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The AUTOCAR HANDBOOK

A Guide to the Motor Car

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THE AUTOCAR HANDBOOK.

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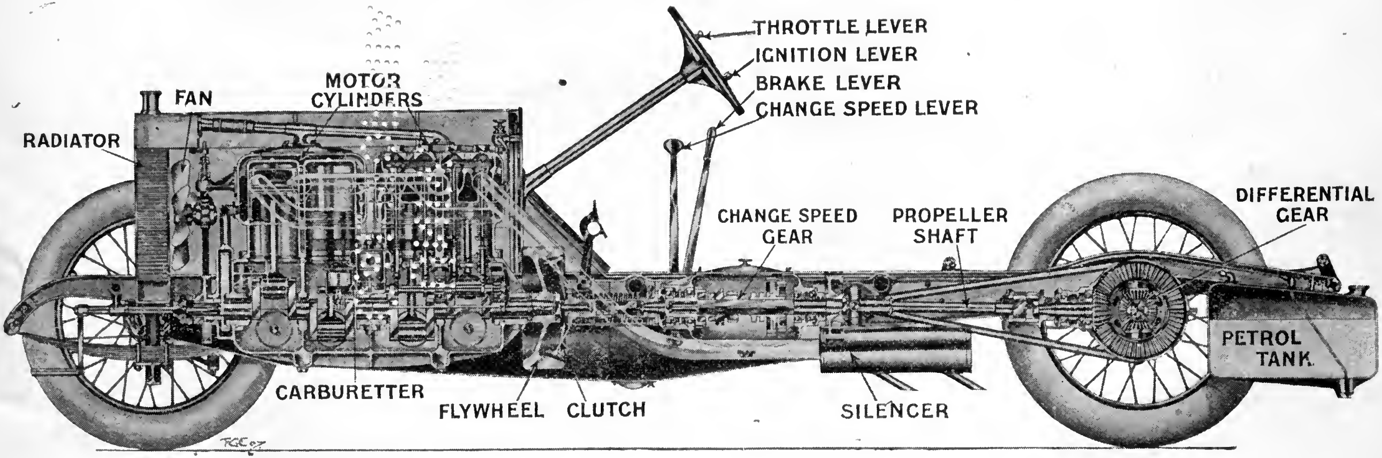
A SECTIONAL DRAWING OF A CHASSIS SHOWING ALL THE WORKING PARTS OF A MODERN MOTOR CAR AND THEIR RELATIVE POSITIONS



THE MECHANICAL FEATURES OF A MOTOR CAR.

THE

Autocar Handbook

A Guide

TO THE

Motor Car.

THIRD EDITION.

Entirely Revised. Many New Illustrations.

London:

ILIFFE & SONS Limited, 20, TUDOR STREET, E.C.

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The Autocar Handbook.

General Introduction.

WITHIN the space at one's disposal in a handbook of this elementary nature, it is quite impossible to deal with any degree of completeness or at adequate length with the theories which govern the functions of various parts of the motor car. Information on this subject may be divided into three classes:—The things one MUST know; the things one SHOULD know; and the things one need NOT know; the last-named being those things knowledge of which, although exceedingly interesting and valuable, is, however, of no immediate utility as regards the successful running and keeping in order of a car. This it is that forms the *raison d'être* of this book. Roughly speaking, then, the information one *must* have will enable one to keep one's car running in good order, whilst what one *should* have will result in the car being actually improved, although the line of demarcation between these two classes of knowledge is not very apparent.

The question which faces, has faced, and will face, every prospective buyer of a motor car is this: Here is a machine at one end of which we have a tank full of petrol, at the other end the wheels go round. How is this brought about? We will therefore trace the course of the petrol with which the car is driven, from the tank in which it is contained to the carburetter wherein it is vaporised and mixed into an explosive gas to the engine, where the explosions of this gas are caused to revolve a flywheel, and hence to the passage of the exhaust gases into the open air. We shall see also as we go along how the potential energy—that is, energy due to its constituents—of the petrol is transformed into kinetic energy, whereby the car is propelled. A motor car may be briefly described as a framework mounted on four road wheels and driven by a gas engine—in fact, that is a motor car reduced to its essential ends. First of all, the engine must be supplied with gas, and for this purpose a gas works is required, and this is formed by a supply of petrol and a carburetter, which we will now briefly consider. The name petrol properly applies to a spirit of a specific weight about 68% as much as water—that is, not quite 7 lbs. to the gallon at 60° F. Of recent years, however, the name has been stretched to cover lower qualities of spirit of a much higher specific gravity, and may be described as a sort of petroleum, only very much thinner and more volatile and with a different smell. Petrol in common with numerous other spirits has the quality of readily evaporating, and forms a highly inflammable gas ; and it is this gas which is used on a car as fuel for the engine whereby it is driven. The carburetter or gas works in which the liquid petrol is transformed into gas, and mixed with the quantity of air requisite to provide an explosive mixture, is an instrument consisting essentially of three parts.

First, an apparatus for maintaining a constant level of petrol in a subsidiary tank, or float chamber, which is kept supplied by the main reservoir ; secondly, a device whereby the petrol is adequately vaporised and mixed with air ; thirdly, a tap or throttle, by means of which the supply of explosive gas to the engine can be regulated.

The Principle of the Explosion Engine.

It is a matter of common knowledge that if ordinary lighting gas be left turned on in a room for any length of time, and that if it be ignited there will be an explosion which will result in the side of the room, if not of the house, being forcibly blown out. In a petrol engine we have essentially a room of very strong material, one side of which, however, is free to move within a guide provided for the purpose. The room, or cylinder, is filled with gas made as we have seen by petrol. This gas is then ignited, its ignition resulting in an explosion which causes the movable side of the chamber or piston to be violently driven outwards along its guide. By means of a crank this linear motion is transformed into a rotary one. It will be seen, therefore, that, first of all, it is necessary to fill one's cylinder with explosive gas ; secondly, to ignite it ; and thirdly, to get rid of the products of combustion of the explosion, so that the cylinder may be filled again with fresh explosive gas. It has been found, however, that if the explosive gas be compressed—that is to say, forced to occupy a smaller space than it would otherwise do at normal temperature and pressure—it is capable when ignited in that state of causing a very greatly enhanced explosion, just as the old muzzle loader was found to carry much farther according as the wads were rammed more tightly home and the powder squeezed into as small a space as possible. The gas engine must therefore provide for the following sequence of operations : The filling of the cylinder with explosive gas, compression of the gas, ignition and explosion of the compressed gas, and exhaustion of the uninflammable products of combustion. This is known, after its discoverer, as the Otto Cycle, and it is upon this principle that all internal combustion engines operate.

It will now be understood that during the performance of these four functions the piston has travelled twice outwards and twice inwards in the cylinder, and this movement has been accompanied, therefore, by two revolutions of the flywheel, which is driven by the crank, as mentioned above. There is accordingly only one explosion—that is to say, only one power impulse during every two revolutions of the crankshaft, whence engines of this type in which each function is performed by a separate stroke are known as four-stroke motors.

Valves and Valve Mechanism.

In order to allow the cylinder to be first of all filled with gas, then to be hermetically closed whilst the piston travels inwards and compresses the gases, still to be hermetically closed, whilst the mixture explodes and drives the piston outwards, and lastly, to be opened to the air so that the products of combustion may be expelled by the inwardly travelling piston, it is necessary to provide doors or valves, two in number—one for the inlet of fresh gas and the other for the exhaustion of the products of combustion. Both inlet valve and exhaust valve only open once in every two revolutions of the crankshaft, and it is accordingly necessary to actuate them through the medium of a half-time shaft, that is to say, a shaft driven at half the speed of the crankshaft. The inlet valve, it will be at once seen, is open during the suction stroke of the piston. During the next two strokes—compression and ignition—both valves are closed, whilst during the next stroke the exhaust valve is open, thus freeing a passage for the waste gases into the open air. The inlet valve is in direct communication with the carburetter already mentioned, whilst the exhaust gases are directed into a muffler or silencer, whereby the sharp explosive report of the exhaust is broken up into a less offensive sound. The valves are generally of the mushroom type, resembling somewhat a very large French nail, the head of which is capable of making superficial contact with a ring-shaped valve seating, for which purpose the stem of the valve runs in a guide. In the normal position the valve is held on to its seating by a spring sufficiently strong to overcome the tendency of the suction stroke to open it, and also to be capable of bringing the valve very sharply back on to its seating after it has been opened. The last-named function is performed by means of a shaft having at certain specified points of its periphery a hump or cam. Whilst the valve is closed the base of its stem bears upon the circular portion of the camshaft, which, as it rotates, brings the hump or cam under the valve stem with a wedge-like action that forces the valve off its seat, to which it is returned at the proper time by the aforementioned spring. Both valves are operated in this manner on all modern cars nowadays, but there are a very large number of older models, still in use at the present time, in which the inlet valve is worked automatically by the suction of the piston upon its suction stroke. The latter means, although it possesses advantages in the way of simplicity, cheapness, and, as some of its advocates still hold, other ways too, suffers from the fact that at high speeds the valve is inclined to remain open for a longer time than is really necessary.

Ignition.

Next to having a supply of gas wherewith to fill one's cylinders, the most important operation to be performed in an explosion engine is to provide a means whereby the gas is ignited at exactly the right time. No part of a car exhibits more plainly the results of careful selection and evolution than the ignition system. In the very early cars, and still in large stationary gas engines, the gas was ignited by being forced into a red hot tube on its compression stroke. This, however, had so many disadvantages—in fact, had no advantages for motor car work—that it speedily gave way to a system whereby an electric spark was made to take place inside the cylinder, and thus ignite a charge of gas, the electricity being furnished by primary or secondary batteries. In modern cars, however, a still more complete and self-contained form of ignition is nearly always provided in the magneto, which generates its own electric current for ignition purposes, and is driven by the engine. Thus there is no waste of energy when the car is not in use, and the system is rendered as far as possible mechanical throughout.

Cooling.

We have seen that the potential energy of petrol can be transformed into the kinetic energy, which is stored up in the form of momentum by the flywheel. Just as energy can be thus transformed, so can forces be transformed ; in fact, to be precise, and to specify exactly how the potential energy in this use is transformed into kinetic energy, it should be stated that the chemical action of the petrol, when ignited with the necessary volume of air, is transformed into heat, which heat is then transformed into linear motion, the last-named being again transformed into rotary motion. The petrol engine, therefore, is a heat engine, and any loss of heat therein is loss of energy. With the flame of an explosion constantly within it, that is to say, occurring from 100 to 1,500 times a minute, the cylinder can hardly be expected to keep cool, and, in fact, unless means are provided for keeping down this heat or despatching it, the cylinder will become so hot as to prevent the piston sliding within it, thus causing the engine such an excessive amount of friction that to revolve it must expend more friction than it has energy ; hence it stops. There are two systems used for keeping the engine at an equable temperature at which the piston and other moving parts will function freely, and the oil used for lubricating will not be carbonised. The first of these is to allow a blast of air to impinge directly upon the walls of the cylinder, which are for this purpose provided with a number of concentric fins, whereby the effective radiating surface is very largely increased. The second, more indirect, but generally regarded at present as a more reliable and serviceable method, consists in surrounding the cylinder with a jacket of water, which is kept in constant circulation. The water heated by the cylinder is conveyed to a radiator consisting of a number of tubes or cells of special section, in which the radiating surface is very much larger in effective area than the surface of the cylinder, and in this radiator the hot water is cooled and once more circulated through the engine, the process continuing *ad infinitum.* To effect this circulation of the cooling water, either a force pump driven by the engine is used or else the system is arranged in such a way that the natural law that hot water rises and cold descends can be taken advantage of, and this is known as the thermo-syphon system of cooling.

Clutch.

Since only one explosion takes place in the gas engine during every two revolutions, and since the engine depends for its power entirely upon the force of that explosion, that is to say, it depends for power upon the speed wherewith its piston is driven outwards, it cannot start from rest or against any resistance by itself, and, in fact, must be started by some auxiliary mechanism or by hand, as only by these means can the cylinder be filled with gases, which can then be brought up to compression. Ignition then takes place, and the engine starts, but it cannot start without a cylinder full of compressed gas. Since the engine depends for its power upon its speed, it is quite obvious that it cannot be directly connected to its load. If it were so, then it would be capable of starting and giving out its full power from rest, otherwise it is not capable of overcoming the resistance of its load due to inertia. It is, in fact, necessary to connect the engine to its load through an elastic coupling, by means of which the engine can be made to take up its load gradually, during which time its speed may be kept up and its full power therefore retained. Such a coupling is known as a friction clutch, and may be of the several varieties which will be described later on. The principle, however, is in all cases the same, that of a surface connected up to the load being brought slowly into frictional contact with a rotating surface attached to the engine. The surfaces are brought together by such a pressure that a certain amount of slip is capable of taking place between them, and only as the resistance of the diminishing load decreases the discs tend to revolve synchronously and form a positive connection.

Arrangement of Engine.

We now have a complete power plant ready to drive any work with which it may be connected. The engine may be composed of one, two, three, four, or six cylinders, whilst in some cases as many as eight have been used. The reason for this multiplication of cylinders is that by this means the explosions and impulses in the engine can be made to follow very quickly one after the other; in fact, the explosive impulses in a six-cylinder engine actually overlap, so that at any point in its rotation one at least of the pistons of the engine is under explosive pressure, whence continuity of torque, that is to say, an even and not jerky turning movement, is obtained, and this is highly desirable, alike from the point of view of economy in freedom from vibration and wear and tear, and comfort in freedom from vibration and constant change of gear—a point which will be dealt with later on. Thus nearly all modern motor cars having any pretensions to completeness, excepting a certain number the makers of which cling to the simplicity, cheapness, and efficiency of the single-cylinder engine, are provided with multi-cylinder engines, the general arrangement of which is upon the following lines: The cylinders are generally of cast-iron, and are cast sometimes separately or in pairs, in rare cases in threes, and increasingly commonly in fours, the latter system being known as the *en bloc* system. Not only for the purpose of keeping dust and dirt away from the reciprocating or working parts, but also to enable a thorough system of lubrication to be easily installed, the connecting rods, cranks, and crankshaft are enclosed in a crank case or crank chamber, which takes the form of an aluminium box, and not only forms a case, but also acts the part of a base plate, and carries the main bearings of the engine. The camshafts for operating the valves are also enclosed within it, and upon its upper portion the cylinders are securely bolted. For the purpose of inspection, etc., the crank chamber is split and bolted together again in such a way as to be fairly easily taken apart. The mechanism for driving the half-time or camshafts is gearing of the cog or spur wheel type, also enclosed in dustproof boxes, usually cast in the same piece with the aluminium crank chamber. The circulating water pump is not infrequently arranged on the same driving-shaft as the magneto, and this is driven by enclosed gearing off one of the camshafts. In order to cause a draught of air to impinge upon the radiator, even when the car is at a standstill, a fan is arranged behind the radiator, and being constantly driven by the engine, induces a forced cooling draught. This fan is generally driven by belt from the crankshaft. The valves may be arranged either both on the same side of the cylinder, or one on one side and the other on the other side of each cylinder, or one may be vertically above the other, the upper one being arranged in an upside-down position. Each system has its own advantages and disadvantages. The most general, however, is the arrangement of the valves side by side, as this requires only a single camshaft for the operation of both sets of valves. The tubes, pipes, or ducts whereby the inlet and exhaust valves are connected with the carburetter and silencer respectively are so arranged, in the first case, to supply an equal quantity of explosive mixture to each cylinder; and in the second case, to allow a free egress for the hot exhaust gases; whilst they are also arranged as far as possible to permit accessibility of the valves and valve mechanism, over which they are necessarily placed. The clutch is generally made an integral portion of the flywheel, which is interposed between the engine and the load which it has to overcome.

We have now gained a rough idea of how the potential energy of the petrol is converted into the kinetic energy, by virtue of which the driving wheels revolve and propel a motor car along. It must not be supposed, however, that all the potential energy contained in the fuel is utilised to advantage; in fact, no less than 80% to 85% is commonly lost either in the heat radiated by the cylinders and their water jackets, the friction of the moving parts of the engine, or the heat of the exhaust gases. The energy utilised may be said to follow the following course: From the petrol tank, along the petrol pipe to the carburetter, up the inlet pipe, through the inlet valve into the cylinder, down the piston and connecting rod into the crankshaft, through the flywheel, through the clutch, down the transmission system into the driving wheels; whilst the lost energy follows the same course as far as the cylinder, where some of it leaks out through the cylinder walls and gets into the air that way; still more of it runs out through the exhaust valve and into the air through the silencer; and yet more runs down the piston and through the connecting rod and into the crankshaft, and through the half-time gearing into the valves or into the water pump or into the magneto, or loses itself in friction.

Transmission.

We have now seen how the potential energy of the petrol is converted into a rotary motion of the engine's flywheel, whence the power can now be drawn off by suitable means for use in the propulsion of the car. Since the engine must rotate at any speed from 1,000 to 2,500 revolutions per minute to give its full power, it is quite obvious that the flywheel cannot be directly coupled through the clutch to the road wheel, as an easy calculation will show that if a road wheel 30in. in diameter were used, the speed of the car would theoretically be from 100 to 250 miles per hour, which is quite absurd, as the wind resistance alone at such a speed as the latter would require well over 100 h.p. to overcome it. Hence the road wheels must be "geared down" in relation to the flywheel in order that they may revolve at a slower rate of speed. The main consideration in the selection of a suitable gear reduction is to obtain the gear ratio which enables the engine to be never overloaded, that is to say, the gear ratio which enables the engine to turn round at a sufficient speed to enable it to give out power adequate to overcome the load imposed upon it. It is for this reason that by lowering the gear of a car a higher speed may frequently be obtained than when the gear is high. If the gear be very high, the engine revolves relatively slowly, and is therefore unable to develop sufficient power to enable it to accelerate and overcome the resistance of the car. The engine, in common parlance, will not "pick up," and at the slightest approach of increased load, due to a heavy road or a slight gradient, the engine must necessarily stop. Although a single fixed reduction of speed between engine and driving wheel has been found to be quite practicable—in fact, many quite moderately powered cars of to-day will run distances of hundreds of miles on one reduction of gear alone—it is found necessary to provide a means whereby the gear ratio between the engine and the road wheels may be altered to suit the load imposed by varying conditions.

Some cars are fitted with two, the most with three, and a number with four such gear variations. Taking the last-named as an instance, the first or lowest gear enables the car to be started up a very severe hill, and is also used for getting away when starting on the level. The second or next highest gear is used for climbing hills, and also occasionally for starting on the level. The third gear is used for general running over "give and take" roads, and is of such a ratio that ordinary hills may be surmounted ; whilst the fourth gear is used over level roads and slight down grades where some speed is required. The mechanism by which a variety of gear ratios may be obtained is known as a *change speed gear box*, and consists of a device whereby one of a series of toothed wheels may be brought into mesh, that is to say, into engagement, with one of another series of toothed wheels. Each of the individuals of each series is of a different size from any other in its series ; hence with two in a series two speeds are obtainable ; with three, three speeds ; and with four, four speeds, and so on, the general arrangement of a modern three-speed gear box with direct drive on top speed being shown photographically in figs. 59 to 63. In the earlier cars one of the shafts bearing one series of gear wheels was placed to one side of the shaft bearing the other series, and whichever gear was in operation, the power was always transmitted through one pair of toothed wheels. Since, however, considerable power is lost in driving through such toothed wheels, the modern gear box is almost universally provided with a means whereby the gear ratio most generally used in running may be utilised without passing the power from one gear wheel to another in the gear box. This "direct drive," as it is called, is obtained by virtually cutting the gear box completely out of operation in the following manner :

The gearshaft, which is coupled to the clutch, is divided into two parts, one of which is attached to the clutch, whilst the other conveys the power to the road wheels. At the side of, or below, this divided shaft is a gearshaft having the usual series of spur wheels, which duly engage with appropriate toothed wheels on the aforementioned clutchshaft. If the gear box be a four-speed one, the drive, when three of the gear ratios are being used, goes first from the clutchshaft to the side gearshaft or layshaft, then from the layshaft to the divided portion of the first gearshaft, and so away to the road wheels ; hence on these three speeds the power is twice transmitted through the spur wheels. On the other gear ratio, however, the layshaft, with its gear wheels, is thrown into a position where none of its gear wheels engage with those on the first gearshaft, the two parts of which are now by some means rigidly connected together so that they form a continuous solid shaft.

In a three-speed gear box having a "direct drive" this is always arranged to be the third or highest gear ; whilst in a four-speed gear box the third gear is very frequently made direct. Some makers, however, make their fourth gear direct in preference to this practice. In order to accord with the law, all vehicles weighing over 4 cwt. must be provided with a means whereby they can be driven in a reverse direction ; hence all gear boxes of cars are provided with a reverse gear, which enables them to be easily manœuvred even in confined spaces. This reverse gear is obtained by introducing a spur wheel between a spur wheel on the clutchshaft and a spur wheel on the layshaft, thus altering the latter's direction of rotation, and through it the direction of the car's travel.

We have now ~~got~~ an engine which will give us power, a clutch which will enable that power to be smoothly coupled to a load, and a gear box which will enable varying ratios of gearing to be used between the power and the load. We thus have a complete power plant. The question which now arises is how to apply this power plant to the propulsion of a car. The most obvious method is to utilise, and drive through, one road wheel, and this idea naturally suggested itself to the earliest designers of automobiles. The disadvantages in the way of lack of accessibility and difficulty of arranging a suitable passenger-carrying body in a vehicle of the tricycle type very soon resulted in two driving wheels being used, whereby a very much increased accessibility and enhanced roominess of body can be obtained. Two driving wheels, however, bring their own problems with them, the most important of which is so to arrange the coupling between them that in turning round a corner the outer one may be free to over-run the inner one as necessitated by its increased distance of travel brought about by an increased radius of curvature. This mechanism is known as a differential gear or balance gear and is fully described both in principle and application in a separate chapter.

Thus we have the essential elements of a complete automobile : A power plant and a source of supply, a coupling by means of which the power can be coupled up to its load, a change speed gear box for varying the gear ratio between the power and the load, and, finally, a differential gear whereby the two driving wheels of the car may be enabled to travel and drive at their correct speeds when going round a curve.

CHAPTER I.

The Choice of a Car.

IN choosing a car, one has a good many things to consider. First, perhaps, comes the sadly sordid question of cost, and this question has several subsidiary ones tacked on to it. Are you prepared to spend enough to buy a thoroughly sound car of well-known make? And are you prepared to devote a proper amount to its upkeep? Do you realise that a certain annual expenditure above and beyond petrol, etc., is necessary to a motor car? Or, are you only disposed to lay out the price of a good second-hand car? Do the claims of petrol, of steam, or of electricity appeal most strongly to you? How many passengers do you desire to accommodate, and what horse-power will you consider necessary. Will you be content with low power which will propel you at decent speed on the level, but will require the lower speeds for hill work, or would you prefer sufficient engine power to carry you up gradients of 1 in 10 without changing down? Do you propose to do your own driving, or is your motoring to be of so strictly amateur a character that you will keep a chauffeur who will do all the driving? Your friend has a So-and-so that never gives him any trouble, and you mean to have the same? Well, there is something in that, provided your friend's requirements and accomplishments are the same as your own; but not necessarily otherwise. Perhaps he will sell you his car. There is nothing like knowing the antecedents of a second-hand investment.

Running Expenses per Mile.

Compared to horse-carriage work, motoring would usually be a great deal cheaper were the owner content with one and a half or even twice the mileage he had previously done with his horses. Hence, for business or professional work, a reliable car shows up very favourably against a carriage. But as a rule the motorist is keen on availing himself of the new means for making long trips, and so spends as much or more than he did before. It is not so much the fuel that costs money, it is the tyre maintenance that runs up the bill. General repairs and deterioration must also be taken into consideration. Many records have been kept, and they exhibit a disconcerting diversity.

The following may be taken as a representative example of a first year's account in respect of a 14 h.p. car covering 5,000 miles:

A Representative First Year's Account.

	£	s.	d.	£	s	d.
Preliminary—						
Car, complete with rugs, lamps, etc. ..				450	0	0

NOTE.—If the car is sold at the end of the year the purchase money would be returned less depreciation. which has been included as as annual expense.

	£	s.	d.	£	s	d.
Expenses—						
Registration, licences, etc.	5	9	0			
Insurance	10	0	0			
				15	9	0
Running expenses—						
Tyres (say one replacement and minor repairs)	8	10	0			
Petrol	13	0	0			
Oils and grease	3	0	0			
Repairs and replacements	10	0	0			
Charging batteries	0	15	0			
Spares and accessories	5	0	0			
				40	5	0
Depreciation—20% of cost				90	0	0
Uncertain—						
Driver, including clothes	90	0	0			
Stabling	12	10	0			
				102	10	0
				£248	4	0

A Representative Second Year's Account.

	£	s.	d.	£	s.	d.
Expenses—						
Driving and carriage licences	4	9	0			
Insurance	10	0	0			
				14	9	0
Running expenses—						
Tyres (a new pair and repairs) ..	20	0	0			
Petrol	13	0	0			
Oils and grease	3	0	0			
Repairs and replacements	15	0	0			
Charging batteries	0	15	0			
				51	15	0
Depreciation of car—say 10% upon the £360, being present value of car ..				36	0	0
				£102	4	0
Uncertain—						
Driver, including clothes	85	0	0			
Stabling	12	10	0—	97	10	0
				£199	14	0

Most amateurs prefer to drive and look after their own cars, so that the sum set down for the driver, etc., would be quite wiped out, and the amounts for Repairs and Replacements considerably reduced.

Many people complain that the prices charged for motor cars are exorbitant. Most of them have never seen a car made, and would wonder how it could be done for the money if they had the opportunity and patience to follow all the different processes through from beginning to end. It must be remembered, too, that in comparatively few cases are patterns as yet sufficiently well established, either in the factory or by fashion, to justify their being turned out in very large quantities. As time goes on, doubtless cars will become cheaper; or, rather, while the prices remain much the same, the value given for those prices will be higher.

Second-hand Cars.

Do not buy a big car just because it is a bargain. It will cost just as much to run second-hand as it did when it was sold new at a (to you) prohibitive price.

Though purchasing a car from a friend has the advantage that you know something of the past of the vehicle, the acquisition of the car may entail the loss of the friend. Whether it is due to difference of treatment, we can't say, but the fact remains that a car which has behaved in the most exemplary manner in the hands of its original owner may display all sorts of unsuspected vices as soon as it is sold and delivered. And this naturally leads to estrangements. It is just the same if one borrows. If you want to get rid of an acquaintance—at any cost—lend him your car. Something is sure to go wrong. He, having gratuitously damaged your property, will conceive himself insulted and injured. Put the thing right? Not he! How dared you lend him such a death-trap, etc., etc.? For your part, nothing can either approach or excuse the unreasonableness of the fellow, and you have done with him for ever!

Variations in the Motor Market.

A good idea of the market value of cars can be obtained by running over the advertisements of second-hand machines in the papers, and by attending one or two auction sales. The prices at which cars are knocked down at these sales are sometimes extremely tempting, so great care should be exercised in purchasing. They sometimes have some radical defect, so that the uninitiated should only buy under expert advice, and by expert bidding. Never bid yourself—retain an unbiassed expert adviser.

A higher-powered car will always sell more readily, *cæteris paribus*, than a lower-powered one, and is worth giving a little more for, in consequence. The same remark applies to the date of production—independently of the condition—of the vehicle; and a well-known make should be secured. Sometimes the makers will oblige with a little biographical information if the number of the car be given them.

