones shown, except that both inlet and exhaust valves are located in the head of the cylinder for extra efficiency, and both are operated by long push rods and overhead rocker arms, as shown. The carbureter is in the usual location.

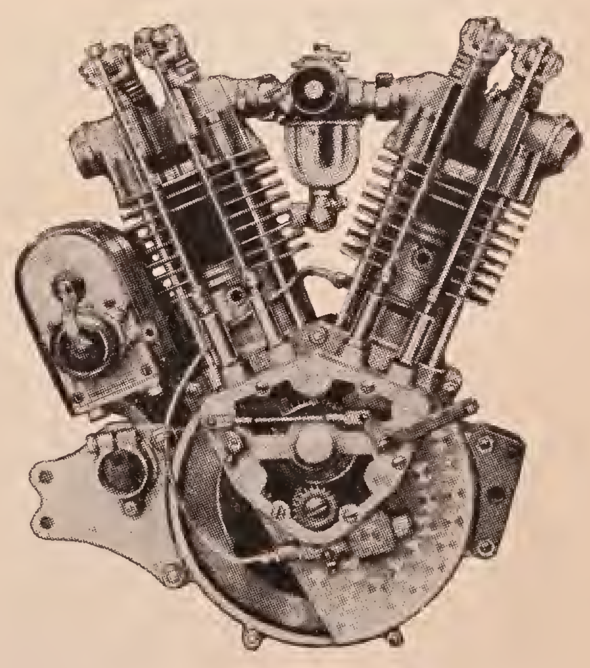


Fig. 21. Pope Twin Motor with Overhead Inlet and Exhaust Valves

Four-Cylinder Type. Figs. 22 and 23 illustrate the Henderson four-cylinder motorcycle. This is also air-cooled and of the L-head type with overhead inlet valve. It is designed for medium-high speed, has a three-bearing four-throw crankshaft, three-ring pistons, an enclosed flywheel, and a bevel-gear reduction. The motor is lubricated by splash from the oil in the base of the crankcase, as will be noted by Fig. 23. This motor is particularly neat, noiseless, and flexible.

European High-Speed Type. Foreigners with their generous experimenting have gone farther in motorcycle design than have our designers in America. The progress, however, has been in the line of experimental work and individual building than in workmanship

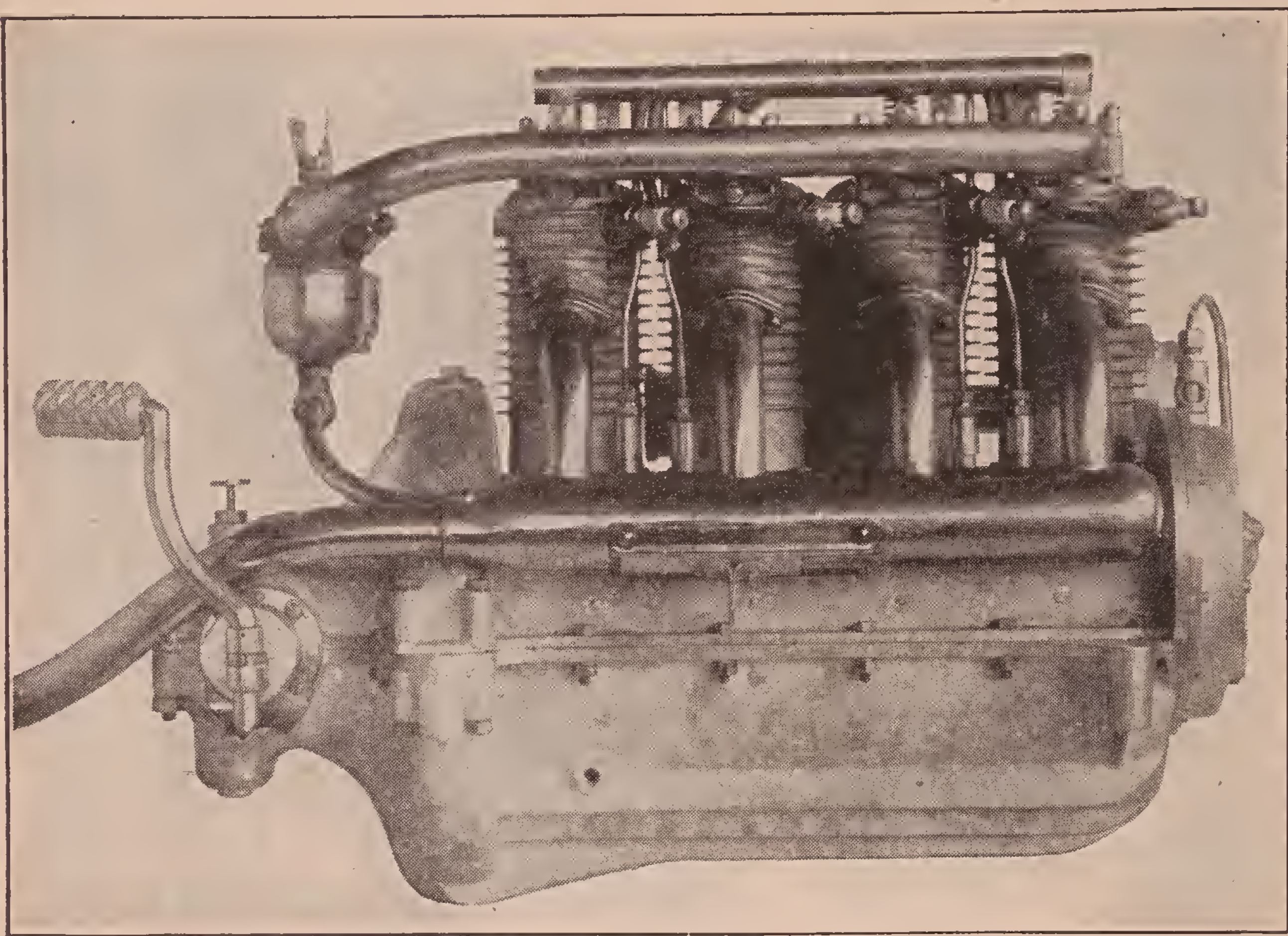


Fig. 22. Side View of Henderson Four-Cylinder Motor

or in accuracy of production, the latter being the American's strong specialization. America, in spite of its heavy road conditions, is not experimenting with water-cooled motors for motorcycles, though

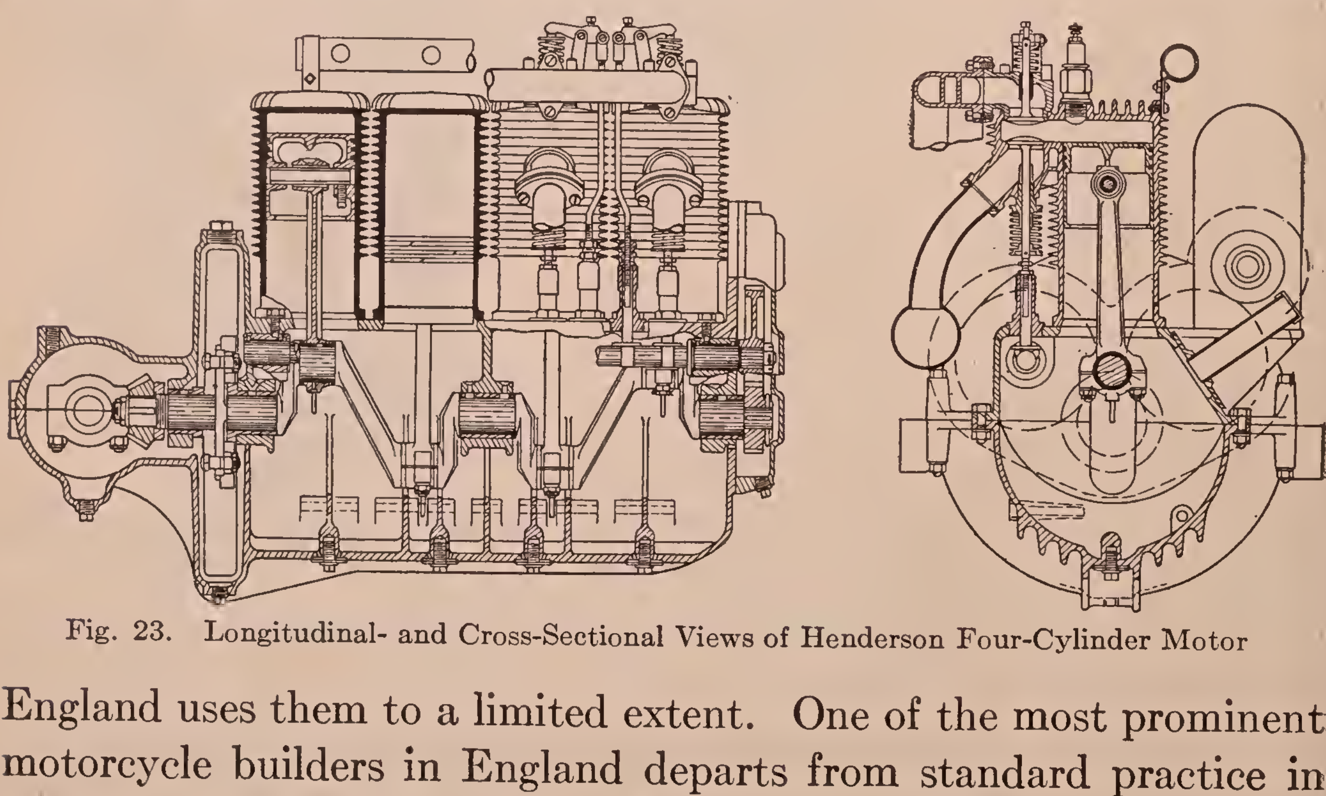


Fig. 23. Longitudinal- and Cross-Sectional Views of Henderson Four-Cylinder Motor

England uses them to a limited extent. One of the most prominent motorcycle builders in England departs from standard practice in adopting both water-cooled and two-cycle principles. Consistent performance as a result of these innovations, coupled with good workmanship, has given this machine great prominence.

