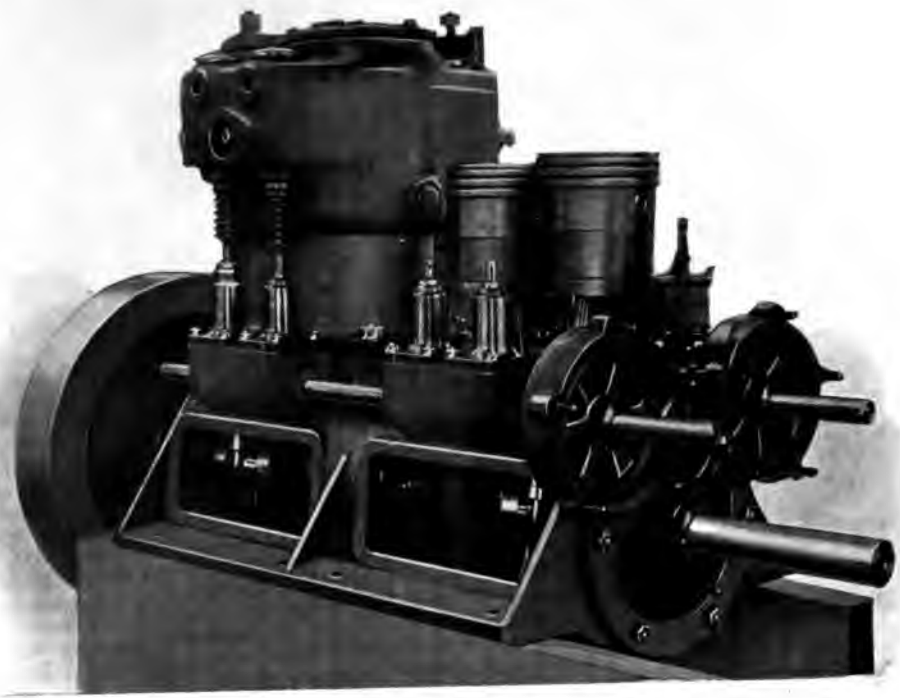
MOTOR-CAR MECHANISM
AND MANAGEMENT

PART I
THE PETROL CAR



BLAKE 25 H.P. PETROL ENGINE, WITH THE RIGHT-HAND PAIR OF CYLINDERS,

MOTOR-CAR MECHANISM

AND MANAGEMENT

BY

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IN THREE PARTS

PART I. THE PETROL CAR. PART II. THE ELECTRICAL CAR
PART III. THE STEAM CAR

PART I. THE PETROL CAR

SECOND EDITION, REVISED

With 36 Illustrations

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PREFACE

The present age is essentially an age of engineering, and it is becoming increasingly important for members of the general public to have some acquaintance with engineering principles. The coming of the bicycle has made some knowledge of engineering necessary to the great army of cycle riders. The advent of the motor-car has rendered it highly essential for the large and increasing number of drivers, be they owners or chauffeurs, to have a fairly close acquaintance with the mechanical principles underlying the machine of which they have the control.

It is not enough that a chauffeur should know how to increase or reduce the speed of his car, or to stop it by the movement of this or that handle; to be thoroughly efficient at his work he should understand the reason for everything, and have an intimate acquaintance with the details of the machinery; the better his knowledge on such matters the better driver will he make. The author has been struck with the very large amount of "rule-of-thumb" driving that is to be found at the present day; in fact the motor-car driver who really thoroughly understands the principles of the machinery of his car is quite an exception. It is, however, not always for want of will, for if the motor-car driver of the present day has one chief characteristic, it is his desire to know the why and the wherefore of everything connected with his car.

The author therefore trusts that this little treatise will be useful both to drivers and those who are about to take up driving.

At the present day there are three distinct types of motor-car in use—the Petrol, which is by far and away the most popular; the Electric, which comes second in favour; and, thirdly, the Steam car.

Each has its own special advantages for certain work, and also, it must be added, its disadvantages, for the modern motor-car is by no means perfect yet. The mechanical principles involved in these three types vary considerably, and the author has thought it best, in the interests of simplicity, to divide this book into three distinct parts; the first dealing with the petrol car, the second with the electric, and the third with the steam car. Each part will be divided into two sections—the Mechanism will be described in detail first, and the Management afterwards, the reason for this division being that it is not possible intelligently to follow remarks on management until the inter-relation of the various parts is understood. It will be assumed that the reader has no previous knowledge of mechanics or engineering, as probably the majority of readers of this book will have had no opportunity or occasion previously of acquainting themselves with the principles underlying the mechanism.

To understand thoroughly how the whole apparatus works, a certain knowledge, not only of mechanical principles, but also of chemistry, electricity and magnetism is required; there will be no attempt, however, to deal exhaustively with these subjects, but they will be treated in quite a simple manner, and only in such a way as to make the working of the special apparatus clear. It would be a great help to the reader in understanding the text if he would take the trouble to perform the few simple experiments described.

It will doubtless be understood that a practical knowledge of the mechanism of the motor-car is not to be obtained simply by reading. It is the author's intention that the information contained in this book should be supplementary to practical instruction. Especial efforts have been made to avoid the use of technical expressions and scientific phraseology, and to bear in mind that the very large majority of its readers will be unacquainted with scientific principles and engineering practice.

W. P. A.

LONDON,
January 1906.

PREFACE TO SECOND EDITION

The call for a second edition of this book so soon after publication is gratifying alike to author and publishers and it may be fairly assumed that it has met a need. At so brief an interval no substantial alterations will be necessary, but several small errors have been rectified, and in places where there was room for misunderstanding the text has been modified. An extra chapter has been added giving additional notes on the management of cars, and also an appendix giving a number of useful diagrams of the machinery in various cars, which will help to familiarise the reader with the general principles of construction.

London, *April*, 1907

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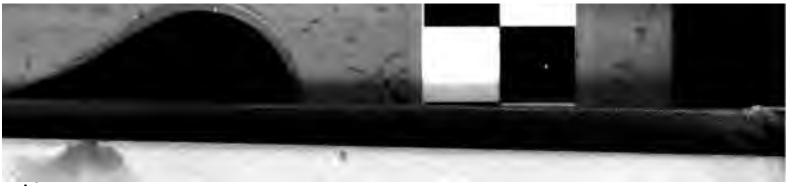
SECTION I—THE MECHANISM OF THE PETROL CAR

INTRODUCTION

THE number of different makes of petrol cars now on the market is very considerable, but, with a few exceptions, the general arrangement is practically the same in all, the differences consisting in modifications of some of the details. Some of these modifications are certainly of considerable importance in securing the quiet and efficient running of the car; but no detailed description of them need be given here, as the general account contained in the following pages will suffice for locating the various pieces of apparatus in any special make of car, and the modifications will be readily mastered if the general principles are understood.

During the reading of Chapter I. special attention is directed to Fig. 1. Each individual part of the machinery is named on this diagram, and when such a part is referred to for the first time it appears in Italics. This illustration (as well as most of the others) is a diagram merely and not a drawing to scale, some of the parts having been proportionately enlarged in order to render them more prominent. Fig. 2 (Plate I.) is from a photographic reproduction of a working sectional diagram, with which the author is able to show graphically the movement of the various parts and their relation to one another; such a working diagram is almost invaluable to a non-technical person in studying the "Otto Cycle," and free use has been made of it



in the subsequent figures when describing the interconnection of the working parts.

Although, no doubt, as experience grows the petrol car will be much simplified in its general arrangement, at present it cannot be considered otherwise than as a complicated machine. It is the custom to mount all the mechanical devices upon the framework or "chassis" of the car. The "body" of the car is made to suit all sorts of conditions and requirements, and will need no further comment on our part.

On the fore part of the chassis is mounted the *Engine*, which is the source of the driving power. This engine, while fairly simple in itself, has to be provided with several external accessories, which for convenience may be considered as separate and distinct systems. First there is a somewhat elaborate *System of Petrol Supply;* secondly, as the engine gets hot in working, the *Cylinder*, in which the explosions take place, needs to be cooled by a *System of Water Circulation;* thirdly, as the mixture of petrol vapour and air is ignited by an electric spark, the whole arrangement of battery, induction coil and sparking device is termed the *Electrical Ignition System;* and, finally, the distribution of oil to the various parts of the engine is somewhat elaborately arranged and may be termed the *Lubrication System.*

When the power has been produced on the *Crank Shaft* of the engine it is transmitted through a *Friction Clutch* to a shaft conveying the power to the rear wheels; behind the friction clutch is the *Change Speed Gear*, which enables the wheels to be driven at varying speeds while the engine is running at a constant rate: and attached to the rear axle is a *Differential Gear*, which enables either of the rear wheels to be turned independently of the other and both to be driven at a uniform rate when the car is proceeding straight forward. That part of the shaft lying between the change

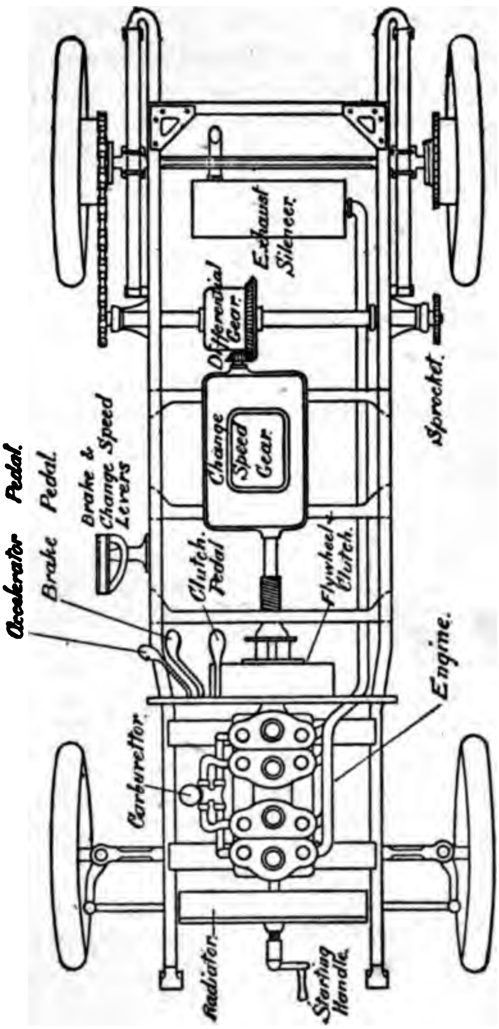
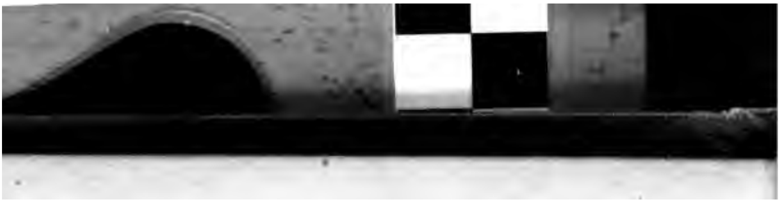


FIG. 1.—General Plan of Chassis.



speed gear and the differential gear is provided with two *Universal Joints*, which allow the rear wheels to rise and fall freely as the springs are compressed or released. The drive may be direct from the shaft or by means of a chain gear through an additional shaft, parallel with the wheel axle and carrying the sprocket wheels and differential gear. In addition to the engine with its parts and the power transmitting gear, other mechanical devices of no little importance are in use, and will receive attention in due course; these consist of the *Brakes*, the *Steering Gear*, the *Wheel Bearings* and *Tyres*.

Our first duty will be to consider the engine, its parts and accessories.

REFERENCE NOTES TO LETTERING IN FIG. 2 (PLATE I)

A. Engine Cylinder.
B. Water Jacket for cooling the Cylinder.
C. Water Circulating Pipes.
D. Cylinder Head or Combustion Chamber.
E. Inlet Valve, *i.e.*, valve admitting explosive mixture of petrol, vapour and air.
F. Pipe from Carburettor where explosive mixture is made.
G. Spark Plug.
H. Exhaust Valve and Pipe.
I. Piston with Piston Rings, also Small End of Connecting-Rod attached to the Piston by the Gudgeon-Pin.
J. Connecting-Rod.
K. Big End of Connecting-Rod. In centre is the Crank Pin surrounded by Big End Bearing or Brass.
L. Crank. The end of the Crank Shaft on right.
M. Balance Weight to counterbalance the weight of the crank and connecting-rod.
N. Gear Wheels operating the Half Speed Shaft.
O. Exhaust Cam attached to Half Speed Shaft.
P. Exhaust Valve Spindle or Rod and Spring.
Q. Crank Chamber Casing.
R. Oil for Splash Lubrication.

N.B.—The arrow shows the direction of rotation.

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PLATE I

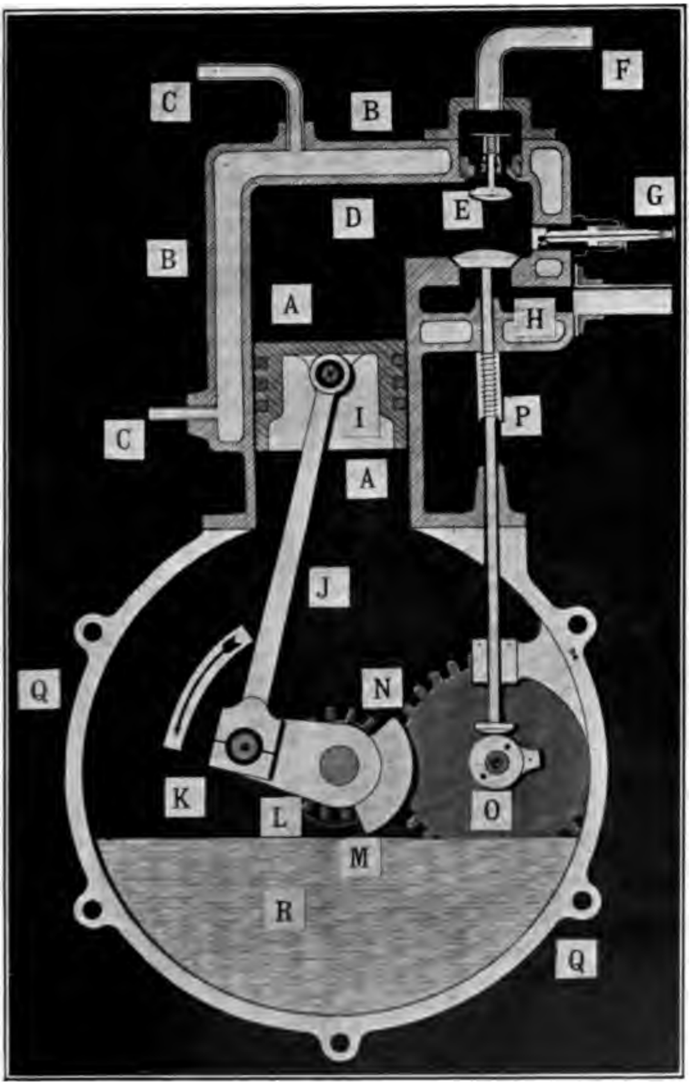

FIG. 2—DIAGRAMMATIC SECTION OF PETROL ENGINE

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CHAPTER I—THE ENGINE

CONTENTS:—The Cylinder — Piston and Connecting-Rod — The Crank Shaft—Valves—The Engine at Work—The Otto Cycle

THE engine belongs to that class of power producer termed an *Internal Combustion Engine*, that is to say the fuel which is the source of its motive-power is burnt inside the cylinder, and not externally as in the case of the steam engine. The Gas Engine and Ordinary Oil Engine are also internal Combustion Engines.. In the petrol engine there is first and foremost the *Cylinder*, in which works the *Piston*. The explosion takes place in the cylinder and drives the piston by means of its force from the top to the bottom of the cylinder; to the under side of the piston is attached the *Connecting-Rod*, the lower end of which is connected to the *Crank Shaft;* on this crank shaft is fitted a heavy *Flywheel*. To admit the petrol vapour at the right moment and to allow of the exhaust gases escaping after the explosion has taken place *Valves* are provided. Each of these parts of the engine proper we will consider in turn.

1. **The Cylinder.**—The material used in the construction of the cylinder is cast iron, and it may be well to note here that cast iron is of a brittle nature. If any lightly made article of this material is handled roughly or dropped, it is very liable to crack and break; however, the quantity used in the cylinder is large and gives ample strength for the purpose. The inside of the cylinder in which the piston works is bored out carefully and truly, so that the piston fits nicely as it moves from end to end. It will be seen that

the piston does not traverse the cylinder throughout its length, and that when the piston is in its topmost position there is a considerable space above; this space is termed the *Combustion Chamber* or *Combustion Head.* This is the space that contains the explosive mixture immediately before firing, and it is in this space that the electric spark sets fire to the gases. When the explosion occurs the piston is driven forward with considerable velocity, until the crank reaches a point exactly opposite to the position it occupied when the piston was at the top of the cylinder. The distance which the piston moves in passing from the top to the bottom of the cylinder is called the stroke of the engine. The power developed by any given engine depends primarily upon the size of the cylinder and the length of the stroke; to compare the power developed by two different cylinders, other conditions being the same, it would be necessary to compare the areas of the piston and the length of the stroke. The volume contained in the cylinder head or combustion chamber is generally one-sixth of the cylinder volume, that is to say the sectional area of the cylinder multiplied by the length of the stroke.

The explosion of the petrol vapour, mixed with air, necessarily produces an intense heat, and this causes the walls of the cylinder to rise considerably in temperature; in fact, were the heat not carried away by some means the walls would actually get red hot. A reference to the diagram will show that the cylinder is provided with a *Water Jacket* or hollow space in the casting, through which cool water is made to circulate round the outside of the cylinder, and so carry away the heat. This will be referred to fully later on.

2. **Piston and Connecting-Rod.**—The *Piston* is generally made of cast iron, and is of considerable depth. The efficiency of an engine will necessarily depend upon the full power of the explosion being utilised, and if any part of the

enclosed space in which the explosion takes place is not thoroughly gas tight, there will be leakage and loss of power; to ensure a really tight joint between the piston and the cylinder, *Piston Rings* are fitted. In the smaller engines there are three, as shown in Fig. 2 (Plate I.); in larger engines there are five; they are fitted into grooves specially cut in the face of the piston, and are made of cast-iron rings turned a trifle larger than the diameter of the cylinder, and then cut with a saw, so that they can be contracted; as they are of cast iron, they are fragile and need careful handling: they are usually slipped into their grooves by passing them over some thin cards, as they will not bear pulling over by hand. As their function is to prevent leakage of the gases past the piston it is essential that the saw-cuts in the several rings should not be one over the other.

The *Connecting-Rod* is attached to the under side of the piston by means of a *Gudgeon-Pin*. This rod is made of steel, and should be of ample dimensions, as it is the sole means of transmitting the power generated by the movement of the piston to the *Crank Shaft*. If the engine is carelessly handled and an explosion takes place prematurely the connecting-rod is likely to be bent. The lower end of the connecting-rod is enlarged to carry the *Big End Brasses* or the bearing in which the *Crank Pin* runs. Although the bearings are called "brasses", gun-metal, an alloy of copper and tin is used; as the reults of general experience, it is not usual to make the rubbing parts of machinery of the same metal; a hard metal and a soft one give very much more durable results, and hard steel shafts or spindles are almost invariably run either in gun-metal or white metal bearings.

3. **The Crank Shaft.**—It is highly important that this part of the engine should be thoroughly well made and

of the best material. Usually the material employed is hard steel, and a crank shaft, forged from the solid metal is greatly to be preferred to one built up in pieces. In an engine working with a reciprocating action every precaution should be taken to prevent vibration, and for this reason the heavy parts are usually balanced; on a single cylinder engine with one crank a balance weight is provided on the opposite side of the crank shaft, this tends to give steadier running. On quite small engines, the crank pin passing through the connecting-rod bearing is sometimes screwed into the crank, but it will be readily realised that the crank pin has to bear the full force of the explosion, and, therefore, needs to be of the most solid and dependable character.

While considering the principles of the engine it will be wise to avoid complicating matters by referring to multiple cylinder engines; a careful study of the arrangement of the crank shaft of a multiple cylinder engine is, therefore, reserved for future consideration. It will be seen on reference to the diagrams that when the piston is at the topmost point the connecting-rod is in a direct line with the crank and centre of the crank shaft; pressure applied to the top of the piston while in this position cannot produce any movement; hence this is called the "dead-point." If the crank is rotated backwards or forwards ever so small a distance, pressure applied to the top of the piston would cause the crank to move. At first it would move slowly, but as it reaches a right angle the speed at which it moves is considerably greater than in the earlier and later parts of the stroke, and the most powerful effect or turning moment is produced near the middle of the stroke. In the petrol engine one explosion only takes place in two revolutions; a reserve of power is, therefore, necessary to carry the crank shaft, connecting-rod, and piston over the two intermediate up-strokes and additional down-stroke; this power is obtained by means of a *Flywheel* connected on the crank shaft, and more generally made a part of the friction clutch, to which reference will be made later. It is sufficient at present to bear in mind that when an explosion has taken place the momentum of the flywheel will carry the moving parts round until a second explosion takes place; in some of the smaller engines the flywheel is enclosed in the *Crank Chamber*.

At either side of the crank is provided a bearing in which the shaft runs; these bearings are made of gun-metal, with arrangements for adjusting and taking up wear. They need special attention, as they bear the brunt of every explosion that takes place; if not properly attended to and oiled with perfect regularity the wear is apt to be considerable. All moving parts and rubbing surfaces in an engine or other piece of machinery need to be lubricated, and although the general systems of lubrication of the engine will receive consideration further on, it will be useful to mention at this point that the crank, crank shaft, connecting-rod, and bearings are enclosed in the *Crank Chamber*, a metal casting attached to the lower side of the cylinder casting. This crank chamber is made watertight, and contains a certain quantity of oil, into which the end of the crank dips, as it moves round its path and splashes the oil on to the moving parts in the chamber. This "splash lubrication" is sufficient to oil efficiently the piston with its rings, the upper end of the connecting-rod, and the crank shaft bearings.

Before a petrol engine can be started it is necessary, first of all, to draw a charge of the explosive mixture into the cylinder, to compress it and to ignite it; in other words, the engine cannot be started until the crank shaft is rotated, so as to bring about the various initial operations. With a motor cycle the difficulty is easily got over by running the machine a short distance over the ground, but with a heavy motor-car this is obviously impossible; a *Starting handle* is, therefore, provided in front of the engine, which operates through gear wheels or chain drive on the crank shaft. By giving a quick turn or two to this handle, the first charges are taken in and fired, and, all being carefully adjusted, the engine starts; once the engine has started, it runs free of the handle, which may then be removed if detachable.

4. **The Valves.**—Two valves are required in the petrol engine, the *Inlet* or *Admission Valve*, through which the explosive mixture is admitted to the engine at the right time; and the *Exhaust Valve* which opens when it is necessary for the exhaust gases to be driven from the cylinder before taking in a fresh supply of the explosive mixture. Until recently the inlet valve has been arranged to work automatically, that is to say, when the piston is making a downward stroke under the influence of the revolving fly-wheel, and after the exhaust gases have been expelled, the suction caused by the moving piston pulls the valve off its seat and sucks in the mixture of gases from the carburettor; normally the valve is kept on its seat by a spring. This automatic valve is open to several objections, as if the seat should by any means become dirty or sticky, it may open too late for a sufficient quantity of explosive gas to be admitted. It is also necessary for the piston to have passed some distance down the cylinder before the suction is sufficiently great to overcome the pull of the spring, and part of the stroke is completed before any of the gas has been admitted; it also closes again before the piston has finished its stroke, on account of the decreased suction. It is a growing custom now to use a mechanical inlet valve, which is opened in a similar manner to the exhaust valve, by means of a cam; it can thus be forced open without suction, and kept open for any prearranged length of time; its special advantage is

that the opening is certain, and the quantity of mixture admitted from time to time is unvaried. In the diagram it will be seen that both the exhaust and inlet valves are of similar shape, and of the so-called "mushroom" type. The head of the valve is bevelled off on the underside, and fits with considerable accuracy into the seat provided immediately underneath. The accurate fit of these two surfaces is highly important, as if they do not fit perfectly they allow gas to escape when under compression.

As one explosion only takes place in two revolutions, it is necessary that the exhaust valve should only open once in every two revolutions, that is immediately after the explosion has taken place, so that as the piston moves from the bottom to the top of the cylinder the exhaust gases may be driven out. The lifting of this valve must necessarily be accomplished by mechanical means, that universally adopted being a *Cam* or "eccentric" working on a shaft which is revolving at half the speed of the crank shaft. A *Gear Wheel* is provided on the crank shaft, the teeth of which engage with the second gear wheel, having twice the number of teeth attached to a short *Half Speed Shaft*, upon which the cam is fixed. The lower end of the exhaust valve rod is almost resting on the lower part of the cam, and when the cam projection strikes the lower end of the exhaust rod the valve is forced upwards, thus allowing the gases to pass away into the exhaust pipe and to the atmosphere.

Leading into a small chamber above the admission valve is the pipe conveying the supply of petrol vapour and air to the engine; there is also a pipe leading from the valve chamber under the exhaust valve, which conveys away the burnt gases; it is almost invariably connected to an exhaust silencer, as the noise made by the gases passing away from the engine at a fairly high pressure is very objectionable. The exhaust pipe near the engine is generally raised to a

very high temperature, and for this reason a stout insulating piece of asbestos cardboard is bolted between the metal faces, otherwise the heat from the exhaust pipe would be communicated to the head of the cylinder and cause considerable trouble.

The point at which the electric spark takes place is indicated in the diagram, immediately above the exhaust valve; the wires conveying the electricity from the sparking apparatus are attached to this *Sparking Plug* and will be fully described later. The position of the sparking plug is not necessarily that shown in the diagram; sometimes it is put into the top of the cylinder, but wherever it is placed the points between which the spark takes place must be situated inside the combustion head. We have now considered the various parts of the engine in detail, and are in a position to follow the working of the engine.

5. **The Engine at Work.**—In the petrol engine of the type we are considering one explosion only (as already explained) takes place in every two revolutions; each upward and downward stroke, however, has its own special duties in the cycle. The system under which the engine works is called the *Otto Cycle*, being the invention of a certain Dr. Otto, who introduced the principle with the first practicable gas engine. This Otto cycle is of considerable importance as, with one exception, it is the only one used for petrol engines. It is also employed in the vast majority of ordinary oil engines and gas engines.

The Otto Cycle.—The four figures of the engine in Plates II. and III. will assist materially in enabling the reader to understand the relative parts of the engine during the complete cycle. In Fig. 3 (Plate II.) the piston is making a downward stroke, the admission valve is open and the explosive mixture is rushing into the cylinder; this will continue until the piston nearly reaches the bottom of the

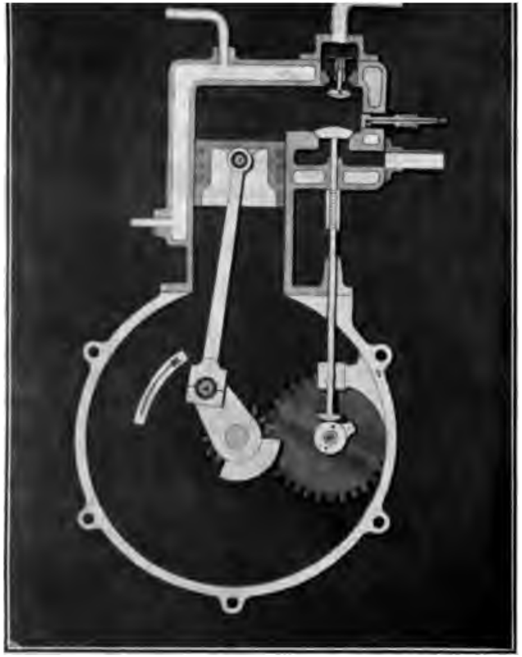

FIG. 3—OTTO CYCLE, THE SUCTION STROKE

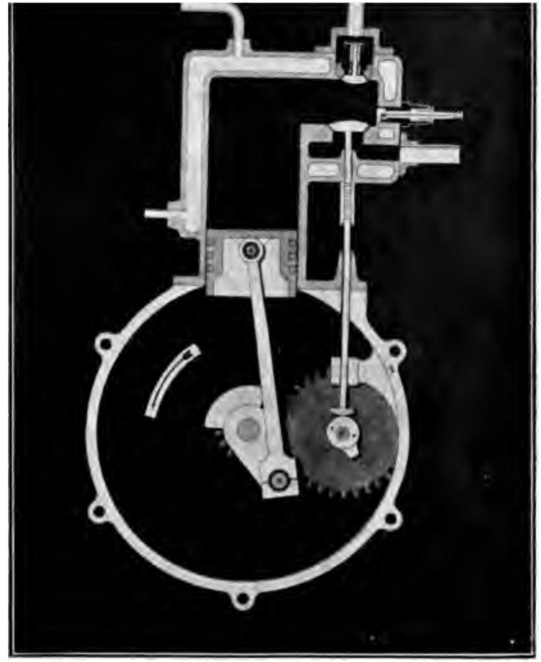

FIG. 4—OTTO CYCLE, THE COMPRESSION STROKE

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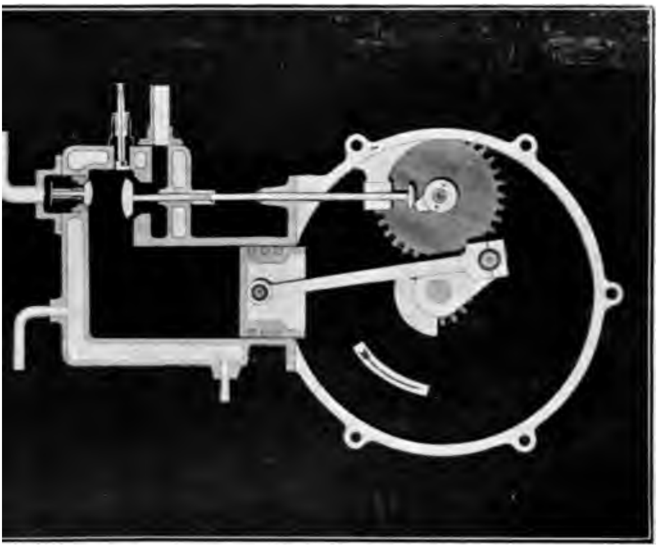

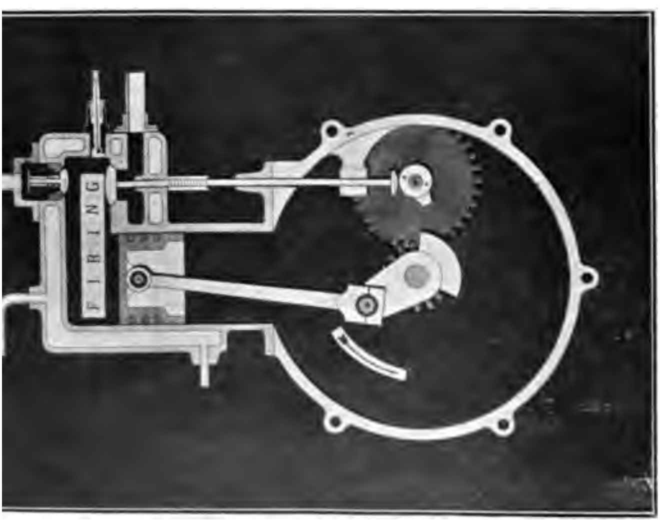
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cylinder. In Fig. 4 (Plate II.) the piston is making an upward stroke, the admission valve it will be noticed is shut, and the charge of explosive gas is of necessity being compressed; this compression takes place until the piston reaches the top of the cylinder when it is at its maximum, the compression when the stroke is complete being from 60 to 80 pounds on the square inch. This compression of the explosive mixture is an important factor in the proceedings, as it is found that a substantially greater efficiency is obtained when the gas is compressed in this way than when fired at atmospheric pressure only. At the completion of the upward compression stroke an electrical contact is made automatically by means of a contact maker on the half-speed shaft, which causes the spark apparatus to send a spark across the points of the spark plug into the explosive mixture. (*See* Fig. 5, Plate III.) The flywheel it must be remembered is carrying round the crank shaft over the dead point; immediately the explosion takes place the piston is given a considerable impulse dowuwards, which continues until it reaches its lowest point; the flywheel again carries the crank past the dead point and the second upward stroke of the cylinder commences. In Fig. 6 (Plate III.) it will be seen that during this upward stroke the cam on the half-speed shaft is opening and holding open the exhaust valve, so that as the piston sweeps upwards it drives out the burnt gases through the exhaust pipe and into the atmosphere. When the piston reaches the topmost point the cam has finished its work, and the exhaust valve is closed by the spring. A new downward stroke immediately commences, the suction opens the admission valve and a fresh charge is taken in.

It might perhaps be worth while to mention in passing that there is a so-called two-stroke petrol engine on the market which makes an explosion every revolution, but it is generally acknowledged that the old Otto cycle holds its own against new comers very satisfactorily in the matter of efficiency, that is power developed from a given quantity of petrol. All references to the constitution of the explosive mixture, the details of the spark ignition, and to the control of the explosion are left to the sections dealing with the "Petrol Supply System" and the "Electrical Ignition System." It is sufficient to know at the present time how the explosive mixture is admitted, and that it is ignited at exactly the right moment by means of the electric spark. It may be mentioned, however, that a considerable variation in the power developed by the engine can be brought about by making the explosion occur slightly before the piston has reached its topmost point on the compression stroke by timing the spark so as to occur early, or its power may be substantially decreased by timing the spark late, that is after the piston has travelled some distance down the cylinder during the explosion stroke. It would perhaps seem almost impossible that the spark should take place before the compression stroke has been completed, but the high speed at which the engine runs makes this possible, as the firing of the whole charge takes an appreciable time, and the full force of the explosion is not felt until the dead point has been passed. The speed of the petrol engine is considerable, varying from normally 500 to about 1500 revolutions per minute. It is not possible to vary the normal speed of an individual engine very largely, and for this reason special means have to be provided for reducing the speed of the car while the engine is running practically at a constant speed; in this respect the petrol engine is at a considerable disadvantage as compared with a steam-engine. While it is possible to advance the spark and attain early ignition when the engine is running at a high speed, it needs to be done with judgment, as, should the explosion take place too early, very heavy strains would be set up in the engine, and serious damage might result; it is, however, usual, notwithstanding, to so arrange the contact-making device that the explosion occurs normally a trifle before the compression stroke is finished. When we are considering the fuel the reason for this will be made plain. Early ignition is a distinct advantage when running at a high speed, but advancing the spark too much, or at lower speeds, might prove disastrous. Good management is also necessary in the matter of retarding the spark, as, if this is done excessively, the explosion is not completed by the time the exhaust valve opens, and a considerable amount of power is wasted without any corresponding gain in reduced petrol consumption; and, if the explosion takes place partially outside the cylinder, a considerable amount of heat passes into the exhaust pipe and silencer; this point will receive fuller attention when the governing of the engine is being considered.

CHAPTER II—THE ENGINE ACCESSORIES

CONTENTS:—The Petrol Supply System—The Carburettor—The Silencer—Water Cooling—Lubrication—Governing

1. **The Petrol Supply System.**—In one sense the petrol engine is a gas engine, for the petrol is not admitted in a liquid condition to the cylinder and so burnt, but, in a piece of apparatus called the *Carburettor*, the vapour which is given off from this highly volatile oil or spirit mixes with the air that is drawn through the apparatus at the time of the suction stroke, and the mixture passing into the engine is simply air saturated to a certain degree with petrol vapour.

The proportions need to be carefully adjusted between the air and quantity of petrol vapour to secure the best explosive effect, and not a little of the success obtained in running a petrol car depends upon the management of the carburettor.

The Carburettor.—The carburettor is therefore a highly important accessory to the engine. The simplest form is that known as the *Surface Carburettor*, which consists of a tank containing the petrol and presenting a large surface to the air drawn through the tank when the engine is at work; the mere passage of the air across the surface of the volatile liquid saturates it to a sufficient degree, provided the petrol is warm enough; at most ordinary temperatures in the British Islands the vaporisation which takes place is sufficient without assistance; but in the winter it is necessary to apply a small degree of warmth to the carburettor to ensure that a sufficient supply of vapour is imparted to the air.

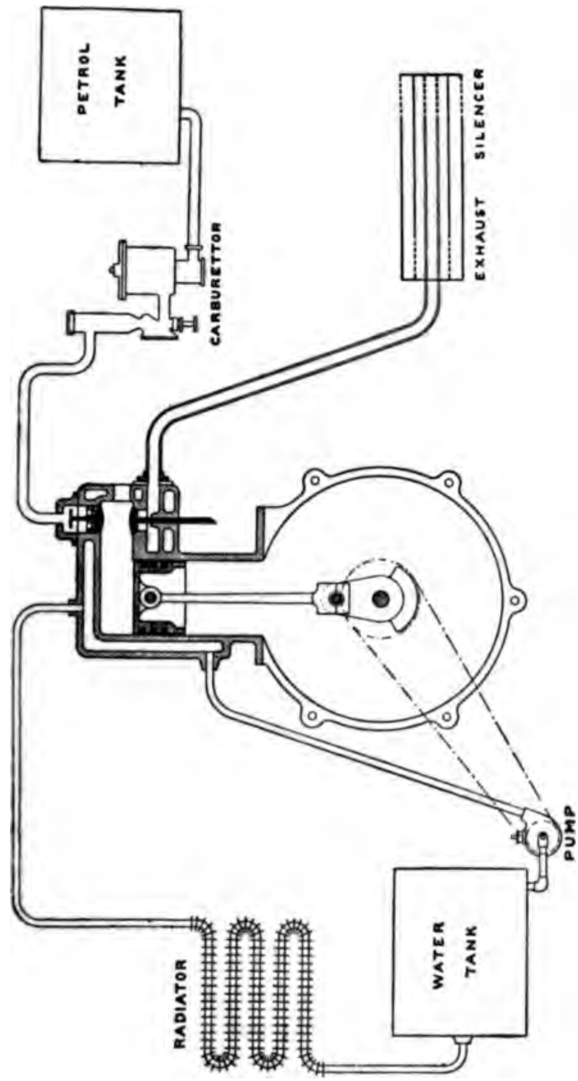

FIG. 7.—Diagram of the Petrol Supply System, Water Cooling and Exhaust Silencer.

The Surface type of carburettor is somewhat cumbersome, and is being rapidly superseded by the *Spray* type in every department of automobile work; it is, however, still used in connection with motor bicycles, and has special advantages for this type of vehicle.

In the motor-car proper, however, the Spray type is universally used, and we may now go on to the consideration of this type. The whole of the petrol supply arrangements are shown in Fig. 7. The *Petrol Tank* in which the spirit is stored is usually placed under the seat of the motor-car, the outlet pipe at the bottom passing direct into the carburettor. The petrol tank needs to be a little above the carburettor level, but the difference must not be too great. From the carburettor the air, mixed with the petrol vapour, passes by the shortest possible route through a large pipe into the admission valve chamber; the pipe needs to be short and large, as the vapour tends to condense in a long pipe; a long and narrow pipe tends also to restrict the passage of the mixture, whereas the supply should be free and prompt.

The carburettor is an extremely ingenious piece of apparatus; that most used is the *Longuemarre;* all others are modifications of this type, and it will suffice to describe this one only. If the reader understands the principle on which it works he will have no difficulty whatever in comprehending the various so-called improvements upon the system.