Judging Second-hand Car Condition.

Apart from an expert examination, the first thing to do on examining a second-hand car is to compare it with the owner's description, point by point. The result will give you some idea of the manner of man you have to deal with. Then turn your attention to the motor, test the compression by turning the engine round slowly, then rock the flywheel backward and forward to try and detect any backlash in the connecting rod bearings. Hold the batteries up to the light to see if the plates are in good condition. Open the gear box and examine the wheels for broken, worn, and burred teeth. Look out for defects in the road wheels and wheel bearings, and jack them up to see whether they spin freely yet without slack. The balance gear can be tested for freedom and backlash at the same time. The tyres should receive very close attention, bad cuts, etc., being searched for in the covers. If they have been recently retreaded. well and good, but this process cannot be repeated indefinitely. One tyre at least should be opened to see what condition the air-tubes are in. Notice that the tyres are of good make and dimensions, and that they are not leaking. A badly-worn starting-handle indicates that the car has either run a long way, or is an awkward one to start, or both. See that the brakes grip and clear well, that the drums and bands are not worn thin, and that further adjustment is available. Notice whether the seating accommodation meets your requirements, what material is used for the upholstering, and whether the body-work is painted and finished to your taste.

Points of the Road Test.

Now let the owner start the motor, while you notice whether the operation is performed easily, and what noise and vibration are set up with the engine running and the car stationary. Look out for drips from leaks at the pump, radiator, etc. Next, secure a full complement of passengers, and occupy one of the back seats yourself, the owner driving. Notice whether the clutch engages smoothly and the gear easily. From the back seat you will be able to judge as to comfort, so far as strength of springs, comfort of seats, vibration on each speed, noise and smell of the exhaust, and dust are concerned ; and what space is available for luggage.

Having completed these observations, take a seat by the driver and carefully watch him change speed and how the control generally of the car is effected. Notice particularly the working of the clutch and both brakes. Even if the owner will allow you to drive his car it is quite useless for you to do this unless you happen to really know something about the particular make, as there is always a certain knack in the driving of every make of car. You will notice the owner start the engine and see it is no effort to him, but if, you have been used to starting some other make of engine you will very likely expend four or five times as much energy in vain, simply because you have not the knack of starting this particular engine. The same remarks apply to gear changing and the control of the car generally. That is to say, a man who is used to it will drive it well. If he cannot drive a car well when he is used to it, it is a proof that either he is a hopelessly bad driver or else that the control of the car is very difficult.

Selling the Old Vehicle.

If you want to sell your car, have any little repainting or other touching up done properly—any suspicion of the tar brush detracts immensely from the appearance. Small repairs and the like should receive equally careful treatment. One never appreciates the value of regular attention to a car so much as when one comes to sell. If the car has been well treated, its smart appearance will do much to effect a sale; but if it looks shabby, it will fetch a good many pounds less. Do not represent the car in too glowing terms, rather let prospective buyers find it better than they expected. Never permit your car to be driven by a prospective purchaser unless you know he is accustomed to that special type.

If you contemplate buying a new car, the makers or agents will often allow a fair price for the old one, and there are a number of depots where cars are sold on commission of from five per cent. to ten per cent., no charge being made if the car is not sold. If you send a car to one of these places, it simplifies matters if, instead of sending all the tools and accessories in the first place, you send only a list of them. It saves questions as to what was sent, and possible loss. When a sale is in course of being effected, the sundries can be sent along for inspection

Hiring and Testing.

In settling your preference between petrol, steam, and electric cars, be careful to make equally lengthy tests of the two first-named, and as long a test as the vendors will afford of the third. Unless you do this you are likely to be over-impressed by the particularly salient features of steam and electricity, and may come later to regret your resolve.

It is advisable to select the same route for each car, in order that the comparison may be not odious, but fair

With regard to hiring: if you have practically settled upon the make of car you prefer and are so placed that hiring for a time may be convenient if you do not finally determine to buy, you may be able to come to terms with the proprietor. If, however, you do resolve to buy you can arrange that the amount paid for hire shall be deducted from the total cost.

Comparative Advantages of Petrol, Steam, and Electric Cars.

The three systems all have their advocates, and all are good in their way. In order to facilitate an impartial judgment, we will tabulate the points for and against each. The difficulty lies in appraising the various points in due proportion. And it must be premised that the points are of only general application; in some cases the advantages and disadvantages might be actually reversed.

The pros and cons of the petrol car are—

Advantages.	Disadvantages.
Capability of running long distances without replenishing supplies.	Occasional unpleasant exhaust, if driver is careless.
Large range of choice.	Physical starting.
Wide dissemination of expert knowledge.	Gear changing (scarcely worth mentioning on a good car).

The advantages and disadvantages of the steam car may be briefly summarised as follow:

Advantages.	Disadvantages.
Great range of power, easily controlled.	Limited number of makes to select from.
Quietness.	Delay in starting.
Freedom from vibration.	Close attention required to indicators.
Easy restarting.	Frequently visible exhaust.

These disadvantages have apparently proved fatal to the lighter type of steam car in this country, no make of which is now extensively on the market. A few of the heavier type, most of them closely approaching the petrol car in general appearance, have a good following.

The points in favour of the electric car are for most purposes counterbalanced by those against it, thus—

Advantages.	Disadvantages.
Quietness.	Expense of running, owing, partly, to the great weight to be driven.
Absence of vibration.	Limited range, from twenty to fifty miles.
Simple and efficient gearing.	Great weight, due to the batteries.
Facility of control.	Time taken to recharge.
Cleanliness.	Small number of charging stations.
Easy starting.	Liability of the batteries to injury
	Slow speed for sustained running.
	High initial cost.

The electric car is, therefore, not suitable for touring purposes, but for town work, such as professional calls, attending theatres and the like. Indeed, where cost is not all-important, the electric car is very suitable, and is being appreciated. Electric cars have special privileges as to running in the parks during the season.

Choosing a New Car.

No one now need hesitate in choosing British cars. In workmanship and design they are, price for price, the equivalent of anything produced upon the Continent. On the other hand, there is a greater range of choice, and some specially pleasing points of design, amongst foreign-built cars, and many of these may be selected with perfect confidence. With regard to the home product, it is, of course, satisfactory to realise that one is within the reach of headquarters for spares and repairs, but at the same time the representative agents of foreign makes much affected on this side of the Channel have well-equipped repair shops, and, moreover, carry very full stocks of spares. In the case of the home works, however, the car purchaser is reminded not to presume too much on his welcome. The manufacturer is in business to make and sell cars, not to play motor instructor in general. But a maker that carries out repairs promptly and well is greatly to be preferred to one who neglects this part of his business.

If the maker of your choice is not within easy reach, it is better to buy through a local agent—if such agent is well versed in motor lore. He has a reputation to maintain in the neighbourhood, and it will be to his interest to see that your car gives you satisfaction. But at the present moment only the leading agents carry a large stock of cars

Considerations of Size and Power.

As to the size of the car, we may remark that it is quite possible to have it too large; and it must be borne in mind that extra size means extra weight and cost and extra cleaning. But it also has more baggage carrying capacity if you are touring with one companion only. For touring *à deux* the two-seated car is not to be preferred to the four-seated variety, though it might seem to be at first sight. In the unoccupied back part the luggage and wraps can be stored with the minimum of inconvenience. On the other hand, for runs near home, if one only wants a single companion, it is a waste of power to use a four-seated body. Some cars are made with a detachable "tonneau," and such a contrivance certainly has its conveniences The more people a car is designed to carry, the more it weighs. This may seem sufficiently obvious, but it does not occur to everybody that the heavier a car is the more it costs to run—not only in petrol consumption, but in wear and tear of tyres, gear, and bearings. Similarly, though a powerful engine covers a multitude of defects in transmission, the defects eventually reveal themselves in the bills for petrol and repairs. Leviathan cars are all very well, but they can seldom be given the rein in this country, and one can usually get as much pleasure at considerably less cost out of a moderately-powered vehicle.

Horse Power Theory.

Horse-power (H.P. or HP.) in engineering means the power which a horse should be able to keep on exerting during a working day. This has been fixed conventionally at lifting a weight of 33,000 lbs. one foot per minute, or lifting 330 lbs. one hundred feet per minute, and so on. While this may be rather over-estimating the capabilities of the ordinary horse, it must be remembered that for short periods he can exert a force of eight or ten mechanical horse-powers, and so a single horse can beat a small car at hill-climbing. B.H.P. means brake (not British !) horse-power. The French and German horse-power is about 1.5 per cent. less than ours. Makers are rather given to under-stating the horse-power of their cars, apparently because each would not like his car of a certain power to be beaten by a rival's car of the same power. But as all can, and most do, play the same game, the evasion is futile.

Three horse-power per passenger, plus 5 h.p. for the car, is ample for all ordinary purposes. Of course, anything above this should make your car a better and faster hill-climber, but it must be remembered that increased hill-speed means extra tyre cost.

General Hints on Purchasing.

If you have a friend who owns a motor car, and is an enthusiastic motorist, discuss the matter with him; but always bear in mind that he is likely to be prejudiced in favour of his car at the moment if it has served him well. If you are innocent of such a friend, just take up your pen, and put your wants and desires, coupled with your financial limit, your mechanical capabilities or leanings, before the Editor of *The Autocar*, who will give your particular case the closest consideration, and advise you to the best of his ability. In so doing, the exact duties required of the car should be stated, and the contour and condition of the roads over which the vehicle will be mostly used given. If storage is at hand ready for the car, it would be well to give its dimensions. In purchasing a car, one fact should always be borne in mind, when determining between a two or four-seated body, particularly if the purchaser has a somewhat shallow purse, and must, to a certain extent, consider ways and means. Friends appear to imagine that because a man is the owner of a four-seated car he never cares to sally forth unless he has a full load, and, *mirabile dictu*. many appear to imagine that free transport must assuredly entail free entertainment. A little lack of firmness in this matter will see the monthly motoring expenses going up like the British export trade in the seventies, and our reader may come to rue the day he elected to buy a motor car at all, not to say a four-seated motor car at that.

Description an Unreliable Guide.

Never buy a car from description alone. A car is not necessarily good because the illustration of it is finely executed ; on the other hand, a cheaply got-up catalogue is likely to represent a poor quality vehicle. The specification may include every refinement one may desire, but it is powerless to portray the quality of material and workmanship, and these two old factors—good material and workmanship — are of more worth than all the latest improvements. Testimonials are often genuine enough, but it is advisable to give entire credit only to those emanating from well-known people. A few words from a friend are more to be considered than a tome from a stranger.

Races and records are not much to go by; they show what the maker (and the driver) can do, but it does not follow that he always does it. Besides, the machines on which these performances are accomplished are usually very differently designed from the stock patterns sold to the public. Hill-climbing trials confined to private owners are the best guide among competitions, though a good car may do poorly in the hands of an incompetent driver. Have nothing to do with cars whose sole recommendation is that they are of this or that "type" or "pattern," but cheaper. Imitation suffers from lack of motive power, and a car that will not sell on its own name and merits is no credit, either to the man who made it or to the man who buys it.

The Motor Show Market.

The man who goes to an exhibition with the intention of selecting a car is likely to become somewhat confused as to a final choice; but if a motor show is in progress at or about the time a purchase is under consideration, a visit will prove highly instructive. The novice, however, should not venture alone and unprotected into the lion's den. Let him betake himself thither accompanied by a friend experienced in such matters, and after consultation as to the description of car he can afford and intends to buy. It will not be necessary to place the order there and then, but the catalogues of the selected makes and all information as to terms can be there most easily acquired and noted. Take these home, digest them at leisure in company with the experienced friend, or expert, or if lacking in both, write the Editor of *The Autocar* as hereinbefore advised. He will advise you fully and, as you will believe, in a most impartial manner.

Having finally decided upon your car, place your order at once, and give the manufacturers as much time as possible to execute it. Work is not improved by being hurried. Stick to the standard pattern as closely as possible. Alterations not only cause delay and expense, but they are liable to upset the general arrangement of the car, to be overlooked, and to put you in bad odour at the works—all things to be avoided.

As most men select cars with petrol engines, or, more properly, internal combustion motors, we will deal with that system first.

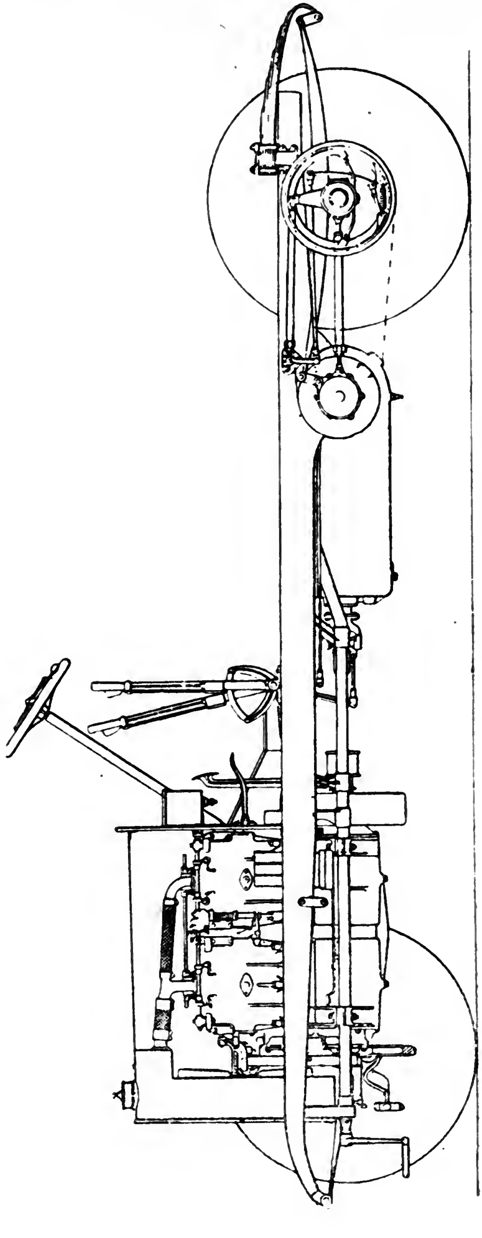


Fig. 1.—Elevation of Chain-driven Car.

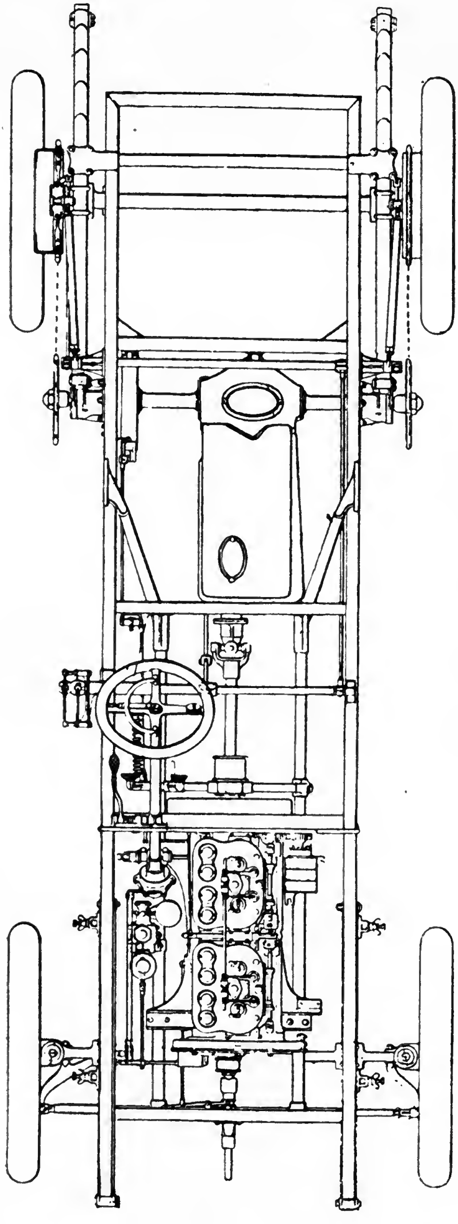


FIG. 2.—PLAN OF CHAIN-DRIVEN CAR.

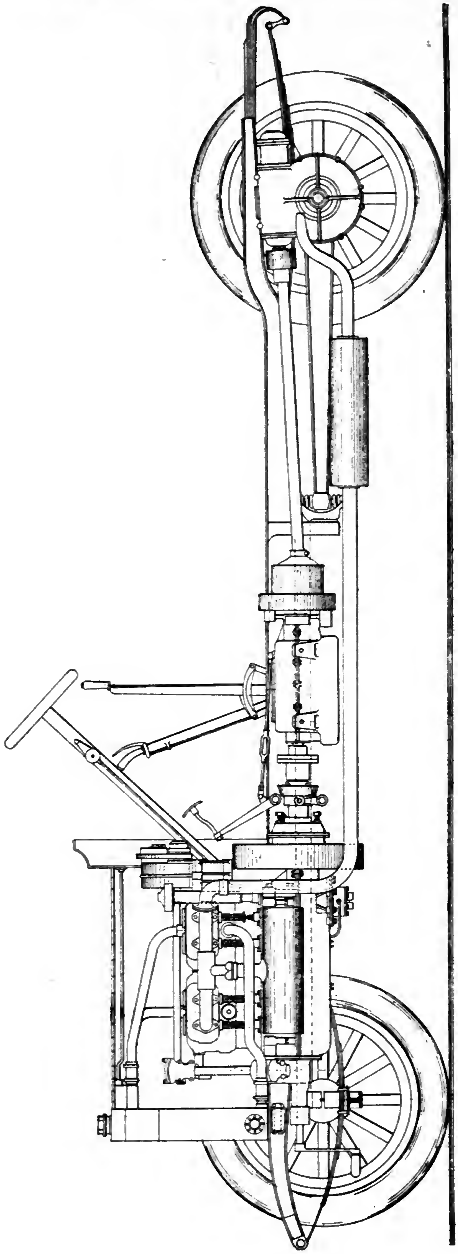


Fig. 3.—Elevation of Gear-driven Car, with Worm Drive to the Back Axle.

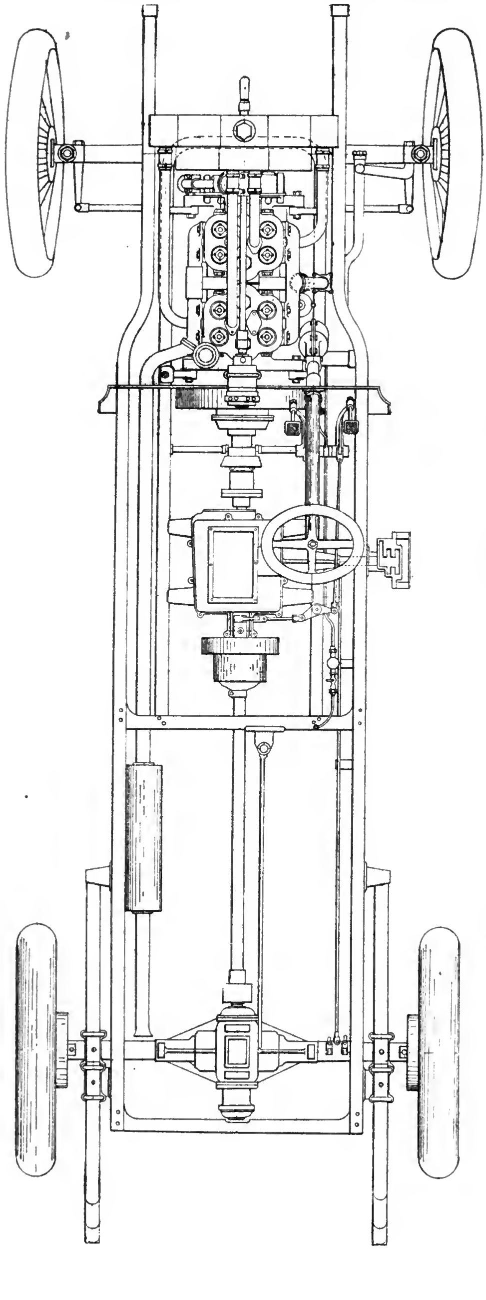


Fig. 4.—Plan of Gear-driven Car, with Worm Drive to the Back Axle.

CHAPTER II.

The Internal Combustion Motor.

THERE is no magic about a petrol motor, it is just a particular kind of gas engine. Petrol is an unscientific term for a petroleum spirit of a certain chemical denomination—one of the hydro-carbons. Coal gas or ordinary illuminating gas is another of the hydro-carbons. Petrol is a highly volatile spirit, and when its vapour is diluted with a certain proportion of air, it will "combust" with extreme rapidity; in the same way as when the air in a room becomes charged with a certain proportion of coal gas, owing to an escape, the introduction of a naked flame into that room causes an explosion. A motor means that which moves, and an engine means an ingenious machine, generally a motor. It is more usual to speak of a petrol *motor* and a steam *engine*, but motor and engine are practically alternatives in automobile parlance. So petrol motor, hydro-carbon motor, explosion motor, and internal combustion motor are more or less equivalents, though one would not speak of a motor using alcohol fuel as a petrol motor, of course. "Internal combustion motor" implies that the fuel is burnt in the motor; instead of outside the same in the fire box or furnace of a boiler, as in a steam engine. Petrol has its equivalents in France, under the name of *essence*, and in America under the name of gasolene. The apparatus by which the petrol vapour and air are mixed together is called a carburetter, or carburator, from the fact that by it the air is charged with the hydro-carbon. We shall have more to say about it presently; for the time being it is enough to know that the gas or mixture is sucked from the carburetter into the engine by the action of the latter.

The Elements of the Motor.

The engine or motor consists primarily of a cylinder, a piston, a crankshaft, and a rod connecting the piston to the crank on the shaft. The cylinder is, of course, hollow and open at one end. The piston slides up and down in the cylinder, like the plunger of a tyre inflator slides up and down in its barrel. The piston operates on the crank through the connecting rod, pretty much as the cyclist turns the crank of his bicycle by his leg from the knee.

The operation of the petrol motor differs from that of the cyclist in that, while with the latter an impulse is communicated to the crankshaft at every half revolution, in a single-cylinder petrol motor there is only one impulse for every other or alternate revolution of the crankshaft.

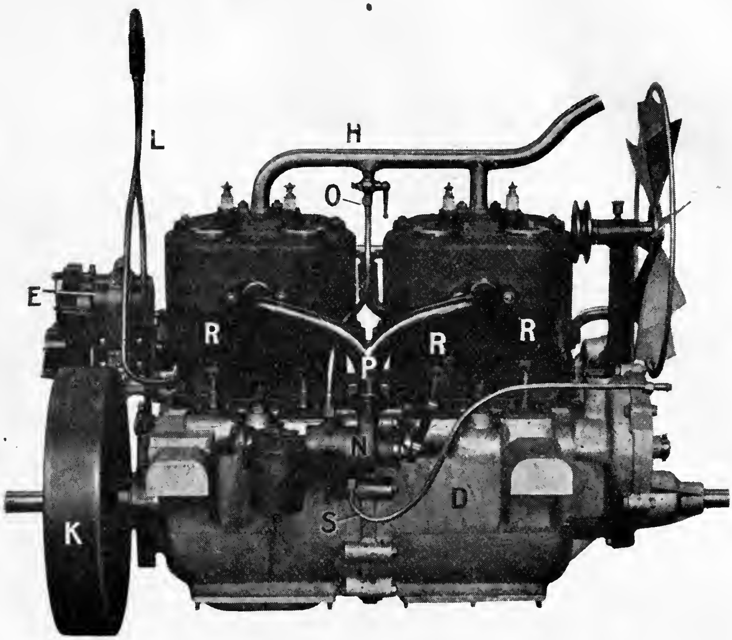


Fig. 5.—Four-cylinder Engine with Magneto Ignition.
(*See also fig.* 6 *on next page.*)

A. Cylinder castings.
B. Exhaust valves.
C. Exhaust pipes.
D. Crank chamber.
E. Magneto.
F. Water pump.
G. Water pipe to cylinder jackets.
H. Water pipe from cylinder jackets to radiator.
J. Oil filling pipes.
K. Flywheel.
L. Oil leads to pressure indicator on dashboard.
M. Fan.
N. Carburetter.
O. Water pipe to carburetter jacket.
P. Induction branch.
Q. Exhaust expansion chamber.
R. Inlet valves.
S. Petrol supply pipe.

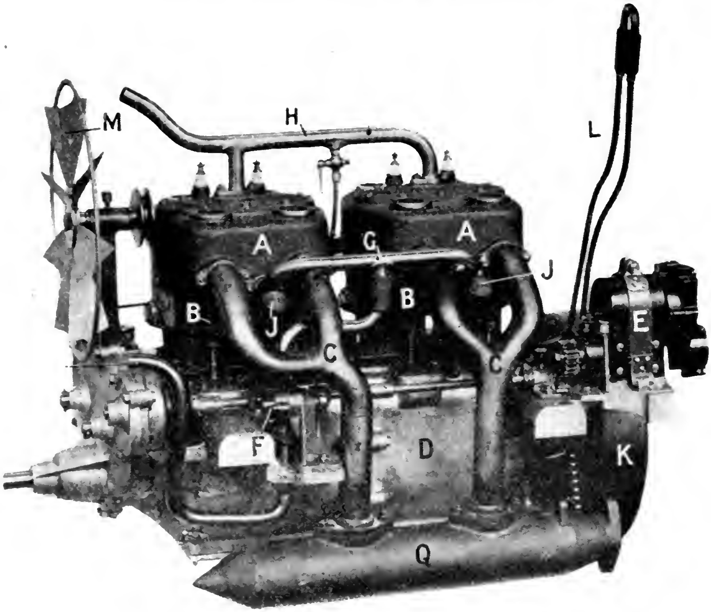


FIG. 6.—FOUR-CYLINDER ENGINE WITH MAGNETO IGNITION.

Otto Cycle of Operations.

By referring to the accompanying illustrations (figs. 7-10), it will be seen that one end of the cylinder A is closed, while the connecting rod J passes through the other end, which is open, on its way from the piston C to the crank pin, or bearing, on the crankshaft K. In the closed end of the cylinder are two valves or doors F and G. F is the inlet valve, and the gas is led to it through a pipe. G is the exhaust valve, and the waste gases pass out through it and the passage or port H to the exhaust box, silencer, or muffler, as it is variously called.

The motor has a cycle or series of four operations: 1, Suction (intake or induction); 2, compression; 3, firing (ignition, combustion, or explosion); and 4, exhaust. They are performed in two revolutions of the crank shaft, corresponding to two outward or downward strokes and two return or upward strokes of the piston.