Europe's greatest advantage, however, in motorcycle construction has been exemplified by the development of the high-speed motorcycle motor. This is ordinarily of the horizontal-opposed type, the most prominent high-speed low-weight construction being the Douglas, a British machine. This motor is able to maintain this high speed through a crankshaft balance which is practically perfect, allowing it to run at the abnormally high speed of 4000 r.p.m. for long periods without fatigue of material, and hence with great efficiency. The motor is of the L-head type with air-cooled cylinders and an outside flywheel. The cylinders being placed opposite each other, the counterbalanced cranks are set 180 degrees apart. The entire motorcycle is said to weigh under 200 pounds and attains speeds well above a mile a minute.

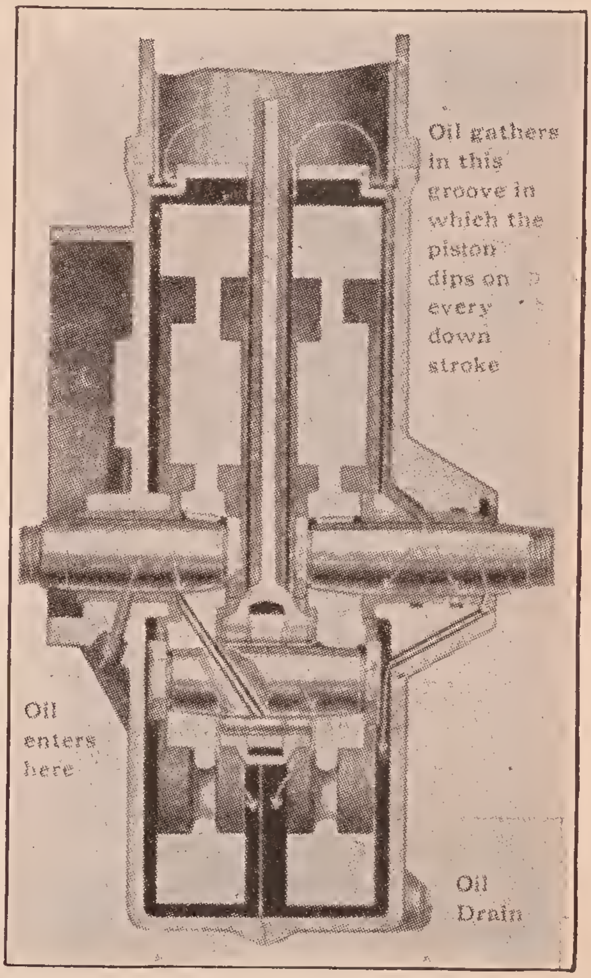


Fig. 24. Excelsior Lubricating Systems

As the high-speed motor is attaining prominence in the automobile world it is very probable that the foreign type of motor will be seen in America within a short time.

Lubrication. *Path of Oil.* A lubricating system as used on the Excelsior motorcycle motor is shown in Fig. 24, and gives the particularly neat method by which motors of this type are oiled. In this case, the oil is first fed to the main bearing on the cam case side, as shown by the arrow. This oil is fed by pressure from a pump and, after covering this bearing, is forced out at the end and flows through the drill hole shown, this bringing it out above by centrifugal force to the connecting-rod bearing. This bearing throws the excess oil out, splashing it in all directions and up through the slot through which the connecting rod runs. From here it runs out on either side and gathers in a groove at the bottom edge of the cylinder. The bottom of the piston drops into this trough of oil every time it comes down, thus carrying the even film with it up the walls of the cylinder. Excess from here flows down the side of the crankcase and feeds the right-hand bearing. Excess from here is caught on the outer end of the shaft and returned to the crankcase, where it is splashed up again into the motor for further use.

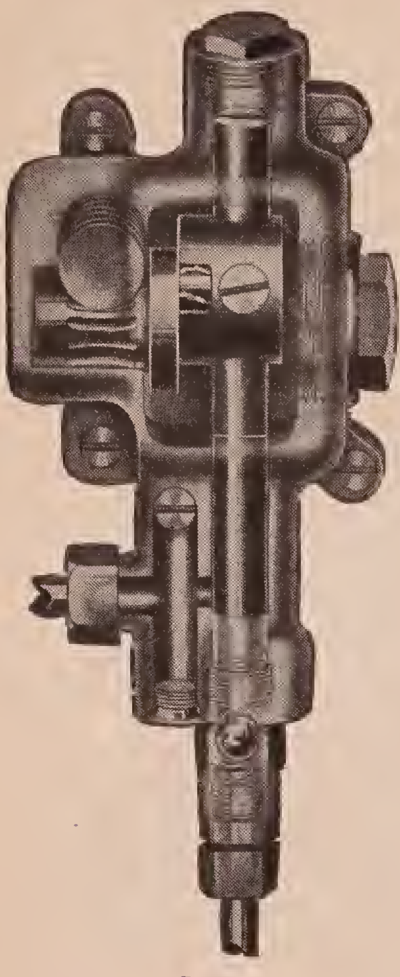


Fig. 25. Excelsior Oil Pump

In a V-type twin-cylinder motor where the oil trough at the bottom of the cylinder cannot catch an even amount on account of the cylinder angularity, the oil is generally allowed to drain back at once on the rear cylinder, and instead of feeding oil to one of the main bearings first, this oil is fed to the forward cylinder by the pump.

Oil Pumps. Fig. 25 shows a type of oil pump which is used to feed the oil to the motor. By this construction a small worm drive from the cam case or magneto gear case turns a small crank which operates a vertical plunger. This plunger cylinder is so arranged that on the top of the stroke oil may flow into the cylinder space, a ball check valve holding the oil from being sucked into the cylinder. On the down stroke, the oil inlet is covered by the piston and the ball check valve opens to allow the plunger to force the cylinderful of oil out of the motor.

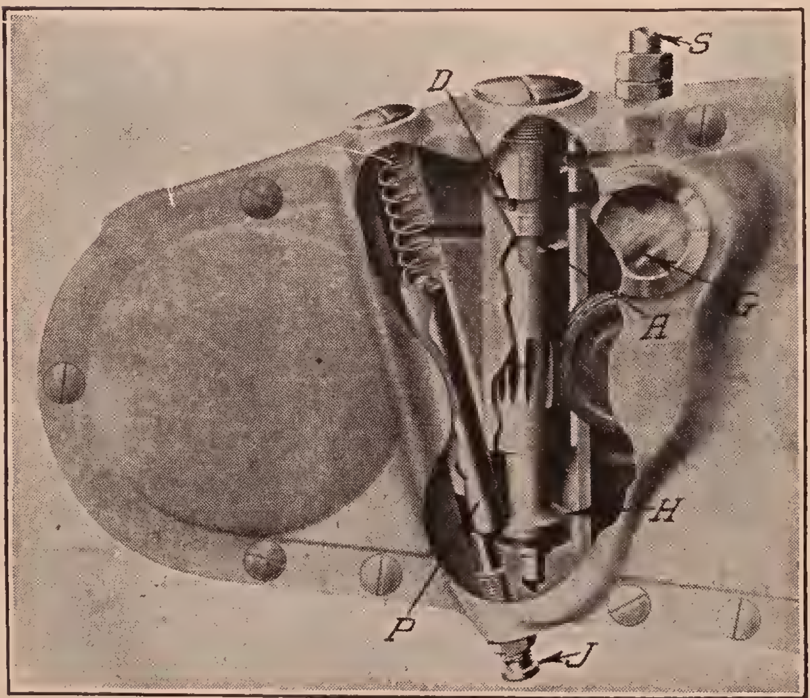


Fig. 26. Harley-Davidson Roller-Cam Pump

Fig. 26 illustrates a special type of pump, in which the plunger *P* is operated by a peculiar-shaped roller cam *H*. The shaft of this roller cam contains the elements of a rotary valve, with openings at A and D, so that the oil is fed positively through a sight feed G on its way to the motor. There are no ball check valves in this construction and a screw J enables one to adjust the amount of oil delivered to the motor within very narrow limits. The intake oil pipe is shown at S. The oil is fed to the motor through the opening G. Since oiling is so important a part of the high-speed motor operation the development of this device has made a change in the reliability of the modern motorcycle.

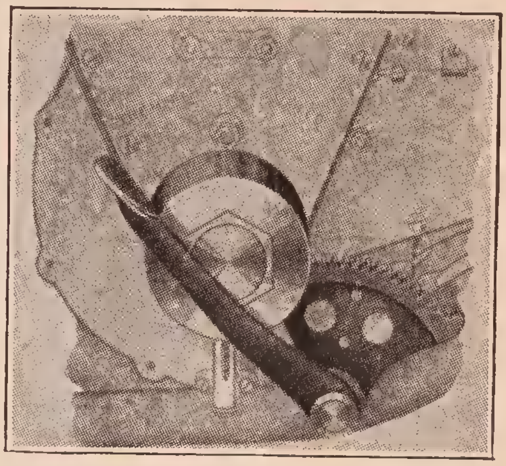


Fig. 27. Flying Merkel Kick Starter

Ignition. The ignition of the modern motorcycle is invariably by magneto, so that no description is necessary other than is given under magneto theory and construction in the section on Electrical Equipment.