Fig. 8 shows a section of the carburettor. It will be seen that it consists of two separate parts, the *Float Chamber* and the *Spray Chamber*. In its normal condition the float chamber is nearly full of petrol and the float floating on top. When in this position the small needle-valve at the base of the chamber is closed and the passage of any further petrol into the chamber is prevented; when, however, the supply gets used up the float sinks, presses against the little arms at A, which, in turn, lift the needle-valve; then a fresh

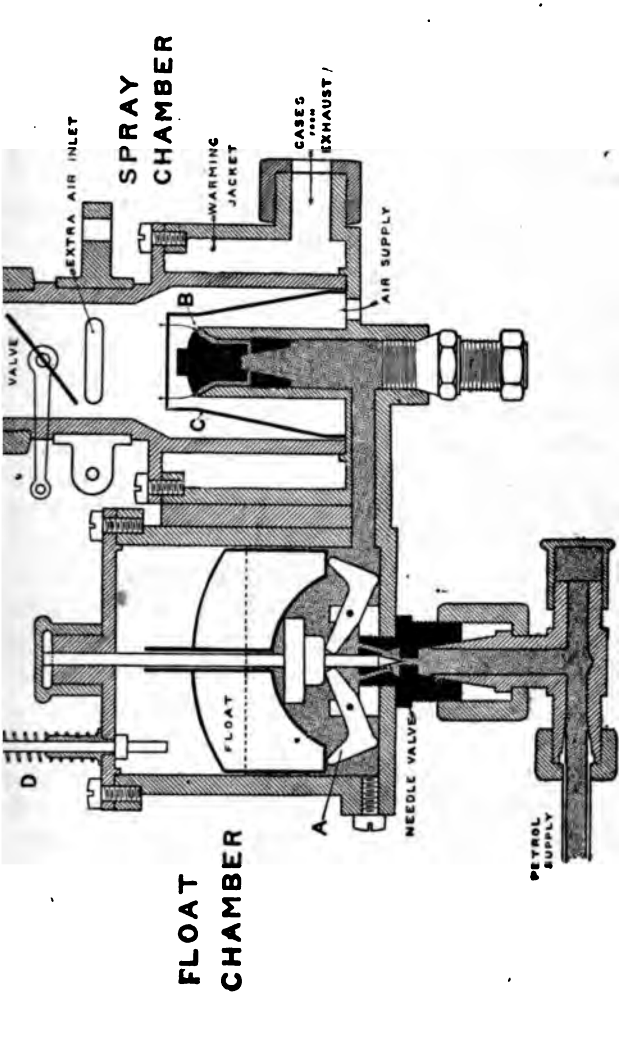

FIG. 8.—Section of Carburettor.

supply of petrol runs in, raises the float, and once again the needle-valve is closed.

The petrol has free exit from the float chamber into the spray chamber, the top of the fine spray tubes at B being a trifle above the level in the float chamber. At the base of the spray chamber will be seen openings admitting air under the hood C.

When the engine is making the suction stroke it creates a partial vacuum in the spray chamber. A small quantity of petrol is sucked through the fine tubes in the form of spray, and at the same time a quantity of air is sucked up through the opening at the bottom; the air mixes in the space above the spray maker with the petrol vapour, and the mixture passes away ready for use in the engine.

It will be seen that if the air openings at the base of the spray chamber are not sufficiently large more petrol will be sucked through the spray tubes; this would be a disadvantage, as the air would be too heavily loaded with petrol vapour to produce the most powerful explosion. On the other hand, if the admission of air is too free, sufficient petrol will not be sucked through the tube, so a somewhat careful adjustment is necessary between the size of the holes in the spray maker and the amount of air admitted at the base.

In the latest type of Longuemarre carburettor a small swinging gate is provided at the air entrance, which, when the engine is working slowly, offers some obstruction to the admission of the air; but when there is a large demand on the carburettor, the air rushing in opens it wider, and thus automatically regulates the supply of air to the actual requirements of the engine.

Above the top of the spray chamber is shown another series of openings for extra air; this is sometimes required in hot weather, when a larger quantity of air is needed for the same amount of petrol to produce the best explosive mixture. This additional supply of air is controlled by hand, and adjustment made when required.

In cold weather the petrol vapour is not formed quite so readily as in hot summer weather, and it is found necessary to heat the petrol so as to convert it into vapour more readily; it is therefore usual to place the carburettor near the engine, where a certain amount of heat will be imparted to it. In many carburettors there is also provided a jacket round the spray chamber, into which some of the hot exhaust gases from the exhaust pipe can be introduced. This additional heating is not necessary in ordinary circumstances; hence it is desirable, when there is a heating-jacket, that some control be also provided, as it is not an advantage for the petrol to vaporise too readily.

The little plunger shown at D is provided for the purpose of agitating the float when starting the engine; by pressing this two or three times a good supply of petrol is ensured in the spray chamber.

In the pipe leading from the carburettor to the engine is introduced a throttle-valve, by means of which the quantity of mixture can be controlled.

A thorough understanding of this important piece of apparatus is very desirable if a driver is thoroughly to comprehend how his machine works and the best way to manage it. If any trouble is experienced in the working of the engine at any time, attention is first turned to the electrical ignition; but if this is found to be in order, the trouble may generally be traced to some fault in the carburettor. We will leave further remarks in this connection until we are dealing with the management of the motor-car.

2. **Silencer.**—In Fig. 7 there is shown, attached to the exhaust pipe, a cylindrical vessel which is termed the *Silencer*. The exhaust valve is always opened before the

explosion is actually completed; thus the gases make their exit from the pipe at considerable pressure, and if the outlet were not obstructed in some way every explosion would create a loud popping noise.

The best cars at the present day are fairly well silenced by some such means as shown in Fig. 7, but no observant person can fail to notice that the great majority of cars make a considerable noise as they progress along the road, and the popping is especially marked in motor bicycles.

There are several types of silencers on the market, but the principle in almost all is the same. The force of explosion requires to be broken up before the exhaust gases strike the air; generally the exhaust pipe leads into an expanding chamber with baffles. In the silencer shown in the diagram the gases arrive at a central tube, pass through perforations in the far end into an outer tube; then through the opposite end into a third tube, from the opposite end of which the gases find their way into the atmosphere; by this means the exhaust gases expand by degrees instead of explosively.

Any form of silencer which creates back pressure, or, in other words, prevents ready exit of the gas into atmosphere, is to be avoided, as back pressure means loss of power as well as other disadvantages.

It sometimes happens that the ignition misses fire, and the explosive mixture finds its way into the silencer unburnt; in this case it is likely that the heat of the exhaust pipe will fire it, and an explosion will occur in the silencer which is apt to be somewhat alarming to novices and also to members of the general public.

As a rule such explosions do not effect much damage; but, if they occurred at all frequently, it would be a sure indication that something was wrong with the management. Many drivers advocate the provision of a by-pass and cock on the exhaust pipe before the silencer, so that when desired the exhaust can be turned directly into the atmosphere without passing through the silencer; by this means a useful indication is given of how the engine is working; such a by-pass is therefore certainly desirable, but only for quite occasional use.

3. **Water Cooling.**—We now pass to the consideration of the arrangements for keeping the cylinder cool during work. On small engines, especially those used on motor bicyles, cooling is successfully managed by the provision of webs or flanges formed on the outside of the cylinder casting; these present a large surface, and, when freely exposed to the air as the bicycle rushes along, the heat is carried away.

In cold weather this system is successful enough, but in hot weather at night motor bicyclists can often observe their engines glowing in the dark at a dull red heat.

While satisfactory for quite small work, a motor-car requires the more efficient water-cooling apparatus. Stationary gas and oil engines are provided with large tanks, and depend upon natural circulation brought about by the rising of the heated water to the top of the tank, and the consequent supply of cold water from the bottom of the tank to take its place. On a motor-car, however, it is not possible to provide tanks of sufficient size to carry the large quantity of cooling water that would be necessary on such a system. It would also be impracticable to pass the water sufficiently rapidly through the water jacket by means of natural circulation.

A small *Pump* is therefore provided (*see* Fig. 7), driven either by belt from the crank shaft or by means of gear wheels or, sometimes by a friction wheel resting on the engine flywheel. This pump, which is of quite small dimensions, forces the water at a considerable speed through the circulating pipes and jacket.

The water leaves the jacket at a considerable temperature and requires to be cooled; this is effected by passing the hot water as it leaves the jacket through the *Radiator*, which, until quite recently, consisted of a series of pipes with flanges or webs on the outside to carry away the heat. This radiator is placed in the forepart of the car, so that as it travels rapidly through the air a quick cooling effect is secured.

Recently a different type of radiator has been introduced, commonly termed the Honeycomb. This is arranged somewhat after the plan of a gigantic honeycomb, the air passing through the six-sided cells, round the outside of which the water circulates freely. A very large cooling surface is presented to the air, and a better result is obtained than by means of the flanged tube radiator.

Provided the car is passing through still air on a cool day or against the wind, sufficient air passes through the cells of the honeycomb to cool the water thoroughly; but if travelling with the wind behind on a hot day, the passage of the air has to be assisted by means of a small fan driven from the crank shaft and placed immediately behind the radiator. In several makes of car the fan and flywheel are combined, the spokes of the flywheel being shaped to form the blades of the fan; this has the advantage of doing away with the driving arrangements, and is perhaps a step in the right direction as tending towards simplicity.

With the honeycomb type of radiator the upper part of the honeycomb forms the tank, and is of small dimensions; in fact, with this arrangement, the water tank as shown in the diagram practically disappears.

4. **Lubrication.**—The importance of keeping all moving parts of the engine and gear and, in fact, the machinery throughout the car, sufficiently lubricated, cannot be overrated; and it is possibly better to err on the side of giving

too much oil than to allow moving parts to get dry. An excessive use of oil, however, is regrettable and expensive, and is a sure sign that a car is being driven by rule of thumb, rather than by an intelligent and careful driver.

From the amount of oil one sees strewn on the roads much used by motor cars, excessive oiling seems to be only too common. To judge the exact amount of oil required by the various parts can only be acquired by experience, but in most high-class cars every help is given by the maker to secure satisfactory results.

Some of the systems of distributing oil are very carefully thought out, and if the driver takes the trouble thoroughly to understand the general arrangement and use of these, there need be no stoppages for want of oil, and no grumbling on the part of the owner on account of the excessive sum expended on lubricating oils.

The more general arrangement adopted for lubricating the engine and its parts is to attach an oil tank to the splash-board immediately in front of the driver with a number of drip sight feed lubricators. Each of these is provided with a tube passing to a part of the mechanism needing to be oiled regularly, and the rate at which the oil drips can be controlled by means of a small milled head screw provided on the top of the feeding-tube, which is of glass.

For most of the moving parts a comparatively light oil is used, but for lubricating the inside of the engine a heavy or "cylinder" oil is required, which will stand the high temperature generated by the combustion of the gases. As already explained this heavy lubricating oil is introduced into the crank chamber and is splashed by the revolving crank on to the various moving parts.

Sometimes a little cupped recess is provided round the lower end of the cylinder, which catches the oil as it is splashed up; as the piston descends its lower end dips into the oil caught in this manner, and then in the upward movement of the piston the oil is distributed all over the surface. It is of course highly important that the level of the oil does not fall below the reach of the crank, and it is usual to provide a small pump by the side of the sight feed lubricators above referred to, which enables a small measured quantity of oil to be forced into the crank chamber at regular intervals.

It may be taken as an invariable rule that wherever two pieces of machinery are rubbing together oil needs to be introduced occasionally to prevent wear and tear. The special parts of a motor car which need lubrication and careful attention in this respect will be pointed out to the driver when he makes acquaintance with the particular machine he is to drive.

Some parts cannot, of course, be readily oiled from a central distributing tank, and have to be provided with separate lubricators, which need individual attention from time to time. It will suffice to call attention here to the fact that the lubricating arrangements form an important accessory to the machinery, and if this point is overlooked trouble is sure to arise. The whole question of lubrication will be dealt with fully in Section II.

5. **Governing.**—One disadvantage that the petrol engine suffers from, in common with all internal combustion engines, is its incapacity to meet a reasonable overload. This is a special drawback in the case of a motor-car engine, as, when a car is running up an incline, the power required is enormously greater than when running under good conditions along a level road. This is well illustrated by the fact that a car in surmounting an incline of 1 in 25, that is a 4 per cent. gradient, takes double the power it requires on a level road, and travelling at a moderate speed not exceeding ten miles an hour.

When it is considered that gradients sometimes exceeding one in seven have to be surmounted, it will be seen that if the engine is not capable of meeting a temporary overload, as is the case with a steam-engine, and more particularly with an electric motor, it becomes necessary to provide an engine sufficiently powerful to negotiate the steepest incline likely to be met with, and at all other times the engine must be working under its normal power. It is just this that makes the governing and control of a petrol engine somewhat complex; it also is not good practice from an engineering point of view persistently to run an engine considerably under its full load.

These remarks will make it obvious that some means of controlling the speed of the engine when working under part load is very necessary. For instance, should an engine working at 20 h.p. have its load reduced more or less suddenly to five or ten, the excessive speed it would attain could not fail to be otherwise than harmful.

There are several distinct methods by which the speed of the engine can be controlled. The most important is, perhaps, the advancing and retarding of the ignition spark as explained on. p. 104. A special lever is provided for this purpose, usually beneath the steering wheel. A second method is varying the supply of the explosive mixture by opening or closing the throttle-valve; this in some cars is done by hand, and in other cars is automatically controlled by means of the governor. A third method of regulating the power of the engine is by varying the mixture of air and petrol vapour; but this can only be done within small limits, and is not, however, generally used for controlling the car when running. A fourth method, more commonly used in connection with motor bicycles and small cars, is the manipulating of the exhaust valve. If the exhaust valve is lifted and held open no fresh charge of explosive mixture can be drawn through the admission valve, as there is necessarily not sufficient suction to force open the valve against the spring holding it on its seat; a similar effect is obtained by holding the exhaust valve down, this prevents the exhaust gases from escaping into the exhaust pipe after the explosion, and once again the admission valve is unable to open as no suction is caused by the downward stroke of the piston.

Although the power and speed of the engine are largely controlled by hand, it has been found necessary, and is customary on large cars, to provide an *Automatic Governor.* In the great majority of cases this works on the throttle-valve, and controls the amount of the explosive mixture supplied to the engine. The governor employed is of the old-fashioned centrifugal type, with some improvements in the details; this is shown in Fig. 9. Here will be seen the two balls attached to a system of pivoted arms and levers connected to a collar A, sliding on the governor spindle B.

The throttle-valve is connected by means of a rod to a pivoted fork engaging in a slot in the collar; when the engine is still the balls are close to the spindle, and are kept in this position by the spring C forcing the collar downwards; in this position the throttle valve is wide open. When the engine starts and the speed rises the balls are thrown out by centrifugal action—centrifugal means "flying from the centre"—from the spindle, the spring is compressed, the collar drawn up, and the movement of the fork acting on the rod closes more or less completely the throttle-valve; the farther the balls fly outwards the more completely closed is the throttle-valve.

At the normal speed the balls stand at a certain distance from the spindle; if a heavier load suddenly comes on the engine the speed temporarily drops, the balls fall toward the spindle, and the throttle-valve is opened more widely, thus admitting a larger volume of the explosive mixture; on the other hand, if, when the engine is running at its normal

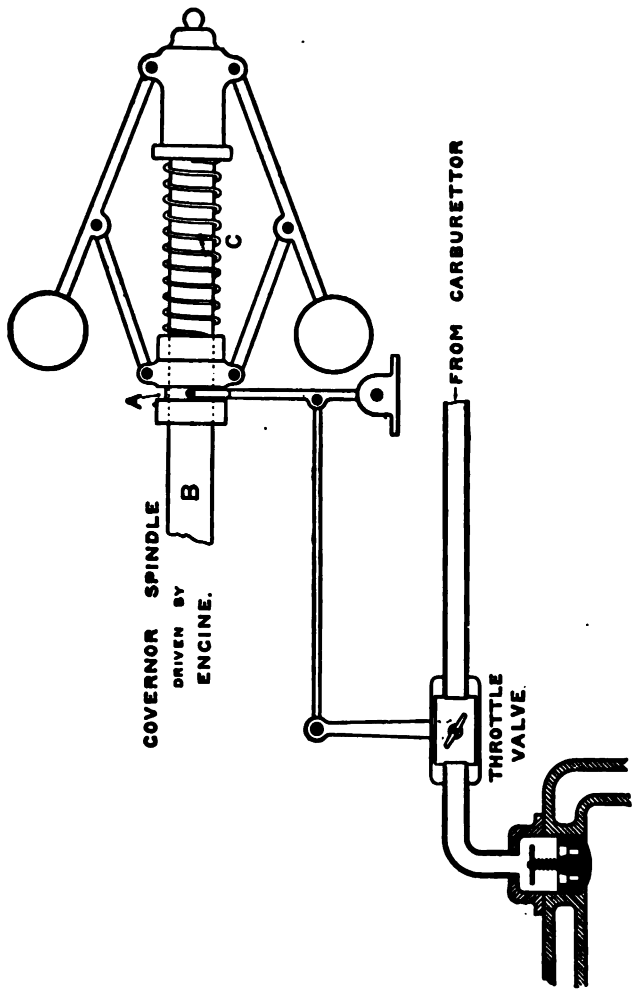

FIG. 9.—Engine Speed Governor.

speed, the load is suddenly reduced the balls fly wider apart, the throttle-valve is still more effectually closed and the speed of the engine is thus kept within limits. Although the more usual plan is to allow this governor to act on the throttle-valve, it can be arranged to act upon the exhaust valve. The control of the engine speed by the advancing and retarding of ignition is a matter requiring judgment, and is therefore best manipulated by hand.

CHAPTER III—ELECTRICAL IGNITION AND ACCESSORIES

CONTENTS:—Sources of Electricity—Conductors and Insulators—Electrical Terms—The Spark Coil or Induction Coil—The Commutator or Contact Maker—Connections—Single Spark Ignition—Lettering of Coil Terminals—Battery or Accumulator—The Spark Plug—Magneto-Ignition—Low-Tension Ignition

No space need be devoted to the consideration of other methods of ignition than the electrical, as its only rival, tube ignition, has now been entirely displaced by it. It may, however, be worth while to mention that the tube ignition was discarded on account of its inflexibility, and the impossibility of controlling the ignition so effectually as by electrical means. In stationary gas and oil engines, however, tube ignition is very commonly used. Flame ignition, by means of which a flame continually burning is drawn at intervals into the combustion chamber to explode the mixture, is still more antiquated than tube ignition, and has so many very distinct disadvantages that it will probably never be seen again on a motor-car engine. A third method, which has received some application, is also practically a thing of the past; this is the catalytic method which took advantage of the curious property possessed by spongy platinum of becoming red hot automatically in a mixture of oxygen and hydrogen; as with the tube and flame ignition this method has no flexibility, such as is possessed by the electrical method.

Electrical ignition is of the first importance to a motor-car driver, who should understand at least a little regarding the principles of electricity; a clear comprehension of the apparatus is more than half the battle.

1. **Sources of Electricity.**—The supply which is given by central stations to the street mains is generated mechanically through the medium of the steam or gas engine and electric generator.

Electricity used for such purposes as telephones and bells is generated in an independent primary battery by chemical means. Whether the electricity be obtained by means of a dynamo or primary battery it is all the same; there is no such thing as good or bad quality electricity; the suitability, however, depends upon its pressure and volume, and whether it be direct or alternating, and it will be necessary to consider what is meant by these terms a little later.

An important point for a motor-car driver is to understand that electricity can be stored in secondary cells, otherwise termed accumulators or storage batteries; and as these are very largely used for operating the ignition apparatus on motor-cars, careful consideration of their construction and arrangement will be dealt with presently.

2. **Conductors and Insulators.** — Electricity is conveyed from the generator to the lamps, induction coils or other "receivers" by means of a **conductor.** This conductor may be taken to resemble a pipe conveying water; but there is, however, this difference, that a return conductor has to be provided; thus two conductors are brought from the generator to the receiver; the one, commonly called the "lead" (pronounced leed), conveying current to the receiver; and the other, termed the "return," carrying it back. How the electricity passes along conductors is not known, but that it does so pass in effect is obvious.

There are good conductors of electricity and bad conductors. The good conductors are always metal; some metals conduct well, others only fairly well, others badly. The good conductors are: — gold, silver, copper and aluminium; gold and silver are obviously not of much use for general electrical purposes, on account of their cost; aluminium is also bulky for general use, and its chief application, so far, has been for overhead conductors on large electrical power transmission schemes.

For all general purposes copper is universally employed for electrical conductors. It has a conductivity very nearly equal to silver, and is comparatively inexpensive; iron is a poor conductor.

It is to be borne in mind that the quantity of electricity which a given conductor will carry depends upon its size; if a conductor has too much electricity forced through it will get hot, perhaps even red hot, and if the volume is excessive it may actually be melted. As an illustration of the difference between a good conductor and a bad conductor it might be mentioned that iron wire of a given size would be melted by a current which would flow without an undue development of heat in a copper conductor of the same size.

There are certain substances that do not conduct electricity; these are termed insulators;—glass, porcelain, and india-rubber may be mentioned as very good insulators or non-conductors. Rubber is largely used for covering conductors when it is necessary to "insulate" them. Cotton is also a fair insulator—a good insulator in fact when thoroughly dried; silk is also an excellent insulator for small wires; dry paper is a good insulator; but all fabrics, such as cotton, silk and paper are liable to absorb moisture, and so their insulating properties may be lost.

There are certain substances which are neither good conductors nor insulators; water is the commonest of these, and if the water holds in solution a small quantity of salt, soda or other alkali, or an acid, it may become a fairly good conductor, but, of course, its conductivity cannot compare with that of copper. Now the result of these considerations is fairly apparent: if a conductor is enclosed in india-rubber of good quality and sufficient thickness, it may be said to be thoroughly insulated; if, however, it is covered with cotton or silk it is only well insulated so long as this remains quite dry. If by any means it becomes wet, a leakage of electricity may take place from the conductor; and it is important to understand that the higher the pressure of electricity, the more liable will it be to leakage.

Although iron is a bad conductor of electricity, yet, if it is employed in a large mass, this does not matter for motoring purposes, as the volume of current to be carried is always small. It has, therefore, become customary to connect one pole of the battery to the frame of the engine, the various parts of which are all connected metallically, and to carry only one conductor from the other pole of the battery to the induction-coil. This conductor needs to be carefully insulated, for if it lies on any part of the frame of the machine, and the insulation is broken off or defective, leakage of the electricity may take place. Thus it is of considerable importance for the driver to see, from time to time, that the conductor has its insulation in thoroughly good order, and that there is no chance of leakage to the frame of the machine.

3. **Electrical Terms.**—In trying to grasp the principles of conductors and insulators, we have used several terms such as *Quantity* or *Volume*, and *Pressure*, and we have also referred to the heat produced by a large quantity of electricity forced through a small conductor. It is now necessary to try and understand what these terms mean.

In the first place, the term *Resistance* must receive consideration. We have seen that some metals are good conductors and others are bad, and that a poor conductor will get hot with a current that does not heat a good conductor of the same size. The heat developed is due to the "resistance" offered to the passage of electricity through the conductor; the resistance, therefore, of the bad conductor is high. Again, if we take a large wire and a small wire of the same metal, the large wire will carry more electricity than the small wire; in other words, the small wire offers more resistance to the passage of electricity than the larger wire; this seems almost unnecessary of explanation, as we should hardly expect a small pipe carrying water to convey the same quantity as a large pipe; however, it is to be borne in mind that the quantity of electricity which can be forced through a given wire depends, first, upon the resistance of the wire; and, secondly, upon the *Pressure* of the electricity; and so we come to a second term.

This can, perhaps, be best explained by referring to a *Primary Cell*, which contains a plate of carbon, a rod of zinc, and several chemicals; the effect of this combination is to set up a "difference of potential," or a difference of level of electricity between the carbon and zinc; if these are connected together by means of a conductor, a current of electricity will flow in consequence. The difference of potential represents much the same thing as the difference of level between, say, two tanks filled with water, and connected together by means of a pipe. If the water in the two tanks is at different levels it will flow from the higher to the lower level. So it is with the battery: the carbon is said to be at a higher level or potential than the zinc, and is termed the positive pole; electricity, therefore, flows through the conductor from the carbon to the zinc, which is termed the negative pole.

Now the pressure set up by a cell depends largely upon the chemicals employed in it. The Leclanché cell, which is commonly used for electric bell work, generates electricity at about one-and-a-half volts, the *volt* being the unit of pressure. The secondary cell, which is used for operating the ignition apparatus, gives, when fully charged, a supply of electricity at a pressure of two volts; now if two secondary cells be connected *in Series;* that is to say, the positive plate of one cell to the negative plate of the next, thus leaving a free positive in one cell and a free negative in the other, four volts will be obtained; if three cells are connected in series, six volts; if four cells, eight volts; and so on, without limit. If the cells are connected with all positive plates together, and all negative plates together, the pressure given is that of one cell, namely, two volts, and they, in effect, form one large cell; with this arrangement the cells are said to be *in Parallel.*

In the dynamo the pressure at which the electricity is generated is entirely under the control of the designer; by adopting a certain winding of the magnets he can make the machine generate electricity at any given pressure. The supply of electricity given from street mains is, as a rule, 100, 200, or 240 volts; but generators are made to supply electricity at a pressure of 400, 500, 1000, up to 30,000 volts.

The quantity or volume of electricity which can be passed through a conductor depends upon its resistance and the pressure of current. The unit of pressure is the *volt*, as we have already seen; the unit of volume is the *ampere*, and the measure of resistance is the *ohm.*

Now, to put it in quite a simple form, if a conductor has a resistance of one ohm, and the current is flowing at the pressure of one volt, the current passing will be one ampere. Take another illustration: if a conductor has a resistance of 50 ohms, and a current is flowing through it at a pressure of 100 volts, the volume of the current will be two amperes.

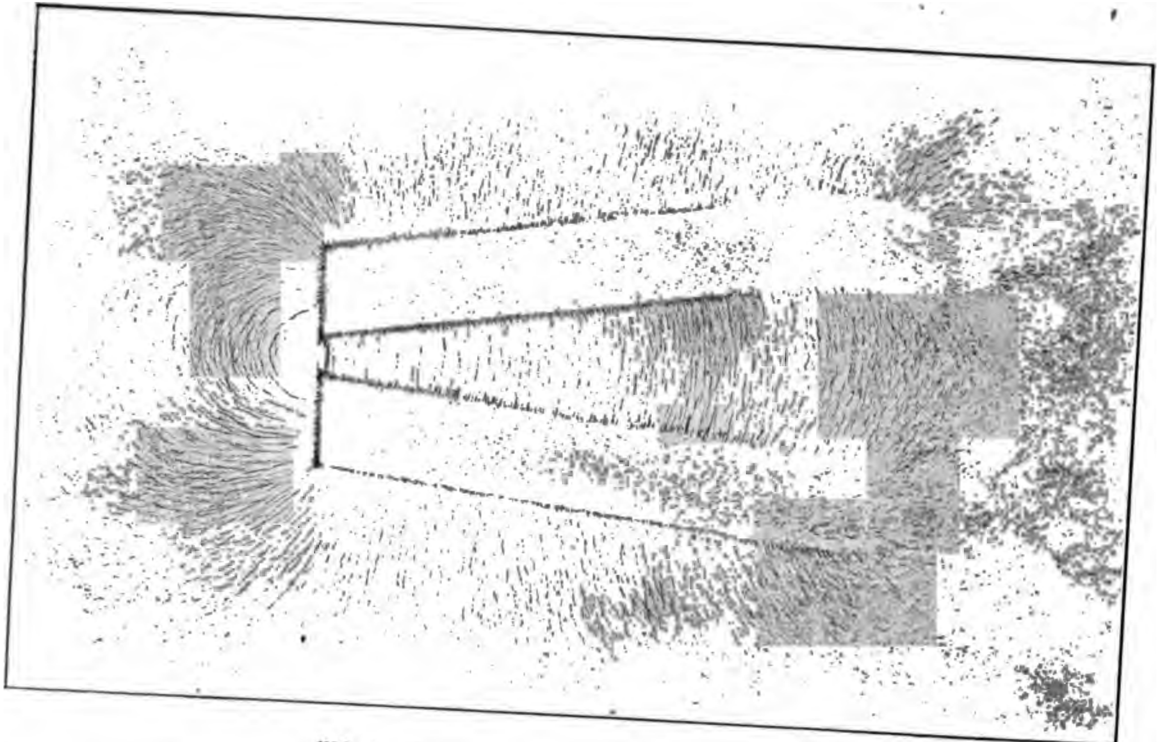

FIG. 10—MAGNETIC LINE OF FORCE DIAGRAM

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4. **The Spark Coil or Induction-Coil.**—If two wires leading from a cell are quickly touched together and separated, a small spark will be seen; if, however, the ends, instead of being touched, are brought together with great care, it will be seen that until they actually touch and are separated, no spark will jump across. Now the spark for igniting the explosive mixture in a petrol engine is required to jump across a considerable gap, and for this purpose electricity at a high pressure is needed. It would not be possible to use a number of cells for this purpose, as to produce a spark capable of jumping across a space of $\frac{1}{32}$ of an inch many thousand volts must be employed, and as each secondary cell only produces two volts it will be seen that some thousand cells would be required to obtain the necessary high pressure; this, of course, is impracticable, and it becomes necessary to employ a little piece of apparatus called the *Induction-Coil*, which will transform the low-pressure electricity, from one or two secondary cells, up to high-pressure electricity, capable of jumping across the gap in the spark-plug.

The induction-coil is really a very simple piece of apparatus, but the principles underlying its operation are rather complicated. As, however, it is our desire to give the reader an intelligent comprehension of every piece of apparatus under his control, the principles will be explained as simply as possible.

It is perhaps unnecessary to describe what a magnet is. Every one knows that it is a piece of hard steel which, having been magnetised, is capable of attracting and holding to itself pieces of iron. This power of attraction is exerted through a considerable distance, and Fig. 10 (Plate IV.) of a horseshoe magnet showing the magnetic *Lines of Force* radiating from the poles will help to explain how the effect takes place. The diagram has been produced by laying a sheet of

paper over the magnet and sprinkling upon it fine iron filings; a gentle tap or two has caused the iron filings to arrange themselves along the lines of force; it is these magnetic lines passing through a piece of iron that cause the magnet to attract the piece of iron to itself. The space through which the lines of force radiate is called the *Magnetic Field*, and in the neighbourhood of the poles where the lines are many the attractive force is greatest. These lines of force, made visible in the diagram are quite invisible to the eye.

It is a curious property of these lines of force that if they are made to pass rapidly across a piece of wire with the ends joined so as to form a complete metal circuit, a current of electricity is produced in the wire. If the wire is made into a coil consisting of a number of turns and the ends are joined, a much larger current of electricity is produced when the magnet is approached towards or withdrawn from it rapidly.

This peculiar property of the magnet is reversible; hence if a current of electricity is passed through the coil of wire it immediately becomes a magnet with a north pole and a south pole, just like an ordinary hard steel magnet. If a piece of soft iron is put into the centre of the coil the magnetism is enormously increased.

With a hard steel magnet the magnetism cannot be got rid of except by heating it to a red heat; but instantly the flow of electricity through the coil is stopped, magnetism ceases, and the piece of soft iron placed in its centre also ceases to be a magnet. This is true however quickly the current is passed into the coil and broken, as the piece of soft iron becomes a magnet immediately on contact and ceases to be a magnet immediately the circuit is broken.

This combination of a coil of wire and a soft iron core is termed the *Electro-Magnet*. The larger the number of turns

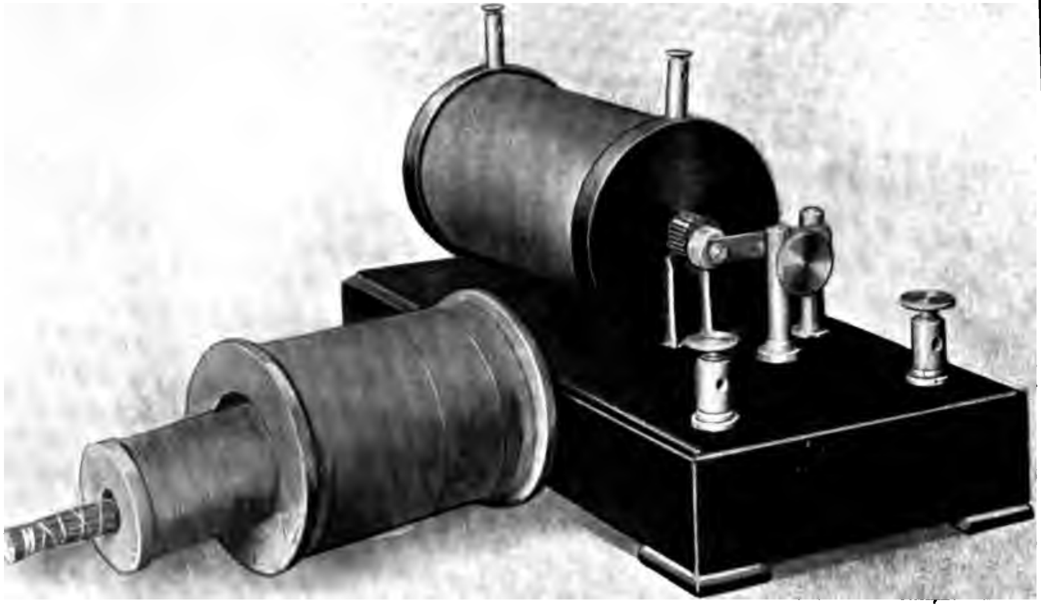

FIG. 11—INDUCTION COIL IN PARTS

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on the coil the stronger the magnet; it is therefore desirable to wind the turns of a coil as closely around the iron core as possible, and the wire must be covered with an insulator to prevent the turns from touching each other; the insulator used in this case is cotton or silk wound on the wire to form a continuous covering.

The induction-coil consists of such an electro-magnet with an iron core made up of a bundle of soft iron wires, instead of a solid bar of iron. A coil of stout wire is wound over the core and a second coil of fine wire is wound over the stout wire. The inner coil of stout wire is called the *Primary Coil*, and the outer coil of fine wire the *Secondary Coil.* In Fig. 11 (Plate V.) is shown a small lecture-table induction coil complete on the right, and on the left are the several parts —iron core, primary and secondary coils—shown separately

The primary, being made of stout wire, has a comparatively small number of turns; but the secondary has a great number of turns of very fine wire. The primary is generally of cotton-covered wire, but the secondary wire is silk covered, as silk is a better insulator. In the secondary not only is silk-covered wire used, but each layer of turns is separated from the others by a piece of paper impregnated with wax, and, after winding, the coil is steeped in melted paraffin wax. The two ends of the secondary coil are carried to two terminals; if we attach conductors to the two terminals and bring them to within about $\frac{1}{8}$ inch of each other, we shall be able to see how this apparatus operates.

Now let us connect one terminal of a two-cell battery to one end of the primary coil and bring a second wire from the other terminal, and rapidly make and break contact with the other end of the coil. Strange to say, a spark jumps across the ends of the secondary each time contact is made and broken on the primary, and as we are only using a four-volt cell on the primary coil we have succeeded in transforming the low-pressure electricity to a very high pressure in the secondary.

To make and break the circuit rapidly through the coil automatically, a *Contact-Breaker* or *Trembler* (*see* Fig. 12) is provided, which consists of a small piece of soft iron mounted on a spring with a contact pillar behind, having a large screw with a platinum tip touching on a platinum contact provided on the spring. The electricity from the battery passes first to this pillar, then through the platinum contacts to the spring, and from the spring to one end of the coil; the other end of the coil is carried direct to the battery. The moment a current flows through the coil the core becomes a magnet and attracts the piece of iron on the spring, draws it forward and consequently breaks the contact between the two platinum pieces. The moment the contact is broken the iron ceases to be a magnet, and the piece of soft iron is released; the two platinum contacts touch again, the current flows once more, the piece of iron is again attracted and contact broken. This goes on with great rapidity, and every time a contact is made a current flows and magnetic lines of force shoot out from the magnet; when the contact is broken the lines vanish. It is the rapid passing of these lines of force through the secondary coil that produces the high-pressure electricity by "induction," hence the term induction-coil. The contact-breaker is clearly seen in Fig. 11 on the complete coil.

The *Condenser* shown beneath the induction-coil in Fig. 12 serves the double purpose of reducing the sparking on the platinum contacts of the trembler or contact-breaker, and also of intensifying the spark at the plug by rendering the make and break more prompt. It is a very simple piece of apparatus, and generally does not appear in connection with the ignition apparatus, as it is fitted into the same box as the induction-coil. It consists of thin sheets of tinfoil

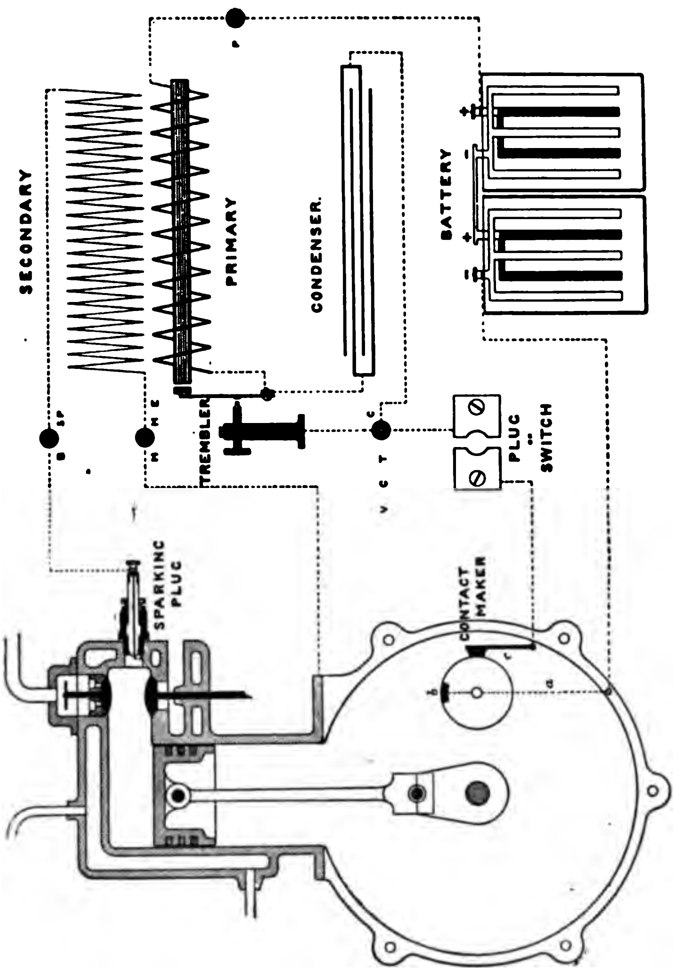


FIG. 12.—Battery Ignition Diagram.

interleaved with sheets of waxed paper, the tinfoil sheets being rather smaller in size than the pieces of paper. Every alternate leaf of tinfoil projects beyond one end of the package, while the other leaves project at the opposite end; they are then connected together so as to form a package of alternate layers of tinfoil separated from each other by sheets of waxed paper, each layer being connected to a platinum contact of the trembler.

It is not unusual to employ a similar condenser across the terminals of the secondary; used in this position it greatly intensifies the spark. For igniting the gases a hot spark is required for a brief moment only, and any device that will increase the certainty of a hot spark passing across the points at the critical moment is of advantage.

The use of platinum pieces on the contact-breaker reduces the burning due to the spark between the two contacts; it also tends to give a brighter spark at the spark-plug.

5. **The Commutator or Contact-Maker.**—We have seen that so long as the induction-coil has no current, or only a steady flow of current passing through the primary, no spark can be produced by the secondary, but on making or breaking contact a spark is produced instantaneously between the ends of the secondary; all that is needed then is to arrange a contact-making device, operated automatically by the engine, which will secure a spark in the combustion chamber at exactly the right moment.

We have seen that the simple making and breaking of a circuit will produce sparks, and in some cases an induction-coil without a contact-breaker is employed. To distinguish between these two types that with the contact-breaker is termed a *Trembler Coil*, and that without, a *Single Spark Coil*. In the latter case, where a single spark is used, it is necessary to provide a contact-maker with platinum points on the engine, very similar to the contact-breaker used on the trembler coil; where a trembler coil is used a contact-maker with a rubbing contact is all that is necessary; this is sometimes called a *Wipe Contact*, and is shown in Fig. 13.

The contact-maker used with a trembler coil consists of a disc of some insulating material, generally ebonite or vulcanised fibre, rigidly fixed on to the half-speed shaft **A**; let

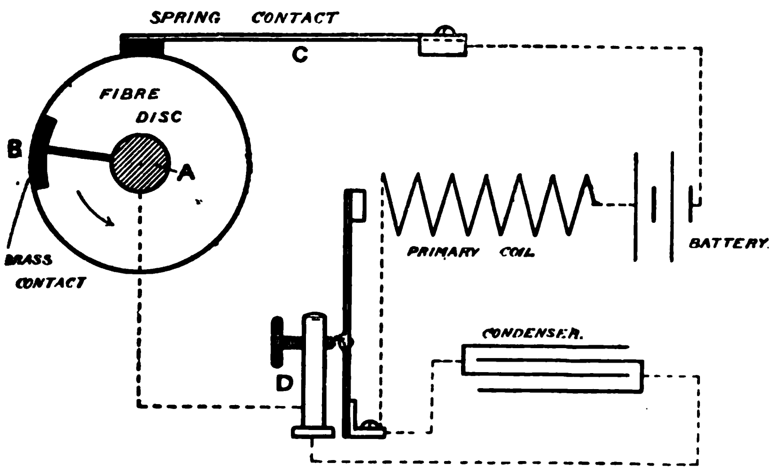


FIG. 13.—Wipe Contact and Trembler Coil Connections.

into a portion of the edge is a small contact piece of brass, **B**, and a connecting wire is carried from this to the half-speed shaft so as to make a continuous connection. A little spring, **C**, rubs on the surface of this disc, and it will be seen that once every revolution the small contact-piece comes into connection with this spring. The spring is connected by means of a copper wire to the pillar of the contact-breaker, **D**, on the induction-coil; from thence it passes through the primary to the battery and back again to the frame of the engine; it will thus be seen that for a short period in each revolution of the half-speed shaft the contact-breaker on the induction-coil will be trembling, and sparks will be passing between the terminals of the secondary, which has been omitted from the diagram for the sake of simplicity.