1, *Suction*—Suppose the exhaust gases of one charge have just been disposed of, the momentum imparted by the last explosion to the crankshaft (and stored up in the flywheel fixed thereto) causes the crank to descend and to draw down the piston C by the rod J. As the piston descends, it tends to create a vacuum in the space E, which is called the combustion chamber or combustion space. The valve F opens, either by reason of the suction, or by mechanical means to be explained later. In either case, as the valve opens, the combustible gas is drawn into the space E through the inlet

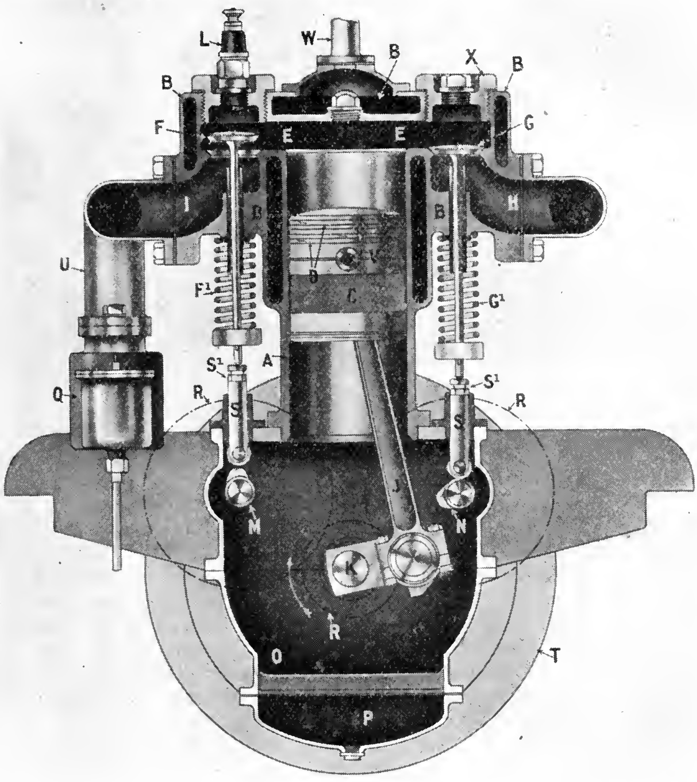


Fig. 7.—Induction Stroke.

First stroke, suction. Inlet valve open.

A, cylinder.
B, water jacket.
C, piston.
D, piston rings.
E, combustion space or chamber.
F, inlet valve.

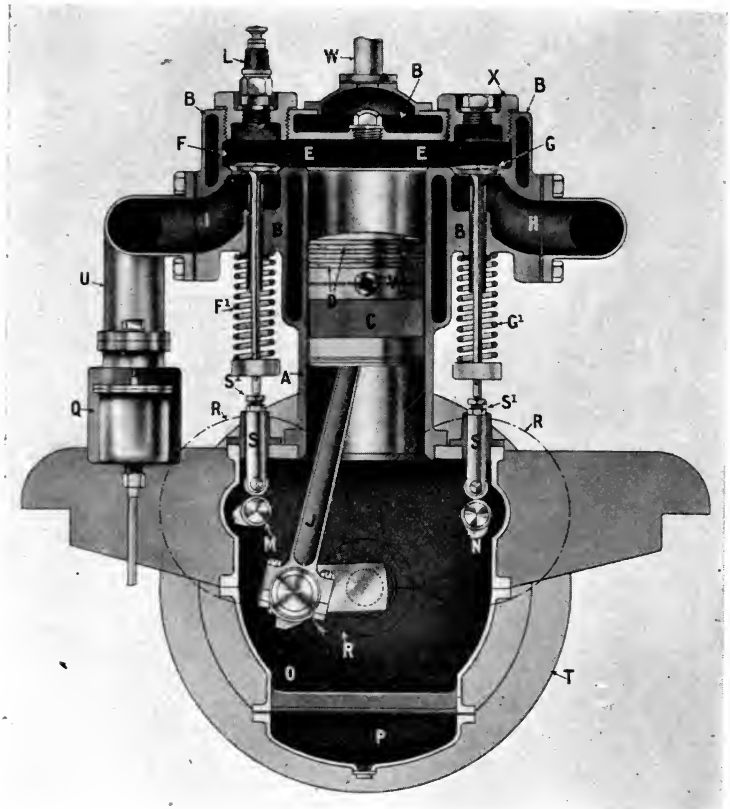


Fig. 8.—Compression Stroke.

Second stroke, compression. Both valves closed.

F1, inlet valve spring.
G, exhaust valve.
G1, exhaust valve spring.
H, exhaust outlet or port.
I, induction or inlet port.

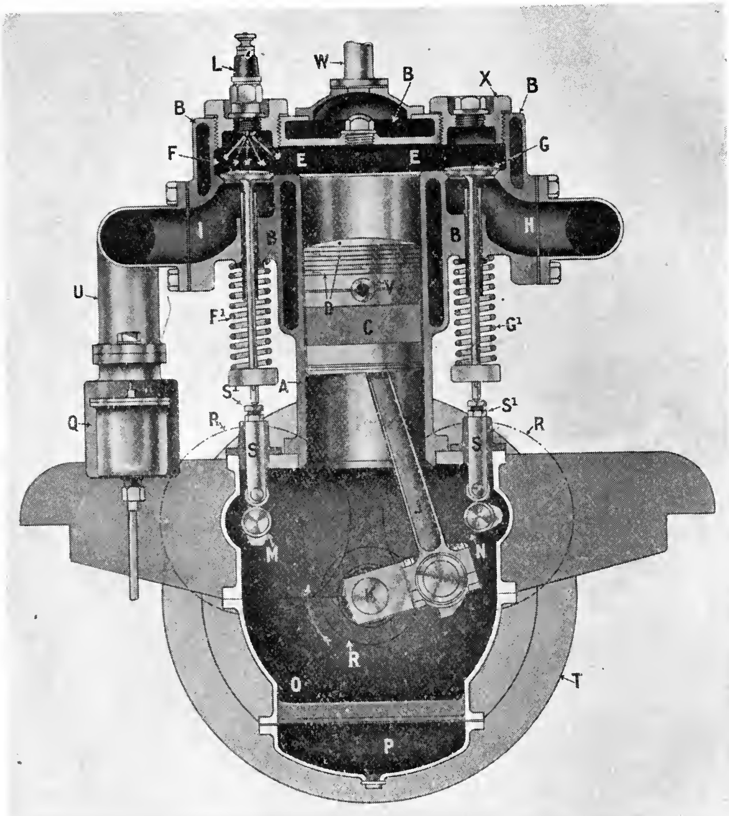


FIG. 9.—FIRING STROKE.

Third stroke, firing or explosion. Both valves still closed.

J, connecting rod.
K, crankshaft.
L, sparking plug.
M, inlet valve cam.

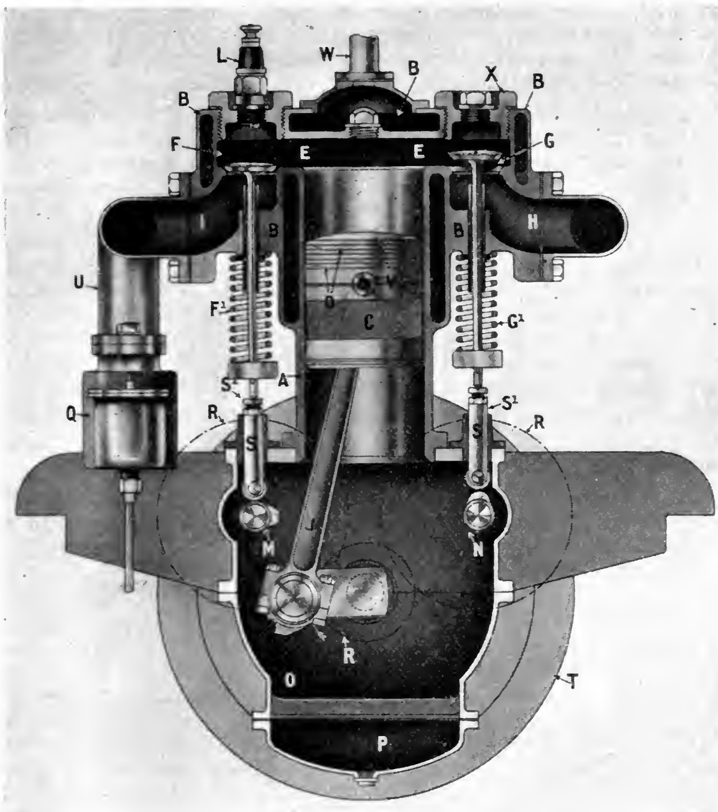


Fig. 10.—Exhaust Stroke.

Fourth stroke, exhaust. Exhaust valve open.

N, exhaust valve cam.
N_1, exhaust valve plunger, operated by cam N.
O, crank chamber.
P, oil sump at bottom of crank chamber.
Q, carburetter.
R, outline of timing wheels.
S, valve tappets.
S_1, adjusting screws of tappets.
T, flywheel.
U, induction or inlet pipe.
V, gudgeon pin.
W, water outlet pipe.
X, valve cap.

valve F. As the piston approaches the end of its downward stroke, the valve F is closed by a spring, and the gas is imprisoned in E. But it is no use firing it yet, because it could not drive the piston any further if we did, so we must let the piston return to its other extreme position near the top of the cylinder. We must not fire it before it gets to the top, else we shall make the piston return too soon and drive the crankshaft round in the reverse direction.

2, *Compression*—As the piston rises (still driven by the momentum), it compresses the gas. This compressing action makes great demands on the momentum, but it is more than worth it, because the subsequent impulse is very much more powerful than it would be if the gas were not compressed.

3, *Firing*—When the piston has got back to the top of its stroke, the compressed gas is fired by an electric spark. The consequent combustion or explosion deals a blow at the top of the piston which drives it down the cylinder with great force. When the piston has nearly got to the bottom of this stroke, the exhaust valve G is opened mechanically, and the hot waste burnt gases begin to rush past it and out through the port H to the silencer.

4, *Exhaust*—As the piston rises for the second time, it sweeps out nearly all the remaining waste gases, and leaves the motor ready to receive the next charge of mixture.

And so on again and again, the whole series recurring five hundred times per minute, for instance, in each cylinder when an engine is running at one thousand revolutions per minute—quite a normal speed with modern engines.

An explosion engine may comprise any number of cylinders, and since it increases the number of power impulses for any fixed number of revolutions of the crankshaft, thereby shortening the time during which the crankshaft is receiving no power impulse, but on the contrary the momentum stored in the flywheel is being called upon to supply power, a multi-cylinder arrangement is much to be preferred on the score of quiet and smooth running, balance, and comfort. It must not be taken for granted, however, that a motor having four cylinders, each of the same dimensions as a motor with a single-cylinder, will give exactly four times the power of the latter. Various causes contribute to the loss of a slight amount of efficiency, which, however, in view of the generally improved conditions resulting from the multiplication of cylinders, can hardly be begrudged.

Single-cylinder engines are highly to be commended on the score of their efficiency and simplicity—when made of a reasonable size and having a maximum limit of actual b.h.p. output at, say, 12 h.p. When their capacity is carried beyond this figure, single-cylinder, or "one-lung," motors are provocative of comparative discomfort, as it is impracticable adequately to balance, *i.e.*, to annul, the reaction on the body of a car of their periodic fierce explosions. The conditions governing road racing with small cars in France have led to the introduction of highly efficient single-cylinder cars, the engines of which, whilst being only nominally of 6 h.p., according to the standard of a couple of years ago, now have no difficulty in yielding something approaching 30 b.h.p. It need hardly be said that such cars, unless subjected to rigorous modifications, are entirely unsuitable for ordinary work, as, until a speed of forty or fifty miles per hour is attained, the explosions express their individuality and distinctness so forcibly that any comfort in the vehicle in which they are installed is out of the

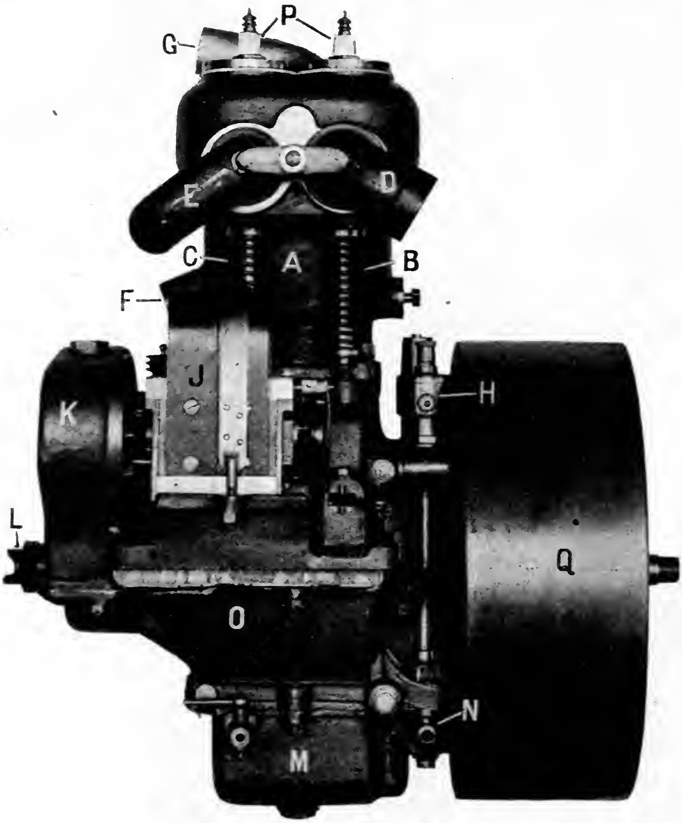


FIG. 11.—SINGLE-CYLINDER ENGINE.

A, cylinder.
B, exhaust valve.
C, inlet valve.
D, exhaust pipe branch.
E, induction pipe.
F, water inlet to cylinder jacket.
G, water outlet to radiator.
W, accumulator ignition contact breaker.
J, magneto.
K, timing wheels case.
L, starting handle clutch.
M, oil sump.
N, oil pressure pump.
O, crank chamber.
P, sparking plugs.
Q, flywheel.

question. It might be thought that the use of a very large flywheel would obviate this difficulty, but such an introduction brings in its train disadvantages which render the idea, except under special and the most favourable conditions, quite impracticable. The three principal disadvantages are: (1) Prohibitive weight. (2) The engine is unable to accelerate with any rapidity, owing to the immense inertia of a large flywheel. (3) Owing to its equally great momentum when speeded up, the clutch must be disconnected whenever it is desired to slow the car, otherwise severe stresses are imposed upon the transmission system, due to the fact that the brakes not only have to retard the car itself, but also, through the transmission, to retard the engine.

Well designed, and when of a reasonable size, a single-cylinder engine is capable of giving the greatest satisfaction. It is cheap to produce, little liable to go wrong, by its very nature it affords the maximum of accessibility, and, further, it is neither troublesome nor costly to run. For some obscure reason, but principally, perhaps, because its unbalanced impulses set every part of the car in vibration, it cannot be rendered as quiet as the multi-cylinder type of engine, but it can be made to furnish extremely smooth

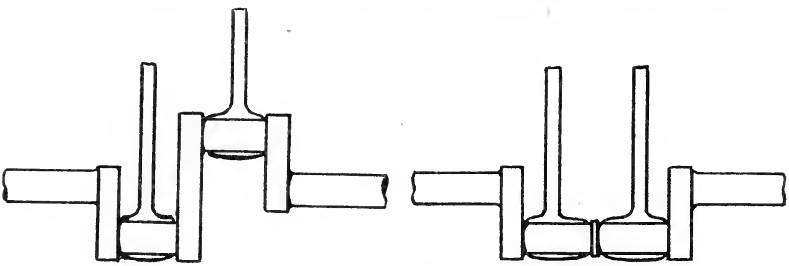


FIG. 12.—TWO-CYLINDER CRANKS, ALTERNATIVE DESIGNS.

running—when its revolutions are kept down to a moderate figure; and its general all-round reliability, together with the advantages enumerated above, have earned for it a place in the opinion of users of moderate means whence it would appear unlikely to be expelled. Fig. 11 shows a modern single-cylinder engine.

The two-cylinder, which at one time was much more popular than it is now, has lost its sway, for the reason that whilst such disadvantages as the single-cylinder motor possesses are doubled, the advantages are not increased in a like ratio. Thus, with the ordinary arrangement of cylinders, one behind the other, it is impossible to obtain a corresponding improvement of balance; whilst even with the cylinders set at 90° to one another, and driving on to a common crankpin, perfect balance is still unattainable, though, it must be admitted, it is nearer attainment.

There are two arrangements of the crankshaft of a two-cylinder motor, these alternatives being exhibited in diagrammatic form in fig. 12. Of them, (*a*) is the more common, and in this case a little thought will show that the cycle of operations is: (1) Impulse, (2) impulse, (3) blank, (4) blank, and so on. The reciprocating parts are balanced, but the explosions are not, as the one impulse follows close on the heels of the other, after which a couple of inoperative strokes occur. In the arrangement indicated in (*b*) the impulse strokes take place at regular and symmetrical intervals, thus: (1) Impulse, (2) blank, (3) impulse, (4) blank, etc., etc., but the reciprocating parts, being attached to a common crankpin, are incapable of being properly balanced. Though for private work the two-cylinder car is being rapidly superseded by the four-cylinder, with its balanced motor and advantages altogether disproportionate to the slight extra complication involved, the two-cylinder still has a field in commercial, especially cab, work, but it is open to question whether it will retain this field very long.

Much was claimed for the three-cylinder engine, which some years ago made a strong bid for popularity, but this type is now completely obsolete, and it is unlikely that it will ever be revived. Here, again, it suffered through having nearly all the disadvantages of the four-cylinder motor, whilst possessing no advantages of its own and none of those inherent in the former.

Of all types of multi-cylinder engines, the four-cylinder is deservedly the most popular, and it is likely to remain so. With this grouping of cylinders the power impulses follow so quickly upon one another that the periods when the energy is not derived immediately from the explosion itself, but is drawn from the fly-wheel, are quite momentary, and their existence, which in the case of the single, double, and triple-cylinder motors, constituted ground for serious objections, are consequently reduced to such a degree as to be practically negligible.

The large preponderance of four-cylinder cars of all powers from 8 to 135 h.p. upon the road to-day justifies the selection of this type for detailed description. From it can easily be deduced an idea of the general arrangement of all the other types of engine.

It may be thought that, since the power impulses to the crank-shaft succeed one another so rapidly—that is to say, the operative cycle of working is: (1) Impulse, (2) impulse, (3) impulse, (4) impulse

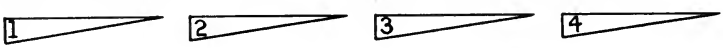


Fig. 13.—Diagram Representing the Power Impulses of a Four-cylinder Engine.

—it would be unnecessary to proceed any further with the multiplication of cylinders, as no material benefit would accrue. This, however, is not the case, for although the explosions are occurring practically all the time, that is to say, except for minute intervals, at least one cylinder is always firing, these explosions do not impose a constant force upon the crankshaft. By their nature the pressure of the explosion, and consequently, therefore, the turning power of the crankshaft, is greatest at the moment when the combustion of the explosive charge in the cylinder is actually taking place. During the subsequent expansion of the exploded gases, although considerable energy is still imparted to the piston, this energy is considerably less violent than the sudden and less lasting force of the explosion. Thus the power transmitted to the crankshaft of a four-cylinder engine may be graphically rendered as in the following diagram (fig. 13), whence it will be realised that the torque of the shaft is decidedly uneven. First there is a big force, and then this dies away, to be followed by another big force, and so on.

Just as the four-cylinder motor scores over the two, so the six-cylinder possesses advantages over the four, for by the introduction of another couple of cylinders the torque diagram is very greatly improved. The impulses are still by no means constant in force, but there is not so much difference between the weakest torque and the strongest. The alternate mountains and valleys of a torque diagram are resolved into a uniformly hilly district.

In a six-cylinder engine the cycle of operations may be expressed as in the following diagram (fig. 14), from which it can be seen that each power stroke not only follows upon, but *overlaps*, the preceding one.

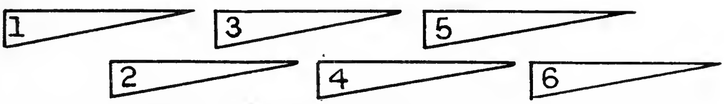


Fig. 14.—Diagram Representing the Power Impulses of a Six-cylinder Engine. (The overlapping of the impulses should be noted.)

Greater evenness of torque can, of course, be obtained by the use of an increased number of cylinders, but the gain does not compensate for the added weight, cost, and complication; hence the six-cylinder engine represents the limit of smooth running to be practically attained with the ordinary explosion engine. It is true that eight-cylinder cars have been made, but they have never risen above the level of freaks, and have never even pretended to be a commercial proposition.

Practices vary considerably in the arrangement of a four-cylinder motor, the cylinders being sometimes cast separately, more often cast in pairs, but very frequently nowadays cast altogether in one bloc, this form of engine being known as a "bloc" or "monobloc." In the last method it is not unusual to incorporate in the cylinder casting the exhaust and inlet pipes, the latter in that case being surrounded by a water jacket. The hot water jacket around the inlet pipe, by enhancing the vaporisation of the petrol, which, mixed with air, passes from the carburetter into this pipe, aids the attainment of a perfectly homogeneous mixture, the effect of which is a direct increase of power.

When the cylinders are cast separately the large amount of external piping required interferes considerably with the engine's accessibility, neatness, and cleanliness. This practice is, therefore, it is not surprising to observe, rapidly waning in popularity.

Casting the cylinders in pairs is a method which enjoys some advantages peculiarly its own, the most notable among which are that the pairs of cylinders can be detached for repair or inspection with a minimum of trouble, whilst double inlet and exhaust ducts can be cast integral with much greater ease and freedom from the likelihood of hidden obstructions than obtains in the case of the monobloc motor.

Although generally the water jackets are cast in one with the cylinders themselves, separate jackets of copper, brass, or steel are sometimes used.

Petrol.

This name properly applies to a spirit weighing about sixty-eight per cent. as much as water—not quite 7 lbs. to the gallon at 60° F. But for years the name has been stretched to cover lower qualities of spirit of as high as .76° specific gravity. There are a number of brands on the market, and so far as our experience goes they are all serviceable, though one kind may suit a particular make of carburetter better than another. It is put up in two-gallon cans, and sold at about 1/3 per gallon. In pouring the petrol into the tank, a perfectly clean funnel with a very fine gauze strainer should be used, as any foreign matter admitted is likely to choke the jet of the carburetter. If the petrol be poured through a piece of fine cambric laid over and depressed into the top of the funnel, the passage of water will be resisted. Wipe the top of the can clean before opening it. Generally the orifice of the can is covered by a screw cap having slots or notches in the top. Such a cap can be turned by the edge of a thin tyre lever, inserted in the notches. The spout of the funnel should not fit the hole in the tank tightly, or the air will not pass freely out of the tank. Some spouts have air-grooves—others may be squeezed slightly to destroy their circular form.

Some Necessary Precautions.

The regulations respecting petrol should be strictly observed; and the fact that petrol is about to be kept on the premises—if the case—should be notified to your fire insurance company.

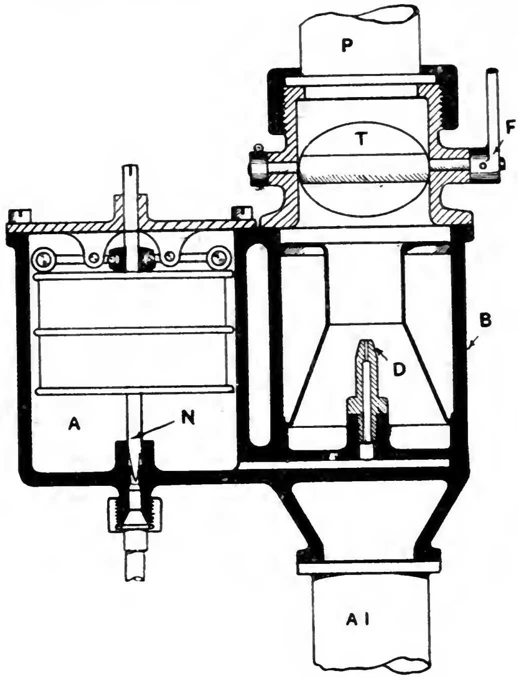
The petrol tank on the car is sometimes set sufficiently high to allow the liquid to gravitate into the carburetter. Where this is not the case, the fuel is forced out of the tank by pressure, generally obtained from the exhaust of the motor.

Petrol, though not explosive in its liquid form, is highly inflammable, and no naked light should ever be brought near it. Lighted matches idly thrown down have accounted for the destruction of a number of cars. Any leakage in the tank, the carburetter, or the connecting pipe should be immediately repaired—the petrol having been previously run off and time given for the vapour to thoroughly disperse. Should any petrol catch light, use one of the special petrol extinguishers; or failing that, throw sand on at once, or salt, or even flour—anything that will exclude the air. Water is worse than useless, as it only spreads the burning spirit about. Of course, if the fire occurs near or under the car, move the latter away at once.

The Carburetter.

It has been said, and with much truth, that the remarkable development of the modern motor car from its initial stages of inefficiency into its present status of what may be called comparative perfection is very largely due to improvements in the design of the carburetter. Up till 1903 there were to be found three types of instruments for effecting the vaporisation of petrol spirit and the admixture with it of sufficient air to form in combination an explosive mixture. The earliest of all carburetters was the "surface" type, in which the inlet pipe of the engine was conducted to a closed chamber in which was a quantity of petrol, the orifice of the pipe being above the level of the liquid. A second pipe was fixed in the chamber, or tank, one end of which was open to the air, whilst the other lay below the level of the petrol. When, owing to the effect of the engine's suction stroke, the air in the petrol chamber was reduced in pressure, a certain amount of air was drawn through the second pipe, which, in passing through the petrol, became sufficiently charged with petrol vapour to form an explosive mixture. The volume of air admitted could be altered at will, likewise the volume of explosive mixture allowed to pass to the engine. The principal disadvantage of the surface carburetter was that spirit of a very low specific gravity, and consequently of high evaporative power was necessary, otherwise a mixture of sufficient explosive power was not provided; its vogue was, therefore, a somewhat short one. The second type of carburetter is known as the "Wick," and is only fitted to one make of car—the Lanchester—on which, however, it appears to give great satisfaction. In this instrument a series of wicks were kept impregnated with spirit, a volume of air being drawn past them. Both the above forms have now given place to the spray carburetter, which, although type differs from type in design, construction, and perhaps application of principle, is more or less the same on all makes of cars. A spray carburetter is, in essentials, a petrol fountain in the inlet pipe, the object of the fountain being to enhance the evaporating capacity of the spirit. Just as in dry weather a fountain will ascend as "solid" water, and descend as intangible spray, so the object of the spray carburetter is to convert liquid petrol directly into petrol vapour, in which state it is capable of being intimately mixed with the requisite quantity of air, the value of the explosive mixture depending to a large extent upon the intimacy with which the petrol and the air are associated.

Fig. 15 represents diagrammatically the sectional elevation of the simplest possible form of spray carburetter. P is the inlet pipe of the engine, which terminates in a funnel-shaped chamber, at the bottom of which is carried the jet by means of which the petrol fountain is to be produced. The suction stroke of the piston in the engine cylinder engenders a reduced pressure in the inlet pipe, with the result that, to fill the vacuum—which, we are told, "Nature abhors"—air rushes in through the orifice around the jet. But at the same time the petrol in communication with the jet is also subject to the reduction of pressure in the pipe, and also rushes out through its jet with the same purpose and into the inlet pipe, when the drops of petrol from the fountain are, on coming into contact with the air rushing through the pipe, rapidly evaporated, mixed with air, and carried as an explosive mixture to the cylinder. It will at once be seen that the proportions of spirit and air are regulated by the relative sizes of that orifice, of the inlet pipe open



A, float chamber.
A1, air inlet pipe.
B, carburetter body.
D, jet.
F, throttle lever.
N, needle valve.
P, induction pipe.
T, throttle valve.

Fig. 15.

to the air and of the orifice of the petrol jet. If the latter were too small, then the amount of petrol sucked into the inlet pipe would be too small. On the other hand, if the air inlet were too small, too large a volume of petrol would be sprayed. The size of the jet, and hence also that of the air inlet pipe, is regulated by the size of the engine which it is to serve with mixture. If the jet and the air intake were both increased in capacity, then the petrol would lose the spraying effect which it derives from issuing from a very small orifice, and the engine would not run smoothly. Again, if in the carburetter of a large engine both the jet and the air intake were unduly small, although of correct relative size, then the engine would suffer a loss in power due to the difficulty of obtaining a sufficient quantity of explosive mixture into the cylinder in the short duration of the inlet stroke.

