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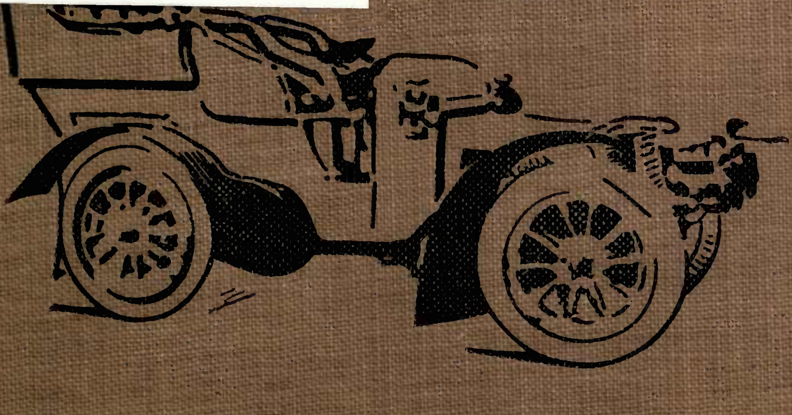
FOR MOTORS

NEW AND ENLARGED EDITION



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A Series of Practical Manuals.

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IGNITION DEVICES

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WITH A CHAPTER

TREATING SPECIALLY OF

STRUCTURAL DETAILS, CHOICE, AND MANAGEMENT OF AUTOMOBILES

By S. R. BOTTONE

AUTHOR OF "AMATEUR ELECTRICIAN'S WORKSHOP," "TALKING MACHINES & RECORDS," "ELECTRICAL ENGINEERING FOR STUDENTS," "MODERN DYNAMOS & BATTERIES ETC., ETC.

NEW EDITION, THOROUGHLY REVISED AND ENLARGED

Fully Illustrated

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1911

Printed in England.

ILLUSTRATIONS.

CHAPTER I.

Choice and Management of Automobiles.

MOTOR cars, tri-cars, and motor bicycles present so much matter of interest, and are entering so largely into our every-day life, that every one should have some knowledge of the principles of their construction. This knowledge, even though it be elementary, is absolutely necessary to the would-be purchaser, otherwise he may be led astray in the choice of a car by its outward appearance, instead of directing his attention to those essentials on which the proper working and convenience of manipulation depend. Although modifications and improvements are being continually introduced, yet the main features of the propelling arrangements adopted by nearly all automobile manufacturers are based on the practice of the leading makers in France, where, owing to the freedom from irksome restrictions on the road, the art of constructing and working light, powerful motors, actuated by petrol, alcohol, steam, or electricity, has reached a higher level of perfection than perhaps in any other country.

The first essential in an automobile is the power of travelling, and this power it obtains from the engine. The type of motor now almost universally adopted for the propulsion of automobiles is a modification of that known as the "internal combustion engine." In this the power is derived from the explosion of a mixture of air and petrol vapour confined in the upper portion of a cylinder, in which travels a piston, connected by a crank to a fly-wheel, and other accessories. Petrol is an extremely volatile spirit (a hydro-carbon), obtained from petroleum by distillation. Being so volatile, it evaporates readily, and forms with air a gaseous mixture, which can readily be ignited by the electric spark. On being thus fired, it explodes, great heat and consequent expansion occurring at the same time. If, before allowing ignition to take place, the gaseous mixture be compressed, the force of the explosion is much exalted—hence, greater power is obtainable from the explosion. For this reason, in all modern gas and petrol engines, great attention is paid to obtaining a proper amount of compression before firing the mixture. The explosion is made to take place by means of a "timed" electric spark when the compression of the gaseous mixture has reached a certain predetermined point.

We reproduce two outline illustrations of a typical petrol motor (Figs. 1 and 2), in order to enable the reader to follow out the principle on which such engines act, and this principle remains the same in all, although modifications are to be found in the constructional detail of the engines turned out by the various makers. We may here mention that the fly-wheel which is shown at the back of the lower portion of Fig. 1, and to the right of Fig. 2, is usually outside the case of the engine itself; but in some of the smaller motors of the cycle pattern, it is itself enclosed, the spindle alone projecting. Fig. 1 is a front section, and Fig. 2 a side view, of the ordinary petrol motor—in which 1 is the cylinder, 2 the cylinder cover, and 3 the chamber containing the crank. This chamber is fitted with two covers, 4 and 5, the latter of which has on it a box, 6, whence arises a stud, 7, carrying a sleeve, 8, whereon is formed the exhaust-valve cam. To this sleeve is keyed the gear-wheel, 9, which is driven by a pinion, 10, fastened to the crank-shaft, 11. Since the number of teeth on the gear-wheel, 9, is twice that of those on the pinion, 10, it revolves at *half* the speed of the crank-shaft, thus operating the exhaust-valve at every alternate in-stroke of the piston. At 12 is the piston, which is furnished with three metal rings, 13, which enable it to make a gas-tight fit in the cylinder; and 14 is the connecting-rod, fitted with brasses at each end. The valve-box, 15, is cast on the side of the cylinder, and communicates with the combustion chamber, 16, by the port. The valve-box has a water-jacket in communication with the water-jacket, 29, 30, of the cylinder, which device prevents the valve-seatings becoming unduly heated. At 17 is an inlet-valve which is automatic in its action, opening by the suction of the piston, against the light spring, 18. A stronger spring, 20, controls the exhaust-valve, 19, which therefore resists the suction stroke, but is lifted from its seat at every second revolution of the engine by the cam on the sleeve, 8. This cam raises the roller, 21, on the bell-crank lever, 22, pivoted at 23, the other end of the bell-crank lever having the push-rod, 24, jointed to it. This rod serves to lift up the exhaust-rod at the right times. The gear-wheel, 9, is made

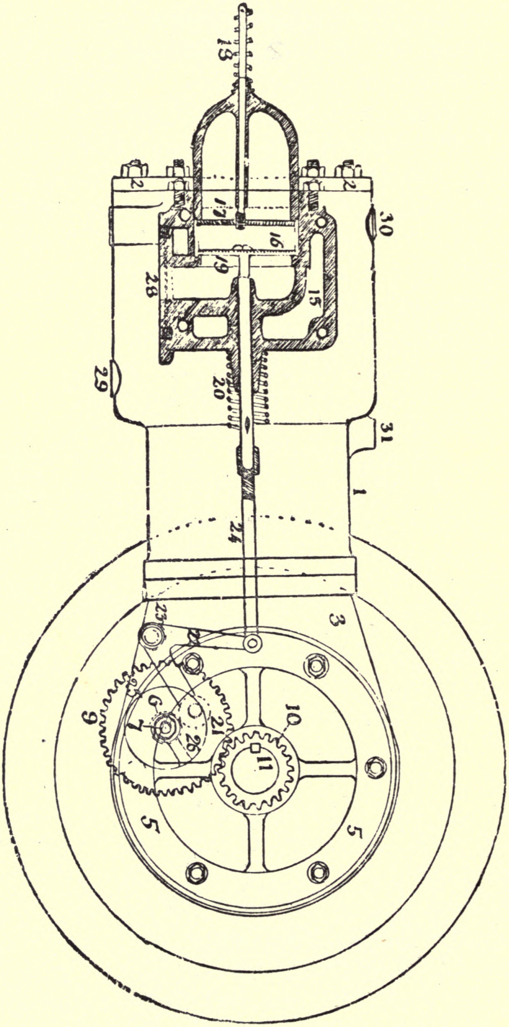

FIG. 1.—PETROL MOTOR (Front Section).

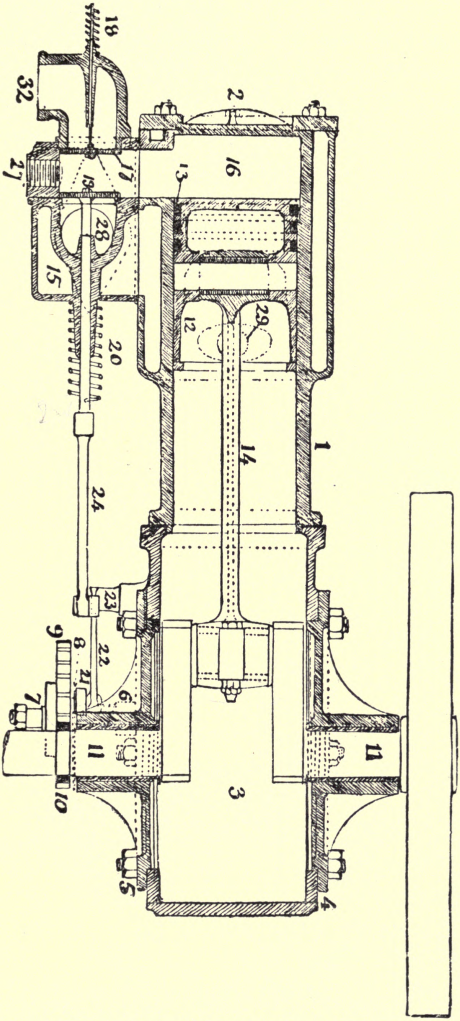

FIG. 2.—PETROL MOTOR (Side View,.

of hard vulcanised fibre, and on its face, formed in one piece with it, is the disc, 25. This serves to "time" the firing spark. On the edge of the disc, 25, is the brass segment, 26, which is in metallic connection with the sleeve, 8. At the extremity of the stud, 7, is an insulating plate (not shown in the illustration), carrying a "brush" or spring which presses on the fibre disc, 26. By this arrangement the electric circuit is completed once at every revolution, between the two extremities of the primary of the coil, magneto, or other ignition device, when the brush passes over the brass segment on the disc. This causes the firing-spark to be produced at the sparking-plug, which is screwed into the valve-box at 27.

The mixture of petrol vapour with air produced in the carburetter, that constitutes the explosive mixture, is led into the engine at 32. At 28 we have the aperture through which the spent, or "exhaust," gases are led away into the silencer. A lubricator, preferable of the "sight-feed" type, is either mounted on the dashboard or screwed into the box at 31. In order to avoid the risk of any part of the engine "binding" or "seizing," owing to any neglect in lubricating the smaller bearings, these should be arranged so as to lubricate themselves automatically: the studs carrying these are therefore drilled from the inside, with holes reaching to these bearings—into which holes sufficient oil is splashed by the crank during its travel, or in some cases a supply of oil is forced in, by means of a small pump, situated near 11. It is important that the inlet-valve, 17, and the exhaust, 19, should be of ample area to avoid throttling the entering charge, or setting up back pressure during the exhaust stroke. The water-jacket, which surrounds the cylinder proper, should have no joints, but be cast in one piece with the cylinder. The entrance for the water is shown at 29, and its exit is at 30. At these points, facings are cast on the cylinder, to which the flanges of the water inlet and outlet pipes are attached by studs and nuts. In the smaller cycle-engines cooling is effected by the rush of the air between the gills of the radiator when the motor is travelling. These gills form an external portion of the combustion chamber and cylinder. Sometimes this cooling is assisted by means of a rotary fan. But in all larger engines the cooling is effected by water circulating in the water-jacket; and this circulation is frequently kept up by means of a small pump actuated by the engine itself.

The position of the petrol tank and the carburetter may be varied to suit the build of the car. We need only briefly mention the old form or "surface" carburetter, in which the air entered into the petrol through a pipe dipping into the petrol tank. The air was sucked up through the petrol, somewhat in the same manner in which tobacco smoke is made to bubble through the water in a "hookah," under the action of the suction of the inlet stroke. In so doing, the air took up a certain quantity of petrol vapour. But the carburetter which meets with most favour at present is of the "spray" or pulverising type, in which a certain given controllable quantity of petrol is allowed to enter from the tank into the carburetter by a valve or faucet—where it is sucked up, broken into spray, mixed with air, and quickly vaporised by the suction of the inlet stroke. In this "spray carburetter," one or more tubes, ending in fine nozzles, dip into the petrol, which is sucked up into the tube and issued from the nozzle in the form of fine spray, where it meets with a stream of air also drawn in under the influence of the sucking action of the inlet stroke of the engine itself. The spray thus produced is received in a "mixing chamber," into which warm air, in suitable proportions, is simultaneously being drawn. At Fig. 3 we give two illustrations of the best modern form of "spray carburetters."

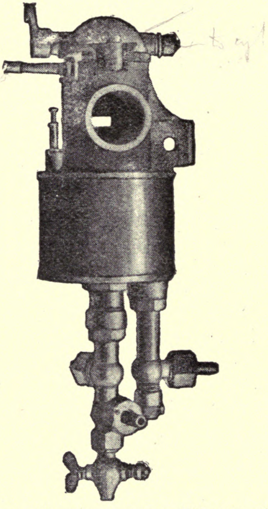

FIG. 3A.—CARBURETTER (Elevation).

The following is a detailed description of the sectional view (Fig. 3 B) :—1. Air intake ; 2. Vapour

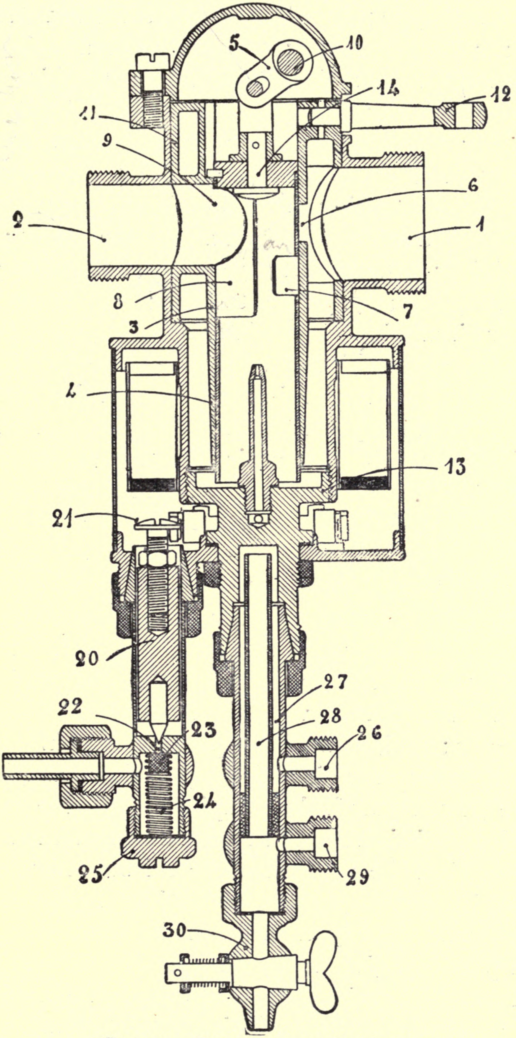

FIG 3B.—CARBURETTER (Section).

outlet to engine; 3. Casting of throttle-valve or sleeve; 4. Sliding tube; 5. Lever arm attached to the throttle valve; 6. Sliding tube; 7. Air port; 8. Mixture outlet; 9. Main outlet; 10. Lever operating tube; 11. Outlet valve; 12. Lever to actuate throttle valve; 13. Annular float; 14. Connections of sliding tube to pin; 20. End of screw; 21. Screw to regulate needle valve; 22. Needle valve; 23. Petrol inlet; 24. Adjusting spring; 25. Cap; 26. Water coupling; 27. Jacket to tube; 28. Inflow tube of water circulation; 29. Water coupling; 30. Drain cock. The petrol jet or sprayer will be seen in the centre of the illustration in the throttle-valve casting.

Working in conjunction with the carburetter, we sometimes have the automatic governor, which serves to regulate the amount of explosive mixture supplied to the combustion chamber. It must be noted that there is a definite proportion in which the gaseous vapour must be mixed with air in order to produce the best results—this proportion being approximately 1 part of vapour or gas to 18 parts of air. Under the influence of the suction-stroke of the engine, a more or less perfect vacuum is produced in the carburetter; and, as we have previously pointed out, this causes both the air and the petrol or gas to rush in—the latter through the spraying nozzle, the former through the air inlet. With an increase of the speed of the engine, the amount of petrol sucked up and sprayed increases much more rapidly than that of the air—consequently, the mixture becomes much too rich in petrol to give its best effect. In order, therefore, to correct this, provision has to be made to admit *more air* to dilute the richer mixture when the engine speed increases. This is effected in different manners by the various makers. In the De Dion type we have the "lantern" form of mixing valve (Fig. 4). In the latest pattern of Longuemare carburetters, a small flap valve covers the air admission; this valve opening more and more in proportion to the suction of the engine, thus causing the air supply to be regulated practically automatically.

We now pass to consider briefly the methods usually employed to transmit the power thus generated. In large stationary engines belt or rope drive is the means that finds most favour; for motor cycles, the V leather belt is that almost universally adopted, while for motor cars and other similar large automobiles, chains, in conjuction with friction clutches, constitute the best means of transmitting the power from the engine to the wheels. By "friction clutch" is understood a disc or drum, either of metal only, or of metal faced with leather, that by means of a lever can be caused to

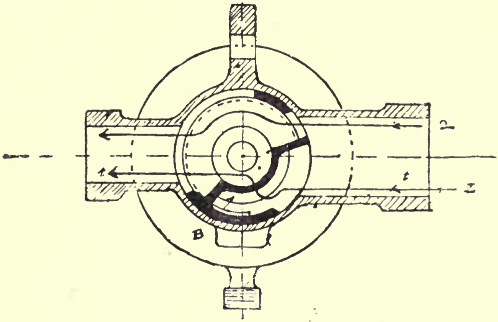

FIG. 4.—"LANTERN" MIXING VALVE.

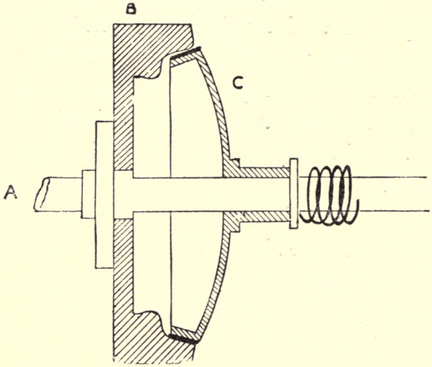

FIG. 5.—SIMPLE CLUTCH.

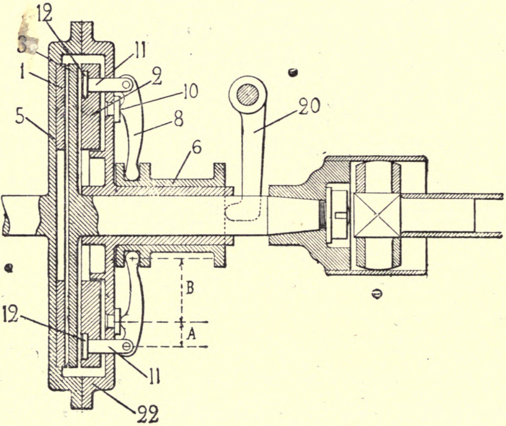

FIG. 6.—DE DION CLUTCH.

press against the suitably coned surface of the fly-wheel, and thus partake of its motion. We illustrate a simple form of clutch in Fig. 5, in which B is the fly-wheel on the shaft, A; C being the clutch proper, attached to the transmission or clutch shaft. Fig. 6 is a sectional view of the more elaborate form of clutch used in the De Dion motor cars. The clutch can be thrown into contact with the fly-wheel, or withdrawn therefrom, by means of a lever. When the clutch is

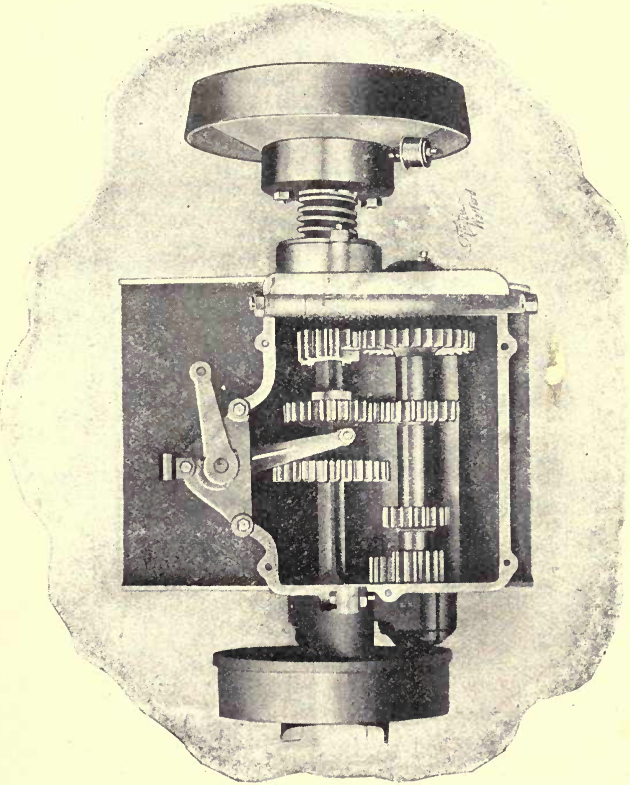

Fig. 7.—Darracq Change-Speed Gear Box.

not in contact with the fly-wheel, the position is said to be *neutral*, or the engine is "out of gear," so that, although the engine may be working, the car is not propelled. The motion thus imparted to the clutch is carried by the clutch shaft to a "gear box," wherein are contained two shafts, on one of which (called the primary) are fixed three cog-wheels of somewhat different diameters, with more or fewer teeth. On the other (the secondary) which is square, are arranged other cog-wheels carried by a sleeve. This sleeve can be slid along its shaft by means of a lever, so that one or other of its gear-wheels can be caused to mesh at will with any given one of the wheels on the other shaft, and thus slacken, increase, or even reverse the rotation. We give at Figs. 7 and 8 illustrations of good forms of gear boxes; the former

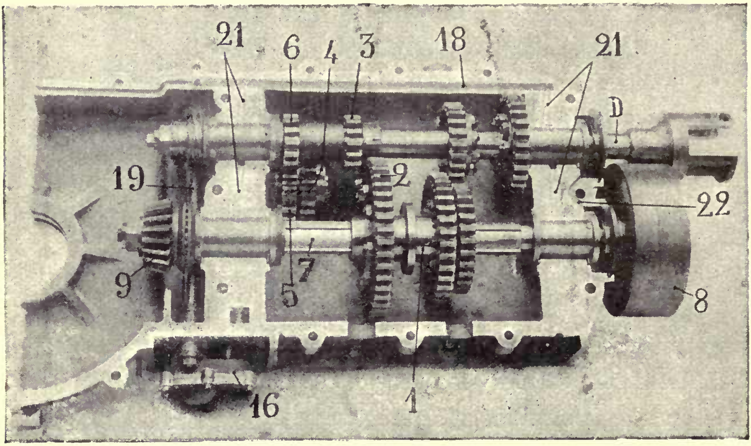

Fig. 8.—De Dion Gear Box.

being the type favoured by Darracq & Co., while the latter is the one adopted by De Dion Bouton & Co. In this illustration the arrangement which allows one wheel to travel faster or slower than the other, so as to enable the car to turn corners, is also shown in part.