Starting. It is hardly probable that the complication of electric starting will be adopted widely for motorcycle use, as it is generally

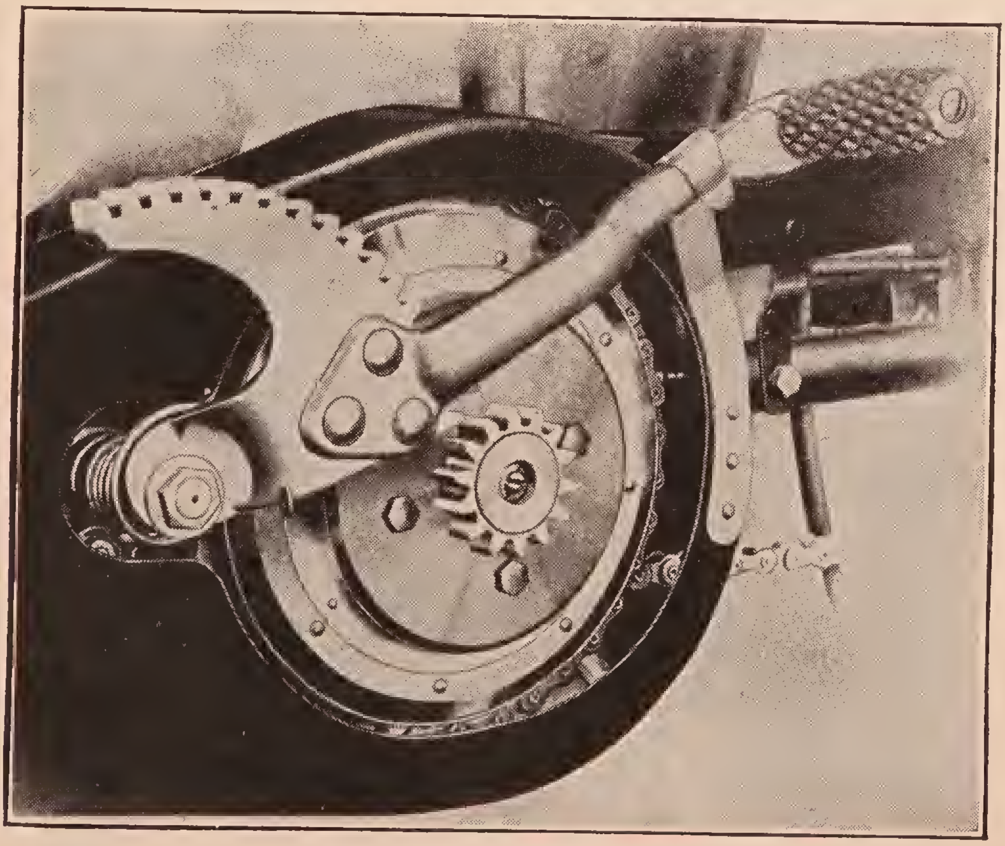


Fig. 28. Indian Kick Starter
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

more trouble to operate a power starter and keep it in repair than to use the simple form of kick starter which has become so popular and which now is fitted to almost all American machines.

Figures 27 and 28 show forms of starters in use on the Merkel and Indian motorcycles, respectively. The main shaft on one side or the other is fitted with a small gear pinion, which is fastened to the shaft on a ratchet or over-running clutch. Off to one side is pivoted a gear quadrant fastened to a pedal, which is often of the folding type. Pushing down on this pedal with the foot meshes the pinion with the quadrant and a quick thrust or kick of a quarter-turn will then turn the motor over several times at fair

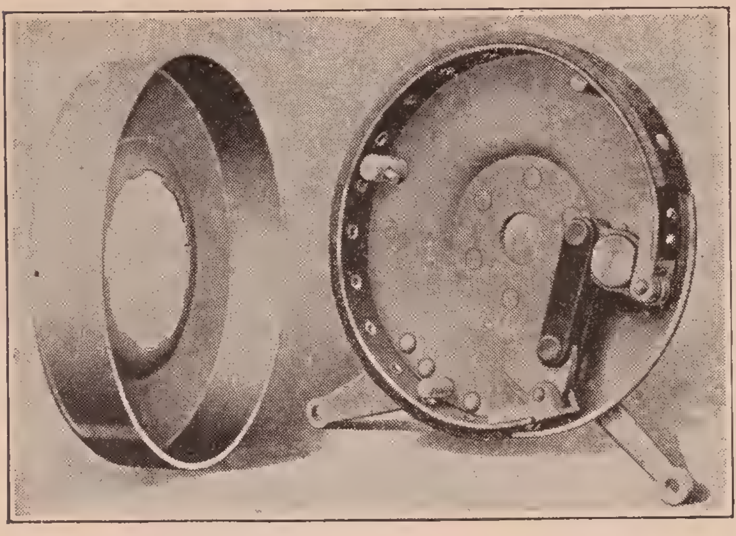


Fig. 29. Typical Expanding-Band Brake
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

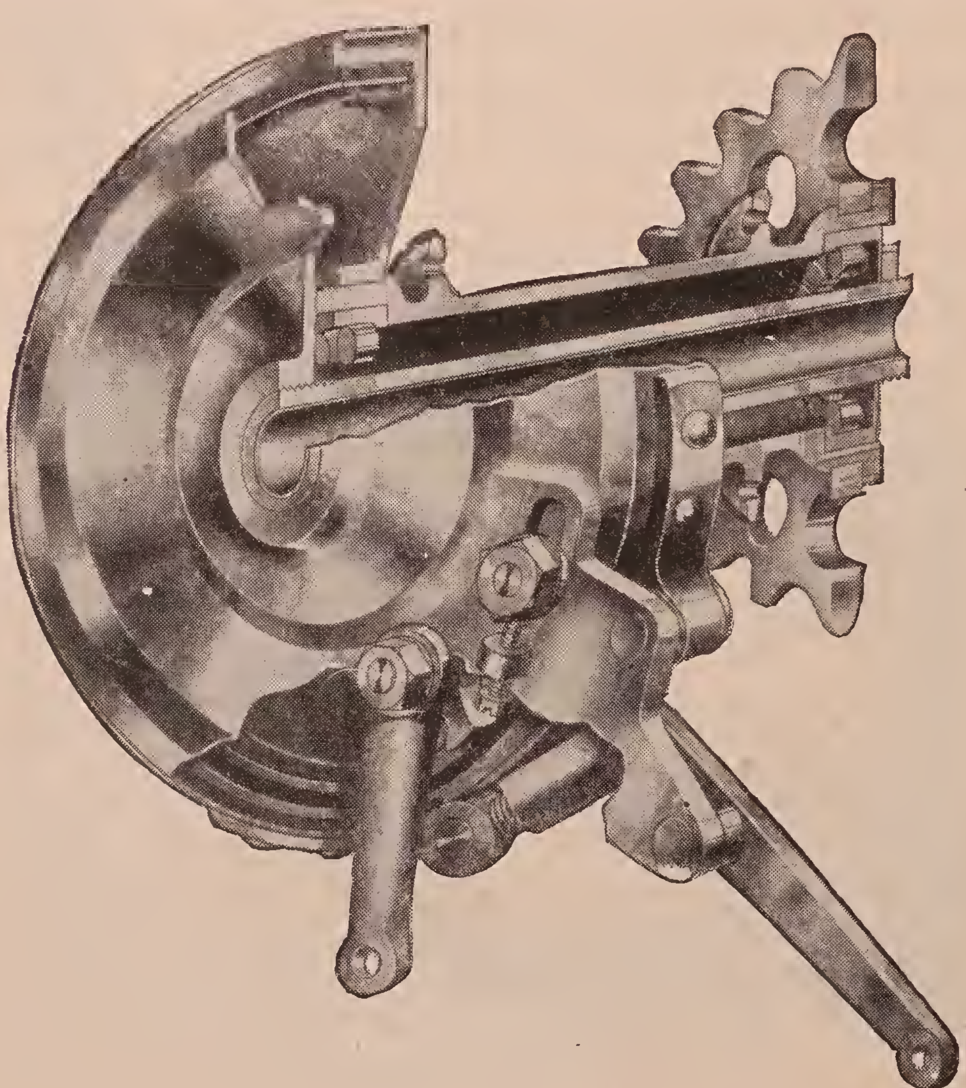


Fig. 30. Typical Double-Acting Band Brake
Courtesy of Excelsior Motor Manufacturing and Supply Company, Chicago

speed. When the motor starts, the small pinion is released and a strong pull brings the quadrant back to its former position out of mesh with its pinion. The pedal is generally fastened in this upward position by means of a clip so that it cannot rattle.

Brakes. A number of types of brake construction are used on motorcycles but they are mostly of the expanding- or contracting-band variety. Fig. 29 shows the construction of an expanding-band brake. The band, shown at *B*, is of springy material and covered with a brake-lining material *F*. This shoe or ring fits inside the brake drum *D*, which is keyed to the rear wheel hub. Operation of the lever *L* pushes the ends of the band *B* apart so that it expands forcibly against the interior of the drum *D*.

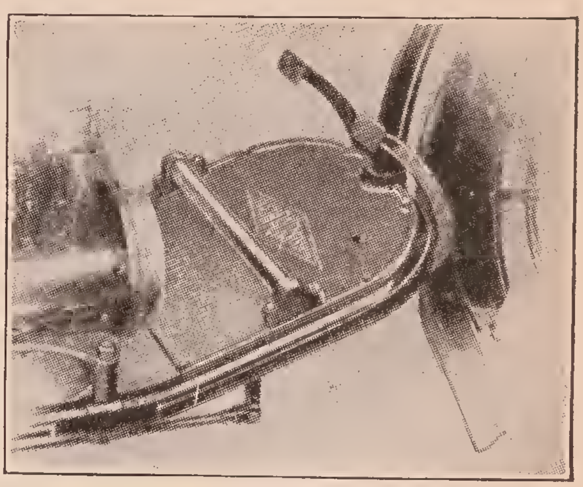


Fig. 31. Henderson Foot Rest and Brake Pedals

A similar band may be fitted outside the drum, but in this case the fabric will be on the inside of the band, and the lever will pull the band tight on the outside of the drum. This is known as the contracting-band brake. Fig. 30 shows the brake used on the Excelsior motorcycle combining both types, the expanding and contracting bands being shown in section with their linings in place. The operation is by two levers shown in the lower part of the illustration.