It will be readily realised that the volume of petrol sprayed depends to a considerable extent upon the level of the liquid in the jet. If the petrol came to within 1-16in. of the jet orifice, it is obvious that more petrol would be sprayed than if it came only within an inch. If, therefore, the jet were in direct communication with the petrol tank, the level of the latter in falling, as more and more liquid was used, would cause the level in the jet to fall in a similar manner, so that less and less petrol would be sprayed, and consequently the mixture would never be the same.

It is accordingly necessary to incorporate into the carburetter a device for automatically maintaining a constant level in the jet. This consists of a chamber, known as the "float chamber," in direct communication, as concerns outlet, with the petrol jet. It is also in communication with the petrol tank *via* a valve controlling the admission of petrol to the chamber, which valve is in turn controlled by a float. The latter is a hollow sealed vessel of thin metal, which, supported by the petrol in the float chamber, operates a needle valve through which fresh supplies of petrol are admitted as required. As soon as the petrol reaches the required height, *i.e.*, generally about 1-16in., below the orifice of the spraying jet, the needle valve is caused to cut off the supply of spirit, whilst it automatically allows more to be admitted as soon as the petrol level sinks.

The needle valve is sometimes at the top of the float chamber, in which case the float may be directly attached to the needle valve, but more often at the bottom, when the needle valve is actuated by the float through a couple of levers, which cause the downward motion of the float to be transformed into an upward motion of the needle valve, and *vice versa*.

Owing to variations in the temperature and pressure of the atmosphere, it is impossible to arrange a carburetter of the essentially simple kind illustrated above which will furnish the best possible explosive mixture under all conditions. Thus, for instance, when the weather is cold more petrol is required in the mixture owing to the difficulty it meets with in evaporating; whilst in warm weather the reverse is the case. An arrangement is accordingly provided whereby the supply of air admitted to the mixture can be varied in volume. This arrangement is called the "extra air inlet." For the sake of convenience, the size of the *main* air intake around the jet is designed to give a "rich" mixture, *i.e.*, one in which the quantity of petrol is in excess of its correct proportion, the extra air inlet being fixed generally some little distance above the jet, and in its simplest form consisting of a rotating or sliding shutter operated by hand. By means of this extra air inlet, differences of temperature can be met with differences by variations in mixture, as also the requirements of the engine. Thus, when running down hill and fast, the engine will give the best results when furnished with more air than it normally requires in moderate running or uphill; and it will be found that the faster the engine runs the more air will it require in order to develop its maximum power.

Many modern carburetters comprise an extra air inlet operated automatically through the medium of a mushroom valve precisely similar to the automatic inlet valve used in some makes of engine. The valve is controlled by a spring loaded to the required degree, as ascertained by experiment, and opens against the action of that spring when, owing to increased speed of the engine, the suction in

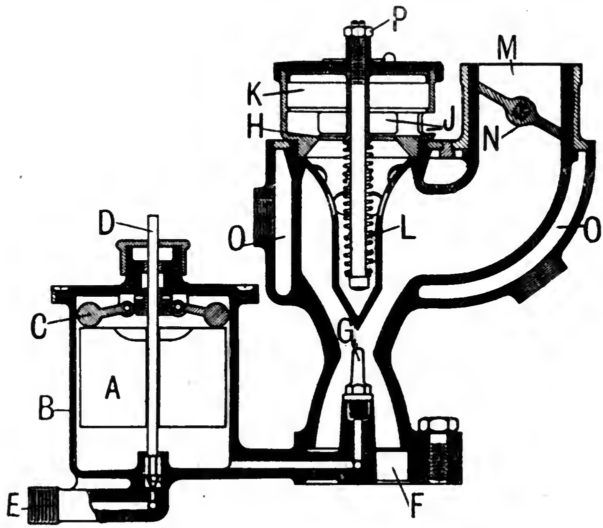


Fig. 16.—Section of Automatic Carburetter.

A, float.
B, float chamber.
C, toggle levers.
D, needle valve spindle.
E, petrol supply.
F, fixed air supply.
G, petrol jet.
H, automatic air valve.
J, air inlet orifices to automatic valve.
K, dashpot or damping chamber.
L, spring of automatic valve.
M, induction pipe leading to engine.
N, throttle valve.
O, water jacket spaces.
P, adjustment of automatic valve.

the mixture pipe becomes greater than usual. In order to prevent the valve from continually opening and closing with every beat of the engine, it is usually fitted with a "dash-pot" or brake, the effect of which is to damp its continuous and varying vibration into a steady and much slower fluctuation.

The rapid evaporation of any fluid is always accompanied by a decrease in temperature, and were steps not taken to guard against the occurrence the carburetter jet would, in cold weather, not infrequently freeze up. Some makers, therefore, completely encase the mixing tubes of their carburetters with hot water-jackets supplied from the jackets around the cylinders; whilst others prefer to rely upon the acquisition of warmth by drawing some of the air for the mixture from a box surrounding the exhaust pipe.

The throttle valve, by means of which the engine is supplied with a larger or smaller volume of explosive mixture, as circumstances dictate to the driver of the car, is situated between the extra air inlet and inlet pipe proper, and may be either of the disc, iris diaphragm, sliding piston, or rotating piston type.

The above remarks apply to the vast majority of modern spray carburetters, but noticeable divergences from standard practice may often be met with. Amongst them the chief development is the introduction of more than one jet ; if two jets be used, one may be small and the other large—the former for use when the engine is "running light," the latter coming into play when the throttle is opened. Any number of jets may be employed, and in general they are cut into and out of action by the operation of the throttle. The advantage of this practice is that it makes for fuel economy, as well as tending to produce a highly homogeneous mixture. Each jet in a multiple-jet carburetter should be provided with its own separate choke tube or air passage.

In several prominent makes of car, the mixing tube of the carburetter is of abnormal length, this being so for two reasons—firstly, in order to keep the float chamber and the jet as low down as possible, and thus enable a good "head" of petrol to be present with a gravity system even on the steepest hills ; and, secondly, to provide a more advantageous opportunity for the petrol vapour and air to intermingle. They pass up the extended mixing tube in the form of a comparatively small amount of rich mixture, which is very closely mixed during its transit up the long pipe (this is not infrequently hot water-jacketed) ; at the upper end of the pipe is the extra air inlet (of whatever kind), which dilutes the rich mixture to the proper degree.

As already indicated, the spray carburetter, having become much more popular than the wick and surface types, soon came to be adopted as standard practice on all petrol cars ; but for some considerable time did not lend itself to the improvement which other parts of the car underwent. This was, no doubt, largely due to the fallacious idea that the ordinary jet sprayed the petrol in the best possible way ; and in consequence there were very few designers who, accepting that fallacy, were able to increase the efficiency of the instrument. It has now, however, been established beyond the possibility of doubt that the earlier types of spray carburetters produced anything but the sort of spray that was to be desired ; on the contrary, they continually injected considerable quantities of liquid petrol into the engine cylinder, with the natural result of coarse running and lack of efficiency. This was especially noticeable in the case of large cars, in which a jet with a very large orifice would be provided with quite a small mixing tube for the evaporation of large volumes of spirit. It is to obviate the likelihood of unvaporised petrol finding its way into the engine cylinder, and to afford every opportunity for the petrol and air mixture to make itself homogeneous, that the "multiple jet" and the long "rich mixture tube" types of carburetter have been evolved.

The Piston and Rings.

The piston is, in form, very like the cylinder, that is to say, it consists of a tube closed at one end. It is made a little smaller in diameter than the bore of the cylinder, so that it may slide freely in the cylinder, and not jam in it when it expands with the heat. In order to prevent leakage between the walls of the piston and cylinder, some three or four grooves are turned in the exterior of the piston near its closed end, and in each groove is placed a piston ring. These rings are generally bored slightly eccentric, and are cut through obliquely at the thinnest part. They are normally a little larger in diameter than the bore of the cylinder, so that they press against the walls of the latter when in action; and at such times the rings should be of perfectly circular form externally, and the cuts or "slots" should be very nearly closed.

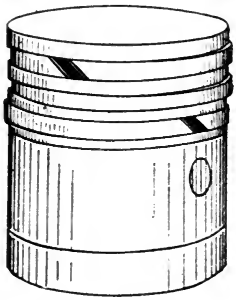


FIG 17 —PISTON WITH RINGS.

Connecting Rod Bearings.

Near the closed end of the piston is mounted a spindle, called the "gudgeon pin." The upper end of the connecting rod rocks on this pin, and it is important that the pin itself should not move, and that the means for fixing it should not get loose and drop away, or considerable damage may be done. It is not within the scope of this book to detail the devices that have been employed, but one of the simplest is to form one of the piston ring grooves coincident with the ends of the gudgeon pin which extends right through the walls of the piston. As the piston and connecting rod, being reciprocating parts, are subject to innumerable and sudden reversals of their direction of motion, they should be made as light as possible, consistently with being strong enough to withstand the explosions and convert the impulses into a rotary motion of the crankshaft. The gudgeon pin end of the connecting rod is called the small end, and the other the big end. The journals, or bearings, at the big end are adjustable, so that wear may be taken up from time to time.

The Crank Case.

The crankshaft is mounted in bearings in a casing called the crank case. The case is usually made of aluminium alloy for lightness; and, with bracket extensions, it forms the means of attaching the motor to the frame of the car; it also serves as an oilbath, into which the cranks dip as they rotate and splash the oil about so that a quantity falls into little ducts which lead to the bearings. The crank case should be made with "manholes," through which the big end bearings may be adjusted; if they are large enough to allow of withdrawing the piston, so much the better. Another arrangement is to divide the crank case horizontally, and fix the crankshaft bearings to the upper part of the case. This allows of the lower portion of the case being detached without disturbing anything else, and when this part is removed, those above it can be dealt with as may be required. A combination of the two plans is best, as the second one entails a lot of upside-down working.

Where the crankshaft has more than two cranks, there should be a bearing on each side of each pair of cranks, otherwise there is a danger of the crankshaft bending, and even breaking, under its work, unless it be made of especially stout section to prevent any "give" taking place.

Function of the Half-speed Shaft.

As each operation of the motor happens only once in two revolutions of the crankshaft, the firing of the charge and the opening of the exhaust valve are controlled by a shaft rotated at half the speed of the crankshaft. For this purpose gear wheels are fixed to the crankshaft and to the "half-speed shaft"; these wheels gear together, and the wheel on the half-speed shaft has twice as many teeth as the wheel on the crankshaft. On the half-speed shaft is fixed a cam, *i.e.*, a ring or collar bearing a hump or projection on its periphery. On this cam stands a rod or plunger, and this plunger is in line with the stem of one of the valves. Hence, at every revolution of the half-speed shaft (and so at every alternate revolution of the crankshaft), the cam comes round and lifts the valve, through the plunger.

The Exhaust Valve.

It should be pointed out that the term valve is used to express both a whole and a part. In the larger sense the "valve" means both the door and its frame—the disc and its seating; in its smaller sense it means the door or disc only. From the form of the disc, and the stem under the disc, this type of valve is called a mushroom valve. Owing to the length of the stem used in motors, the valve looks perhaps more like a French nail than a mushroom. The seating forms a shoulder in a passage communicating with the combustion space on the one hand and the exhaust pipe on the other. Sometimes the exhaust valve is arranged directly over the combustion space in the cylinder head, but more often it is arranged in an exhaust valve box at the side of the cylinder, as shown in the illustrations. It will be observed that the upper part of the stem works in a guide, and that a plate or washer is mounted on the lower part of the stem. Between the guide and the washer there is a strong spring, which normally holds the valve tight down on its seating. The edge of the valve and the seating are generally bevelled, and carefully ground to the same angle, so hat the valve may be gastight when closed.

It will be remembered that the exhaust valve is only open during one of the return strokes of the piston. This corresponds to half a turn of the crankshaft, and to a quarter of a turn of the half-speed shaft. Hence the hump only occupies about a quarter of the periphery of the cam. In practice, it is found best to allow the exhaust valve to open before the piston has quite finished its driving stroke, and to close exactly at the top of the return stroke. The valve should open fully and close completely as promptly as possible, but each end of the hump must be inclined—the forward end to lift the valve plunger in ordinary running, the rearward end to do the same in case the engine is accidentally reversed. Were it not for this last consideration, the hump might have a radial or precipitous end. Sometimes a hinged arm is interposed between the surface of the cam and the foot of the plunger; this is useful in overcoming the transverse action set up by the inclines when operating directly on the plunger, and (when an adjustable arm is used) in providing means for controlling the motor by varying the lift of the valve. The exhaust passage or port, the valve itself, and the exhaust pipe should be of ample dimensions, so that the exhaust gases may be cleared out with as little resistance as possible. A good many motors are now constructed with a large chamber, into which the exhaust ports of all the cylinders open. This provides for more ready expansion of the gases than if they are led directly into the more or less restricted exhaust pipe.

When the cylinders of the motor are separate castings, the branches of the exhaust pipe should be connected in such a way as to allow for a slight relative movement due to unequal expansion of the cylinders.

Silencing the Exhaust.

The object of the exhaust box is to silence or muffle the noise of the exhaust. At the same time it must allow of the ultimate egress of the gases as freely as possible, otherwise it will set up a back pressure, which will reduce the effective power of the engine. In the box are a number of tubes or plates, which turn the stream of exhaust gases first one way and then another, as in a maze, allowing them all the time to expand more and more, and ultimately allowing them to pass out through a number of fine holes or a pipe. These holes, or the pipe, should not point directly towards the ground; if they do, the exhaust will greatly augment the dust raised; they are usually directed backward. The box should be of good dimensions; and should be carried under the back part of the car, so that the occupants may not be troubled by any fumes emitted by it. Do not forget that the exhaust pipe and box get extremely hot, and nothing liable to be damaged by heat (fingers, tyres, eatables, etc.) should be brought near them.

The Inlet Valve.

The inlet valve may be opened either by the suction of the piston, or, generally nowadays, positively like the exhaust. Where the latter form is employed, it is operated by a cam on a half-speed shaft like the exhaust valve. In fact, the valve parts can be made duplicates of each other, thus reducing the number of "spares" that should be carried. The contention that an engine with mechanically-operated inlet valves can be run slower than one with automatic inlet valves is to some extent supported by practice. But, however the valve is operated, the charge is drawn into the cylinder by the so-called suction of the piston.

The inlet valve is arranged in the port or passage connecting the inlet pipe with the combustion space. The inlet valves with their boxes may be arranged on the same side of the cylinders as the exhaust valves, in which case they are all operated from cams on a single shaft. If, however, the inlet valves are arranged on the other side of the cylinders, a second half-speed gear and shaft are necessary, but the various parts are rendered more easily accessible, and the timing of the exhaust and inlet valves can be regulated independently. This timing is a very important matter, as, unless the valves open and close just at the right times, the engine will not give off its full power. The close fitting of the valve head on to its seating is also important, and to facilitate the grinding-in of the valve, the head should be provided with a screwdriver slot.

The inlet and exhaust ports should be short, and, generally, the combustion space should be as free from pockets as possible, as these tend to retain portions of the exhaust gases which mingle with, and deteriorate, the incoming charges of combustible gas. Externally, also, the motor should present a clean appearance, and all fixings should be well secured and readily accessible.

CHAPTER III.

Ignition.

WE now come to one of the most interesting parts of the whole subject. If you know nothing of electricity, never mind. No one knows for certain what it *is*, but it is fairly easy to learn enough of what it *does* for the present purpose. Although magneto ignition is now the more prominent, it will be convenient to deal with the battery and coil system first.

The object of either apparatus is to obtain a spark in the combustion chamber, and this spark is made to occur between two points set a little distance apart. The space between the two points forms a breach in the electric circuit, and the electricity in jumping the breach causes the desired flame or spark.

Elementary Electricity.

One analogy is extremely useful to remember—electricity and wiring are very like water and piping. Suppose we have a tank of water and a large pipe having both ends connected to the tank. Means are provided for causing the water to circulate slowly through the tank and pipe, as by introducing a pump into the system. We next make a breach in the pipe. What happens? The water simply dribbles down from the breach, and we are done. We must get enough pressure on the water to make it jump across the gap. Instead of increasing the power of the pump, we will introduce into each of the broken ends of the large pipe a length of small pipe, and direct the free ends of these at each other, leaving a short gap between them as before. The pump insists on the water getting round the system in a certain time, and so it has to pass through the first length of small pipe at very high speed. There is only a small quantity of water in the small pipe, but it is under great pressure. Consequently it squirts out of the end of this small pipe and right across the gap into the end of the other one. By working the pump intermittently we can get intermittent squirts.

The interpretation is as follows: The tank of water corresponds to a collection or battery of cells, from which electricity will flow. The large pipe is the (primary) wire or other conductor through which the electricity flows in full volume, but at a low pressure. The pump, in combination with the small pipes, suggests (rather imperfectly) the induction coil, by which the (primary or low-tension) current of large volume and low pressure provokes in the secondary or high-tension winding a current of small volume and high pressure. The small pipes also correspond to the high-tension wire, and the gap between them is the gap between the points of the sparking plug which is screwed into the combustion space of the motor. The intermittent working is effected by a contact breaker, a device which is introduced into the primary circuit, and allows the electricity to flow for only short periods at regular intervals, as required for the sparking to take place in turn with the other operations of the motor.

The wire is more like the hole in the pipe than like the pipe itself, so the wires that have to carry the electricity away from the battery to the coil, and away from the coil to the sparking plug, must be provided with a covering or insulation to keep the current to its course. Like a schoolboy, the current displays a wonderful avidity for getting home, so the insulation of the return wires is of little, if any, importance; and, indeed, in practice, the latter wires are largely dispensed with, the metal work of the car being used for most of the return conductor. As to the outgoing wires or "leads," if the insulation is defective in the neighbourhood of conducting material, we must expect to lose our electricity—it will "short circuit," *i.e.*, take a short cut for home, without doing its work; like we lose water from a leaky pipe, only more so. A somewhat similar point is that, though electricity, like water, will take the path of least resistance, yet where there are other outlets, some of the current may be expected to flow through them—the whole river does not run out through the main channel of the delta.

Electricity is rather more like gas than water in one quality. Water may be regarded as incompressible, but electricity appears to have a certain amount of elasticity; if it meets with an obstruction to its flow, it will gather or compress, and then, if the obstruction be not too great, will spring past it.

The quantity or volume of electric current is calculated in ampères, and is measured by an instrument called an ampèremeter or ammeter. The pressure of the current is reckoned in volts, by a voltmeter. The product of ampères and volts is called watts. For example, 10 ampères × 5 volts = 50 watts, or ½ ampère × 10,000 volts = 5,000 watts.

Magneto Ignition.

The great objection to the use of batteries, whether wet or dry, is that the supply of electricity is not permanent—the former kind requires recharging from time to time, the latter has not even a renewable existence. One looks, therefore, for a source of electricity that will be replenished "while you go on" instead of "while you wait." And it is found in the magneto system, by which a dynamo driven by the engine generates electricity at a very small expenditure of power.

The dynamo consists essentially of a number of steel magnets of ∩ or "horseshoe" shape, arranged so as to form a tunnel or long arch, and an armature wound with insulated copper wire and disposed along the arch so as to lie between the ends or poles of the several magnets. The magnets are excited in the first place by a powerful dynamo, and, as they retain their magnetism for a very long time (sometimes for a number of years), they are called permanent magnets. This term distinguishes them from electro-magnets, which are made (as in the case of the core of a trembler coil) of soft iron, and are only excited so long as a current of electricity is passing through wiring coiled round them.

The flat horseshoe magnets sold largely as toys are permanent magnets, and "lines of force" pass across from one pole, called the north or positive, to the other, which is called the south or negative. If a conductor of magnetism (such as iron, but not brass or copper) be introduced between the poles, the lines will tend to deflect and pass straight through the conductor. The armature, being of soft iron, induces the lines of force to pass through it in this way.

The Armature Winding.

Now it was discovered by Faraday that if a circuit of copper wire be caused to cut these lines of magnetic force, an electric current would be set up in the wire. The current flows in one direction when the wire passes across the lines, say, upwards; and it flows in the opposite direction when the wire crosses the lines the other way. This is called an alternating current. In practice, the armature is provided with two, deep, longitudinal grooves, one diametrically opposite the other, so that the transverse section looks something like the letter H. Insulated copper wire is wound on to the armature lengthwise, so as to lie in the grooves. The wire used is short and thick or long and thin, according as a low-tension or a high-tension current is required. A spindle is mounted on a brass plate or bridge at each end of the armature, and bearings are provided for the spindles, so that the armature may be rotated by the engine. The armature, with its winding, takes the form of a solid cylinder, and the magnets are fitted with concave pole pieces, almost in contact with which the armature rotates.

Generation of the Current.

When the crossbar of the "core" of the armature lies transversely between the pole pieces, the lines of force run directly through it (fig. 18); and even when the armature has been turned through such an angle that the bar points for the upper part of one pole piece and

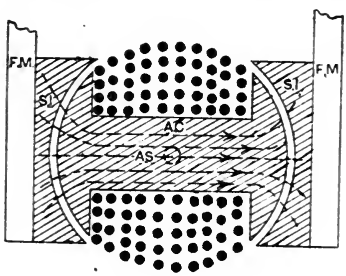


FIG. 18.

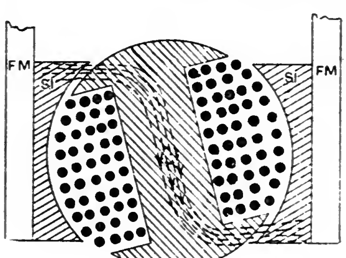


FIG. 19.

FIGS. 18-19.—LINES OF FORCE.

A C, armature core.
A S, armature spindle.
F M, ends of horseshoe magnets.
S I, pole pieces.

the lower part of the other. the bulk of the lines will prefer to take the distorted path through the core instead of running directly across from pole to pole through the air (fig. 19). But while the core is turning from this position to about the vertical, the copper wire will cut all the lines of force (fig. 20). The uppermost lines of force starting from the north pole will jump from the lower part of the south pole to the upper part thereof ; and the lowermost lines of force entering the south pole will drop from the upper to the lower part

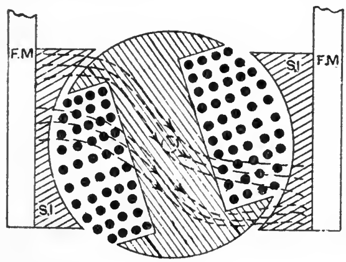


FIG. 20.

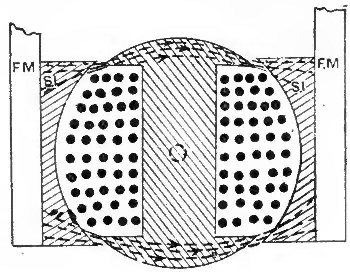


FIG. 21.

of the north pole. As each jump and drop takes place, the lines of force are cut by the coils of the armature winding, and a current is set up therein. By the time the core has reached a vertical position the current will have attained its maximum, and the lines of force divided into two parts, one passing through the upper segment of the armature and the other through the lower (fig. 21).

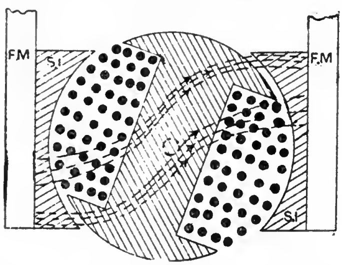


FIG. 22.

Then, as the armature continues its turning movement, the cutting begins again, but the opposite way —both as to the lines and the coil, so that the current continues to flow in the same direction, but with decreasing intensity (fig. 22). When the core has become horizontal again the current has ceased, and on restarting it flows in the opposite direction. When the most lines of force are being cut, that is, about the times the core attains its vertical positions, the currents are at their highest or "maximum," and it is at or about one of these two times that the current is generally utilised. When no lines of force are being cut, the voltage falls to zero.

The Armature Spindle.

One can, by suitable adaptations, draw off the electricity generated, either as an alternating or as a continuous current. For an alternating current one end of the armature winding is generally earthed to the body of the armature, and the other is passed axially through one end of the armature spindle which is made hollow for the purpose. This end of the wire is insulated from the spindle, and is either furnished with a metal terminal or is connected to a metallic ring; the terminal or the ring is suitably insulated from "earth." If a terminal is used, the current is received by a spring blade or brush bearing either directly against the end of it or through a carbon rod or other suitable conductor. In the case of a ring "commutator," the same rotates co-axially with the armature, and a brush bears upon its periphery. The blade or brush is insulated, and the current is led therethrough to an insulated wire, which is connected up to the apparatus to be operated. A continuous current is not often used for magneto ignition. In conjunction with and coupled to the primary circuit is a "condenser"; the construction and function of this are described later when dealing with the induction coil—its characteristics being the same as in the magneto.

The High Tension Magneto.

Nearly all high-tension magnetos are arranged upon the lines illustrated in figs. 23, 24, and 25. The primary and secondary windings are continuous, as before, and from the point of junction between them the primary current is led to the insulated platinum point of the contact breaker, the principal points of which rotate

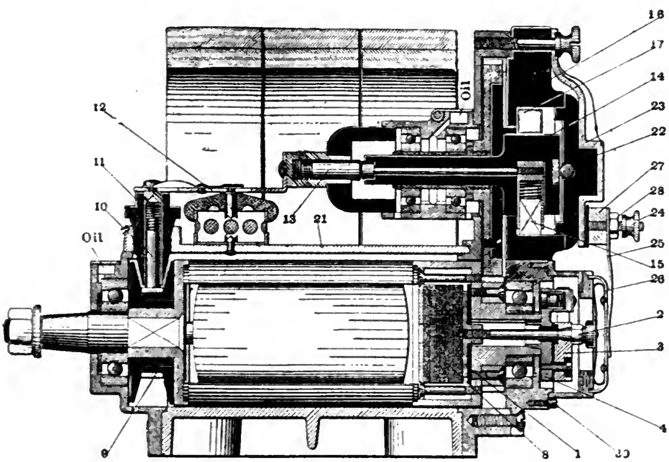


Fig. 23.—High Tension D4 Magneto. Longitudinal Section

with the armature. The other platinum point is on one end of a rocking lever, the other end of which, in revolving, makes contact with two rollers arranged diametrically opposite to one another on a plate. Each time the lever strikes a roller the contact is broken at the platinum points, and a high tension current is induced in the secondary winding. The result of this is the occurrence of the usual firing spark, the time of which can be advanced and retarded by rocking the plate carrying the rollers. The condenser also rotates with the armature, being mounted on one end thereof. The live end of the secondary winding is connected to an insulated slip-ring at the other end of the machine. The current is collected from the ring by a radial carbon brush, and is led therefrom to another radial brush which is rotated at half the speed of the armature and distributes the high tension current to a number of

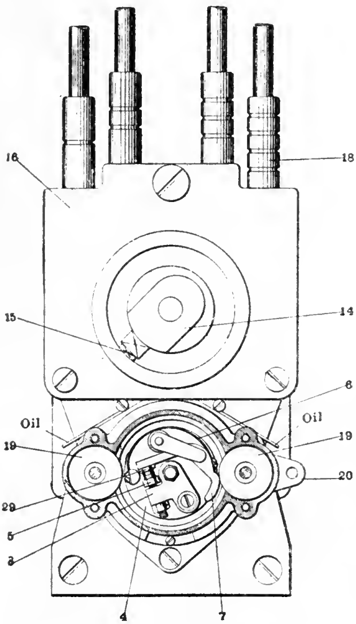


FIG. 24.—HIGH TENSION MAGNETO. END VIEW.