The power having been thus carried as far as the change-speed gear box, is now transmitted to the driving-wheels—either directly, by means of suitable pinions from the secondary shaft to the rear wheels through the differential, or else by means of sprocket wheel and chains to the rear wheels. We show, at Fig. 9, the position of these relative parts. In this illustration 37 represents the engine, behind which is seen the clutch ; a shaft proceeding from which carries the power to the change-gear box. It must be noted that, in order to take up any strain, this shaft is jointed to the clutch, and again to the shaft of the gear box, by means of a form of Hook's joint, known as a "cardan." This joint consists practically in two forks set at right angles to one another, with crossed pins between them, so that if the driving wheels were to fall or rise owing to any inequality in the road, no strain would thereby be put on this shaft. In this illustration, directly behind the change-speed gear box, is seen the differential, which, as we have already explained, enables one of the wheels to turn independently of the other.

It must be remembered that, in the modern types of motor cars, the engine, with its radiator, is placed in front, near the steering wheels, while the driven wheels are invariably at the back of the car. This

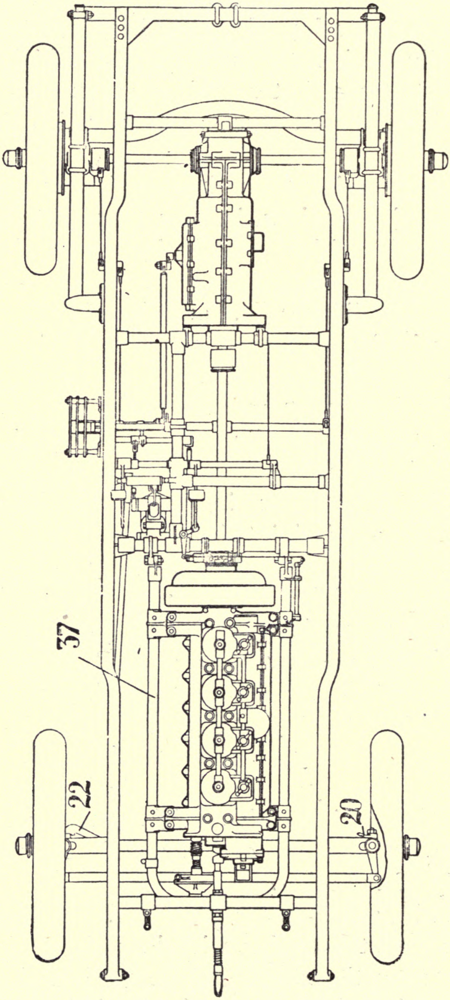

FIG. 9.—PLAN OF CHASSIS.

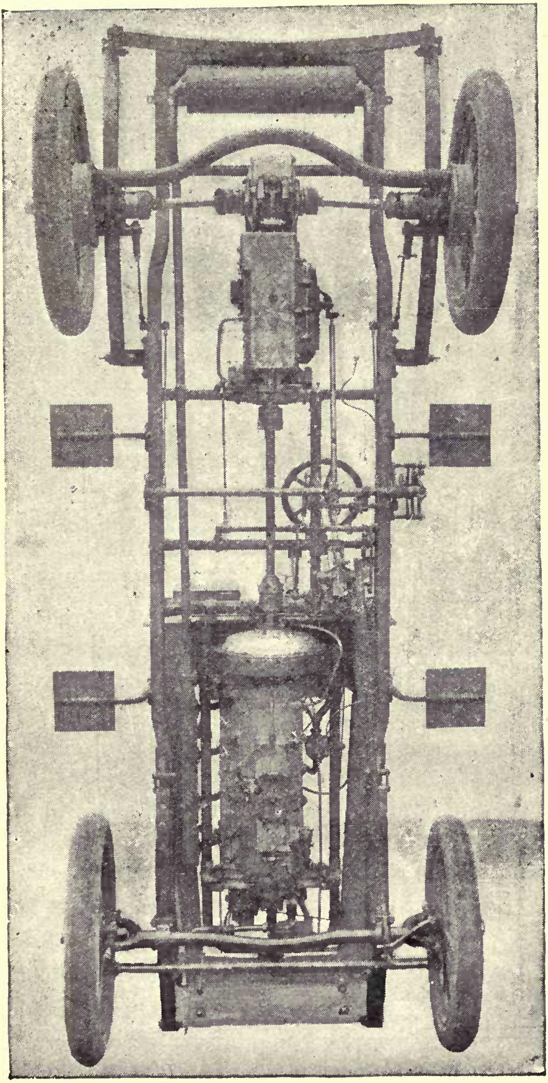

Fig. 10.—Chassis, as seen from below.

may be clearly seen in Fig. 10, which shows the position of all the parts as seen from below. Before going farther we may explain the manner in which the differential works. It consists, as shown at Fig. 11, of three or more conical gear wheels, carried on a portion of the driving shaft. These small conical gear wheels, shown in the centre of the illustration, mesh into the teeth of two crown wheels—that in the illustration appear standing a little apart from them to the right and to the left, but which, when in action, mesh firmly into the conical gear wheels. These two crown wheels themselves are fixed to the inner ends of the two halves of the axle, which is cut at this portion and supported by sleeves. A moment's consideration will show that when the gear is in mesh, although the axle is in two pieces, it acts as though it were one solid shaft, and the rate of motion of both wheels is the same ; but if by any means one road wheel be held back (by greater friction on the road, or otherwise), the mere fact of its retardation will, by the action of the cone-crowned wheel, cause the other road wheel to travel faster.

We now pass on to consider the method adopted for steering. The front axle has two jointed ends on which the steering wheels are free to rotate ; and these two ends are connected together by means of a cranked bar, so that any motion given to this bar is imparted to both wheels. The steering is effected on the wheel and inclined pillar principle, and consists of a pillar or shaft mounted on, and passing through, a hollow standard attached to the floor of the car, at a considerable angle of inclination. The upper end terminates in a large wheel within easy reach of the driver, while the lower extremity is connected to a simple form of worm gear with a rather quick thread, which engages in a toothed quadrant;

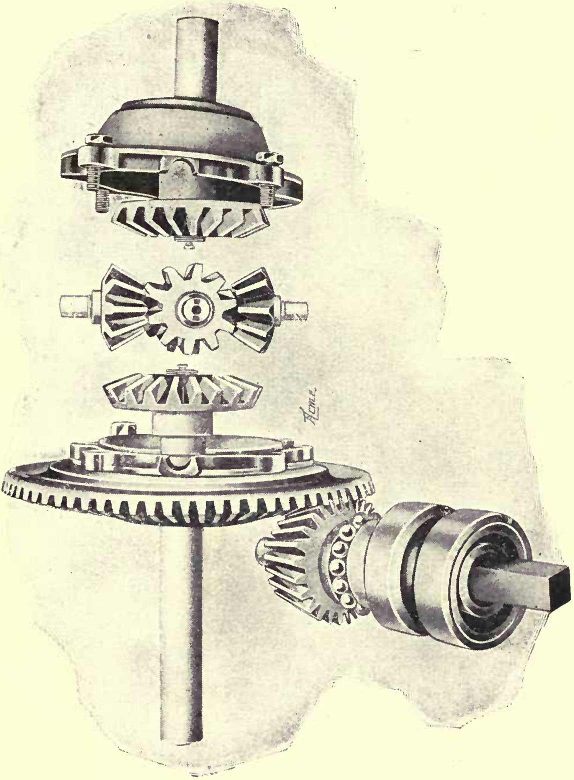

FIG. 11.—DIFFERENTIAL GEAR.

this latter being pivoted and carrying an arm. This arm is connected up to one of the steering axles by means of a jointed rod. The two axles being, as aforesaid, connected together, it is evident that, when the steering wheel is turned, the screw or worm will cause the quadrant arm to push the connecting-rod backwards or forwards, thus conveying the motion to the two wheels. Our Fig. 12 will give a clear idea of the construction of the steering arrangements.

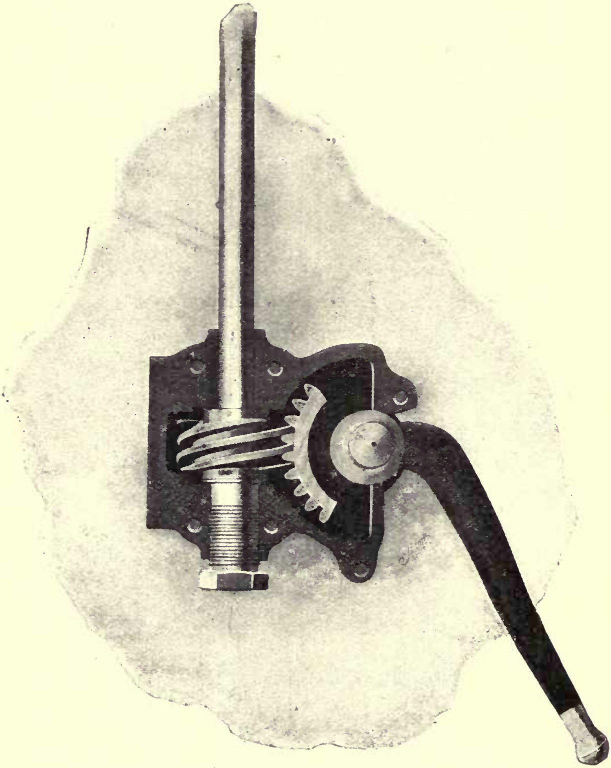

FIG. 12.—DARRACQ STEERING GEAR.

It will be noticed that this system is quite irreversible, so that road shocks cannot affect the position of the wheels. Consequently, the steering is perfectly under control of the driver, with a minimum of exertion on his part. The mode in which the movable ends of the axle are strongly connected to the rigid central portion is well shown at the two sides of Fig. 13.

The position of the water tank, of the petrol tank, and of the carburetter, is largely a matter of convenience; in any case, easy access should be obtainable to the mechanism by opening in front, or otherwise. The radiator, of which we give an illustration at Fig. 13, is usually placed in front, and is kept cool, not only by the circulation of water (either natural or artificially driven by a small pump), but also by the rush of air through the honeycombed surface of the radiator, sometimes assisted by a draught created by a rotary fan. Besides these essential portions, every motor car is furnished with a removable cranked handle, by means of which the engine can be started by hand without driving the road wheels, until it has drawn the exploded mixture from the carburetter into the cylinder, and fired a charge or two (the road wheels having been previously thrown out of gear with the engine by moving the clutch handle into the neutral position); after which it can be allowed to do its work automatically, and the road wheels thrown into gear when required.

In the foregoing description we have only mentioned a single-cylinder engine; the reader must, however, be prepared to meet with many cars that are furnished with two, four, or even six cylinders. In these cases there is no particular difference in the construction of each cylinder (which are generally cast in one case), except only that the cranks, which

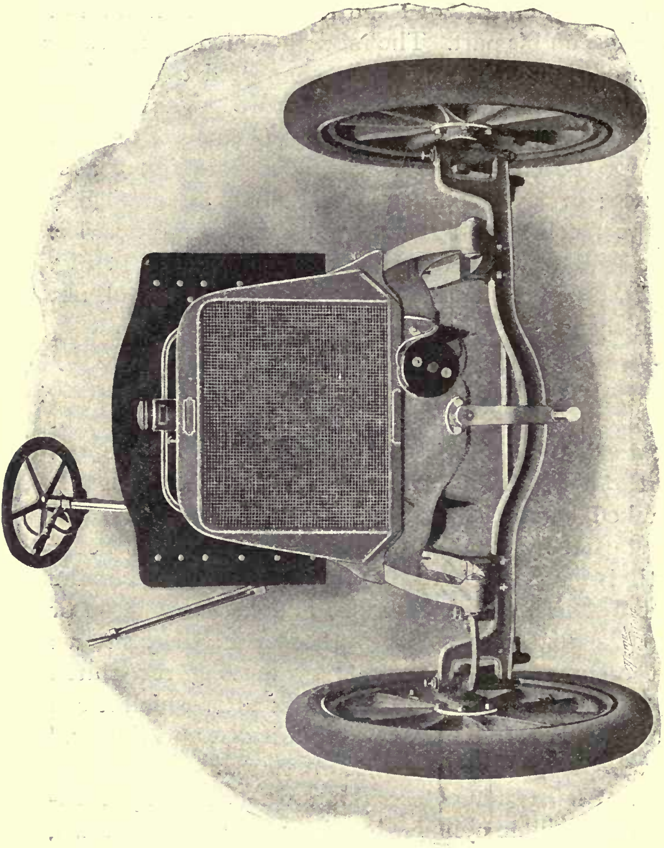

Fig. 13.—Showing Honeycomb Radiator, Steering Wheel, and Swivel Joints of Front Wheels.

are connected to the fly-wheel, are usually placed at such an angle that they receive the impulses of the explosions, not simultaneously, but at different portions of their stroke. This is effected by setting the cranks at an angle of 180° from each other. By this means a very good balance is obtained; and the explosions, or impulses, follow one another in quick succession. In the case wherein two pistons move in the same direction simultaneously, it is not so easy to obtain a good balance. At Fig. 14 the reader will find an illustration of a single-cylinder engine of the Darracq type.

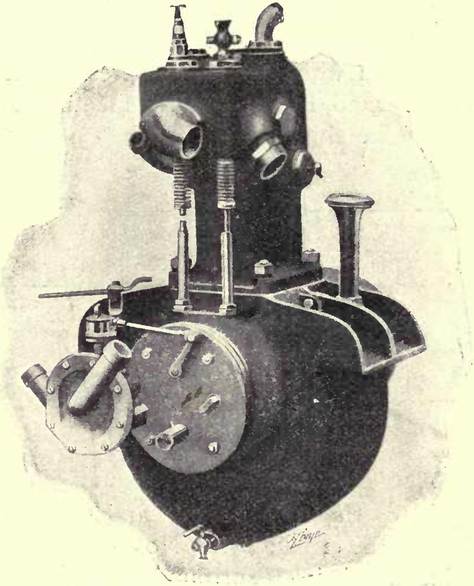

FIG. 14.—8 H.P. SINGLE-CYLINDER MOTOR.

Although not essential to the efficient working of a petrol or gas engine, a device intended to minimise the noise made by the out-rush of the exploded mixture, and, therefore known as a "silencer," is now universally adopted. The scope of the silencer is to lower the pressure of the escaping spent gases before they come into contact with the outer atmosphere. For this purpose the "exhaust" gases are led from the engine into a chamber or box, generally of steel or aluminium, in which the initial pressure at which these were ejected, is reduced by meeting with resistance. In the simplest form, Fig. 15, the silencer consists of two tubes—the inner and smaller one of which fits on the exhaust (see No. 28 of Figs. 1 and 2) of engine, and is itself surrounded by a second and larger tube, closed at both ends. Both these tubes are perforated round their sides with numerous small holes, and it is in passing through them that the exploded gases meet with resistance, and consequently become reduced in pressure. The greater the pressure at which the exhaust gases issue, the more noise will be made by their impact with the air. Hence, in all good silencers, every precaution is

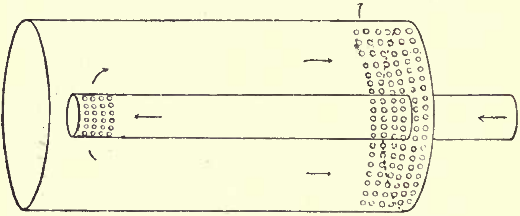

FIG. 15.—SIMPLE SILENCER.

taken to reduce the pressure quickly, and, at the same time, not to produce "back pressure," which would greatly militate against the proper working of the engine. Few people are aware of the enormous influence the silencer may exert in this direction. In one of the latest forms of silencers, the spent gases, after leaving the exhaust, enter by a perforated tube into an hour-glass-shaped receiver, from the further end of which they pass through numerous perforations into an outer cylindrical casing, whence they finally issue at the same end, but on the *outside* of the tube by which they originally entered. Fig. 16 is a section of this, the "Universal" Silencer.

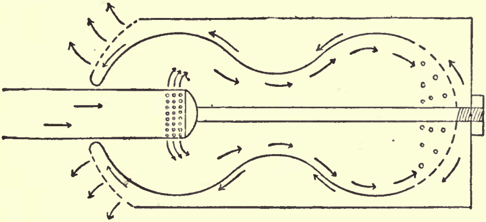

FIG. 16.—UNIVERSAL SILENCER.

The only point that now needs notice is that connected with the brake, by means of which pressure can be brought to bear either on the wheels themselves, or on the differential, so as to assist in checking the motion when it is required to stop the car. The brake gear varies with different makers. In some cases it takes the form of a band which is tightened round a drum forming part of the axle, either in continuation with the change-speed gear, or with the differential. This latter plan is not particularly recommended, as it may strain the differential itself. Or it is effected by means of what is known as the expanding clutch, in which a pair of metal segments of a circle, united together at one extremity by a pin, so that they can open out somewhat like the legs of a pair of compasses, are caused to expand and press against the inside of a drum, under the action of an oblong piece of metal pressing near the joint, by the influence of the brake handle or pedal.

A word or two as to the series of operations to be executed in starting the car may not be out of place here. The petrol and water tanks must first be filled, the former with good petroleum spirit having a sp. gr. of 0·68 at 60° Fahr., the latter with clean, preferably soft, water. The ignition apparatus, be it coil and accumulator, or magneto and its attachments, should be then looked to, especially as regards good and clean contacts. When an accumulator is used, its electrical condition must be ascertained, and the E. M. F. of each cell carefully measured by voltmeter. It should show 2 volts per single cell, or 4 volts for the usual double-cell form, and must not be allowed to fall below 1·9 in the former, or 3·8 volts in the latter case, without re-charging.

When filling the tank with petrol, a funnel with a fine gauze filter should be used, to prevent any particles of dirt from passing in with the petrol. In the absence of fine gauze, a piece of very fine linen may be employed. The radiator is now to be filled with water through the top cap. Before starting up, it should be seen that the change-speed lever is in the neutral notch, that the hand-brake is "on": and that the petrol tap is open. The main switch should then be turned "on," and the "timing" lever moved to its fully-retarded position, so that the ignition will occur immediately after the cranks have passed the inner dead centre, and no risk will be run from back-firing. Afterwards, the starting-handle (crank) is taken in the right hand and pressed inwards towards the motor, turning the handle from bottom to top, clockwise. This motion is continued steadily, but not necessarily with any great expenditure of energy, until nearing the top, and, at this instant, the movement of the crank is accelerated, in order to cause the crank-shaft to pass quickly over the upper dead centre. The motor should then start. This acceleration is usually followed by the automatic withdrawal of the crank-handle as the crank-shaft runs ahead of the engaging.

Should the motor not start, lifting slightly for a moment the float-needle so as to "flood" the carburetter, and, if necessary, putting a few drops of petrol in each cylinder through the compression taps, will remedy the defect. As soon as the motor turns, it is well to make sure that the water circulation is working properly, and that the lubricator is correctly adjusted to give the required feed of oil. The driver then takes his seat, holding the steering-wheel in his left hand and depressing the clutch-pedal with his left foot. He then brings back the brake-lever (which had been applied), and changes over the change-speed lever from the neutral notch to the first-speed notch; if a slight resistance be felt, he should not attempt to force the lever, but should allow the clutch-pedal to rise slightly for a moment, fully depressing it again, and the lever can then be slowly moved into the notch, easily and noiselessly. Then he gradually lets in the clutch.

To pass from one speed (gear) to a higher one he will always begin by de-clutching, then move the lever up one notch and let the clutch in gently, as before recommended. To revert to a lower "gear," he should never attempt to effect this until the car's speed has fallen almost to the one desired. In ascending a steep hill, a lower gear should be brought into play as soon as the car shows any decided tendency to slow down. Under ordinary circumstances the speed of the car is controlled solely by regulating that of the engine, or, when slowing down for traffic, by simply de-clutching. In other cases when a quick stop or a rapid slackening of speed is necessary, besides de-clutching, the brakes should be used. The clutches should be always let in gently. To pass from the forward motion to the reverse the car should always be brought to a complete standstill and the change speed lever be brought back to the neutral notch before any attempt is made to introduce the reversing gear. For a sharp stop, both brakes should be applied. On a long descent, or in cases in which the brakes have to be used for some time, they should be used alternately to avoid heating. In preference, the hand-brake should be used, which, as it acts directly on the back wheel, does not strain the differential.