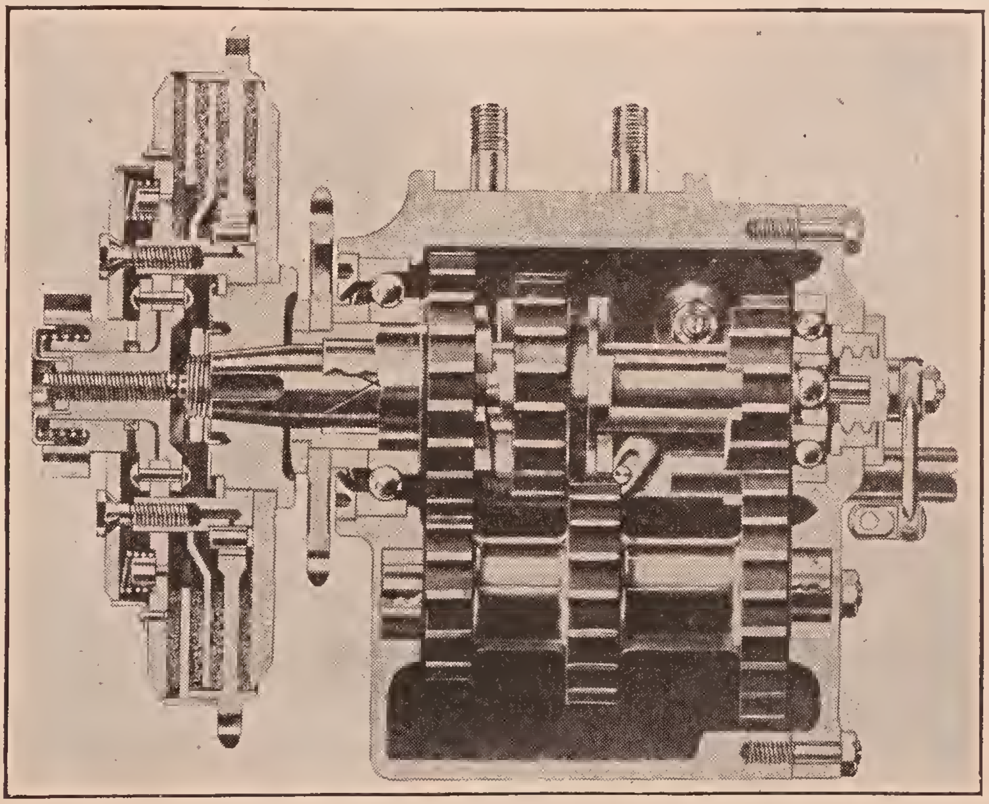


Fig. 32. Indian Multiple-Disk Clutch and 3-Speed Gearset

Fig. 31 illustrates the pedals fitted to the Henderson motorcycle, and operating the brakes of this complete little machine.

Drive. *Belt Drive.* The simplest form of motorcycle transmission, and one which until recently was commonly used, consists of a belt running over two V-shaped, or flat-faced pulleys, as shown in Fig. 10. One pulley is attached to the crankshaft of the motor, and the other to the hub of the rear wheel. With the increasing power of modern motors a successful belt drive is becoming almost impossible from the limitation in pulley sizes possible with motorcycle construction.

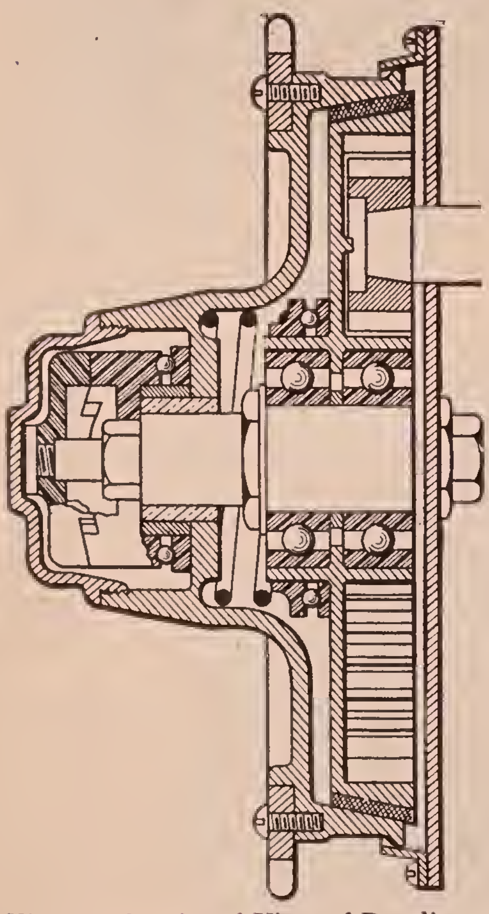


Fig. 33. Sectional View of Reading-Standard Cone Clutch

Shaft Drive. The Pierce Company of Buffalo built a number of shaft-driven motorcycles a few years ago, but at present none of this type are being manufactured in this country. With a four-cylinder motor, shaft drive is very practicable and probably will be revived as four-cylinder machines become more popular.

Chains. The highest degree of efficiency is obtained with a single chain running over sprockets on the crankshaft of the motor and on the hub of the rear wheel, as on a bicycle. Such a transmission is found on the Flanders twin-cylinder machine, Fig. 8, and has proved very successful. In this particular instance a chain case is used to avoid dust and to hold an oil supply.

Clutches. Several kinds of clutches are used on motorcycles, the one most used being of the multiple-dry-disk type, as shown at the left end of Fig. 32. This consists of a number of thin metallic disks faced with fabric brake-lining material and keyed alternately to the center shaft and the containing drum. When springs are allowed to thrust these plates tightly together the amount of friction generated makes a reliable drive between the drum and the central shaft. Suitable mechanism is arranged so that, when it is desired to disengage the clutch, a lever or pedal can release this spring pressure and allow the disks to run free without friction between them.

Metal-to-metal clutches consist of a set of metal disks brought into or out of contact by means of a lever. These are generally run in oil to prevent their heating. When the spring pressure is applied

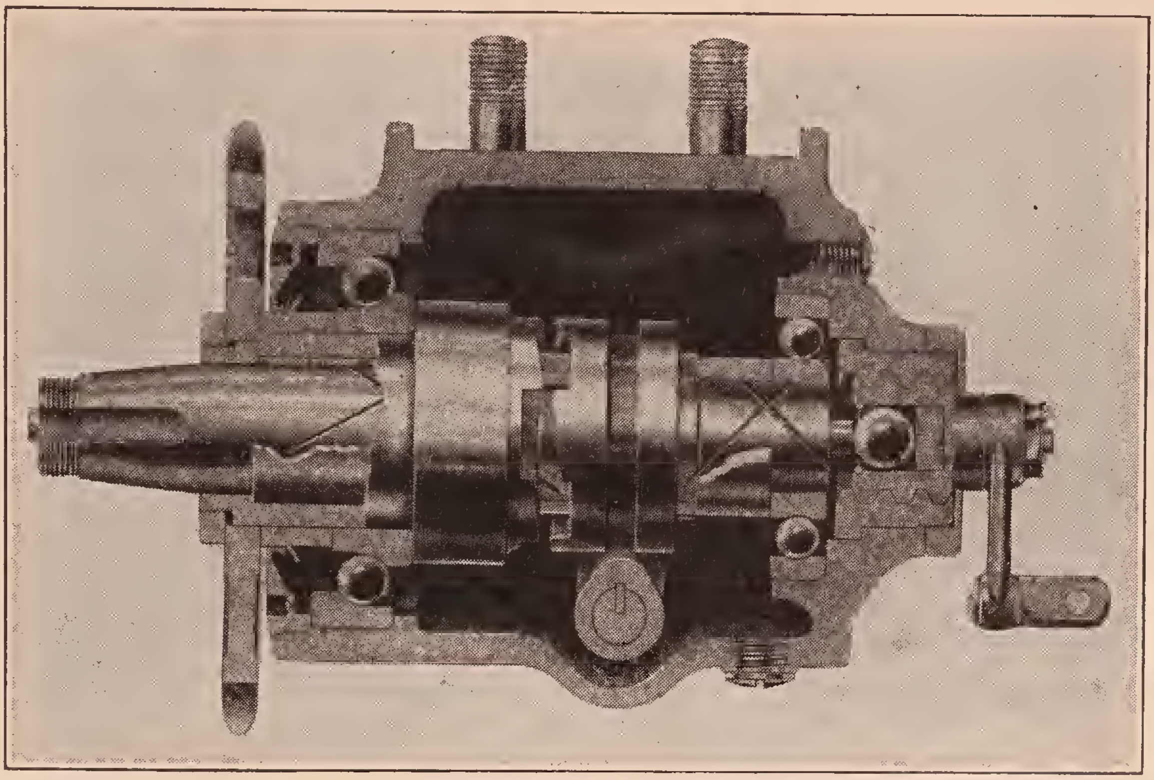


Fig. 34. Indian Neutral Countershaft
Courtesy of Hendee Manufacturing Company, Springfield, Massachusetts

it takes a number of revolutions to drive out the oil from between the plates and thus prevents a grabbing clutch.

The Reading-Standard motorcycle, instead of employing a countershaft back of the motor, fits an internal-gear countershaft to the side of the crankcase and drives from this to the main-drive sprocket by means of an ordinary automobile-type cone clutch.

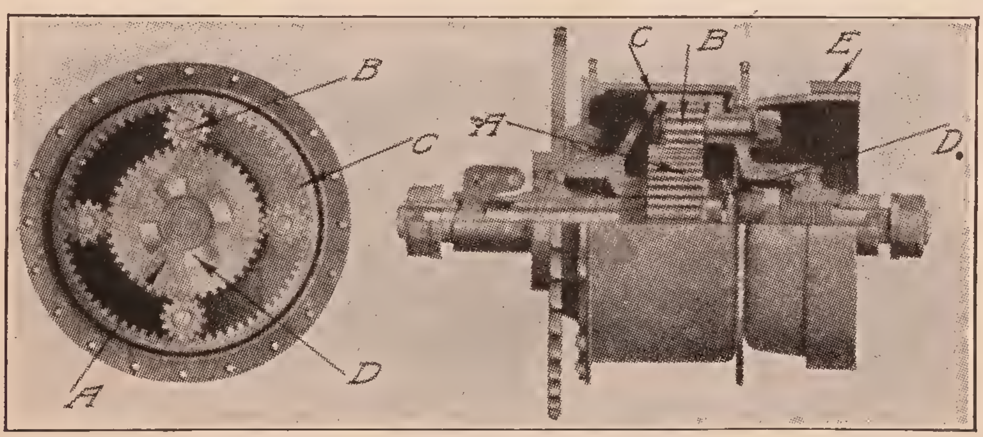


Fig. 35. Henderson Planetary Transmission

This is shown in Fig. 33. A cone on this clutch is faced with leather and operates exactly like an automobile clutch.

Gearsets or Change=Speed Mechanisms. Modern motorcycles are almost invariably fitted with change-speed gears which might be classed as one, two, and three-speed types.

One-Speed. The one-speed gear—if it can be so called—is merely a dog clutch arrangement, Fig. 34, used to disconnect the motor from the rear wheels when the clutch is in engagement. The central part is a ring which can be moved from right to left in order to fit the notches in its face into those on an adjacent ring connected to the driving sprocket. The sliding of this member is accomplished by means of the small lever.