1. Brass plate.
2. Contact-breaker screw.
3. Platinum screw block.
4. Contact-breaker disc.
5. Long platinum screw.
6. Contact-breaker spring.
7. Contact-breaker lever.
8. Condenser.
9. Slip ring.
10. Carbon brush.
11. Carbon holder.
12. Connecting bridge.
13. Contact carbon.
14. Rotating distributer piece.
15. Distributer carbon.
16. Distributer disc.

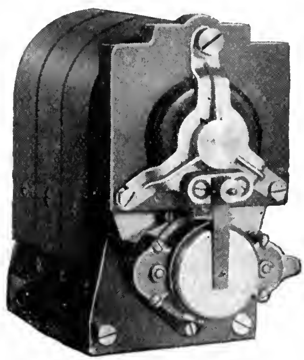


FIG. 25.—HIGH TENSION MAGNETO WHICH IN GENERAL APPEARANCE IS THE SAME AS FIGS. 23 AND 24.

17. Metallic segments.
18. Contact plug.
19. Fibre roller.
20. Timing lever.
21. Dust cover.
22. Cover.
23. Triangular clamp.
24. Nut for switch wire (short circuit)
25. Spring for fastening brass cap.
26. Brass cap.
27. Brass block for fastening spring of brass cap.
28. Fixing bolt.
29. Short platinum screw.
30. Stop screw for timing lever

insulated metal blocks and thence to the sparking plugs in turn. A swich terminal is provided for short circuiting the primary current when the magneto is being driven but not used. A spark-gap is arranged between one of the high tension leads and earth to avoid breaking down the insulations in case one or more of the sparking plug connections is at fault. Both the contact breaker and the distributer covers are very readily detached, and accessibility is a strong feature of the whole machine.

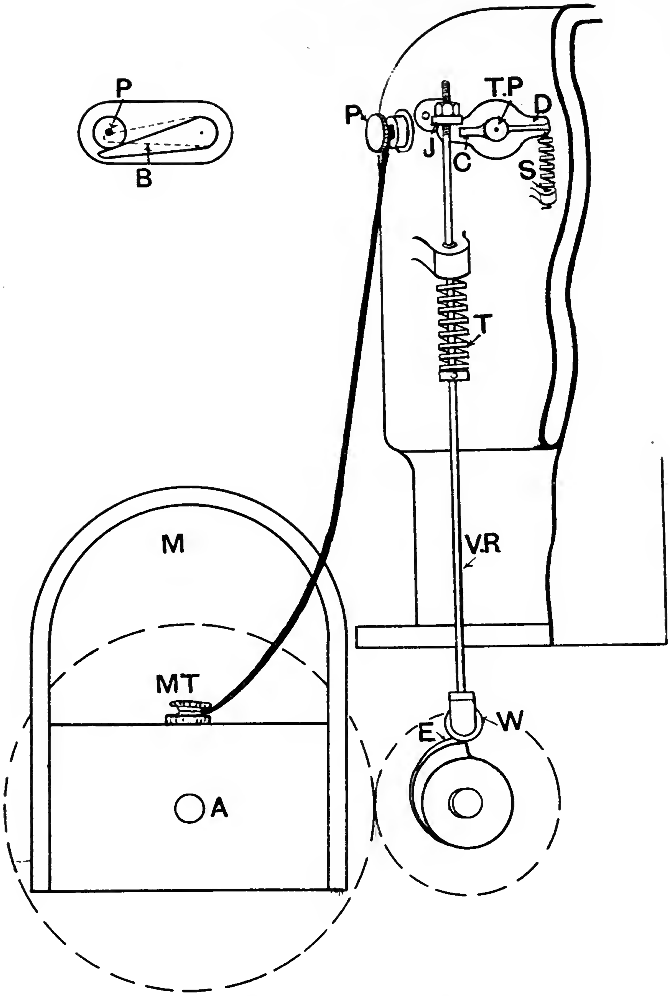


Fig. 26.—The Simms-Bosch Low-tension Magneto System.

A, armature spindle.
B, contact lever inside cylinder, operated by C.
C, D, arms attached to spindle of B.
E cam operating make-and-break.
J, tappet acting on C and attached to VR.
M, magnets.
MT, terminal of low tension wiring.
P, insulated plug.
T, spring pulling down VR.
TP, tappet lever pivot.
VR, tappet rod.
W, roller of VR lifted by E.

Low Tension Magneto.

So far as the magnets, the armature core, and the sleeve are concerned, the low-tension magneto is similar to the high-tension system just described. The armature winding, however, consists of a single length of insulated wire, one end of which is earthed, while the other end is connected to an insulated terminal.

Combustion Chamber Contact Breaker.

In low-tension magneto ignition a spark is produced in the combustion chamber, the sparking points in the latter case being really of the nature of a contact breaker. Two holes are formed in the walls of the cylinder head. In one hole is secured an insulated pin P. A wire connects the outer end of this pin with the terminal MT on the magneto; the other end of the pin projects into the combustion space. In the other hole oscillates another pin, the bearing being made gastight so that there may be no leakage of compression. This pin carries one arm B inside the cylinder and two (C D) outside. A spring S is connected to the outer arm D so as to hold the inner arm normally in contact with the inner end of the insulated pin. Close to the other outer arm C is a vertical rod VR, the lower end of which is provided with a roller W running on the periphery of the cam. The rod is mounted in a guide, and is provided with a spring T, which impels the rod downwards. To the upper end of the rod is secured a projection or tappet J adapted to strike the outer arm C on the coned pin.

As the cam E rotates it holds the tappet J on the rod clear of the second arm until the shoulder of the cam passes under the roller, when the rod VR drops suddenly, and the tappet, knocking the second arm, oscillates the coned pin, and causes the inner arm B to break contact with the insulated pin P. As the pin is earthed, the electric circuit is complete as long as the inner arm remains in contact with the insulated pin. But the separation of these parts breaks the circuit, and the momentary continuation of the flow of current is exhibited in the form of a spark; and as this spark occurs within the combustion space, the charge of compressed gas therein is ignited. The cam E lifts the rod VR, and so allows the inner arm to resume contact with the insulated pin, in plenty of time before another break is required for the next spark. By swinging the rod VR a little to right or left of the axis of the cam, the shoulder can be made to operate earlier or later, and the time of sparking varied. The apparatus is comparatively simple, but has many disadvantages. It is not quiet in action, and the various parts are liable to wear rapidly and get out of adjustment. In modern cars it has been almost entirely displaced by the high-tension magneto system.

Battery Ignition.

The battery may be either of the primary or of the secondary order. But the words "primary" and "secondary" do not here refer

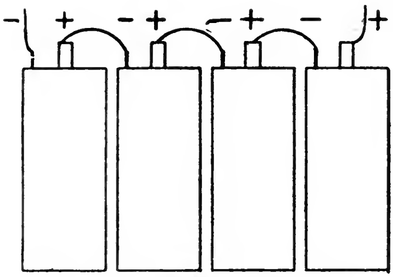


FIG. 27.—DRY BATTERY, WIRED IN SERIES.

to the degree of pressure in the current, so much as to the manner in which the electricity arrives in them. A primary battery usually consists of three or four separate cells, each comprising a zinc element and a carbon element. The zinc is commonly employed to form the casing of the cell itself, while the carbon is in the shape of a bar. The bar is packed round with a depolariser of oxide of manganese and bits of carbon. The space between the wrapping of depolariser and the inside of the zinc casing is filled in with a damp paste compounded of plaster of Paris and sal ammoniac. The top of the cell is sealed (except for a vent hole) with pitch, marine glue, or the like. The carbon is the positive pole of the battery, and the zinc is the negative; each is provided with a screw-threaded pillar or other "terminal," and the positive terminal in one cell is coupled up to the negative in the next cell by metal wires or strips. This is called wiring or coupling "in series," and it gives a comparatively high voltage with a comparatively low expenditure of current. If all the positive (carbon) terminals were connected together, and all the negative (zinc) terminals were connected together, the cells would be said to be coupled "in parallel," and the battery would give a great volume of current at a low voltage or pressure.

When the cells are coupled up in series, only three connecting wires are employed, as shown in the illustration. The carbon terminal of the one end cell and the zinc terminal of the other end cell become the positive and negative terminals of the whole battery. If the zincs of the cells form the exteriors thereof, it is necessary to insulate the cells from each other, and this is usually accomplished by enveloping each cell in an indiarubber wrapping, holes being made for the passage of the coupling wires. The cells should be packed firmly in a box, as vibration would rub the insulation through and spoil the battery. The chemical action of the constituents of the cells is converted into electricity of low pressure—only about 1.25 to 1.5 volts per cell; and as over four volts are required, it is necessary to employ three or four cells. Primary batteries are clean to use, and give little trouble, but they cannot be recharged again and again like secondary batteries.

The Accumulator.

Primary batteries are often called dry batteries, as there is little, if any, free liquid in them; and also to distinguish them from secondary batteries, in which the electrolyte is generally all liquid, though occasionally it is prepared in the state of a jelly.

The secondary battery or accumulator generally consists of two cells only, as secondary cells have a higher individual voltage than primary have. The (secondary) cells are generally put up in a single casing, constructed of sheet celluloid, with a central partition. It is essential that this partition be perfectly sealed. In each cell is a series of plates, positive and negative alternately, one more negative plate than positive, and as a rule there are three or five plates in each cell, both the outside ones being negatives.

The plates are made of lead alloy in skeleton or grid form of different patterns, according to the ideas of the manufacturer. The spaces in the plates are pasted in with oxide of lead. When the cells are charged, the paste in the positive plates becomes converted into peroxide of lead, while that in the negative plates becomes pure spongy lead. The cells are filled up above the tops of the plates with an electrolyte, usually consisting of a solution of sulphuric acid. The proper specific gravity of the solution is 1.190 or 1.200, and in preparing it distilled water or rain water should be used—not tap, spring, or well water. Further, the acid should be poured slowly into the water, the converse process being dangerous. If the electrolyte is found not to cover the tops of the plates, the loss is probably due to evaporation, and a little distilled water should be added until the plates are submerged to the extent of one-eighth to a quarter of an inch. If the quantity of electrolyte has been reduced by spilling, it should be made up by adding some of the proper solution. Jelly electrolyte has the advantage that it cannot spill, but it is liable to increase the internal resistance of the battery and decrease the capacity.

A secondary or storage battery has no inherent electricity in it, as a primary or dry battery has; it requires to be charged either from other batteries or from a dynamo, as described further on. Illustrations of accumulators will be found in figs. 28, 32, etc.

The Conductors.

Having obtained our supply of electricity, we will prepare to make use of it, remembering that the battery is ever on the watch for a chance to short circuit, and that this form of indulgence is very bad for its internal economy, besides being wasteful of current. In choosing the wire for the primary or low-tension current, we must remember that it has to carry a fair volume of electricity, and it must therefore be comparatively thick; it will also have to be bent about a good deal, and will be subject to plenty of vibration, so it should be as flexible as possible. A cable constructed of a large number of fine wires will therefore be better for the purpose than one consisting of only three or four thick wires. It should be of ample length, as it is much more liable to break away from the terminals or connections if stretched tightly between them; any slack can be wound round, say, a cedar pencil, to form it into a spiral. As the current to be conveyed is of small pressure, the insulation, while perfect in itself, need not be very thick. But for the same reason, the connections or joints between the terminals of the battery and the terminals of the wire should be of ample surface and perfectly clean. There are lots of different patterns of terminals on the market, and it is better to use these, though fairly

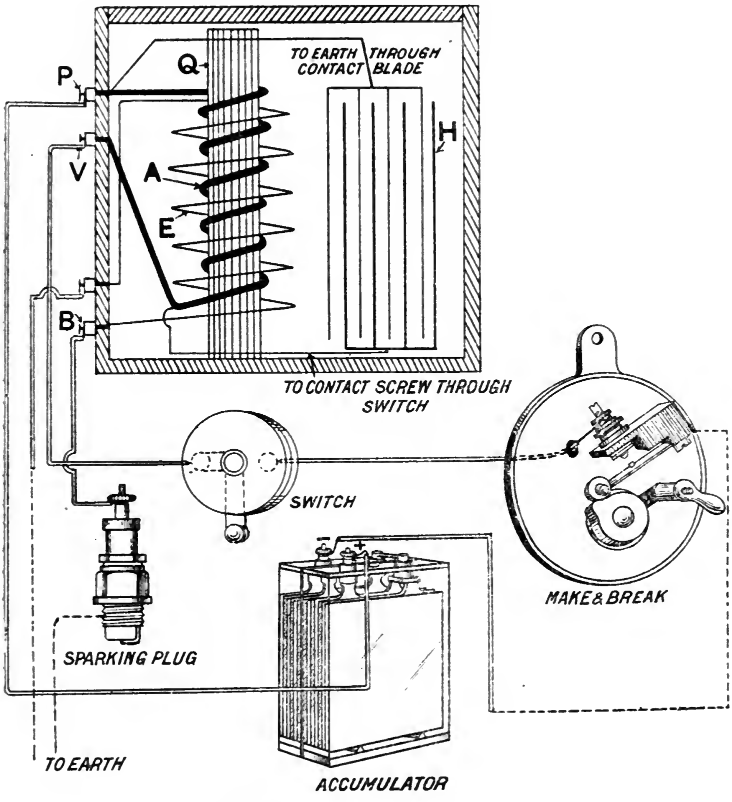


Fig. 28.—Electric Ignition System, with Plain Coil.

A, primary wire coil.
B. secondary wire terminals.
E, secondary wire coil.
H, condenser.
P, battery terminal of primary wire.
Q, soft iron wire core.
V, contact breaker terminal of primary wire.

good terminals can be made with the ends of the wire itself. The ends of the wire have to be stripped of the insulation in either case, and if it is decided to solder the wire terminal, use resin for the flux, as the acid generally employed is corrosive.

One end of the wire is secured to the positive terminal (generally coloured red) of the battery; the other end is secured to the terminal marked P (pile = battery) of the induction coil if of foreign manufacture, or B (battery) if an English one. The different systems of wiring are dealt with later on.

The Induction Coil.

The name induction coil is indicative of the principle on which this apparatus acts. If two wires or other conductors are arranged parallel to one another, and an electric current is passed through one of them, it is found that a current also passes through the other one at the same time if the circuit of the second conductor is completed. There is no analogy to water here, and no explanation, intelligible to non-technical minds, has been offered of the phenomenon, so far as we know. The wire through which the current is passed positively is called the primary, and the wire in which the current is induced is called the secondary. It has further been found that, if the primary and secondary wires are different in diameter and length and in number of turns, the induced current will differ in volume and pressure from the primary current.

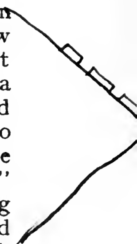
This useful fact is availed of in coils for motor ignition to secure a current of great pressure or intensity and small volume, from a primary current of low pressure and greater volume, as given off by the battery. For this purpose the primary wire in the coil is made thick and short, while the secondary is thin and long. But the form of the spark bears some proportion to the secondary wire, and as we want a "fat" spark, the secondary wire must not be too attenuated in proportion to the primary. Fortunately, the wires need not be straight; the effect is obtainable even if they be wound into spirals. The effect is considerably augmented if a bar, or, better still, a bundle of wires, of soft iron be introduced as a core to the whole arrangement. Lastly, it is necessary that the different wires, and even the different plies or layers of wire, be insulated from each other.

Hence the coil takes the form shown in the illustration (fig. 28). Right in the middle we have the bundle of soft iron wires Q. Around these is wound a couple of layers of insulated thick primary wire A, the ends being connected within the casing to the terminals P, V. The primary wire or coil A is then enclosed in a substantial insulator, such as a tube of vulcanite. Next comes the fine high-tension wire E. This is not only covered with insulation, but each layer is insulated from the next, though the wire itself is continuous. The ends of the secondary coil E are attached to the terminals B within the casing; and the coil as a whole receives a liberal coating of paraffin wax insulation. H is a condenser, which will be referred to presently.

At the moments when the battery current passes and ceases to pass through the coil A, high-tension currents are induced in the coil E. But before the current can pass from the battery, the primary circuit must be completed, and we will therefore pursue its course from the coil. The wire from the battery being connected to the terminal P, the next wire is connected to the other end of the primary coil by the terminal V. The remarks made with reference to the battery and coil wire apply to this one also; it may be called the "coil and contact breaker" wire.

The Contact Breaker.

As the spark in each cylinder is required regularly once in two revolutions of the crankshaft, the current is caused to flow just at these times. The device employed for completing the circuit during the necessary periods, one might well expect to be called a "contact maker," and its full title is doubtless "contact maker and breaker;" but as its function of breaking the circuit happens to be even more important than that of making it, its common name is that of "contact breaker." It is sometimes called a "commutator," but that application is best reserved for another electrical fitting to be mentioned hereafter. The contact breaker is also adapted to provide means for timing the sparking, that is, causing the flash to occur a little earlier or later in the motor's cycle of operations. But the ordinary actuation of the contact breaker is effected by a rotating part mounted on, or driven by, the half-speed gear of the engine, the same gear as is used for working the exhaust valve.



Supposing for the moment that the contact breaker is in the "make" position, the primary current passes therethrough, and the primary circuit is completed by a conductor connected to the other terminal of the battery. This conductor may consist entirely of a wire, or it may be partly "earth" and partly wire.

Wiring to "Earth" or "Masse."

This term "earth" is so inappropriate in connection with motor ignition that a few words may well be devoted to explaining it. Early experimenters with the electric telegraph discovered that, instead of connecting the two instruments by outward and return conducting wires, satisfactory results were obtained if the greater portion of the return wire was cut away, and the two short end portions connected to the instruments were sunk in the earth. Under these conditions the earth itself forms a conductor between the two ends of the return wire, and so completes the circuit. In motor car ignition it would be impracticable to use the earth in this way, but the metal work of the car serves as an equivalent, and when it is availed of the old expression "earth" is used. The French term "masse" is considerably better, as being more general.

The Make-and-Break Contact Breaker.

There are two principal types of contact breaker, known respectively as the make-and-break and the wipe. In the former (fig. 29), the rotating part consists of a disc C having a projection on it. The wire from the coil is connected to the terminal M which is in metallic contact with the pillar I S. This pillar carries two screws A S and L S, the latter serving to prevent A S from turning after it has been adjusted to any desired position. A cover is fitted to the working parts to exclude dust and wet. This cover is provided with holes for the passage of two screws. Nuts screwed on to the screws hold the cover in position.

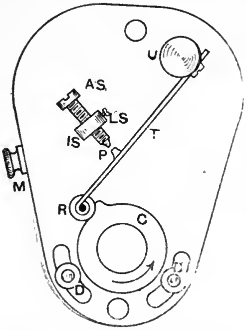


FIG. 29.—MAKE-AND-BREAK CONTACT BREAKER, POSITIVE TYPE.

A S, adjustable contact screw.
C, cam disc.
L S, lock screw for A S.
D D, studs.
I S, insulated support for A S.
P, platinum points.
R, roller on blade.
M, terminal.
T, spring blade.
U, pillar.

The pear-shaped base into which the terminal M, the pillar I S, and the screws are fixed, is made of vulcanite or other insulating material. A spring blade or trembler T is fixed to the pillar U by a screw. On the free end of T is a block or roller R which rubs on the periphery of the disc C. When the projection comes round, the blade is lifted by it, and makes contact with the point of the screw A S. This contact completes the primary circuit; the current enters by M, and passes through I S to A S, and from A S it passes to T and C, which are the beginning of earth or masse. But the contact is of very short duration, as directly the projection on the cam C has passed under the roller or block R the blade T springs away from the point of the screw A S. As soon as T and A S separate the current is cut off, and it remains cut off until in the course of the cam's rotation, the projection lifts the blade into contact with the screw again.

The Trembler Spark.

Completing the contact has very much the same effect as turning on a tap in a water system. Just as the water fills the pipes, so the electricity charges the primary wires, and the passage of this low-tension current through the primary winding or coil (A fig. 28) induces a current of high-tension in the secondary winding or coil E in the same figure. When the contact is broken between T and A S, the flow of current is checked, and it piles up or compresses, and then bursts across with a small spark. This spark is accompanied by a much fiercer one at the points of the sparking plug; but of that anon. The spark in the contact breaker would be very much larger were it not for the use of a condenser; but even as it is, it is found necessary to furnish the screw and the blade with tips or "points" P of the refractory metal platinum to withstand the heat; common metals very quickly get burnt, and so prevent the free passage of the current. As platinum is even more expensive than gold, the temptation to provide substitutes is not always withstood, and one must be careful to get these parts from reputable houses, when purchasing "spares." The two platinum tips should be flat-faced, and come quite evenly into contact, so that ample area may be given for the flow of the current.

Function of the Condenser.

The condenser just referred to acts as a buffer or compensating device. It is constructed of a number of sheets of tinfoil, insulated from one another by sheets of paraffined paper. Half the sheets of tinfoil are connected to one wire, and the alternate ones are connected to another. The other ends of the wires are connected indirectly to the screw A S and blade T (or corresponding parts) of the contact breaker. When the primary current strives to continue flowing after the contact is broken, a good deal of it passes into the condenser. And when the contact is again made, the electricity stored in the condenser helps to re-establish the flow quickly. That is not a wholly satisfactory explanation, but it is as far as one can take the matter in such an elementary book as the present. These flowing and compressing and bursting actions of the current are performed with extraordinary rapidity.

Advancing and Retarding the Ignition.

In order to be able to vary the moment of sparking relatively to the operations of the motor, the insulating baseplate can be turned about the axis of the disc. The turning movement is limited by the studs D D (carrying split pins) projecting through the curved slots. The driver effects the movement through a rod connected to the baseplate. The disc C generally rotates contra clockwise, so that if the baseplate is turned to the right or clockwise, the projection will meet the block sooner, and the ignition will be advanced. If the baseplate be moved in the opposite direction the projection will meet the block later, and the ignition will be retarded. The speed of the engine is, under ordinary circumstances, increased or decreased, according as the ignition is advanced or retarded. The movement of the baseplate does not alter the relative positions of any of the parts mounted upon it, it only alters the position of all of these relatively to the disc C.

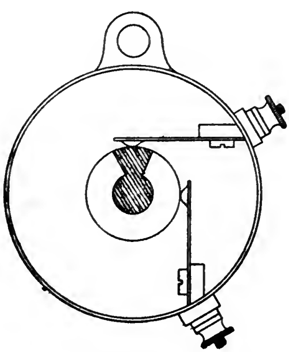


FIG. 30.—TWO-CYLINDER WIPE CONTACT BREAKER.

Wipe Contact Breakers

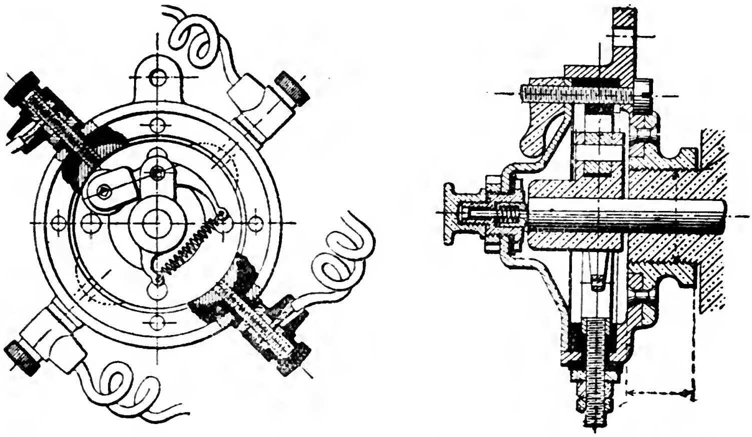
There are several kinds of wipe contact breaker, but they nearly all differ essentially from the make-and-break in that the rotating part has neither notches nor projections.

In the wipe contact breaker shown in fig. 30, it will be observed that there is a sector of metal let into the disc, which in this type of contact breaker is constructed of vulcanised fibre or other insulating material. The metal sector is in permanent metallic contact with the half-speed shaft, and so with the motor, which is, in turn, connected, generally through part of the car frame, with a short wire leading back to the battery. Bearing on the periphery of the disc are two blocks, carried by spring blades, which are mounted on insulated supports connected with the terminals. There are two blades, because the particular contact breaker illustrated is intended for a two-cylinder motor; they are arranged in positions corresponding to the intervals at which the respective impulses are adapted to take place—either at intervals of 1 and 3, as shown, or of 2 and 2, as the case may be. The rocking of the baseplate for timing the ignition affects both blades alike, but each blade is "wired" independently to the coil or coils. Sometimes a separate coil is used for each cylinder, but now it is very usual to employ a single coil in conjunction with a distributing device for the high-tension current. The latter is probably the better arrangement, as tending to evenness of action in the various cylinders. We will describe it more fully in connection with the high-tension circuit.

As the metal sector comes under each blade or "brush" (a dynamo term), the primary current passes therethrough. Owing to the large arc of the sector, the current flows for a comparatively long time. But as the half-speed shaft turns in the oiled bearings, and oil separates the teeth of the half-speed gear wheels and also the crankshaft from its bearings in the fixed part of the motor, the current has not by any means an ideal path back to the battery; and a wipe contact breaker may often be considerably improved by fitting, first, a spring to bear on a metallic part of the disc or on the end of the half-speed shaft; and second, a wire leading direct from this spring back to the battery.

The Internal Wipe Contact Breaker.

Figs. 31 and 32 represent another pattern of wipe contact breaker. This one is intended for a four-cylinder motor, but it may be modified to suit motors having any other number of cylinders. The construction is the converse of the last. In this case there is only one brush, and it is mounted on, and rotates with, the half-speed shaft, while metal segments, corresponding in number to the cylinders, are carried by the case, which may be moved about its centre to regulate the time of firing. The brush is pivoted to an arm fixed to the half-speed shaft, and is furnished with a roller, which runs round the vulcanised fibre lining (with metallic insertions) in the case. A spring couples the other end of the brush to a second arm on the half-speed shaft, and forces the roller into close contact with its path. The metal segments are in one with terminals projecting through the rim of the case, and each terminal has its own low-tension wire connection. The primary circuits are completed in turn as the brush runs over each metal segment; but here again there are a number of films of oil to be overcome before "earth" is properly reached, and the spring contact pressing on the end of the half-speed shaft forms a useful addition.



FIGS. 31 AND 32.—INTERNAL WIPE CONTACT BREAKER, FOR FOUR-CYLINDER MOTOR.

Trembler Coil Theory.

With a trembler coil an extremely rapid make-and-break device is employed on the coil itself, and is adapted to operate while the wipe contact breaker is in the make position, *i.e.*, while the brush is moving over the metal segment, or *vice versâ*, as the case may be. With a make-and-break contact breaker, the trembler on the coil would vibrate during the time the platinum points of the screw and blade remained in contact. The trembler movements are constructed in different ways, each maker striving to get the fastest action, but the principle is the same in all. A light metal blade (K), resilient either in itself or by reason of a separate spring (S), is held by one end on the coil, and frequently carries an iron plate or armature in line with the core of soft iron wire. This blade, or one (M) which it overlaps, carries a platinum point opposite the platinum-pointed end of an adjustable screw N. The device, as a whole, is introduced into the primary circuit, the wires being indirectly connected to the parts carrying the two platinum points.