At the conclusion of a run the driver should make an invariable practice of seeing that the hand-brake is applied before he leaves the seat, and that the change-speed lever is quite in its neutral notch. He should then stop the motor by turning off the switch, and should close the petrol feed-tap. It is always advisable at the end of a day's run to clean the inside of the cylinder. For this purpose the compression taps should be opened, and in them a spoonful of paraffin should be poured. The motor is then gently turned until no more vapour from the paraffin leaves the taps. By this means any sediment liable to clog the piston rings is dissolved away.

If the engine does not start after the crank-handle has been turned as above described, and fails to do so after two or three attempts, it is probable that the proportions of air and petrol vapour in the explosive mixture are not correct, or that the ignition apparatus requires attention. The explosive mixture can be adjusted by altering the position of the air and vapour levers until the motor fires regularly. The alteration in the supply of air and of vapour must be done carefully and gradually, as a very little makes a vast difference in the result. It is quite worth while to try the effect of making alterations in the quality and quantity (richness in petrol vapour) of the mixture, as the experience gained by such a procedure is far more valuable than any amount of theorizing. Of course, in all motors fitted with automatic regulation of air and petrol in the carburetter, the above precautions will hardly ever be required. The car should always be started slowly, remembering that the speed can be slackened by closing the throttle valve, and that the ignition should be advanced for high speeds or retarded whenever the engine is running more slowly, from whatever cause.

The following excellent hints, based on those drawn up by J. W. Packard, embody the chief points to be attended to and avoided in motor-car driving: "Do not forget to turn on the petrol and spark before attempting to start. Don't forget to turn oil on, and to close any half-compression device that may be fitted to the engine after starting. Don't try to run the carriage without oil in any of the oil-cups. Don't try to run without petrol in tanks. Don't leave your car with water in the tank or jackets in frosty weather. Don't jerk in your clutch; bring it up gradually. Never let the engine knock. Don't start down a hill at a rapid rate and then jam on the brakes. Don't try to turn corners rapidly, particularly if the brakes are on. Don't forget to turn off all lubricators when shutting down. Don't tighten clutches so that they drag or bite. Don't neglect to turn off petrol at night. Don't take anything to pieces unless it is absolutely necessary, and, even then, without noticing how it is put together. Don't neglect to keep all contact points clean. Don't allow any bellhanger or cycle repair man to add 'improvements' to your car. Don't use cheap or poor lubricating oil. Don't let your engine 'race' at any time, or run at an excessive speed when using low-speed gear. Don't leave your car unattended with engine running. Don't leave your licence at home. Don't expect that all you have to do is to pull the lever; learn to understand thoroughly the mechanism and adjustment of your machine."

Lubrication is a very essential point in the working of a motor-car. We have already pointed out how the smaller bearings are automatically lubricated by the "splashing" of the crank in its travel—

oil being supplied by means of holes drilled for this purpose into the studs connected with these. The oil is injected into the crank case at intervals, and is carried in a container fixed on the dash-board of the car. A pump is combined with this, and, by this means, a charge of oil can be injected into the crank case when required. In many cars an automatic device supplies the oil from the tank, or container, into a number of tubes leading to the engine, bearings, pumps, etc., the oil being forced up a tube in the centre of the container by means of pressure from the exhaust box. The oil used for these smaller parts must be of a thinner nature than that employed for the gear boxes and heavier gearing, and should flow freely.

The nature of the oil to be used will vary with the parts to be lubricated ; as a general rule, we may say that the thickest mineral (hydro-carbon) oil that will *flow freely* will be the most advantageous. The tendency with motor drivers at the present day is to use a thin oil. For water-cooled motors, an oil of medium viscosity, which will stand a fire test of 470° Fahr. without charring, will be found generally useful. For gear boxes, a heavy black hydro-carbon oil, standing a fire test of 400° Fahr. will be found most suitable. By "black" we do not mean dirty oil, but simply the natural dark colour of the oil. Many drivers use semi-solid lubricants in the gear boxes ; to this there is no objection, provided the lubricant can find its way to the parts at which lubrication is needed, as a semi-solid lubricant has the advantage of preventing the entrance of dust, dirt, and grit, to the bearings. It must be remembered that the gear boxes must be real "oil baths," so that the gear wheels themselves dip half way into the oil. Many employ, for this latter purpose, lubricants containing finely-divided graphite or plumbago, and this, except for the difficulty of application, is an ideal lubricant. As it is, in the case of a bearing or piston which has got slightly injured through want of lubrication, it is perhaps the only thing that will bring the surfaces back again into good condition.

Most careful attention must be given to timely lubrication of the engine, and the container should be replenished at intervals of not more than an hour, or an hour and a half of actual running time. On the other hand, the lubrication, especially with lighter oils, must not be overdone, though, with well-constructed engines, precautions are taken to prevent any surplus oil finding its way into the combustion chamber.

In the choice of a car, the following points require careful notice. There should be as few moving parts as is consistent with obtaining the movements desired. All machinery should be easily accessible. Water tank, water circulation, or other means of cooling should be ample; lubrication also readily effected. A very important part is that all portions should be interchangeable, and be capable of being supplied by the maker of the car. Lock-nuts should be of the helicoidal type. The machine should be strongly built so that repairs may limit themselves to the replacement of worn or damaged parts. Wherever there are wearing parts, provision must be made that the wear may be readily taken up by the users. With regard to the engines proper, the best result is obtained by fitting these vertically—horizontally placed engines being almost entirely discarded. An engine requiring to run at an excessive speed to give its listed power, should also be avoided ; most modern motor-car engines give their normal output at an average speed of 1,800 R.P.M Ribs in cylinder covers not only strengthen the same, but help to dissipate the heat by radiation. The silencer should be chosen to work as noiselessly as possible, consistent with not producing any appreciable back pressure.

A governor which automatically reduces the speed of the engine when the car is stopped, is a great convenience. If too much complication be not introduced in effecting the result, that type of lubrication which automatically cuts off the supply of oil when the engine comes to a standstill, is desirable. The amount of petrol used will naturally vary not only with the power of the engine, but also with the amount of work put upon it. We have purposely omitted any detailed description of the timing apparatus used in connection with the electrical firing device employed for the purpose of igniting the gaseous mixture supplied to the combustion chamber by the carburetter. This, as we have already noticed, consists in a fibre disc actuated by the half-speed shaft (see Fig. 1, 26) ; and we shall reserve fuller description until we treat of the different forms of electric ignition which constitute the subject of our next chapter.

We can hardly conclude this chapter without some notice of those combustion engines which are specially adapted either for stationary work or for the driving of launches. In these it is convenient to be able to use a cheaper hydrocarbon than petrol, and, in the case of launches, very much safer. There has, therefore, naturally arisen an urgent demand for an engine using paraffin or other safe heavy oil, in as satisfactory a manner as petrol; and this demand has been rendered greater because petrol is costly when used in the quantities required in a motor boat; wheras paraffin is cheap, and moreover, easily procurable. Its drawback, however, lies in the fact that an engine cannot be started on it when all is cold, and it usually becomes a question of heating a vaporiser by a blow-lamp, or running on petrol until the exhaust gases have heated the vaporiser. The former method means that starting cannot be effected immediately, as with petrol; and this, under certain circumstances, may, in a boat, lead to serious consequences. Many engineers have been engaged on solving this problem, and we have selected as an illustration of the manner in which this difficulty can be overcome the Parsons' engine, not because it is the only one of its kind, but because it is typical of all that is best in the fulfilment of the requirements of the case. It will be borne in mind that such engines are not required to run at *high speeds*, but are intended for *long runs* at full power, and, therefore, the Parsons' engine is not to be classed with the light motor-car engines using petrol only, and running, for the most of the time, throttled down.

In the first place, no external vaporiser is used, nor is any lamp used for starting, so that there is no possibility of its blowing out, or ejecting burning oil, or requiring cleaning. To start such an engine, of which we give an illustration. in section, at Fig. 17, a

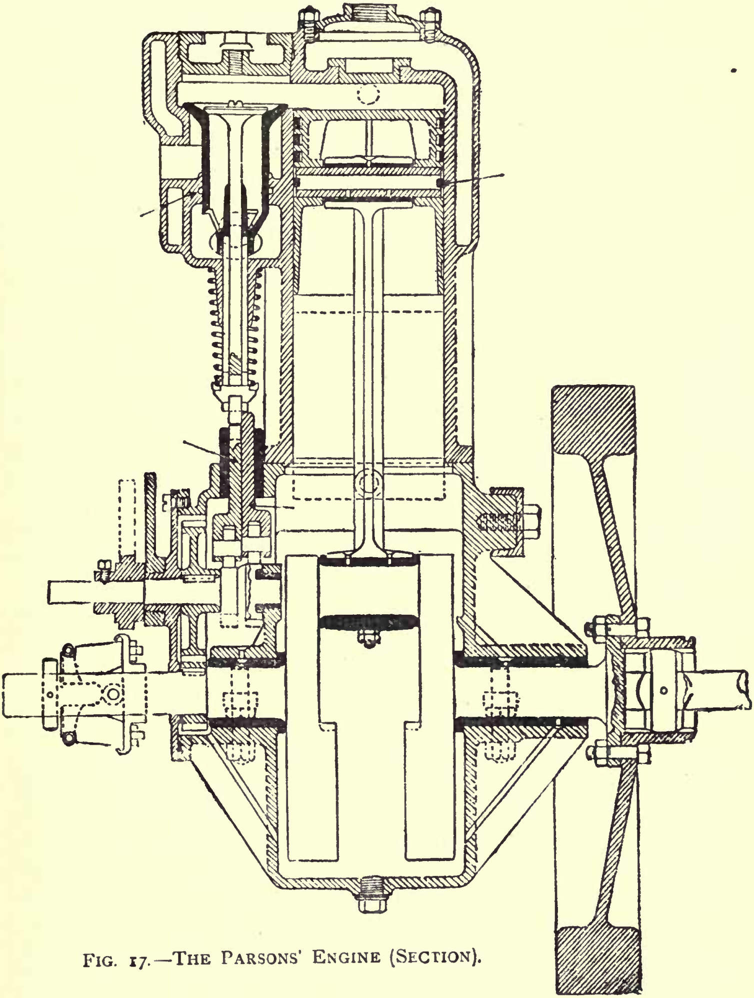

FIG. 17.—THE PARSONS' ENGINE (SECTION).

little petrol is used in the carburetter, not necessarily more than the float-chamber full ; and this is arranged for, either by fitting a small filler to the carburetter, or by connecting a small tank to the two-way cock. The former plan does away entirely with the petrol tank and accompanying pipes, and there is then only paraffin connected with the carburetter ; the latter plan affords the advange that the engine can be run on either fuel, as desired. If a filler is used for starting, then a portable air-tight can is provided, holding enough petrol for, perhaps, a dozen starts, and filled as required. Alcohol fuel, or any mixture of fuel, may be used instead of paraffin, and in the same way. In all cases, the fuel is used through the same carburetter, which is of the ordinary petrol type, and not what is known as the paraffin carburetter, requiring heat for the vaporisation of the fuel. After starting on petrol, the paraffin, or other fuel, is turned on, and the engine continues to run with no more smoke or smell than with petrol. Sometimes it is necessary to alter slightly the feed adjustment to the jet of the carburetter according to the fuel used, by means of the adjustable needle valve , but, if set for one fuel, it need not be altered for starting on petrol.

Referring to the section of the engine here shown, it will be seen that the valves are combined, and that the exhaust valve is seated upon the hollow tubular inlet valve. The exhaust, in passing through the latter, heats it up and emerges through ports at the bottom of the valve, and away out at the exhaust connection. The paraffin is vaporised , but only the moment before it enters the cylinder. When using paraffin there is no vaporisation in the carburetter, and no additional heat required for it; and, therefore, there can be no subsequent recondensation in pipes between the carburetter and the inlet valve, nor can any liquid paraffin reach the combustion chamber. The vaporisation is perfect, and the amount of heat such that no prejudicial effect is noticeable even if the engine continues to run on petrol. In the latter case, warm air from near the exhaust pipe is supplied to the carburetter; but with paraffin this warming is not necessary. Both valves are mechanically operated by separate cams; but while the exhaust valve has full lift, the inlet valve, owing to its large area, has about half the lift as the exhaust, yet the opening is the same, owing to its large diameter. No extra work is put upon the cams and rollers, as the large valve lifts on the suction-stroke only. One spring, cotter, and washer, closes both valves; and, on the exhaust stroke, the inner valve only lifts, whilst on the inlet stroke both lift together—the exhaust remaining seated upon the inlet. All gear-wheels are enclosed, and there is only one cam shaft. The crank chamber can be taken apart without disturbing the crank shaft, etc.; and in all sizes, except the "single cylinder," the supporting arms are in one with the lower half of the crank chamber, which thus forms a bed-plate and avoids anything getting out of line if the engine is separated for adjustment. In all models of the Parsons' engine, a universal joint is provided for connection to a propeller shaft, thus allowing a vertical engine with a raking shaft. We may also mention that, up to the 28 or 32 h.p. engines, the crank shaft is carried by the upper half of the crank chamber, so that this, along with the cylinders, piston, crank shaft, etc., all come away together, thus avoiding drawing pistons out of cylinders.

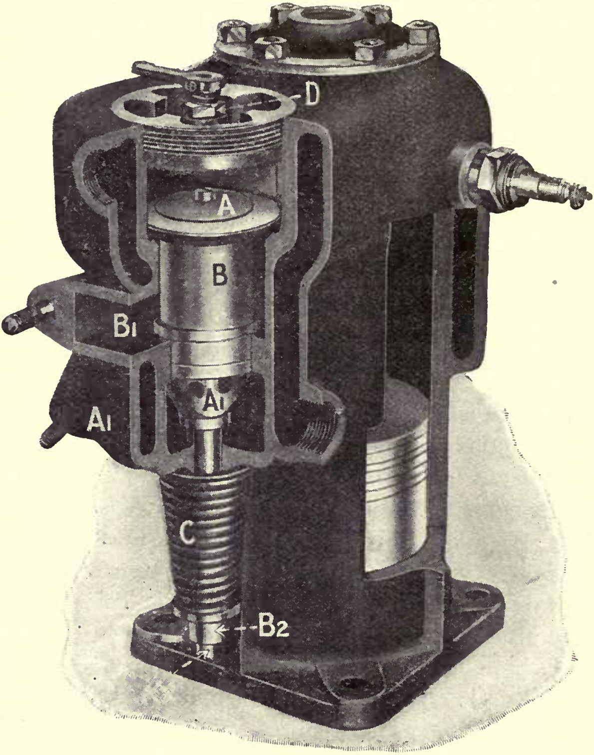

FIG. 18.—THE PARSONS' ENGINE. (POSITION OF VALVES ON THE INLET STROKE.)

Ample water space, easily cleaned out, is provided round cylinder and valves—the water being supplied by a pump, as usual. The lubrication is automatic in all parts. The exhaust branch pipe in the multi-cylinder engines is arranged to allow for its expansion when hot, so as not to force the cylinders out of line,

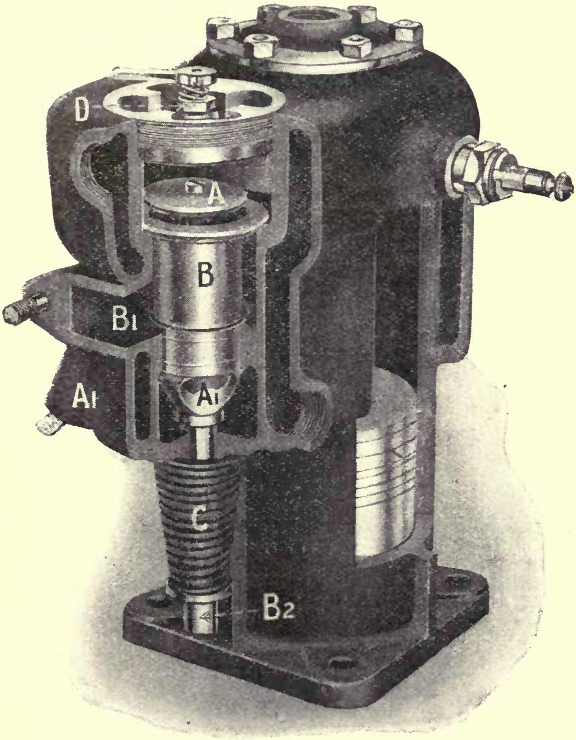

FIG. 19.—THE PARSONS' ENGINE.
(POSITION OF VALVES ON THE EXHAUST STROKE.)

and all connections are so designed that any one cylinder may be removed easily without disturbing the others.

Ignition is usually arranged by battery and coil; but, if desired, a "Bottone" enclosed dynamo or magneto can be fitted, driven by the engine, and so connected that the engine starts on the battery, runs on the dynamo, and, at the same time, keeps the accumulator charged—the dynamo furnishing low tension current to the coil in the same way as the battery. This is a simple and reliable duplicate ignition, which has stood the test of time, and has none of the drawbacks of the usual low or high tension ignition; whilst, should the dynamo break down (a very unlikely thing), there is always the battery to fall back upon. With regard to the oil consumption, from trials recently made, it was found that about four-fifths of a pint of paraffin was used for each brake-horse-power hour; and, in the reliability tests, in which a Parsons' boat gained the highest mark —only fifteen gallons of paraffin were consumed in as many hours when running at about ten knots, which gives about a farthing's-worth of paraffin for a nautical mile.

CHAPTER II.

Various Methods of Ignition.

EVER since the advent of the gas-engine, and of its congener, the "oil-engine," much ingenuity has been displayed in the construction of suitable contrivances for igniting the explosive mixture. It will be evident, on the slightest consideration, that the conditions to be fulfilled will necessarily vary with the varying circumstances in which the engine is to be employed, and that an igniter which would be eminently suitable for a stationary gas-engine might be quite inapplicable to a portable petrol motor forming part of a motor-car, or of a motor-bicycle. As so much interest has of late been evinced in this subject, we make no apology for presenting the following epitome of the more important devices in use for this purpose, with a few remarks as to their fitness or unsuitability for certain particular requirements.

In the very earliest commercially successful gas-engine—that of M. Lenoir (1860)—the means adopted for firing the explosive mixture was an electric spark. As in this engine no attempt was made to secure compression of the gaseous mixture, no particular care was taken to *time* the spark. As the piston advanced it drew in an explosive mixture of gas and air, and about mid-stroke this was ignited by an electric spark.

In the Otto and Langen engine (1867), in which also there was no compression, the ignition was effected by a small gas flame, to which the gaseous mixture gained access at the desired moment through the action of a special slide-valve, which opened and closed a port-hole facing the gas flame. In the Otto engine of 1876 *compression* was adopted, and the compressed mixture was fired just when the forward stroke was about to begin, by means of a slide-valve alternately uncovering and covering a hole facing a small gas flame. In the "Priestman" petroleum engine, electric ignition, in the shape of sparks generated by an induction coil, was the means first adopted; the slide-valve being the same as in the Otto.

In more recent forms of stationary oil-engines the ignition is effected by a flame produced by a blow-through oil lamp, of the "Ætna" or "Primus" type, but this lamp itself requires frequent attention to keep up the supply of vaporised oil on which its own flame depends. For all stationary work no form of ignition is perhaps so satisfactory as that adopted by Crossley Bros., in which a tube, either of porcelain or of a suitable metal, is kept nearly white-hot by a Bunsen flame playing in its interior.

Neither tube nor direct flame ignition lends itself readily to small petrol motors, such as are usually adopted in motor-cars, tri-cars, and bicycles; and for these electric ignition presents many advantages. The means employed for igniting by electricity are various:—Firstly, maintaining a thin platinum wire (placed close to the slide-valve) in a state of incandescence by the current from a battery. Secondly, producing, by the aid of a coil and battery, a continuous stream of sparks before the slide-valve. Thirdly, the production with the coil and battery of sparks between the platinum points of an igniter, which is inserted in the explosion chamber of the engine, the time at which these sparks take place being controlled by a cam, or other device that makes (or breaks) the circuit at the required instant. Fourthly, the production of sparks directly from a magneto-machine, or from a dynamo driven by the motor itself. Fifthly, producing sparks from a composite machine called a "dynamo-coil,"[1] in which the field-magnet and its winding form at the same time the core and primary of the sparking coil, which therefore admits of accurate timing of the spark by interrupting the circuit in the primary. Of these the first may be dismissed from further consideration, since it is very difficult to maintain a platinum wire at the point of incandescence by the battery current without either fusing it, if the current exceeds the normal, or allowing it to become too cool if the current falls below that point. Besides this defect the platinum wire is very apt to become encrusted with unburnt carbon derived from the gas. The fourth method is open to the objection that efficient sparks are produced by the magneto (or dynamo) only when the speed at which it is driven reaches a certain point; and, moreover, that when that speed is increased, there is considerable risk of breaking down the insulation of the generator. These objections have not much weight when the engine is stationary, running at a practically constant speed; but they become serious in cases of motor-cars, or any other vehicles in which the speed is liable to sudden variations. We are, therefore, driven to the conclusion that coil ignition in some form or other is the best for general purposes. It may be pointed out here that even in the case of stationary engines electric ignition is superior to any form of flame or tube, as it economises gas or vapour.