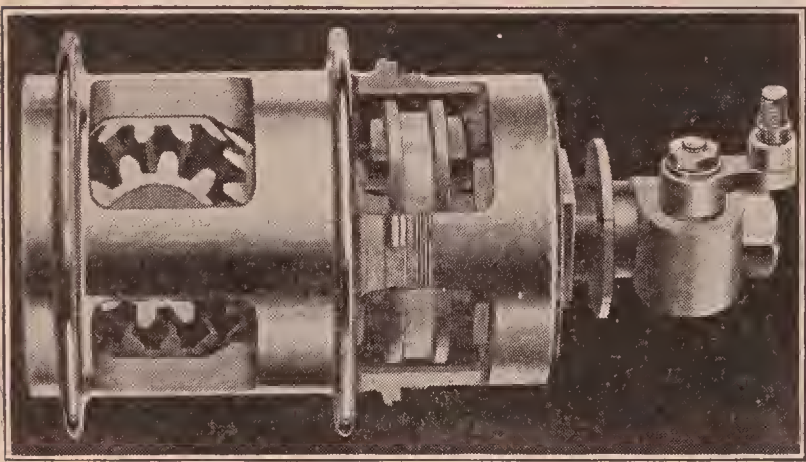


Fig. 36. Harley-Davidson Two-Speed Gearset

Two-Speed Planetary. The two-speed gear is the most common one in use for motorcycles and may be found in two varieties, planetary—or epicyclic—and sliding. The principle of the epicyclic type is explained in Fig. 35, which is a cut of the two-speed gearset used on the Henderson four-cylinder motorcycle.

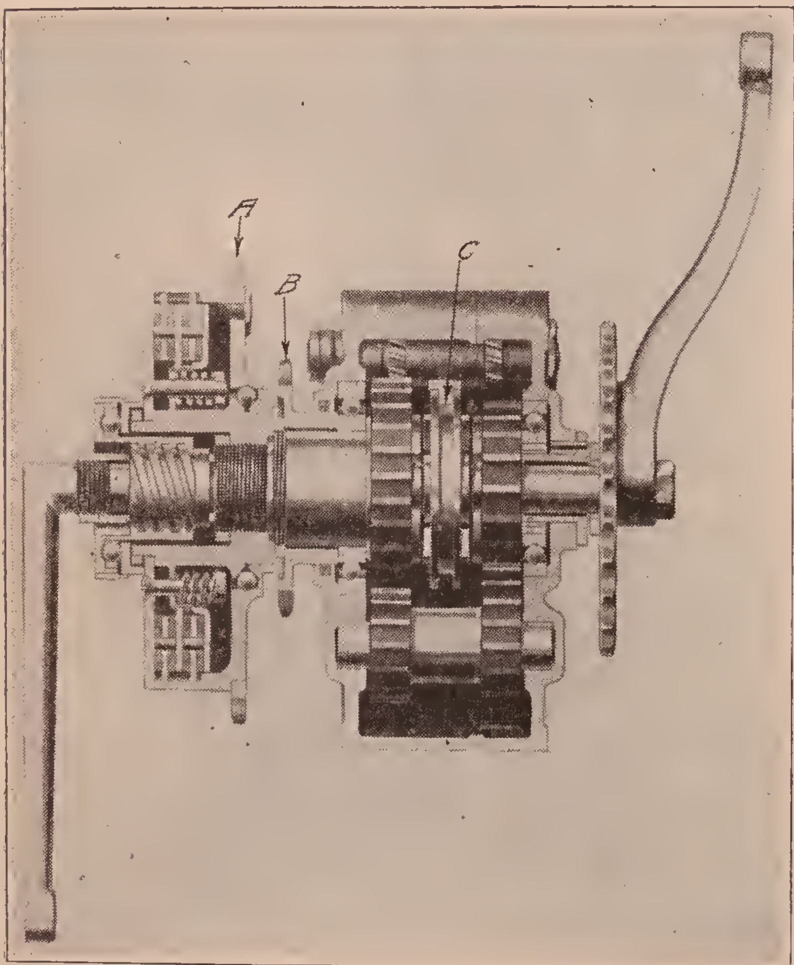


Fig. 37. Dayton Multiple-Disk Clutch and Sliding-Gear, Two-Speed Transmission

First, there is a central toothed wheel, a spur gear, shown at *A*. This is mounted, surrounded by several smaller gears *B*, the teeth meshing. All these gears *B* are mounted on a single construction, so that they rotate together. Outside of these pinions *B* is a large gear *C* with internal teeth meshing in the teeth of the smaller gears.

Suppose that *A* is a driving member and is rotating by the power of the motorcycle motor. If the outer ring *C* is free to revolve and the pinions B stand still, the ring C will revolve in the opposite direction from the central gear A and nothing will be driven. The pinions B

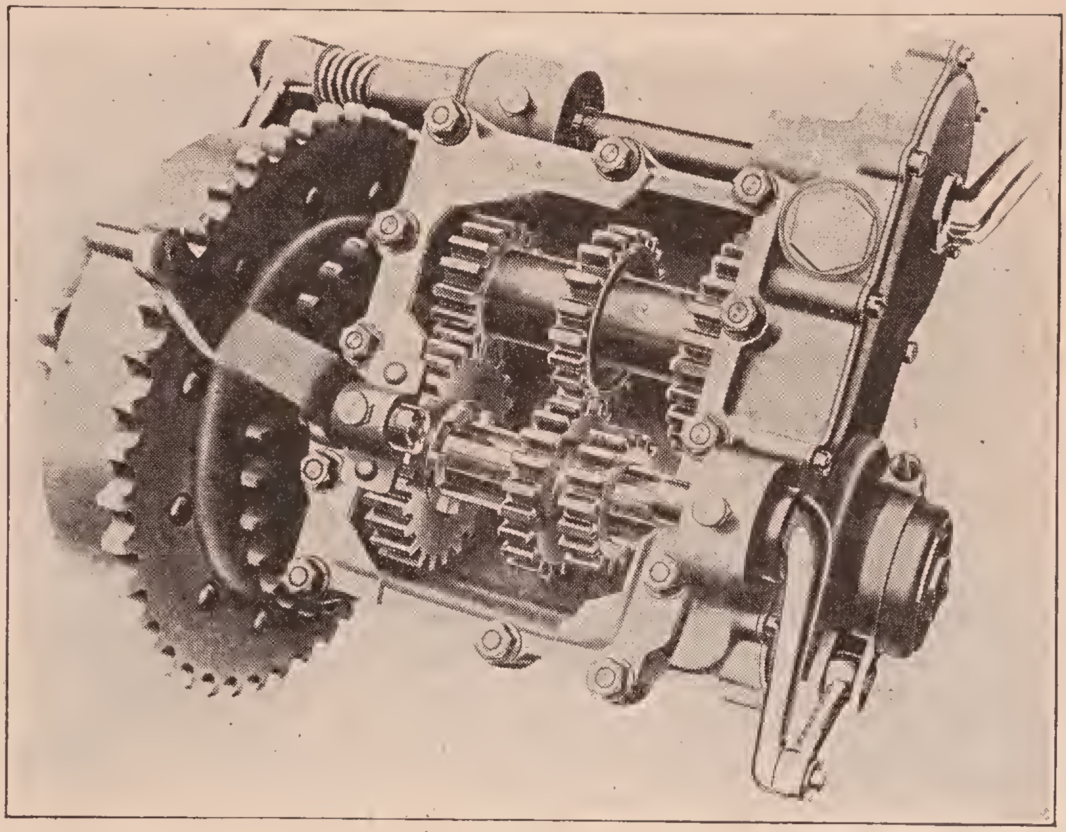


Fig. 38. Harley-Davidson Three-Speed Transmission

are fastened to the rear wheel of the motorcycle so that these stand still when the motorcycle is standing still. If while the gears are rotating on motor power, the outer ring C is held still by means of a

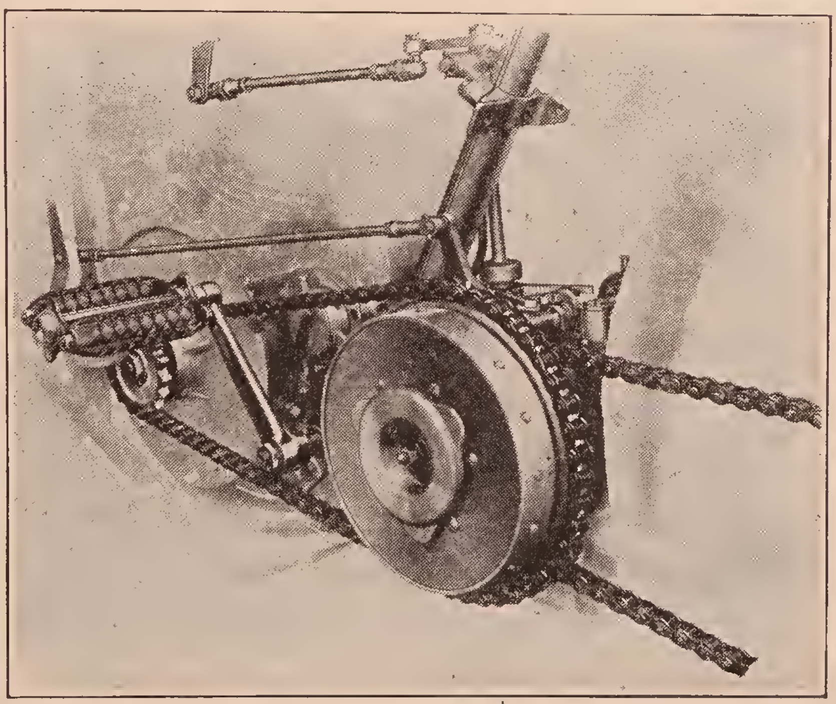


Fig. 39. Method of Mounting Transmission in Harley-Davidson Frame

brake as at E, then the four pinions B will roll between A and C with a sun-and-planet motion at one-half the revolutions of A, about the center of the wheel as a center. This gives low gear with a two-to-one reduction. If the brake E is released and the dog clutch D thrown into engagement, connecting the drive sprocket solidly with the gear A, then the whole planetary mechanism will revolve as a unit *without gears and rotating on high.* That feature has made the planetary gearset popular.

Fig. 36 shows a Harley-Davidson two-speed wheel hub which works on the same principle, except that bevel gears are used.