Normally the platinum points are held in contact by the pressure of the spring, so the path is complete ready for the passage of the current. Hence, when the circuit is "made" by the contact breaker, the current is admitted to the primary winding A of the coil. The current has the effect of "exciting" the soft iron core Q, *i.e.*, causes it to act as a magnet which promptly attracts the plate or armature, bending down the blade which carries it. But the necessary consequence of bending down the blade is to separate the platinum points, and so break the circuit. On the current ceasing, the core loses its magnetism and releases the armature. with the result that the blade springs up again and re-establishes

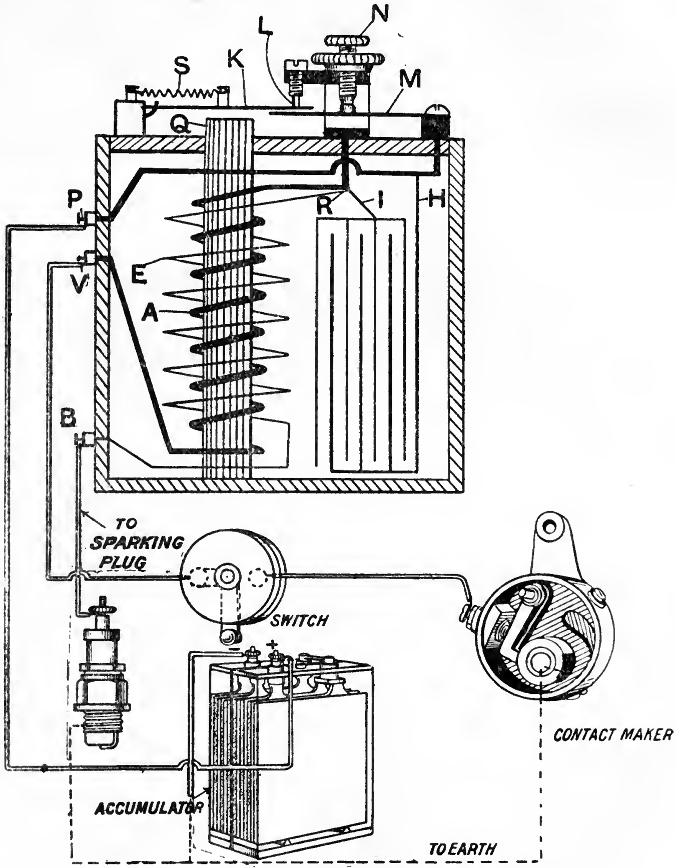


FIG. 33.—ELECTRIC IGNITION SYSTEM WITH TREMBLER COIL.

A, primary wire coil.
B, secondary wire terminal.
B, secondary wire coil.
H I, condenser leads from blade M and screw N.
K, armature blade.
L, adjustable stop.
M, trembler blade with platinum point.
N, platinum pointed screw.
P, battery terminal of primary wire.
Q, soft iron wire core.
R, common connection of primary and secondary winding and condenser.
S, trembler blade spring.
V, contact breaker terminal of primary wire.

the contact between the platinums. This remakes the circuit, the core is remagnetised, the plate attracted, and contact again broken. And so on, again and again, with extreme rapidity.

Of course, the block and segment of the contact breaker do not continue in contact for more than a small fraction of a second on each occasion, but this is long enough for numerous inductions of high-tension current, and the flashing of a stream of sparks, the individuals of which follow each other far too quickly to be distinguished by the human eye. This kind of coil has two incidental advantages arising from the buzzing sound set up by the vibration of the trembler. First, the emission of the sound is evidence of the satisfactory condition of the ignition system to a large extent; and second, it serves as a warning to switch off the current before leaving the car, if it happens to stop while the contact breaker is "on the make."

The High Tension Circuit.

So much for the primary or low-tension circuit. The secondary or high-tension circuit now remains to be disposed of. We have seen how the high-tension current is induced in the fine secondary winding of the coil. The induction coil really comprises two coils—the primary and the secondary; and each of these is often referred to as a winding, primary or secondary, or high or low-tension respectively, as the case may be. One point may be noticed at once—while the primary circuit is sometimes furnished with a complete return wire, the secondary circuit is practically always arranged with an earth return. There are good reasons for this. In the first place, the sparking plug can be made quite a simple affair if the return is by earth. Secondly, as the plug is tightly secured in a stationary part of the motor, the "earth" affords a comparatively good path for the current. And thirdly, the powerful nature of the high-tension current enables it to overcome any little obstacles to its flow that it may encounter. But while the high pressure of the secondary current is a good reason for earthing the return, it is an equally good reason for very carefully insulating the wire conducting the current from the coil to the sparking plug.

As compared with the low-tension wire for the primary circuit, the high-tension wire should have a very much thicker envelope of insulation, and even then the wire should be kept away from metal parts as much as possible. The coil should be arranged as near as may be to the sparking plugs, so that the length of high-tension wire may be reduced to a minimum. The actual wire should be of fine strands, to ensure durability, but there need not be as many strands in this wire as in the low-tension, as the volume of current flowing through it is so much less. The high-tension wire is attached to the terminal B (bougie, literally candle) on a foreign coil, or S P (sparking plug) on an English one. The return circuit often enters the coil by the same terminal as the low-tension return, the one terminal serving for both. The high-tension wire should be only a little longer than necessary; partly because the thick insulation makes it too stiff for any excess to be wound into neat spirals, and partly because the longer it is the more chance there is of its finding opportunities to leak.

High Tension Distributers.

If the engine has only one cylinder, there will be only one high-tension wire; but if there are two or more cylinders, there will be a wire for each, and there may be a coil for each. In the latter case there will be independent primary wires from the contact breaker to the respective coils, and independent high-tension wires from the respective coils to the corresponding sparking plugs. But, as stated, it is common practice nowadays to employ a single coil for all the cylinders, and to direct the high-tension current to each plug in turn. For this purpose a distributer is employed. In appearance, and to a certain extent in action, the distributer resembles a contact breaker. A single high-tension wire leads from the coil to a terminal which is in metallic contact with a rotating arm. As the arm rotates it communicates the current, in turn, to each of a number of metal blocks, which are connected up to the respective sparking plugs by separate lengths of high-tension wire. The arm is rotated by the motor, and, of course, at such a rate that the high tension current is transmitted to each plug at the correct period in the cycle of operations.

The high-tension wires should be carried in a vulcanite or fibre tube extending along the top of the motor. Opposite each cylinder a hole is made in the tube, and the proper wire led therethrough to its plug. This arrangement prevents both entanglement of the wires and loss of current.

The Sparking Plug.

The sparking plug is designed with the object of providing within the combustion chamber of the motor, a gap in the secondary or high-tension electrical circuit, so that the current, in jumping the gap, may cause a spark or flame that will ignite the charge of gas and impart an impulse to the piston and rotation to the crankshaft. The gap, which should measure about one-thirty-second of an inch, is provided between two points, which are best made of platinum to stand the heat. One point is formed on one end of an insulated pin or thin rod. The other point is formed on a short wire secured to the metal body D of the plug. The body is screwed into the wall of the combustion chamber of the motor, and the second point is thus "earthed" to the secondary winding of the induction coil, one end of this winding being itself earthed, as already mentioned. Sometimes discs or blocks of various shapes are employed instead of wire points, and plugs thus constructed may spark at more than one place. Fig. 34 shows a type of sparking plug with one central insulated rod and two "earthed" wires screwed into the body D of the plug. The spark may jump from or to either one side or the other.

Porcelain is the material generally employed for insulating the pin in the plug, though mica and other materials are sometimes used. The pin is secured in the centre of the insulation B, and projects from it at each end. The outer projecting end is fixed to a terminal A for connecting up the high-tension wire, and it is a convenience, especially in a motor having several cylinders, if the connection can be made and unmade instantaneously. The body of the plug is provided with an external screw-thread and with flats, whereby it may be screwed into the head of the motor. It is also screw-threaded internally to receive a hollow screw C. The insulation B is formed with a collar or swelling, which rests on a washer in the lower part of the body, and the hollow screw is screwed down on the top of it so as to hold it in place. The asbestos packing washer G is introduced below the collar to ensure a gas-tight joint, and to prevent the pressure of the metal parts crushing the porcelain. A washer of asbestos and copper should be used in securing the plug in the motor, to ensure close-fitting and prevent leakage of compression.

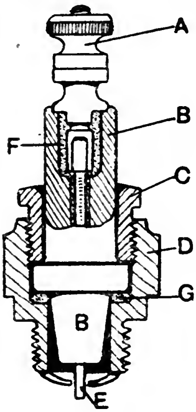


Fig. 34.—Section of a Sparking Plug.

A, terminal nut.
B, porcelain insulator.
C, gland sleeve.
D, metal body.
E, central electrode.
F, cement filling.
G, copper and asbestos packing washer.

Many plugs are made with the ends of both wires bent to form the gap, but as the porcelain will sometimes slip round a little when the terminal is being tightened up, it is better for the central wire to be left straight, and only the short one bent; then the turning of the central wire will not disturb the width of the gap so much. Of course, if the gap is too wide, the current will not jump it, and there will be no spark and no impulse. Plugs vary greatly in price, and individual cheap ones will sometimes give better results than other individuals at five times the price. Some are specially constructed to allow for easy refitting of the porcelains in case of fracture.

Wiring.

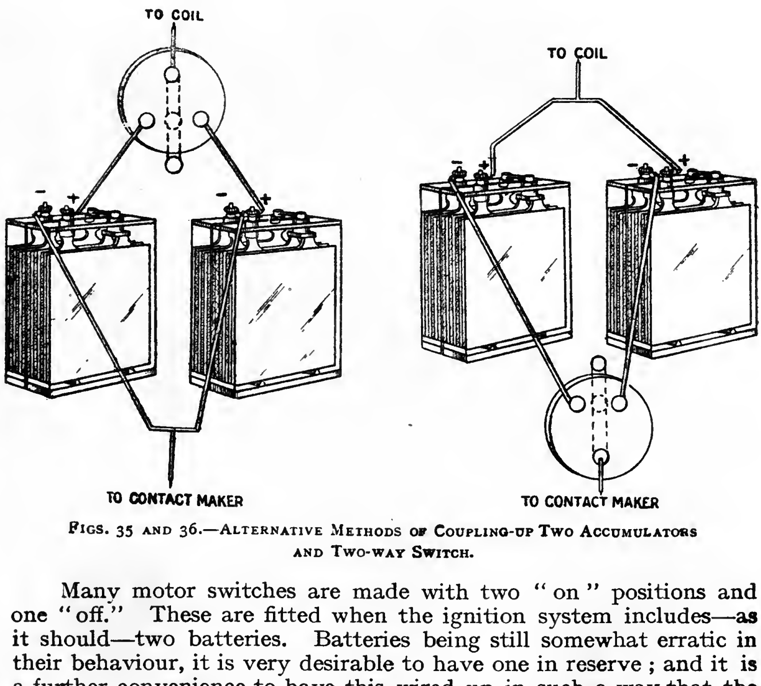
The wiring, or system of coupling up the various terminals, in the ignition system is of vital importance, as, unless correctly done, no effective sparking will result, and serious damage may be done to the apparatus. Every car should be accompanied by a book of directions containing an easily-understood diagram of the wiring. But this should be backed up by the driver's own knowledge of the subject, and the following hints and illustrations will enable him to deal with most of the cases he is likely to come across.

As to the battery. The positive pole is generally coloured red, or it may be marked with a plus or "positive" sign + ; it forms the terminal of the positive plates, which are of a chocolate colour, when the battery is charged. The reddish coloured plates have the red coloured terminal. This positive terminal is generally coupled to the coil.

The negative pole of the battery is generally coloured black, or it may be marked with a minus or "negative" sign —; it forms the terminal of the negative plates, which are of a greyish colour, and two of which form the outside plates of each cell. This negative terminal is generally wired to the contact breaker, either directly or *viâ* "earth."

The Electric Switch.

An electric switch is familiar to everyone in these days. It comprises a spring-controlled handle, the movements of which open and close a gap between two metal fittings introduced into the circuit, so that the current is cut off or allowed to flow, as required. Some switches are made with a handle that can be detached when leaving the car, thus protecting it to a certain extent against meddlers.



FIGS. 35 AND 36.—ALTERNATIVE METHODS OF COUPLING-UP TWO ACCUMULATORS AND TWO-WAY SWITCH.

Many motor switches are made with two "on" positions and one "off." These are fitted when the ignition system includes—as it should—two batteries. Batteries being still somewhat erratic in their behaviour, it is very desirable to have one in reserve; and it is a further convenience to have this wired up in such a way that the movement of the switch from one "on" position to the other will enable it to be brought into action should the other battery for any cause cease firing. The two accumulators should be coupled "in parallel," that is, the two positive terminals should be coupled together, and the two negative terminals should be coupled together. The two-way switch should be introduced into one (either) of these couplings, and the switch and the remaining coupling should be connected by single wires to the coil and to the contact breaker (or to earth) or *vice versâ*, as the case may be. Then, though both accumulators will be directly connected either to the coil or to the contact breaker the primary circuit will only be completed through one accumulator at a time, according to which side the switch handle is moved over to. When the handle is in the middle position, the switch will cut out both accumulators. Instead of a coupling and single wire, it is often more convenient to run two separate wires from the two like terminals of the accumulators to the single corresponding terminal of the coil or contact breaker (or earth). Or one may run one wire from this single terminal (or earth) to the terminal of one accumulator and a short wire thence to the similar terminal of the other accumulator. The switch wiring must remain as before.

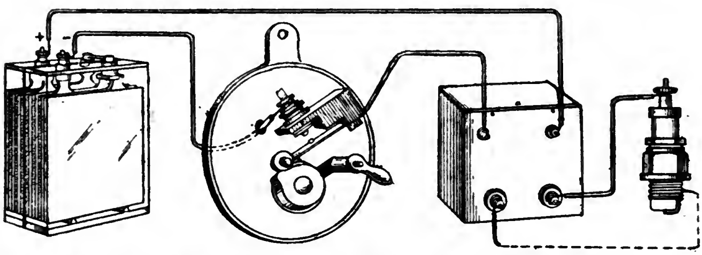


Fig. 37.—System of Wiring with Four-terminal Non-trembler Coil. Make-and-break Contact Breaker, and Return Primary Wire.

Connecting to "Earth."

As there are two windings (primary and secondary) in the coil, one may naturally expect to find four terminals on the casing, one for each end of each winding. And sometimes this is the case: the two primary terminals being for connection to the battery and contact breaker respectively, and the two secondary terminals being for the sparking plug wire and "earth" return respectively. (See figs. 28 and 37.)

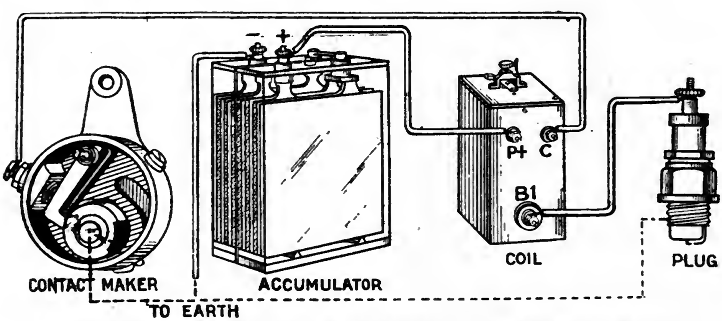


Fig. 38.—System of Wiring with Three-terminal Trembler Coil, Wipe Contact Breaker, and Barth Returns.

More often, however, if a coil has four terminals, the fourth is intended to be connected to earth instead of to the contact breaker, which is then made with only one terminal. It is now usual to provide the coil with only three external terminals, the earth end of the secondary winding being connected, inside the casing, to the "con-

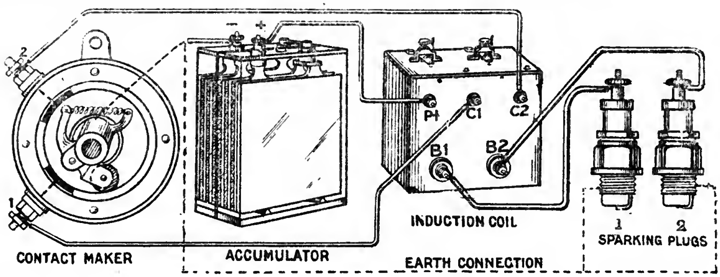


FIG. 39.—SYSTEM OF WIRING WITH FIVE-TERMINAL, DOUBLE COIL, WIPE CONTACT BREAKER, EARTH RETURNS, AND TWO SPARKING PLUGS.

tact breaker" terminal of the primary winding. With this construction, at the moment of making contact, both the primary and secondary currents pass through the coil-contact-breaker wire, the primary current being earthed only between the battery and the contact breaker on the motor. The same idea is carried out further where two or more coils are boxed up

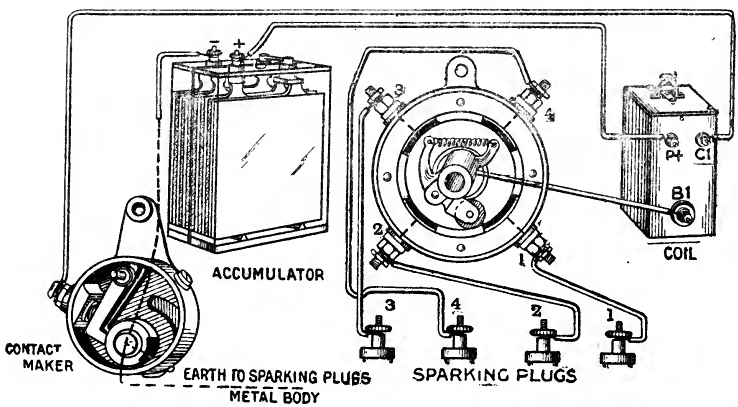


FIG. 40.—SYSTEM OF WIRING WITH SINGLE TREMBLER COIL, WIPE CONTACT BREAKER, DISTRIBUTER (ARRANGED FOR PROPER ORDER OF FIRING), FOUR SPARKING PLUGS, AND EARTH RETURNS.

together in the ignition system of a motor having two or more cylinders. Here, one end of each primary winding is taken to the inner end of a single terminal P+, the exposed end of which is coupled up to the battery; the other ends of the primary winding being provided with separate terminals, which are wired to the corresponding terminals of the contact breaker. And the earth ends of the secondary windings may also be taken to a single terminal, while the other ends are connected to separate terminals for the respective sparking plugs.

Marks on Coil Terminals.

The terminals on the coils are marked with letters indicating not the parts from which they spring, but the parts to which they are to be coupled or wired. Unfortunately, there is no standard system of marking, and the same letters often mean one thing on one coil and something else on another. Especially is this the case as between coils of British and foreign manufacture. Thus—

Letter.	*Meaning on British Coil*	*and on Foreign Coil.*
B	Battery	Bougie (sparking plug)
C	Contact breaker	Contact breaker
E	Earth	——
M	Machine (earth)	Masse (earth) or Moteur (contact breaker)
P	Positive (pole of battery)	Pile (battery)
S or S P	Sparking plug	——
T	——	Trembleur (contact breaker)
V	——	Vibrateur (contact breaker)
+	Positive pole of battery	Positive pole of battery

It may be gathered, therefore, that coils having terminals marked E, S, or S P are to have the British renderings attached to the markings; while T or V on a coil will direct one to read it *à la francais*. If none of these letters were on the coil, we should know that C meant contact breaker in any case; and B would mean sparking plug, as there would not be two B's on the coil, and the "battery" terminal would be marked either P (positive or pile) or + (positive). On a four-terminal coil M means earth; on a three-terminal coil it would mean "moteur," that is, contact breaker, if there were no terminal marked C, T, or V. Two letters to one terminal would mean that the two wires indicated by the respective letters were to be connected to it.

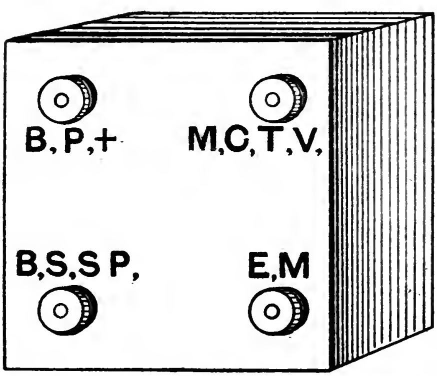


FIG. 41.—ALTERNATIVE LETTERINGS ON FOUR-TERMINAL COIL.

Identifying Connections.

In the ignition systems of motors having two or more cylinders, the sparking plug boss, the contact breaker arm or block (*i.e.*, the duplicated, non-rotating element of the contact breaker), the contact breaker terminal on the coil, and the trembler blade, in each set should be marked with a corresponding number. If it has not been done by the maker, you will be wise to do it at your leisure as soon as possible, as it may save a lot of hunting about and mistaken diagnosis on the road. It is also a convenience to use wiring differing in appearance, by colour or otherwise, for the different sections, so that each wire can be identified at different points in its length with certainty and dispatch.

Dual Ignition.

As it is often easier to start up a car on battery and coil ignition than by a magneto, and as with the former system it is frequently possible to restart the car simply by switching on; and, further, with a view to immunity from total failures of the ignition, many users of magneto ignition prefer to employ an accumulator and coil system as well. This means a certain amount of complication, and, in order to reduce it as far as may be, the two systems are often combined to a greater or less extent, and are then referred to as dual ignition. In this, the one set of plugs and the one distributer are used in common for both systems, and a switch is employed, which serves to couple up the battery and coil, while it cuts out the magneto, and *vice-versa*. The switch also serves to short circuit the primary of the magneto, both when the battery is in use and when both systems are switched off.

Some consider the better method when dual ignition is required is the fitting of two entirely separate systems. In this case faults may develop in either of the systems, but will not necessitate a stoppage of the car unless *both* go wrong, which, with reasonable care, is a remote contingency if the magneto and other parts of the ignition outfit be of sound manufacture. In independent dual ignition the magneto and its wiring remain exactly the same as they are when it is the sole ignition, but the engine is fitted with a separate contact breaker and distributer, generally driven off the camshaft, which deliver current to a set of plugs entirely disconnected from those which are served by the magneto, a single high-tension coil being used. The usual practice is to have the magneto plugs accommodated in the caps which cover the inlet valve, as the magneto provides the ignition which is most generally used—in fact, always, except in case of trouble and when starting—and experiment has shown that this situation of the plug is advantageous in providing a very rapid inflammation of the explosive charge in the cylinder. The battery plugs are not infrequently carried in the exhaust valve caps, but nowadays many manufacturers provide their engine cylinders with secondary plug ports, in which the battery plugs can be screwed.

This form of dual ignition suffers under the disadvantage that it is a somewhat costly undertaking to install it upon an existing car already fitted with a magneto, as it requires the provision of a separate distributer. A cheaper method, and one which has achieved a large measure of popularity, is that in which the high-tension distributer already incorporated in the magneto is employed to distribute also the current supplied by the accumulators. For this purpose a switch is provided, which cuts the connection between the magneto armature and the distributer carbon, and connects the latter up to a small trembler coil. As it is impossible, or rather impracticable, to isolate the contact breaker used in connection with the magneto circuit, a separate contact breaker has to be used, but is installed on the same plate, and is generally operated by the same mechanism which actuates that of the magneto. Only one set of sparking plugs is used. In this lies a certain disadvantage, since if a plug develops a fault, that fault is equally apparent in both ignition systems, as, in fact, is any other trouble on the engine side of the contact breaker, as these portions of the mechanism are common to both. The virtue of this "dual ignition," as opposed to the previously described "double ignition," is that a cheap and handy means is provided for starting up on the switch, as when the magneto is cut out, the installation is exactly the same as that on an ordinary coil ignition car. At the same time a secondary form of ignition is furnished in case of anything going amiss in either the armature winding, the condenser, or the contact breaker of the magneto circuit, the repair of which would probably be not easily effected on the road.

Most of the magneto manufacturers have placed dual ignition systems upon the market, and in general they have met with considerable success. The auxiliary coil is usually housed in a brass case carried on the dashboard, and provided with two knobs, one a switch for cutting out the magneto or the coil, as the case may be, the other for "tickling" the trembler blade of the coil so as to produce a spark when the accumulator contact breaker on the magneto is not breaking the circuit. The accumulator contact breaker is similar to that of the magneto, and is of the positive make and break variety; therefore, for switch starting, means of manually vibrating the trembler have to be provided. In running on the accumulator system, the trembler can be cut out, if desired, thus forming a positive make and break system.

Double Pole Ignition.

Some years ago the external spark gap came into general use, but owing to its inutility, and to the fact that when uncovered it provided a possible source of danger, it fell into disuse. By using a properly designed plug, in which both poles are insulated from the body of the cylinder, an *internal* spark gap can be obtained, and in this way the explosive mixture can be ignited at two points at once, which, because it enhances the rapidity of combustion, and furnishes, as it were, a homogeneous explosion, is claimed to be an advantage. Only one of the plugs has to be specially made this having two exterior terminals; the other is an ordinary standard plug; but instead of its terminal being connected directly to the coil or magneto (whichever is used), it is connected up to one of the poles of the special plug. The two plugs are therefore connected up "in series." Strictly speaking, the spark does not take place over both sets of points at *exactly* the same time, but the ordinary plug fires probably a billionth (or less) of a second after the other—a quite imperceptible interval. A considerable advantage of this two-pole system is what may be termed the enhanced impulsiveness of the spark. After the first gap has been crossed, it seems as though nothing can prevent the second being traversed, and soot and oil have a much less deterrent effect than in the case of an ordinary plug.

CHAPTER IV.

Lubrication.

THERE is no doubt that in the earlier days of motoring failure was more often due to the want of a sound and reliable lubricating system than to any other inherent fault. This is a matter that, like carburation, has been given a very large amount of attention by manufacturers, and the consequence is that the modern car reaches, in this respect, a very high standard of excellence.

The principal desiderata of a lubricating system are as follow: (1) The flow of oil must be absolutely certain, (2) visible, (3) have a volume proportional to the speed at which the engine is running, and (4) the apparatus must be reliable and simple.

The most general system now in use is that in which the engine crank chamber has its lower half much deeper and more pronouncedly boat-shaped than the upper half, and itself provides a vessel for the lubricating oil. The crank chamber is, then, in section

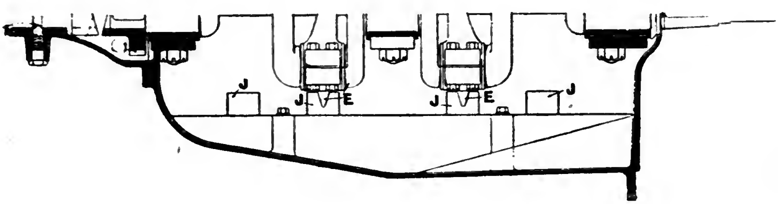


Fig. 42.—Section of Oil Sump of Crank Chamber.
E, dippers on connecting rod ends. J, oil troughs under connecting rods.

something like fig. 42, from which it will be seen that when the crankshaft revolves the big ends of the connecting rods dip into troughs of oil, and carrying away enough to lubricate themselves, also "splash" so large a quantity upon the walls of the cylinders and crank chamber that sufficient lubrication is thereby provided for the pistons and the camshaft.

A small direct-acting pump is put into communication with the oil supply, and draws oil thence, and delivers it to the oil troughs. For the purpose of acquainting the driver with the state of working of the system, a visible drip, consisting of a glass tube or inverted glass cup, through which the flow of oil can be seen and gauged by the frequency of spots, is introduced between the pump and the crank chamber. This little apparatus is mounted upon the dashboard, and the arrangement is generally such that oil is forced by the pump up to the sight feed, whence it falls by gravity down a pipe into the oil troughs.