Whatever form of coil be adopted (with the sole exception of the dynamo or magneto and coil and its modifications) a battery must be employed in conjunction with it, to supply the current necessary to cause it to produce sparks. Now, it is just at the battery that all the troubles begin. In stationary engines it is a nuisance to have to replace dry cells, or to dismount and remount primary cells of any kind. The former quickly fail to give sufficient current, and must be replaced; the latter more gradually, but just as surely, lose power, and must be renovated. The only battery that can be depended upon to give a sufficiently equable current for any length of time is an accumulator of fairly large ampere-hour capacity. This is really the best—we might say the only satisfactory—source of current which can be used for working the coil. But the accumulator must be recharged. This is not a serious matter in the case of stationary engines, where access can be had to a charging station, or where a portion of the power of the engine can be diverted from the general work to drive a dynamo from which a spare accumulator can be charged. But when we come to deal with accumulators to be fitted into petrol-engined launches, motor-cars, or motor-bicycles, in which so much depends on the condition of the accumulators, and when it is frequently impossible to have recourse to a charging station, some means of maintaining the accumulator charged to a working point becomes a matter of the highest importance.

We can now pass to the consideration of the requirements in a dynamo suitable for stationary gas or petroleum engines. Circumstances only can decide whether it will be more convenient to allow a portion of the spare power of the engine to be employed continuously for the purpose of keeping the accumulators charged, or whether a certain time in each day shall be set aside to attain this end. In the former case the dynamo must be fitted with some automatic device (called a "cut-in and cut-out") which shall break the circuit between the dynamo and the accumulator whenever the dynamo gives less than the required charging voltage, and shall complete the circuit when the voltage reaches the necessary point. The automatic cut-in and cut-out is an absolute necessity in all cases in which the engine is subjected to variations in speed, due to different loads being put on it. In the case of a certain time each day being set aside solely for charging, the employment of the cut-out, though convenient, is not imperative, since the dynamo attendant, by keeping his eye on the voltmeter, can immediately switch out the dynamo if he finds the voltage falls below the necessary 2·5 volt per cell.

It is hardly necessary to remark that whatever type of dynamo be employed it must be *shunt* wound, or, if *compound*, the shunt coils alone must be employed. *Series* wound machines and *alternators* are of no use for this purpose. The particular type of machine is of no great moment; ring and drum armatures are the best, but the outward form, all other things being equal, is of some importance. In large establishments in which the dynamo can be kept away from the general workshops, any good dynamo, whether open or enclosed, is admissible, and in fact the open type presents some advantage in allowing easy access to the brushes for regulation. But in all cases in which dirt or dust is present in the dynamo-room the machine should be of the enclosed type. We do not mean by this that the dynamo should simply be enclosed by a covering, whether of wood or of metal; but that its construction should be such that the entirety of its working parts (with the exception of shaft and driving pulley) should be enclosed in *iron*, this iron forming an active portion of its field-magnet system. The first real iron-clad dynamo was devised by Mr. Tighe in 1882. In this a single wound pole arose from the centre of an iron cylinder, the top of the cylinder being dome-shaped and forming the other pole of the dynamo, the armature playing between the central pole-piece and the dome. A very similar pattern, excepting that the cylinder terminated in a circular cap, was designed by Mordey for the Brush Company. This form has been largely adopted by more recent makers as being at once efficient, compact, and having its working parts fully protected by the massive outer iron cylinder or case.

The exterior form of the enclosed dynamo is evidently not of so much moment as its adaptability to the varying speeds to which it may be subjected. In the earlier types of enclosed dynamos, dating, as we have seen, from about 1882, and applied principally to keeping up the charge in accumulators for stationary engines, neither the question of weight nor the capability of self-adaptation to great and sudden variations in speed were of paramount importance. But, with the advent of the automobile, it became imperative that the dynamo should be at once light, compact, efficient, and capable of being driven at greatly different rates, without either injuring the accumulators, which it is destined to charge, or risking the breakdown of its own insulation. It is difficult to unite in one machine all these requirements. If the dynamo be very small, and contain but little iron, it must be driven at a high speed, and must be wound with fine wire, and this fine wire presents resistance to the current, which results in *heating*. To be efficient, the dynamo must have a certain amount of iron in it, duly proportioned to the wire on the armature and field-magnet system. This means that all the *metal* parts of the enclosed dynamo should, as far as possible, be of iron, and that this iron should form an active portion of the field magnet and armature. This, of course, does not apply to the armature conductors, nor to the F.M. coils which are, in all modern machines, of copper.

By carefully proportioning the machine it is possible to construct an enclosed dynamo, weighing about 6 lbs. to 8 lbs., which shall be well able to charge the four-volt accumulators usually employed in motor cars, etc. If the machine take the form of an upright cylinder, or even a square box, with, of course, the contained upright field-magnet core and armature, it is possible to construct it so that no electrically useless metal is used except that for the bearings, the brushes, and the lubricator. But this leaves untouched the question of *speed variation.* As far as injury to the accumulator is concerned, this difficulty can be got over in several ways—such as, for instance, a hand-governed resistance, more and more of which can be switched in when and as the speed increases. Or an automatic cut-in and cut-out can be adopted, which shall complete the circuit when the speed attains a certain point, and break it again if it exceed a given range, to remake it when the speed falls to within the "safe charging limit." But an automatic cut-out is rather delicate in its action, and the jolting and trembling of the motor car is not conducive to its satisfactory behaviour. Neither of the above-mentioned devices, nor indeed anything external to the dynamo, can prevent injury to this latter if the speed be greatly in excess of the normal. But it is possible to control the output of the dynamo by altering the strength of its magnetic field, and this can be done automatically by cutting out more and more of the field-magnet coils as the speed increases, or, what amounts to the same thing, automatically inserting a dead resistance in the field-magnet circuit when this occurs.

Having pointed out the requirements for electric ignition, we will proceed to describe briefly the more successful appliances that have been employed for the purpose. The first device (apart from the coil) which was used was a modification of Breguet's "torpedo exploder." In this, a soft-iron armature was hinged in front of the poles of a powerful compound permanent magnet, the two limbs of which were coiled with fine wire. On striking a lever attached to the armature this latter was suddenly removed from its proximity to the poles of the said magnet; returning after the stroke by the action of a spring in connection with the lever. This sudden motion of the armature, by setting free the magnet's lines of force, induced a current of high E.M.F. in the coils surrounding the magnet's limbs, which current was led by suitable wire to the slide-valve opening, or to the ignition plug of the engine, where it produced a spark. The lever was actuated by a cam on the half-speed shaft of the engine itself.

In order to facilitate a clear conception of the manner in which the electric current is set up by means of magnets, be these permanent, as in the case of "magnetos," or temporary, as in dynamos, it will not be out of place here to refresh the reader's memory by stating the fact, that around the poles of every magnet (be it permanent or temporarily energized by the circulation of an electric current) there exists a space, permeated by the magnetic force, exerted by the magnet; this space is called "the magnetic field," and the directions in which this force is manifested are known as "the lines of force."

It must be distinctly understood that these terms are merely convenient methods of expressing our views, and that there are no more tangible *lines* of force emanating from a magnet than there are "rays" of light emanating from a candle. Still, a very good idea may be obtained of the direction and distribution of the magnetic force round a magnet's poles by laying a sheet of white paper over the poles of a horseshoe magnet, and lightly sifting on it some fine iron filings, which, on gently tapping the paper, will be seen to arrange themselves in positions indicating the distribution of the magnetic force, but in one plane only.

Now it is found that if any conductor be moved between the poles of a magnet so as to "*cut*" these imaginary lines of force, a current of electricity is set up in the conductor, which current will vary in strength in accordance with the number of lines cut in a given time. In like manner, if a conductor, previously shielded from the action of a magnet's poles (by means of an iron screen or otherwise), be suddenly exposed to their action by the removal of the screen, a current is momentarily set up; and again, another current (in the opposite direction) is elicited if the shielding screen be as suddenly replaced. In order to "cut" the lines of force, it is evident that either the conductor or the screen must be *moved*; and as rotary motion is the most convenient in practice, it is usual to arrange the conductor (or conductors) *lengthwise* round the periphery of a cylinder of soft iron, mounted on a spindle, and capable of being rotated. Such an arrangement is known as an "armature." A typical view of an armature, with a single turn of wire (conductor) passed lengthwise over and under it, is shown at Fig. 20. This is illustrated as lying between the extensions N S (known as "pole-pieces"), of a horseshoe magnet. The shaded parts indicate the magnetic lines of force; the arrow shows the direction of rotation imparted to the armature; while the letters P (positive), N (negative), denote the electrical conditon of the conductor, A B, in different portions of its travel. From this it will be seen that, on starting from the top of the figure, and moving counter-clockwise towards the north pole of the magnet, the conductor, A, at first practically cuts no lines of force, but simply glides between them ; but as it continues its travel, it cuts an increasing number of these lines, until it has travelled through 90° of arc, when the maximum number of lines is reached. This is also the point where the electro-motive force, and therefore the current set up, is at its highest. Continuing the motion, the number of lines cut and the current resulting therefrom decreases, until on arriving at 180° no lines are cut, and therefore no current is evolved.

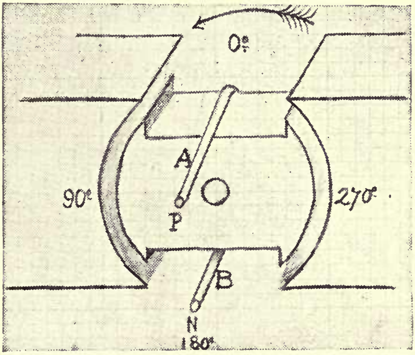

FIG. 20.

The observant reader will notice that the electrical condition of the extremity, A, of the conductor, besides rising and falling, while it passes from 0° to 180°, changes from *positive* to *negative* as it commences its upward journey from 180° to 360°, owing to its cutting the lines of force *in the opposite direction*. This means, that if we collect the current evolved at the extremity, A, of the conductor, during one entire revolution, we shall find it change direction at each semi-revolution. In practice, for ignition purposes, it is immaterial whether the current delivered by the armature be unidirection or alternating, so that usually the extremity, A, of the wire, or conductor, is connected up to an insulated metal ring on the spindle, while the opposite extremity is fastened bodily to the iron cylinder of the armature itself, through which it can complete the circuit through the frame of the engine, cycle, or car. Also, as the electrical effects are exalted in proportion to the number of conductors cutting the lines of force, armatures are not fitted with a single conductor, but are channeled out longitudinally; and in the channel is wound several hundred turns of wire—the starting and terminating extremities of which are brought out and connected as described above. A complete armature, wound with wire longitudinally in the

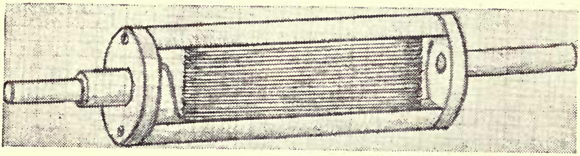

FIG. 21.—H OR SHUTTLE ARMATURE.

channel—usually bound to prevent the wire rising by centrifugal tendency—is shown at Fig. 21, where the brass caps or "heads," to which the spindle is affixed, and which bear the the insulated ring connected to one extremity of the armature wire, are also depicted.

The current produced is picked up, on the one side, by the frame of the engine, and, on the other, by a spring or "brush" which presses against the insulated ring. If, instead of using a continuous ring to collect the current, a number of separate segments, each insulated from its neighbour, be arranged in an annular form on the spindle, and the opposite segments be connected to the opposite extremities, A and B, of the conductor, or conductors wound on the armature, it is possible to collect, by means of two insulated "brushes" pressing against the opposite sides of this segmental collector, or "commutator," a current that will flow continuously in one direction, and be "alternating." But in magneto machines for ignition purposes, "rectified" currents are rarely employed. On the other hand, they are largely employed in lighting, plating, and accumulator charging, for which dynamos, fitted with commutators, are alone admissible.

To the above brief outline of the mode in which a magneto or a dynamo acts, we need only add one fact—of a knowledge of which makers of magnetos avail themselves in the construction and application of these machines for ignition purposes—and this is, that if the current flowing through the armature be suddenly arrested, a much heavier discharge takes place than is due to the lines of force cut, owing to a kind of electrical momentum set up in the wire coiled in the armature, which momentum, in expending itself, sets up a momentary current in the opposite direction, exceeding the original current in intensity, in proportion to the number of turns of wire there are wound on the armature.

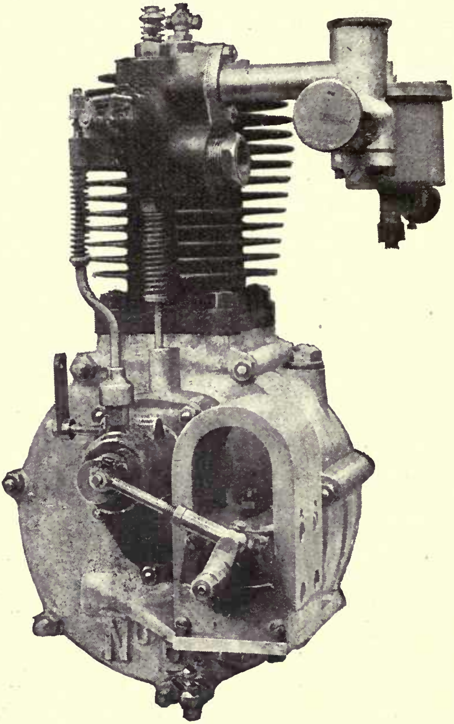

FIG. 22.—SIMMS MFG. CO.'S 1900 $2\frac{3}{4}$-H.P. MOTOR, FITTED WITH SIMMS-BOSCH MAGNETO.

A more modern application of the magneto machine to the purpose of ignition was that known as the "Simms-Bosch." In this we had three permanent horseshoe magnets, bestriding the pole-pieces, in which was bored out a cylindrical tunnel to take the armature. The armature itself was a fixture, wound with wire suitable to produce the required

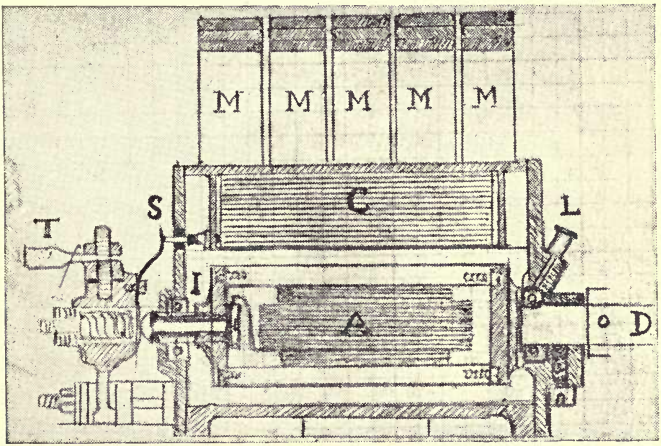

FIG. 23.—THE BASSÉE MICHEL MAGNETO.

spark, which was obtained, not by causing the armature to rotate or to oscillate so as to cut lines of force, but by imparting a reciprocating movement to a soft-iron envelope, which lay between the armature and the magnets, and which, by virtue of this movement, uncovered the wound portion of the armature, giving rise to a momentary electric current, which evidenced itself in the form of a spark at the ignition-plug. As in the Breguet magneto, the motion was imparted by a cam and lever on the engine. The Simms-Bosch magneto admitted of very accurate timing, and marked a distinct advance upon the older form in which the armature moved.

Fig. 22 represents the Simms-Bosch magneto igniter in position on the Simms motor. The weight of these appliances varies with the purpose and speed for which they are intended. Thus, for stationary engines, running at not less than 60 R.P.M., the weight is 28 lbs.; for automobiles, to run at not less than 300 R.P.M., 20 lbs.; for very light work, cycles, etc., at a speed of not less than 300 R.P.M., the weight is 7¼ lbs.

Magneto igniters of this type, in which the current (owing to the wire wound on the armature being of coarse gauge) is rather large in volume, but of comparatively speaking low E.M.F., are usually spoken of as "low-tension magnetos."

As another example of this form of magneto, we give, at Fig. 23, an illustration of the Bassée Michel, which is extensively used in the De Dion cars. The armature, A, revolves at the speed of the crank shaft, and is driven direct by means of the cardan-jointed spindle and sleeve, D. It runs on ball bearings shown at each end of the spindle, which are lubricated at L. It has five compound magnets, M M M M M, a current terminal at T, a condenser at C, and an insulated plate, which presses against a spring thrust-pin, S. One end of the armature is insulated, as shown at I. At each half turn of the armature, the current, alternately + and —, passes through the contact breaker at the moment when the current has reached its maximum.

Closely allied to the low-tension magneto is the very neat and efficient igniter brought out in 1899 by the Elbridge Electrical Manufacturing Co., U.S.A. Two sizes were put on the market; the larger, marked "S," being a circular carcass, two-pole drum armature dynamo, series wound; size 10 ins. high and about 10 ins. from end to end of shaft. The weight is 47 lbs. Owing to the special construction and winding of this machine, no "sparking" or "induction" coil is needed, a bright spark being always obtained at the breaking of the circuit. This dynamo will not lose its magnetism when short-circuited, and will always increase its output at the moment when the spark is obtained. The bearings are extra long, lined with Babbitt metal, and the lubrication is effected by "wick" oilers, the reservoirs holding enough oil for a week's run. The commutator is constructed of tempered copper, and is very wide. The brushes are of carbon of ample carrying capacity, and no harm is done if the dynamo be accidentally run backwards. The normal speed of this machine is 1,400 R.P.M., and as all the working parts are included in the frame of the machine, they are well protected from external injury.

A smaller size, "R," is intended specially for small launches, automobiles, and where the larger machine would be too heavy. The general principles of construction are the same; but the dynamo itself is of the "enclosed" type, so as to protect the working parts from dust and dirt. The weight is only 14 lbs., which is less than that of an ordinary coil and accumulators; the height is 6½ ins., and the extreme length 9¾ ins., while the normal speed for driving to give good sparks is 1,600 R.P.M. Special attention is given to all bearings, so that the machine can be run continuously for a long period without showing appreciable wear. The brushes are of carbon and copper combined, thus insuring good conductivity and sparklessness. The bearings are made of Holmes's "fibre-graphite" composition, and require no oil whatever. Owing to the nature of the circuit, these Elbridge sparking dynamos require the employment of a "wiping" or dotting contact at the point of spark production. They are not adapted for use with the ordinary sparking plug, in which there is a gap between two platinum points.

In the "dynamo-coil" protected by the writer in 1899, the problem of obtaining a steady and certain flow of "hot" sparks, as from an induction coil, without the annoyance, weight, and uncertainty of batteries or accumulators, was first successfully grappled with.

The dynamo-coil, as its name implies, is a hybrid between a dynamo and an induction coil. Let the reader imagine an ordinary series-wound dynamo of such size and shape as to fit easily into the space generally allotted to the sparking-coil in a motor car. It is convenient, though by no means indispensable, that there should be only one field-magnet core, and this built of the softest iron wire possible. Around this are wound the series coils of the dynamo proper. So far, there is practically no difference between this and an ordinary series-wound dynamo. Over the series coils, but quite independent of them, and well insulated, are wound several thousand turns of fine wire, precisely similar to the secondary of an induction coil, the two extremities of which are connected to terminals (or other electrodes) that serve to convey the induced current to any point at which it is desired to produce the spark. Fig. 24, which is a partially sectional view of one of the older types of the "dynamo-coil," gives an idea of the general disposition of the parts, but does not indicate the proper connection to firing plug, the devices by which the exact timing of the spark is effected. nor the means adopted to enable the dynamo coil to adapt itself to variations in the speed of the engine. In this figure A is a soft iron wire bundle, which serves at once as the core of the coil and as the field-magnet of the dynamo; F F show the position of the coarse-wire winding, which renders the machine at once an efficient series-wound dynamo, and imparts magnetism to the core as in an induction coil. Thence the wire is led to the brushes I I, whence the current generated by the armature D is picked up. J is the commutator,

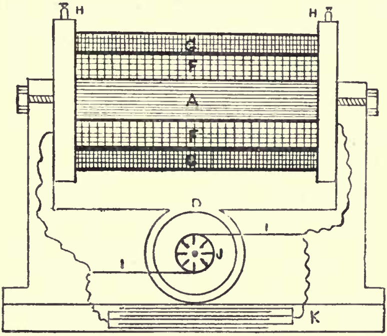

FIG. 24.

G G are the secondary coils, the terminations of which are brought out at H H. (In the modern type of dynamo coil *only one* wire is required for connection to firing plug.) A condenser K is in shunt with the primary winding.

It will be evident that as long as the potential of the current flowing round the core A remains the same, no current will be generated in G G; but if any interruption be made in the primary circuit, a heavy flash will occur between the points of the sparking plug attached to the terminals H H. No vibrating contact-breaker is required; a simple plunger, P, Fig. 25, which is affixed as a kind of stud to one side of the dynamo-coil base, and which is actuated by the half-speed cam, serves to break contact, and this act of breaking contact can be timed with the greatest nicety, so as to insure firing at the most opportune moment. Figs. 25 and 26 are side and back eleva-

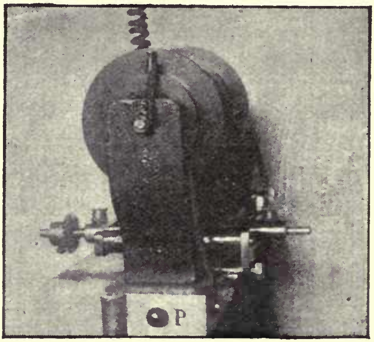

FIG. 25.

tions of the perfected forms of the dynamo-coil. The base is an aluminium case, containing the condenser and fitted with the plunger P, and a bolting-down lug on each side. This bears upon it the dynamo carcass, surmounted in its turn by the "coil" portion. To the left of Fig. 25 are seen the bearings, the driving gear, and the lubricator—the right hand showing the commutator and brush end of the machine. The only wire necessary for connection to firing plug is seen attached to the plug at the top of the coil.