Two-Speed Sliding Gear. Fig. 37 shows a Dayton sliding-gear two-speed transmission fitted with a multiple-disk clutch shown in section. This clutch is operated by a lever or pedal and, when in engagement, enables the sprocket A to drive through the gear mechanism to the sprocket B, which is the main-drive sprocket. If the small cam ring, shown in the center of the gearset, is moved to the left by a lever, the dogs engage a shaft from A direct to B, so that one is driving on high gear. On releasing the clutch, the cam ring C can be shifted to the right to mesh with the smaller gear on that side, which is driven by the sprocket A. This gear now drives through the two lower back gears, back through the upper left-hand gear to the sprocket B, which now, instead of traveling with A, travels at about half its speed. This is low-gear position. This type of gearset is used on a number of prominent motorcycles, the differences being mainly in details.

Fig. 40. Simple Passenger Attachment for Motorcycles

Three-Speed Sliding. Fig. 38 shows a three-speed gear fitted to the Harley-Davidson and operating on the same principle as the two-speed gears just mentioned. At the extreme left is shown the clutch and the large and small sprockets. The lower shaft to the gearset is the main shaft, and the two gears at the right on this lower shaft slide on keys on the shaft. The shaft is driven by a big sprocket, while the smaller sprocket is fastened to the left-hand gear. If the two sliding gears are shifted to the left, a dog engages them with the left-hand gear, these dogs being clearly seen in the cut. If the gears move to the position shown in the cut the machine is on second speed, driving through the four gears which are in mesh. If the two gears are shifted farther to the right the right-hand one of the two lower gears comes in mesh with the right-hand big gear, and the machine is on its lowest gear ratio. The method of mounting this gearset on the Harley-Davidson is shown in Fig. 39.

A smaller three-speed gearset used on the Indian motor-cycle is shown in Fig. 32 in connection with the disk clutch attached. In this case, a single sliding gear on the principal shaft makes all the connections and gives a progressive gearset of extreme simplicity. A gearset is a necessity on motorcycles intended for passenger use.

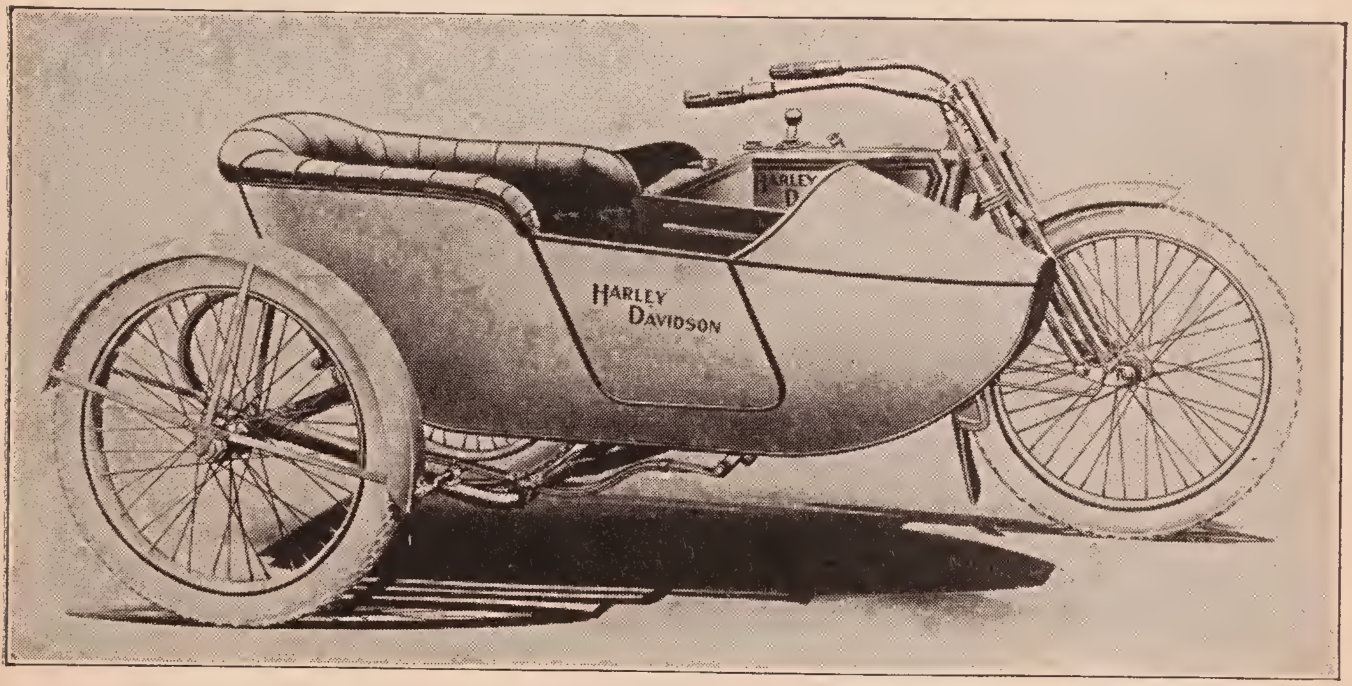


Fig. 41. Harley-Davidson Side Car
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

Passenger Attachments. The motorcycle has become so popular a vehicle that owners wish to take their friends with them. Hence has come about the popularity of passenger attachments. Fig. 40 shows the simplest type of passenger attachment for motorcycles, this being an extra seat fastening at the back of the driver's seat, making the machine into a tandem vehicle. Many thousands of these are in use in America. While at first they were viewed with a certain degree of contempt by the automobilist, they have become accepted as a proper means of conveyance. Many who are not possessors of this attachment fit a heavy cushion to the luggage carrier at the rear and mount a passenger on this.

Seeking for more dignity in a passenger attachment, motorcycle riders have adopted sidecars as a solution, as shown in Fig. 41. Separate upholstered-body constructions are fitted with an extra wheel, all of which attaches to the side of an ordinary motorcycle so that the passenger may be carried in a comfortable conveyance alongside the driver.

The Harley-Davidson Company also manufactures what is called a commercial van, Fig. 42. This, it will be noticed, is built on the same chassis as the regulation side car, Fig. 41, a box taking the place of the passenger body. Sidecars are becoming more popular every year as the length of good roads is increasing. Their chief disadvantage is the side strain caused by the pull of the third wheel.

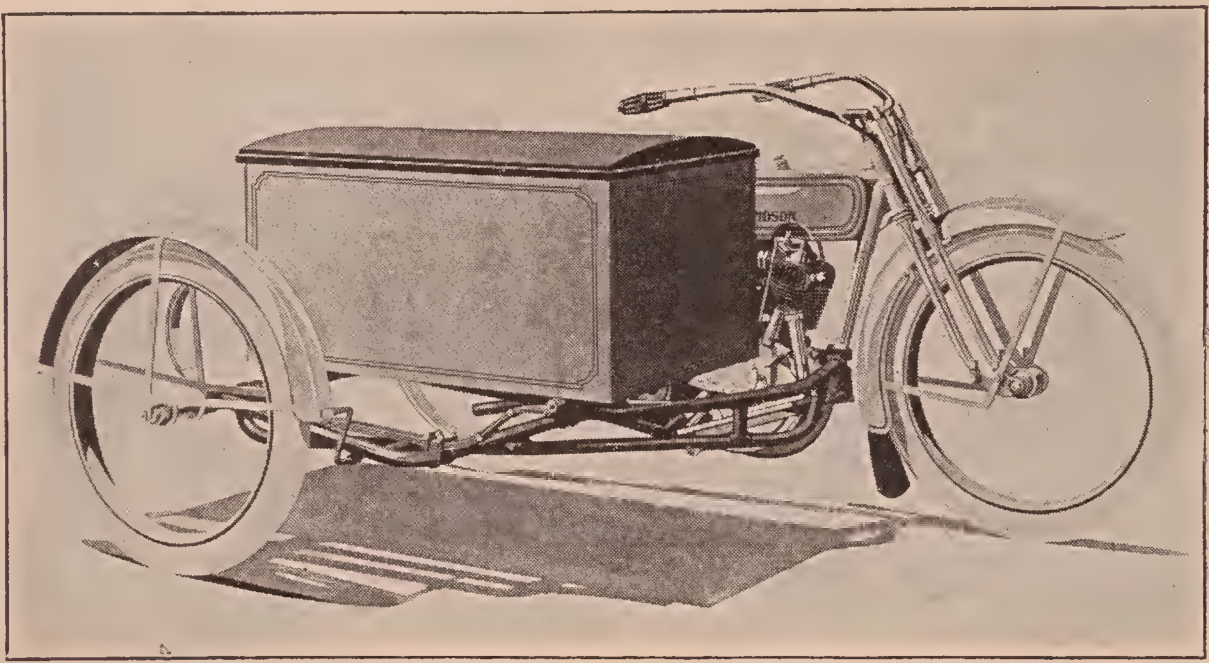


Fig. 42. Harley-Davidson Commercial Van
Courtesy of Harley-Davidson Motor Company, Milwaukee, Wisconsin

Novelties in Motorcycle Equipment. The motorcycle manufacturers have lately made several substantial additions to their equipment. One of these is the three-wheeled motorcycle in which seats for two or three passengers are built around the rear axle. In the face of the failure of the cyclecar and light-car types and its reduction of the price of the smaller standard-tread cars to considerably less than $500, this new form of tricycle seems hardly justified. A number of improvements have also been made in the styles of package vans. Still another novelty has been put out by the Davis Sewing Machine Company, consisting of a three-wheeled chassis carrying a fully equipped chemical engine, Fig. 43. Such a device has so much more speed than the horse-drawn chemical engine and is so much lighter than the combination chemical and steam fire engine that its adoption should be a matter of time only. So many fires are put out by the aid of a few hand grenades or by