The contact-maker is generally arranged so that it can be rotated a short distance on the half-speed shaft; in other cases it is the spring which is movable, so that the contact-piece meets it early or late according to its position. By this means the spark is advanced or retarded.

6. **Connections.**—It will now be well to trace the connections by means of Fig. 12. Starting from the positive terminal of the battery a wire is carried to the terminal marked **P** on the induction-coil. Thence the current passes through the primary winding to the spring of the contact-maker, across to the contact-screw and thence to the terminal **C** on the coil. A wire is carried from this terminal to the *Plug* or *Switch*, and from the switch another wire is carried to the brush or contact-spring *c*. Whenever the metal contact piece *b* on the contact-maker touches the spring, a connection is made with the half-speed shaft which is metallically connected to the frame of the engine, thus the current passes to earth, and the circuit is completed by a wire from the frame of the machine to the negative terminal of the battery. When the switch is on, current passes whenever contact piece *b* meets the contact spring *c*.

On the secondary side it will be seen that one end of the coil is carried by means of a connecting wire to the body of the engine, the other end going direct to the sparking plug, which has only one terminal. This terminal is connected to the centre sparking contact in the plug, and the other sparking contact is connected to the frame of the machine; thus in the secondary circuit the only gap is that between the two spark contacts in the plug.

The action of the whole arrangement must now be quite clear. It is only necessary to set the contact-maker so that the brass contact piece touches the spring on the completion of the compression stroke, in order that the charge in the cylinder may be exploded. By slightly rotating the contact spring the spark can be advanced or retarded as already described.

7. **Single Spark Ignition.**—When the single spark ignition is used in place of the trembler coil the contact-maker on the half-speed shaft is replaced by a small cam, **A**

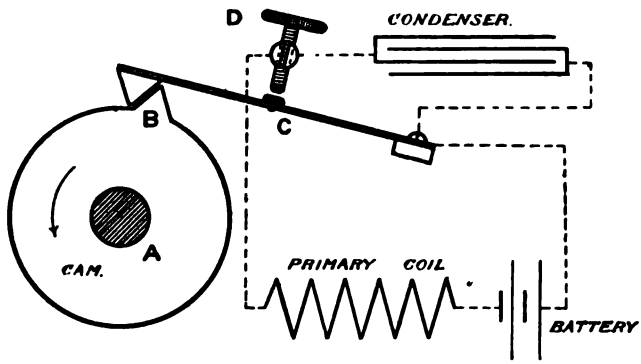


FIG. 14.—Single Spark Connection.

(*see* Fig. 14), which is so set that at the required moment the projecting part **B** forces the spring **C** of the contact-maker on to the platinum-tipped screw **D**. This is connected to the induction-coil in exactly the same way as the trembler illustrated in Fig. 12. Thus, so long as the cam is pressing the spring against the contact-screw, current passes through the primary of the induction-coil. There is, however, no object in keeping the contacts together for any length of time, as the spark only occurs immediately on the making of the contact and again immediately on the breaking of the contact, and the more frequent these sparks are the better; thus the cam has a very short range and simply strikes

the tip of the spring so as to make momentary contact between the platinum tips; the sparks on the make and break are therefore practically identical.

The trembler-coil, which gives a continuous stream of sparks so long as the contact is made, is preferred for motor-car work; the single spark contact-maker is more generally employed with the motor-cycle.

8. **Lettering of Coil Terminals.**—Although, technically speaking, it is a small matter, a knowledge of the arrangement of the terminals of the induction-coil is somewhat important to the motor-car driver; in Fig. 12 we have therefore shown the general arrangement of the terminals of the induction-coil, which are shown as black circular dots and marked with various letters. The induction-coil is usually fitted into a small square box, and has three or four terminals; in the case of the four terminal coils, two are provided for the primary and two for the secondary. The two primary are shown beneath the coil, the left-hand one marked V, C, or T, and the right-hand one marked P.

A great many induction-coils used in English cars are made in France, and are provided with letters (given on the *left* of the terminals in the diagram), which are the initials of French words; the English lettering is given on the right. In the English coils, C, meaning Contact, is the initial letter applied to that terminal which goes to the contact-maker on the half-speed shaft; this terminal on French coils is marked V, C or T, initial letters for Vibrateur, Contact and Trembleur. The V and T mean that the terminal is connected to the trembler, the C means exactly the same as the English, that is to say, the terminal is to be connected to the contact-maker on the half-speed shaft. The other terminal connected to the primary winding is marked P on both French and English coils; the P on the French coils signifies Pile or battery, and the P on the English coil signifies Positive pole of the battery.

The remaining two terminals shown above the trembler are connected to the secondary winding; one of these in the French coil is marked M, which signifies Masse or body of the engine, and on English coils M or E, meaning Motor or "Earth," in other words the frame of the machine. The other terminal is marked B on the French coils, meaning Bougie or Spark-Plug; and on English coils, S P, signifying Spark-Plug.

In the case of coils provided with three terminals, one is common to one end of both primary and secondary, and is marked M or E; this is connected externally to the frame of the machine, and the other connection will be somewhat different, as shown in Fig. 13. The secondary is not shown, but the end not connected to the spark-plug terminal will be connected to the same terminal as the contact-pillar D. The third terminal is attached to the free end of the primary, and is connected to the battery positive, the battery negative being connected to the spring of the contact-maker.

In single-spark coils the trembler is dispensed with, and the near end of the primary (*see* Fig. 12) is connected direct to terminal C, the free end of the condenser being connected to terminal M or E, the other connections are as for the trembler-coil. These connections require careful study.

9. **Battery** or **Accumulator.**—The electric cells almost universally employed for working the ignition apparatus on a motor-car or motor-bicycle are what are termed secondary cells or accumulators; that is to say, they are so constituted that a charge of electricity can be imparted to them which they will afterwards give out as required.

It is important to understand the difference between the secondary cells or accumulators and primary cells; the commonest form of the primary cell is the Leclanché

which is used very largely for electric bells and telephones another cell, which is becoming fairly well known, is the so-called "Dry" cell, which is simply a Leclanché cell, with the top sealed in to prevent evaporation of the liquid.

Primary cells almost invariably contain a carbon plate and a zinc plate. In the case of a Leclanché cell the carbon plate is surrounded with some broken pieces of carbon and oxide of manganese, and the whole cell filled with a solution of sal-ammoniac. It is only necessary to connect the terminals by means of a piece of wire in order to allow the electricity to pass through; this can be shown in various ways by a galvanometer or other detector, or by placing the two wires side by side on the tongue but *not touching;* if electricity is being generated, the placing of the wires on the tongue will produce a strong s nsation of acidity, which will immediately cease if one of the wires be removed. This is a very simple and ready means of testing whether there is *any* current in a cell; but the experiment must never be tried with more than three or four cells, as the tongue would then be burned.

The secondary cell, or accumulator, consists of a number of lead plates placed face to face in the containing box. but separated from actual contact by celluloid separators; the alternate plates are connected together and brought out to two terminals. There is always an uneven number of plates; the two outer plates and all connected to them are termed the negative, and those between them the positive plates.

If two clean pieces or plates of lead are connected to a source of electricity, direct or continuous, and placed in water acidulated with sulphuric acid, it will be noticed that bubbles are given off from the surface of both pieces of lead, and after a time one becomes brown, while the other remains of a dull lead grey colour. The surface of that which has become brown has been "per-oxidised," this is the *positive* plate, while that of the other has become converted into spongy lead, this is the *negative* plate; the amount of peroxide and spongy lead "formed" on the lead depends upon the length of time the plates are subject to the action of the current. When the charging current is cut off it will be found that they give off a current of electricity on their own account.

A secondary cell or accumulator is therefore a very simple piece of apparatus, consisting, as it does, only of the "formed" lead plates immersed in dilute sulphuric acid. The quantity of electricity, however, that can be stored by a secondary cell is proportional to the surface of the "active material" on the plates, and the larger the surface of peroxide of lead on the positive and of spongy lead on the negative, the greater will be its "capacity" for storing electricity. Very many plans have been devised for increasing the surface of lead plates for this purpose, and the most usual type of cell employed in motor-car work contains what are termed "pasted" plates; this signifies that the plates are really "grids," or frames of lead with hollow spaces all over the surface which have been filled with a paste made of red lead and other chemicals. This paste forms a hard cement, and when the plates are put into the dilute acid (termed *Electrolyte*), and are connected to a source of electricity, the red lead is changed into brown peroxide of lead on the positive plates, and grey spongy lead on the negative plates. This plan not only enables a large surface to be obtained in a small cell, but also reduces the time necessary for "forming" the plates, and thus the cost is reduced.

The *Electrolyte* is simply strong sulphuric acid mixed with water in such proportions that the specific gravity is about 1·2, more generally termed 1200 in accordance with marking of the hydrometer used for testing the specific gravity of acids. If ever it falls to the lot of a reader to mix the strong sulphuric acid with water, it is necessary to caution him to add the acid to the water, and not *vice versâ*, as the mixing of the two produces great heat, and water added to the strong acid would cause an explosion.

As sulphuric acid is a powerful corrosive, which destroys any fabric, especially linen, that it happens to fall upon, it needs very careful handling.

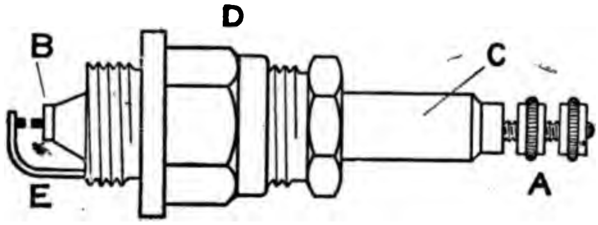


FIG. 15.—Spark-Plug.

A box containing one set of positive and one set of negative plates is termed a *Cell*, a box divided into two or more divisions each with its sets of plates is termed a *Battery*. A secondary cell with lead plates gives a current of electricity at a pressure of two volts; and a two-cell battery four volts, if

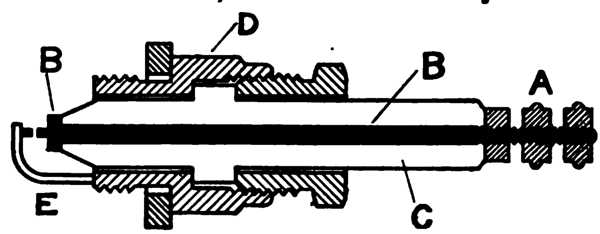


FIG. 16.—Section of Spark-Plug.

the positive plates of one cell are connected to the negative plates of the next cell, leaving one positive and one negative free; in other words, if they are connected in series. If connected in parallel, that is, all positives connected together, and all negatives connected together, two volts will be the pressure, no matter how many cells there may be; when connected in series two volts may be taken for each cell; thus a three-cell battery gives six volts, a four-cell eight volts, and so on.

10. **The Spark-Plug.**—Although a simple piece of apparatus the spark-plug will need a short notice. A reference to Figs. 15 and 16 will show that the single terminal, A, is connected with a central conductor, B, passing out at the opposite end. This central conductor is embedded in an insulator, C, of high quality; in some plugs porcelain or glass is used, in others the insulator is built up of discs of mica; but whatever the material used it must be of the highest quality as an insulator, and fireproof. The central conductor with the insulator is mounted in a brass fitting, D, with the lower end screwed to fit into the socket or recess provided in the combustion head. A short piece of wire, E, is screwed into the inner edge of the brass fitting, which forms with the end of the central conductor the spark gap. This gap is usually 1-16th of an inch or rather more across. We shall have occasion to consider the spark-plug in fuller detail when we are dealing with the management of the apparatus.

11. **Magneto-Ignition.**—In view of the difficulty which is sometimes found in charging secondary cells, and it may be added the trouble which these sometimes give in inexperienced hands, the Magneto-Ignition has recently been coming largely into favour. The magneto machine is simply an electric generator, in which the armature revolves in a magnetic field provided by permanent steel magnets. The dynamo, which is the more usual form of electric generator, is provided with electro-magnets instead of permanent magnets. We have already seen that a steel magnet owes its attractive power to the lines of force that radiate from the poles. We have also seen that when these lines of force cut through a closed electric circuit, electricity is generated therein.

The armature in the case of magneto-machines is simply a shuttle-shaped piece of iron, wound from end to end with a number of turns of cotton or silk-covered copper wire; this is mounted on a spindle running in bearings at either end of the system of magnets, and is caused to revolve at a high speed in the magnetic field. The two ends of the wire wound on the armature are brought out to two collecting rings mounted on the spindle outside the bearings. Upon these collecting rings press *Brushes* or flexible strips of metal, to which wires are attached conveying the current to the spark apparatus. The armature is driven either by means of gear wheels from the engine shaft or by a friction-wheel driven from the flywheel, and as soon as the shaft of the engine is made to revolve by means of the starting handle, sparks are generated for igniting the charge at the correct moment. With a small dynamo the sparks would not be available soon enough, as the electro-magnets take some time to "excite"; it would of course be possible to excite the magnets from a battery; but then there would be no advantage in this system, which has been devised to dispense with the battery.

Now let us try and consider the construction of this apparatus in fuller detail. There are several systems of magneto-ignition in use, but the principles involved are very much the same in all cases. As, perhaps, the simplest illustration of the principles of the magneto-ignition, the Eisemann system will be described, and the general arrangement of the Eisemann Magneto is given in Fig. 17.

First, there is the magnet built up of a number of sections of steel bars bent into horseshoe shape; these are all suitably hardened, and are strongly magnetised. On the inner ends are mounted soft iron pole pieces, A, bored out to form a tube in which the armature will run. These pole pieces of course do not touch each other, and there is in consequence a strong magnetic field between them.

In the diagram one side of the magnet has been cut away to show the *Armature* in position; this hardly needs

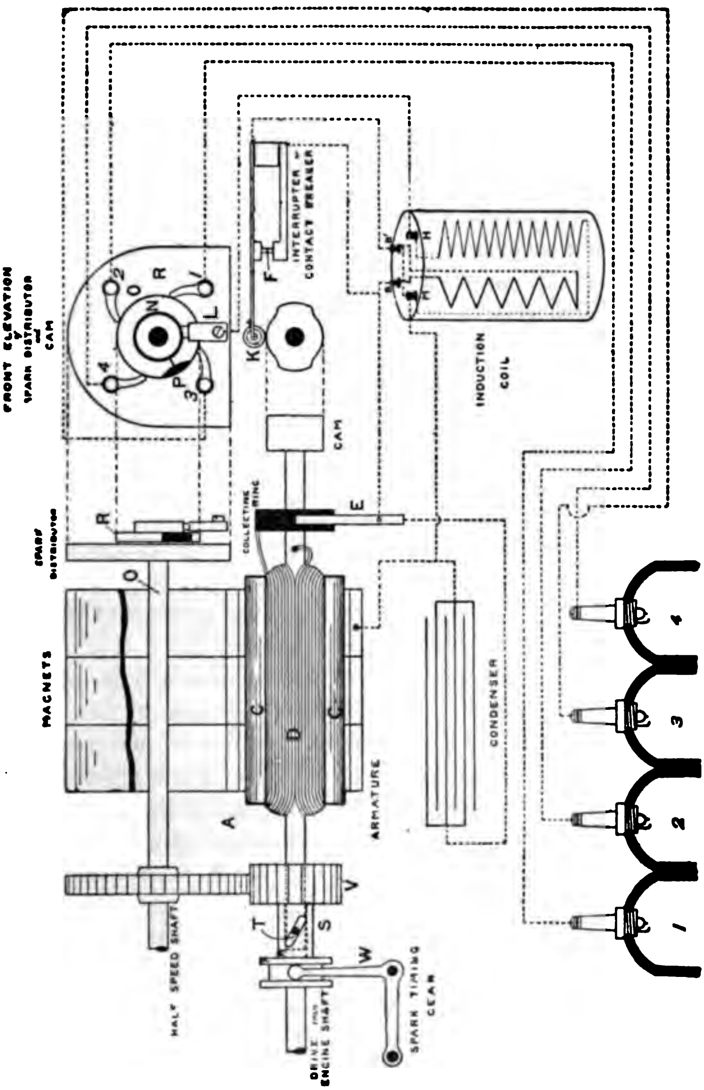


FIG. 17.—Diagram of Eisemann Magneto System.

describing. The shuttle-shaped piece of soft iron, C, is clear seen and also the turns of the wires, D. One end, howeve of the wire is secured to the spindle, the other end beir attached to a solitary collecting ring. The reason for this that the return wire from the induction-coil is connected the metal frame of the magneto machine, a second collectir ring and brush being thereby dispensed with. The collectir ring (which is not shown on the diagram) consists of a di of insulating material mounted on the spindle and carryir on its outer edge a metal ring; upon this rests the brush,] which is thus always in contact with the free end of tl armature winding. From the brush a conductor is carri to one terminal of an induction-coil; this terminal is co nected inside the coil to the primary winding; the other er of the primary winding is connected to terminal M, whi is also connected to terminal B^1.

There is no reason why two terminals should be provid here, as one would serve equally well. From terminal M (B a conductor is brought back to the body of the magneto, th a complete circuit is established from the armature throug the primary winding back to the armature.

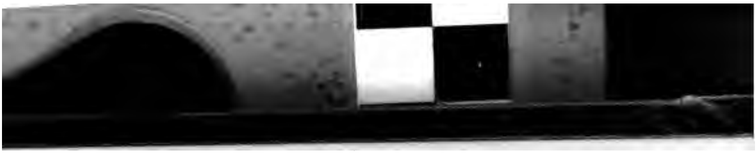
There is, however, fixed across the terminals B and B^1 *Interrupter* or *Contact-Breaker*, this is operated by the *Ca* fixed to the spindle of the magneto. In the normal positic the two platinum contacts, F, of the interrupter are press together, but whenever the projecting parts of the cam stril the little wheel, K, at the end of the spring carrying tl upper point, the two contacts are separated.

Let us see what happens: in the normal position tl points are together, the ends of the primary in the inductic coil are therefore "short-circuited," and no current pass through the coil; the moment, however, the cam knocks tl points apart a current of considerable volume passes throug the primary coil, and naturally a high-tension current generated in the secondary coil. The two ends of the secondary coil are connected to terminals M and H.

In the diagram the apparatus is shown to be supplying a four-cylinder engine. As the one induction coil is made to serve for all four cylinders a *Spark Distributor* has to be provided which will pass the high-tension spark to each cylinder in turn. Following the connections from terminal H we find it attached to a spring buffer, L, pressing on a continuous metal ring, N, mounted on a second spindle, O, carried by the upper part of the magnet and driven by means of gear wheels from the armature spindle. The continuous ring is connected to the brass piece, P, of a contact-maker which revolves with the continuous ring. Rubbing on different parts of the insulating disc, R, are four little collecting contacts, which, in turn, touch the brass of the contact-maker connected to the terminal H; from each of the collecting contacts a conductor is carried to the spark-plug of one of the cylinders.* Now, just at the moment that the cam breaks the circuit of the interrupter, the metal contact piece of the spark distributor is touching one of the four collecting contacts; thus a high-tension current is generated in the secondary coil, a spark jumps across the gap, and a charge in the corresponding cylinder is fired. Of course, in a one-cylinder engine supplied with this apparatus no spark distributor is necessary, the wire from the terminal H being carried direct to the spark-plug. It will be borne in mind that the second end of the secondary coil is attached to the terminal B^1 (M), and is thus connected to the frame of the engine to which the frame of the magneto is screwed.

The Eisemann system comprises a low tension generator and an induction-coil for producing a high-tension spark. It is, however, possible to wind the armature of the magneto with sufficiently fine wire to produce a high-tension current

* For explanation of the arrangement of the connections see page 59.



direct from the armature. This is done in the Simms-Bosch method, and thus the induction-coil is done away with.

It would only be confusing to the reader at this stage of study to attempt to describe in detail other systems of magneto-ignition. If he grasps the few essential principles regarding the construction and working of a magneto machine he will readily grasp the details of any special system.

It may, perhaps, be well to allude to the ingenious means by which the spark is advanced and retarded in the Eisemann system. The armature spindle, it will be noticed, terminates in a collar, S, in the *Spark-Timing Gear.* A pin, T, is screwed into the spindle and engages in a slot in the sliding collar, which is driven from the engine shaft; this sliding collar also carries a gear wheel, V, engaging another on the half-speed shaft, which operates the spark distributor. A bell-crank lever, W, enables the loose collar to be moved backwards and forwards over the end of the armature spindle; as it is moved the slot causes the pin to rotate the armature. Thus, according to the position of the collar, the cam strikes the interrupter earlier or later, and thus the spark is advanced or retarded.

12. **Low-Tension Ignition.**—Before passing from the consideration of the different systems of ignition it will be necessary to devote a short space to what is termed *Low-Tension Ignition.*

If two wires from a single secondary cell are touched together and separated with rapidity, a bright spark will be seen. If a number of cells in series are used instead of one, the spark is proportionately greater; if, however, the wires, instead of being touched together and then separated, are approached very carefully, it will be seen that no spark occurs until they actually touch, in other words the low-tension current has no power of jumping across a gap. If a low-tension spark is to be employed for ignition purposes it is necessary to provide a spark-plug in which the contacts are actually touching in the normal position, but are separated mechanically the moment the charge is to be fired. This mechanical separation of the contacts is the chief objection to the low-tension system; but the electro-magnetic plug, in which the contacts are drawn apart by a magnet, recently introduced, may possibly lead to this system, which has several advantages, being more generally adopted.

The low-tension sparks may be considerably intensified by passing the current through a simple electro-magnet, consisting of iron core, with a large number of turns of insulated wire wound round it; when the contact is broken an "extra current," as it is called, is induced in the windings of the coil, in the same way as a high-tension current is induced in the secondary winding of an induction-coil. The effect of this is to considerably increase the intensity of the spark which would be given by a secondary cell alone.

In the low-tension system, with battery, it is usual to employ eight secondary cells (giving 16 volts) and the electro-magnet, which is termed the "self-induction" coil.

The makers of the high-tension system, briefly referred to above, Messrs. Simms and Bosch, have devised a low-tension magneto-ignition. The generator is exactly similar to that described under the Eisemann system, except that the armature is fixed, and that a shield of soft iron is fitted between the poles of the magnet and the armature; this shield is caused to rock by means of a little crank attached to the engine shaft; at the moment a spark is required the shield is turned slightly on one side, so that the lines of force pass momentarily through the winding of the armature; as the magnetic field is very intense the spark produced is also intense. A little cam, also worked from the engine shaft, separates the contacts on the spark-plug at the critical moment.

The special advantages of the low-tension system will be apparent when we are discussing the management of the electrical ignition apparatus.

CHAPTER IV—A. MULTIPLE-CYLINDER ENGINES
B. THE PETROL

CONTENTS :—Arrangement of the Cylinders—Ignition Arrangements—Nature of Petrol—Some Simple Experiments

A.—MULTIPLE-CYLINDER ENGINES.

1. **Arrangement of the Cylinders.**—The main purpose of multiplying the number of cylinders is to give increased power. Single-cylinder petrol engines vary in power from $1\frac{3}{4}$ up to 9 and 10 horse-power; occasionally they are made rather larger, but the practice, when higher powers are required, is to double, treble, or quadruple the number of cylinders.

Within the power limit required by an ordinary road-car the multiplication of small cylinders is a decided advantage. In the first place, a more even turning moment is obtained; four explosions at a quarter of the power of one large explosion must obviously be preferable to the latter.

As an explosion only takes place once in every two revolutions in the ordinary Otto cycle,the provision of two cylinders produces much the same result as would be obtained by an engine having an explosion every revolution. Four cylinders would give practically the same result as a double-acting single-cylinder steam-engine in which steam is admitted twice during a revolution, once on the down-stroke and again on the up-stroke. Petrol engines cannot be made to run so steadily as the steam-engine, on account of the difficulty of balancing the various parts; the multiplication of cylinders, however, does tend materially to steady the driving arrangements and to reduce vibration in the car.

In a two-cylinder engine the cranks are placed opposite each other, or 180° apart; in a three-cylinder engine the cranks are placed 120° apart; in a four-cylinder engine the outer cranks are placed 180° apart from the two inner cranks, this being the latest and most approved practice. As the various parts of the units tend to counterbalance each other, counter-balance weights (as shown in the diagram of the single-cylinder engine) are dispensed with.

With multi-cylinder engines the explosions are arranged so far as possible to take place at equal intervals. In the two-cylinder engine there will be an explosion once every revolution of the crank shaft, but of necessity the two explosions follow each other in quick succession; with the three-cylinder engine, once in two-thirds of a revolution; and in a four-cylinder engine, once in every half revolution. The method of firing the cylinders in a four-cylinder engine is somewhat peculiar. Numbering the cylinders from one end to the other, first No. 1 is fired, then No. 2, No. 4, and, lastly, No. 3. By this method the tendency of the engine to rock is minimised.

The cams for operating the exhaust valves are all mounted on one shaft; and where mechanically operated inlet valves are employed, as is now almost invariably the case, the cams are either mounted on the same cam shaft as the exhaust cams, or, if the valves happen to be on the other side of the cylinder, they are mounted on a separate cam shaft.

Attention is directed to the engine shown in the frontispiece. This is a 30-h.p. four-cylinder engine, made by Mr. F. C. Blake. The crank chamber doors have been removed, and a glimpse of the cranks can be seen. The exhaust and inlet valves are on opposite sides of the cylinder, and operated by independent cam shafts; the gear wheels, driving the cam

shafts, can be plainly seen on the right-hand side of the picture. For the sake of compactness and convenience an intermediate gear wheel is used between the pinion on the crank shaft and the gear wheels fixed to the cam shafts. One pair of cylinders is shown in place, but the other has been removed so as to display the pistons with rings and connecting-rods. A heavy flywheel is seen at the far end of the shaft.

There is some difference of opinion as to the number of bearings which should be used to support the crank-shaft; the peculiar construction of the crank-shaft necessarily tends towards undue flexibility. Some makers provide one supporting bearing between the two pairs of cranks, in addition, of course, to the two outer bearings; there can be no question, however, that Mr. Blake's arrangement of a bearing between each crank is the best practice, although, necessarily, it is more expensive.

Ignition Arrangements.—In the spark arrangements there are several points which will need consideration. With the ordinary battery ignition it is usual to have a separate induction-coil for each cylinder; one battery, however, is used and one contact-maker on the half-speed shaft. Instead, however, of there being one contact spring or brush there is a spring for each cylinder; in a two-cylinder engine there will be two contact springs exactly opposite each other; in the three-cylinder engine, three springs 120° apart; and in the four-cylinder engine, four springs 90° apart.

With multi-cylinder engines in motor-cars trembler coils are almost invariably used, but on motor-bicycles provided with two cylinders single-spark contact-makers are commonly provided with one cam projection and two contact springs.

The connections to the several induction-coils and the method of connecting up the wires will be readily understood

10. **The Spark-Plug.**—Although a simple piece of apparatus the spark-plug will need a short notice. A reference to Figs. 15 and 16 will show that the single terminal, A, is connected with a central conductor, B, passing out at the opposite end. This central conductor is embedded in an insulator, C, of high quality; in some plugs porcelain or glass is used, in others the insulator is built up of discs of mica; but whatever the material used it must be of the highest quality as an insulator, and fireproof. The central conductor with the insulator is mounted in a brass fitting, D, with the lower end screwed to fit into the socket or recess provided in the combustion head. A short piece of wire, E, is screwed into the inner edge of the brass fitting, which forms with the end of the central conductor the spark gap. This gap is usually 1-16th of an inch or rather more across. We shall have occasion to consider the spark-plug in fuller detail when we are dealing with the management of the apparatus.

11. **Magneto-Ignition.**—In view of the difficulty which is sometimes found in charging secondary cells, and it may be added the trouble which these sometimes give in inexperienced hands, the Magneto-Ignition has recently been coming largely into favour. The magneto machine is simply an electric generator, in which the armature revolves in a magnetic field provided by permanent steel magnets. The dynamo, which is the more usual form of electric generator, is provided with electro-magnets instead of permanent magnets. We have already seen that a steel magnet owes its attractive power to the lines of force that radiate from the poles. We have also seen that when these lines of force cut through a closed electric circuit, electricity is generated therein.

The armature in the case of magneto-machines is simply a shuttle-shaped piece of iron, wound from end to end with a number of turns of cotton or silk-covered copper wire; this

this subject. A satisfactory idea as to its properties cannot be gained by reading, and several simple experiments will be described which readers should themselves try and should persevere with until they succeed in getting a uniformity of results. When the author first attempted to carry out these experiments he found it very difficult to secure the same effect twice running.

Petrol, as its name implies, is one of the many products of petroleum. Crude petroleum, like coal gas tar, contains many things; and, when subjected to distillation, highly volatile liquids pass over at comparatively low temperatures.

When crude petroleum is distilled, petroleum ether is given off between 104° and 158° F.; gasoline, between 158° and 176° F.; and volatile liquids of various densities between 176° and 302° F. The whole group is termed petroleum spirit or *Petrol*. After the first distillation petrol has to be re-distilled and refined, as it is a most important matter that the spirit used for petrol engines should leave no residue after burning.

If crude petroleum is distilled above 302° F., paraffin, the common lamp oil, is obtained; this also has to be refined and distilled before it is fit for use. We need not, however, devote much consideration to the other products of crude petroleum, as the petroleum spirit is the only one suitable for driving petrol engines as at present designed. It will, however, be of interest to note in passing that ordinary stationary oil engines use paraffin and even the heavier petroleum oils, and as the supply of petrol is limited, in fact is entirely dependent on the demand for the heavier oils, it may be that the vaporising arrangements of the petrol engine will have to be considerably modified to suit the denser products of petroleum.

The quality of petrol is determined by its density or *Specific Gravity, i.e.*, its density as compared with water.

The lighter the oil the more volatile, and, therefore, the better for use in the petrol engine; the best quality has a density of ·68 at 60° F. It is not, however, always possible to obtain oil of such density, and as the various qualities of petroleum spirit range from ·667 to ·737, the purchaser of petrol should take the trouble to see that he is provided with what he pays for. The density is measured by means of a densimeter, an inexpensive little instrument. In the present state of the market a specific gravity of ·7 or ·72 is the limit for high-quality petrol. It will be readily understood that high-density petrol signifies less volatility and more trouble with carburation in cold weather.

Owing to the extremely volatile and inflammable nature of petrol it will be best, when carrying out the following experiments, to have a small bottle of petrol available, which should be kept carefully corked, except when taking small quantities from it for the experiments. The keeping of the bottle corked is important, as should it be knocked over the petrol would vaporise very rapidly and serious consequences might ensue. One of the first lessons to be taken to heart in connection with petrol is that it is dangerous stuff to have to do with, and that too much precaution cannot be taken in handling it.

2. **Some Simple Experiments.**—*Experiment* 1. Put a very small quantity of petrol into a saucer, the upturned bottom of an egg-cup, or some other similar receptacle, and apply a light. It will be seen that vigorous combustion ensues, and that a bright flame is the result; it will also be noticed that a considerable volume of smoke is given off, so that if a piece of clean metal be held in the flame it will become thickly coated with lamp black. This experiment proves that petrol contains a large quantity of carbon; as a matter of fact its chemical formula is C_6H_{14}, that is to say, it contains six atoms of Carbon and fourteen of Hydrogen.

The carbon atom is much heavier than the hydrogen, and the proportion by weight is 84 per cent. of carbon and 16 per cent. of hydrogen. It is hardly necessary to point out that both carbon and hydrogen combine with the oxygen of the air during combustion, the carbon and oxygen forming carbonic acid gas and the hydrogen and oxygen forming water.

Experiment 2.—Place about half a teaspoonful of petrol in a clean saucer and leave it for five or six minutes; if the weather is warm it will all have evaporated. Now take a similar quantity, place it in the saucer and blow gently upon it; in one minute every trace of it will have disappeared. We thus see that although the petrol vaporises very readily when exposed to the air, yet the rapidity with which it vaporises is enormously increased by a gentle current of air over the surface. The carburettor is the special device adopted for securing rapid vaporisation. As we have already seen, the petrol is sprayed through fine holes on to the side of the vaporiser and a current of air is drawn briskly over the surface thus oiled. The vaporisation is still further facilitated by the application of heat, and as in cold weather it would not be sufficiently rapid, special arrangements are made for warming the carburettor. These were pointed out when describing the engine.

Experiment 3.—Procure an old soda-water bottle and thoroughly dry it; also obtain a small glass tube drawn out to a thin point at one end and smooth at the other; this will form a dropping tube. Dip the fine end an inch or two into the petrol, place a finger over the top end, and then allow three small drops to fall straight to the bottom of the soda-water bottle; cover the top of the soda-water bottle with the hand to keep the vapour enclosed, and replace the remainder of the petrol in the bottle and cork it. Wait a few seconds, and then apply a light, taking care to keep the

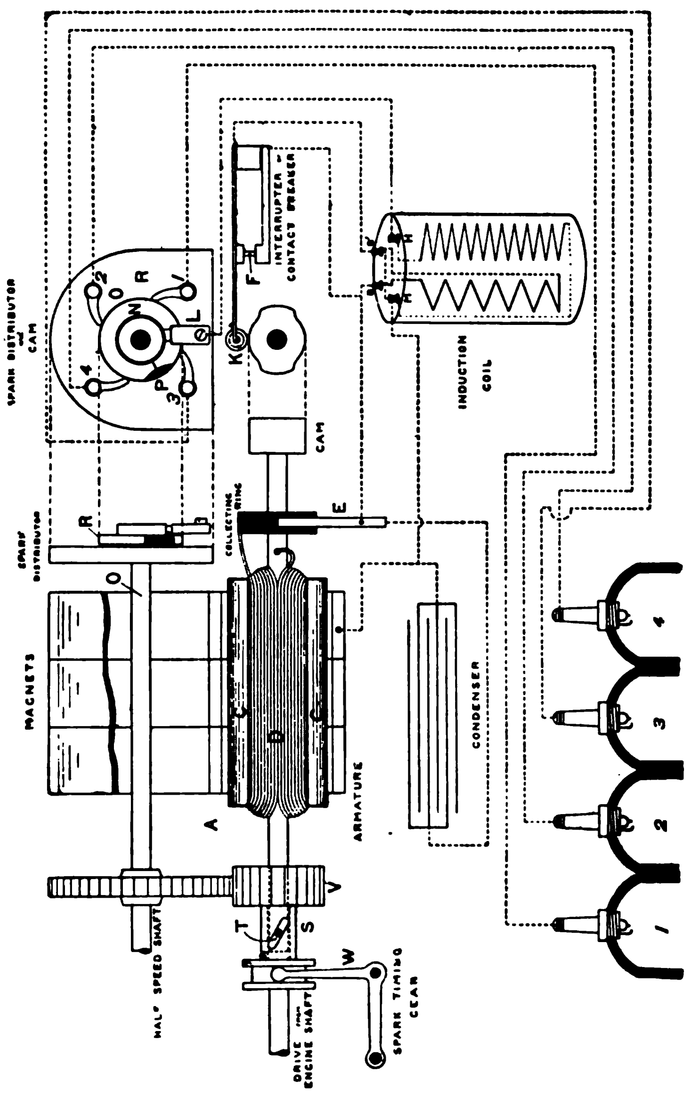


FIG. 17.—Diagram of Eisemann Magneto System.

describing. The shuttle-shaped piece of soft iron, C, is clearly seen and also the turns of the wires, D. One end, however, of the wire is secured to the spindle, the other end being attached to a solitary collecting ring. The reason for this is that the return wire from the induction-coil is connected to the metal frame of the magneto machine, a second collecting ring and brush being thereby dispensed with. The collecting ring (which is not shown on the diagram) consists of a disc of insulating material mounted on the spindle and carrying on its outer edge a metal ring; upon this rests the brush, E, which is thus always in contact with the free end of the armature winding. From the brush a conductor is carried to one terminal of an induction-coil; this terminal is connected inside the coil to the primary winding; the other end of the primary winding is connected to terminal M, which is also connected to terminal B^1.

There is no reason why two terminals should be provided here, as one would serve equally well. From terminal M (B^1) a conductor is brought back to the body of the magneto, thus a complete circuit is established from the armature through the primary winding back to the armature.

There is, however, fixed across the terminals B and B^1 an *Interrupter* or *Contact-Breaker*, this is operated by the *Cam* fixed to the spindle of the magneto. In the normal position the two platinum contacts, F, of the interrupter are pressed together, but whenever the projecting parts of the cam strike the little wheel, K, at the end of the spring carrying the upper point, the two contacts are separated.

Let us see what happens: in the normal position the points are together, the ends of the primary in the induction coil are therefore "short-circuited," and no current passes through the coil; the moment, however, the cam knocks the points apart a current of considerable volume passes through the primary coil, and naturally a high-tension current is generated in the secondary coil. The two ends of the secondary coil are connected to terminals M and H.

In the diagram the apparatus is shown to be supplying a four-cylinder engine. As the one induction coil is made to serve for all four cylinders a *Spark Distributor* has to be provided which will pass the high-tension spark to each cylinder in turn. Following the connections from terminal H we find it attached to a spring buffer, L, pressing on a continuous metal ring, N, mounted on a second spindle, O, carried by the upper part of the magnet and driven by means of gear wheels from the armature spindle. The continuous ring is connected to the brass piece, P, of a contact-maker which revolves with the continuous ring. Rubbing on different parts of the insulating disc, R, are four little collecting contacts, which, in turn, touch the brass of the contact-maker connected to the terminal H; from each of the collecting contacts a conductor is carried to the spark-plug of one of the cylinders.* Now, just at the moment that the cam breaks the circuit of the interrupter, the metal contact piece of the spark distributor is touching one of the four collecting contacts; thus a high-tension current is generated in the secondary coil, a spark jumps across the gap, and a charge in the corresponding cylinder is fired. Of course, in a one-cylinder engine supplied with this apparatus no spark distributor is necessary, the wire from the terminal H being carried direct to the spark-plug. It will be borne in mind that the second end of the secondary coil is attached to the terminal B^1 (M), and is thus connected to the frame of the engine to which the frame of the magneto is screwed.

The Eisemann system comprises a low tension generator and an induction-coil for producing a high-tension spark. It is, however, possible to wind the armature of the magneto with sufficiently fine wire to produce a high-tension current

* For explanation of the arrangement of the connections see page 59.

CHAPTER V—THE CHASSIS AND DRIVING-GEAR

CONTENTS :—The Frame—Clutch—Change-Speed Gear—Driving Shaft—Differential Gear—Brakes

1. **The Frame.**—In our introductory remarks we gave a brief outline of the arrangements of the mechanical parts of the motor-car. It now becomes necessary to study some of these parts carefully. In the first place, the frame, together with the engine and all the gear carried upon it, is generally made quite independently of the body, and is termed the *Chassis*. Dealing with the frame itself, we find that this is usually constructed of small steel girders, braced together at various points throughout their length. In smaller cars a tubular frame is used, and in some of the light cars woodwork is introduced, and has its special advantages. On large cars rigidity is of considerable importance, but on small cars a certain degree of flexibility is a desirable quality, and for this reason American hickory wood has been found thoroughly suitable. On large cars the weight of the machinery to be carried, to say nothing of the body, is great, and the general planning and constructional work is that of an engineer rather than of a carriage builder.