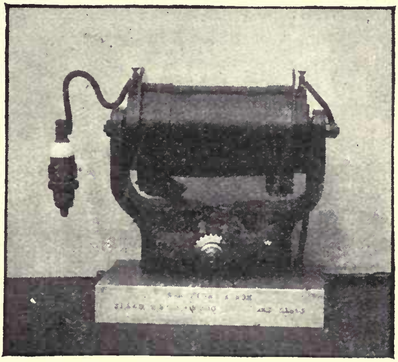

FIG. 26.

The idea embodied in the dynamo-coil has been largely taken up by different makers of ignition devices, and has resulted in the production of "high-tension magnetos." In these machines the accumulator, or primary battery, as a means of exciting the coil, is entirely discarded, and the coil itself (if separate) is not furnished with a vibrating contact breaker, but is called into action at the instant that the current, set up by the coarse wire (or "primary") winding of the armature, has reached its point of maximum intensity, and which is caused to coincide with the correct time for firing the gaseous mixture in the explosion chamber, by means of a suitable contact or "plunger." In some of these high-tension magnetos the coil, or secondary, is entirely distinct and separate from the armature with its coarse-wire winding; as, for instance, in the "Eisemann"; while in others, as, for example, the "Simms Bosch" Arc Light, the "Gianoli," etc., the secondary winding, which constitutes the true *coil* or "high-tension" portion of the machine, is wound *over* the primary of the armature. In either mode of construction a "condenser," to take up the "extra" current set up in the coils of the primary winding, is an absolute necessity, to ensure effective sparking.

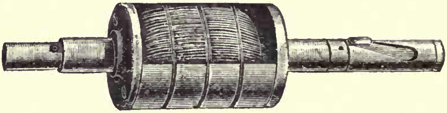

FIG. 27.

Leaving the description of the mode of constructing the coil and the condenser for future consideration, we give as examples of the "high-tension" magneto system a brief description of the "Eisemann," the "Simms Bosch," and the "Gianoli," as being typical of machines of this class.

The Eisemann was the first of the "high-tension" magnetos to be put on the market, and differs from most of its successors, inasmuch as it has a separate coil, which is used to transform the low-tension current set up by the armature into one of sufficiently high tension to actuate the ordinary sparking plug. By this means a very large current can be obtained, since the whole of the armature channel can be filled with stout copper wire (see Fig. 27), and no space is taken up by any finer wire, which is not only more difficult to insulate properly (on an armature), but does not give so hot a spark. Another speciality

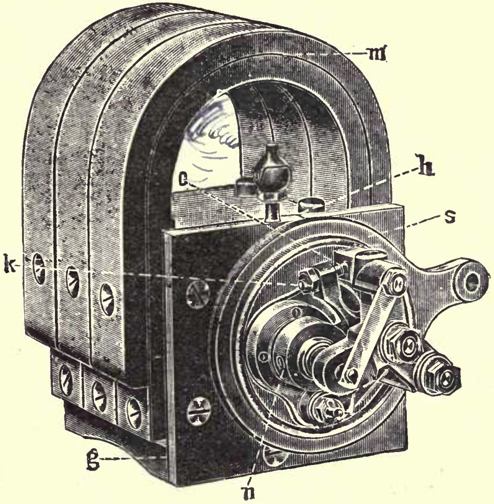

Fig. 28.—The Eisemann Magneto

M, Magnets.
C, Platinum points.
K, Adjusting nut.
S, Timing disc.
N, Steel cam.
H, Mark on timing disc which corresponds with a similar mark on the body of magneto when timing disc is in advanced position.

of this system lies in the arrangement of the contact-breaker, which is *in parallel* with the primary winding of the coil, instead of being, as in other makes, in *series* with it. This allows a larger current to be obtained from the armature, since, as the resistance of the primary winding of the coil is cut out, a larger current can flow. This arrangement of the contact-breaker in parallel favours the production of a much more powerful spark ; because, as the spark occurs when the current flows through the coil, and not when it ceases, advantage is taken of the fact already mentioned of the production of the "extra" current to increase the volume of the current passing through the coil when the platinum contacts are separated.

At Fig. 28 we give a general view of this magneto, adapted to use with single cylinder engines. For engines with two, four, or more cylinders, the Eisemann magnetos are similar in general construction, but larger and more powerful, and are also fitted with a high-tension *distributor.* The armature cannot be seen, as it lies between the lower extremities of the limbs of the magnets *m.* The cam *n* causing the "makes" and "breaks" is carried on the armature shaft. The platinum points are situate at *c*, and one of the nuts, by means of which they may be adjusted, is shown at *k.* The timing disc (shown separately on a larger scale at Fig. 30) can swing through an angle of 29°, which is sufficient to allow the spark to be advanced or retarded to the greatest required extent. At Fig. 29 is given an illustration of an Eisemann magneto with "distributor" (seen just below H), suitable for a four-cylinder engine. The field magnets consist of six horseshoe magnets screwed to soft-iron pole pieces, which embrace the armature, without quite touching it, for about three-quarters of its total diameter, half on each side. The clearance, in order to secure great efficiency, is hardly more than the thickness of a sheet of writing-paper. The armature, shown at Fig. 27, which rotates between these pole pieces, is of the Siemen's **H** type. On being rotated while in this position an electric current is set up in its coils. This current, as we have seen, is not a steady one, but rises to a maximum and falls to zero *twice* during every revolution. The "break" of the primary circuit is arranged so that it shall take place when the current is near its maximum. The

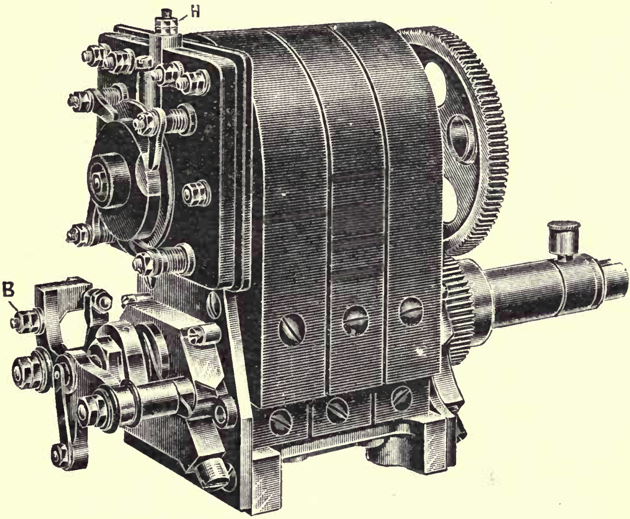

FIG. 29.

two ends of the armature spindle (see Fig. 27) are separate, and are screwed into the brass end-plates of the armature. The spindle runs in long bearings in brass-bearing plates. These are furnished with sufficient lubrication, a small hole being provided for surplus oil, so as to prevent its reaching any part where its presence might be harmful. The timing disc is shown separately at Fig. 30 with the contact-

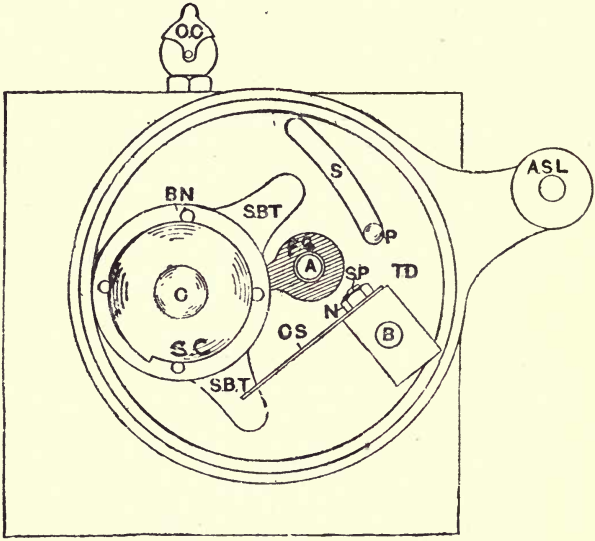

FIG. 30.

C, Copper plug on armature shaft.
SC, Steel cam.
BN, Brass nut holding.
SBT, Springy brass tongues.
TD, Timing disc.
FS, Forked steel piece.
P, Pin working in slot, S.
A and B, Steel pins.
CS, Contact spring held by N, nut, and SP, split pin.
OC, Oil cup.
ASL, Advance spark lever.

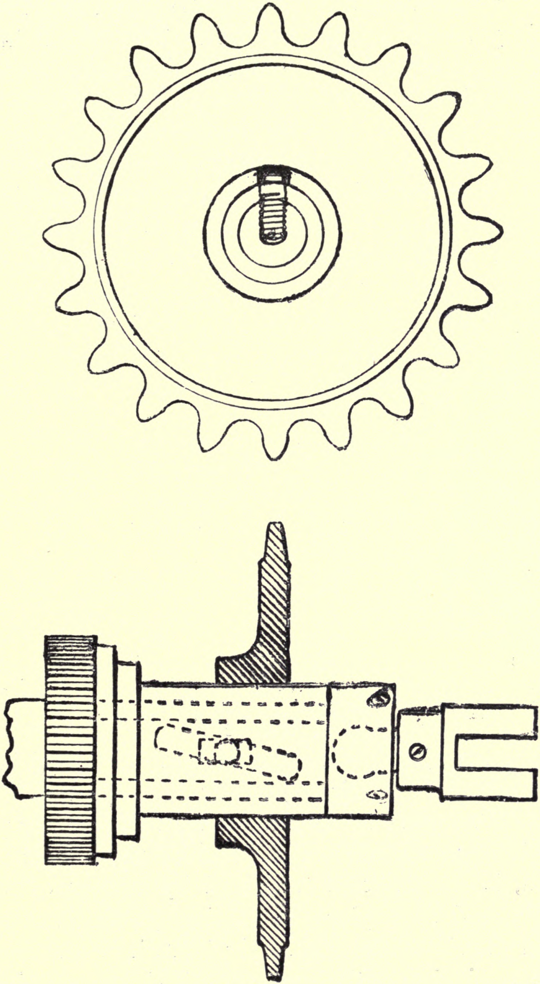

FIG. 31.

breaker removed, and is eccentric to the armature bearing, about which it turns. The pin P in the bearing plate passes through the slot S, the length of which limits the extent of "advance" or "retard" of firing.

When used on 2, 3, 4, and 6 cylinders, these magnetos have the advance and retard arranged in a different manner, by means of a pin working in a diagonal slot, with a sleeve over the same, upon which the driving sprocket is fixed (see the two illustrations forming Fig. 31). The springy brass tongues, S B T (Fig. 30), press the timing disc against the bearing plate, and are themselves secured by a nut on the outside of the bearing. The steel cam, S C, rotates with the armature shaft. One end of the armature coil (or wiring) passes through the centre of the shaft and makes contact with the copper plug, C, which protrudes from the end of the shaft; from which, however, it is insulated by means of fibre. The forked steel piece, F S, makes good contact between the shaft and the steel pin, A, its ends bearing upon the inside of the cam, S C. This forked piece is shown separately at Fig. 32.

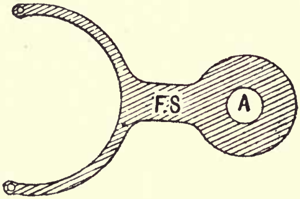

FIG. 32.

We can now, by the aid of Fig. 33, form some idea of the connection and working. One end of the armature coil, or wiring, is "earthed" to the machine, and the other end is, as we have just stated, brought out through the armature spindle, and is in electrical connection with one of the platinum points, P, which is insulated from the frame. Near this spot the wire, P W, leading to the primary of the coil, is taken off. The bell-crank lever, B L (see also Figs. 34 and 35), carrying the second platinum point, P, is in connection with the frame; hence, while these points are in contact, the current has a free passage to "earth," and completes its circuit at the "earthed" end of the armature. The lever, B L, is held by a spring against the cam, C; which cam rotates with the armature,

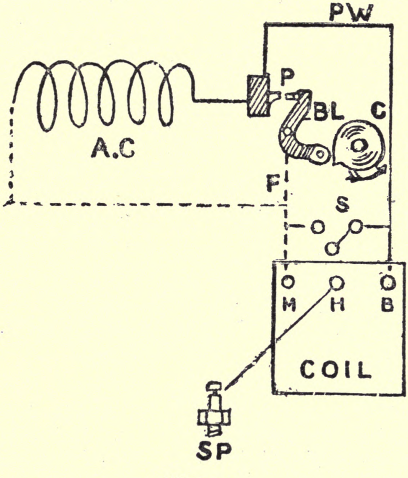

FIG. 33.

causing the necessary “ makes ” and “ breaks ” at the platinum points. When the points, P, are separated, the earth circuit is broken, and the current can flow only down the wire, P W, through the coil, and thence through the frame to the armature : this can only happen when the switch, S (Fig. 33) is open, as in the diagram. When it is *closed* it conducts the current to earth without its passing through the coil. It will be noticed that even when the switch, S, is open, the armature itself is not on open circuit. On the other hand, the armature current flows along a path of very low resistance, namely, to earth ; or, in other words, the armature is short-circuited. This is, in fact, its normal condition, and it is, as already explained, never advisable to run a magneto on open circuit. Under running conditions, with the switch *open*, there is a permanent

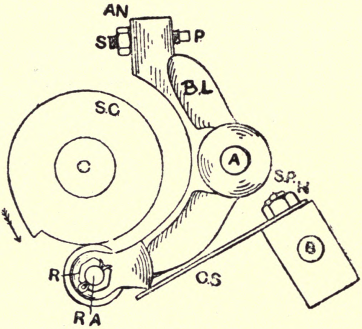

FIG. 34.

BL,	Bell-crank lever.	AN,	Adjusting nut.
P,	Platinum contact.	R,	Roller.
S,	Screw, carrying platinum.	AR,	Axle of roller.

connection through the coil, but no appreciable current passes this way until the points P are separated. This is due to the fact that the "earth" circuit presents far less resistance, so that practically the whole current takes the easier route. When, under the influence of the cam, C, the points, P, separate, there is consequently a sudden rush of current along the only path left open, namely, through the *coil*. It is at this instant that the spark occurs at the plug, S P (Fig. 33). In other words, the spark occurs when the current *begins* to flow through the coil, and not, as in an accumulator system, when it *ceases* so to do. If the switch were wired in the usual way, and the switch opened, the armature would be running on an open circuit for a part of every revolution. The earth circuit being broken when the armature current is near its maximum, there would arise violent and destructive

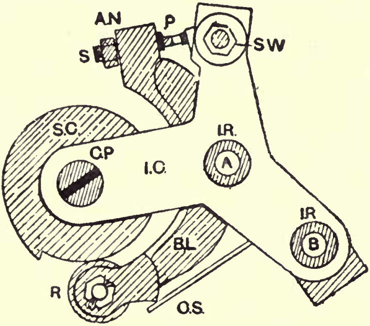

FIG. 35.

IC, Insulated casting	SW, Nut holding spring.
CP, Carbon pencil.	IR, Insulating rings.

sparking at the platinum points. Careful attention must therefore be given to the correct wiring of the switch.

By the aid of the foregoing explanations, with their accompanying diagrams, the reader can easily follow the path of the current, which is as follows :—Starting from the end of the armature coil which is insulated from the machine, the current flows along the copper plug, C (Figs. 30, 33, 34), which is insulated from the armature. Thence it passes through the carbon pencil, C P (Fig. 35), and the spring partly seen between S and B L in (Fig. 35), till it reaches the platinum points, C (Fig. 28); also shown at P in Figs. 33, 34, and 35. From that point, when the platinum points are in contact, the current flows across them into the bell-crank lever, B L (Figs. 33, 34, and 35), going through the forked steel piece, F S (Figs. 30 and 32), to the "earthed" end of the armature coil, and thus completes its circuit.

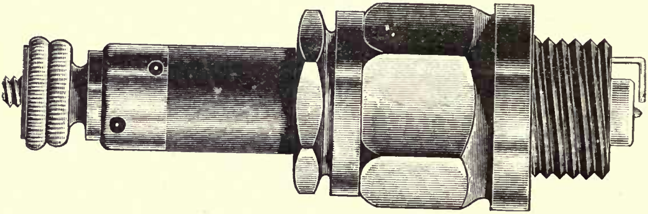

FIG. 36.

In the foregoing description the reader will bear in mind that the term "earthed" means simply connected electrically to the uninsulated body of the machine. When the platinum points, P, are separated the current has no other path open to it from the casting, I C (Fig. 35), except through the wire leading to the switch or induction coil. The other end of the primary of the said coil being "earthed," the current passes to the frame, back to the magneto, completing its circuit as before. The connection of the *positive* end of the secondary of the coil to the sparking plug is shown at S P (Fig. 33), the negative end of the secondary being, as usual, connected to frame, or "earthed." The general appearance of a sparking plug (actual size) is given at Fig. 36.

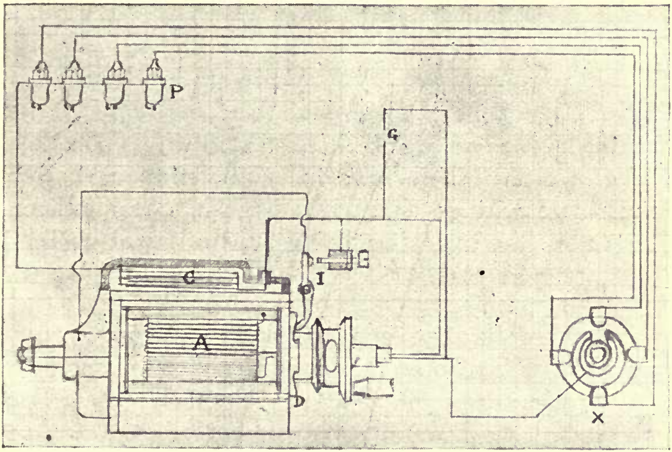

FIG. 37.
THE SIMMS-BOSCH "ARC LIGHT HIGH-TENSION MAGNETO."

We may now pass on to consider the Simms-Bosch "Arc Light" magneto, of which we give a sectional view at Fig. 37, showing the mode of connection to distributor and plugs when used with a four-cylinder engine. Of course, if there be only one or two cylinders to fire, the distributor, X, will be furnished with only one or two contacts to correspond. The timing gear forms an integral part of the magneto, the lever of which is operated in the usual manner by a cam. The armature, A, consists as usual in a channeled cylinder of iron, in the channel of which are two separate and independent windings. The "primary" is made up of comparatively few turns of coarse wire, wound round the "web" of the armature. Over this, or even alongside of it, is wound the "secondary," consisting of many turns of fine insulated wire. For the sake of clearness we have, in our illustration, shown these two wirings as lying alongside one another, instead of the secondary being superimposed on the primary. In practice it is immaterial which plan is adopted, provided the two windings be perfectly insulated from one another, and the gauge and quantity of wire in each be in due proportion.

The armature is *stationary* in the tunnel of the pole-pieces of three powerful compound horseshoe magnets. An oscillating iron sleeve, or "shield," slotted at its two opposite sides, and fitting with great exactitude between the inside of the tunnel and the outside of the armature, serves alternately to shield and to expose the armature to the lines of force emanating from the magnet, according to whether the sleeve, by the oscillatory motion imparted to it, *uncovers* or *covers* the wound portion of the armature. Mounted at one end of the armature is a form of interrupter or contact-breaker, I, D, the scope of which is to break suddenly the primary circuit, at the instant at which the current induced therein by the magnetic flux reaches its maximum. This sudden interruption of the primary circuit elicits at the same instant a powerful high-tension current in the secondary circuit. One end of each winding is in connection with the metal-work of the machine ; the other ends are passed through suitable insulators and connected to metal rings, whence the current is picked up by carbon brushes, and passed on to the sparking plug, P, by means of a well-insulated cable.

As the secondary winding of the armature forms practically a *coil*, it is essential to the efficient working of this magneto that it should be provided with a *condenser*, C, which is shown in our illustration in the recess just above the armature. It is connected in the usual manner, namely, in shunt with the two halves of the contact-breaker or interrupter, on the primary circuit. To prevent any injury to the primary circuit, in the event of the connection between sparking plug and secondary becoming broken, a device, known as a "safety-spark gap," G, is arranged on the secondary circuit, which serves as a safety-valve against any excessive generation of current.

The next magneto to claim our attention is the "Gianoli," which embodies a modification in the mode in which the circuit is suddenly broken, that renders it worthy of separate notice. As is usual with high-tension magnetos, the machine consists essentially of a set of magnets with pole-pieces, and an armature wound with two separate, well-insulated and independent windings, of which the inner, or one nearer the core, is of comparatively coarse wire, and constitutes the *primary*; while the exterior layers, which occupy about twice the space of this primary, consist of numerous turns of fine wire, and form the *secondary*. The usual minor fittings, as used in other magnetos, are also present, such as contacts, insulators, terminals, main shaft bearings, lubricators, etc., and are clearly shown in our sectional illustration, Fig. 38.