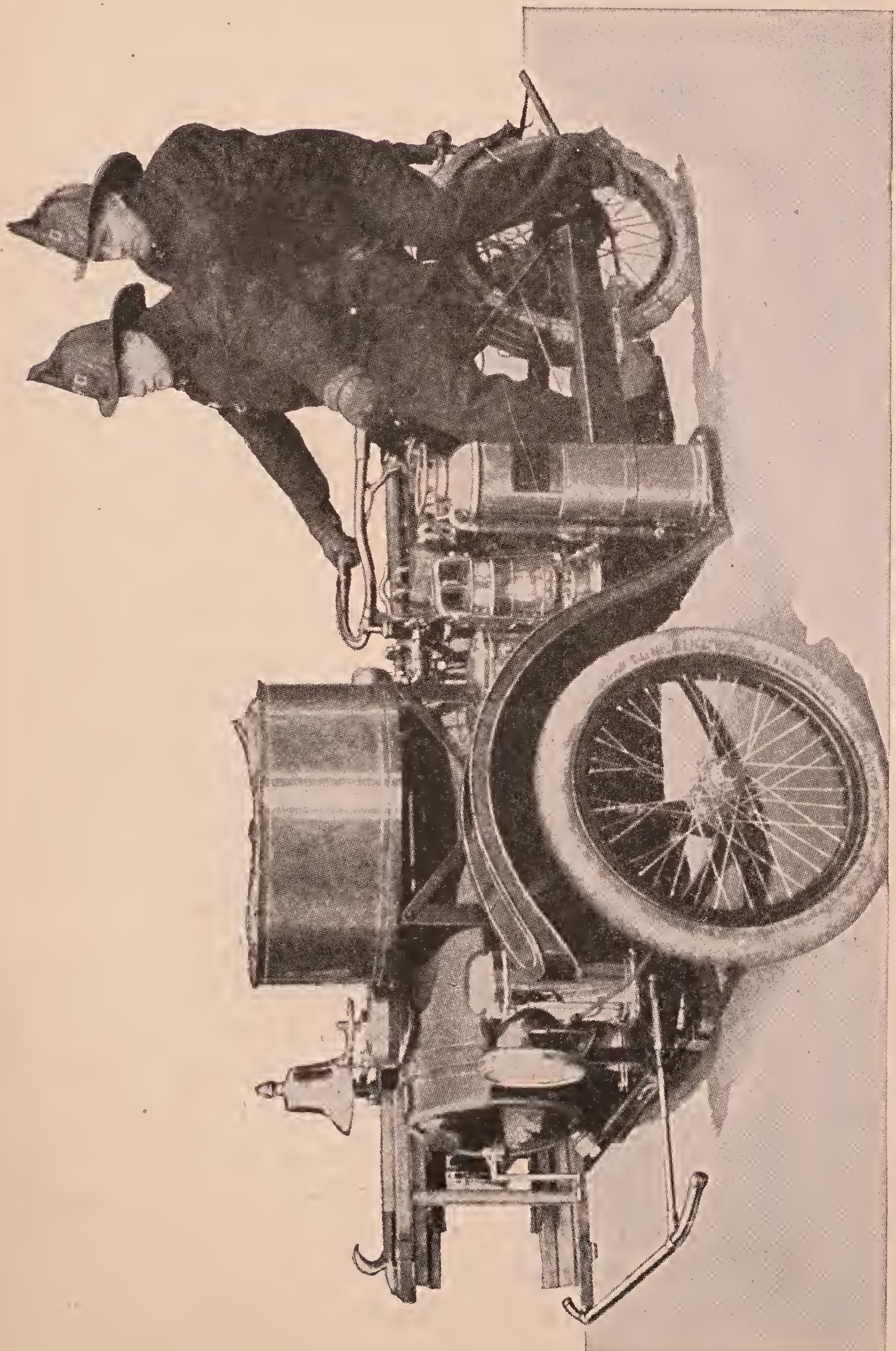


Fig. 43. Dayton Tricar Chemical—a Well-Built Chemical Fire Engine, Capable of High Speed
Courtesy of Davis Sewing Machine Company, Dayton, Ohio

the "chemical", that a light engine of this type, capable of 30 to 45 miles, would be a distinct advantage.

This is particularly true in suburban districts where neither the water supply nor the fire-fighting equipment are always adequate.

This tricar is well built, the chemical equipment being carried on a steel frame running from the front axle to the crankcase. The load is carefully balanced and seats are provided for two men.

OPERATION OF MOTORCYCLES

The Motor. Obviously the most important part of a motorcycle is the prime mover, and in order to handle his mount intelligently, it is well for the rider to understand something about the principle upon which the motor operates. The motor, as previously stated, usually consists of a four-cycle type of single- or twin-cylinder gasoline engine or explosion motor. The explosive mixture, which furnishes the source of power, consists of vaporized gasoline and air combined in the proper proportions through the action of the carbureter. This mixture is drawn into the cylinder of the engine by the suction of the piston in its downstroke. The upstroke then compresses the mixture. Just at the completion of the upstroke this charge of compressed gas is ignited by an electric spark, which causes it to explode, thereby forcing the piston downward. Then, when the piston comes up again the exhaust valve opens and the burnt charge is forced out. It is thus seen that there are four distinct actions which take place, namely, admission, compression, explosion, and exhaust, and as these operations are accomplished in four strokes of the engine, such a motor is called a four-cycle engine.

When the motor is in good working order it requires practically no attention other than to supply it with fuel and keep it properly lubricated. When any serious trouble occurs, it is a safe plan to take the machine to an expert and have it properly repaired, and this will usually prove the cheapest way in the end. Some of the more common sources of trouble may, however, be located by the use of a little common-sense and judgment. It is of fundamental importance that the motor should be securely attached to its base, as otherwise it may be twisted around by the belt or chain, thus throwing it out of alignment. It is, therefore, a good plan to go over the motor and its connections, from time to time, tightening up all loose nuts and bolts.

A very common form of trouble is indicated by a knock or pound, which will ordinarily be found to be due either to lost motion, or to premature ignition. The pounding, due to lost motion, indicates too much play between parts which have relative motion, and would most commonly be caused by looseness of connecting-rod or crankshaft bearings. Premature ignition, on the other hand, causes pounding of a sharper and more metallic sound, and may be due either to the fact that the spark is advanced too far, or to overheating. In some cases it may also be caused by carbon deposits in the cylinder, which become incandescent and cause premature ignition of the gas in this manner. A good way to locate a knock is by the sense of sound, which may be assisted by putting a piece of metal, such as a heavy wire, against different parts of the motor, while holding the other end between the teeth. The source of the trouble will then be indicated by excessive vibration as the wire approaches it.

The forming of carbon in the cylinder is objectionable since it causes overheating and loss of power, as well as premature ignition. This can be avoided by occasionally injecting into the cylinders a small quantity of kerosene while the motor is warm, turning the engine over a few times, and leaving it thus over night. The kerosene should then be forced out by turning over the motor. The foul oil should then be drained from the crankcase and replaced with fresh oil.

The leakage of gases from the cylinder, escaping past the pistons, due either to wear in the cylinder or piston rings, is likely to cause overheating of the upper part of the crankcase. When it is found difficult to turn the engine over, the cause is probably due to the overheating and consequent binding of the piston.

Valves. In order to obtain the best results from the motor it is important that the valves should be properly seated, and that the springs should be neither too stiff nor too weak. It is somewhat commonly supposed that grinding the valves will prove a cure for almost any of the ills to which the gasoline motor is heir. This is a mistake, and valve grinding should not be resorted to unless it is necessary. The grinding of valves is a comparatively simple process, but should not be carried to excess, as it lowers the valve on its seat, which amounts to the same thing as lengthening the valve stem and preventing the valve from seating properly, thereby causing a difficulty greater than that which the grinding was expected to relieve. In order to grind a valve, a paste should be made from emery and oil. This should be put both on the seat and on the edge of the valve itself. Then the valve should be placed in position and turned slowly in its seat by means of a screwdriver, meanwhile maintaining a steady pressure; while the turning should for the most part be in one direction, an occasional part-turn backward should be taken. During the process care should be exercised to see that the pressure is in a perfectly vertical direction, as otherwise an uneven grinding will result. In order to tell when this process has been continued long enough, and the valve is properly ground, the surface of the valve seat, and the valve, may be coated with smoke from a candle. The valve should be placed carefully in its seat and turned completely around once, and then examined. If the grinding has been properly done a complete, bright ring will be seen all the way around the valve. Breaks in this ring indicate that the grinding should be continued.

Carbureter. The proper action of the carbureter is of vital importance to the smooth operation of the motor, and on this account, when anything goes wrong, it is very common for a beginner to decide at once that the trouble is in the carbureter and begin to tinker with it. As a matter of fact, however, it would be wise for the novice not to attempt any adjustment of the carbureter until he has made a careful study of the type he is using.

The motor should ordinarily start without priming the carbureter, unless it has been standing a long time, or unless the weather is cold. In case it does not start readily, priming may be resorted to, although it should be remembered that over-priming does more harm than good, since the motor then becomes supplied with too rich a mixture, which is as hard to fire as one which is not rich enough. If the gasoline refuses to flow altogether, even after priming, the trouble can sometimes be relieved by blowing into the opening of the gasoline tank. Ordinarily, about the only attention the carbureter requires is an occasional cleaning, the frequency of which depends very largely upon the quality of the fuel used, and the care with which it is strained. In case the spray nozzle becomes so seriously choked that blowing into the tank will not relieve it, the difficulty can usually be overcome by holding the finger on the priming pin until the carbureter floods, while simultaneously racing the motor.

The adjustment of the carbureter can be determined by observing the exhaust. If the mixture is too rich, black smoke and red flame will appear. If it is not rich enough it will be indicated by yellow flame, while normal conditions are indicated by blue flame. An important point to bear in mind is that the proper mixture varies with atmospheric conditions, and a richer mixture is required in cold or damp weather than when it is hot or dry.

Ignition. In connection with the ignition system, it is necessary to be sure that all connections are clean and firmly made, and that the insulation is sound throughout, and in case of battery ignition it is, of course, necessary to see that the batteries are in good condition. In order to get the best results from the batteries it is well to have an ammeter with which to test them. New batteries should test from 15 to 18 amperes and about 1.5 volts. When a battery has run down to 4 or 5 amperes it can no longer be depended upon and should be thrown out. Each cell should be tested separately, and it is never well to connect an old cell with new ones, as the old cell tends to reduce the life of the new ones. The terminals of a battery should never be short-circuited by testing directly across them with a wire or screwdriver, as a battery can be completely exhausted in this way in a short time. It is well to go over all joints and connections periodically, making a careful examination to see that all binding posts and set screws are tight, and that all points of electrical contact are bright and clean. The insulation should also be examined from time to time, looking not only for spots where the insulation has been worn away by chafing, but also for any places where it has become saturated with oil. Inspection of this sort is particularly important in the secondary winding, where the insulation must be much more perfect on account of the high voltage employed than in the case of the low-tension primary wiring. In regard to the contact breaker, it is important to see that it is properly adjusted, and that the platinum tip is clean and bright.