2. **The Clutch.**—Passing in order along the frame from the engine, the first mechanical contrivance we meet with is the *Friction-Clutch;* the crank-shaft of the engine generally terminates in a heavy flywheel, the use for which we have already studied. The driving shaft beyond this point is connected to the crank-shaft by means of the clutch; when this is in gear the shaft driving the road wheels is in move-

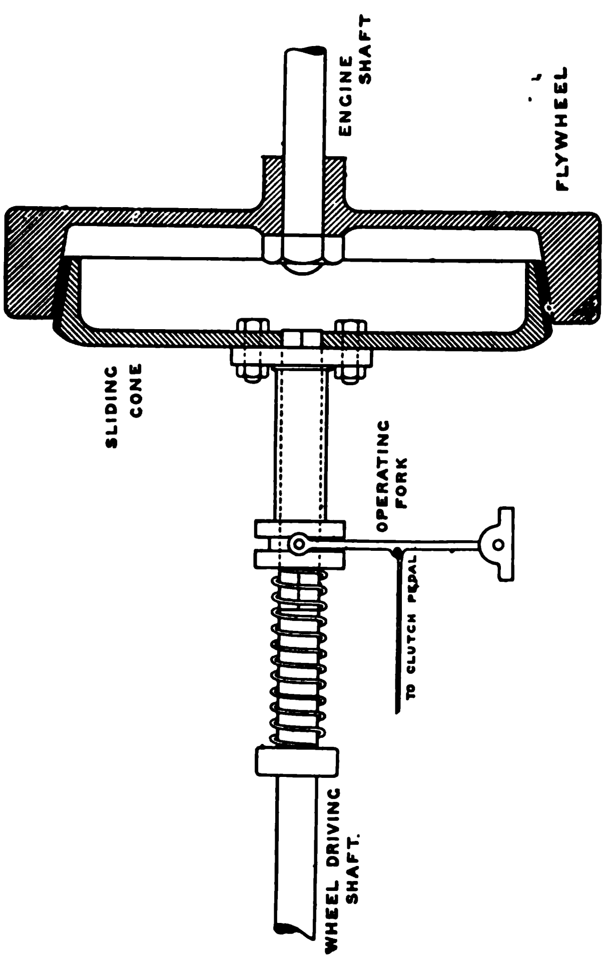


FIG. 18.—Section of Clutch.

ment; but when the clutch is out of gear the driving shaft is still, so far as the movement imparted to it by the engine is concerned. The need for this clutch is one of the peculiar objections to the petrol engine.

The starting of the engine necessitates, as we have seen, the use of a special starting handle; this could not be operated were the engine crank-shaft coupled direct to the driving-wheels; it would also be most objectionable to have to adopt such a plan of restarting in the course of a drive whenever it became necessary to slow down or stop the car. It often happens, too, while the car is running, that it is necessary to shut off the driving power; with a steam-engine or electric motor there is not the least difficulty in doing this; but with the petrol engine it is different. Once the engine is started, therefore, if the car has to be stopped, or for any other reason the power needs to be taken from the driving shaft, the clutch is detached.

In Fig. 18 we have a section of the simplest form, namely, the *Cone-Clutch*. Coupled to the extreme end of the engine crank-shaft is the flywheel, which is recessed out to receive the sliding cone of the clutch; this slides on the squared end of the wheel-driving shaft, and an operating fork engages in a special collar, by means of which the sliding cone can be moved backwards and forwards. In the normal position the spring forces the cone on to its seat inside the flywheel, and when in this position the friction between the two surfaces is so great that the engine shaft will drive the wheel shaft. The cone of the clutch is faced with leather, so as to secure a better grip with the flywheel, and also to facilitate the slow application and withdrawal of the cone. Metal to metal would give too uncertain a result, and it is quite likely that the two metal surfaces might "seize," so that it would be difficult to withdraw the cone.

With the leather facing it is possible by careful adjustment to allow a steady "slip," which when starting is a necessity, as the engine is running at pretty nearly its normal speed, and when the car is standing still the clutch cone is motionless; the coupling of the two therefore requires much care. The operating fork is connected to a pedal in front of the driver, who is thus able at a moment's notice, by a movement of his foot, to take out the cone; the need for operating this with rapidity will be more fully discussed when dealing with management.

There are many modifications of the simple cone-clutch, but the principle is the same throughout, that is to say in the friction-clutches the grip between two surfaces in contact is utilised.

A simple cone-clutch has the disadvantage of creating a fairly considerable end-thrust on the engine shaft. The spring forcing the cone forward is of necessity a strong spring, and it will thus be seen that when the cone is "home," the spring will be pushing the engine shaft forward with some pressure. Several improvements upon this form of clutch dispose of this end-thrust difficulty.

3. **Change-Speed Gear.**—Next in order comes a gear for changing the speed of the driving shaft. It has already been pointed out that the range of speed of a petrol engine is small, and if the power is to be maintained the speed must also be maintained. This is an important consideration, especially in mounting hills where the full power of the engine is called into requisition and the speed of the car is of necessity lower than normal. It may thus be taken generally that the steeper the hill the higher the power required from the engine and the slower the travel of the car. It is obvious, therefore, that the slowing down of the engine on a steep hill would result in a loss of valuable and essential power; every explosion which takes place in the engine within a given time represents so much

power. Under varying conditions, therefore, the speed of the engine must be maintained, while the speed of the car varies, and this can only be brought about by arranging for the driving shaft to be driven at different speeds while the speed of the engine shaft remains practically constant.

The change-speed gear commonly in use consists of two series of toothed wheels of various sizes arranged in a gear box. One set of these wheels is rigidly secured on to the clutch shaft; these engage as required with another set of toothed wheels sliding on the driving shaft and prevented from rotating by a "feather" or key. One of the large levers by the driver's right-hand side is used for operating this gear. When it is desired to change the speed the clutch has first to be disengaged, as changing toothed wheels in this way would not be permissible while the driving power was on; the movement of the lever first disengages the wheels in gear, and then brings another set into gear.

Generally three forward speeds are provided on a full-sized car, and also a reverse. It is often necessary to reverse or back a car, and as the petrol engine must always run in one direction the reversing of the car must be managed by gear. The most usual method is by causing a gear wheel on the clutch shaft to engage with an intermediate gear wheel, which in turn engages with a pinion on the driving shaft; by this means the driving shaft is made to revolve in the same direction as the engine shaft. The gear box is made oil-tight, and partially filled with oil, so that all the wheels are continually running in a bath of oil; this not only reduces wear and tear but also reduces loss of power; it is, therefore, important that this box be kept properly supplied with oil.

4. **Driving Shaft.**—From the shaft leaving the gear box power may be transmitted to the wheel or driving axle, either by means of a steel shaft, or by means of chain trans-

mission gear. Where the former method is adopted it will be apparent that a rigid steel shaft cannot be used, as, owing to the spring attachment of the wheels to the frame carrying all the gear, there must of necessity be movement between the frame and the wheels. This movement is provided for by fitting *Universal Joints* on either end of the section of shaft between the gear box and axle. These universal joints are a mechanical appliance which has been known in engineering circles for a great many years; one particular modification of it was devised by M. Cardan, and owing to its application to motor-car work having been first made in France, the joints have been universally called Cardan joints, and the shaft a Cardan shaft. It consists simply of a fork on both of the shaft ends which are to be coupled, these are placed at right angles to each other and pivoted; thus a rigid drive is secured while a considerable play or movement of the movable shaft is allowed in any direction. The Cardan joints only provide for vertical movements between the wheel and the frame, but, owing to the manner of suspension on the springs, a "fore and aft" movement is also provided for by one end of the shaft being made square, and fitting in a square socket on the universal joint.

In the case of the chain drive a short driving shaft is fixed immediately behind the gear box parallel to the driving wheel axle, and at right angles to the spindle in the gear box, to which it is geared by means of bevel wheels. At each end of the driving shaft is fixed a small sprocket wheel which drives on to the road wheels through chains. The sprocket wheels attached to the road wheels are part of the wheel hub, the wheels together with the sprockets being free to run on the end of the main axle, the axle itself being fixed rigidly to the frame.

5. **Differential Gear.**—Whether the drive be direct through a shaft or through chains, it is necessary for the

driving wheels to be free to turn independently of each other. As the driving power must, of necessity, be coupled to both wheels a special device termed the *Differential Gear* is provided, which, while allowing the full power of the engine to be transmitted equally to the two wheels, leaves them free to turn on their axles independently.

This is a somewhat difficult piece of apparatus to describe

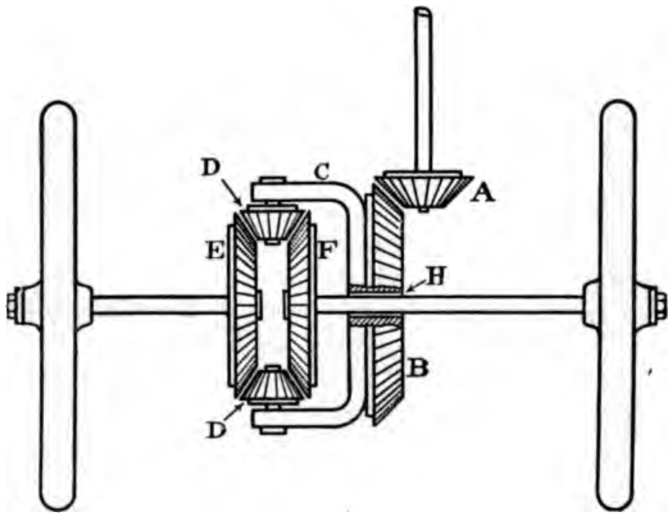


FIG. 19.—Differential Gear.

in words; no diagram would enable a non-technical person clearly to understand its operation, and some hints will be given later how some simple experiments may be made with the rear wheels of a car that will make its operation clearer. Briefly, it consists of two similar bevel gear wheels, E and F (see Fig. 19), facing each other in the same box. Fitting into these gear wheels is a small pinion or series of pinions, D, generally four placed 90° apart, and each free to turn on its own axis. The wheel shaft is divided, and the large bevel wheels, E and F, are rigidly attached to each end. The pivots of the four bevel wheels are fixed into the outer case, C, of the differential which forms part of another large bevel wheel, B, into which a small bevel pinion, A, attached to the crank-shaft, gears. When in operation the Cardan shaft revolves and the bevel wheel drives the case of the differential gear; this causes the pivots of the bevel pinions to revolve in the direction that the driving wheels revolve.

So long as the speed of the driving-wheels is the same, the small pinions carry round with them the large bevel wheels on the driving-wheel shaft. If now one wheel requires to move faster than the other, as for instance when turning a corner, it is free to do so, power being still transmitted to both wheels as required, the only difference being that the large bevel wheels are revolving at different speeds, and, consequently, the small bevel wheels are revolving on their pivots.

The chief objection to the direct or Cardan shaft drive is the dividing of the rear axle into two parts, which is mechanically bad; if, however, the whole apparatus is designed and constructed by competent persons the parts can be made sufficiently rigid to form a perfectly satisfactory job.

As in the direct drive, a differential gear must be provided with the chain drive; but, in this case, instead of the axle being divided into two parts, the driving shaft is divided.

The differential gear, like the change-speed gear, needs to be continuously lubricated; the case is therefore made oil-tight and partially filled with lubricating oil. If this gear were allowed to run dry the wear and tear on the bevel wheels would be excessive, and the power absorbed would be considerable.

Brakes.—A highly important part of a motor-car equipment is the brake gear. The weight of a motor-car is much greater for its size than that of an ordinary vehicle. The speed of an ordinary vehicle is not expected to exceed twelve miles an hour under most favourable conditions; not so with the motor-car. The limit of speed as fixed by law at the present time is twenty miles per hour, and this is *sometimes* exceeded! A weighty car moving at such a velocity forms a very formidable object on a public road, and, with whatever skill it may be driven, times are certain to arise when the application of considerable brake power is necessary.

Before brakes are applied to a petrol car the clutch is disengaged, which can be done momentarily; but, notwithstanding the instantaneous removal of the driving power, the momentum with which a car is moving at twenty miles an hour calls for some very powerful means of braking if the car is to be stopped or checked materially in a reasonable distance. It is well to bear in mind that the operation of stopping a car moving at such a velocity means the generation of a considerable amount of heat. So many foot-pounds of energy have been put into the car in raising it to the speed at which it is travelling, and practically the same number of foot-pounds of energy must be reconverted into heat in overcoming the momentum of the car. It is therefore important to so arrange the brake that the heat generated will be readily and harmlessly dissipated.

In the early days of the motor-car, and also with bicycles, it was usual to apply the brake power to the tyres of the wheels. So long as tyres are of iron or of solid rubber this method is convenient, and as the heat generated is spread over a large surface but little harm is done to the tyres.

With pneumatic tyres, however, the conditions are wholly different. In the first place a brake should be available at any moment, quite independently of the condition of any other part of the car. The pneumatic tyre is always liable to puncture, and if a tyre upon which a brake is supposed to act is suddenly let down by a puncture or burst it is wholly useless. A tyre burst or puncture makes it imperative that the car be immediately stopped, and if such a puncture occurs when the car is travelling at a high speed there is all the more need for an efficient brake to be applied without delay. Thus brakes applied to pneumatic tyres are a mistake, and if any reader is unfortunate enough to come into possession of a car provided with them, the best advice that can be given is to have them immediately discarded and proper band brakes fitted.

Drum or band brakes are almost invariably fitted to the driving wheels of all modern cars. They consist of a drum running truly on the wheel hub and generally provided with flanges on either side. Between the flanges and bent round the drum is a steel band with leather facing on the inside; the two ends of this brake band should be secured to the brake lever, which is the second of the two long lever handles placed at the right hand of the motor-car driver. The handle should be so designed that when pulled over the *two* ends of the brake band are drawn together; a small movement of the handle will thus secure a strong gripping action on the brake drum.

The special type of brake in which one end of the band is fixed to the chassis frame and the other end only to the handle is to be avoided, as, should it be necessary to apply the brake when the car is running on the reverse, the tendency will be to slacken the band. Many accidents have occurred through the use of this modification of the band brake. Both brakes acting on the rear driving wheels are connected by a system of small rods or flexible steel cable to the one handle, and should have been so devised that in the event of one brake being inoperative from any cause the second brake should be available.

In view of the important part that brakes serve in connection with the motor-car, it would be a great mistake to be dependent upon one only, and in addition to the band or

drum brake just described, it is the usual practice to provide a second brake operated by a pedal in front of the driver. This additional brake is applied to different parts of the driving shaft according to the make of the car, and, beyond pointing out the necessity for an efficient auxiliary brake, there will be no need to describe it in detail; it should, however, be fixed as near as possible to the driving-wheels, and it would be a decided advantage if, when the pedal is depressed, the clutch were thrown out by the one operation. In some cars the clutch is thrown out of gear by the application of the band brakes also, but emergencies sometimes arise when it is desirable to keep the engine coupled while the brake is applied; both brakes should, therefore, not be arranged to disengage the clutch automatically when applied.

It should be mentioned that the provision of a second brake is required by law. It should not, however, be necessary to study the provisions made by legislation. Any one who assumes the responsibility of driving a road locomotive should have sufficient sense of responsibility to see that the car he drives has every possible provision made for the securing of the safety of the general public, to say nothing of his own skin, quite apart from any question of law.

As with the hand or side lever brake, it is important to have the pedal brake arranged so that it is operative in whichever direction the car may be moving.

In addition to two brakes, a car should be provided with a *Sprag*, which can be released promptly; the need for this is, that should a car come to a stop on a hill, it may be convenient, if not actually necessary, to drop the sprag before the car can obtain any velocity backwards. If the dropping of the sprag has been left until the car is moving backwards with some speed it is extremely probable that if it grips the rod will be bent, and thus become useless; or, if it is of stout dimensions, the car may even jump over it.

THE PETROL CAR

SECTION II—THE MANAGEMENT OF THE PETROL CAR

INTRODUCTION

HAVING made a careful study of the various parts of the Motor Car Mechanism, the reader should now have a very fair grasp of the general details of construction and interconnection of the various parts. Without a knowledge of these points it would be difficult for the novice to understand at all clearly many of the special points which have to be observed in managing the car.

For purposes of comparison and reference the same order as under Section I. will be followed. Firstly, the engine and its several parts will receive consideration; various suggestions will then be given in connection with the petrol supply system, the silencer, water cooling, lubrication and governing, in due order; then the very important subject of electrical ignition will receive careful attention; and, finally, the management of the car, under ordinary working conditions and on the road, will be dealt with.

CHAPTER I—THE ENGINE

CONTENTS :—The Cylinder—Piston—Crank-Shaft—Valves—The Engine at Work

1. **The Cylinder.**—As it is in the cylinder of the engine that the power is generated, it is highly essential that, in running, the cylinder should be kept in the very best possible condition. One of the commonest failings of a beginner is so to manage matters that the inside of the cylinder becomes dirty, and a deposit forms which tends to reduce considerably the power and efficiency of the engine. Generally speaking, this is due primarily to using too much petrol, in other words too rich a mixture. We have seen, when studying the fuel, that if there is too much petrol for the air introduced there must of necessity be a surplus of unburnt carbon, which, being liberated in solid form, clings to the walls of the cylinder and combustion chamber, and causes much trouble to a tyro.

The deposit may be removed by carefully scraping the inside of the cylinder ; but if the driver of the car finds there is a general tendency for this deposit to form he must modify his use of the petrol, that is more air must be admitted. Sometimes this deposit accumulates to such an extent in the combustion chamber that it gets hot, and self-ignition occurs the charge being fired without help from the electric spark. If self-ignition is suspected, it may be tested by cutting off the spark, and if the engine continues to run the necessary proof is obtained.

If, owing to a deposit in the cylinder, the engine is running unsatisfactorily, an improvement should be effected by using a weak explosive mixture, that is a mixture containing an extra quantity of air; this will prevent trouble from self-firing.

Another cause of deposit in the cylinder is due to over-lubrication, or the use of improper oils, the oils used in the cylinder must be capable of standing high temperatures. Burnt lubricating oil leaves a sticky deposit, which can be removed by injecting a little paraffin into the combustion head, either through the little cock or through the spark-plug orifice; too much paraffin tends to form a hard carbon deposit inside the cylinder.

The instructions given as to keeping the cylinder clean apply equally to the inside surface of the combustion head.

Owing to the high temperature at which the exhaust gases leave the cylinder the exhaust pipe attains a very high temperature, and it is desirable to isolate it from the combustion head as effectively as possible, it being important to keep the combustion head cool, otherwise the valves are apt to get burnt and their surfaces pitted. The most efficient way of isolating the exhaust pipe from the combustion head is to put in asbestos packing between the exhaust-pipe flange and the engine casting.

2. **Piston.**—We have already seen the need for piston-rings, and also for keeping the cuts in these rings well apart, so as to give the compressed gases that may happen to leak through these joints as long a path as possible. When it becomes necessary to dismantle the engine and take out the piston, it is important to avoid inadvertently pushing the piston end up into the combustion head when the connecting-rod has been detached from the crank. If this is done, it is quite possible that one of the piston-rings may expand and lock the piston into the top of the cylinder, presenting an extremely difficult problem in the matter of removal.

After an engine has been running for some time it is probable that a knocking will be observed. This may be due to the bearings at either end of the connecting-rod having become loose through wear. If the knock is due to this cause, it will be observed every time the direction of the crank is reversed; there will also be a knock when the explosion occurs. The cure is to adjust the bearings; this can be readily done on the big end, as provision is made for adjustment; but the small brass in which the gudgeon-pin runs is best replaced.

3. **Crank-Shaft.**—The satisfactory running of the engine largely depends upon the crank and bearings being in correct alignment, and running true; should the crank-shaft by any mischance be forced out of truth it will need to be put right without delay. The bearings also will need careful attention and adjustment from time to time, as, practically, the whole brunt of the explosion comes upon the crank-shaft bearings.

Sometimes a knock is developed when one end of the crank-shaft is higher than the other, and the whole weight of the crank-shaft and flywheel is consequently carried from side to side. The cure is to pack up the lower brass until the alignment of the shaft is true, that is until it is accurately at right angles to the piston-rod.

4. **Valves.**—Although the mechanically operated inlet or admission valve is coming largely into favour, and is pretty certain to supersede the automatic valve, this is not yet the case. The special point to take note of regarding the automatic admission valve is that the spring is properly suited to its work; too strong a spring will not admit sufficient mixture during the suction, and with too weak a spring the valve will not close with sufficient rapidity to prevent some of the mixture being forced back again; and when it does close it will be with considerable force. New springs are generally provided of sufficient length to enable pieces

to be cut off until the right strength is obtained; a better arrangement would be some means of hand adjustment.

As springs are liable to become soft owing to the heat developed it is well to carry spare ones, and, to avoid any possibility of losing time on the road, a complete duplicate admission valve with seat should be carried, which can be promptly exchanged for that in use if it is suspected to be giving trouble.

The great advantage of the mechanically operated valve is, that there is no trouble with springs; the valve is opened at a definite point and closed with equal certainty at the right moment.

Both the inlet and the exhaust valve are subject to high temperatures, the exhaust valve particularly so; for during the exhaust stroke the burnt gases at a high temperature pass over both surfaces, the result being that they become "pitted," and if not ground in fresh from time to time the joint will not be tight. If it is suspected that the valves are not fitting with perfect accuracy on their seats, they should be taken out and examined, and if the surfaces show signs of pitting they must be ground in.

The mushroom heads of both valves are provided with screw-driver slots, by means of which they can be turned round on their seats. The grinding process consists of first making a paste of emery powder of very fine quality—that used for cleaning knives is suitable; the valve seat is then smeared with this, and by means of an ordinary screw-driver or one fitted into a brace the mushroom head is moved to and fro in a circular direction, until both seat and valve fit accurately. Too much care cannot be taken during this process in preventing any of the emery powder getting into the working parts of the engine; a piece of cotton waste should be so placed as to catch any that escapes.

When grinding in valves care should be taken to avoid cutting rings on the surfaces, by lifting the mushroom from time to time and so changing slightly the position of the rubbing surfaces.

Occasionally the surfaces become dirty only, and grinding in is not then necessary; washing with a small quantity of paraffin or petrol will in such a case put matters right.

With a new valve difficulty may be experienced through the spindle or rod carrying the mushroom head fitting too tightly into its tube. When cold it should only fit fairly well, *i.e.*, not too tightly, owing to the fact that the rod expands more than the tube, and when hot will fit better than when cold; if too tight a fit when cold, it will stick when hot, and not allow the head to move freely; in this case the spindle can be reduced with emery powder.

Lubrication of valve spindles is not to be thought of; oil is sure to cause stickiness and want of freedom of movement.

5. **The Engine at Work.**—*Compression.* An essential feature in the Otto cycle is the compression of the charge before firing. If the compression is bad the explosion will lack power, and the best effect will not be obtained from the fuel. It may be taken roughly that the higher the compression the more efficient the engine; with a pressure of 60 lbs. on the square inch at the completion of its compression stroke the efficiency of the engine is about ·37, that is to say 37 per cent. of the fuel value of the charge is transformed into work in the engine. With 100 lbs. pressure the efficiency is increased to ·45.*

When a gas is compressed it is heated in the operation. If this heat is not lost during the process of compression, that is to say not absorbed by the walls of the cylinder, it helps to expand the charge and give greater pressure. It thus follows that when the engine is working at a high speed the interval allowed for absorption of heat by the

* Such efficient results are not generally obtainable in practice.

walls is less than when working slowly, and the compression is also higher; thus it follows that when an engine is running at a high speed its efficiency is greater than at a low speed on this account alone.

Another result of the heating of the charge is that it ignites more readily. From these notes it will be gathered how important a matter it is that the compression should always be in good order. There are several causes that operate unfavourably in this connection, and it will be well to devote a little time to the consideration of possible causes of loss of compression.

Probably the most common of these is leakage through the valves. We have already dealt with this question under Valves, and have shown how the trouble may be disposed of. There is also the possibility of leakage past the piston and piston-rings; this also has received consideration. A moment's thought will suffice to show that there are several joints where parts are screwed on to the combustion head; for instance, the spark-plug orifice, the lubricator or compression-cock, and occasionally the cylinder is built up of several parts screwed together. If it is suspected that joints are leaking, a little paraffin should be squirted round them, and the crank turned against compression by means of the starting-handle. If bubbles form round the joints, new ones will have to be made. To effect this, the joint should be broken and both surfaces carefully cleaned, and a joint, either of asbestos or copper wire, inserted, or possibly a combination of both. If copper wire is used it should be of about number 16 gauge, with the ends filed and butted together. When surfaces are screwed tightly together, the copper becomes flattened out and forms a satisfactory joint.

If compression is good it will be found difficult to turn even a 6 h.p. engine against the compression by hand; it is therefore, usual to provide a means of partially relieving the compression during starting operations, and for this purpose a small cock is provided on the combustion head which can be opened to any extent that may be required; obviously it will be best not to open this more than is actually necessary for starting the engine.

The usual degree of compression when turning by hand should be about 80 lbs., and, if desired, a small pressure-gauge can be obtained to screw into the combustion head to test the pressure, but this ought not to be necessary when a driver has had a little experience in handling his engine.

In a multi-cylinder engine each cylinder can be tested for compression by opening the cocks of all the other cylinders in succession and trying with the starting-handle.

Power of Engine.—The power which an engine develops depends upon the area of the piston top, the length of the stroke, the average pressure in the cylinder during the explosion, and the number of explosions per minute. The whole of the power developed in the cylinder is not available for actual work, for there are losses due to friction in the engine itself; there is also a loss during the compression stroke due to back pressure and a slight loss during the suction stroke.

The power developed in the cylinder can be calculated by the aid of an *Indicator Diagram,* which records the pressure inside the cylinder at various parts of the stroke. During the downward suction stroke the pressure inside the cylinder is slightly below atmospheric pressure; as soon as the inlet valve is closed and compression commences the pressure rises until, on the completion of the stroke, it is between 40 and 60 lbs. on the square inch. Ignition then takes place, and the pressure in the cylinder rises for a brief moment up to about 300 lbs. on the square inch, and during the downward stroke the pressure falls off. The moment the exhaust valve is opened the balance of the explosion or expansion of the gases takes place through the exhaust pipe and silencer to the atmosphere. If the opening were complete and instantaneous the pressure inside the cylinder would fall instantly to atmospheric pressure, but none of the variations in pressure are instantaneous. In calculating the power developed, an allowance has to be made for the negative work done during the compression stroke, which necessarily involves the absorption of some of the power developed during the explosion.

The calculation of the power from the pressure diagram, cylinder dimensions, and speed gives what is termed *Indicated Horse Power* (I.H.P.); but, owing to frictional and other losses in the engine, the actual power developed on the crank-shaft is substantially less. The power available on the crank shaft is termed the *Brake Horse Power* (B.H.P.), or the horse power that the engine will give when tested by means of a friction-brake. When the H.P. of a petrol engine is spoken of it is this brake horse power that is meant; and if it is suspected that an engine stated to be capable of giving so much horse power is not up to the mark, it may be tested and the actual power developed ascertained. The test, however, would be of no value unless the compression is good, the explosive mixture properly proportioned, and all other adjustments made to secure the best results.

A simple and useful form of air friction-brake has recently been introduced, which should prove of considerable value for testing the power of petrol engines; this can be used by an intelligent person, but to test with the ordinary friction-brake expert handling is necessary.

Engine Faults.—There are so many different means of regulating and controlling the petrol engine, each one of which depends largely upon the judgment of the driver for successful adjustment, that it is not surprising to find that when an engine is running, especially in inexperienced hands, difficulties of various kinds arise.

We have already alluded to Self-Ignition, or, as it is sometimes termed, Pre-Ignition, due to the accumulation of deposit in the combustion head, and, in addition to this, there is what is termed *Back-fire, Mis-fire,* and *Silencer Explosions,* which require to be properly understood.

Back-fire is an explosion which tends to drive the engine in the wrong direction. The word "tend" is used advisedly, as when an engine is running at a fair speed, and a considerable momentum is stored in the flywheel, an explosion may have a tendency to drive the engine the wrong way, but the power may not be sufficient to overcome the forward movement. Nevertheless, whether it succeeds in reversing the engine or only in checking its movements it is a thing to be avoided, as it brings immense strain upon the moving parts.

Back-firing may result from leaving the lever controlling the advance and retard of the spark too far over towards the advance when the engine is running slow. It may possibly have been necessary to stop the engine when running at a high speed; this probably will have been done by shutting off the throttle and spark, and it is quite possible under these circumstances to omit to retard the spark. It is also quite likely that although the lever was correctly placed when shutting down it may have been shifted subsequently. In starting again the driver ought, first, to see that the lever is at the retard position; should this, however, have been forgotten the explosion will take place too soon, and will drive the crank in the wrong direction, giving a violent blow to the person operating the handle. The term is sometimes applied to an explosion that takes place inside the silencer; this, however, is an incorrect use of the term.

Mis-fire results almost invariably from faults in the ignition apparatus, and is fully discussed in chap. iii.

The cause of silencer explosions is referred to in chap. ii. under "Silencer."

CHAPTER II—THE ENGINE ACCESSORIES

CONTENTS :—The Petrol Supply System—Silencer—Water Cooling—Lubrication—Governing and Control

1. **The Petrol Supply System.**—There is only one subject of greater importance than the proper regulation of the fuel supply in securing the regular and steady running of the petrol engine, that is the Ignition, which will be dealt with fully in due course.

From the study of the fuel we have seen how small a variation in the quantity of petrol will make all the difference between the manufacture of a powerful explosive mixture and an almost useless mixture; the need for careful adjustment is therefore apparent.

It is, of course, not possible actually to measure the proportions of petrol and air passing through the carburettor, and adjustment must be made as required to give the best results under varying conditions; the exact adjustment necessary can only be ascertained by actual experience. The fuel experiments described in Section I. should, however, be of material assistance in indicating the need for careful and proper adjustment, if the best results are to be secured. Excess of petrol is, perhaps, to be most carefully avoided, as not only is solid carbon produced, but it will be readily understood that if combustion is not complete some of the heat value of the fuel will be wasted. On the other hand, if too small a quantity of petrol is used the power of the engine will be reduced. When large powers are not required from the engine it is an advantage to run with a weak mixture.

Except in warm weather it is customary, before operating the starting-handle, to press the plunger of the carburettor, and so force a small quantity of petrol through: it is, however, possible to do this with too much energy, and it is easy to prevent the engine from starting by overdoing it.

If a car has been standing a considerable time it is possible that the petrol which has remained in the carburettor may have become stale; in other words, the more volatile portion will have evaporated, and left only the denser portion, which, especially in cold weather, will not give a suitable mixture for starting the engine.

It is well to bear in mind that many qualities of petrol consist of a mixture of spirits of varying degrees of volatility, and that if left where evaporation can take place, the more volatile comes off fairly rapidly, and leaves behind what is termed stale petrol, needing a much higher temperature than is usually employed in the carburettor to vaporise it.

In the handling of petrol every care must be taken to prevent dust and dirt getting mixed with it. Too much care in this respect cannot be exercised, as a very small amount of dirt will block up the passages in the carburettor, and prevent a proper supply of petrol passing through. Whenever the petrol tank is filled a funnel should be used with fine wire gauze screen. It is a good plan also to have a tube of the same fine gauze let into the admission hole of the petrol tank. If it is suspected at any time that foreign matter has got into the petrol, the whole apparatus, and especially the carburettor, should be carefully overhauled, and the passages cleared.

With the float-feed carburettor it sometimes happens that a very small hole develops in the float, thus destroying its buoyancy; the float in such a case does not close the needle-valve when the float chamber is full, and thus the carburettor becomes flooded. The best way to ascertain whether such a hole has developed is to immerse the float in hot water; small bubbles driven out by the expansion of the contained air and vaporisation of the petrol will indicate the exact spot, and the leak can be stopped by means of a touch of solder when the petrol enclosed has been driven out.

Should there be a leakage of petrol on the car it should be found and remedied immediately, as such a leakage is dangerous at any time and in any place.

As petrol vaporises a certain degree of cold is produced, and it is quite possible for the cold to be so intense that the petrol will freeze. Should such a trouble occur, an extra degree of heat must be imparted to the carburettor.

Another trouble sometimes experienced with the carburettor is flooding with water. If a car is being run in especially damp and heavy weather the moisture from the air may become condensed, and the water will mix with the petrol; if this occurs there is likely to be a loss of power, and occasionally mis-fires; in some forms of carburettor such a trouble cannot arise.

Occasionally the jolting of a car along a road will cause flooding of the carburettor. The float is jolted up and down in its chamber, and the needle-valve admits rushes of petrol when not required; to remedy this partially close the cock on the supply tank.

In the general handling of petrol it will be well to observe, as a fixed and inviolable rule, that a naked light must never be taken near tanks containing petrol, be they full or empty. Most cars are provided with small electric lamps supplied from the ignition battery, which enable the mechanical parts of the petrol car to be examined at night, if anything is wrong; this is a very wise arrangement, as under no circumstances could the electric light ignite the petrol vapour.

Should a quantity of petrol be upset in a building, the first thing to do is to see that all windows and doors are widely opened, so as to give the vapour an opportunity of escaping, and all naked lights that may be burning should be promptly extinguished. If by chance overturned petrol catches alight, the only thing to do is to smother the flame; this can be most effectually done by throwing sand upon it. In all petrol motor houses and places where petrol is stored some buckets of sand should be kept handy in case of emergency.

2. **Silencer.**—Allusion has already been made to the desirability of isolating the exhaust pipe from the combustion head of the engine, on account of the high degree of heat that is developed in the exhaust. Sometimes the heat developed is excessive, owing to the persistent retarding of the spark. When this happens the explosive mixture passes from the cylinder into the exhaust only partially burnt, and combustion continues while on its way through the exhaust pipe and silencer. Such mismanagement is to be deprecated, as the high temperature of the burning gases will destroy the seats of the exhaust valve, and will also cause the steel spindle to "scale"; it must be remembered, too, that not only is harm done to the engine, but that the passing away of gases prematurely in this manner means loss of power and waste of petrol.

Unburnt gases pass from the cylinder into the silencer, when mis-fire occurs, and it is possible that the charge may become ignited by the heated exhaust pipe, or possibly by the flame from the subsequent explosion, and a loud and violent explosion takes place which is somewhat alarming, not only to the driver but also to the public in the neighbourhood. If such an explosion be repeated within a short interval the cause should be ascertained, and remedied without delay; as a rule, no serious harm results from the silencer explosions. It has already been explained that the application of the term back-fire to this kind of explosion is incorrect.

Silencer explosions of a less degree of violence sometimes occur through the undue retarding of the ignition. In this case the exhaust valve opens before the explosion is complete, and thus part of the explosion takes place beyond the exhaust valve. This is, as has just been explained, destructive, and it must be at once remedied by properly advancing the ignition.

If it is attempted to control the engine by cutting off the spark instead of using the throttle, silencer explosions are very likely to occur, as, in this case, with each successive suction stroke fresh gases are drawn into the cylinder, and must of necessity pass unignited into the silencer, where if the temperature is sufficiently high they will explode. Attempting to control the running of an engine by cutting off the spark is to be deprecated; it is, however, a method very commonly in use in connection with motor-cycles, the result being the popping which is so disturbing to the nerves of other users of the roads, and especially of the horses. This popping in motor-bicycles is also produced by the lifting of the exhaust valve.

When a motor-cycle is being run through traffic neither of these methods should be resorted to for controlling the engine; on the open road it must be left to the choice of the driver as to which of the several methods at his disposal he makes use of, but it is important to bear in mind that several of these methods result in considerable waste of petrol.

3. **Water Cooling.**—The gilled tube radiator has an advantage over the honeycomb type in allowing a freer passage for the circulating water; it is also very much to be preferred on the less expensive types of cars, as the honeycomb radiator, to be reliable, needs to be made with very great care, and, in consequence, is costly. There is less liability with the tube form of radiator to leakage than with the honeycomb, and should leakage occur with the latter it

is a very difficult matter to remedy it; in fact, it is almost an impossibility on the road. With a high-class car, and where the quality of the workmanship is undoubted, the honeycomb type has several distinct advantages. It is a good mechanical job, is an excellent water cooler, and therefore reduces the quantity required to the minimum; it also has a very neat appearance.

A trouble sometimes experienced with the tube radiators is the enclosing of a small quantity of air in the bend of one of the tubes. This more particularly happens when filling the water tank after the radiator has been emptied. The bubble of air effectually prevents circulation, and a fault commonly known to motor-car drivers termed *Air-lock* is the result; it very soon makes itself manifest by the boiling of the water in the upper part, while the lower still remains cool. An air-cock is usually provided on the top of the radiator, and opening this may possibly cure the trouble; if not, the water must be drained off while the engine is running, and at the same time the tank must be filled as fast as the water runs away; by this means the bubble is swept out.

The tank needs to be filled from time to time to make up for evaporation, and when this becomes necessary it is important to use only pure water, preferably rain water. Care should be taken, too, to see that it is clean, and contains no floating organic matter. This precaution is all the more important with the honeycomb type of radiator, as the spaces through which the water has to circulate are extremely small.

As the function of a radiator is to disperse as rapidly as possible the heat brought into it from the engine, anything that helps to increase its radiating power must be an advantage; all parts of the radiator must, therefore, be made a dead black. It is not unusual to see honeycomb radiators with a very bright surface; this, of course, looks very nice, but polished metal is a bad radiator of heat, and metal with a dead black surface is the best possible radiator.

It should be remembered that when a car is running with the wind there will be very little air passing over the radiator tubes. In this case it may be necessary so to arrange the running of the engine that the least possible heat is generated: this especially applies during hot weather.

Overheating of the engine may arise quite independently of the efficiency of the water-cooling arrangements; over-lubrication, too rich a mixture, the persistent slipping of the clutch, and the working of the engine at a poor efficiency, from whatever cause, are the more usual reasons. In some cars there is an especial tendency for the engine to overheat when hill climbing, and at all times it is necessary to keep the possibility of overheating in mind; for should this occur, and no immediate cause or remedy be apparent, the engine must be given a rest to allow it to cool down.

During the winter, frost requires to be specially guarded against. Should the water in the water-jacket of the engine freeze, the result will be that the iron casting will burst; the only remedy for this is a new cylinder, a serious and expensive matter. If, therefore, the car, when at rest, is exposed at any time to frost the only real safeguard is to empty the water-jacket and radiator. When at home it is best to arrange for the heating of the motor-car house; but when away it is not always possible to find the necessary means, and too strong a word of caution cannot be given in this connection, as the expense and inconvenience of a burst water-jacket is no small matter. A distinctly ingenious method of repair has been recently described: a saturated solution of copper sulphate was introduced into a cracked water-jacket, and this trickling through the crack deposited a coating of copper, which by degrees filled it up. It took some three or four days, however, before the deposit of copper effectually stopped the crack, so that such a process is distinctly tedious.

One very common cause of leakage in the water circulating pipes is due to a rigid connection to the radiator. The vibration of the car, which is inevitable, causes the pipes to shake to such an extent that in course of time a crack appears at one of the fixed ends, generally that attached to the radiator. In most recent cars the practice has been adopted of attaching the circulating pipes, which are made as short and as light as possible, to the engine and radiator by means of short lengths of stout rubber hose, some three or four inches long; the vibration is thus absorbed and leakage prevented.

The weight of water required for cooling purposes on a petrol car is a distinct consideration, and for this reason the honeycomb radiator is preferable to the tube, as the cellular formation provides a very large area for cooling purposes, and the quantity of water required is proportionately small.

Occasionally when the cooling water refuses to circulate the fault is to be found in the pump, and it is a good plan to run the engine a short time before commencing a journey, to ascertain that the circulation is perfect; a few minutes only are required for this, and much trouble and vexation on the road may thus be avoided.

4. **Lubrication.**—To many a beginner unacquainted with machinery, and particularly engines, the supply of lubricating oil seems to be as important as the provision of petrol itself. Troubles of all kinds are frequently put down to want of lubricating oil, which is accordingly supplied superabundantly, thus possibly aggravating the very difficulty which it is supposed to remedy. While it is quite proper to be particular about the provision of a sufficient and regular supply of oil, yet its true function simply as a

lubricant should not be confused with the fuel properties of the petrol.

It must already have become apparent that much trouble may be experienced through the use of unsuitable oil; the driver of a motor-car should therefore make himself acquainted, as early as possible in his career, with the different qualities and properties of the oil used in motor-car work.

The special characteristics of lubricants which are of interest to the driver will now be briefly noticed. In the first place animal and vegetable oils are not suitable on account of their ready decomposition at high temperatures, and the consequent production of corrosive acids and pitch. Although possibly they might be used for the bearings which run cool, there can be no point in employing them, as quite satisfactory (if not superior) results are obtained with the mineral oils. It is probably within the experience of most readers to have observed that animal and vegetable oils have a corrosive action upon brass; the verdigris which is so often observed on brass bearings where this class of lubricant is used is due to the action of acid on the copper.