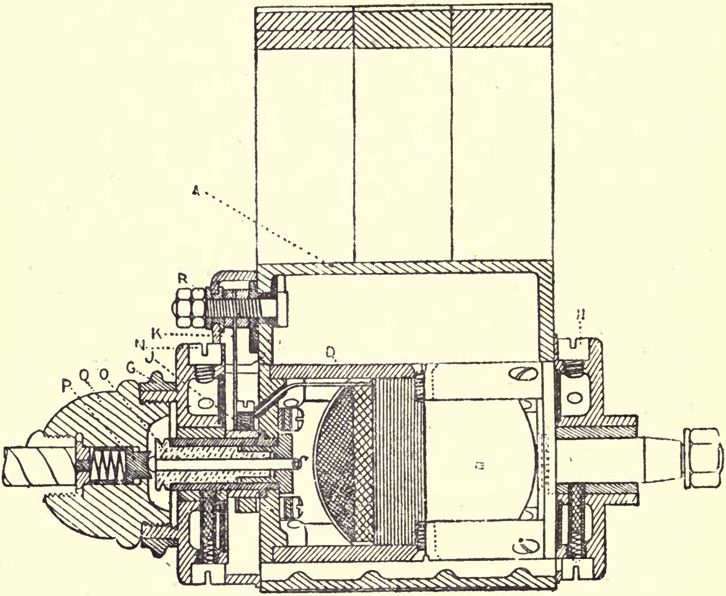

Fig. 38.—The "Gianoli" High-Tension Magneto.

But the "Gianoli" magneto differs in two main features from those previously described, inasmuch that, firstly, the interruption or "break" in the circuit is effected automatically by the effect of the induced magnetism in the core of the armature, without needing any mechanical device or springs; and, secondly, the manner in which the advancement or retardation in the ignition is governed, by shifting the pole-pieces through a given angle of an arc by means of a "timing" lever—this having the effect of moving the magnetic field (and consequently the lines of force) into another position, as may be required. The mode in which the "automatic interrupter" operates is shown in Fig. 39. A thin plate of soft iron, which plays the same part as the iron bob in the contact-breaker of an ordinary induction coil, is attached to one extremity of a light spring. In front of this latter is another spring,

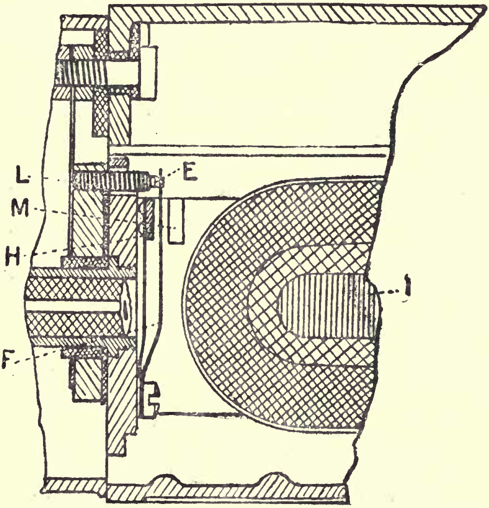

FIG. 39.

bearing at its end (a little above the soft-iron plate) a platinum contact-tip. Both these springs are held in place in front of the cheeks of the armature by a screw common to both, as shown near the bottom, to the left of Fig. 39. The platinum-tipped spring in its normal condition rests against an adjustable platinum-tipped contact-screw, thus completing the primary circuit. The wound armature is provided with small soft-iron polar extensions (one of which is shown in the illustration, facing the upper end of the spring and iron bob). When the armature rotates

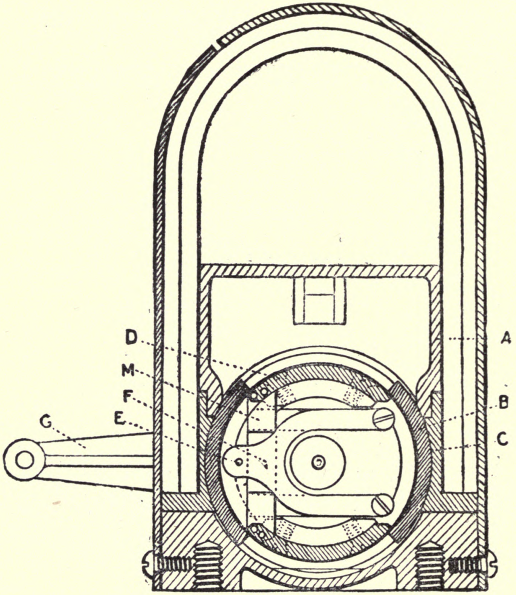

FIG. 40.

it becomes magnetised by the inductive influence of the field-magnets, and when the polar extensions are facing the iron bob (which is made to correspond with the point of maximum electrical intensity), the iron bob is strongly attracted, and strikes against the inner surface of the outer spring. This causes an instantaneous rupture between the two platinum contacts, thereby setting up a powerful current in the secondary, which current is led, in the usual manner, to the sparking plug or plugs. This attraction of the iron plate or bob is rapid at all speeds, and corresponds with the instant at which the highest electrical tension is set up in the armature wires, thus producing a succession of sparks at each "maximum" period or phase of the armature's rotation. This enables starting to be easily accomplished.

Another important advantage is, that no matter how fast the armature may be driven, it is impossible for an *excess* of current to be generated, thus avoiding injury to the armature winding, or necessity of having a "safety" spark gap. In fact, the iron plate vibrator acts as a perfect electro-magnetic governor, and always breaks the circuit at the same voltage, irrespective of *speed*.

The position of the movable pole-pieces, with the means adopted to carry them through the desired number of degrees of arc, to secure advancement or retardation of firing, the polar extensions of armature. that serve to attract the plate or "bob," are well shown in our Fig. 40.

CHAPTER III.

PRIMARY AND SECONDARY COILS.

THERE can be but little doubt, in view of the experience gained during the last few years, in driving automobiles, whether large or small, that instruments of the class just described —viz., those in which the necessary sparking current is obtained from a dynamo, having either permanent magnets ("magnetos") or temporary ones ("dynamos")—constitute at once the most efficient, the lightest, and most satisfactory means of securing the ignition of the gaseous mixture in the combustion chamber. But there are many engines, both stationary and mobile, which are fitted with coils; and many of our readers may have occasion to use, to repair, or even to make coils suitable for this purpose. Hence a general description, followed by a few hints as to construction, will be acceptable.

For the purpose under consideration coils may be divided into two classes, viz., (1) those wound with one continuous length of wire; (2) those in which there are two separate windings—one of a comparatively coarse wire, called "the primary," and another of finer wire known as "the secondary." Those of the first class, or "simple primary," can (speaking generally) only be employed where a *wiping* contact is admissible, and therefore we shall dismiss them with a very brief notice. Coils of the second class can be subdivided into those which have a vibrating contact-breaker as an essential portion of the coil, and those in which the make and break of the contact is effected by some mechanical device, actuated by a cam on the engine itself.

The principle of action of the coil is very simple, and although during the work of a coil there are concomitant actions going on which somewhat complicate matters, it will not be necessary for our purpose to go very deeply into these points.

The first fact that claims our attention is, that if we take a length of wire and coil it into a helix, a momentary current sent through the helix sets up two actions. (1) On *making* contact with source of current, a momentary current in the *opposite* direction to the main current is set up in the wire. But as this current is only transient, and weaker than the main current, its presence can only be detected by the momentary weakening of the main current. (2) On *breaking* contact with the source of current, another wave of current is set up in the helix—this time in the *same* direction as that of the main current.

It must be particularly noted that these effects are transient, and produced at the instants of "making" and "breaking" contact only, and are not in evidence *while* the main current is flowing. The currents thus set up were originally called "extra" currents, but are now known by the more appropriate one of "self-induction currents." Each turn of the helix has a given E.M.F. induced in it, so that the resulting E.M.F. is proportional to the number of turns in the helix, multiplied by the original E.M.F.; but since we cannot *produce* energy, but only change its form, we find that the *volume* of current (the amperes) is diminished in like ratio. So that if we supply a current of 1 ampere at 1 volt pressure to a coil consisting of 1,000 turns of wire, we may expect, when breaking circuit, to get a momentary current of $\frac{1}{1000}$ of an ampere, at 1,000 volts pressure, less, of course, a certain amount of loss due to the conversion of part of the energy into heat, and dissipation of the magnetic field, etc. The second point that demands attention is that if two distinct wires lie side by side, but not in electrical contact, and momentary contact be made with any source of current and one of the wires, a similar transient current will be set up in the adjacent wire, but in the opposite direction to that of the inducing current. Owing to the damping effect of the "make" self-induced current in the first wire, the "make" induced current in the second wire is not very strong. On *breaking* contact between the source of current and the first, or "primary" wire, a second momentary current is set up in the second (or "secondary") wire. But this is now in the *same* direction as the originally "primary" current was, and since it is not checked by any counter-effect from the primary, the resulting "break-contact" current is much more powerful than the corresponding "make-contact" current was.

It will be evident that if we coil the primary wire into the shape of a tight helix, and surround this with a large number of convolutions of secondary wire, we can exalt the E.M.F. (lowering in like degree the volume of current in amperes) to almost any desired extent, dependent on the ratio between the number of turns on primary and secondary respectively. If, instead of winding the primary wire into a coil without any core, we wind it upon a core of *soft iron*, as this latter will concentrate the magnetic field, instead of allowing it to stray, we shall largely increase the induction effect, both on primary and secondary windings. We are now in a position to understand what is essential to the production of a good sparking coil, whether "simple primary" or "secondary."

In the first case we require a soft iron core, to concentrate the magnetic field set up, overwound with a sufficient number of turns of insulated wire to raise the E.M.F. set up by the battery to a sufficient degree to enable it to produce a spark of the length desired; and, lastly, some device for making and breaking contact between the battery and the primary at the time and the place where the spark is required. In the second case, besides the iron core, the primary, and the contact-breaker, we require some means of taking up the self-induced current, which we cannot in this case utilise, and which is actually detrimental to the efficient working of the secondary. Over this primary we must have a sufficient number of turns of a finer secondary wire, entirely separate and insulated from the primary, to set up an induced E.M.F. sufficiently high to produce a spark of the desired length. For this case also we must have a means of making and breaking contact with the battery, accumulator, or other source of current. This second form of coil differs, however, from the first, inasmuch as the contact-breaking arrangement is quite independent of the *place* at which the spark is produced, so that the contact need not be made and broken at the spot where the ignition is required.

The following details as to dimensions, gauge of wire, and general mode of construction, may be useful to those desirous of building a "primary" coil, suitable for gas or petrol-vapour ignition. It should be noted that this type of coil is suitable only for those cases in which the act of "contact-breaking" can be effected at the spot where ignition is desired.

A couple of hard-wood heads (oak or beach), 4 ins. square by 1 in. thick, should be planed up, and soaked for some time in melted paraffin wax. Through the centre of these a hole $\frac{3}{4}$ in. in diameter must be put. A bundle of perfectly straight soft iron wire, No. 22 B.W.G. (carefully annealed in the fire, and allowed to cool slowly in the ashes), is now to be made up into a cylindrical core, 12 ins. long, $\frac{3}{4}$ in. diameter. The simplest way of doing this is to get a couple of curtain rings $\frac{3}{4}$ in. inside diameter, and having made up a bundle of wires nearly the desired size, place a ring on each end, at about $\frac{1}{2}$ in. from each extremity, then cautiously push in more wires until the whole is firm and solid.

A piece of 1-in. wide tape is now taken and wrapped spirally from end to end, as tightly as ever it can be drawn, and the termination stitched down to the layer below, so as to prevent uncoiling. Any excess of tape can now be cut of and the rings removed. Over the completed core it will be advisable to roll and paste down one turn of stout brown paper, which should be rolled with a flat board on a flat table, so as to cause it to lay tightly, flatly, and smoothly. This being done, the core is allowed to dry thoroughly, after which it should be allowed to simmer in hot melted paraffin wax until no more bubbles appear ; then reared up on end to drain and cool. When cold, the core is fitted and glued into the holes in the wooden heads (these being slightly enlarged by rubbing round with a circular stick covered with sandpaper, if necessary). The ends of the core should come up flush with the outside faces of the heads, and in order to insure a perfectly rigid fit, it may be advisable to drive two or three short lengths of the No. 22 iron wire into the centre of the core at each end, so as to swell it at these points. Care, of course, must be taken that the heads stand perfectly square and parallel to each other. A small hole (about $\frac{1}{16}$ in. diameter) to allow of the passage of No. 18 double cotton-covered copper wire, is now drilled through one of the heads, close to, but not touching, the core. Through this hole is pushed from the *inside* about 3 ins. of a 4-lb. hank of No. 18 double cotton-covered copper wire, and the core wound evenly from end to end. As this wire is pliable, and not too fine to handle, the winding may be done by hand with perfect ease; but it may be done more quickly if the core be set up between centres and rotated while the wire is being gently pulled. Care must be taken to wind the wire on evenly and closely, so as to leave no spaces between the rows.

When one layer has been laid on, the wire should be fastened back, or held by an assistant, so that it should not uncoil, and the layer then basted with hot melted paraffin wax, any excess being melted off by passing over the surface of the layer with a strip of hoop-iron, about $\frac{3}{4}$ in. wide, made sufficiently hot to melt the paraffin wax, but not to burn it.

Winding always in the same direction, but returning towards the head at which the start was made, a second layer of wire is now put on, with all the precautions indicated above. This is also paraffined, and the winding and basting continued in like manner until the whole of the wire has been wound on, which will take about seventeen layers. Care should be taken to terminate with an *odd* number of layers, so as to get the finishing end of the wire close to the head opposite to that from which the start was made. A hole is now made in the head at this point in a line with the other hole, the wire end pulled through to the outside, and cut off at a distance of about 3 ins. from the face of this head.

A few sheets of demy paper are now prepared by dipping in melted paraffin wax and hanging up to drain. When cold, these are cut into strips about 18 ins. long and of sufficient width to lie *exactly* between the heads of the coil. About six of these strips are now bound, one after the other, tightly round the last layer of the wire and fastened down by warming the last edge with the hot hoop-iron strip, so as to cause the paraffin to melt and stick. Over this, as a finish, one turn of sheet ebonite ($\frac{1}{64}$ in. thick) should be rolled round, little holes being made in the opposing edges with a hot wire, and then stitched together with a suitable length of strong black silk twist. Two holes, to take the screw-shanks of two terminals, are now drilled, one in the centre of the edge of each of the heads, nearest the projecting wire ends. The wires are straightened out, bared of their covering, and cleaned bright with a bit of emery cloth, looped once round the stem of the corresponding terminal, which is then screwed up tight. The excess of wire is now cut off flush with the terminal.

The coil may now be tested by connecting one terminal to a wire from one pole of a 2-volt accumulator, or a couple of large dry cells coupled in series; then quickly making and breaking contact with the other terminal by means of a second wire proceeding from the other pole of the accumulator. A bright and heavy flash should appear each time contact is broken. Care should be taken, in making these trials, not to leave the battery connected with the coil, because, as the resistance of the wire on it is but low (about 2 ohms), the battery would soon be run down.

It will be readily understood that the form of such a coil may be somewhat varied to suit the exigencies of space, convenience of stowage, etc. The heads may be round instead of square, and the coil may be made only 6 ins. long instead of 12 ins., the winding being effected with No. 20 wire instead of No. 18, provided about 2,500 turns be got on the core. To work such a coil, any cell capable of sending about 2 amperes through will cause it to give a good heavy flash, capable of firing the gaseous mixture. The best cell to employ for the purpose is undoubtedly a 4-volt accumulator, of about 14 ampere-hour capacity.

We now proceed to show the means which may be adopted to effect the firing of the gaseous mixture at the right time and place when a "primary" coil, such as described in our last few sections, is employed. The simplest means which may be used in stationary oil or gas engines consists in connecting up the body of the cylinder to the negative wire of the coil, and arranging a platinum-faced L-shaped brass piece, pivoted at the bend, which wipes across a wire or a nipple situated just in front of a hole in the combustion chamber. This L-piece is in circuit with the battery and the other wire of the coil, and is caused to "wipe" across the nipple by means of a cam connected to any rotating portion of the engine. To bring this L-piece into the "off" position after having received the push from the cam, it is furnished with a counter-spring. Of course, the cam must be set in such a position as to insure the spark being produced at the right instant.

Another simple means consists in inserting a porcelain plug in the ignition-chamber of the cylinder, this plug bearing up its centre two wires, insulated from each other and projecting into the cylinder, one shorter wire terminating in a platinum stud, and the other bearing a platinum-tipped spring. This plug is inserted in the cylinder in such a position that, when the piston has reached the point of greatest compression, it pushes the platinum-tipped spring against the platinum stud, thus completing the circuit between the battery and coil, wires from which are connected to the externally-protruding wires (or, better, terminals) of the porcelain plug. Directly the piston has passed the dead-point, and begins to travel outwardly, contact is broken between the platinum-tipped spring. Hence a spark is produced in the combustion chamber, and the charge is fired.

The great defect in these two modes of firing is the difficulty of timing the spark while the engine is in motion. Now this power of timing the spark (and, consequently, the explosion) is a matter of the highest importance, especially for motor car and cycle work, in which the speed and power may have to be suddenly and largely varied.

Let us suppose, for the sake of example, that the explosions were made to take place, in starting the engine, when the piston is at the beginning of its *inward* stroke, with its crank quite straight, or at the "dead-point." It is evident that the piston could not move: consequently, the explosion would only strain the firing chamber, and do nothing else. Therefore it is essential, in *starting* the engine, that the explosion should not take place until the piston has passed the dead-point; but the further the piston has travelled before ignition is effected, the less the compression, and consequently the less the power exerted. Once the engine is well started, the momentum of the fly-wheel will carry the piston over the dead-point, even if the ignition takes place at the instant of greatest compression, which is the time of greatest efficiency.

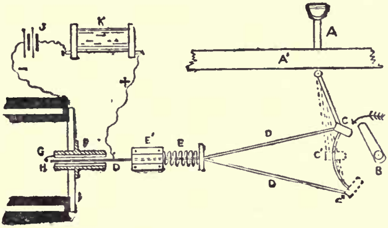

FIG. 41.

One simple means of effecting the change of "timing" the spark, when a primary coil is used to effect ignition, is shown conventionally at Fig. 41. Let A be a handle or lever, capable of being set at any point by "notching" or by screw and nut. This plays in any convenient portion of the frame of the car, cycle, or engine A′. The lower extremity of this handle-bar or lever has a hinged rod extension, which engages in a tooth C, which can be run along the quadrant of the trapezoidal plunger D D. This tooth is struck by the half-speed cam B, once in each revolution, at the same time driving the trapeze rod backwards (against the pressure of the spring E) and causing the platinum boss H, of the plunger D, to wipe against the platinum tip G of the ignition-plug F. Directly the spring returns the rod, a spark is produced between G and H, owing to the "break" which then occurs in the circuit between the battery J and the coil K, at the point G H. (The reader will observe, for the sake of clearness, we have placed the half-speed cam separate from the engine and cylinder; whereas, in practice, it would form part and parcel thereof.) When the tooth is in the position depicted at C, the firing would take place *before* the piston has reached the end of its inward stroke, just before the full compression has taken place. If, by lowering the lever A, the tooth were set as shown at C′, firing would occur at the instant when the piston is at the point of greatest compression, while, if by yet further lowering the lever A, the tooth or lug were placed in the position indicated by the dotted figure at C″, the firing would be retarded until the piston had travelled somewhat on its outward stroke, and so on for any intermediate positions.

It is advisable that the "live," +, or positive wire of the coil should be connected to the platinum-tipped rod D, which must be insulated. This is effected by lining the interior of the ignition-plug with porcelain, and the extension of the rod D, where it passes into the guide E′, should also be insulated. The negative or — pole of the battery J must be "earthed," that is to say, connected to any part of the engine frame.

It will be evident, from a moment's examination of the figure, that this arrangement admits of considerable variation to suit particular requirements, such as firing the charge from the *outside* of the cylinder (as was formerly done in stationary engines). To effect this, an insulated V-shaped brass lever pivoted at its apex, and pushed on one side by a suitable spring, rubs against a springy wire or plate, both being affixed over against the hole in the cylinder where the explosion is desired. When the extension of the trapeze D is pushed backward by the impact of the cam B striking the tooth C, it causes the upper limb of the lever to slide off the wire or plate, thus breaking the circuit between battery and coil at the point, when a spark is produced, and explosion of the gaseous mixture results.

As the contact is a rubbing or "wiping" one, the surfaces always remain bright by friction. After contact has been broken, and the cam B has passed over the tooth C, the counter-spring pressing on the V-shaped lever reasserts its power, and slides the lever on the wire or against the plate, again making contact. Connection must be made between the negative end of the battery and engine on the one hand, and between the positive end of coil and V-piece on the other.

Since the advent of the "dynamo coil" and of the "magneto," in which the timing of the ignition has been rendered both simple and certain, ignition by primary coil, except only for gas-burner lighting, has become almost entirely obsolete, and we have mentioned it here mainly for the sake of historical sequence. There is, however, one notable exception as regards primary coils, and that is to be found in the sparking plug recently patented by Major J. A. Torrens, and which, in view of its simplicity, its susceptibility of being easily and accurately timed, promises to be largely employed—and which we will therefore describe somewhat in detail.