Many, especially powerful, cars have a lubrication system in which their parts are supplied with oil with great certitude. For

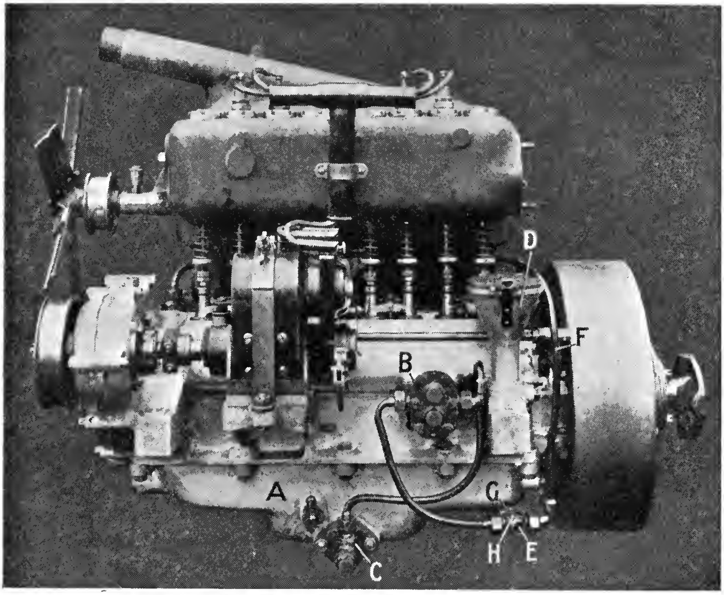


FIG. 43.—PRESSURE LUBRICATION SYSTEM, SHOWING OIL PUMP.

A, oil sump on crank chamber.
B, oil pressure pump.
C, filter and oil outlet from sump.
D, oil filling pipe.
E, lead to pressure gauge.
F, oil pipe to engine bearings.
G, oil return to sump.
H, pressure relief valve.

this purpose the crankshaft is made hollow, and along this oil is forced from the pump by means of an annular collar fitting smoothly upon the shaft, the latter having a small hole inside the collar, so that, although the shaft is rotating, oil can still be forced into it. Both at the crankshaft and big end bearings the shaft is drilled with transverse holes, which allow the lubricant to pass directly into the bearings. The oil falls out into the crank chamber, but is first splashed up by the big ends on to the pistons, etc.

The crank chamber is frequently provided with a false bottom, below which is the oil sump, and communication between the two is by a filter, which retains any tiny granules of metal which have become mixed with it. It then passes into the sump, and eventually into the pump again, which puts it once more into circulation. In this way the same oil is used time after time, thus allowing its lubricating qualities to be taken full advantage of.

In neat cases the lubrication pump is attached directly to the crank chamber sump, as if this be done a length of piping is thereby avoided. In this position it is driven by a bevel or skew gear from the camshaft. The pump is also not infrequently mounted at the flywheel end of the camshaft, where it is practically hidden in the crank chamber casting. This situation is specially advantageous when the hollow crankshaft system is used, as the pipe connecting the pump up to the hollow crankshaft may be then cast into the end of the crank chamber.

Lubricating systems in which the pressure of the exhaust is used in place of the positive pump found considerable favour at one time, but they are not often found nowadays, except, of course, upon old models of certain makes.

CHAPTER V.

Cooling.

THE heat attending the combustion of the charges of gas, and the heat arising from the rapid movements of the piston in the cylinder, would together produce a temperature which would be fatal to the lubricating oil and liable to produce distortion of the parts of the motor if not prevented by some counteracting influence. A petrol motor being a heat engine, all cooling devices detract from the ideal efficiency of the machine, and perhaps some day our motors will be "lagged" with a heat-retaining jacket. But that is not yet. On the other hand, most motors will run better when a little warmed up than when stone cold.

The Radiation System.

The simplest way to keep down the heat is to provide the motor with radiating fins cast on to the cylinder, especially around the head and exhaust valve box. These fins catch the air as the car travels along, and transmit some of the heat of the motor to it. This answers very well in small-powered motors, say up to 3 h.p. or 4 h.p., so long as the load is light, the pace good, and the charges of gas small. But when the rate of movement through the air is reduced, and more gas is required—as in hill-climbing—the motor is apt to get too hot, and the power falls off rapidly. This may be due to burning of the lubricating oil, or to the heat expanding the gas as it enters and so preventing charges of full value being drawn in, or to other causes. Whatever the reason, the effect is that much of the power disappears just when it is most wanted, and simple air-cooling is for the time being practically non-existent in European cars. Better results are obtained if the natural draught be augmented by a fan, preferably an enclosed fan. This takes a little power to drive, but so little that it is much more than repaid by the superior cooling effects.

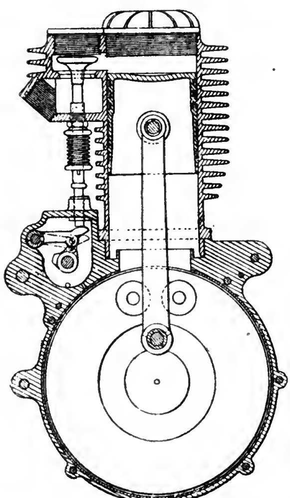


FIG. 44.—AIR-COOLED MOTOR, WITH RADIATING FINS.

Thermo-syphon Water Cooling.

Water-cooling, however, is almost universal on motor cars. This system is really a modification of air-cooling, as the water, after being heated in the motor, is subjected to the cooling effects of an air draught prior to being returned to the motor; and this circulation is kept up continuously.

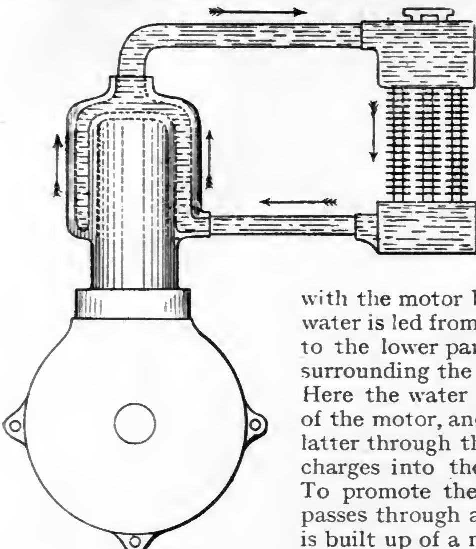


Fig. 45.—Water-cooled Motor—Thermo-syphon System of Circulation.

Natural or thermo-syphon circulation, depending on the fact that hot water ascends and cold water descends in a system, is employed in several well-known instances. In it a water tank is connected with the motor by two pipes. The cooler water is led from the lower part of the tank to the lower part of a jacket or envelope surrounding the cylinder, valve boxes, etc. Here the water absorbs much of the heat of the motor, and rises from the top of the latter through the second pipe, which discharges into the upper part of the tank. To promote the cooling effect, the water passes through a cooler or radiator, which is built up of a number of short lengths of pipe, to which fins or gills are soldered to disperse the heat of the water in the pipe.

Fig. 46.—A Gilled Tube Radiator.

The principal advantage of this system is that all pump troubles are avoided ; but against this must be put the facts that a comparatively large bulk of water must be carried, as the circulation is slow and the evaporation considerable. All the water passages should be of large proportions and free from sharp bends and other obstructions to the flow of water. The radiator should be well exposed to the draught, which should be supplemented by a fan.

Pump Circulation.

When a circulating pump is used, a much less quantity of water is required than if the same engine were cooled on the thermo-syphon system, just described, and, this being so, the radiator, with its tank sides and head, can be made smaller and lighter. The pump is now generally gear driven off the half-time shaft, and, drawing the cooled water from the lower portion

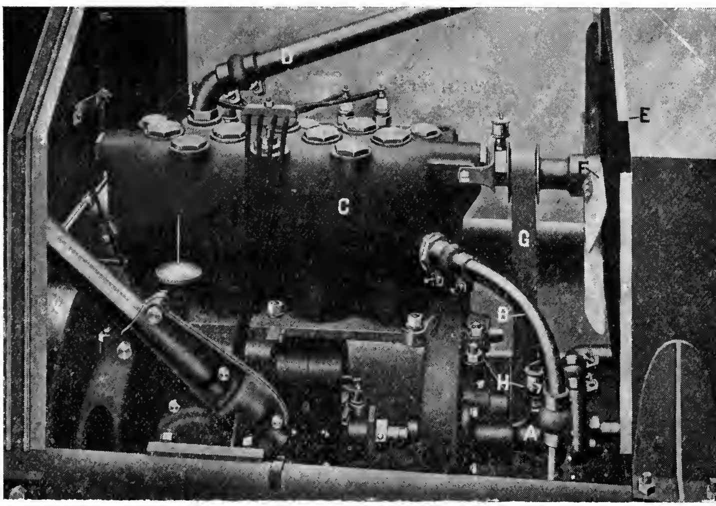


FIG. 47.—WATER-COOLING SYSTEM.

A, water pump.
B, water pipe to cylinder jacket.
C, cylinder jacket.
D, water outlet pipe from jacket to radiator.
E, radiator.
F, cooling fan.
G, fan belt.
H, fan belt pulley on crankshaft of engine.

of the radiator, delivers it to the lower portions of the cylinder jackets, preferably on the exhaust side beneath the exhaust valve chamber, driving it upwards through the jackets, and back to the top of the radiator by pipes leading from over the crowns of the combustion chambers, or as near thereto as possible. Separate water tanks are now almost obsolete.

The Honeycomb Cooler

In the honeycomb type of cooler, the water is contained in a skeleton structure of exceedingly thin tubes, with intervening water spaces running fore and aft. A small water tank is contained in the surrounding framework of the cooler. These coolers hold only a small quantity of water, but they are so efficient that evaporation is very slight, and replenishments are needed correspondingly seldom. The draught set up by the motion of the car is assisted by a fan, driven by the motor. Sometimes the fan is located immediately behind the cooler, when it is generally rotated by a belt. In other cars the motor is boxed in nearly air-tight by a shield underneath and a closed bonnet above, and the flywheel (which is behind the motor) has its spokes constructed as vanes, so that the air is drawn right through the "engine room."

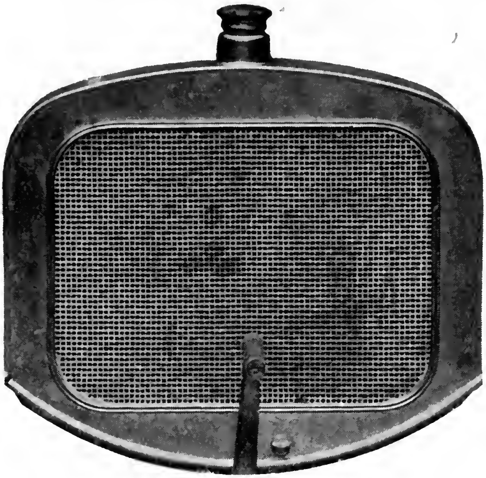


FIG. 48.—A HONEYCOMB RADIATOR.

Water-circulating pumps act rotatively, and either by centrifugal or positive action. They were originally driven by friction from, say, the edge of the flywheel; and sometimes positively through chains, but, as already suggested, generally by spur wheel gearing.

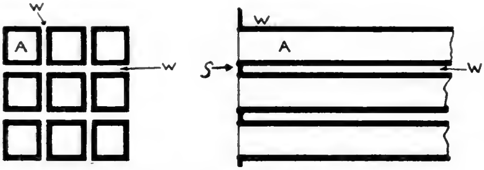


FIG. 49.—SECTION OF HONEYCOMB RADIATOR, FRONT AND SIDE ELEVATION.

A, air space.
W, water space.
S, solder joining the tubes.

Every water-circulating system should be provided with means for draining off every drop of water. Some systems have been so efficient that they have been frozen up during a run in cold weather. But the trouble usually consists in cracked jackets and leaking

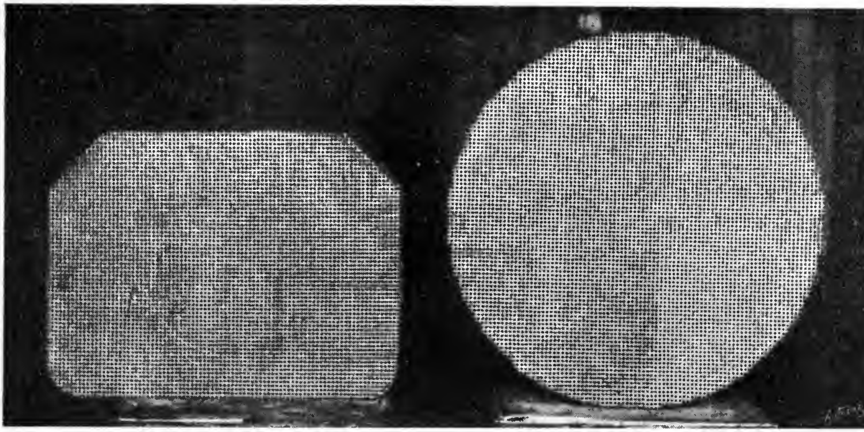


Fig. 50.—Honeycomb Radiators, before being fitted with Copper Casings and Water Tank.

radiators, owing to the freezing of water negligently left in them when the car is put to bed. And neither a cracked cylinder nor a leaky honeycomb radiator is an easy thing to repair.

CHAPTER VI.

Control.

IN all cars some means are provided giving the driver control of the engine from his seat. The majority of modern cars have a lever and a quadrant on the steering wheel, which lever is in direct communication with, and controls, the throttle, regulating the supply of mixture to the cylinders as required by the exigencies of the moment. Very often two levers are to be found on the steering wheel, the second one in such cases being connected to the ignition timing; the two levers are known as the "throttle" and "ignition" levers respectively. The former is usually to be identified by reason of its being somewhat longer than the other, the reason for this additional length being to bring the handle of the lever more conveniently to the driver's hand, as it is far more frequently used than the ignition lever. On some cars the ignition lever is fitted to a quadrant on the dashboard, within reach of the driver.

A very prevalent and commendable practice is the fitting of a third, small, pedal—which preferably should be on the extreme right of the floorboard, although only too often, for manufacturing convenience, it is placed between the two large (brake and clutch) pedals. This small pedal is connected to the throttle control, and either supplements or replaces the hand lever on the wheel. As a supplemental pedal, the better plan, the whole of the driving in towns and traffic, and a great deal of country driving, is done with the right foot, the hand lever being used only as a stop—holding the throttle open to the point at which it is set when the pedal is released.

Two or three modern cars still retain the once-prevalent practice of fitting the throttle lever under the steering wheel, but in the opinion of the majority of drivers this is not so convenient a plan, for the driver's hands are, when steering, naturally in position above the wheel, so that the most convenient place for the levers would obviously seem to be above the wheel too. Also, the lever under the wheel is likely to be unintentionally moved by the driver's knees, coat, or rug.

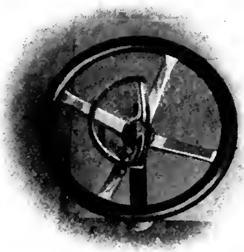


FIG. 51.—CONTROL LEVERS ABOVE STEERING WHEEL.

Just one more alternative method is worthy of note, and that has reference to cars fitted with only a pedal controlled throttle. In such cases some form of hand controlled stop should be, and usually is, provided, for it is impossible to set the "slow running" position of the throttle permanently for all climatic conditions—in winter it must be wider open than in summer to run the engine at a minimum speed when stationary.

CHAPTER VII.

The Starting Gear.

THE means provided for starting the motor usually consist of a crank handle of suitable length placed in front of and below the radiator, in the case at least of vertical engines. The boss of the handle fits on to the end of the motor shaft or a shaft geared to it, and has inclined teeth to engage corresponding teeth or a cross pin on the shaft. The inclination of the teeth is such as to release the handle when the motor begins to drive, so that the operator may not be struck by it. Very rarely the handle is detachable altogether—when it is liable to be lost; in most makes, a stop prevents the handle coming right off, and so it is always ready for use.

It is very important that the ignition should be well retarded before attempting to start the motor, as, if too far advanced, the motor is very likely to begin driving the wrong way, and as the handle does not release under these circumstances, a severely strained or broken wrist is the probable result. A few cars are so arranged that the starting handle cannot be pushed home unless the ignition is retarded.

With a four-cylinder motor the chances are that it will stop with one or other of the cylinders ready to fire, so that such an engine can often be restarted by merely switching on the current, after retarding the ignition. A few makers now provide means for starting the motor from the driver's seat, and we hope to see this practice extended, although such a fitting must tend to a little further complication.

There are various ways in which the idea can be carried out. According to one method a separate carburetting device is employed; the waste gases are pumped out of the cylinders and charges of fresh gas are pumped in. The current is then switched on to produce a spark in the cylinder which happens to have its piston in the right position, and the engine starts. Another way is to cause the motor to pump air into a reservoir just before stopping, and then to employ the compressed air to operate the motor on restarting. Or a spring may be used in a somewhat similar way, the spring being first wound up by the motor, which is afterwards restarted by the reaction of the spring. One of the simplest ways is to fit a "free wheel" clutch on the engine and wind a cord or chain around it. The other end of the cord is connected to a lever near the driver's seat, which lever can be operated by the foot, the engine being started without the driver leaving his seat.

CHAPTER VIII.

The Flywheel.

THE only portion of the motor remaining to be dealt with is the flywheel. The object of this is to equalise the rotation of the crankshaft by storing up the force of the impulses and giving it out again during the exhaust, induction, and compression strokes. In motors having more than one cylinder the flywheel effect is less necessary in rough proportion to the number of cylinders, as the impulses are more frequent, and some, if not all, of the idle strokes are balanced more or less by impulses. Or, to put it more directly, the single-cylinder engine stands most in need of a powerful flywheel.

A large diameter flywheel is of more effect than a smaller one of the same weight and proportions, as in the former the weight acts at a greater leverage. For this reason it is desirable to make the rim the heaviest part of the wheel. The momentum of the mass of metal resists changes of speed, whether they tend towards increase or towards decrease, and to this is due the equalising effect of the flywheel. Were it not for the flywheel or some equivalent device, the motor and the car would be for ever nagging at one another, the motor driving the car on each impulse stroke, and the car driving the motor at other times. As in other nagging, there would be a violent interchange of "torque."

CHAPTER IX.

The Transmission Gear.

As the essential purpose of a motor car is locomotion, some means must be provided for transmitting the motion of the motor to one or more of the road wheels. But in designing the transmission gear several main considerations have to be borne in mind. For example, it would not be convenient to have the motor and the road wheels indissolubly connected, as this would mean that the engine could not be started without moving the car along, and that the car could not be stopped without also stopping the engine. Hence means are provided for making and breaking the continuity between the engine and the transmission gear ; and a clutch of the friction type is employed, so that after the engine is started and the gearing is connected up, the car may be set in motion gradually by letting the parts of the clutch engage slowly. By releasing the clutch the car can be stopped without stopping the engine, and the speed of the car can be controlled to a large extent by alternately letting in and taking out the clutch, though it is mainly controlled by the throttle and sparking. Cars may be run down steep hills by gravitation, with the clutch out : the clutch being let in, and the engine thus restarted, on approaching the bottom.

Transmission Considerations.

Another consideration to be taken into account is that the driving road wheels must be rotated very much slower than the crankshaft of the engine, otherwise the car would run a great deal too fast even if the motor were powerful enough to drive it like this at all. Supposing the motor runs at 700 revolutions per minute, and the driving wheels are 36in. in diameter, if the wheels rotated at the same speed as the crankshaft the car would travel at about seventy-five miles an hour—a speed which is not encouraged in this country. The transmission must therefore, at least, provide for rotating the road wheels at something like one-third or one-quarter the speed of the crankshaft.

But even then two other considerations come in ; and these must be carefully distinguished. First, the engine would not be able to drive the car uphill unless exceptionally powerful. And second, it would not be possible to drive the car slowly unless the engine were exceptionally flexible. The point to keep clearly in mind here is that when a car is going slowly uphill, as much power is required to propel it at the slow speed as at a fast speed on the level, the total work to be done in each second or other period of time being at least as great in the first case as in the second. To go slowly on the level involves less work per second; and the slow speed here is accompanied by diminished power of the engine—one cannot climb a hill by merely reducing the speed of the engine. Quite the reverse in fact, as the power of the engine falls off greatly as the "r.p.m." (revolutions per minute) are reduced.

Therefore the transmision gear must include a positive means for disengaging, and a clutch; it must operate as a reducing gear even for the normal speeds, and further reductions must be available for hill-climbing and starting purposes.

Nor are these all the points. Two others remain: Means must be provided for allowing the two driving wheels to rotate at different speeds when turning corners; and lastly, the fact that it may be occasionally necessary to drive the car backwards must be taken into consideration.

The Balance Gear.

The mechanism by which the power is properly distributed between the driving road wheels when the car is turning corners and describing other curves is called a "balance gear" or "differential gear." The term differential is sometimes applied to the variable speed mechanism; and though the application is, in a sense, correct, it is best to confine the word to its ordinary usage or avoid it altogether. To some people the action of a balance gear is an incomprehensible mystery, so we will take the explanation in easy stages.

Curved Track Effects.

If you examine the tracks of a car on a curve, as at a street corner, you will see that the outer wheels had to travel a greater distance than the inner wheels. The function of the balance gear is to allow the outer driving wheel to travel faster and farther than the inner one on a curve, and yet to drive both the wheels effectively all the time.

To understand how this is done, first take a grocer's balance or pair of scales (1 in fig. 53). Move it upwards by the loop at the middle of the beam, and you will find, of course, that, so long as the scales are not interfered with, they will move upwards at the same speed as the loop and as each other. Do the same again, but hold up a stick so that the side of one of the scales will rub against it. The free scale will now move up faster than the one subjected to the friction against the stick, the beam swinging out of the horizontal, but the *average* speed and distance travelled by the two scales will be equal to those of the loop. Now, for the beam substitute a pulley; and for the scales, a cord passed over the pulley and having equal weights at each end (2). Experiments tried with the scales will have similar results when tried with the pulley, cord, and weights.

Next take two rotatable rods, set them in line, and fix a drum on each. Remove the weights from the cord, wind the ends of the cord (one right hand and the other left hand) round the two drums, and secure them (3). Now draw the pulley slowly away, and the cords will rotate the rods equally and in the same direction. Repeat the process, resting one hand lightly on one rod; this rod will then be rotated slower than the other, but the pulley will

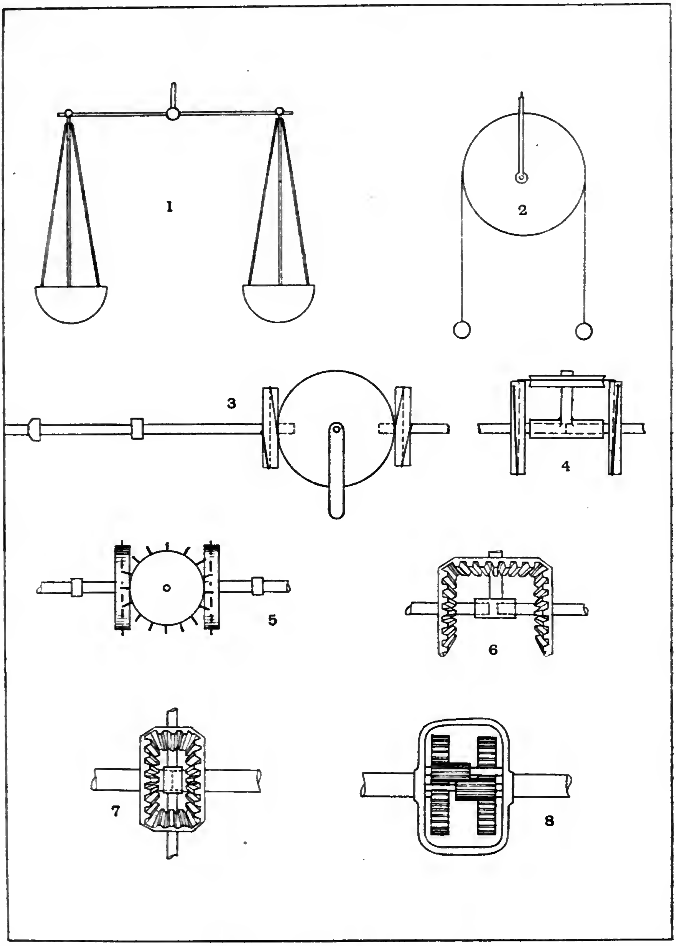


FIG. 53.—BALANCE GEARING.

turn on its axis, and so cause the average of the two rotations to be the same as before. We will now take a T piece having a hollow crossbar, and fit this over the ends of the rods (4); the pulley we will pivot on the top of the stem. We can now only rotate our pulley round the axis of the rods, instead of drawing it away, but the experiments will result exactly as before—both drums will be rotated, and if one is retarded the other will be accelerated to an equal extent, the pulley again turning on its axis. We can see the action even more plainly if we dispense with our cord, and stick pins radially and equidistantly into the circumferences of the drums and pulley (5). If we merely turn the pulley round the axis of the rods, the respective rods and drums will be rotated equally ; but if we retard one of the rods, the pulley will begin to rotate on its own axis also, and will rotate the other rod and drum proportionately faster.

Construction of the Gear.

The next step brings us within reach of a practical balance gear—for the pins we substitute bevel teeth (6). Generally the gear is more compactly constructed, by using smaller bevel pinion " pulleys " and more of them, and our T piece is developed into a kind of skeleton frame, often called a " star," or even a " spider" (7). Encircling the spider is fitted a gear wheel of some kind, by which it may be rotated, and the power is transmitted in balance fashion by the pinions to the bevel wheels on the two rods. These two rods, of course, are the two parts of the balance geared axle, and have the road wheels fixed directly to them.

It is quite possible to construct balance or differential gears without wheels of the bevel type at all.

One of the best forms of balance gear is constructed of straight wheels. A large straight wheel is mounted on each half of the axle, a suitable space being left between ; a wide pinion gears with each wheel, and the overlapping parts of the pinions gear with each other in the space between the large wheels. The pinions are mounted on spindles carried by the casing, to the exterior of which casing the driving gear wheel is fixed (8). A little consideration of this mechanism will show that it has precisely the same effect as the bevel balance gear previously dealt with. There are many other forms of " differential," and some of them exhibit a high order of ingenuity.

The Clutch.

Two of the principal desiderata in the friction clutch are, that it should engage gradually, and should transmit the motion, when fully engaged, without loss by slip. One type of clutch that has been very largely used is shown in fig. 54. The back of the flywheel is made concave, and a convex disc is mounted on the clutchshaft sleeve behind the flywheel. The conical surface of the disc is faced with leather. A strong spring thrusts the sleeve forward, and forces the convex disc into the concave flywheel. The friction set up by the contacting surfaces causes the motion of the crankshaft and flywheel to be transmitted to the clutch disc and its shaft. The disc can be withdrawn and let in more or less gradually by a pedal lever, one end of which engages with the clutchshaft sleeve. An objection to this form is that the pressure of the spring sets up a good deal of thrust, and that the bearings provided to meet the thrust are subject to great friction.