One very important property of lubricating oils is that the higher the temperature to which they are submitted the more fluid do they become, until at last highly refined oils pass off entirely into gas; there is no residue liable to become charred into a hard carbonaceous deposit. The heavy crank chamber oil which is used in the cylinder becomes at the temperature of the cylinder walls as fluid as ordinary household paraffin; the lighter oil, too, used for lubrication of the bearings, also becomes considerably more fluid when in use in the warm bearings.

The converse is also true, namely, if the temperature is lowered the oils become more viscous; for this reason, in some makes of car, devices have been adopted for warming the oils before they pass through the sight-feed lubricators. By this means the fluidity of oils is approximately the same whatever the atmospheric temperature may be, and the rate of drop recommended by makers may be always regulated to the same. If an engine is just starting up from cold, setting the sight-feed lubricators to work at the normal rate before the oil has become warm will necessitate further adjustment later on when the temperature of the oil has risen.

After a certain degree of cold has been reached all oils "set," or lose their fluid condition; the *Setting-Point* varies considerably with different oils. Most oils used in connection with motor-cars should set at a temperature between 30° and 40° F.

The suitability of oils required to stand a high temperature is ascertained by the *Flash Point*. When oils are slowly heated to a high temperature a thin smoke is given off after a time, which, on the application of a flame, takes fire with a quick flash. The temperature that gives rise to this smoke is termed the flash point; it is, of course, possible to heat the oil still further, so that on applying a flame it takes fire and burns continuously; this is called the *Burning-Point*. It is important to use oils of high flash point for cylinder lubrication, and those supplied for this purpose range from 550° F. to 450° F., the former being for air-cooled engines and the latter for water-cooled engines.

If the reader has no previous knowledge of lubricating oils for such a purpose he cannot do better than make careful inquiries as to the make, quality, and nature of the oils recommended for various parts of the machinery by the maker of the motor-car, who, generally speaking, has no direct interest in the sale of the oil.

The importance of lubricating machinery has led to the exercise of a considerable amount of ingenuity in devising simple and convenient lubricators. Of the various systems in use may be instanced:

(1) The *Oil Bath*, used with the change-speed and differential gears; in this the parts to be lubricated are actually immersed in a bath of oil.

(2) *Splash Lubrication*, used for the cylinder and crank chamber.

(3) *Forced Lubrication*, which consists of a small pump supplying oil under pressure through tubes to the different bearings.

(4) *Ring Lubrication*, which is commonly used for the main engine bearings; here a ring is suspended from the journal in a recess provided in the brass and dipping into a small reservoir of oil below the bearing. The rotary motion of the journal causes the ring to revolve, and thus a continual supply of oil is brought up from the reservoir below to the bearing.

(5) *Sight-Feed* or *Drip Lubrication:* in this case oil is brought from a tank and distributed by means of pipes to the various bearings, the supply to the pipes being through glass tubes arranged with an adjustable valve, through which the oil passes in drops, the number of drops per minute being regulated by a milled headed screw. Occasionally some of the separate bearings have an independent sight-feed lubricator with a reservoir of oil, dropping tube and adjustable screw.

(6) *Automatic Lubrication* has been introduced on some of the leading cars; with this no attention is required for the regulation of the supply. When the engine is running oil is distributed from a central tank through distribution tubes to each bearing with perfect regularity, by means of a revolving spindle running in conjunction with the engine, and provided with little cups or recesses which dole out the oil according to the speed of the engine.

7) *Grease Lubrication* has many advantages for such parts as do not need very close and careful attention. A special lubricator is designed for use with grease; that most commonly known is *Stauffer's Lubricator*. It consists of a cup containing the grease provided with a screw cap; a hole in the base of the cup leads to the journal; by small turns of the cap some of the grease is squeezed into the bearing. A very small movement is sufficient, as a rule only about a quarter of a turn is necessary, when running, for every hundred miles; but a slight turn should be given every day before starting. One advantage possessed by this lubricator is that should the bearing get hot the grease melts and runs down over the bearing. As the vibration of the car tends to shake screwed parts loose, several grease lubricators have been devised with self-locking caps.

If by any chance through the supply of grease running short it becomes necessary to use oil with this type of lubricator, it is important to see that the hole passing from the cup to the journal is free from grease; otherwise the oil will be effectually prevented from penetrating to the journal. A small quantity of finely powdered graphite may be mixed with grease lubricants with advantage. Graphite is an excellent lubricator, and some fifteen per cent. of it thoroughly incorporated with the grease is useful.

An important point to be remembered is, that cotton waste or cloths soaked with oil are liable to spontaneous combustion; care should, therefore, be taken not to store for any length of time any quantity of this material; either the waste should be thrown away or burnt, or the cloths, if of any value, cleaned. Several motor-car fires have arisen solely from this cause; the oily waste has been put into one of the tool boxes, and allowed to remain there until the heat generated by the oxidisation of the oil actually casued them to break into fiames.

5. **Governing and Control.**—In the handling of a motor-car, the governing or control forms one of the most important and difficult of problems; the speed of the engine needs to be controlled quite independently of the speed of the car; at times great power, which means full speed, is required from the engine; while slow speed is necessary in the car; at other times the high speed of the car requires only a relatively small amount of power; it is these conflicting conditions that make automatic control impossible.

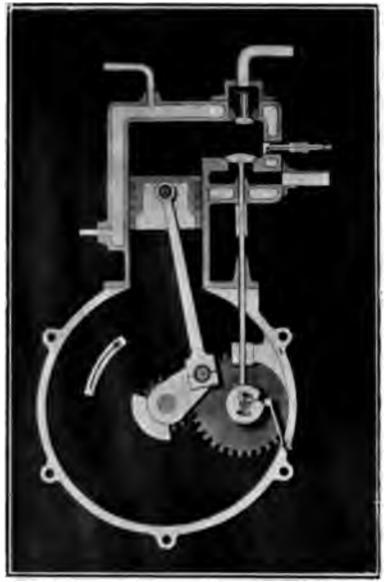
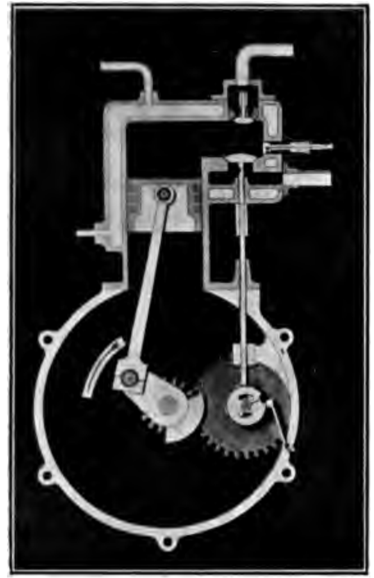
As we have already seen, a governor is provided for keeping the speed of the engine within limits independently of other conditions, and also independently of the driver. This, however, is not of any great value in the actual handling of the car, as it acts chiefly in the capacity of a safety check in the event of the speed of the engine tending to rise to unsafe limits. The speed of a car sometimes needs to be increased with great rapidity, and the engine has to be called upon for its full power; for this purpose an *Accelerator* is provided, which takes the form of a pedal in front of the driver; this, acting through a series of rods or flexible wire, prevents the governor from closing the throttle-valve. This piece of apparatus is used when the full power of the engine is required, such as when mounting a hill. It is also most convenient for slowing down and for accelerating the speed of the car whilst threading a way amongst traffic.

Apart from the governor the speed of the car is controlled primarily by three methods: by the use of the throttle, the advancing and retarding of the spark, and the variation of the mixture of petrol vapour and air. If the throttle is to be used for controlling the car independently of the governor, special provision needs to be made so that the governor is independent, and able to cut down the speed of the engine if it rises substantially. The advantage of using the throttle is, that by a simple movement of the lever the power of the engine and the speed can be controlled within fairly wide limits. It has the disadvantage, however, that when the throttle is closed the compression in the engine is reduced, and thereby the fuel efficiency of the engine is also reduced. It has already been pointed out that the higher the compression, provided no risk of pre-ignition is run, which practically determines the limit, the more efficient will be the engine; however, although the fuel is used wastefully, yet the silence of working and ease of control renders this method of special value when running through traffic.

Varying the lead, or advance of the spark, is more especially useful for securing higher power when the engine is running at a high speed. It is necessary to remember that the actual time taken between the contact established in the battery circuit and the ignition of the gas in the combustion chamber is very appreciable, and for this reason a lead is always given to the contact-maker when the advancing and retarding lever is in the mid position.

This can be readily explained by a reference to Plate VI. In Fig. 20 the crank is shown at the dead point, the contact-maker will be observed just touching the spring or brush; in other words, at this moment the spark will be formed in the combustion head. Were it not that the explosion occupies an appreciable time, and that the crank and other moving parts of the engine are being carried round by the momentum of the flywheel, no motion would be given to the crank. In consulting this diagram, therefore, it will be remembered that although for convenience it is shown on the dead point, the explosion will actually be effective. The two remaining figures show the contact-maker in a position necessary to secure the advancing and retarding of the spark. For convenience the contact-maker has been made movable, while the brush is fixed. In actual practice it is almost invariably

PLATE VI

SPARK ADVANCING AND RETARDING

FIG. 20—NORMAL POSITION

FIG. 21—ADVANCE POSITION

FIG. 22—RETARD POSITION

To face page 104

[redacted]

the case that the brush spring is movable, while the contact-maker is rigidly fixed to the half-speed shaft.

In Fig. 21 the contact-maker has been rotated backwards to the extreme end of the slots. The contact between the spring and the brass contact piece will, therefore, take place after the crank is long past the dead point, in other words by making the contact late the spark is retarded. Fig. 22 shows the contact-maker rotated forward to the end of the slots; thus the spark will occur before the crank reaches the dead point; in other words, the spark is advanced.

As a matter of fact, in the normal position the contact with the spring is generally arranged to take place a little before the crank reaches the dead point, owing to the loss of time which results between the actual making of contact and the occurrence of the full force of the explosion. The greater the speed of the engine the more important does this time-lag become, and it is for this reason that the advancing of the spark as the speed increases becomes so essential a part of the engine control.

CHAPTER III—ELECTRICAL IGNITION

CONTENTS:—Wiring—Spark-Plug—Battery—Induction Coil—Commutator—Testing for Faults—Battery

WHEN trouble arises with the working of an engine, in the great majority of cases the fault will be found in connection with the ignition; electricity, especially high-pressure electricity, has a way of finding paths for itself which it is not intended to run along, and the flow along the proper path is readily interrupted if proper care is not taken.

Faults are most likely to occur in the following order in the

(1) Wiring.
(2) Spark-Plug.
(3) Battery.
(4) Induction-Coil.
(5) Commutator.

(1) **Wiring.**—Dealing with these in turn the special points it is necessary to bear in mind are the facility with which a low-pressure circuit is broken or interrupted, and the ease with which the high-tension current manages to leak across insulating surfaces. "Short circuit" and leakage have also to be guarded against in the low-pressure circuit.

Dealing first with the low-tension wires, it is important that the metal surfaces and wire ends be thoroughly clean and securely attached to their various terminals; also that the terminals be screwed up tight, and that there is no possibility of their working loose; to ensure these conditions every terminal should be provided with a locking nut. Where the wire is attached to the frame of the motor, especial care must be taken to see that the metal surface to which the wire is attached is bright and free from rust and scale. It must also be seen that the piece of metal that the frame wire is attached to is soundly connected metallically to the main body of the engine, and that there is an easy path for the electricity through the journal to the commutator or contact-maker. It occasionally happens that a good metallic contact is not made through a journal and bearing, owing to the fact that the oil makes a continuous envelope around the journal, and, being an excellent insulator, low-tension electricity cannot cross the gap; it is unusual in a motor-car to meet with this difficulty, but should it arise the only alternative would be a spring contact-piece attached to the brass sector and rubbing on the journal.

A low-tension current is fairly readily insulated, but owing to the fact that one pole of the battery is connected to the frame of the motor, the wires must be efficiently covered; it is usual to employ vulcanised-rubber-covered wires wrapped in tape and finally braided with jute, and served over all with black "compound"; the braiding simply serves to protect the rubber from mechanical injury. It must not be forgotten that rubber is highly inflammable, and also easily melted by heat; the wires must therefore be carried as far away from any hot metal as possible. It has become customary recently to enclose all the low-tension wires in a brass tube, leaving only a few inches of the insulated wire exposed near the several contacts; this is an excellent plan, the straggling wires to be seen on a car of only two or three years ago looked most untidy, and were the cause of a great deal of trouble. The sum of our considerations then with regard to the low-tension wires is that all contacts must be clean, all terminals tightly screwed up, and the insulation perfect.

With the high-tension wires the conditions are somewhat different. Although it is highly desirable to see that all contacts are clean and carefully made, the high-tension current will jump across a fairly considerable gap, and, curiously enough, a gap is sometimes of distinct advantage, as we shall see later. The insulation of the wires becomes a question of importance, and high-tension wires generally have a much thicker rubber insulation than the low-tension wires; it is usual, too, to provide a covering of rubber alone without tape and braiding; extra care is, therefore, necessary to keep the wires away from any hot metal and from positions where mechanical injury might result. Here again it has become customary to enclose in a tube the wires passing from spark coils to the various cylinders.

As the spark will jump a considerable distance, and one end of the coil is attached to the frame, the insulation of the wire must be excellent, and the wire itself must not approach too closely to any of the metal work on the engine by which the electricity could escape or pass by a short path instead of through the spark-plug.

The thick insulation of these wires is liable to deteriorate, especially if not of the best quality, and, may be, cracks will form. If these cracks become filled with dirt or moisture a leakage of the electricity is likely to occur, and the spark at the plug, if not actually stopped, will be weak. The chief points to be guarded against with the high-tension current, therefore, are leakage across dirty or damp surfaces, and jumping across small gaps and escaping to the frame of the engine or "earth."

A word regarding the preparation of wire ends may be useful. When the end of an insulated wire needs trimming for attachment to a terminal, it is best to cut back the insulation completely for about an inch; and if the wire is taped and braided, the braiding should be removed, and the tape peeled off the rubber carefully for another half-inch, without cutting or injuring the rubber. The wire will probably have a thick coating of rubber, and the conductor in the centre will be stranded or composed of a bunch of small wires; to cut the rubber off, a circular cut should be made with a sharp penknife one inch from the end; the cut should penetrate the rubber, but not injure the wires. A longitudinal cut should then be made from the circular cut to the end with the point of the knife; to do this the wire will be laid on a piece of wood and the cut made downwards, care being taken, as before, not to damage the wires; if the cuts have been neatly made the insulation can be readily peeled off. The wires should now be lightly scraped and then twisted tightly together, and to keep them from spreading or straggling it is best to solder all together; straggling strands are apt to touch across terminals and cause leakage or "short circuit." If a small "flexible" wire is being cleaned, the cotton insulation is best cut gently with a sharp knife, and scraped off till the conductor is free. If cotton or rubber is allowed to remain on the wire end it may effectually prevent contact being made with the metal of the terminal. Although a high-tension current will overcome most obstructions, the same precautions should be taken to secure a good metallic connection throughout.

(2) **Spark-Plug.**—In the spark-plug two things have especially to be guarded against—surface leakage and dirty contacts. The high-tension current passes with great facility over a considerable surface, if moist or dirty; the insulating surface, therefore, between the terminal and the metal part of the plug must be thoroughly clean, and also constructed of suitable material. The plug becomes hot after the engine has been running for some time; but before starting it may be cold, and a thick film of moisture is likely to form on the insulator if made of porcelain. For this reason one maker

has adopted mica for the insulator; this has not the same attraction for moisture as porcelain or glass, and, as it is also fireproof, it makes a perfect insulator for such a purpose; after the engine has started and the spark-plug has become hot there can be no difficulty from surface leakage due to condensation.

Dirty spark contacts are generally caused by the accumulation of oily matter, which, in course of time, becomes carbonised by the heat. A spark does not readily jump across surfaces coated with a film of oily matter; it, however, more readily jumps across dirty contacts when hot than when cold; and it often happens that while an engine has been running without fault one day, when an attempt is made to start the next day failure results simply through dirty contacts. The remedy is to take the plug out, and clean the contacts with a piece of sand or emery paper.

To get over this difficulty of dirty contacts, which is by no means uncommon, many drivers employ what is termed an *External Spark Gap*; this consists of interposing between the high-tension conductor and the spark-plug terminal a spark gap formed by two pointed screws with the points separated about $\frac{1}{16}$ inch. It would be difficult to explain to non-technical readers the action of this gap, but it has the effect in practice of causing the spark to jump across dirty contacts more readily than would be the case without it. If required it can be placed in such a position in front of the driver that the sparks can be seen, and if there is failure at any of the cylinders with the sparking arrangements, the driver becomes aware of the fact at once. The spark gaps can quite as readily be attached to the induction-coil as to the terminal of the spark-plug.

(3) **Battery.**—Trouble with the ignition arising from battery faults will be dealt with on page 119. It is customary and wise to carry two batteries, so that if that in

use fails, the second can be substituted by turning the handle of the two-way switch.

(4) **Induction-Coil.**—Faults at the induction-coil are most likely to occur either at the terminals or at the contact-breaker. If a fault arises at a terminal, this can be readily ascertained by inspecting the connections and seeing that the screws are tight.

The fault at the contact-breaker will most likely be due to want of adjustment in the contact screw, for the platinum contacts gradually burn away through the sparking, and need to be adjusted from time to time; eventually new contacts will have to be provided. When purchasing induction-coils it is desirable to see that substantial pieces of platinum are provided at the contacts; otherwise the need for new ones will arise within a very short time. When adjusting the screw care must always be taken to see that there is sufficient play for the trembler, and that it moves neither too fast nor too slow. Very occasionally trouble occurs through the platinum pieces becoming loose and not making proper contact either with the adjusting screw or with the steel spring; if such trouble arises, the defective part must be removed, and the loose platinum secured by a few taps from a hammer. It is wise to carry a complete set of spare pieces for the induction-coil, so that any faulty part can be quickly replaced without delay.

To prevent any possibility of surface leakage, the upper part of the coil between the terminals must be kept carefully cleaned. The windings inside the coil occasionally give way, and in this case it is strongly recommended that no attempt be made by an inexperienced person to remedy the trouble; much the safest, as well as most economical, way in the end, will be to send the coil to the maker to be overhauled and repaired.

(5) **Commutator.**—Trouble with the commutator is most

likely to arise either through want of connection between the journal and bearing (as already described), or through a film of metal dust forming on the fibre in the neighbourhood of the contact piece, thus causing early ignition; the remedy for this is to see that the surface is kept clean. The trouble is not nearly so likely to arise with the low-tension commutator as with the high-tension distributor, which needs a very small accumulation of metal dust to cause the spark to jump considerably earlier than it should do. This difficulty has recently been got over by combining the spark gap with the high-tension distributor; thus the metal contact piece does not actually touch the various connectors, but approaches it within a short space, and the spark jumps across the gap: this is an excellent method of solving the difficulty.

(6) **Testing for Faults.**—In the event of the car stopping, it is best at once to turn attention to the ignition, as in nine cases out of ten the fault will be found in this connection. First, the spark should be tested; if the attachment of the wires to the spark-plug can be easily disconnected the simplest way will be to detach it from the terminal, and, holding it by the rubber insulation a little distance back from the bare end, the engine is then turned so as to make contact, and the bare end should be approached to the body of the engine. If a clear bright spark about half an inch long jumps across the space it is most likely that the fault is not in the ignition; however, this is not certain, and before it can be definitely decided the state of the battery must be known, and it must also be certain that the wires and connections are all in good order.

If the spark seems all right, a loose contact may possibly be the cause of the trouble, and it is the quickest if this is suspected, to pass quickly over all the terminals and see that they are screwed down tight. It very occasionally happens that one of the wires is broken inside the insulation; in this case it is difficult to trace, and if all other efforts to ascertain the cause of the failure have been unsuccessful, the wires should be replaced one by one, it being desirable to carry a set of spare lengths for this purpose, with ends ready trimmed.

If the connections are in order it is well to remember that the spark does not jump so readily across the spark points inside the cylinder when the charge is under compression as in the open air; and it may be that while a fair spark is given outside, the force may be insufficient to overcome the resistance inside; it is possible, therefore, to have the spark points too far apart; the correct distance is about $\frac{3}{32}$ of an inch. A thin film of oil on the points will also greatly decrease the power of the spark to jump across the small gap. For these reasons a coil giving a $\frac{1}{2}$-inch spark in the air is necessary to ensure the spark jumping over one-fourth of the distance in the cylinder. If a spark-plug is suspected as being the cause of the trouble it is best to substitute a spare one, and thus avoid delay in attempting to find the remedy on the road.

It has been stated that the spark should be bright, and when considering the principles of the induction-coil we found that although the spark from the induction-coil would pass without the aid of a condenser, yet the effect of adding the condenser was greatly to increase the intensity of the spark. If the spark lacks intensity when testing, it may be that some fault has occurred to the condenser, and, if handy, a spare one should be connected between the trembler-spring and contact pillar (*see* Fig. 12). A thin spark may also be due to a feeble battery, and if the remedy is not found it may be necessary to run with the compression cock slightly open, so as to assist the spark to jump the gap.

If the high-tension wire is not readily detachable from the spark-plug the spark test may be carried out by bringing a piece of stout wire from the frame of the machine to within a short distance of the terminal. Good connection must, however, be made to the body of the machine *first*; otherwise a severe shock to the operator will result.

(7) **Battery.**—*Charging Arrangements.* However conveniently one may be placed in the neighbourhood of a garage or other place where accumulators can be charged, occasions are certain to arise when a knowledge of how to connect up the cells and put in the charge is essential.

The most usual method is to take a supply from the electric lighting street mains, and connect the battery in circuit with some lamps. The number and power of the lamps will depend upon the voltage of the circuit and the charging rate of the battery. We will assume that a four-volt battery is to be charged from a 200-volt lighting circuit, and that the charging rate is three amperes. To get approximately the right current through the battery it will be necessary to use ten 16 c.p. lamps, each taking ⅓ of an ampere. It is, of course, possible to charge the battery at a much lower current, but the time taken will be proportionately longer: if the capacity of the battery is 16 ampere-hours, three amperes will charge it in, say, six hours. If unable to connect it on to a circuit in series with ten 16 c.p. lamps, it can be charged at the rate of 1 ampere, giving it about 18 hours' charge, with, say, four 16 c.p. lamps; in this case the cells might be connected in the evening and left all night.

Possibly the simplest way of connecting up to an existing circuit is by means of a switch; if the switch cover is removed, the wires can be hooked into each of the contact pieces, and brought to the battery, and charging can be started forthwith on connection being made, the switch, of course, being left "off."

It is of the greatest importance that connection is made properly, that is to say the positive wire of the lighting circuit must be connected with the positive pole of the battery. There is generally no difficulty in ascertaining the polarity of the battery to be charged, as the poles are painted, positive red, negative black or bright blue; even if not painted they are generally marked with a plus or minus sign. Should none of these distinguishing marks be visible, an inspection of the plates through the transparent celluloid sides of the box will enable the connection of the brown or positive plate to one of the terminals to be traced. The chief difficulty will be found in ascertaining the polarity of the charging current, especially when this is taken from the street service. The simplest way to ascertain this is by means of a piece of "pole-testing paper" which, when moistened and touched by the two wires leading from the switch will turn a carmine colour on the negative pole. The wire giving rise to the carmine colour must be attached to the negative pole of the battery, that is to the grey spongy lead plate.

If positive is put to negative, the battery will simply assist the lighting circuit in making the lamps extra brilliant until the cells have been thoroughly discharged; after this the current will then continue to flow through the battery and charging will have begun in the wrong direction, that is to say the positive plate will become converted into the spongy lead and the negative plate into per-oxide of lead; this "reversing" of a cell is very damaging to its constitution. If pole-testing paper is not available, two little pieces of lead dipped into acidulated water will answer the purpose equally well; that becoming brown is attached to the positive wire.

In the absence of a pole-tester or pieces of lead and the necessary acid, it may be more convenient to ascertain the current direction by means of a magnetic needle. In this case the following mnemonic rule should be helpful. A single wire will be carried close over the magnetic needle and parallel to it, and will cause the needle to deflect either to the right hand or to the left as soon as current is turned on. It must be understood that a single wire conveying the current has to be carried over the needle; not a piece of flexible with current flowing in the two conductors, because the action of one would neutralise that of the other. It is, of course, necessary that connection be made through the lamps which are to be used in series with the battery when charging, a direct connection of the two wires without the lamps would cause a big flash and the fuses on the distribution board would burn out.

Let us assume that the wire passing from the right contact-piece of the switch is carried over the needle from the South to North and thence to the left contact-piece as soon as the contact is established; we will also assume that the North pole of the needle deflects to the West; the right contact will then be positive and must be connected to the red or positive terminal on the battery. The mnemonic word which will enable this fact to be retained is S.N.O.W., that is to say if the current is flowing from the South to the North Over the needle the deflection will be to the West. The current is supposed to flow from the positive to the negative, therefore a deflection to the West of the wire will always prove that the terminal or contact from which the wire is brought to the South end of the needle is positive. If the deflection happens to be to the East instead of to the West the terminal will of course be negative and will have to be connected with the negative terminal of the battery.

A word of caution is necessary regarding the use of current from the lighting circuits as, particularly in London, quite half of the Central stations supply alternating current instead of direct or continuous current. This alternating current is quite useless for charging motor-car batteries. Either the pole-testing paper or the little plates of lead will serve as a sufficient indicator of an alternating current, as it will not be possible to distinguish one wire from the other if the current is alternating.

In country houses with a private installation possibly the best plan is to connect the two-cell battery up to three cells of the lighting battery, positive plates to positive plates as before. In this case, however, it will be necessary to insert a small adjustable resistance and also a little ammeter in the circuit; the current should be kept adjusted to about the normal charging rate by varying the resistance. If the lighting battery is small, and the motor-car battery large, it will be best to take current from the regulating cells of the house battery, as these are, generally speaking, less used than the remainder of the cells; they may also be charged at the same time as the lighting battery, being connected and the resistance adjusted as before. With a private house installation it may be safely assumed that the current is direct.

In most town installations current is now supplied at about 200 volts; some few are still supplied at 100 volts, which was at one time fashionable, but a considerable variety of voltages are actually in use at the present day, 100, 110, 200, 220 and 230 being the more common. In estimating the number of 16 c.p. lamps to place in series with the battery when charging it will only be necessary to know whether the voltage is in the neighbourhood of 100 or 200, as for all practical purposes the same number of lamps will suit for the odd figures. We have already seen that about ten 16 c.p. lamps are necessary on a 200-volt circuit when charging a battery at a normal rate of three amperes. If the voltage of the circuit is 100, five lamps only will be necessary to give three amperes through the battery. Very occasionally a 50-volt battery is found in a private house; in this case five 8 c.p. lamps will give the required current. To ascertain the voltage of an installation it may be necessary to detach one of the lamps; the voltage and c.p. will then be seen frosted on to the clear glass near the brass collar.

It will now be instructive to follow the charging of a battery from the beginning; we will assume that a two-cell battery is to be charged from three lighting cells at 3 amperes. The positive pole of the charging cells, as we have learnt, must be connected to the positive pole of the ignition battery, and the negative to the negative for the purpose of charging. If we had the means of testing the specific gravity of the electrolyte or acid we should find, if the cell has been fully discharged, that it would be about 1170.

When charging is commenced the resistance is adjusted till the charging current is 3 amperes at first; and if a voltmeter is connected to the battery terminals we shall find that the pressure is about 2·2 volts per cell. There is no perceptible difference in the appearance of the plates at first, but after charging has proceeded some hours bubbles begin to be given off, and the ammeter shows that the current is falling and is no longer 3 amperes; we must, therefore, alter the resistance so as to bring the current up to 3 amperes again. Towards the end of the charge gas will be given off freely from both of the plates, and the free gasing of the cells is one indication that they are charged; if now the pressure of the cells is tested with a small voltmeter it will be found that they are taking about 2·5 volts for one cell, or 5 volts for the two cells; the charging is now complete, and they may be disconnected from the charging source. If now we are in a position to test the specific gravity of the electrolyte we shall find that it has risen to about 1200; this is another indication that the cells are charged. After disconnecting the cells it will be found on testing with the voltmeter that the volts are now only about 2 volts per cell, and this will be their normal pressure during discharging. It will perhaps be as well to understand what the gases are that play so important a part in the process of charging; that given off at the positive plate is oxygen, and that liberated from the negative plate is hydrogen; these two gases when chemically combined—not mixed—form water, and what really takes place when charging is going on is, that the current of electricity divides the oxygen and hydrogen in the water so that they are given off in the form of gas. These two gases mixed in the proportions given off are highly explosive, and if a light were to be brought to the little vent on the top of the cells they would be blown to pieces; care must, therefore, be taken that no light is ever brought near enough to these vents to ignite the gases either when charging or at any other time; this explosion when the gases are lighted is the actual chemical combination of the gases forming into water again.

If we had been careful to keep the current properly adjusted to three amperes throughout the charge we should have found, if the nominal capacity of the battery is 20 ampere-hours, that it would have taken rather more than seven hours before the plates began to gas freely, as there is some loss in storing electricity. All cells should be marked on the outside with the capacity in ampere-hours; it is unfortunately the practice to mark motor-car cells with the ampere-hours when working with an ignition coil; this was a wholly unnecessary and misleading innovation, and when purchasers are obtaining new cells they must take good care to ascertain that they are being provided with cells marked with the *actual* capacity in ampere-hours.

Battery Faults.—It is always desirable to know before starting out for a run that the battery contains sufficient charge; this may generally be ascertained by the use of a small voltmeter and low resistance lamp. First, the lamp should be connected across the terminals, and allowed to burn for some minutes before the voltmeter test is applied; the reason for this is that when a battery is almost run down it has the power of recovering its full voltage if allowed to rest for a short time, and if a battery is tested in this condition it will give the full two volts, or thereabouts, and the driver has no means of knowing how long the charge will last. If the low-resistance lamp is connected in circuit some time before the voltmeter test is made, it will bring the voltage down to the point reached at this particular state of the discharge. If, after the lamp has been connected some time, the voltage falls to less than 1.8 volts per cell, it is a sufficient indication that the battery has but little left, and it will fail before many miles have been run; if a battery is fully discharged there will be no need to test with the voltmeter, as the lamp will first glow brightly and then rapidly fall off to a dull red.

The lamp used with a two-cell battery should be a 4-volt lamp of not less than three-candle power, taking roughly about three amperes. If a lamp taking a very much smaller current is used it will need to be on circuit a longer time before the voltmeter test is made. Really, the only means of judging the current contained in the cell is by the voltage tested on closed circuit, *i.e.*, through the lamp. Without this test little indication can be obtained of the condition of the battery, and, if it is suspected that the charge is low, it is important not only to know this to avoid inconvenience, but it is very damaging to the battery itself to be discharged beyond its proper capacity. Nothing ruins a battery so quickly as persistently running it right out. Overcharging also must be avoided, as long gassing tends to disintegrate the active material or paste which falls to the bottom of the cells and needs to be removed.

Faults sometimes arise through the leakage of the electrolyte from the boxes, which are generally made of celluloid. This material has a very distinct advantage in that the plates can be inspected and the level of the electrolyte readily ascertained; accumulators enclosed in boxes of opaque material should never be used. One objection to celluloid, however, is that it is a rather light material to use with the very heavy lead plates, and if a battery happens to slip when being handled the celluloid is liable to be damaged; if it falls only for a short distance and alights on a corner, a small hole is likely to be made, through which the electrolyte will leak away. Owing to the kind of high-water mark which is left at the top of the acid, it is not easy to see at a first glance when a cell has been completely emptied of electrolyte, and the author calls to mind a case of this kind where one of the two cells ran dry and the leakage entirely escaped notice for a long time; the cause of the failure of the ignition apparatus being, of course, a great puzzle.

Another possible fault is a small hole in the partition-piece between the two cells. Should there be such a hole the two cells act like one, and the positive and negative plates connected together will discharge themselves at a rate depending upon the size of the hole. Should a cell run down rapidly and no cause be apparent, one of the cells should be emptied completely, and if, after a time, the electrolyte passes from the full to the empty cell the fault will have been discovered, and must, of course, be remedied before any satisfactory result can be obtained.

Occasionally cracks develop in the celluloid. If it is necessary to mend a crack or a hole, a solution can be made of celluloid in amyl acetate, and after the crack has been cleaned a strip of celluloid can be glued on with this solution. Celluloid is very largely used for making photographic films, and old films may be used in making the solution and strips, after the gelatine has been removed. Celluloid is highly inflammable and will burn with a very fierce flame; care must be taken, therefore, never to allow a flame to play on the surface of anything constructed of this material.

When charging cells in series with lamps of high voltage every care must be taken that no short circuit occurs or spark form between the wires in contact with the celluloid, otherwise a hole will be very quickly burnt in the box.

Battery faults often occur at the terminals; the electrolyte, being strongly acid, readily attacks the brass terminals, and, if they are not kept clean and protected in some way from the acid, the contact surfaces are liable to become so corroded that a good connection with the wires is difficult. Should corrosion have set in the terminals' heads must be taken off and the metal-work thoroughly cleaned before they are attached again; all the metal-work, except the surfaces actually in contact with the wire, should be protected with special enamel paint, sometimes termed acid-proof paint, or with a little vaseline. Vaseline and paint, however, are insulators, and must not be allowed to come between the surfaces in contact.

After a battery has been in use some time, it will probably be found that a deposit forms at the bottom of the box, and if this deposit is allowed to collect to such an extent that it covers the bottom of the plate, internal short circuit or leakage between the plates may take place and the capacity of a battery be very materially reduced. It sometimes happens, too, that, notwithstanding the use of separators between the plates, some of the active material falls between the plates and establishes a contact from the positive to the negative. When trouble arises from either of these causes, it may be necessary to take the plates out of the boxes, clean away the deposit, and remove any short circuiting pieces causing the trouble, but this should only be done if vigorous shaking and emptying out the electrolyte fails to effect a cure.

Still another fault may arise through the growth of the positive plate. As lead becomes converted into peroxide of lead it grows materially in bulk, and if a sufficient space has not been allowed inside the boxes the growth may cause them to bulge out and burst; the author has seen several cases of this kind. In purchasing new cells it is desirable to see that fair space has been allowed between the edge of the positive plate and the cells for this growth. When this fault is met with, there is no remedy but to hand the battery over to the makers for repair.

Occasionally, through want of proper treatment, such as allowing the cells to run right out or leaving them discharged for a long period, the plates "sulphate"; this is evidenced by their becoming coated with a white deposit. When a cell is badly sulphated the capacity is much reduced, and the only cure is a considerable overcharge or a succession of overcharges, that is to say the battery must remain on the charging circuit for a long time after gassing has begun; and it would be well if the charging current employed were less than the normal, so that the cell may receive a long steady charge at a low rate.

If it becomes necessary to make up for evaporation of the electrolyte, pure soft water should be added, preferably distilled water; any addition of acid is not to be thought of, as the quantity in the cell does not diminish.

(8) **Magneto.**—Although there appears to be so strong a tendency to adopt the magneto machine in place of the battery ignition, the former is not without its disadvantages; the fact, however, that it does away at once with the trouble of getting the battery charged at fairly frequent intervals appeals to all those who have had difficulty through the cells running down unexpectedly, and also through the

trouble that often arises from not being able to get cell recharged just when required.

It is desirable, if not necessary, to be provided with a se of dry cells or an accumulator in conjunction with the mag neto. Sometimes it is not easy to start the engine with magneto alone, and there is, of course, a possibility that th magneto itself may fail; this latter, however, is an unlikel contingency; and, as some of the more recent magnetos hav been designed to produce a bright spark at a low rate o speed the need of an auxiliary battery is not so marked a with the earlier types, when a useful spark could not b obtained at a low rate of speed. It is not sufficient to b provided with a battery only, but there must also be a suit able induction-coil. If the magneto is so arranged as t work in conjunction with an auxiliary battery, all arrange ments will be properly made; but if, after a car has bee purchased, it is found that no battery auxiliary is provide for, and the owner desires to have it added, it would be jus as well to allow the maker of the car to provide the necessar apparatus, as it would be quite impossible for one unskille in electrical work to ensure the working together of th various parts. As an illustration of the difficulty it may b mentioned that, while a coil may have been made to suit th magneto, it is quite possible that the windings would b wholly unsuitable for the pressure given by a 4-volt battery

One disadvantage of the magneto is its expense; the firs expense, perhaps, is not a great matter, as it forms only small proportion of the total cost of the car; the proportion however, is fairly considerable in the case of a motor bicycle The running cost, however, is not to be disregarded; in th first case, the power absorbed is considerable, and is bein continually taken from the power available for drivin the car; with battery ignition no power is taken fro the engine; again, the energy absorbed costs more than i supplied by means of batteries, the undoubted convenience, however, of the magneto is worth some additional cost. The power absorbed may be a serious item in small power cars when surmounting a hill.

Should any breakdown occur to the magneto machine itself it would be wisest to send it at once to the makers, as expert knowledge is required to trace out any internal fault.

CHAPTER IV—THE CHASSIS AND DRIVING-GEAR

CONTENTS:—Clutch—Change-Speed Gear—Driving Shaft and Chain—Differential Gear—Brakes—Wheels—Wheel Bearings—Carriage Springs—Steering Gear—Tyres

(1) **Clutch.**—Not a few of the difficulties experienced in running a motor-car arise from faults in the clutch. There is a certain amount of wear and tear between the leather facing and the hollow cone into which it beds; this can be easily understood when it is remembered that the clutch is allowed to slip when coupling the engine through, and at other times. This causes wear, and, after a while, there is a tendency for the clutch to become too fierce; that is to say, instead of quietly allowing a steady slip the surface is gripped suddenly, or seized before the two halves have attained the same speed; the objection to this will be at once clear. Just before starting the engine is running at a high rate of speed and the car is motionless. The clutch is allowed to engage slowly, and the surfaces come lightly in contact, a certain amount of power is transmitted to the clutch through the friction of the surfaces, which increases by degrees as the speed of the car increases.

If the slip continues steadily, according to the degree of pressure on the pedal, in course of time the car will be moving at such a rate that the cone of the clutch is running at the same speed as the flywheel of the engine. When this point has been reached the clutch pedal may be released and the spring allowed to press the cone home firmly. If, however, the clutch seizes before the speed of the cone has risen to the speed of the engine flywheel, a violent jerking of the car will result; this seizing of the surfaces is described on page 70, and is more generally met with when a new leather facing has been put on to the cone. The only way to meet the difficulty is to apply the clutch with exceptional care until the surfaces have settled down to the work. The tendency to seize may also be modified by a judicious use of lubricants between the surfaces, but let it not be forgotten that it is a *friction*-clutch. It also sometimes arises when the leather has worn down to such an extent that the rivets, by means of which the leather is secured to the metal face of the cone, have become exposed and rub on the flywheel surface. These rivets are generally of copper or soft metal, which has a great tendency to seïze with cast iron, even in spite of sufficient lubrication. When fierceness is due to this cause the rivets must be hammered down until they are well below the surface of the leather face.

Occasionally fierceness is caused by grit getting between the surfaces; the only remedy for this is to take the clutch to pieces and clean it; too strong a spring is also a possible cause of fierceness.

Should a clutch have seized so firmly that it is difficult to disengage the cone, it may be freed by putting in the high-speed gear, and rocking the car backwards and forwards by hand.

Any general tendency to fierceness in a clutch must be carefully watched and guarded against; otherwise, in cases of emergency, the fault may involve real danger.

Another fault commonly experienced in the clutch is the exact reverse of seizing, that is to say, a tendency to slip. To avoid fierceness it is necessary not to have too great a thickness of leather on the face of the cone, and as a very small movement forward will cause the surfaces to engage, it is obvious that a small amount of wear may possibly prevent the two surfaces coming into sufficiently close contact. In this case there will be continual slip between the engine and flywheel, thus preventing the full power being transmitted to the wheels. Besides reducing the power available for driving the car, power is wasted in the heating of the clutch when continual slip takes place; a slipping clutch must, therefore, be remedied by the adjustment of the parts, or by providing a new leather face to the cone.

Occasionally slip is caused, not so much by the surfaces having worn as by the use of too much lubricant on the leather. In this case a proper degree of grip may be secured by shaking Fuller's earth between the surfaces; a small quantity only should be used.