The following is a condensation of the principle of Major Torrens' specification:

The improved apparatus consists of a single primary coil, having two breaks in the circuit, one of which is normally open, and is closed by any suitable mechanical means when the engine is working, such as by a cam of the two-to-one gear; while the other is normally closed, and is opened by the establishment of a current in the inductance coil, when the first gap or break is closed somewhat in the same manner that an ordinary contact-breaker has its hammer attracted by the iron core when the battery current is allowed to flow, thus breaking the contact immediately on the passage of the energising current. The spark produced at the second gap which is arranged to be placed in the combustion chamber, or at any rate in contact with a portion of the explosive charge, depends upon what is commonly called the "extra current" in the primary induction coil circuit. (The reader will remember that this device is specially intended to make use of a primary coil only, therefore doing away with all the inconveniences due to the employment of the high-tension currents inherent to this system.) The spark is proportional to the rate of change of magnetic flux due to the current in that coil. Consequently the quicker the breaking of the circuit at the sparking electrodes can be effected the greater will be the "extra current." To effect a sudden break one of the sparking electrodes (which is movable) is quickly retracted from contact with the other by a blow from an iron plunger which forms the core of the primary coil, which, in obedience to the laws that govern the action of the solenoid, is instantly sucked up towards the centre of the primary coil on the advent of the energising current. Farther, since the rate of change of magnetic flux will not be at a maximum if the circuit be broken before the said current has reached its steady value, the distance between this movable core and the movable electrode is spaced so as to allow the energising current time to have reached its full value before the blow is delivered. The movable electrode is returned to its normal position in contact with the fixed electrode by its own weight, or preferably by means of a spring, and is relieved of any weight or impact due to the return of the magnetic core by providing a rest or stop for the latter, which is secured to a fixed part of the plug. The interior space in which the movable electrode and magnetic core slide, and which is in communication with the interior of the cylinder, is made gas-tight, and the sliding magnetic core which preferably fills up as much as possible of the space which is not occupied by the movable electrode is fluted longitudinally, or otherwise formed to allow the free passage of air during its movement.

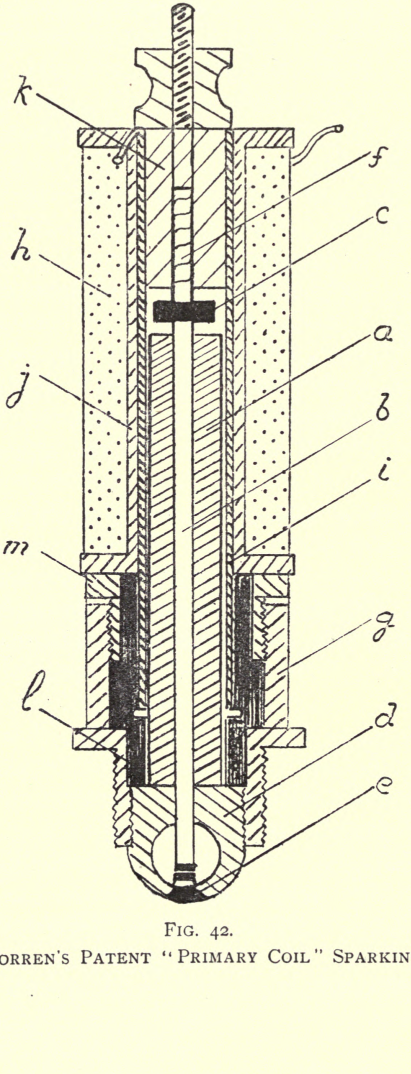

Fig. 42.
Major Torren's Patent "Primary Coil" Sparking Plug

In Fig. 42 we have a longitudinal section of this "primary coil" sparking plug. As shown here, a hollow, fluted, iron or steel sliding core or hammer, *a*, surrounds a rod, *b*, of non-magnetic metal, which constitutes the movable sparking electrode, which is tipped with platinum in the usual manner. The electrode, *b*, is urged into contact with *e* by means of a light spring, *f*, while the core, *a*, normally rests on the ledge of a stirrup, *d*, which is screwed into the threaded plug, *g*, and which carries the fixed electrode, the face of which is also platinum-tipped. The electrode, *b*, is formed with a collar, *c*, between which and the near end of the core, *a*, is a certain clearance or space, the amount of which is determined by the electrical and magnetic constants of the inductance coil. The parts *a* and *b* are enclosed within a non-magnetic metal tube, *i*, occupying the core of the solenoid bobbin, *j*, and closed at its upper end by a plug, *k*, of brass, or of other non-magnetic metal, which is cored to serve as a guide for the electrode, *b*, and also forms an abutment for the spring, *f*. The bobbin, *j*, and the tube, *i*, are insulated from the plug, *g*, by the insulating packing, *l*, and an externally screw-threaded insulating ferrule, *m*, on which the metal plug, *g*, is screwed.

The electric circuit is completed from a suitable battery, accumulator, or low-tension magneto, through the coil, *h*, bobbin, *j*, tube, *i*, plug, *k*, spring, *f*, electrodes, *b* and *e*, and stirrup, *d*, to the metal plug, *g*, which is screwed into the engine castings.

We can now pass to the consideration of the "secondary" coil, which is the one usually employed for the petrol-engine ignition, as it lends itself readily to the solution of the problem of producing the spark at any part of the circuit, independently of the point at which the battery contact is broken.

As the satisfactory working of petrol motors is largely dependent on the efficiency of the coil, we shall enter rather fully into the principles which govern its action, and follow on by giving such constructional details as will enable the reader to make a serviceable coil if desired, or to localise the faults and repair the same in a coil which may not be doing its proper work.

The "secondary," "sparking," or "Ruhmkorff" coil consists in six essential portions—viz., (*a*) the iron bundle or core, (*b*) the primary winding, (*c*) the secondary winding, (*d*) the contact breaker, (*e*) the condenser, (*f*) the insulation, (*s*) screw tip, (P) connections.

At Fig. 43 we give an illustration of a typical coil in which all these parts are shown. As in the various makes of coils these parts may be modified in form or in position, we have lettered these portions, and shall make use of the same lettering in the following illustrations to indicate the same parts, whatever may be the changes introduced, either in form or in position.

The iron core *a* consists in a cylindrical bundle of annealed soft iron wire, the diameter of the core being usually about $\frac{1}{8}$ of its total length. It is essential to the good working of a coil that the iron should be exceedingly soft, so that it may quickly and fully take up the lines of force arising from the passage of an electric current, and as quickly return to its normal condition when the flow ceases. For this reason it is

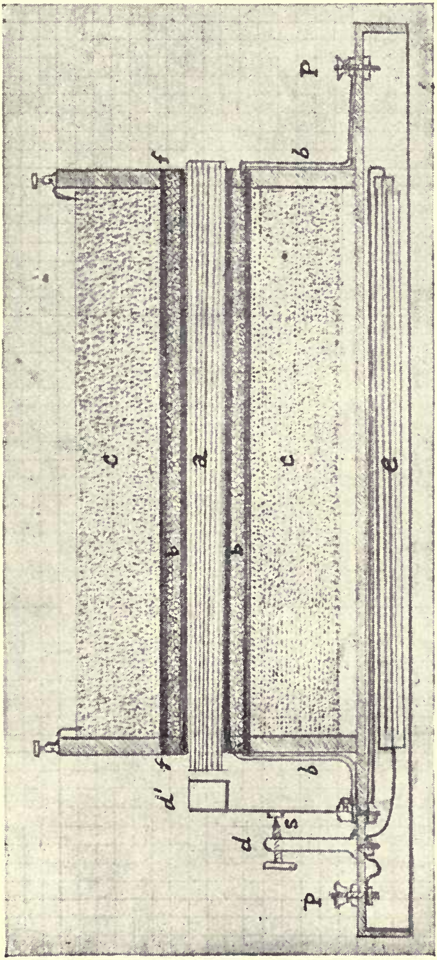

Fig. 43.—Section of Ruhmkorff Coil.

usual to "anneal" the bundle of soft iron wires constituting the core by bringing it to a bright red heat in a clear fire and allowing it to cool very gradually afterwards. The function of the core is to concentrate the lines of magnetic force set up by the primary current in its flow round the coils of the primary wire *b*, as closely as possible to the space occupied by the coils of the secondary winding *c*. In all those cases in which a "trembling" contact-breaker, *d d'*, is attached to the coil, it also serves to make and break rapidly the contact between the battery (or other source of current) and the coils of the primary, which it does automatically, by acquiring magnetism, and attracting the iron bob *d'* when the current is *on* (during the contact of the spring against the platinum-tipped screw *d*), and as suddenly allowing it to fly back, and thus re-establish the contact, when the contact has thus been broken.

When the two ends of the primary P P are connected to a battery or accumulator, the current flows along through the contact screw *d* to the contact spring supporting the bob or hammer *d'* round the coils of the primary *b b b b*. In so doing the current magnetises the core *a*, attracts the hammer *d'*, and breaks contact between the spring and the screw on the pillar *d*. This causes the core to lose its magnetism, which, ceasing to pull the hammer *d'*, allows the spring to reassert its power, bringing it again in contact with the screw tip *s*, when the same series of movements recur, and continues as long as current is supplied by the battery, and, as we have explained, the result of this making and breaking contact between the primary coil and the battery is to set up transient currents in the primary wire.

Surrounding the primary wire coils *b*, but carefully separated from them by the insulating material *f*, is the secondary wiring, consisting of several thousands of turns of fine wire, *c c*. These are not connected in any way to the primary coils *b b*—nevertheless by influence, at the instant that contact is made and broken on the primary circuit, currents are induced in the coils of the secondary; and these currents are higher in tension and smaller in quantity than those flowing through the primary coils, in the same ratio that the windings of the secondary exceed the windings of the primary.

We have also noticed that the current self-induced in the primary wire *b*, being *opposed* to the battery current, sets up a counteracting effect. The end served by the condenser *e* is to take up and store this self-induced current until the next contact takes place, so as to minimise the lowering of magnetisation, which would otherwise take place in the iron core at these instants. By this means, the pressure or E.M.F. set up in the secondary wire is greatly exalted when the "breaks" take place, so much so, that a coil that will barely give $\frac{1}{16}$-in. spark without a condenser will easily furnish an inch spark if fitted with a suitable one. The condenser consists virtually of two sheets of tinfoil separated from each other by some insulating material, usually paraffined paper. In order that it may take up the self-induced current set up in the primary, these two sheets of tinfoil are connected respectively—one to the beginning of the primary wire *b*, where it joins the spring of the contact-breaker *d′*, and the other to the pillar carrying the screw of the contact breaker *d*. In order to save space it is usual to cut the tinfoil sheets into many squares, and to form two separate booklets by joining two sets of half the number of sheets along one edge, to lap the pages of one book into the pages of the other, separating each page with a sheet of paraffined paper. The last essential we have to consider is the insulation *ff*. This is perhaps the most important of all. When it is remembered that to produce a ½-in. spark in air, a pressure of 25,000 volts is needed, it will be abundantly evident that to withstand the pressures set up in ¾-in. or 1-in. spark coils, the insulating material must be of the very best, and must be used in such a way as to insure the highest insulation at those points wherein the tendency to leakage is great.

Tape dressed with shellac varnish is the insulation usually employed between the iron core and the primary wire. The primary wire itself may be either cotton or silk covered ; in either case it should be well basted with melted paraffin wax. This excellent insulator is also used to saturate the paper separating each layer of secondary wire, and also to seal up the heads of the coil. Paraffin wax, when employed for insulating purposes, should be preliminarily melted up with some dry powdered chalk, allowed to settle while still fluid, and poured off from the dregs. This treatment removes any acid which might be present in the commercial article. As paraffin when at all burnt is not nearly so good an insulator as when in its normal state, the greatest care must be taken not to overheat it. For this reason it is advisable to melt it, and keep it melted, *à bain Marie*, or in a water-jacketed vessel.

The insulation between the primary and secondary windings should be *ebonite*, either in the shape of a thin, cylindrical, hollow tube, made all in one piece, and which fits tightly over the wound primary, or else as a tube, made by rolling thin ebonite sheet (about $\frac{1}{64}$ in. thick) tightly round the primary, and fastening down the edge with Prout's elastic glue, applied with an iron sufficiently hot to melt it. Seven turns of sheet of the afore-mentioned thickness will give sufficient insulation. This tube should extend quite to the end of the core, in those coils in which a contact-breaker is employed *on* the coil, and should project $\frac{1}{2}$ in. at each end *beyond* the core in those in which the contact is broken by mechanical means, independent of the coil. The "heads" of the coil, to which the outer connection, or "terminals," are affixed, should also be of ebonite, as also the outer case or jacket.

Although it is possible to wind a serviceable coil with bare copper wire for the secondary, depending only on the intervening air as the insulation, yet as this requires a special "spacing" winder, to insure each succeeding turn of wire lying at a determinate distance from its neighbour, we shall not make any further mention of this except to advise our readers who may by chance have to repair a coil wound with bare wire, to discard this, and rewind with silk-covered wire of the same gauge. We therefore recommend silk covering as the insulation of the secondary, supplemented with copious basting with melted paraffin wax.

We summarise the contents of this section by saying that when a current is interrupted in its passage along a coil of primary wire surrounded by a coil of secondary wire, an induced current is set up in the coils of this secondary wire, and can be drawn off from its extremities; that this current is transient and manifests itself at the instant of making and breaking contact only at the primary; that the pressure of the current thus set up bears the same relation to that of the original current, as do the number of turns of wire contained in the secondary to those contained in the primary. Also that, to minimise the "backlash" effect of the self-induction in the primary itself it is necessary to use a condenser; and, lastly, that the most perfect insulation of the secondary is absolutely essential to the production of a good long spark. We can now turn to the constructional details.

We will take as our first example a coil capable of of giving sparks of about 1 in. long *in air*, since by varying the quantities of the wires used, and the general dimensions of the parts in proportion to the length of spark required, coils capable of giving ½-in. or ¾-in. sparks can be constructed.

We will begin by describing a coil fitted with "trembler"—that is to say, a contact-breaker actuated by the iron core itself, and then point out the modifications required in connections, etc., where it is intended that the contact should be made and broken by mechanical means only.

The core should consist in a bundle of perfectly straight soft iron wires, 7 ins. long, sufficient in number to make a solid cylinder ¾ in. in diameter. To make this a couple of brass curtain-rings ¾ in. inside diameter should be procured, the iron wires placed in these while being held at about 6 ins. apart. When the rings are nearly full, additional wires should be cautiously pushed in at the centre of the extremities until no more can be inserted, and the rings fit quite tightly. Under this treatment the middle of the bundle may bulge a little. This can be remedied by binding tightly a turn or two of the same soft iron wire round the centre, and twisting the ends of this binding wire together. Care must be taken that the two ends of the bundle are perfectly level. If not so, they must be bound round, and filed until they are. The iron core should now be placed in a clear fire, until it gets red-hot ; then the fire allowed to die down, go out, and get quite cold. This insures the thorough annealing of the iron bundle, a point of the highest importance.

The next operation is to bind this core tightly round with tape. Having pushed one of the rings down on the core for about an inch, from one extremity, one turn of tape, about ½ in. wide, is to be bound round the bared end, pulling as tightly as possible, continuing the winding spirally downwards towards the ring. An assistant will now push the ring further down, and remove any iron wire binders that may have been used, the tape winding being continued spirally towards the other end, as tightly as possible, until both rings have been drawn off, and the tape bound round from end to end. The termination of the tape is now stitched down to the layer below, and cut off flush with the core.

To prevent the core rusting, and to insure good insulation between the iron of the core and the primary, it is desirable to soak the completed and taped core in melted paraffin wax until no more bubbles make their appearance. It should then be reared on end to drain and set.

The next operation is to wind this core with two layers (about ½ lb.) No. 18 d.c.c. wire. Finer wire *may* be used, such as No. 20; but owing to the "choking" effect produced by the high self-induction of the finer wire, this necessitates the use of more accumulator cells to get the same current. If coarser wire were to be used, too much current would flow, and the accumulator would "run down" too quickly.

The core may be wound with this primary wire either entirely by hand, or better, by driving a French nail some distance in the centre of the iron bundle at one end and a flattened iron wire at the other, then supporting the core by these two projections between the slits made at the top of two standards erected on a baseboard. The wire end should be bent into the shape of a crank or handle, so that a rotary motion may be easily imparted to the core. Fastening down one end of the No. 18 wire by tying, at about ½ in. from the extremity of the core (leaving about 3 ins. free for after-connection), the operator winds on tightly, evenly, and closely, one layer of the said wire, until he reaches to within ½ in. of the other extremity of the core, when, winding always in the same direction, he winds on a second layer, riding over the first, and when he arrives at the starting extremity he ties the end firmly down and cuts off the wire, leaving as before a free piece, 3 ins. in length. The wound core is again treated as before with a bath of melted paraffin wax, then reared on end to drain and set.

We now turn our attention to the insulation between the primary and the secondary. This is of the highest importance, and a little care expended on this part will be well repaid by the greatly superior results in point of spark length, and by the durability of the coil when once made.

If possible, an ebonite tube of sufficient inside diameter to allow the wound core to be slid into it with a fair fit should be chosen. This should have a wall thickness or "shell," from $\frac{3}{32}$ in. to $\frac{1}{8}$ in. The length should be that of the iron core. If the coil is to be of the square pattern, with trembler, and fitted with heads, the two ends of the tube should have screw-threads cut in them for a length of about $\frac{3}{8}$ in., on which the heads can afterwards be screwed.

If circumstances prevent the operator from procuring a solid tube, a very good substitute can be made by taking a strip of very thin sheet ebonite (about $\frac{1}{64}$ in. thick) as wide as the core, and of sufficient length to make about seven turns round the core. A wooden mandrel or form, about $\frac{1}{4}$ in. less in diameter than the wound core, and an inch or two longer, is now procured. The sheet of ebonite is placed in a vessel of boiling water. This will soften it sufficiently to enable it to be rolled tightly round the wooden cylinder, so as to form a tube, which must be tied down tightly with wide tape, laid on spirally. When the tube is quite cold and hard the tape will be removed, when it will be found that the ebonite will retain its shape—viz., of a tube rather less in diameter than the wound core.

This tube must be allowed to dry thoroughly from any adherent moisture, and then coaxed over the wound core, which it will embrace firmly by reason of its springiness. The extreme outside lap of the ebonite forming this tube should be lifted slightly, and a brush, charged with a thick solution of shellac dissolved in methylated spirits, run along the edge for a depth of about $\frac{1}{4}$ in. The lap should then be allowed to fall back in its place, and pressed well down. After this the tube should again be tightly bound round with tape and set aside to dry. By this means a well-fitting insulating tube is obtained. A built-up tube of this type is quite equal to a solid tube as regards its insulating powers, etc.—and for coils to which it is not necessary to screw on heads, quite as convenient; but of course it would be impracticable to cut a thread on such a tube, so that in using a built-up tube it will be necessary, if heads are to be fitted, to put plain holes through these latter, and cement them on with hot melted shellac or good sealing-wax.

The tube having been fitted and the tape removed, the winding of the secondary constitutes the next step. For this purpose a winder must be constructed. On a board 9 ins. long, 6 ins. wide, and 1 in. thick, are erected two standards, one at each end centrally. These standards should be 8 ins. high, $1\frac{1}{2}$ ins. wide, and $\frac{1}{2}$ in. thick. Through the centres of the lower ends of these standards, at about 2 ins. from the base and exactly facing one another, $\frac{1}{8}$-in. holes should be drilled to admit of the passage of a $\frac{1}{8}$-in. steel rod, which serves to go through a central hole of the bobbin containing the silk-covered wire with which the secondary is wound.

At a height of about 4½ ins. from this first pair of holes a second pair is drilled in the standards, also exactly opposite one another, and a slit ⅛ in. wide cut down to reach these holes from the top ends of the standards. These serve to support a second rod, which, in its turn, carries the core, etc., on which the secondary wire is to be wound. But this second rod is not all in one piece. On the one side it consists in an ⅛-in. hard iron round rod, about 4½ ins. long, nicely pointed at one end, which can be pushed in the centre of the iron core between the iron wires, and at the other end, of a rod made of No. 16 soft-iron wire about 1 ft. long, doubled at its middle, and twisted together nearly up to the end, so as to form a kind of two-tined fork at that extremity, where the "tines" must be bent forward parallel to each other, at a distance of about ½ in. apart. At about the middle the twisted rod is bent twice at right angles, so as to form a crank or handle. The prongs of the fork having been pushed in between the iron wires of the wound primary, at the opposite end to which the pointed rod was forced in, the primary, with its ebonite insulation on, is slung between the slits in the standards, and is ready for winding by turning the cranked handle.

The wire to be used for winding the secondary is No. 36 silk-covered copper. If *good* single-covered can be procured, free from unevenness, and particularly from bare places, it is to be preferred to double-covered, as it lies closer, and hence nearer to the intense inducing field; but if the covering be faulty it will be better to have recourse to double-covered wire. The quantity of wire required will be about ½ lb. for a ½-in. spark coil, or about 1 lb. if the coil is intended to give 1-in. spark.

Before proceeding with the actual winding it will be needful to prepare sufficient paraffined paper to place between each layer of wire in order to insulate the succeeding layers the one from the other. As we shall require paraffined paper for the condenser also, it will be advisable to make the whole at one operation.

To prepare paraffined paper some twelve or fourteen sheets of good white demy paper, free from specks and holes, must be chosen by examination between a strong light and the eye, all defective sheets being rejected. The size should be about 22 ins. by 18 ins. About thirty-nine strips 9 ins. long by 6 ins. wide will be required for insulating the secondary, and about sixty squares 5 ins. long by 6 ins. for the condenser. By laying the sheets of paper evenly and squarely one over the other on a flat board, these two sizes may be cut out with the aid of a straight metal rule and sharp knife at one operation for each size. A tin dish (a large baking dish will do nicely) rather larger than the sheets should now be selected, and in this should be placed sufficient paraffin wax (previously rendered neutral by chalk—see page 108) to cover the bottom to a depth of ½ in. when melted. The dish should then be cautiously heated, preferably *à bain Marie*, until the wax is all fused. The paper should then be introduced sheet by sheet, and, when thoroughly permeated, withdrawn a sheet at a time, care being taken to remove all superfluity of wax by drawing the paper over the edge of the tin, and allowing it to drain by one corner into the dish, which must be kept at one steady temperature (about 150° Fahr.) during the whole of the operation. After draining, each sheet should be hung up by one corner, with a pin bent into an S, on a line to set hard. If any sheets are unduly thick at places, or show blobs of congealed wax, these should be placed between sheets of thick white blotting-paper, and run over with a fairly hot iron.