A common cause of trouble in the ignition system is due to soot on the points of the spark plug. The spark plug should accordingly be removed occasionally and the points cleaned.

The magneto is very seldom the cause of trouble, and, under ordinary conditions, should not be tampered with by an inexperienced person. One common source of trouble with the magneto, which can easily be relieved, is due to the binding of the carbon brush in its holder, thereby preventing proper contact between the brush and the commutator. The same thing will result if the spring which holds the brush against the commutator becomes weak or is broken.

Lubrication. The matter of lubrication has already been mentioned, but it is so vital to the satisfactory operation and to the life of a motorcycle that it will bear repetition. The oiling should not be a perfunctory operation to be taken care of at random, but should be done methodically at intervals depending upon the grade of oil used. Of course, it is possible to go to extremes and oil too frequently, but too much oil is preferable to too little.

Only the best grade of oils should be used, as the difference in cost is only slight and a poor oil is sure to cause trouble. The manufacturers are always glad to give advice as to the kind and grade of oil best suited to their make of motor, and one would do well to be guided by such advice, since no one knows a machine so well as the maker, and it is to his interest as well that the machine give a good account of itself.

Tires. The principal point to be borne in mind in connection with the tires is that they should be kept pumped up hard, as riding on soft tires is likely to injure both the casing and inner tube, as well as requiring more power to drive the machine. A tire pump should always be carried when on the road and the condition of the tires examined frequently for any indication of softness.

A spare inner tube, sprinkled with tire powder and carefully folded and enclosed in a separate package, should be carried along, for replacement in case of a puncture or a blow-out. In addition, a tire-repair outfit should always form part of the rider's equipment, for making quick repairs on the road.

In replacing tires with metal tire tools, care should be taken not to chip the enamel off the rim, as this will cause it to rust and the rust will in turn injure the tires. On this account it is well to paint the rims occasionally as a guard against rust. Grease and oil are very injurious to rubber, and should never be allowed to remain on the tires, but should be washed off at once with gasoline.

Control. The speed and amount of power developed by a motorcycle depend upon two factors: the quantity of gas supplied to the motor and the time at which the spark occurs with relation to the position of the piston in its travel back and for thin the cylinder.

The devices for controlling these two factors or for regulating the *throttle* and *spark* should be conveniently located so that they can be manipulated instantly while at the same time keeping the hands in position upon the handlebars.

Nearly all the earlier machines were equipped with the *twist-grip type of control,* in which twisting one grip varies the position of the throttle, and the other the position of the spark. This type of control has the disadvantage that, in heavy going, where a firm hold on the handlebars is necessary, the rider is in danger of twisting one or both of the grips unintentionally, thereby varying the position of the throttle or spark at the wrong time. This objection is overcome to a large extent by having the twist grip located in front of secondary grips, which are rigidly attached to the handlebars.

Handlebar or lever control is rapidly coming into favor, this consisting of levers placed in front of the grips with rod and knuckle joints or wire cable leading therefrom to the carbureter and spark mechanism. Cable seems to be the more satisfactory, as with its use there is no lost motion, as in case of the rod and knuckle-joint system. An advantage of the lever type of control is that the exact position of the levers can be seen at a glance.

Whatever the type of control, the rider should so accustom himself to its manipulation that he can, in case of emergency, throw off the power and apply the brakes instantly. In fact, these operations should be so familiar as to become automatic.

General Instructions. Before starting out, the rider should be sure that he has an ample supply of gasoline and oil in the tanks, never using anything but strained gasoline. The machine should be well oiled and the tires examined to see if they have sufficient air. All bolts, nuts, and screws should be gone over, and tightened if necessary. The wiring should be examined for loose connections or breaks in the insulation, and the batteries should be tested with an ammeter. Any excessive slack in belt or chain should be taken up. If these matters are attended to systematically before starting out, many an awkward and embarrassing delay on the road will be avoided.

The matter of physical comfort while on the road is of importance, and in order that the greatest degree of comfort be obtained the saddle should be placed fairly low and not too far back. The handlebars should be high enough to avoid the necessity of stretching or bending forward, and the bars should be so shaped that the hands rest upon them in a position which is easy upon the wrists.

The rider should become so familiar with his machine that he can tell when it is running properly by the sound. Any unusual noise is a sure indication of something wrong, and the machine should be stopped instantly and examined for the cause. It is probable that the trouble can be located and repaired in a moment if attended to at once, but if allowed to go on it might easily develop into something which would cause serious injury to the machine. The motor should not be run for long periods of time on the stand and should never be allowed to race unnecessarily.

No definite rules can be given for governing the rider's conduct when on the road, other than that which would be dictated by common-sense, and a proper consideration for the rights of other vehicles, and particularly for pedestrians, and one must, of course, take into consideration the rules in regard to speed limit which obtain in the particular locality through which he is driving. The machine should be kept under control at all times, so that it can be brought to a stop almost instantly in case of any sudden obstruction in the traffic, and it is well not to drive too close to the vehicle ahead, as this may stop suddenly, while the one behind you does not stop, thus causing an awkward, if not serious, situation. In turning corners, or passing other vehicles, a wide curve should always be taken in order to avoid the tendency to skid, which arises from taking sharp turns at high speed. Always slow up when turning a corner.

One of the principal causes which has brought the motorcycle into disrepute is the excessive noise caused by riders opening the muffler cut-out unnecessarily. There are times when it is necessary to do this, but the use of the cut-out should never be carried to excess.

When starting on a trip which will keep the rider out after dark, the lighting system should be examined to see that it is in good condition, as it is required that the motorcyclist show a head light and a tail light at all times after dusk sets in.

Upon returning from a ride the motorcycle should always be cleaned before putting it away, or at least as soon as possible thereafter. The longer the cleaning process is delayed, the more difficult an operation does it become. Mud which is allowed to cake upon the cooling flanges of the motor cuts off the circulation of the air, and causes overheating. Oil running down from the bearings collects dirt, which is sure to work back into the bearings sooner or later and cause trouble, while the presence of mud and moisture on the machine causes rust, which soon injures the appearance of the machine, if it does not do more serious harm. In fact, cleanliness at all times, and in connection with all parts of the machine, is a golden rule of motorcycling, and is an investment of time which will give large returns in the satisfactory operation and life of the machine.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART I

---

1. What is an electromagnet, and how is it used?

2. Explain what is meant by (a) a short-circuit; (b) a ground.

3. A certain 12-volt starting motor required an average current of 80 amperes to turn the automobile engine over fast enough to start it. How many horsepower is developed by the starting motor?

4. Describe the process of generating an e.m.f. wave by a dynamo.

5. If pure water is an insulator, why is it necessary to keep the spark plugs and other parts of the secondary circuit dry?

6. What is a dynamotor?

7. Give the rule for determining the direction of current flow in a solenoid winding.

8. What is meant by voltage drop?

9. Give the diagrams of series, shunt, and compound generator windings.

10. Explain how rotation is produced in an electric motor.

11. Give diagram of a lighting circuit for an automobile, showing lights in multiple.

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART II

---

1. What is meant by "polarization" in batteries?

2. (a) Explain how soot forms on the spark plug. (b) Give its effect on ignition. (c) Tell how this trouble is overcome in the design of the spark plug.

3. What is the characteristic of the Duplex ignition system.

4. Sketch the Dixie magneto.

5. Describe and illustrate a single-cylinder high-tension ignition system.

6. Give the possible firing orders in a six-cylinder motor.

7. Describe briefly the true high-tension type of magneto shown in Fig. 63.

8. Give two reasons why the coil and vibrator is unsatisfactory for ignition work.

9. (a) Why should an engine never be driven at normal speed with the spark retarded? (b) When is retardation necessary and why?

10. Give diagram of a single-cylinder low-tension ignition system and tell why it is not used for automobile engines?

11. Give the three general causes of failure of ignition circuits.

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART III

---

1. Describe the principle of the Ward-Leonard external controller for constant-current generators.

2. Why are automatic battery cut-outs required on starting-lighting circuits?

3. Describe briefly the Auto-Lite automatic-engagement type of driving connection.

4. Explain briefly the principle of the Splitdorf "built-in" controller.

5. Describe the action of the Westinghouse starting switch shown in Fig. 163.

6. Under what general principle are constant-potential generators regulated?

7. What are dimmers, and why are they required?

8. Describe how a constant-current starting-lighting generator is regulated by means of the windings.

9. What is the average starting speed for motors and the usual voltage of the starting system?

10. Give several advantages of the single-wire over the two-wire starting-lighting system.

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART IV

---

1. Give the approximate sizes of wire which should be used for starting circuit, the charging circuit between generator and battery, and for the horn in any starting-lighting system.

2. What must be done before using the engine as a brake on the Scripps-Booth cars?

3. When are fuses unnecessary in a starting-lighting system?

4. Give the causes of failure of the starting motor to operate when using the Bosch-Rushmore system.

5. Make a sketch of the windings on a four-pole Auto-Lite generator.

6. Sketch and explain the Delco constant-voltage control method of regulation.

7. Sketch the Bijur installation used on the Hupmobile.

8. Give a wiring diagram showing the essentials of the Delco starting-motor circuit as used on their 6—24-volt system.

9. Explain the method of regulating the generator in the Bijur system.

10. Show by diagram what connections are made when the three-way switch of the Bijur system on the Scripps-Booth is at *on* and *idle* positions?

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRICAL EQUIPMENT FOR GASOLINE CARS

PART V

---

1. How can a storage battery be tested with a hydrometer? Why is this important?

2. Give wiring diagram for the Simms-Huff starting-lighting system.

3. How is the starting motor mounted on a Reo?

4. How would you test the regulating brush in a Leece-Neville starting-lighting system?

5. How would you determine that the regulator was not working properly in a Gray and Davis Ford installation?

6. Sketch from memory the North East wiring diagram for a system using 7-volt lamps.

7. What car uses a ratchet reversing switch?

8. With a Remy installation on an Oakland, say, what would be the cause of failure of the lights while the starting motor operates?

9. When making a test with a voltmeter for a ground on a starting-lighting system, what does a reading of four volts or over indicate?

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