Some novices at motor-car driving, who have a knowledge of machinery and belts, may possibly think of applying rosin in place of Fuller's earth or French chalk; this would be a great mistake, as it is difficult stuff to get rid of, and will cause fierceness.

These remarks apply chiefly to the cone-clutch with leather face, which is that most largely employed. Many ingenious modifications of the simple clutch have been devised, but even in these the same faults are liable to arise, but possibly in a lesser degree.

In clutches employing metal to metal faces ample lubrication is of great importance, as metal to metal, in the absence of oil, tends to seize; in this case the friction generates a high temperature, and the metal actually fuses together, causing a seizure which it may be very difficult to remedy.

Slip is sometimes due to the spring being too weak, and failing to press the surfaces into sufficiently intimate contact, in this case the adjusting screw must be tightened up so as to compress the spring, or a new and stronger spring fitted.

Seeing the importance that this part plays in the management of the motor-car, it becomes essential that the driver should by careful experiment and adjustment arrange that the clutch grips sufficiently and not too readily, and allows of ready slip without any tendency to seize, and allows also the full power of the engine to be transmitted without slip to the car when surmounting an incline. To secure these results it is necessary that the leather surface be true, and sufficiently, but not too much, lubricated; that the rivets are well below the leather surface; and that the spring is neither too strong nor too weak. In a car which has been in use for any length of time satisfactory working of the clutch cannot be secured unless the engine shaft, and the shaft to which the cone is attached, are truly centre to centre and in line; trouble is sometimes caused through the wear of the bearings and the consequent want of alignment of the two shafts, in this case the bearings must be packed up.

2. **Change-Speed Gear.**—As with the clutch, the efficient manipulation of the change-speed gear needs practice. Two rules never to be forgotten are: (1) On no account must the change-speed gear be moved until the clutch has been disengaged; and (2) the reverse must never be brought into gear until the car has absolutely stopped. It would be ridiculous to expect to reverse the car until an actual stoppage has taken place, and a heavy strain will be brought upon the engine and car, if such a thing is attempted.

When passing from one speed to another it is necessary to disengage the clutch effectually and promptly, the handle must then be pressed over firmly and decisively; there must be no uncertainty or undue delay, but the two operations must be separate and distinct. Want of precision will mean unpleasant grinding of the gear wheels, and delay means serious loss of way, a matter of considerable importance if the car be surmounting an incline; the manipulation of the gear will make all the difference between mounting, or failing to mount, a steep incline. Every attempt to mesh the wheels with the clutch partially disengaged will cause a severe grinding of the opposed edges of the teeth, and may possibly result in broken teeth. To facilitate meshing, the teeth of the wheels are generally rounded off or bevelled so that they will more readily slip into gear, even though not exactly opposite.

It is well to bear in mind that the whole of the power is transmitted from the engine to the driving-wheel through this gear; it is, therefore, necessary that it should be kept thoroughly lubricated and clean. For this purpose an easily removed inspection door should be fitted in the case, so that the gear can be inspected at fairly frequent intervals. Dirt must be rigidly excluded from the case; a little road grit admitted will very soon play havoc with the wearing surfaces of the teeth. Some wear of the gear wheels must, of necessity, take place, and renewal will be required from time to time; it is difficult to state any rule in this connection, as so much depends upon the quality of the material and workmanship, the amount of use to which the car is put, and upon the care exercised in its management and manipulation.

The spindle bearings will need to be kept clean and free from grit, and should any undue wear take place it will be necessary to have them rebushed; otherwise there will be a leakage of oil from the gear box.

3. **Driving-Shaft and Chain.**—The universal joint at each end of the driving-shaft should be protected from access of road dust. The only satisfactory way of securing this is by enclosing them in a kind of bag of waterproof material tied at both ends, sufficient room must be left in the bag to admit of the full play of the joints; covering the joints in this way must not lead to the omission of the necessary

oiling; much oil, of course, is neither necessary nor desirable, as the amount of movement that actually takes place is small. The oiling, however, must not by any means be neglected, as a continual revolution of the parts will mean wear and tear and loss of power if neglected.

In a chain-driven car, where the chain runs in the open, as is almost invariably the case, dirt must be excluded so far as possible from the wearing surfaces. This is generally effected by immersing them in melted fat or tallow that sets at ordinary temperatures. If the treatment has been properly carried out in the first case, there is no need to give any special attention to the chains until some two or three thousand miles have been covered; after this it is best to remove them and wash them thoroughly in paraffin until all grit and grease is removed. When clean remove the chain and wipe off all the paraffin, then immerse in a bath of hot tallow, and when thoroughly soaked the tallow is allowed to set before the chain is removed; by this means all interstices will be filled with the solid fat. It is an advantage to mix a small quantity of plumbago with the tallow; but it is not easy to get it to enter the joints, as it tends to sink to the bottom of the pan. Although the use of tallow for lubricating chains is generally preferred, an excellent lubricant is formed by making a paste of paraffin and plumbago, and applying it to all the rubbing surfaces by means of a brush. If only the plumbago can be made to adhere sufficiently to the surface it makes an ideal lubricant, as dust does not stick to it.

The adjustment of a chain needs care; if too tight, power is lost through undue friction, and a breakage is not unlikely. On the other hand, if it is too loose, a breakage may also result; and should the chain cause a "knock" at any time through the jumping of a tooth this is a sure sign that it is dangerously loose. A broken chain when a car is running at a high speed, or going up hill, may cause a serious accident.

A rod or stretcher bar, with necessary adjusting nuts, is provided, so as to enable the tightness of the chain to be adjusted, and also to prevent varying tension, which would otherwise be caused by the rise and fall of the frame on the springs. After a car has run for some distance it will be found that the chain has become somewhat loose through stretching, or, in the case of a new car, through the wearing into place of the various parts; when this occurs the slack must be taken up by lengthening the bar. If stretching of the chain is considerable, it may be necessary to shorten it by taking out a complete link.

Wearing of the pivots and links is, of course, inevitable, and a fairly frequent inspection must be made to see that none of the pivot holes have worn unduly; if either pivot or pivot holes have worn to any appreciable extent new links or pivots should be substituted. If a complete spare chain is not carried with the car it is essential that at least one or two spare links and pivots are always ready to hand.

4. **Differential Gear.**—When used in conjunction with the chain-drive the only points to be observed in the management of the differential gear are that the lubrication is attended to, and that inspection of the parts is made from time to time, to see that all is well.

Used in conjunction with the Cardan shaft, however, more attention is needed. In the first place, the great objection to the use of the direct drive is that to enable the differential gear to operate, the main wheel axle has to be divided into two parts. This, mechanically speaking, is a great disadvantage, as, should any heavy strain come upon the rear wheels, the compound axle is not unlikely to be bent; should this happen, it is a very difficult matter to get it straightened until the car has been sent to the repairing shop, and even then, unless it is done with considerable care, it will fail to run true, thus causing excessive wear in the differential gear. If, however, the design of the axle and gear is good, the divided shaft will be constructed of such mechanical strength that bending is not likely to occur.

It is of the first importance that the differential gear should be well made and the teeth truly cut. If there is any undue friction the road wheels will not be entirely free to turn independently of each other as they should; any want of freedom in this respect will result in undue wear and tear of the tyres—an expensive consideration. This will be better understood if the action of the gear is clearly comprehended. The simplest way to see how the apparatus works is to "jack" up the hind wheels, so that they can be freely turned by hand, and see that the bearings are free and well oiled.

First, place the change-speed gear in the neutral notch, then rotate the Cardan shaft by hand in the customary direction; it will be found that both wheels will revolve in the same direction forward and at the same speed.

Now hold one of the wheels, and rotate the Cardan shaft as before; the free wheel will revolve forwards. Fixing the second wheel and revolving the Cardan shaft will cause the first wheel to revolve in the same manner.

Again, fix the Cardan shaft by placing the change-speed gear on the low speed; also let in the clutch, then rotate one of the driving wheels, and it will be found that the other revolves in the opposite direction; the same holds good whichever wheel is rotated.

It will thus be seen that while the two wheels are quite independent of each other, they are equally driven through the Cardan shaft and gear. Now apply these experiments in practice.

If a car is going straight forward, the two wheels are revolving at the same rate, and are receiving an equal amount of power from the engine. If the car is turning a corner the outer wheel will tend to move at a greater rate than the inner; this it is free to do owing to the differential gear. Ordinary carriage wheels are quite independent of each other. Assume for a moment that the differential gear itself is not in good order, and there is undue friction between the toothed wheels; the tendency will be to rotate the inner wheel at a faster rate than it really requires to be travelling, and to prevent the outer wheel from turning at the speed required; this will, of necessity, lead to a grinding action between the tyres and the road, and will also mean loss of power in the differential gear itself.

These facts demonstrate the necessity not only for taking care when the car is purchased that the differential gear is accurately made, but also that it receives attention from time to time in ordinary use, so that any undue wear may be quickly detected, especially if either or both of the rear wheels have been subject to heavy strain through a collision or otherwise.

Although much stress has been laid upon the possibility of the differential gear and axle being deranged, yet, with proper care in driving, there is not likely to be any trouble from this cause, and many leading engineers much prefer the direct to the chain drive, at any rate in moderate-powered cars.

Reference has so far only been made to the differential gear with bevelled wheels, but a form which is receiving a good deal of favour at the present time is the *Epicyclic* or *Crypto* gear, in which ordinary square-toothed wheels are used in place of the bevelled wheels. The reason for this growing preference is that it is easier to cut the teeth accurately, and so obtain a freer running gear; it is also less expensive than the highly finished bevelled gear.

5. **Brakes.**—The handling of a motor-car brake is a very different thing to the manipulation of an ordinary carriage or cart brake. We have already seen that the weight of a motor-car is considerable; its velocity is also, generally speaking, high. The momentum to be overcome is therefore very great, and as it is frequently necessary to pull up a car travelling at a high rate of speed within a comparatively short distance, the efficiency of the brake and the manner in which it is used become of extreme importance. In case of emergency it is allowable to apply the brake of an ordinary carriage with the fullest possible power; this, however, is not the case with a motor-car with rubber tyres, provided the brakes are proportioned to the size of the car, as, should the power be applied too suddenly, the momentum will be sufficient to overcome the friction between the tyres and the road, especially if the road surface is dusty or greasy, and cause the car to skid. This skidding will generate heat in the tyre itself to such a degree as to raise the part in contact with the ground to the softening temperature of the rubber, which then serves as a lubricant. The result, in effect, is that too severe an application of the brake actually defeats the object of the driver by allowing the car to travel farther than would have been the case had he applied the power with greater judgment and care; the wearing of flats on the tyres is also a matter of moment. If skidding starts, all power further to check the speed of the car is lost to the driver, thus creating a sense of helplessness which is very distressing in a case of serious emergency.

The position and adjustment of the brake pedal and lever should be such that the full power may be applied without undue exertion on the part of the driver. It is easy to remember that in the early days of the development of the motor-car the position of the pedal and also the method of applying the power left very much to be desired; in most good cars of the present day, however, this point has received careful consideration. The author calls to mind one car that he drove in which it was almost impossible to apply the brake effectively on a hill without rising from the seat and placing the whole weight of the body upon it.

The pedal brake is commonly used in the ordinary manœuvring of the car, and the more powerful hand-brakes as auxiliary or emergency brakes; the hand lever used with the latter enables great power to be obtained, and it is necessary to apply them gradually and cautiously if skidding is to be avoided.

It is desirable to remember that skidding takes place most readily on greasy roads, and especially on smooth town pavements when wet, but there is also a strong tendency on road surfaces where there is much grit and sand.

On town roads with a greasy surface too much care cannot be exercised in applying the brake; a sudden application has often resulted in a car being completely turned round, so that the driver finds himself looking down the road which he has just been traversing. The suddenness with which a skid of this kind takes place is remarkable and alarming, and in a street through which much traffic is running a serious accident might result.

It is perhaps needless to remark that no attempt must be made to lubricate the brake drum and bands, although, if the brakes are unduly fierce or squeak, a minute quantity of oil or grease may be applied.

The various parts of the brake require careful overlooking from time to time, as, owing to the friction and absence of lubrication, there must necessarily be wear and tear between the rubbing parts and need for adjustment and replacement of the worn parts.

6. **Wheels.**—The advent of high speed has resulted in considerable modification in the construction of the wheels, and the magnified bicycle wheel has been discarded in all but

small and cheap cars. The danger of collapse with the wire spoke wheels has become very much greater since the size and weight of cars has increased, and since the demand for high speed has arisen. With small cars the use of the wire wheels is mechanically sound, provided they are constructed with care; they are also light.

The form now almost universally used with medium and large cars is the artillery wheel, in which the rim is carried by spokes of oak. With these it is possible to turn sharp corners more abruptly than is the case with wire wheels. The strain, however, on the wheels, whatever their construction, is enormous when a car turns a sharp corner at a high velocity. Sometimes it is necessary to swerve very rapidly out of the direct line when one has to avoid running over anything. The sudden twist brings immense strain to bear upon the wheels and also upon the bearings and on the tyres. Owing to the very high speed at which corners are taken, cases of collapse would probably be of more frequent occurrence were the tyres solid; at the present time a certain amount of give in the pneumatic tyre serves to absorb some of the strain which would otherwise be transmitted to the wheel spokes. A very simple experiment will serve to illustrate one of the effects produced by abrupt turns.

If a bicycle wheel running on ball bearings is removed from a bicycle, held in two hands by means of the spindle and a turning movement given to the wheel, there will be no difficulty in holding it while it is running at any speed; if a quick movement is made with one of the hands while the wheel is revolving at a high rate the spinning motion will tend to twist the spindle out of the hand, and the running wheel becomes an exceedingly difficult object to hold. By means of this experiment some idea can be obtained of the heavy pressure which takes place on the bearings if a sudden turn is given while the wheels are revolving at a high velocity.

The low build and heavy weight of a car makes overturning almost impossible, but, notwithstanding, the sudden whisking of a car round a sharp corner without any attempt to reduce speed is a highly reprehensible practice. Not only are the tyres grievously injured by the inevitable skid, but great strains are set up in the wheels and bearings and considerable risk is run of some accident occurring; the road surface also is injured. When it is considered how little time is saved by turning a corner at a high speed, the absurdity of the practice must be manifest; it is out of all proportion to the personal risk, actual damage done, and the not remote possibility of damage to another vehicle or foot passenger round the bend.

Occasionally, through the bending of an axle, the wheels get out of track; in other words, they tend to run in different directions; the result is undue wear and tear of the tyres through the grinding action on the road surface. If an accident occurs it is well to see that the wheels run truly afterwards, as a very small degree out of truth will cause a very unsatisfactory reduction in the useful life of the tyres.

The distribution of the weight upon the tyres does not always receive the consideration that it should. The benefit of large-power engines may be largely lost owing to insufficient weight on the driving wheels. The engine is usually placed in the fore part of the car, and, omitting all consideration of passengers for the moment, the bulk of the weight is on the leading wheels; a full load of passengers adds weight on the drivers, but often not sufficient to give the wheels a good grip on the road. The chief advantages obtained by the use of high-powered engines are rapid starting and quick hill climbing, but without sufficient weight on the drivers the only effect of such engines will be to cause the wheels to slip and grind the tyres to pieces. As a matter of fact, with the exception of racing cars, a moderate-powered engine is much to be preferred, as it is very rarely in ordinary running that the full advantage of the high-powered engine can be obtained. One method of securing a high tractive power would be to drive all four road wheels from the engine, but this necessarily adds materially to the complication and expense.

At the recent exhibition at Olympia a car was shown in which this method has been adopted, but the transmission of power to the pivoted steering wheels is not an easy problem, and with a properly designed car with weight well distributed there should be no need of such a method of drive in cars intended for ordinary road use.

7. **Wheel Bearings.**—The bearings almost universally adopted for motor-cars are of the ball kind, although some attempts have been made to adopt roller bearings. The extreme simplicity and frictionless nature of the ball bearing sometimes lead to its neglect. Within limits a ball bearing will run while dry, but not for long; heat is soon generated, and a grinding action takes place; it will, however, not set up a screech like an ordinary bearing, it is important, therefore, to see that the lubrication is properly attended to; a superabundance of oil is wholly unnecessary.

Road grit must be rigidly excluded from ball bearings. This note is by no means superfluous, as badly-constructed bearings are not uncommon; when dirt obtains access to the ball-race, washing out with paraffin must be resorted to. The most serious mishap that can occur in a ball bearing is the splitting of one of the balls; the two halves will play havoc with the other balls, if not promptly removed. When balls get worn out of truth, as they do after a time, the set should be discarded. If one or several balls only appear to have worn, it is a mistake to substitute new ones to replace these while retaining the remainder, as the larger diameter of the new balls will cause them to carry the bulk of the dead weight, and risk of breakage is great; a complete new set should be introduced.

8. **Carriage Springs.**—The carriage springs used with motor-cars need to be very much more substantial than those used on ordinary vehicles. Too great resilience is most objectionable, and in a well-designed car special attention will have been given to proportioning the springs to the load to be carried. It is by no means uncommon to see a car oscillating, and the occupants being shaken up and down somewhat violently after some obstacle or depression in the road has been passed over. The object of the springs is to absorb the shocks given to the wheels while travelling over the unequal surface of the road; a perfect spring would do this without allowing the shock to be felt appreciably by the occupants of the car.

If the springs of a car are strong enough for their work, it is desirable to occasionally apply a little oil between the leaves so as to reduce wear and tear; but if they are at all weak, it is best to leave the springs dry, so that the increased friction may help to reduce oscillation, and to make the running easier.

9. **Steering Gear.**—The parts of the steering gear must not be neglected. The pivots need to be well lock-nutted and secured, and it is also necessary to see that these and other parts needing only occasional attention are inspected every few hundred miles, as wear and tear are always tending to reduce the size of parts, which, if neglected, may lead to a very serious accident and possibly loss of life.

10. **Tyres.**—Notwithstanding the high first cost of pneumatic tyres they are almost universally employed in motor-cars in preference to solid tyres, owing to the greater comfort and ease in running experienced. The high first cost, and cost of repair and upkeep, render it essential that they receive every care.

The chief causes of deterioration are: (1) Running with tyres insufficiently inflated. (2) Allowing moisture to have access to the interior of the cover. (3) Contact of the tyre with rusty wheel rims. (4) Contact with oil and grease. (5) Exposure to dry heat. (6) Rubbing friction as distinguished from rolling friction, arising from improper handling of the machinery.

(1) Dealing with these points in order, a common fault with a beginner is a fear of pumping up the tyres too hard. A deflated tyre results not only in excessive wear of the cover, but there is also a considerable risk of the inner tube being cut between the rim and the ground owing to the bumping of the car over obstructions. It would be best, if the driver is lacking in experience, to ascertain from the maker of his tyres the pressure recommended, and as small-pressure gauges are now provided for the purpose of testing tyre pressures, there should be no difficulty in maintaining the right degree. The greater the weight to be carried by a car, the greater should be the degree of inflation.

With a tight tyre it will be found necessary to give a few strokes of the pump once every fortnight. If it is necessary to pump more often, it is due to a small leak, either at the valve, or through a small puncture.

It is of course possible to pump the tyres too tight, and it is well to remember that the continual running over the road surface causes them to get hot and the air inside to expand in consequence. When a tyre is properly inflated and the car loaded, the depression should not be above two-fifths of an inch; never more than three-fifths.

(2) While water is of advantage to the outside of a tyre, it is most objectionable inside, and the wheels should never be washed down with the tyres deflated. It is necessary, from time to time, to tighten the wing nuts, and so keep the joint between the tyre and the rim perfectly secure. If

water gets inside it will cause the linings of the cover to rot.

(3) Rusty rims are caused either by allowing water to get inside the tyre, or by failing to remove the mud from the crevice between the tyre and the rim after returning from a run on damp roads. Rust will eat into the tyre cover and destroy it: if there is any reason to suspect that the rims are getting rusty, the covers should be removed and the rims cleaned and varnished.

(4) Oil and grease must be carefully prevented from coming in contact with either the outer or inner tube, as they destroy rubber. This especially applies to spare tubes that are carried, as they are generally stored in the tool-box in the neighbourhood of oil cans and oily cloths. Inner tubes should be kept in a bag containing a small quantity of French chalk.

(5) Dry heat will cause rubber to perish; this needs chiefly to be guarded against in the garage or coachhouse.

(6) Undue rubbing friction may be due to imperfect alignment of wheels, faulty differential gear, the sharp turning of corners, skidding through the too sudden application of brake, and want of careful driving. If the wheels are not running on parallel tracks a grinding action will take place, and will do as much damage in a few miles as would be caused by the natural wear of tyres due to rolling friction in 1000 miles. A faulty differential gear will also produce a rubbing action tending to tear the rubber surfaces to pieces. The ill effect of turning corners too sharply has already been referred to, and a careful driver will make a point of disengaging the clutch while taking a sharp turn. The wear of the tyres due to slip has been referred to fully under Brakes. If a car is not started carefully a jerking action will result, causing a good deal of wear on the tyre surfaces; if the clutch is let in gently the car will start smoothly.

It is important that the driver should have some knowledge of the repair of tyres, for trouble is more likely than not to occur on the road, where expert assistance is not available. As to the execution of repairs, the author prefers to recommend the excellent little pamphlets issued by the makers; these should be studied carefully and carried in the tool-box until the driver has acquired sufficient experience.

There should be no delay in stopping a car immediately a puncture is suspected. It is hardly necessary to make the same observation with regard to a burst tyre, but it may be well to state that a burst tyre, when travelling at a high speed, often leads to loss of control, and many lives have been lost through the sudden and unexpected bursting of the tyre; a burst is generally due to neglect or carelessness. A partially deflated tyre is more liable to puncture than a well-pumped tyre, and there is considerable danger of a burst if a car is made to take a corner at too great a speed with the tyre insufficiently inflated; the cover is torn away from the rim and the inner tube bursts through the aperture. After repair on the road a car should be driven slowly, and if any substantial repairs have been made to a tyre it is well, when possible, to give plenty of time for it to dry and harden.

It is desirable with a car in regular use to have the tyres taken off, examined, and treated with French chalk every 1000 miles; if sufficient dry lubrication is not used between the tube and cover the former will be spoiled; if French chalk is not available, finely-powdered blacklead will serve equally well. When a car is frequently used the tyres should be left inflated, but if likely to be left for any length of time it is well to let the pressure down a little when out of use. If a car is put aside for a lengthy period, the wheels should be jacked up and the tyres completely deflated.

When a car comes in from a run a point should always be made of passing the hand over the surfaces of the tyres, to ascertain if nails or thorns are adhering, or if any serious cuts have resulted during the run; also, when a tyre has to be repaired for puncture, the inside of the cover should be carefully felt all over before the repaired tube is replaced, as it sometimes happens that a nail, completely bedded in the thick substance of the cover and not noticeable on the outer surface, is protruding inwardly.

CHAPTER V—GENERAL MANAGEMENT

CONTENTS :—Dust and Dirt—Noises in the Machinery—Tools and Spare Parts—Breakdown Causes—Stoppage—Partial Breakdowns—Preparing to start—On the Road—Qualities needed by Drivers—Speed—Corners—Cross Roads—Overtaking—Conclusion

'HERE are certain points connected with the management of he car which have not so far been dealt with in describing he various parts of the mechanism. It is now proposed to evote a little space to the handling of the whole car.

1. **Dust and Dirt.**—Cleanliness is a most essential haracteristic in the general management of a car. A special ord of caution in this direction is necessary, owing to he absence of any pressing need to overhaul a car and lean it down immediately it comes in; it is so easily put way and forgotten, especially if the owner is its customary river and no special attendant is employed to look after and eep it in order; after a long day's run, especially when one s tired, there is a great temptation to leave the cleaning ntil the following morning. If this practice is followed nuch greater labour is entailed on the following day, and, if he whole car cannot be cleaned at once, such parts as will uffer by neglect should receive attention overnight.

As a means of preventing dirt from having too ready ccess to the machinery it has recently become customary to rovide a metal shield, or sometimes a leather apron, beneath he machinery, so that the dust raised from the road is preented in some degree from invading the mechanism. This s a very desirable arrangement, but the covering of the nachinery in this manner must not lead to neglect.

Two points need to be borne in mind with regard to the road dust, its penetrating nature and its destructive character. It is astonishing what minute cracks and crevices it will find its way iuto, and if such cracks give access to bearings and other rubbing surfaces the wear and tear is likely to be serious.

2. **Noises in the Machinery.**—Noises of various kinds are most useful in helping to indicate trouble or the approach of trouble. By means of "knocks" of various kinds an expert driver can tell when any part of the machinery is needing adjustment, or even worn-out parts are needing replacement. Reference has already been made to the knocks caused in the engine bearings by a loose chain; another distinctive sound is a rattle resulting from a bolt or nut having become loose.

In the petrol car there is a considerable amount of vibration, and therefore always a tendency for nuts and bolts to become loose if not properly secured. There are several devices in use for locking bolts; the most common is the use of a double nut, the second one being screwed up tight against the first after it has been screwed well home; this device is termed a *lock nut.* Where the necessity for keeping the nut screwed up tight is not great a *split pin* may be inserted in a hole drilled in the screw above the nut; this will, at any rate, prevent the latter from coming loose and being lost. Nuts used without *washers* are especially liable to unscrew; the most effective washer is a steel spring washer. A patent nut, termed a *self-locking nut,* is also a most useful locking device.

A third distinctive noise which the driver of a car should be alert to notice is a squeak, arising from a dry bearing or other part needing oiling; if such a squeak comes from a bearing it must receive immediate attention, otherwise it may get abnormally hot and seize. Sometimes bearings are lined with a white metal, which melts at a fairly low temperature, and it is quite possible for a dry bearing to become so hot that this metal will melt out. In any case, if a hot bearing is suspected, the car should be immediately stopped and careful search made; generally a liberal supply of oil will suffice to set matters right, but, should the bearing have seized, it may be necessary to take it out and clean the surfaces; this, of course, applies to split bearings. If the journal seizes in a solid brass bearing it may be very difficult to remove it. To avoid trouble of this kind see, first, that the car is oiled properly and regularly, and the trouble is not then likely to occur; should it happen, however, in spite of this, the moment a squeak is heard search out the cause.

Very often it is by no means an easy matter to locate a squeak; it seems to evade the seeker's attention, first appearing to come from one part and then from another. The best way is to feel round all the bearings and, if one is abnormally hot, it is a pretty sure indication that the trouble has been found. If, after careful search, no warm bearing can be found, the only remedy is to oil all moving parts. Some parts with little wear and tear and no special arrangements made for oiling are quite liable to become dry through neglect, so that, if a squeak is not readily located, it is well to give a general oil round in all the less important parts. From these remarks it will be seen that a driver needs to be on the alert to detect various noises which may indicate immediate need of attention in some part of the machinery.

3. **Tools and Spare Parts.**—Perfection is not to be expected, even in an expert chauffeur, and it is well that a full complement of spare parts, nuts, springs, and so on, be carried wherever the car goes. It is far better to carry a superabundant supply than to find oneself short in a case of emergency, far away, possibly, from any town or village. It

may be taken as a general rule that any small part liable to loss or wear should be carried in duplicate.

It is desirable to have a complete outfit of all tools likely to be needed on the road. Spanners to fit all nuts, one or two screwdrivers, a heavy hammer, preferably of copper, several files of different degrees of fineness, two pairs of pliers with good cutting edges, &c.

When purchasing a new car it is well to see that all special spanners are provided which are necessary for the adjustment of particular parts, in addition to the customary spanner and tool set. Sometimes it happens that the head of a bolt is not accessible to the ordinary spanner, and in this case a box spanner is needed; it may be that several differently-shaped box spanners are required, and before completing the purchase of a car it should be stipulated that a complete set of tools is to be provided, including all necessary box spanners and other special tools needed for the adjustment, removal and replacement of the various parts of the mechanism.

4. **Breakdown Causes.**—A *resumé* of the causes of breakdown may be useful. Some stress has already been laid upon the need for cleanliness and general care of the car. If parts are kept thoroughly clean, and well lubricated, all bolts and screws carefully tightened from time to time and wearing parts taken out and examined at intervals, breakdowns on the road should be infrequent. No motor-car as at present made is perfect, and very few drivers are skilled engineers; and until the average driver thoroughly understands his car and the engineering principles involved, breakdowns must of necessity occur from time to time.

Stoppage.—In the event of a stoppage, the reason for which is not at once apparent, it may fairly safely be assumed that something is wrong with the electrical igni-ion; instructions have already been given (page 112) for tracing out such faults and remedying the same. If the fault does not lie with the electrical apparatus, it is likely that the engine is at fault; the cylinder may have become hot and the piston thus robbed of its freedom by expansion and loss of lubrication at a high temperature, one of the bearings may have seized, or the exhaust valve spindle broken.

If the cause is still undiscovered, attention should be turned to the petrol supply (*see* page 91); the trouble may be leakage, want of proper adjustment, the shaking loose of parts, and possibly, in some cars in cold weather, the freezing of the petrol. If the car has been running over rough roads it is possible that the carburettor may have become flooded; the remedy is to close the stopcock partially. If it is found that the supply of petrol is not right, and the fault is not at once apparent, a stoppage of some of the fine orifices may be suspected. Again, condensed water in the carburettor is a possible cause of trouble.

Partial Breakdowns.—These are first likely to result in the ignition through the running down of the battery, want of adjustment of the trembler screws, or the shaking loose of one of the terminals. Dirty points on the spark-plugs are also to be suspected.

If the ignition is in good order the compression may possibly be unsatisfactory; loss of compression will be due either to the valves or leakage past the piston-rings.

Loss of power is often due to the slipping of the clutch. If the surfaces are so worn that they do not give an effective grip, the nuts must be tightened.

Next to this, the proper adjustment of the mixture and the satisfactory working of the carburettor must be looked to.

Breakdown due to the gearing and other parts of the car outside of the engine will generally be quickly localised.

5. **Preparing to Start.**—The most certain way of providing against any possible breakdown on the road is to

have the car properly overhauled before the run is commenced. A little experience will soon teach the driver what parts need to be examined, and perhaps adjusted before a long run is commenced. The battery will be tested, the wires and connections carefully looked over, and all terminals and screws tightened where necessary; the induction-coils and tremblers will be tested separately; the spark-plug contacts will be cleaned; the carburettor pipes, taps and moving parts inspected; the level of the liquids in the water and petrol tanks measured, and any deficiency made up; the oiling of the various gears attended to; the working of the various levers examined; all bolts, nuts and parts likely to have become loose inspected; and, finally, when all parts have been examined the engine should be given a run round for a sufficient time to indicate that the water-circulating gear is in thorough trim.

So far as the tyres are concerned these ought to have been examined when the car came into the garage, as it would be foolish to leave any overhauling that may be necessary until just before starting out on a run; the hands should invariably be passed over the surface of each of the tyres, if unprotected rubber is used, to find whether there be nails or other foreign material adhering. With protected tyres a careful examination of the surface which underlies the band should be made after the wheels have been washed down and are clean.

Detailed directions for starting a car cannot very well be given here as the various makers adopt different arrangements of the adjusting levers and pedals.

The following general instructions should, however, prove useful to a tyro. After all preliminary matters have been attended to, and the moment of starting has arrived,

(1) Set the gear handle lever in the neutral notch.
(2) Set the ignition lever at the retard position.
(3) Open the throttle-valve fully.

(4) Open the petrol supply cock.

(5) Agitate the carburettor float to flood the carburettor momentarily. This must not be overdone, or the engine may refuse to start.

(6) Switch on the battery.

(7) Put the starting-handle into gear and pull it upwards smartly, taking care to pull it out of gear when the pull is finished. The engine should now be moving.

(8) When the engine is running freely the throttle must be partially closed to prevent racing.

(9) Mount the seat and advance the ignition lever to its normal position.

(10) Press on the clutch-pedal and disengage the clutch.

(11) Put the change-speed gear lever into the first-speed forward notch.

(12) Let the clutch in gently and the car will start, when fairly under weigh the clutch should be disengaged and the second speed brought into gear, and after a brief interval, if all is clear, the third speed may be brought into use.

6. **On the Road.**—Very little useful purpose would be served by describing in detail how the car is to be controlled and regulated on the road, as this knowledge can only be satisfactorily accumulated by actual personal experience. If, however, the principles of the machinery have been carefully studied, and that which actually takes place when the various levers and handles are manipulated is understood, a driver will very soon learn how to use the various adjustments in an intelligent manner.

Qualities needed by Drivers.—The first essential in a successful driver is a cool head and ready judgment in case of emergency.

If a car is travelling at the customary rate along a high road utilised by slow-moving traffic and foot-passengers as well as by quick-moving motor-cars, rapid decision and prompt action will certainly be needed before many hundreds of miles have been traversed. Before anything like the legal speed is attempted a driver must possess that confidence which arises from knowledge and experience, and beginners should be careful not to run at high speeds until the adjustment and management are thoroughly learnt.

When it is remembered that the motor-car is nothing less than a locomotive running with the utmost freedom on the public road without even the restriction of special rails, as employed with the trains and trams, and that railway locomotive drivers have to pass through many years of training before they are permitted to take charge of a passenger locomotive, the need for careful training and practice ought to be obvious.

Notwithstanding the loud and frequent protests on the part of writers in the motor-car journals and magazines, the outcry against careless and inconsiderate driving is too amply justified, and all true friends of motoring will do their utmost to safeguard against rash driving by inexperienced persons. Not a little of the animus that has been raised against motoring as a whole has been due to the great want of thought for the ordinary users of the road. The author is of opinion that much of the apparently reckless driving is due not so much to want of consideration on the part of the drivers as to the absence of a proper appreciation of the dangers and risks incurred by the ordinary users of the road.

While travelling rapidly and smoothly along a high road and possessed of a full knowledge of the splendid controllability of the car, it is difficult for a driver thoroughly to appreciate the feeling of bicycle-riders and drivers of horse-drawn vehicles when the car whizzes past them at double the speed that they have been accustomed to until recently; and, as a matter of fact, the danger does not lie in his manipulation so much as in the nervousness and unexpected behaviour of the other parties. The most trying time for a bicycle-rider or a driver is when the car is overtaking the bicyclist, for then the amount of room the driver of the car is proposing to leave is an unknown quantity, and often it is far too little.

It is a curious physiological fact, and one ever to be remembered by a motor-car driver, that to novices and those who have not acquired confidence in cycle riding the approach of a large rapidly moving vehicle actually induces a feeling of attraction and a desire to fall off the machine in front of the approaching monster; of course, such nervous people should not ride on roads where motor-cars are likely to be met with, but then, unfortunately, motor-cars do not confine their attention to specified roads, and are quite as likely to be met in country lanes as on the high roads, and the fact cannot be ignored that the bicycle-rider has an equal right with the motor-car driver to the use of the road.

While the author has had many most uncomfortable experiences with motor-cars when cycling, he can only call to mind one occasion where a little courteous consideration was shown to a small party of cyclists with whom he was riding in the neighbourhood of Poynings, Sussex. The road was dusty and not too wide, and a distinctly grateful sensation was created among the cyclists by the obvious slowing down of an approaching motor-car simply for the purpose of passing. If drivers would realise the feeling of gratitude which arises in the case of such considerate conduct there would be far less complaint and perceptibly decreased animosity against motoring. The author would feel amply repaid for the labour involved in the preparation of this book if every reader would make up his mind to err on the side of over-consideration for other users of the road, rather than show that disregard or even contempt of their rights and feelings which is all too common.

It is not sufficient to possess a clear comprehension of the construction and principles of a motor-car and a long and varied experience of the running of the machinery, but the driver should also possess an intimate knowledge of the rights and rules of the road, and a good knowledge of the provisions of the Motor-Car Act.

Speed.—The sensation of travelling in an open car at a high rate of speed is most exhilarating, and, where it can be safely indulged in, there is little to be said against the practice. It must, however, not be forgotten that the occasions in which high speed may be freely indulged in are few and far between on the much-used roads in this country. Any attempt to run at a high speed through a village or past houses standing close to the road, no matter how deserted it may appear, is altogether inexcusable. The possibility of a child suddenly rushing out of a cottage or garden is always too real a terror, and when the saving in time is considered the absurdity of the practice becomes at once apparent.

Suppose for a moment that it is proposed to run up to the full legal speed limit through a village half a mile in length. At twenty miles an hour the distance is covered in one and a half minutes ; if the speed were reduced, say, to ten miles an hour, the time required would be three minutes, the time saved by travelling at the excessive speed is a paltry one and a half minutes. Is it worth while taking and creating the very great risk for such a small gain ? At 30 miles an hour the total gain is two minutes, at 40 two and a quarter minutes, at 50 two and two-fifths, at 60 two and a half, thus for every ten miles increase the time gained is proportionately less, while the risk rises by leaps and bounds. Even at night there can be no certainty of any road being deserted. To give a specific illustration, the author has been impressed with the great risks run by the driving of motor-cars at a very high speed through the village of Roehampton Surrey, simply that the high velocity acquired in running down one hill may be utilised in ascending the hill on the far side; here the practice is commonly indulged in by night, and sooner or later will inevitably result in disaster.

Corners.—Very especial risk is run in turning sharp corners, especially in the country, where the roads twist and turn in a characteristic manner, and in very many cases are deep down between high hedges and steep banks. It is perfectly impossible to foresee what will be met with on getting round the corner; the country roads are not only used for wheel traffic but also as footpaths, no other provision being made for foot passengers. If a young and restive horse, or even a woman wheeling her child and market produce home in a perambulator, is suddenly faced by the apparition of a car travelling at high speed, it is no wonder if they are suddenly seized with a panic which renders of no avail any amount of judgment and coolness or skill in handling on the part of the driver in preventing a catastrophe.

Whether in shady country lanes or in perfectly open roads, the driver of a car needs to realise that turning a corner at a high speed inevitably means the side-skidding of the whole car, bringing heavy wear and tear on the tyre surfaces. Very few persons interested in motoring can have failed to notice the broad skid marks—sometimes twelve inches wide—left by a car after turning a corner at a high speed; the damage done to the tyres by such practice is incalculable, and the saving in time is absolutely negligible.

Both caution as well as care for a car therefore demand a slowing down at all corners.

Cross-Roads.—Cross-roads are another potential source of danger to a car travelling at high speed. It constantly happens that by-roads crossing the main roads are bordered by high hedges, walls, or buildings up to the very point of junction, so that any object travelling on the main road is quite invisible. Many serious accidents have occurred through failure of drivers to slow down their cars when approaching such crossings. When one considers the care taken to safeguard level crossings on railways, the absolute necessity for care at cross-roads must be apparent.

Overtaking.—While it is true that a motor-car is the best-controlled vehicle in the world, owing to the perfection of its brakes when in order, too much reliance must not be placed on this fact, as the mere stopping of a car quickly in a case of emergency will not ensure immunity from accident. A special caution is ofttimes necessary when overtaking a vehicle, especially a bicycle; nothing is easier than to mistake the noise made by a motor-car approaching from behind for that made by one that has just passed. The author remembers the considerable risk he once ran of being cut to pieces on a railway through an exactly similar cause. While walking on the down line an up train had passed, and the thought occurred to him how easily the sound of an approaching train might be merged in that of a train just passed. Acting on this thought he turned his head, and, to his horror, beheld an express down train within an uncomfortably short distance behind, leaving only just time for him to step rapidly on to the up-line; had he not turned at this moment the chance of any escape was remote. The same effect has been noticed in connection with motor-cars and trams on the public roads, and shows the need for especial caution when overhauling other vehicles.

7. **Conclusion.**—Lest the remarks contained in this chapter should give rise to the impression that the author is in any way antagonistic to the motor-car, it would be well to state most emphatically that, on the contrary, he is an enthusiastic believer in the future of the automobile. He, however, clearly recognises that nothing but harm can come to the

industry by careless, inconsiderate and ignorant driving Already so strong a feeling has been roused in country districts against the motor-car that legislation is threatening which may prove to be a most serious hindrance to the advance of automobilism. All true friends of the movement must realise that if the motor-car is to have the free and unrestricted use of the ordinary roads it must be proved by drivers that the vehicle is not only handy and convenient, but that it is in no way a nuisance to other users of the roads.

That the motor-car itself has been brought to a high state of perfection, considered from the point of view of its quiet steady running and general controllability, is apparent. All that is now necessary is that the drivers of these beautiful pieces of mechanism should be worthy of the task they undertake, and show all courtesy and consideration to the general users of the roads and the utmost solicitude for the safety and lives of little children and old people who will always be found in the neighbourhood of, and walking upon, country roads. Once again the author desires to emphasise the fact that very few country roads are provided with foot-paths, and pedestrians have equal rights to the use of the roads with drivers of vehicles.