The bobbin of No. 36 silk-covered wire is now placed between the standards of the winder, and supported by running the lower rod through the central hole in the bobbin. The beginning of the wire is now found and unrolled. Three or four inches of this is coiled into a tight helix round a small pencil, which is then withdrawn, leaving only a helix of wire. This is taken up to the primary, which has been previously slung between standards, as directed above, and the wire tied to the ebonite tube, say, at the left-hand extremity, at about ½ in. from the end, leaving the helix free for future connection to terminals.

Now by turning the handle the wire can be wound off the lower bobbin and caused to coil round the ebonite tube. Before commencing to wind, it will be necessary to put a turn or two of paraffined paper tightly round the ebonite tube, so as to get a perfectly smooth surface to wind on. When the edge of this paper has been pulled very tightly, it can be made to adhere to the paper below by gently warming along the edge with a hot iron, which will melt the wax and cause it to adhere. The handle can now be turned and the wire wound on, the greatest care being taken to lay it on smoothly, closely, and without either gaps between coil and coil or any coil overriding the other. Kinks must also be avoided, as they are detrimental. Should any bare place show itself in the wire, this must be wrapped round with fine silk. Should a break occur, the broken extremities must be bared of covering, cleaned till quite bright, with a bit of finest emery paper, twisted together, soldered by the aid of a stout, hot copper rod and soft solder, using a little rosin as a flux. No soldering fluid may be used, as this would certainly cause the wire to rot and break. When the repair has been neatly executed, the joined portion should be carefully bound round with some fine floss-silk to insure insulation. The winding must be continued until the operator reaches to within ½ in. of the right-hand end of the tube, when he will stop, and, fastening the wire so that it should not uncoil, he will cover the layer of wire just laid on with a turn and a half of paraffined paper, taking care that the end of the wire running off the bobbin lies under the lap of the paper when this passes over it. The paper must be pulled very tightly and smoothly, so as to be perfectly cylindrical and without any creases, and then fastened down, as was the first paper. Again turning the handle (always in the same direction), the operator winds on a second layer of wire until he reaches the left-hand extremity, stopping, however, about two turns short of where he started. This is to cause the length of the coils to diminish slightly as the successive layers are wound on, with a view to preventing the upper layers sparking down and short-circuiting to the ones below. Using all the precautions recommended above, the operator continues winding, putting on the first paper, then the layer of wire, then paper, and so on, until the whole of the pound of No. 36 wire has been coiled on, with the exception of about 6 ins., which must be left free for future attachment to terminal.

Te prevent uncoiling, two or three turns of paraffined paper should be rolled tightly round the last layer of wire, taking care to bring the free 6-in. end of wire out from between the turns of paper, where it can, like the starting end, be coiled into a tight helix. Besides fastening the edges of the last lap of paper down by heating, it will be well to bind the whole round with a wide silk ribbon, laid on spirally, so as to reach from one end to the other, when it can be stitched down and any excess cut off.

The winding of the secondary being thus completed, the entire wound coil should be plunged bodily in a vessel containing melted paraffin wax. The temperature must not be allowed to exceed 150 degrees Fahr. If the vessel be deep enough to allow the paraffin to entirely cover the coil, so much the better; it may be left therein until no more bubbles appear. When this occurs the wax may be allowed to cool a little, until it is just beginning to get pasty, when the coil should be withdrawn, and set on end (over the vessel supported by two side sticks) to drain and set hard. Should the vessel be shallow, the coil should be set on end, and the upper end repeatedly basted with the hot paraffin wax. The vessel may now be removed from the source of heat, allowed to cool as before, the basting being continued until the paraffin begins to get pasty, when the coil can be set up to drain, as previously recommended.

The condenser next demands our careful attention.

From $\frac{1}{4}$ lb. of ordinary tinfoil we cut out fifty rectangular sheets $6\frac{1}{2}$ ins. long by 4 ins. wide, and having placed our paraffin-paper sheets (see page 116), the size of which is 6 ins. by 5 ins., close at hand, we lay three of these squarely one over the other on a flat board. In order that the sheets should not shift during the subsequent building-up of the condenser, it will be well to drive eight stout pins, upright, into the board just round the edges of the paper, two at opposite sides of each corner.

We now lay a tinfoil sheet over the paraffin paper so as to leave a margin of about $\frac{1}{2}$ in. wide all round the tinfoil, except on the *left-hand side*, where the tinfoil should extend beyond the edge of the paper by 1 in. Over this is placed a second sheet of paraffined paper squarely between the pin-guides, then a second sheet of tinfoil. But this time the overlapping inch of tinfoil must be to the *right-hand side* of the operator. Now another sheet of paper is placed over the last tinfoil, over which is laid another tinfoil, with *its* overlap to the left; and so on, paper, tinfoil, paper, tinfoil, until the whole tally of sheets have been laid on.

Particular care must be taken that the sheets of tinfoil extend *alternately* to the *left* and to the *right* of the covering papers.

Three or four sheets of paraffined paper should now be laid over the whole, and a rather warm iron (just sufficiently heated to soften the paraffin wax on the paper, but not enough to make it run) laid on the top. In order to prevent adhesion to the iron, it will be well to place a sheet of blotting-paper, of the same size as the paraffined-paper sheets, between the iron and these latter. The iron should be left on until quite cold. Removing the iron and the guide-pins, the operator now passes a thin knife-blade between the board and the first paper, and thus lifts the condenser without disturbing the sheets. If the last operation has been nicely done, the sheets will adhere together, and form a fairly solid block. If not, it will be advisable to put a long "binder" of paraffined paper round the condenser about its narrower width, leaving its tinfoil ends projecting at the longer extremities. This binder can be fastened down upon itself by running a little paraffin wax along its edge, with a moderately warm iron.

When all is set and cold, two straight pieces of No. 20 copper wire, about 6 ins. long, are made perfectly clean, and laid one on each of the projecting ends of the tinfoil sheets. These are carefully smoothed out, and then rolled round the wire in the shape of a cigarette, with the wire as a core, until by rolling the edge of the condenser is reached. The wires should project about 2 ins. beyond the rolled tinfoils. A needle should now be threaded with some clean *bare* No. 36 or 38 copper wire, and the tinfoil rolls stitched neatly round the wire cores. These latter serve for making connections between the coil wires and the condenser.

In making the condenser the following points require particular attention:—(1) The paper must be free from all pin-holes or thin places. (2) It must be well and *evenly* coated with paraffin wax, but must not have any excess or "blobs." (3) The tinfoils must leave a margin of paper all round except at overlap extremities. The overlaps, or "tabs," must be alternately to the right and the left of the length of the paraffined sheets. (4) Each sheet of paper, as it is laid on, should be pressed down firmly and squarely (if needful, aided by a *clean* warm iron), so as to form a solid block. (5) No paraffin should be allowed to flow between the extending "tabs" of tinfoil, otherwise good metallic contact cannot be made to the coil itself. (6) Great care should be exercised not to tear the protruding tinfoil extension.

We can now take up the contact-breaker or "trembler." As our coil is to be as compact as possible, we shall do away with the stand or base on which ordinary Ruhmkorff coils are mounted, and let all the adjustments and accessories be fitted to the coil-heads, etc., themselves.

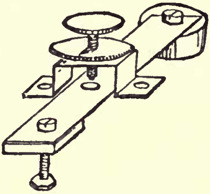

FIG. 44.

The contact-breaker, Fig. 44, consists of two portions—the vibrating spring, with its hammer and base, and a brass strap, which strides over it, carrying the contact-screw and lock-nut. The former should be made of a piece of steel (a clock-spring straightened out does very well) about $\frac{1}{50}$ in. thick, $\frac{3}{8}$ in. wide, and 2 ins. long. A $\frac{1}{8}$-in. hole is drilled in the centre of each extremity of this, and a bare $\frac{1}{16}$-in. hole in the middle of the strip. It is needless to remark that the steel must be softened by heat to admit of these holes being drilled, and that the finished spring must again be tempered to a deep blue and plunged in water. From a piece of soft-iron rod is now cut the hammer, which should be $\frac{5}{8}$ in. in diameter, and $\frac{1}{2}$ in. long, the two ends being filed perfectly flat and parallel. In the centre of this is put a hole (not reaching quite through), which must be tapped to take a $\frac{1}{8}$-in. Whitworth screw. The iron is then carefully softened and annealed by bringing to a red-heat and gradual cooling. While this is going on we put a short piece of No. 16 platinum wire through the small hole in the centre of the spring, when by gently hammering with a flat-faced hammer on a smooth steel anvil we rivet the platinum in, causing it to spread somewhat on the upper surface, so as to form a stud or button, about $\frac{1}{8}$ in. in diameter. This is to form one contact. A little square of brass is now filed up from a piece of $\frac{1}{8}$-in. hard steel, to form a base for one end of the spring. This should be $\frac{3}{8}$ in. square, and have a $\frac{1}{8}$-in. hole put through its centre, corresponding to the hole at one extremity of the spring. The annealed iron hammer is now cleaned and attached to the spring by a suitable short cheese-headed screw, care being taken that the iron bob be placed on the side of the spring opposite to that on which the platinum button has been splayed out widest. To fasten the contact-breaker down to the case of the coil a similar screw (only rather larger) is selected to go through the holes in the spring and block. This screw should be fitted below with a small square or hexagonal brass nut, to enable contact to be made with one of the coil terminals, as described later on. The brass strap may be either a casting, or made from $\frac{1}{8}$-in. sheet brass, bent four times at right angles, thus _⊓_. It should be $\frac{1}{2}$ in. wide, $3\frac{1}{4}$ ins. long before bending, and 2 ins. from end to end when bent into shape. The feet should be $\frac{1}{2}$ in. long, the height of the bridging piece $\frac{5}{8}$ in. clear from the base, and the width of the opening $\frac{5}{8}$ in. A $\frac{1}{8}$-in. hole is put through the centre of each foot to admit the screws by which the strap is to be attached to the coil. A hole is also to be bored and tapped through the centre of the bridging piece, to take a $\frac{1}{8}$-in. Whitworth brass screw, with $\frac{5}{8}$-in. milled head. This latter screw must be fitted with a $\frac{3}{4}$-in. lock-nut, also milled round its edge, and a $\frac{1}{16}$-in. hole drilled carefully for about $\frac{1}{4}$ in. up the centre of the stem of the screw, into which is fitted, by gentle hammering and burring, a piece of No. 16 platinum wire, which should project about $\frac{1}{8}$ in. beyond the tip of the screw.

We can now proceed to make the outer box or case, and fit the coil therein, making the proper connections to condenser, contact-breaker, and terminals. The case may be made of any hard, well-seasoned wood, such as teak, mahogany, or walnut. If the coil has been nicely wound it will not exceed in diameter $2\frac{1}{2}$ ins., in which case the inside dimensions of the box may be $3\frac{1}{2}$ ins. square by $6\frac{3}{4}$ ins. long. The wood with which it is constructed should be $\frac{3}{8}$ in. thick when planed up, so that the external dimensions will be those of a square upright box $4\frac{1}{4}$ ins. in the sides, and $7\frac{1}{2}$ ins. high, including the bottom and cover, which latter is not to be fastened down until the coil and condenser have been put in place. Should, however, through careless winding, the diameter of the coil exceed $2\frac{1}{2}$ ins., the width of the sides of the box must be correspondingly increased—otherwise there will not be space enough for the condenser to lie in without coming into dangerous proximity to the secondary wire. The sides and bottom of the box should be dovetailed together, as it is not advisable to use metal screws near the coil. The box may, or may not, be polished; but, in either case, to insure its being a good insulator, it should be allowed to soak for some time in melted paraffin wax, previous to finishing. The bottom and sides of the box being of wood, as above described, the $4\frac{1}{4}$-in. square forming the top cover may be made out of a piece of ebonite, $\frac{1}{4}$ in. or $\frac{3}{8}$ in. thick, cut to fit squarely on the top of the box, and nicely polished. Holes will have to be put through this cover, two each side, to enable it to be screwed down to the box, one at each corner, just clearing the inside of the box, to take the primary and secondary terminals, one nearer the centre to take the screw destined to hold the vibrating-screw in place, and a pair for the screws holding down the brass strap; besides this, one larger hole, very near the centre, to admit the passage of a portion of the iron core. The exact position of this latter will depend on the bulk of the wound coil itself, so that it may be left for perforation until the coil has been placed in the box.

To assemble the parts of the coil in the box we proceed as follows: Starting with the wound coil, we scrape away any excrescences of paraffin wax from the cylindrical surface. We then draw out carefully the two free ends of the primary wire which we had left for attachment, and having straightened them out, we pass each one through a short piece of $\frac{}{8}$-in. indiarubber tubing. In like manner, using every precaution not to break the wire, we find and straighten out the free ends of the secondary (No. 36) wire. These two ends should both be at the same end of the coil as that at which the primary was started and finished. These wires should also be incased in indiarubber tubing. Two or three turns of thin ($\frac{1}{64}$ in.) sheet ebonite, of the same width as the wound portion of the coil, should now be wrapped tightly round the coil, and fastened thereto by binding round with silk twist, leaving the two primary and two secondary wire ends protruding at one extremity. We now take the condenser, and by gently coaxing it round a bottle filled with warm water, cause it to take a semi-circular shape, so as to fit partially round the coil, with *its* two wire ends projecting from the same extremity as the coil wire ends. We now place the condenser in the box (see Fig. 45), wires uppermost, keeping it as far away from the centre as possible. We then insert the wound coil, wire ends uppermost, as far away from the condenser as the space in the box will allow, but taking care that the entire bobbin stands perfectly upright, with the centre of the iron bundle in the exact centre of the side to which it is nearest. (The iron bundle should project about $\frac{1}{4}$ in. above the level of the box.) In order to retain it in this position previous to the next step, it will be well to insert a few wedges of paraffined paper between the coil and the condenser.

We now arrange the wires so that the primary ends stand out as far as possible from the secondaries, especially these two latter, from each other, as, if they are less than 1 in. apart, there will be a tendency to spark to each other. Having seen to this important point, we melt carefully some clean paraffin wax, not making it too hot (about 150°), and pour it into the box, so as to fill up all interstices in the case, and bring the surface of the melted wax up to a $\frac{1}{4}$ in. of the level of the top of the box.

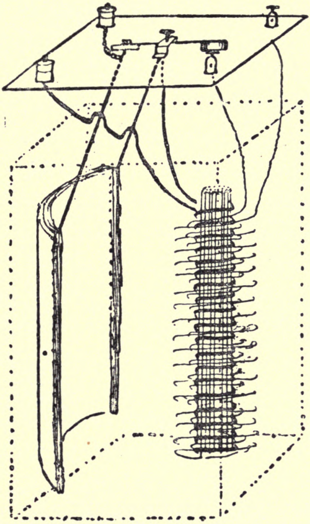

FIG. 45.

We can now make the $\frac{3}{4}$-in. hole in the ebonite top or cover of the case, into which the extremity of the iron core will enter, and allow the hammer of the spring to play in front of. By placing the iron bob centrally in this hole, we shall be able to mark the spot in the cover at which to make the hole for the screw holding down the spring and its little base-block. We now place the strap in position, striding over the spring, with the platinum-tipped screw touching the centre of the platinum boss on the said spring, and mark off and then drill the holes to receive the screws which serve to hold the strap in its place. As it is not advisable to use solder at any of these junctions, we must allow one of the strap screws to project a little beyond the underneath of the cover, and fit it with a small nut.

The four terminals are now inserted near the four corners of the cover. The two primaries should be rather larger, and of a different pattern from those intended for the secondary ; but all four should be fitted with nuts below to facilitate connections to wires without soldering. We now coil the ends of the secondary wires (previously incased in indiarubber tubing), each one respectively round a small French nail, so as to produce a neat helix. Withdrawing the nail, we do likewise with the two condenser wires. (This gives elasticity to the wire ends, and allows us to manipulate them, and also to close the cover without fear of breaking the wires.) Baring the ends of the secondary wire, and cleaning them bright with a bit of fine emery cloth, we clench them under the nuts belonging to the secondary terminals. In like manner we connect the two ends of the primary wire, one to the nutted screw holding down the brass strap, and the other to the nearer large or primary terminal. Taking one of the wires proceeding from the condenser, we bare and clean it at about its centre, and here we pass it under the nut at the bottom of the screw that holds down the vibrating spring, carrying the remainder to the other primary terminal, under the nut of which its bared and cleaned end is to be firmly clenched, any excess being cut off with the cutting pliers. Lastly, we carry the other condenser wire to the strap screw where we had previously put the first end of the primary wire, and having unscrewed the nut, we twist the wires together, and clench them both under the same nut. Care must be taken in making these connections—first, that the nuts clench firmly the wires ; secondly, that the secondary wires are not severed in tightening up the nuts ; thirdly, that the wires do not touch or cross each other at any point. The primary wires and the condenser wires (except only those two which are joined under the strap nut) will be sufficiently insulated from each other where near, by the insertion of a piece of paraffined paper. This, however, is not the case with the secondary wires—these *must* be kept at as great a distance as practicable from each other, well covered in indiarubber tubing ; otherwise leakage, even to the point of sparking across to each other, will be sure to occur. When we are satisfied that this is the case, we cautiously lower the cover, taking care that the wires do not get displaced, and screw down the cover by the eight side screws.

The outlines of the case are only faintly drawn in the illustration, but will give a general idea of the arrangement of the parts and the connection of wires. The cover is shown somewhat raised.

If it be desired to mount the coil without the trembler, and to depend entirely on the mechanical break for obtaining the spark, the mode of fitting up will be somewhat different. The case may take the form either of a box, as previously described, or, as is often used, of an ebonite tube of rather large diameter, fitted with flanged ebonite heads, about $\frac{3}{8}$ in. thick of which enter into the tube up to flange or shoulder, and can be fastened thereto by three small lateral screws. No contact-breaker will be required. The coil and the condenser having been got ready, as previously described, an ebonite tube of suitable size to contain both easily is obtained, of such a length as to contain the entire coil and iron bundle (which in this case need not be longer than the wound portion of the coil) without touching the cover. The primary and secondary wire ends having been drawn out as directed in the last section, one end of the secondary wire is taken through a small hole drilled near one edge of the cover, near to which is inserted one of the secondary terminals; and under the shank of this terminal the bared and cleaned wire is clenched. The tube with its contained coil and condenser, is now turned with its open end uppermost, and the coil and condenser being supported upright, and as far as possible from one another, melted paraffin wax is poured in until the iron core is entirely covered, there being left protruding the ends of one secondary, the two primaries, and two condenser wires only. When the wax has set and is quite hard, the ends of the primary wire nearer the iron core are bared, as also one of the condenser wires. The free end of the secondary wire (which for this purpose should have been so coiled round the core so as to terminate at the opposite extremity to the one already secured to the terminal) is also bared. Then the starting extremity of the secondary is wrapped round the finishing end of the primary, and soldered thereto, using *resin only* as a flux. In like manner one of the condenser wires is coiled round the starting end of primary and soldered to it. The three ends of wire are now each respectively covered with indiarubber tubing, except just at the extremities, where they will have to pass through the upper cover and be connected to three separate terminals, situated at three equidistant points near the circumference of the cover. The cover should now be fastened in its place by three short lateral screws passing through the tube. The terminal to which the single condenser wire is connected should be marked K (see Fig. 46); the solitary terminal to which the single (or finishing) secondary wire was carried at the back end of the coil should be marked S +. In like manner the terminal to which the joined secondary and primary are connected may be marked A; while the one making con

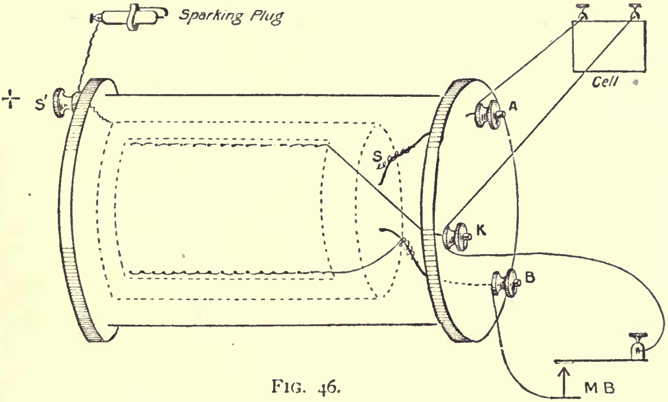

FIG. 46.

nection to the conjoined primary and condenser wires will receive the mark B.

As it is essential to the proper working of the coil that the terminal S + should be in a positive state when the coil is connected to its battery or accumulator, and as its condition will vary according to which pole of the battery is connected up to B and K respectively, it will be advisable to test this, and mark one of these terminals with + when found. This is easily done by connecting up the battery to A and K, first in the one direction and then in the other, an assistant in the meantime *rapidly* making and breaking contact with a piece of wire between K and B, the operator, *not* the assistant, holding at the same time his knuckle at about ½ in. from S +. When the proper poles of the battery are being used, a fairly strong spark will pass from S + to the operator; but if the battery is wrongly connected, there will be either none at all or else a very faint one. In performing this trial the operator should be careful not to come into contact with his assistant, otherwise they will both receive a pretty sharp shock; and the assistant must be careful not to leave the testing wire in contact with both terminals K and B for any appreciable length of time, but simply to flash it across the two; otherwise he will heat the wire and run down the battery. In using such a coil the terminal S + is taken to the ignition plug of the motor, the cell connected by its proper poles to A and K; while two separate wires connect K to the spring of the mechanical break (M B), and B to the body of the engine respectively.

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