If the industry is not hampered by legislation or by the stirring up of popular feeling, its development will undoubtedly surpass the most sanguine anticipations.

Those who have been observing the steady increase in the number of cars registered in London will not fail to have been astonished at the pace at which cars have been put upon the streets, especially recently. The motor omnibus, too, has evidently more than fulfilled the expectations of the companies who have introduced them, and an immense addition is promised in the near future.

As an illustration of the splendidly prosperous state of the industry, it may be mentioned that at the November 1905

Exhibition at Olympia one English firm advertised that it had on hand orders to the value of no less than £130,000, and after the close of the Exhibition it was announced that orders to the value of over £2,000,000 had been booked by the exhibitors.

The English-made motor-car has largely displaced the foreign-made article, and it is incumbent upon the Legislature that it introduces no unnecessary restrictions which shall hamper this new and exceedingly important industry.

CHAPTER VI—FURTHER NOTES ON GENERAL MANAGEMENT.

CONTENTS :—Racing the Engine—Clutch—Skidding—Manipulation of Brakes—Construction of Cars—Accessibility—Night Driving

IN an elementary book which has for its object the instruction of the popular mind there is always the risk of being too concise and of omitting necessary details. While the two parts of the book dealing with the mechanism and management of the motor-car are fairly comprehensive, that is, for the learner, it appears to the author that several points especially relating to the handling of the mechanism might have received a little fuller notice, and for this reason the following notes have been added in the form of an extra chapter which seems to follow naturally the second part dealing with the management of the Motor-Car.

1. **Racing the Engine.**—The author has noticed a common tendency amongst drivers of cars, especially chauffeurs, to race the engine when running light, especially at times of testing in the Garage. It should be understood that this racing at excessive speeds is extremely harmful to the constitution of the engine and those responsible for the care of motor-cars should see that this form of carelessness is not indulged in. There can be no possible reason for causing the engines to race round until they fairly hum when the ignition arrangements are being tested. The author has not infrequently seen engines raced in this way to such an extent that he momentarily expected to see pieces of the machinery flying about. It should be understood that, at the normal speed, a petrol engine runs quietly. Drivers should learn to judge by

sound when an engine is running at its normal speed, which speed should not be exceeded.

2. **Clutch.**—The author did not emphasise as strongly as he should have done the need for manipulating the clutch with great care. In the first place, when it is necessary to disengage in ordinary running conditions, the power of the engine should be kept in check and the governor allowed to operate. If care is not taken in this respect and the clutch is disengaged abruptly when the engine is running at high power and the governor cut out the racing above referred to is sure to occur, to the detriment of the engine.

On again applying the clutch an increase in the power of the engine should be left until the clutch is in and the driving shaft running at the same speed as the engine shaft.

One thing to be specially guarded against is letting the clutch in too promptly. If through careless handling the engine is running at high speed and the clutch is allowed to suddenly engage while the car is standing still, something has got to go; possibly the clutch will slip, but should it be in the least degree fierce the sprocket wheel studs, with chain driven cars, run considerable risk of being damaged and perhaps torn off; or the gears may be stripped; in any case heavy strains are set up.

These remarks apply especially to single and double cylinder cars where the turning moment is uneven. With the latter the two explosions follow in rapid succession and the wrench is serious if the power is applied too suddenly.

3. **Skidding.**—As dealt with on page 136 this important subject has not received the consideration it needs and the following additional notes should be useful.

When a car is travelling over a greasy road and a side skid of the back wheels occurs it should be remembered that under no circumstances should brakes be applied, or if they are in use they should be promptly released. The reason for this is simple; we have already seen in considering the subject of braking that if the brakes are put on too hard the wheels get locked and the car skids on the tyres; it was explained that when this happens the grip on the road is less than if the wheels had been free. The application of this to sideslip will be clear; if, for any reason the wheels have begun to slip the application of brakes will lessen the chance of their obtaining grip again quickly.

Side-skidding or side-slip has generally its origin in either the wheels turning too fast for the progress of the car or the application of brakes injudiciously. Once the normal rolling action of the wheel on the road is lost the friction between the road and the tyre is reduced and the vehicle is likely to slew or slip sideways. It is obvious, then, that if a car is proceeding over a greasy road and the driver becomes aware of the fact that the wheels are slipping he must immediately reduce the power or declutch entirely; he must also be especially cautious as to how he applies the brakes; they must be put on, if it is necessary to use them, with the utmost care, and if any indication of side-slip is given they must be immediately released.

As a rule a side-slip occurs with great suddenness and the course of action to adopt is to release either brakes or clutch and make a quick turn with the steering wheel in the direction in which the car is proceeding.

In addition to skidding of the back wheels it is quite possible for the front wheels to skid, especially when turning a corner of a greasy road. In this case the application of brakes which operate on the rear wheels is essential, otherwise, seeing that the steering wheels have lost their grip on the road, a collision with the kerbstone or a lamp-post is inevitable. To avoid skidding with the front wheels corners should be turned quietly and with as wide a sweep as possible. Any attempt to turn a corner abruptly on a greasy road will probably result in loss of steering power.

It might be well to point out that at *no time* is it advisable to attempt to take corners abruptly. A great deal of the harum-scarum driving which is so prevalent shows plainly that it is not realised how much the life of the front tyres depends upon taking corners easily. If a car is moving at a high speed and the steering wheels are turned abruptly the front wheels are pushed over the surface of the ground and a considerable grinding and tearing action takes place. I have met owners of cars who have expressed astonishment at the rapidity with which the front tyres wear out and very frequently the blame is put on the tyre maker, whereas the fault is entirely due to carelessness in handling the car.

4. **Manipulation of Brakes.**—This is a subject that does not receive the consideration that it should. When persons are learning to drive cars the proper handling of the brakes should form a special part of the instruction. More frequently than not a beginner learns to use the pedal brake only and is quite unfamiliar with the use of the side lever brake until he has been driving for a considerable time. It is desirable that a learner should not leave the acquirement of knowledge as to how to apply the side brakes skilfully until the pedal brake is out of order or adjustment; otherwise, in case of emergency the brake handle will be pushed over too hard and skidding will be started. Both pedal brake and side lever brake must be handled lightly and intelligently if they are to work efficiently.

In addition to the use of the ordinary brakes the learner should make a point of knowing how to run on the compression. It will, perhaps, be advisable to explain exactly what this term means. So long as an engine is developing power it is, of course, driving a car when the clutch is in; if, however, the gas supply is completely cut off, or the spark stopped, the engine will cease to develop power, but at the proper period of the cycle the gas inside the cylinder will be compressed as usual. Thus, if a car is running down hill with the gas or spark cut off and the clutch in, the momentum of the car will be driving the engine against the compression and this will in effect act as a brake. On the top speed, of course, the braking effect will be least, as for one revolution of the road wheels the engine makes the smallest number of revolutions. With the second speed the braking effect is proportionately greater and each reduction in the gearing will give a still more powerful effect.

If a car is proceeding along the level and comes to the brow of a steep hill the gear will probably be in the top speed; if there is a clear run and it is thought safe to proceed down the hill at a good pace the gear may be left in the top speed. If, however, the hill is a steep one or in any way dangerous it would be wise to slow down before the brow is reached and change into the second speed, or, possibly, even into the third. Generally speaking, however, the braking effect of the second speed will be found amply sufficient to hold the car in check.

If a driver has learnt the art of running on the compression he can run up hill or down dale in the open country without using brakes at all, provided the engine compression is good. In the case of a short hill the throttle only need be closed, but when a long hill is encountered the spark may be switched off also, and the energy of the battery saved. Many serious accidents have occurred solely on account of the lack of knowledge as to how brakes should be adjusted and used. It is well to bear in mind that it is foolishness to start careering down hill without a thought of the enormous momentum required to be overcome if a quick stop or prompt reduction of speed becomes necessary.

The terrible Handcross Hill disaster, which will be fresh in the minds of every one, was undoubtedly due to an error of judgment on the part of the driver on starting down hill. There is little doubt but that had he started running down the hill quietly on the compression, he would have been able to keep the speed of the 'bus in check by the application of other brakes when he found that the compression was inadequate. If a car is started down hill at a great speed there is most serious risk of the driver not being able to get the speed under control. A driver must ever feel that he has his car well in hand and that he has braking power to spare for all emergencies, never forgetting the possibility of skidding if the brakes are applied too suddenly.

It must not be forgotten that in most cars the pedal brake and clutch are connected so that the clutch is out before the brake acts, and thus in putting on the pedal brake the braking effect of the compression is taken off. If it is found necessary to bring the pedal brake into operation when running on the compression the movement of the pedal must be done smartly; otherwise, as soon as the clutch is detached the car will bound forward.

If a car is driven skilfully brakes will be used but little. It may take time to acquire the necessary experience to be able to control speed, especially in traffic driving, so as to avoid any frequent use of the brakes, but the author has observed that many drivers make no effort to drive in traffic without constantly applying brakes. When the road is clear there is a sudden dash forward up to the next traffic block when brakes are applied heavily and the car brought down to the speed of the vehicles in front. As soon as the way is open again all power is turned on to get forward with a rapid acceleration, the dash ahead is continued until another block in the traffic requires heavy application of the brakes again. This method of driving is the acme of bad driving. A good driver, knowing that he will certainly encounter a block some distance ahead, even though he has got a clear run for the time being, will, after passing through a block, accelerate the speed of the car at a reasonable rate and will also check the speed some distance before the next block is reached without using the brakes and he will arrive at his destination very little, if any, later than he would have done had he adopted the "dash-ahead, jam-on-brakes" method; the advantage to the machinery generally by the more careful driving is untold.

While referring to careful driving, a brief note on the attitude of the driver when in charge of the car will perhaps not be out of place. A dependable driver will always have the appearance of intelligently watching over the progress of the car and of the valuable mechanism under his charge. One frequently sees a certain class of driver lolling back in his seat with hands resting negligently on the steering wheel, his feet conspicuously placed on the pedals, knees high in the air, and his whole attitude that of a man reclining with the utmost abandon in an easy chair. Presumably this attitude is assumed to indicate to the general public his masterful control of the machine under his care, but to anybody in the slightest degree acquainted with motor cars this attitude suggests a dangerous form of ignorance which, sooner or later, will be attended with disastrous results; and if any owner of a car finds his chauffeur adopting this attitude he would be wise to find another at the shortest possible notice.

5. **Construction of Cars.**—Although great improvement has taken place in recent years in the general arrangement and construction of motor-car machinery there is still great room for improvement in many details and it is not at all uncommon to find that parts where strength and solidity are essential, are cut down to ridiculously fine scantlings. In one case coming under the author's notice both sprocket wheels on a chain-driven French car came away, through the shearing of the studs, within a few weeks of each other; the

bolts were absurdly too small for the strains they were expected to carry. In chain-driven cars it is as well to examine the chains, especially the linking bolts and the sprocket-wheel studs and bolts, at fairly frequent intervals. This fault of lightness in construction is not so obvious in the best English-made cars as in those made in France and America.

6. **Accessibility.**—One serious fault in the construction of cars is the small attention given to making the many parts accessible for repairs and adjustment. There certainly has been considerable improvement in the last few years, but there yet remains very much to be done in this direction. The various appliances are huddled together in such a manner that it is a physical impossibility to get at screws and bolts without unshipping a considerable part of the machinery. This is a most serious fault, as if a part which needs adjustment is very difficult of access it is not to be wondered at if a chauffeur, or even the owner, omits to give it the proper attention.

Remarks on this heading can only of course be general, but the author would earnestly urge upon the manufacturers of cars to see to it that all parts needing attention—and there are very few that do not at one time or another—are so arranged that they can be detached, examined, and adjusted with the least possible trouble. Buyers of cars, not deeply versed in engineering matters and motor cars in particular, would be wise, if before purchasing, they obtained the advice of some friend or expert thoroughly qualified to advise them as to selection. It will not only save them much trouble in the future, but probably heavy expenses, and possibly a serious accident.

7. **Night Driving.**—It is as well to caution a learner that driving at night has its own special difficulties. The head lights throw their rays directly in front of a car and owing to the absence of shadow it is difficult to distinguish

the distance and sometimes the shape of objects in front. The light too is thrown uniformly on all objects within the range of the lamp and on a dark night these objects shine out brightly as a disc surrounded by inky blackness. The effect of continually looking at this bright disc is to render it very difficult sometimes to judge one's position on the road, and not a few accidents have been caused by drivers running obliquely on to one bank at the side of the road so that the car has been overturned; this probably is the explanation of Mr. St. John Harmsworth's accident.

The difficulty of distinguishing one's exact position is rendered all the greater when travelling at quick speeds and the very brilliant headlights which are affected by some owners, rather increase than diminish the risk. It very often happens that along country roads, especially at turnings, lofty trees stand close along the road side and it is quite possible to run point blank into the trunk of such a tree on a dark night if not travelling with caution.

These remarks will suffice to emphasise the need for very careful driving at night, especially along unfamiliar roads. Thirty to forty miles an hour is a safe pace along many roads in daytime, which it would be foolishness to attempt to traverse at over 12 to 15 miles an hour at night time.

In the absence of any regulation requiring all vehicles to carry tail lights there is considerable danger of running into the rear of a slow moving cart when overtaken. Country carts in particular have a way of suddenly looming up out of the darkness on a moonless night and as no sound gives warning—the hearing being dulled by the rush of air past the ears and the noises of the car—constant watchfulness is necessary. A general law enforcing the carrying of efficient front and tail lights by all vehicles throughout the country is imperative.

Another word of caution is necessary on the subject of the automobile road signs. It frequently happens that these are placed in such positions that they are not visible on dark nights and unless a powerful light is used giving a wide circle of illumination they are quite likely to be missed. It is becoming increasingly necessary for these signs to be placed by a street lamp or provided with some special illumination.

APPENDIX

As a supplement to the simple diagrams illustrating the principles of the different parts of the petrol motor-car, the author has thought that a few clear illustrations of the parts of actual cars would probably be useful to the learner. The following illustrations have been specially selected on account of the clearness with which the action of the different pieces of apparatus is indicated; they are also largely typical, and a careful study of these diagrams, in conjunction with the brief description, should be a valuable help in obtaining a closer knowledge of the principles underlying the working of the apparatus.

In Fig. 23 is given a 4-cylinder engine for a 15 h.p. Clement Talbot car. The diagram and notes are self-explanatory.

Longuemarre Carburettor (Fig. 24).—The special feature of this modification of the Longuemarre carburettor is the automatic arrangement for supplying air and mixing it with the petrol vapour. In Fig. 24, A is the float chamber, B the automatic mixing chamber, C a cylindrical throttle, D the gas pipe carrying a rich mixture of petrol vapour from the spray chamber, and E is the pipe conveying the mixed gases to the engine. Fig. 24A is a section of the automatic chamber B with the throttle. *n* is the exit to the engine. The cylinder *r* slides inside the tube when *y* is drawn outwards, and closes the opening through *n*. The petrol vapour passes in through *m* and is mixed with the extra air passing through *x*, which is provided with holes in the manner shown, so as to ensure a thorough mixture of air and vapour. A kind of cylindrical float *a* rises and falls in the chamber *b*. The piston *g* is part of *a*, and when the suction of

AA, cylinder barrels
BB, water jacket casings
CC, compression chambers
DD, water jacket spaces
D_1, water delivery from cylinders to radiator
EE, pistons
E_1, gudgeon pins
E_2, little end bearings
F, connecting rods!
F_1 F_1, big end bearings
F_2, clip retaining bottom half big end bearing
G, brass covers to water jackets
H H, crank pins
I I, crankshaft
I_1 I_1, crankshaft bearings
I_2, ball thrust bearings
I_3, produced end of crankshaft taking clutch
J J, crank chamber walls
J_1 J_1, lower end of crank chamber forming oil well only
, central diaphragm of crank chamber carrying central crankshaft bearing
K K, half time gear casing
K_1 K_1, half-time gearing
L, distributer spindle bevel **driving gear**
L_1, **distributer and contact** maker case
N, vacuum tube and oil **filler** to crank chamber
O, exhaust valve
O_1, exhaust valve **tappet** guide
O_2, exhaust valve tappet
P, exhaust valve camshaft
P_1, exhaust cam
R, water delivery to cylinder jackets

Section of 4-Cylinder Engine on 15 h.p. Talbot Car.

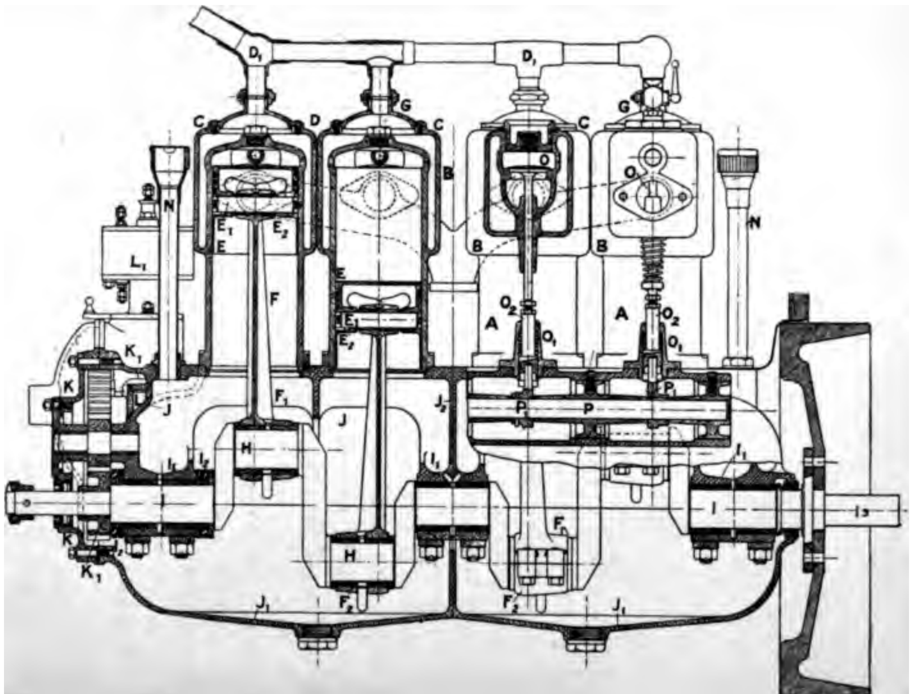


Fig. 23.

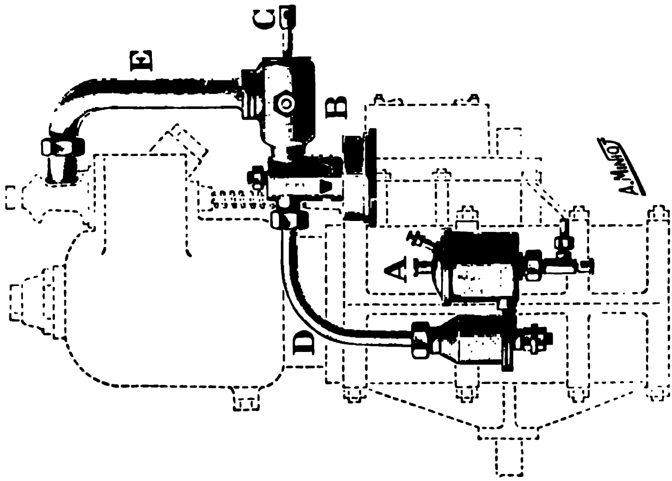


FIG. 24

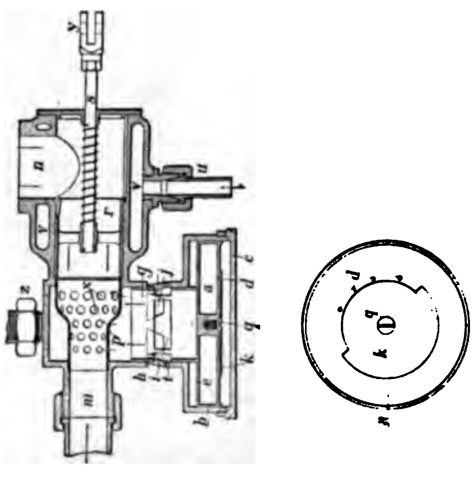


FIG. 24A

the engine occurs *a* will be drawn upwards, thus causing the openings in *g* to come opposite to the openings in *i* and *j*. It will be seen that *a*, rising and falling in *b*, acts as a kind of dashpot, and the readiness with which it rises and falls is governed by the holes *d* and *e* in the upper and lower sides of *a*. The number of holes open can be altered by rotating the plate *k*; thus the movement is controlled as desired. The action of this arrangement should now be clear. The faster the engine is moving the higher *a* will be sucked, and the wider do the openings *i* and *j* become. *v* is a hot air jacket surrounding the throttle, which prevents freezing.

SECTION OF CARBURETTOR ON 12–16 H.P. DECAUVILLE CAR.

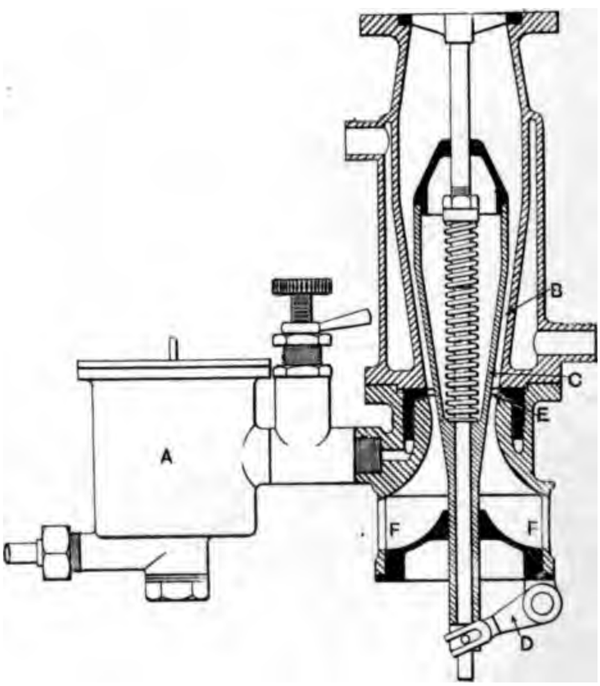


FIG. 2

Carburettor on 12–16 h.p. Decauville Car (Fig. 25).—This carburettor is a modification of the Longuemarre spray type. A is the float chamber, and the petrol passes to a number of fine holes E in the wall of the hollow cone B. Into this hollow cone fits a second cone C, which can be moved vertically by an outside lever D, sliding on the spindle and compressing the spring. By raising the inner cone it will be seen that the space between the inner and outer cones can be increased, thus regulating the quantity of air entering at F. The upper end of the carburettor is attached to the induction tube. On the suction stroke it will be readily understood that air is drawn in through F and petrol through E, which latter spreads over the cone C thus securing rapid evaporation and thorough mixture with the air.

Jet Carburettor used on the 12–16 h.p. Vauxhall Car.

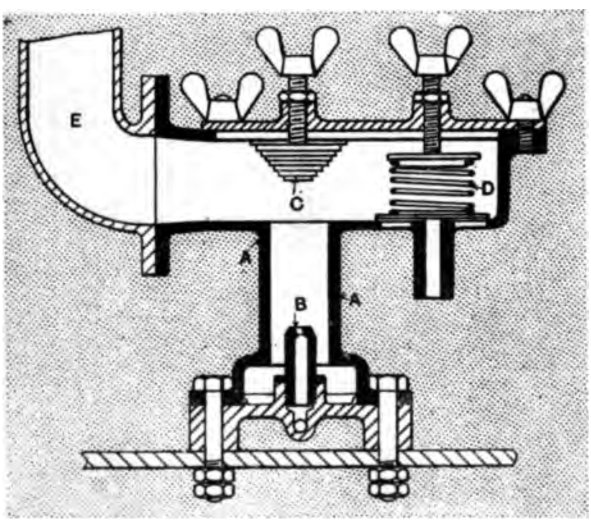


Fig. 26.

A type of carburettor, not dealt with in the body of the book,

SECTION OF CARBURETTOR USED ON SUNBEAM CAR.

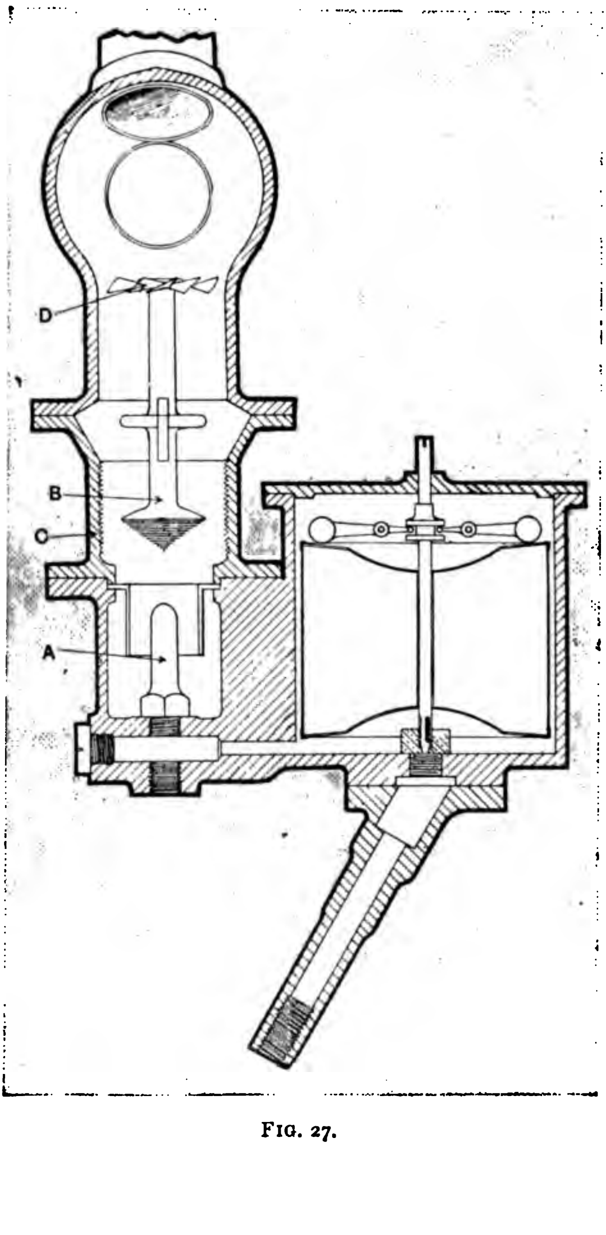


FIG. 27.

hich is receiving some favour is the Jet Carburettor, in which single jet of petrol is sprayed from a nozzle instead of a amber of fine jets used in the spray type. The principle is of urse the same, but it is thought by some to be simpler and more rtain in its action than the spray type.

In the illustration given the jet nozzle is shown at B. When e engine is sucking in the gas mixture through the induction

SECTION OF CLUTCH OF 12–16 H.P. DECAUVILLE CAR.

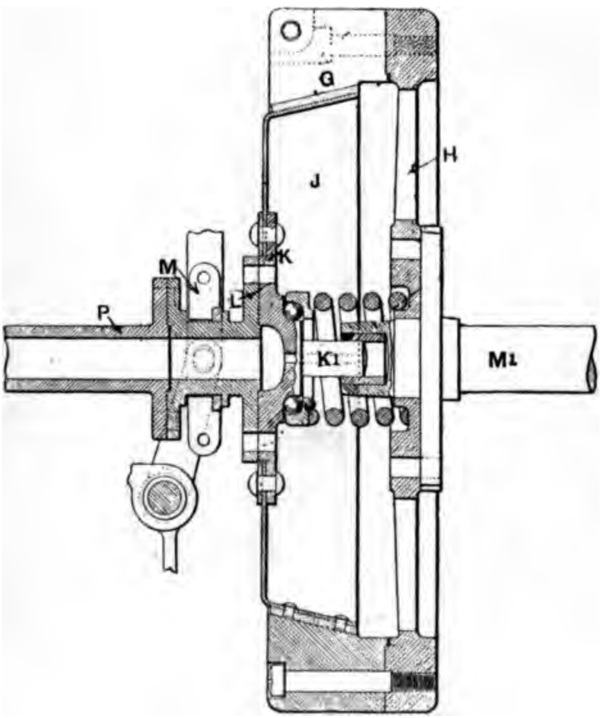


FIG. 28.

pe E, a little fountain of petrol rises through B and strikes the omising mushroom C immediately above. This has a large

SECTION OF CLUTCH ON THE SUNBEAM CAR.

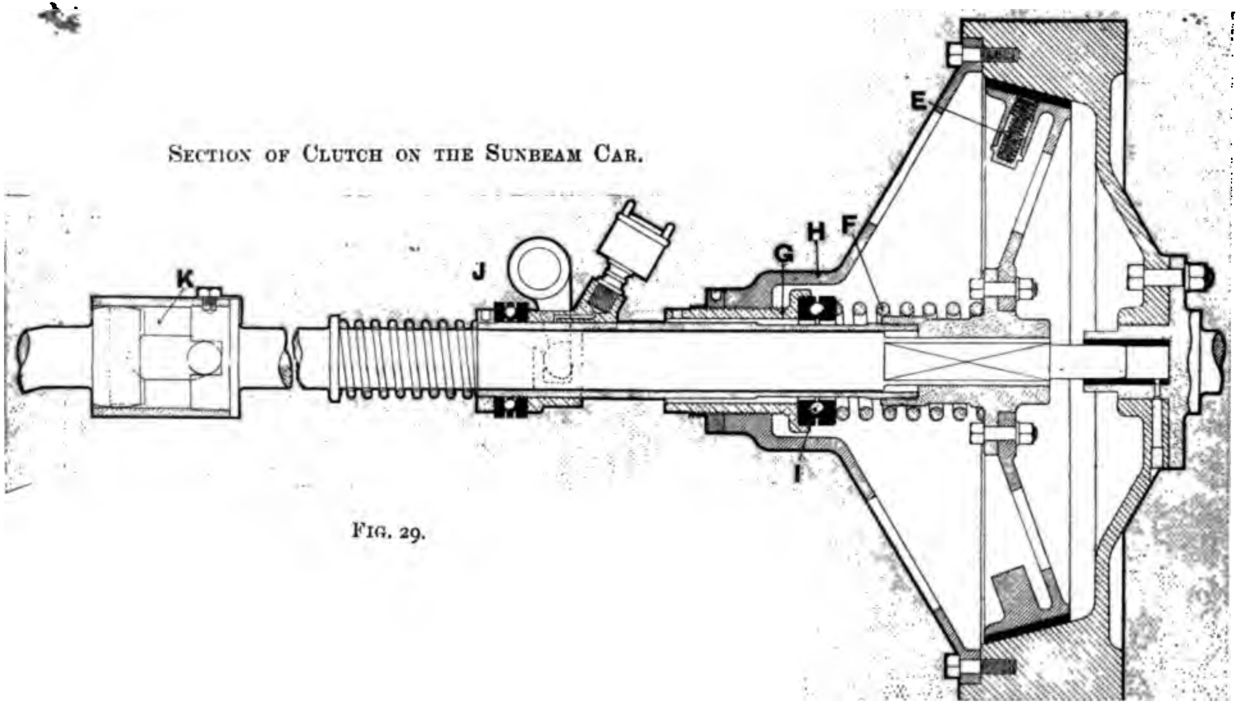


FIG. 29.

surface, and the air rushing in through D passes over it, and the petrol is rapidly vaporised.

CARBURETTOR USED ON THE 12–16 H.P. VAUXHALL CAR (Fig. 27). —This is of the jet type. The tank chamber is clearly indicated on the right. A is the jet nozzle, B is the atomiser, and D is a small fan which is caused to revolve by the movement of the gases in the tube, its object being to more thoroughly mix the petrol vapour with the air. It will be noticed that the walls of the chamber immediately above the jet are corrugated, so as to increase the surface and more rapidly vaporise the petrol that splashes on to the sides.

CLUTCH OF 12–16 H.P. DECAUVILLE CAR (Fig. 28).—Shaft M1 is part of the engine crankshaft, and to it is rigidly attached the flywheel G provided with an internal cone seating. The cone J is faced with leather and riveted. It is rigidly attached to the sleeve P sliding on the spindle. The powerful spiral spring in the normal position forces the clutch cone into the flywheel seating. When the clutch pedal is depressed the fork M compresses the spring and disengages the clutch. K1 is an extension of P and slides in the recess in the end of M1, thus keeping the clutch cone true centrally with the seating.

CLUTCH ON THE SUNBEAM CAR (Fig. 29).—In this a leather faced cone fits into the recessed flywheel. This cone is provided with bosses on the inside containing springs shown at E, which press the leather outwards. By this means the clutch is rendered sweeter in its action. The pressure caused by the spring F can be varied by screwing inwards or outwards the block G, which is supported by the frame H carried by the flywheel. The clutch is operated by the arm J, which causes the clutch sleeve to slide over the centre spindle or driving shaft. The universal joint K is provided on the spindle so as to take up any slight difference there might be between the centre of the shaft passing to the gear box and the clutch.

CHANGE-SPEED GEAR ON VAUXHALL CAR (Fig. 30).—Three speeds forward are provided and a reverse, the top speed forward being direct drive. This represents the form of gear most in favour at the present day.

The shaft V is connected to the clutch, and drives the sle
running through the ball bearings to which the gear wheel I

CHANGE-SPEED GEAR ON 12–16 H.P. VAUXHALL CAR.

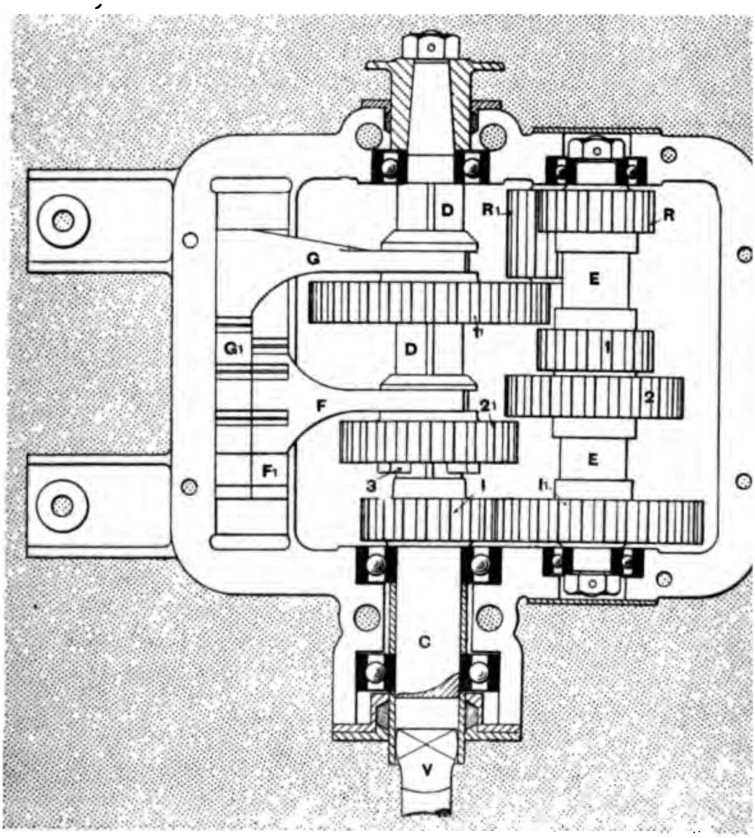


FIG. 30.

connected. C is an extension of the square shaft D, and ru
inside the sleeve. When the clutch is engaged the sleeve revol
outside C, and with it gear wheel I. This gear wheel is alw
engaged with gear wheel I_1, driving the secondary gear shaft E,

which the gear wheel R also 1 and 2 are rigidly connected; R_1 is always in mesh with R. Gear wheels 1_1 and 2_1 are free to slide on the square shaft D, and are moved in either direction by forks G and F respectively; in the diagram they are shown in the neutral position. In this position, when the clutch is engaged, I and I_1, together with R and R_1, also 1 and 2, will be revolving, but the shaft D will be stationary. If now fork G is moved upwards so that 1_1 engages with R_1 the driving wheels will be reversed. If on the other hand it were moved downwards so as to mesh with gear wheel 1, the lowest speed forward would be obtained. If fork F is moved upwards so that the gear wheel 2_1 engages with 2, the intermediate speed would be obtained. If fork F is moved downwards the dogs of the clutch 3 will engage with similar dogs on the boss of I, and the square shaft D will be rigidly coupled to the sleeve driven by V; thus a direct connection is obtained between V and the driving shaft, and the top speed is obtained.

Change-Speed Gear on Standard Car (Fig. 31).—This is similar in general arrangement to the Vauxhall gear previously described. With this gear four speeds forward are given and one reverse. The direct drive, however, is on the third speed. A is the primary shaft connected with the clutch at 3; this is enlarged to a toothed wheel A_1 always engaging with the toothed wheel A_4 on the secondary shaft B. All the gear wheels revolving on B are rigidly interconnected. A_2 is the square shaft upon which the primary gear wheels slide. It is connected through the universal joint to shaft C, which is the propeller shaft. A_3 is a brake drum rigidly connected to A_2, upon which the foot brake operates. The primary gear wheels are moved by means of the forks and rods shown at the foot of the drawing. The reverse is obtained by shifting the primary gear wheel I & R until it meshes with R, the intermediate gear wheel fitted below the secondary shaft B. When I & R engages with 1 the first speed forward is obtained; when 2 and 2 engage, the second speed forward is obtained; when the dogs 3 and 3 of the clutch engage, the third speed forward is obtained; this being the direct drive, A and A_2 being connected direct. When 4 and 4

PLAN VIEW OF CHANGE-SPEED GEAR ON STANDARD CAR.

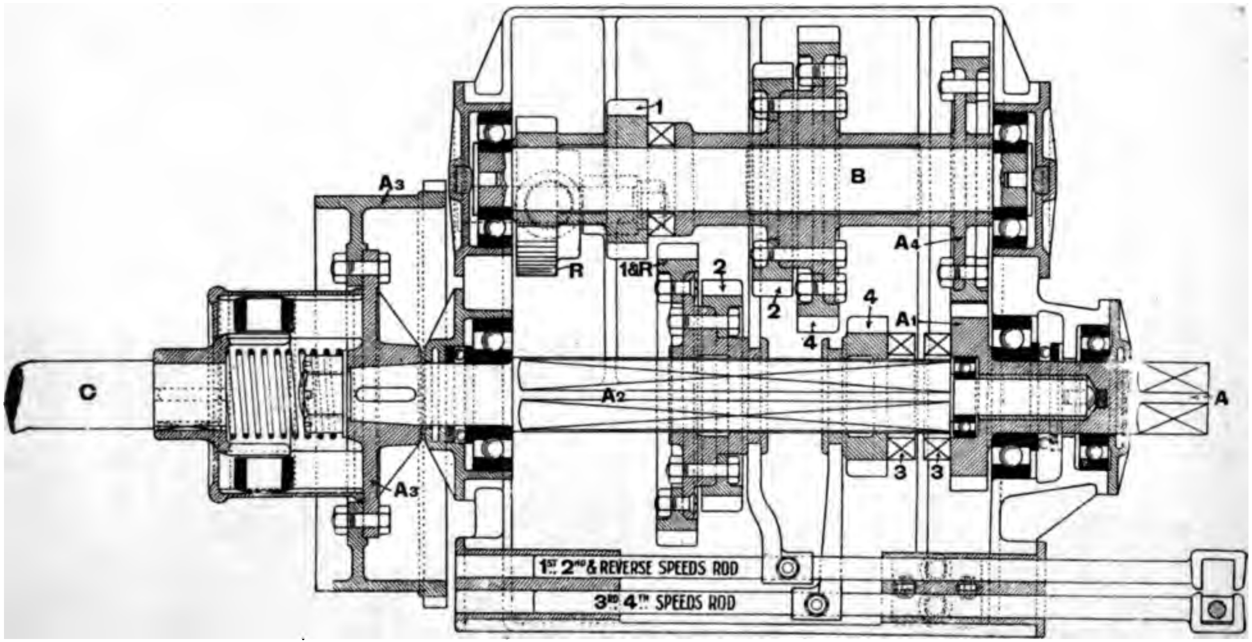


FIG. 31.

SECTION OF DIFFERENTIAL GEAR AND REAR AXLE ON STANDARD CAR.

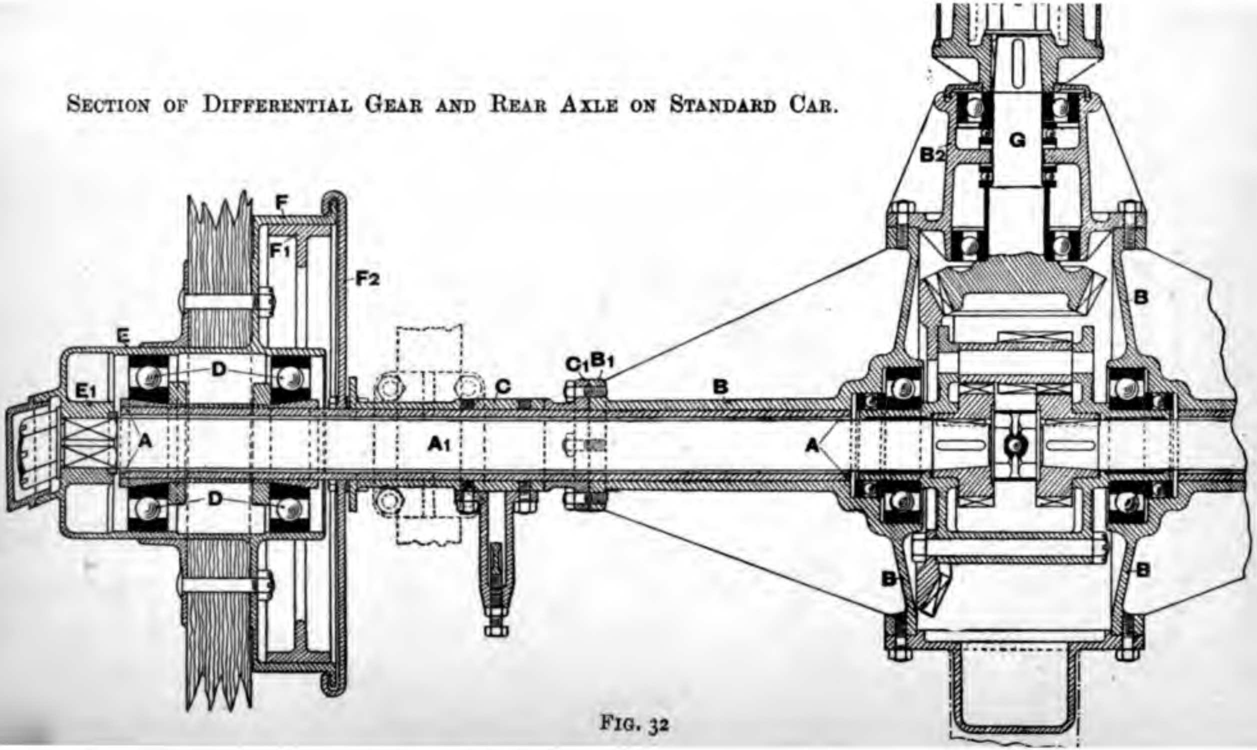


FIG. 32

engage, the fourth speed is obtained. In considering this diagram it is all-important to remember that the reduced end of A_2 revolves inside A at all times, except when the clutch 3 and 3 is in gear.

STEERING GEAR ON 12–16 H.P. DECAUVILLE CAR.

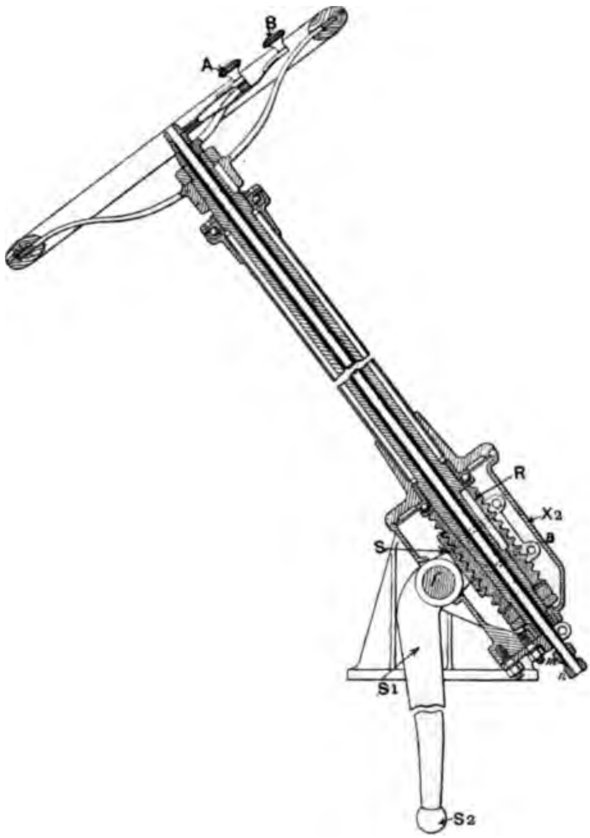


FIG. 33

REAR AXLE ON STANDARD CAR (Fig. 32). — In this gear, instead of bevelled pinions and wheels being used, ordinary square-toothed wheels are provided. This type of gear is preferable to the bevelled pinions, as it is less likely to get out of adjustment, and does not require in the first instance such careful workmanship. It is necessary to point out that the rear shaft A_1 is divided in the middle, with ordinary square-toothed wheels rigidly secured to the ends. The spindles of the pinions are fixed rigidly into the large bevel wheel which revolves freely on the shaft A_1 and is set in motion by the bevelled driving pinion rigidly attached to the driving shaft G. The outer ends of shaft A_1 are rigidly attached to E_1, which forms part of E, the metal hub of the road-wheel. The whole of the outer casing of the differential gear B, B_2 and C is secured to the frame of the motor-car and is therefore stationary; A_1 together with the gears revolves inside this casing. The end of shaft A_1 is shown square at E_1 and carries the hub of the wheel which revolves round the casing A on the ball bearings D. F is the brake drum and F_1 the brake shoes.

Steering Gear on Decauville Car (Fig. 33).—The hand wheel is attached to the steering column, the lower part of which carries a sharply-pitched screw R operating a gun-metal nut S, provided with trunnions or pivots engaging with the short fork ends on the steering lever S_1, which is pivoted at *f*. It will thus be seen that if the hand wheel is turned in one direction the screw will cause the arm S_1 to move forwards, and if the hand wheel is turned in the other direction it will move backwards. The levers and rods connecting the steering gear with the front wheels are connected to S_2. The handles A and B attached to the steering wheel are provided for adjusting the ignition and air admission to the carburettor. The handle A moves a central rod passing right through the steering column to the nut *n*. Handle B is connected to a tube or sleeve fitting over the central rod which is connected to nut *m*. A system of rods connects each of these nuts to the carburettor and commutator.

Steering Gear on Standard Car (Fig. 34).—This may be considered as supplementary to the diagram of Decauville steering gear, and is given as it renders the detail a little

[redacted]

more clearly. A is the rod passing through the steering pillar attached to the hand wheel. B is a thrust block, which

DETAIL OF STEERING GEAR ON STANDARD CAR.

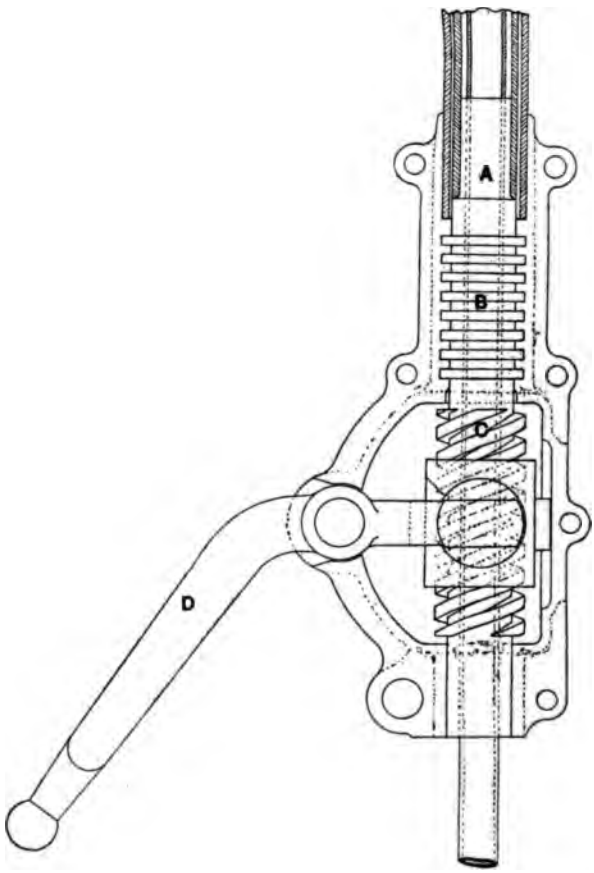


FIG. 34.

prevents any up or down movement of the steering pillar. C is a quick thread screw—in this case it contains several independent threads—which operates the block attached to the steering arm D. Whichever way the steering pillar is turned the block will travel along the screw and cause D to move. D, in turn, is connected by a series of rods to the steering wheels.

Brake on Vauxhall Car (Fig. 35).—This brake is of the external type, as distinguished from the internal type more

Foot Brake on the Vauxhall Car.

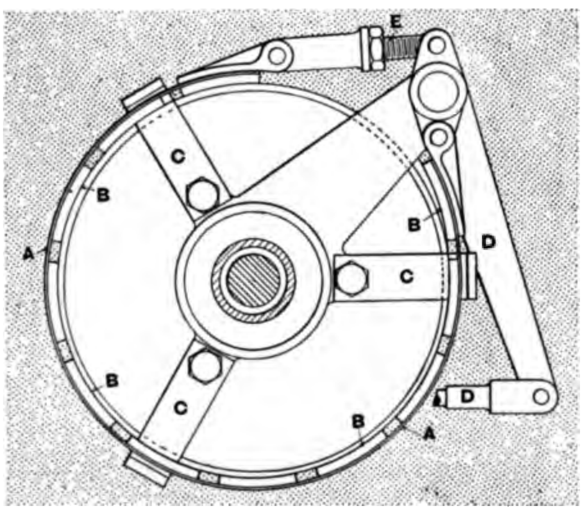


Fig. 35.

commonly used on the driving wheels, an illustration of which is given in the description of the brake on the Decauville car. The foot brake on the Vauxhall car consists of a revolving steel drum, surrounded by a steel band, carrying on the inner face gun-metal brake plates. When the brake is inoperative the steel band is slack, and the brake blocks lightly rubbing on the drum. When it becomes necessary to apply the brake, the brake pedal is depressed, drawing inwards the arm D, thus tightening the brake band and forcing the blocks into contact with the brake drum. It will be seen that both ends of the brake band are drawn together, so that the brake works equally well whichever way the car is proceeding. The same type of brake is used in many cars, but more generally the brake blocks are of fibre, leather, or some similar material.

The common fault with brakes of this type is the shaking and rattling of the steel band when loose, and in the special brake illustrated on p. 185 this is prevented by the steady arms C. The adjustment of the brake is effected by turning the nut E.

BRAKE ON THE DECAUVILLE CAR.

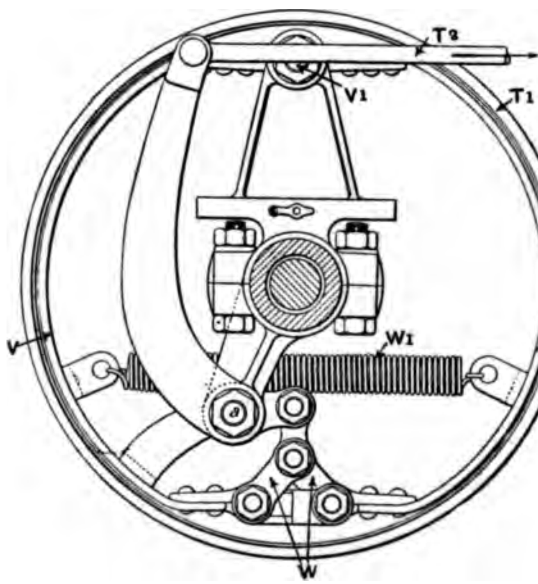


FIG. 36.

BRAKE ON DECAUVILLE CAR (Fig. 36).—This brake is one of the two side brakes attached to the rear wheels. T_1 is the drum fixed to the hub of the wheel. V and V are two internal brake shoes, hinged at V_1, and connected to the toggle joint W. When the rod T_2 is pulled in the direction of the arrow the toggle joint is compressed and the brake shoes forced outwards into contact with the drum. When the pull on T_2 is released the brake shoes are pulled clear of the drum by means of the spring W1.

GLOSSARY

Accelerate.—To increase speed continually; the acceleration of a body falling under the influence of gravity follows a fixed law; the acceleration of a motor-car follows no fixed rule.

Accumulator.—The use of the term for electrical purposes signifies a cell which, when attached to a suitable source of electricity, accumulates or stores electricity. (*See* page 47.)

Acetylene.—A gas produced from carbide of calcium and water, largely used for lighting motor-car head lamps, is very poisonous if breathed; mixed with air it forms a violent explosive.

Act.—A motor-car driver in Great Britain must make a point of thoroughly understanding both the Motor Car Act, 1903 (cost 1½*d.*), and the Rules and Orders issued by the Local Government Board. These are as follows: (1) Statutory Rules and Orders 1903, No. 998, dated November 19, 1903; (2) Addendum to (1), No. 998*, dated November 20, 1903; (3) Statutory Rules and Orders 1904, No. 315, dated March 9, 1904; (4) Addendum to (3), No. 315*, dated March 10, 1904; (5) Statutory Rules and Orders, 1904, No. 1809, dated December 27, 1904; (6) Addendum to (5), No. 1809A, dated December 28, 1904; (7) Addendum to (5), No. 1809B, dated December 1904. The price of each of the above is 1*d.*, so the whole set is obtainable for 8½*d.*

Admission pipe and valve.—The pipe conveying the explosive mixture from the carburettor to the admission valve. Sometimes erroneously called induction pipe and induction valve.

Air.—A mixture of the gases oxygen and nitrogen in the proportion of 21 to 79 measured by volume. Also contains minute quantities of other gases. To avoid lengthy explanation, reference to the nitrogen has been omitted from pages 63 to 67. It is what is termed an "inert" gas, that is it will not support combustion, and its presence in air damps the force of the explosion in an internal combustion engine.

Air resistance.—When a vehicle is travelling rapidly through the air the resistance of the air absorbs power; the higher the speed the greater the power required to overcome the air resistance. A car travelling with a hood or cover requires considerably more power than one without, travelling at the same speed. A stiff head wind necessitates an increase in the driving power owing to the greater resistance of the air.

Alternating current.—A current of electricity changing or reversing direction rapidly instead of flowing steadily in one direction as the direct or continuous current is supposed to. The alternations in a public supply may be from 25 to 100 complete reversals or periods per second. This type of current is of no use for charging ignition cells, but a rotary transformer or motor generator may be used for this purpose, taking alternating current to drive the motor and giving out continuous current from the generator.

Aluminium.—A metal largely present in clays aud earths, produced from Bauxite by electric smelting. It is one of the lightest metals and is largely used in motor-car construction to reduce weight. It is also a good conductor of electricity.

Ammeter.—A gauge or index for measuring the volume of currents of electricity in amperes.

Ampere.—The *unit* of volume or quantity of electricity. (*See* under "Pressure.")

Ampere hour.—An electrical unit signifying a current of electricity having a volume of one ampere flowing continuously for one hour. Used to measure the capacity of accumulators. (*See* page 119.)

Anneal.—To soften metals generally or glass by heating and cooling slowly. Brass is annealed by heating and plunging it into cold water; a brass tube is hardened by bending and needs to be annealed.

Armature.—Either (*a*) a piece of soft iron placed on or before the poles of a magnet, or (*b*) that part of an electric generator which rotates in the magnetic field (*see* page 52), and generates the electricity.

Asbestos.—A fibrous mineral, fireproof and a bad conductor of heat; manufactured into cardboard and cord and used for making joints in pipes and parts of machinery where great heat is developed. Also largely used for lagging (covering) steam and hot-water pipes where it is wished to prevent condensation and loss of heat.

Backfire.—An explosion in an internal combustion engine which tends to drive it in the opposite direction to that in which it is moving. (*See* page 89.)

Backlash.—A freedom of movement backwards in machinery without reversing its direction. Backlash in spur or chain gear is a sign that the parts are worn; if bad, the parts will need to be adjusted or renewed.

Battery.—Two or more electric cells (*q.v.*).

Big end.—The lower end of an engine connecting-rod enlarged to carry the big end bearing or brasses which surround the crank pin. (*See* page 4.)

Black lead.—A very pure form of carbon obtained from mines in the form of graphite; is an admirable lubricant, but difficult to apply to rubbing surfaces. Also termed plumbago.

Blow.—An electrical fuse or cut-out is said to blow when it burns out and breaks the circuit.

Boss.—A cylindrical mass of metal forming part of a machine; the solid centre of a pulley, or wheel, through which the shaft passes is a boss.

Brake.—A device for absorbing the momentum of a vehicle and stopping it. It acts by friction; considerable heat is generated between the rubbing parts. A special form of brake is used for absorbing and testing the power of an engine and is commonly called a friction-brake.

Brass.—An alloy of zinc, tin and copper in various proportions. Owing to the use of such alloy in bearings of machinery the soft metal linings of bearings are commonly termed "brasses."

Broach.—To enlarge a round hole in a piece of metal with a special steel tool termed a broach.

Brush.—A metal spring piece resting on a rotating commutator either to collect electricity generated (as in the dynamo), or to establish contact at definite intervals (as in the contact-maker on a petrol engine). *See* pages 43 and 52.

Bush.—A piece of soft metal let into a mass of hard metal and drilled to form a spindle bearing. If a bush becomes worn a new one must be put in ; this is termed rebushing.

Cam.—A device by which movement is imparted to pieces of machinery at regular intervals ; it usually consists of a metal disc with a projection on the outer edge which strikes a tappet ; for illustration *see* page 4, where a cam is used to open the exhaust valve. A cam is mounted on a cam shaft ; the projecting part is called the cam head.

Capacity.—As applied to an engine cylinder the term signifies the whole volume of that part lying between the top of the piston in its highest position and the piston top in its lowest position. As applied to electric accumulators, capacity is the measure of the quantity of electricity a given cell can contain ; it is measured in ampere-hours. Thus, an ignition cell labelled as having a capacity of, say, 20 ampere-hours, should give a current of two amperes for 10 hours without the volts falling below 1.8 per cell. If discharged at a high rate, say 5 amperes, the capacity will be less than 20 ampere-hours ; that is to say the volts will have fallen to 1.8 volts before the expiration of 4 hours. If discharged at less than 2 amperes the capacity would be a little more than 20 ampere-hours. This variation of capacity according to the discharge-rate is a peculiar property of the lead accumulator. Be it observed that the discharge should be taken *continuously* through a resistance or lamps. A statement that a given cell has a capacity of so many ampere-hours when the discharge is supposed to take place intermittently, as with the ignition apparatus, and its capacity is considerably less, probably half, is made with intent to deceive and is fraudulent.

Carbide of calcium.—A chemical compound of carbon and calcium. It is produced commercially in the electric furnace. If wetted, carbide of calcium gives off acetylene gas very freely ; this gas (*q.v.*) is a brilliant illuminant.

Carbon.—An elementary substance largely associated with life ; *e.g.*, it forms the great bulk of the compounds constituting the solid matter in trees. Combines very readily with oxygen to form carbon dioxide when combustion has been started by heating it in the presence of air.

Cardan joint.—A particular form of universal joint. A method of coupling two rotating shafts so that while one remains rigid the other is free to move laterally.

Casting.—A mass of metal formed by pouring the molten metal into a mould. Cast metal is generally more brittle than wrought, *i.e.*, hammered or rolled metal. A casting shrinks considerably in cooling and allowance has to be made for this by making the mould larger than the finished article is to be.

Caulk.—To fill up cracks and crevices by forcing in some soft material which will effectually prevent leakages through the cracks. Socket and spigot pipes are caulked first by hammering in tow round the joint and afterwards hammering in lead by means of special caulking tools.

Caution.—The motor-car driver should not only be thoroughly acquainted with the caution signs placed along the roadside for his use, but he should also make a practice of observing them. The special caution signs now in use are given in the Local Government Board Circular, dated March 10, 1904, No. 315*, and styled Addendum to the Motor Cars (Use and Construction) Order 1904.

Cell (electrical).—A small box, jar, or other vessel, containing plates (electrodes) and chemicals of various sorts with a view to producing or storing electricity. A cell that produces electricity, that is generates it, is termed a primary cell, that which stores it when charged is termed a secondary cell, storage cell or accumulator. Two or more cells form a battery.

Celluloid.—A flexible transparent substance somewhat resembling gelatine in appearance. It is produced by the treatment of cotton or cellulose with nitric and sulphuric acids. The resulting material (gun cotton) being dissolved in ether and spirits of wine forms, after evaporation of the spirit, a hard close material of highly inflammable nature. Its inflammability is a source of real danger if not borne in mind and carefully guarded against.

Centrifugal force.—The force which causes parts of a revolving object to tend to fly from the centre of rotation. This force is made use of in the centrifugal governor and the centrifugal pump; in the latter case the water is admitted to the centre of the pump and thrown by the rotating wheel to the outside and thence is forced through the delivery pipe.

Chassis.—*See* pages 68 and 126.

Circuit.—The connecting wires and cables with receiver (lamp, motor, &c.) and generator forming a continuous conducting path for a current of electricity. A circuit is said to be "broken" when a break is made in the conductor so that current no longer flows; the circuit is "made" when the connection is established so that current flows.

Cog-wheel.—A tooth wheel with teeth carefully made to engage in the teeth of a similar wheel so that movement or power is transmitted from one to the other.

Collar.—A metal ring attached to, or forming part of, a spindle or shaft, generally employed to prevent movement of the spindle in the direction of its length or axis, or of a piece of machinery along the spindle.

Combustion.—Burning, or, commonly, the process of the chemical combination of oxygen with other substances, such as carbon or hydrogen gas. Combustion may be prolonged, as in the burning of coal in an open fire; or explosive, as with petrol mixture in a petrol engine.

Commutator.—A disc or cylinder attached to a spindle or shaft and rotating truly with it, built up of metal contact pieces or segments mounted on insulating material so that an electric current is conveyed from the moving shaft or machinery attached thereto to the brushes resting on the commutator, the purpose being that the different segments shall make contact with the brushes at stated intervals only.

Conductor.—Any substance that will conduct or allow electricity to pass through itself.

Conductivity.—The relative capacities of substances for conducting electricity irrespective of the mass or volume of the conductor; *e.g.*, the conductivity of copper is high, that of German silver is relatively low. The conductivity of a metal is measured in its relation to silver; that of silver being taken as 100, copper is 94, aluminium 55, and iron 16.

Connection.—*See* Contact. Wires used to connect pieces of electrica apparatus are termed connections, or connecting wires.

Contact.—To make contact or connection is to complete or to make an electrical circuit (*q.v.*). A contact or contact piece is a piece of metal which "makes" circuit; *e.g.*, the platinum contacts on the contact maker. *See* page 40.

Copper.—A metal of great value for commercial and engineering purposes. Alloys readily with most other metals, forming brass, bronze, gun-metal, &c. &c. It is one of the best conductors of electricity and is more largely used for electrical conductors than any other metal.

Current.—An electrical conductor is said to have a current of electricity flowing in it when circuit has been made. This is a convenient expression only; it is not known whether any flow actually takes place or not.

Cut-out.—A device inserted in an electrical circuit to break the circuit in the event of an excess of current passing through it. More commonly a "fusible" cut-out is used (*see* Fuse), but mechanical and automatic cut outs of many kinds are used.

Density.—The weight of a substance in relation to its volume. The specific gravity of a substance is its density in comparison with a given standard; this standard with gases is hydrogen, the density of which, for the sake of comparison, is taken as unity; with liquids and solids the standard is water at 32° F., and atmospheric pressure. Thus a given volume, say a cubic inch or cubic foot of copper weighs 8.79 times the same volume of water; its specific gravity or density is therefore 8.79. Again, a given volume of petrol weighs, say .68 of the same volume of water; its density is thus .68. The density of petrol is measured with a densimeter. A hydrometer is used with most fluids for the same purpose. The hydrometer and densimeter are instruments of the same kind, but graduated differently.

Detent.—*See* Pawl.

Diagram, Indicator.—A diagram drawn by an instrument termed an engine indicator. The diagram shows the pressure in the engine cylinder throughout the stroke, or, with a petrol engine, throughout the cycle; from this diagram the indicated horse-power is easily calculated.

Detector.—A small electrical instrument consisting of a galvanometer or current indicator and several primary cells. Used for testing the continuity of electrical circuits.

Dished wheels.—Wheels intentionally inclined inwards on their axles so that the width apart on the road surface is less than the width at the top.

Drum.—A brake drum is the metal rim or ring rigidly attached to the hub of a wheel or to the driving-shaft on which the brake band rubs.

Dry cell.—A primary cell with sealed top and often containing some absorbent material which soaks up the electrolyte. It is only "dry" because it is entirely sealed and does not leak. If the electrolyte gets dried up, electricity will not be generated. Some forms of the dry cell are useful for ignition purposes.

Dynamo.—A mechanical generator of electricity. The term is applied to both direct and alternating current generators, but more generally to direct current machines, the alternating current generator being called an alternator.

Earth, Earthing.—A term used to signify the connection of the return conductor in an electric circuit to the earth at two points so that the mass of the earth really forms part of the circuit. This is a very common plan in telegraphy and sometimes in telephony. The use of the term has been extended to the connection of a continuous mass of metal in the return circuit where there is no metallic connection to the earth at all. In a motor-car the mass of the metal work of engine and chassis is made use of in this way. *See* page 47.

Ebonite.—A black substance capable of being worked into various shapes by moulding when hot or cutting. It consists of a mixture of rubber and sulphur, and is a splendid electrical insulator. It is used for the tops of induction-coils; also as insulating material in contact-makers, &c.

Eccentric.—A disc mounted rigidly on a rotating shaft with its centre or axis parallel to the axis of the shaft, but the centres do not correspond, the result being that the disc is out of truth and rises and falls carrying with it the eccentric strap and rod attached thereto. Its action is similar to that of the cam, but in place of a quick striking movement, the eccentric rod and strap are moving throughout the revolution of the shaft.

Electrolyte.—The chemical solution or liquid in a cell. In a Leclanché primary cell the electrolyte is a solution of sal-ammoniac; in a secondary cell it is diluted sulphuric acid.

Excite.—The current of electricity passing through the coils of an electro-magnet is said to excite the magnet. The magnet or field coils of a direct current dynamo are excited from the current produced by the dynamo. The field coils of an alternator have to be excited from an outside source, as an alternating current has very little magnetising effect.

Expand.—The explosion in a petrol engine is not instantaneous, but is practically continuous through the stroke. At the moment of ignition the pressure is greatest, but the gases formed expand under the influence of the heat until the exhaust valve is opened and expansion is continued in the silencer: thus a fairly large part of force of the expansion is not utilised.

Extra current.—*See* page 57.

Fault (electrical).—Either a weak spot in the insulation of the wires or other part of a circuit allowing leakage; or, a broken connection preventing the passage of electricity.

Feather.—A strip of metal used to secure a wheel, pulley, or other piece of mechanism to a rotating shaft, which, while preventing the shaft from revolving inside the wheel boss, admits of the wheel sliding along the shaft. An illustration will be found in the change-speed gear.

Flexible coupling.—A coupling between two shafts, which, while admitting the free transmission of power between them, leaves one at liberty to move in any direction laterally while the other runs in fixed bearings. The universal joint is a flexible coupling ; in small pieces of machinery a spring is sometimes used.

Fuse or Safety fuse.—Generally a piece of metal or wire, inserted in an electrical circuit, of smaller section, or lower melting-point, than the connecting wires, so that, in the event of an excessive current passing, the fuse melts before damage has been done to the other wires, or to the apparatus. *See* Cut-out.

Galvanometer.—An electrical instrument for testing or measuring small currents of electricity ; in its simplest form it consists of a compass needle freely suspended inside a coil of insulated wire. When a current passes through the coil the needle is deflected to the right hand or left, depending on the direction of the current. If provided with a scale the amount of the deflection will give a rough indication of the strength of the current.

Gassing.—In the early stages of the charging of an accumulator quite small quantities of oxygen and hydrogen gas are given off from the plates: but near the end of the charge a considerable quantity is given off. When the cell is gasing freely it is evidence that the charging is finished, and the cell should be disconnected.

Gear.—A term in mechanics generally applied to devices for transmitting motion or power from one part of a machine to another. There are many types of gear, the more general being (*a*) gear wheels or spur-gear, *i.e.*, cog-wheels or toothed wheels in which the teeth "engage" or "mesh"; (*b*) bevel gear, *i.e.*, toothed wheels with teeth on the bevel or at an angle with each other ; (*c*) worm-gear, by which motion given to a spindle with a screw or worm cut on the surface is imparted to a toothed wheel with peculiarly cut teeth engaging with the worm ; this is generally used where a considerable reduction in speed is required from the worm spindle to the wheel. There are many other forms of gear, but the above are more commonly employed in motor-cars. To "throw out of gear," one toothed wheel is moved so that its teeth no longer mesh with those of its companion, *e.g.*, when the change-speed gear lever is at the neutral notch the wheels have been thrown out of gear.

Gland.—*See* Stuffing-box.

Gradient.—The steepness of a gradient is measured in terms of the vertical rise in a given distance of travel ; *e.g.*, a gradient of 1 in 20 signifies a rise of 1 foot vertically in every 20 feet of the road surface, not of the horizontal distance.

Grinding in.—The term applied to treating valves, so as to cause them to fit accurately the faces of valves which have become worn. *See* page 84.

Gudgeon-pin.—The pin attaching the upper end of the connecting-rod of a petrol engine to the under side of the piston.

High-tension electricity.—High-pressure electricity, such as that produced by an induction-coil. *See* page 39. High-tension electricity will jump across a gap between two live conductors in the form of a spark; low-tension electricity will not do this.

Horse-power.—A commonly employed unit of power or capacity of an engine for doing work. Strictly speaking it is the unit of useful work —a force that is capable of lifting vertically a dead weight of 33,000 pounds through a distance of 1 foot in 1 minute is termed 1 horse-power. The term, however, is used very loosely and sometimes misleadingly. For instance, the H.P. of a steam-engine is generally stated in "Indicated" H.P., the useful work (that is the "Brake" H.P.) such an engine can do is only about $\frac{9}{10}$ of the I.H.P. The term "Nominal" H.P. is still more misleading, and should be abolished altogether; it is more generally used in conjunction with boiler capacities, but sometimes also by old-fashioned engine-makers in conjunction with engines; roughly it is three times the value of an Indicated H.P. Care should always be taken when purchasing engines to see that the *brake* horse-power (B.H.P.) is stated. A petrol engine is generally rated on this basis, but this must not be taken for granted, as there is plenty of room for dishonesty in this direction.

Hydrometer.—An instrument for measuring the density or specific gravity of liquids. A hydrometer for measuring the specific gravity of sulphuric acid (for accumulators) should be graduated from 1100 to 1250; these figures really signify 1.100 and 1.250, but the decimal point is generally dropped.

Indicator.—*See* Diagram.

Induction.—A term applied in motor-car phraseology, but somewhat erroneously, to the drawing of the explosive mixture into the engine. (*See* Admission pipe and valve). In electricity it signifies the production of electricity in a coil or apparatus at a distance from the inducing current, and not connected thereto by conductors; *e.g.*, induction coil. *See* page 40.

Insulator.—In electricity, a substance that does not conduct electricity to any appreciable extent. (*See* page 33.) Also used of bodies that do not conduct heat appreciably. Mica and asbestos are heat insulators.

India-rubber.—One of the best known electrical insulators, largely used for insulating wires and cables. In this connection it is more generally vulcanised (treated with sulphur at a temperature of 280° F). Vulcanised rubber perishes in contact with the air less readily than pure rubber. Also extensively used for the manufacture of rubber tyres. Its value for both of these purposes is often largely depreciated by mixing with it in the process of manufacture an excess of "compound." Excessive quantities are used in cheap rubber articles, and in no other class of goods is it more necessary to warn the purchaser to buy only from honest and reliable tradesfolk.

Joint.—Pipes conveying fluids under pressure need to be jointed carefully to prevent leakage. Pipes with flanged ends bolted together have generally some "packing" between the flange faces; this may be an asbestos ring, a metal disc treated with red lead paste or a ring of soft wire (possibly copper), which is squeezed flat when the bolts are screwed up. Joints in different parts of an engine also need to be packed in a similar way. If a joint subject to high pressure is badly packed the "packing" may be blown out and the joint will have to be "made" again.

Joint (universal).—*See* Cardan joint.

Journal.—That part of a revolving shaft or spindle which runs inside the bearing.

Key.—An engineering term applied to a tapering or wedge-shaped piece of metal used to rigidly secure a pulley, wheel, or other piece of mechanism to a revolving shaft. A "key-way" is the longitudinal slot cut in the shaft, and also in the pulley or wheel boss into which the tapered key fits.

Magnet and Magnetic field.—*See* page 37.

Mica.—A peculiar mineral found in the form of large crystals, which can readily be divided by splitting into sheets of almost any degree of thinness. The sheets are very transparent, and it forms a valuable electrical and heat insulator. It is used in many motor-car appliances.

Misfire.—The failure of an explosive charge admitted to the cylinder of an internal combustion engine to ignite at the critical moment, so that the gases pass from the engine unused.

Momentum.—The force stored in a moving body: the momentum in the revolving fly-wheel of a petrol engine carries the moving parts through their various operations between the explosions. The momentum of a motor-car travelling at high speed may, in the case of a collision, cause considerable damage.

Motor.—This term is correctly applied to a machine for developing power. It is incorrectly applied to a *motor-car*, sometimes by those who certainly ought to know better.

Negative.—In electricity, *see* page 48. In most primary cells, plates of carbon and zinc are employed. The carbon is positive (+), the zinc negative (−).

Oxide.—A chemical combination of oxygen with (1) a metal *e.g.*, oxide of iron, aluminium oxide, peroxide of lead, or (2) a non-metal, *e.g.*, carbon dioxide.

Packing.—*See* Joint.

Paraffin wax.—A pure, white and hard wax. An excellent electrical insulator, sometimes called solid paraffin or simply paraffin, which is confusing.

Pawl.—A pivoted bar or catch-piece arranged to fall into the teeth of a ratchet or tooth wheel as it rotates in one direction to prevent a back motion when the wheel-moving power is withdrawn. The pawl or detent may act by gravity or by a spring.

Pinion.—The smaller of a pair of toothed wheels, whether spur, bevel or mitre, &c.

Pitch.—The pitch of a tooth on a spur-wheel governs the size and shape. These teeth have to be scientifically designed and cut, otherwise they will not engage properly. Badly designed and cut teeth will result in noisy running and heavy wear. Teeth of a certain pitch will not mesh properly with teeth of a different pitch; it is therefore of great importance when purchasing new gear wheels to see that they are suitable.

Platinum.—One of the rare metals, nearly as costly as gold. Valuable owing to the difficulty with which it is oxydised; is used to tip the screws of make and break contacts, for which purpose it is especially suitable as the contacts always remain clean.

Play.—In machinery a freedom to move; sometimes a great fault in badly designed machinery, *e.g.*, if toothed wheels do not fit nicely there will be play between the teeth—noisy play in fact. In certain parts of machinery some play is essential; whether play is too much or too little is a matter of judgment and experience.

Plumbago.—*See* Black lead.

Positive.—*See* page 47; also *see* Negative.

Pressure.—That which tends to cause movement. In electricity that which on a circuit being closed causes a flow of electricity through the circuit. The volt is the unit of pressure. The volume of current which will flow in a given circuit depends upon the resistance of the circuit and also upon the pressure. The relation between the pressure, volume and resistance is expressed by the simple equation $C = \frac{E}{R}$ where C is the volume or current measured in amperes, E is the pressure measured in volts, and R the resistance measured in ohms. This is termed Ohm's Law. Thus if E is 200 volts and R is 20 ohms then the current will be $\frac{200}{20} = 10$ amperes.

Primary coil.—*See* page 39.

Pulley.—A wheel or drum, varying greatly in shape, keyed to a rotating shaft, and upon which a belt or rope runs for the purpose of transmitting motion or power. There are (1) the simple flat belt pulley, (2) a flanged pulley with flanges on either edge to prevent the belt slipping off sideways; (3) a grooved pulley for rope drive; (4) a split pulley divided to enable it to be fixed to a line of shafting without taking it down; often a most serious consideration; (5) a fast and loose pulley for stopping at will the motion of the shaft receiving power. This is really two pulleys, one keyed to the shaft, the other close beside it, and of the same diameter, running loose so that by a side movement the belt can be shifted from the fast to the loose pulley and *vice versa.* There are many other forms of pulley.

Resistance.—*See* Pressure.

Rocker.—The device on a petrol engine carrying the brush or brushes resting on the contact-maker or commutator enabling them to be rocked forward or back so as to secure the advance and retard of the spark. Moving the rocker against the direction in which the contact-maker is revolving will advance the spark, the reverse movement will retard the spark.

Secondary.—For Secondary Coil *see* page 39. For Secondary Cell, *see* page 48.

Short circuit.—Short circuit occurs when the current is diverted from the desired path through lamps or motor, &c., and flows through a path of less resistance owing to the conductors near the poles of the battery becoming united, either directly or otherwise. The wires are said to be short circuited, also the source, and the receiver. Short circuiting generally results in a heavy excess of electricity passing, which "blows" the fuses near the source of supply.

Sleeve.—A tube into which a rod or shaft is inserted. The split rear wheel axle in a Cardan shaft driven car is carried in a sleeve.

Specific gravity.—*See* Density.

Sprag.—A stout forked rod attached to the underside of a motor-car which can be lowered at a moment's notice if the car tends to run backwards down a hill. Every car should be provided with this safety device.

Sprocket-wheel.—A toothed wheel with teeth specially designed for use with chain drive.

Spur-wheels.—*See* Gear.

Storage battery.—*See* Accumulator.

Strap.—A metal band around a piece of machinery. The eccentric strap surrounds the eccentric and carries the eccentric rod.

Stuffing-box.—A metal sleeve or box containing packing and screwed to a piece of machinery through which a moving rod passes. When screwed up it compresses the packing around the rod and thus makes a tight joint while leaving the rod free to move.

Sulphuric acid.—A powerful corrosive acid. Termed vitriol or oil of vitriol. Used, diluted, for the electrolyte in secondary cells; needs to be very pure for this purpose—the "commercial" acid is not good enough.

Switch.—An electrical device for making or breaking circuit promptly. A two-way switch is used with two ignition batteries, by means of which either of the two batteries may be brought into instant use or current be entirely switched off.

Tappet.—An arm or rod which is touched by a cam in order to impart an intermittent movement to the rod; used as a valve motion in the petrol engine.

Terminal.—Also called Binding Screw. A screw with milled headed nut to which a wire inside a piece of electrical apparatus is brought for the purpose of enabling the outside wires to be easily connected.

Thread of screws.—The spiral turns on a screw are called the thread; the number of threads per inch of length varies enormously, also the shape and size of the thread. There are several standard threads in use, the Whitworth and the British Association being mostly used. There is also the Gas thread, chiefly used for screwed pipes. The non-standard threads are numerous and are termed bastard threads. Some practical acquaintance with screw threads must form part of an intelligent motor-car driver's stock in trade.

Toothed wheels.—*See* Gear.

Universal joint.—*See* Cardan joint.

Volt.—*See* Pressure.

Voltmeter.—An instrument for measuring electrical pressure in volts.

Vulcanite.—*See* Ebonite.

Vulcanised fibre.—A useful insulating material of brick red colour largely used in the ignition apparatus of a motor-car.

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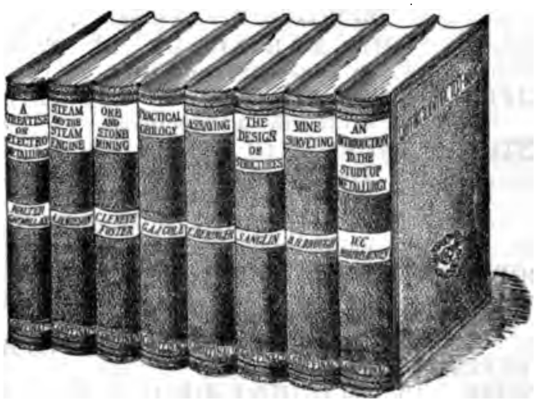

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