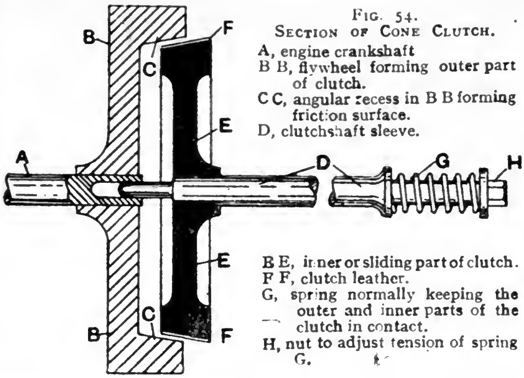


FIG. 54.
SECTION OF CONE CLUTCH.
A, engine crankshaft
B B, flywheel forming outer part of clutch.
C C, angular recess in B B forming friction surface.
D, clutchshaft sleeve.
B E, inner or sliding part of clutch.
F F, clutch leather.
G, spring normally keeping the outer and inner parts of the clutch in contact.
H, nut to adjust tension of spring G.

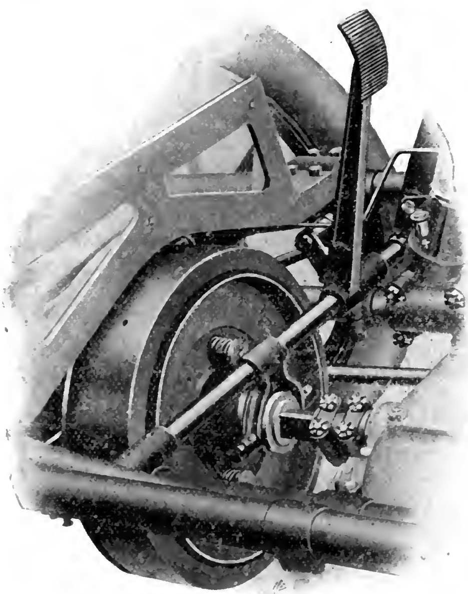


FIG. 55.—CLUTCH WITH THREE EQUIDISTANT SPRINGS.

To avoid this the internal clutch (fig. 56) is sometimes used. Here the clutch disc is directed backwards instead of forwards, and the concave surface is formed on a ring which is bolted to the flywheel. The spring is enclosed between the flywheel and the disc. The thrust of the spring is thus taken by the clutch parts themselves, and sets up no friction externally, except when the clutch is released, and then the friction is often helpful rather than otherwise.

There are a number of other different kinds of clutches, some acting by expansion of the inner part, some by lateral pressure of a series of plates, and another by the gradual winding up and contraction of a metal coil. Others, again, are combined with the variable speed gear, so that each speed is brought into action by its own clutch. In this case no separate clutch pedal is required. As a rule, however, clutches are engaged by an adjustable spring, and are withdrawn from action by a pedal lever acting upon the movable part. Formerly the pedals were operated by a downward movement, but it is now usual to adapt them to be

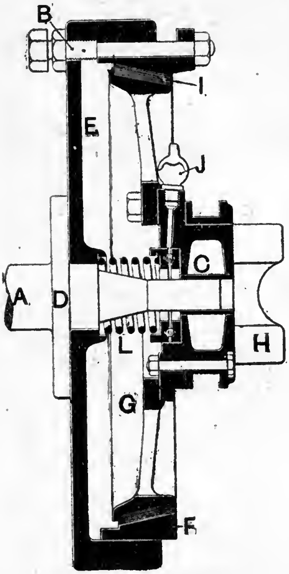


FIG. 56.—SECTION OF INTERNAL CLUTCH.

A, engine crankshaft.
B, clutch-adjusting bolt.
C, sleeve carrying inner or movable part G.
D, crankshaft flange.
E, flywheel.
F, ring bolted to flywheel.
G, inner part of clutch.
H, driving jaw of clutch.
I, clutch leather.
J, lubricator.
L, clutch spring.

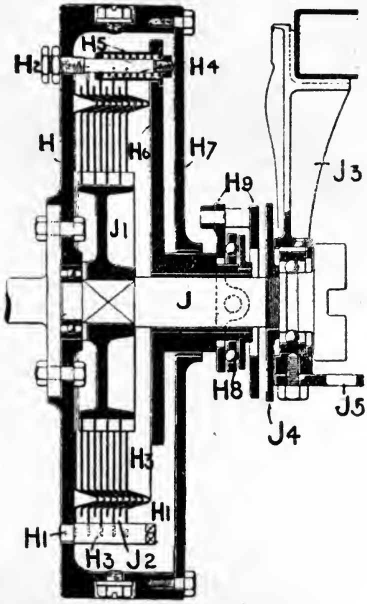


FIG. 57.—SECTION OF PLATE CLUTCH.

H, hollow flywheel
H1, driving guide pins.
H2, screwed pins adjusting H4.
H3, driving discs.
H4, clutch springs.
H5, spring cases engaging with H6.
H6, three-armed spider, controlled by H 9.
H7, cover (oil tight).
H8, ball thrust bearing.
H9, clutch fork mechanism.
J, shaft.
J1, driven member (externally toothed casting).
J2, slotted discs engaging with J1.
J3, bracket.
J4, brake flange to J.
J5, stay bracing to J3.

thrust forward. The motion should be fairly easy, otherwise the clutch (the left) leg will get very tired on long journeys.

Elastic and Flexible Connections.

A perfectly-adjusted clutch would just transmit the full power of the motor and no more, so that in the event of an untoward shock the clutch would slip and prevent strain of the parts. This state of affairs being difficult to attain, more difficult to maintain, and not ideal in other respects even when secured, a few transmission systems have included an elastic connection between the clutch and the transmission. This, if well-designed, contributes largely to smoothness of action and absence of injury; while the effects of clumsily letting in the clutch are reduced. In some systems, again, a flexible or self-adjusting joint is employed. The object of this is

A, engine crankshaft.
BB, flywheel forming outer part of clutch.
C, clutchshaft.
BE, arms attached to clutch sleeve P carrying the clutch segments FF.
F1 F1, lugs on the ends of the segments FF.
GG, right and left-handed screws, engaging in the lugs F1.
HH, arms attached to the screws GG.
H1, H1, links connecting HH to J.
J, sliding sleeve on clutch sleeve P, actuating clutch.
P, sleeve carrying the arms EE.

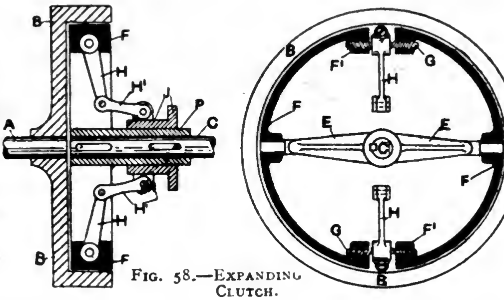


FIG. 58.—EXPANDING CLUTCH.

to allow the parts to accommodate themselves to any accidental disalignment, which would otherwise set up great friction and wear. All well-designed modern cars include this flexible joint between the clutch and gear box.

Variable Speed Gears.

To obtain the best results the motor should run at one speed all the time—uphill, downhill, and on the level. This would involve having a gearing that would vary its speed and power between zero and a maximum, according to the "load" or work to be done; and it should adjust itself automatically. This is unnecessary but some very clever attempts have been made to do it, and with a fair measure of success experimentally. But as none are prominently on the market, we need not deal with them here.

Two or three alternatives present themselves as the next best thing. One can have a large number of gears, so that the engine may be run at nearly its full power in climbing hills of various gradients. Or one may use an engine so powerful that it will climb all ordinary hills on the highest gear, one or perhaps two low gears being provided for starting and for exceptional "banks." In this case the motor is (or should be) run very much below its full power in the ordinary way. Some motors are now so "flexible" that they will drive a car at only four or five miles an hour while still nominally on the "top speed," *i.e.*, with the highest gear in. The largest cars generally have four forward speeds, and smaller ones three, or sometimes only two. Unless the two-speeded car has lots of power it is a very trying instrument. For one is sure to come across numerous rises that it cannot quite manage on the top speed, and which, in consequence, have to be crawled up on the low speed, with the engine running to waste. The most reasonable compromise would appear to be a motor powerful enough to take all small gradients on the top gear, combined with a transmission providing at least two lower gears for hills properly so-called. The reversing gear is practically always combined with the variable speed gear.

The Chain drive type of gearing has been practically discarded as a feature in the design of modern cars, although one or two makers fit the engine across the chassis to convey the final drive to the back axle by means of a large single chain.

The Gear Drive,

"cardan," "arbor," "propeller-shaft," or "live axle" gear is almost universal. The variable speed gear is devised with the clutch-shaft and gearshaft in line; and for the top speed these two

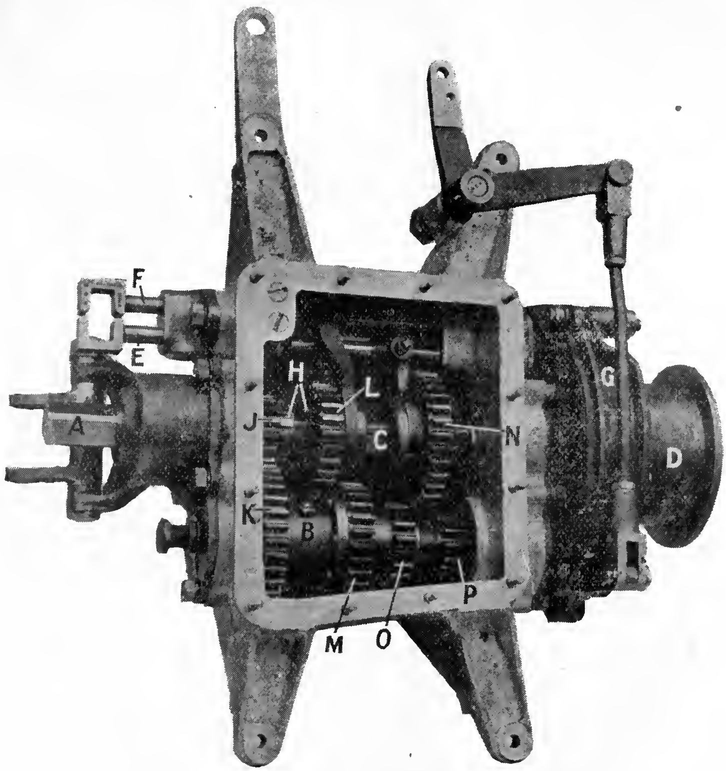


Fig. 59.—Direct Drive Gear Box, Neutral Position.

A, intermediate or clutchshaft.
B, secondary shaft.
C, primary shaft.
D, casing of universal joint on propeller-shaft.
E, selector rod of first and reverse speeds.
F, selector rod of second speed and direct drive.
G, propeller shaft brake.
H, dog clutches forming direct drive.
J, driving intermediate pinion.
K, driven intermediate pinion.
L, driven wheel of second speed.
M, driving wheel of second speed.
N, driven wheel of first speed and reverse.
O, driving wheel of first speed.
P, driving wheel of reverse.

shafts are coupled together and rotate as one, the power being transmitted direct instead of through spur wheels. There are at least three speeds forward and one reverse, the two lower speeds and the reverse being obtained by the spur wheels. The construction is very ingenious, and may be described thus: The rear end of the clutchshaft and the forward end of the gearshaft telescope into each other. The gearshaft is made of square

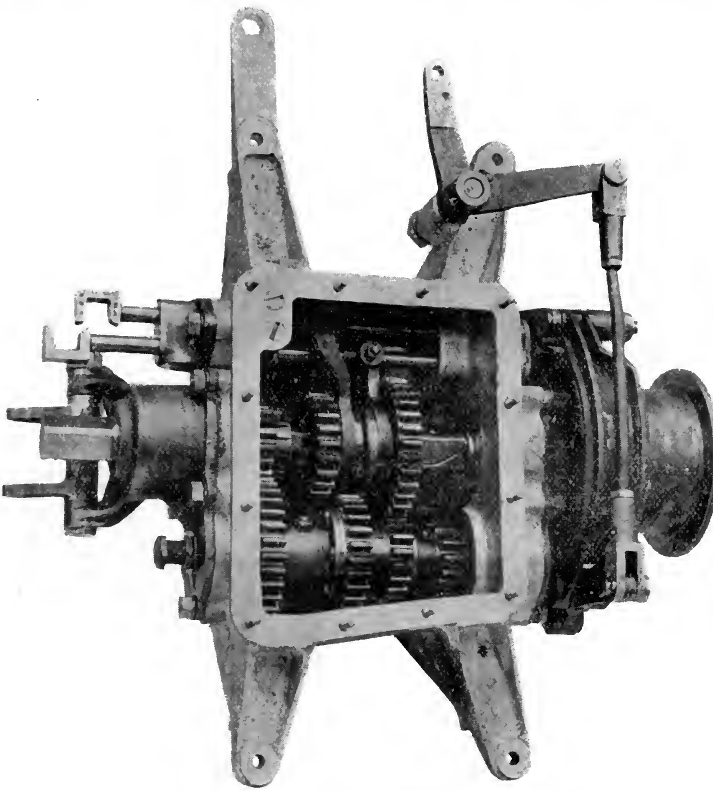


Fig. 60.—Direct Drive Gear Box, First Speed Position.

section, and on it is mounted a sleeve carrying two spur wheels of different sizes. On the forward end of the sleeve are two strong "dogs" or projections. while on the rear end of the clutchshaft is fixed a wide spur pinion having similar dogs in its back face. A second gearshaft is mounted parallel to the first, and on this are fixed two "forward" spur wheels corresponding in diameter to the two on the first gearshaft. On the same secondary is fixed one of a pair of what are termed intermediate pinions: the other, the driving pinion, is secured to the clutchshaft extension just inside the gear box. These two intermediate pinions are permanently in mesh, running loosely when the top direct drive is in gear, but being utilised for all the other speeds, including the reverse. A small pinion, one of a train of wheels forming the reverse drive, is also fixed to the secondary shaft. The various pinions or gear wheels

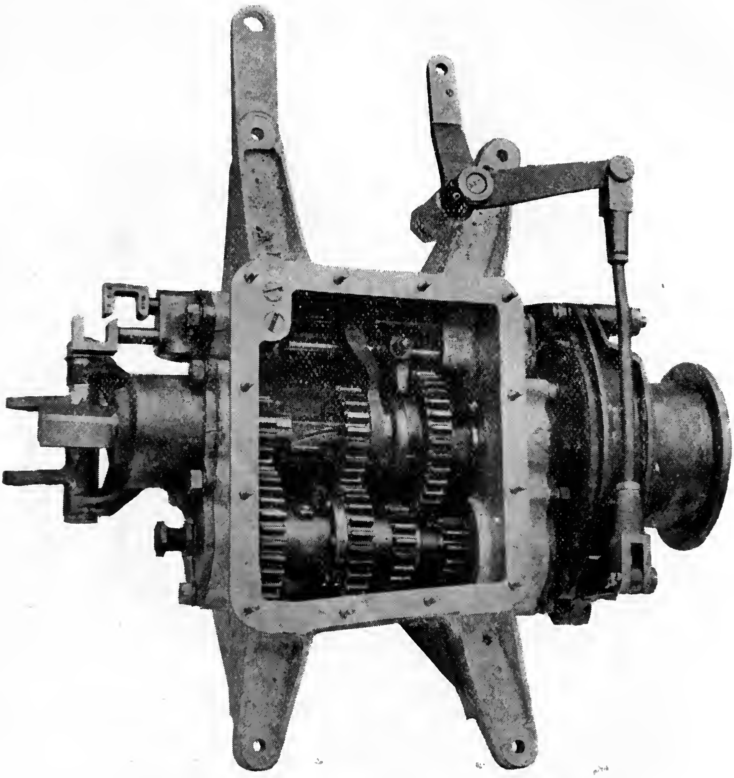


FIG. 61.—DIRECT DRIVE GEAR BOX, SECOND SPEED POSITION.

referred to above are seen in figs. 59 to 63, which illustrate the various positions taken up by each series when the drive is being conveyed by first, second, top, and reverse gears. The "neutral" position—when no gear is engaged—is also shown.

For the top speed the clutchshaft and first gearshaft are coupled together by moving the sleeve forward until the dogs thereon enter the recesses in the spur wheel on the clutchshaft. This is the "direct drive," and is so called because no power is lost by transmitting it through the second gearshaft; indeed, in some forms of the gear, the second shaft is not even rotated when the top speed is "in." For the two lower speeds, the sleeve is moved back so as to disengage the dog clutch and bring one of the wheels on the sleeve into gear with the fellow wheel on the second shaft. Now the power is transmitted from the pinion

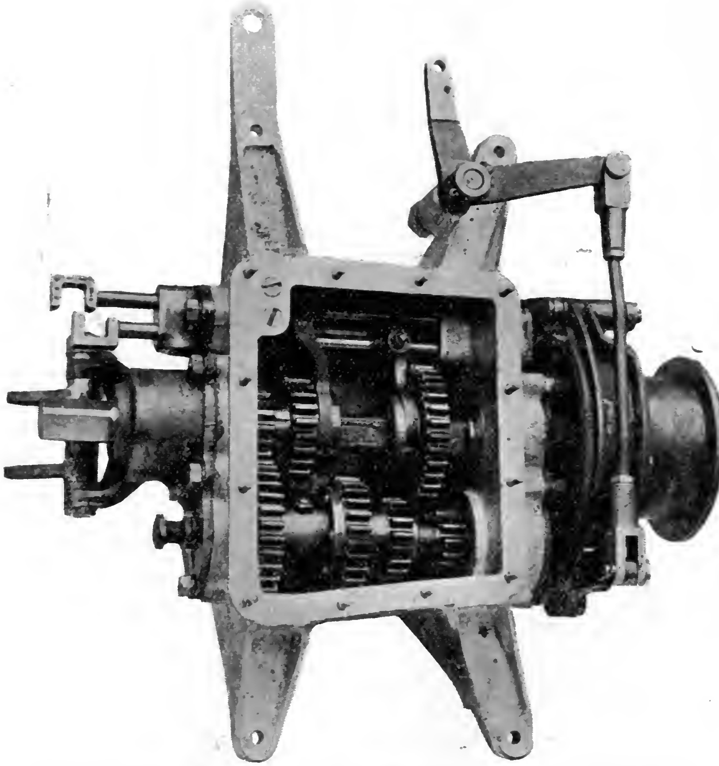


FIG. 62.—DIRECT DRIVE GEAR BOX, TOP SPEED POSITION, THE DOG CLUTCHES ON THE FACES OF PINIONS J AND L (see fig. 59) BEING IN MESH.

on the clutchshaft to the largest wheel on the second shaft, and then back from one of the smaller wheels on this shaft to the wheel in gear with it on the sleeve, and so to the first gearshaft. This is not unlike the "back gear" of a lathe. For reversing purposes a fourth wheel on the second shaft is geared with the larger wheel on the sleeve through an intermediate wheel.

This form of gear is often modified to give four speeds, and then the third speed is sometimes made to give the direct drive, if the fourth is too high for general use.

In nearly all cars the gear is changed by a hand lever pivoted at the right hand side and working, in some cases, in a slotted quadrant. Recesses in the quadrant receive a safety catch worked by a finger lever on the hand lever, and hold the latter in the

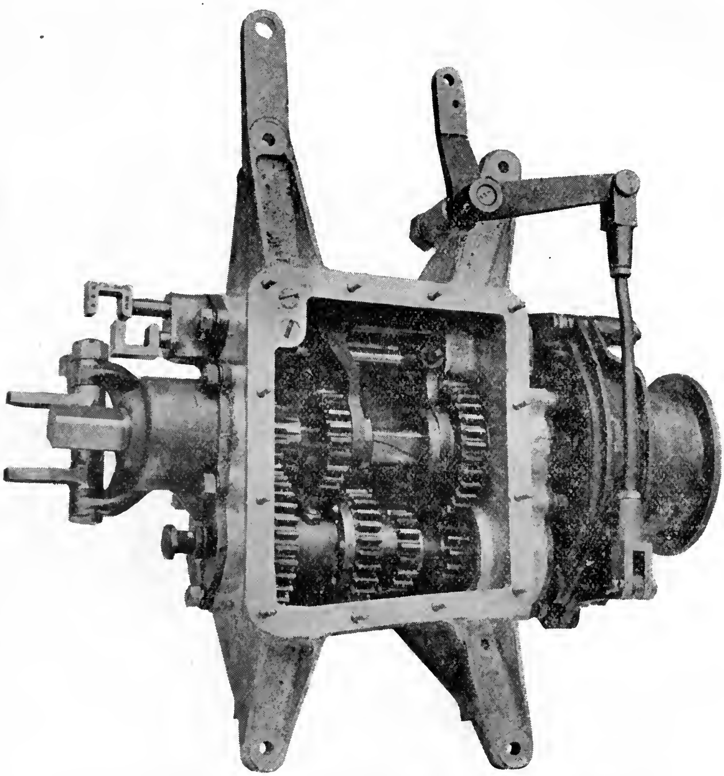


FIG. 63.—DIRECT DRIVE GEAR BOX, REVERSE WHEELS IN MESH.
(The intermediate pinion is not shown, being underneath the two wheels N P (see fig. 59).

different positions to which it is set in changing gear. The gate change quadrant is so called from its having two or more slots side by side, and an opening or gate between them through which the lever is moved with a lateral motion in passing from one slot to the other. In this case the different gear sleeves have separate forks and actuating rods (F and E in fig. 59), which are engaged by a "finger" when the hand lever is moved sideways. Strong spring retainers should be fitted for automatically locking the rods, forks, and gear sleeves that are not at the moment under the direct control of the hand lever.

A special catch of some sort should be provided to prevent the gear lever being moved so as to bring the reverse into action in mistake for one of the forward gears.

The Live Axle.

To the rear end of the first gearshaft is connected, by a universal joint, the cardan-shaft proper. The power is transmitted to the balance-geared axle by bevel or by worm gearing and a speed reduction between the motor and road wheels is made at this point, the bevel pinion on the cardan-shaft being only a fraction of the size of the bevel wheel on the balance gear casing. Sometimes a second universal joint is introduced near the rear end of the cardan-shaft. To be really "universal" the two axes of the joint should intersect, but this is seldom the case, and it is not of great importance. The joints are used to compensate for the movement of the springs, which, of course, in this case, come between the road wheels and the frame on which the variable gear box is mounted. The parts of the shaft should be as nearly as possible in line during average running conditions; otherwise, an excessive amount of work will be put on the joint or joints. Some longitudinal play should also be provided for in the shaft.

In this type of transmission the road wheels are driven direct by the parts of the balance-geared axle, which is here called a "live axle," to distinguish it from the non-rotating axle on which the wheels revolve in the old chain driven type. The parts of the live axle are mounted in bearings in a tubular casing, which is in turn secured to the rear springs, and thus to the frame of the car. The casing is enlarged centrally to enclose the balance gear and driving bevel wheel. and also to enclose and provide a bearing for the bevel pinion. In fact, a bearing ought to be, and now often is, provided for the tail end of the cardan-shaft behind the pinion as well as in front, as it is very important that the relative positions of the bevel pinion and bevel wheel should be perfectly maintained. Not only is there a tendency for the bevel wheels to push apart, but, owing to the resistance to propulsion offered by the road wheels, the pinion tries to climb up the bevel wheel, and so rotate the axle casing. This should be met by providing the casing with a radial arm, or "torque rod" which should extend forward about as far as the forward universal joint in the cardan-shaft, where it should be connected, with a small amount of elasticity, to the car frame. A neat way of resisting the rotative tendency of the live axle casing is to dispense with the rear universal joint, and continue the part of the casing containing the tail of the shaft, along the shaft, nearly to the front universal joint. This answers the purpose well, and makes for simplicity at the same time.

Points of the Live Axle.

As the axle casing has to preserve the positions of both the driving bevel wheels and the balance gear wheels, it must be well

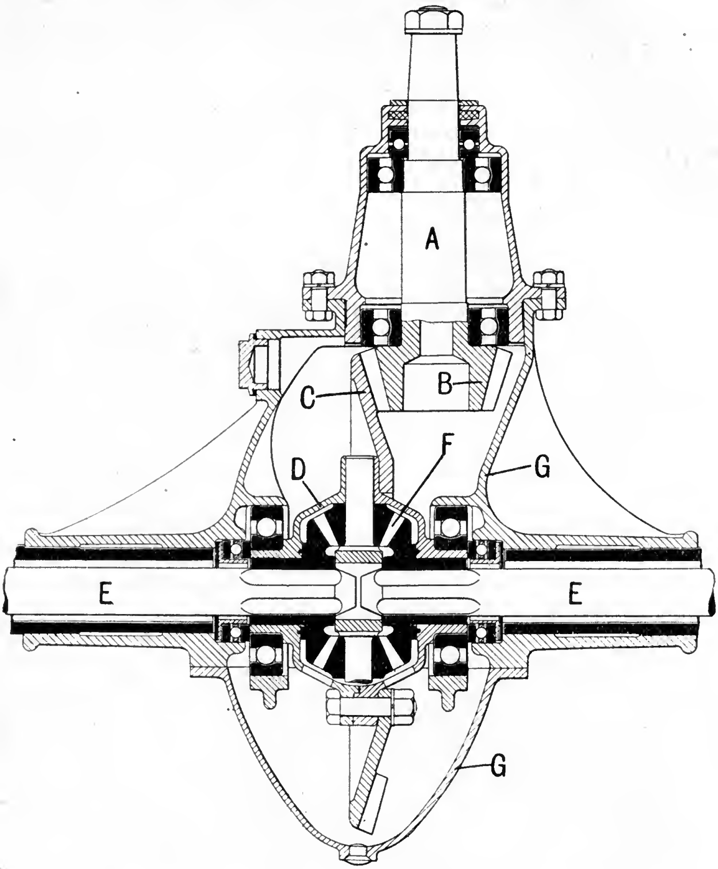


FIG. 64.—SECTION OF CENTRE OF LIVE AXLE, WITH BEVEL DRIVE AND BEVEL DIFFERENTIAL.

A, bevel pinion shaft.
B, bevel pinion.
C, crown bevel wheel.
D, differential case.
E, driving axles.
F, differential bevel gear pinions.
G, axle casing.

designed, well constructed, and not skimped in weight. In fact, the live axle, with its casing, is a delicate, though large, piece of mechanism; and in order to spare it, in some degree, a good many makers avoid attaching the road wheels directly to the parts of the axle. Instead, they mount the road wheels on short, hollow stationary axles, formed by extensions of the casing. The ends of the live axle and of the hubs project beyond the hollow axles, and are locked so as to rotate together, as by stars or carriers on the axle engaging in radial recesses in the outer faces of the hubs. In this way the live axle serves to drive the wheels without being burdened with their weight. This is good so long as the locking device is strong enough.

This type of gearing scores on the points of neatness and its comparative immunity from the ravages of wet and grit, though the joints of the shaft should always be carefully encased in leather or metal covers and packed with grease.

Other Gear Devices.

To deal with all the other systems of gearing would require a book by itself, but one or two may be briefly referred to. In some old two-speed gears the wheels are always in mesh, but the wheels on one shaft are loose and are coupled up thereto by expanding clutches. The expansion of one clutch is accompanied by the contraction of the other. Change of gear thus automatically involves clutch release, and the ordinary pedal-operated friction clutch is dispensed with.

On several cars of American origin, and a few British, the motor-shaft is set transversely and carries a box containing epicyclic gearing, and motion is transmitted from this drum to the live axle by a single chain.

Epicyclic or "Crypto" gearing is not easily understood, even with a model before one. The most familiar example of it is that fitted to the hubs of two-speed bicycles. A centre or sun wheel is surrounded by an internally-toothed wheel of considerably larger diameter. One or more planet pinions are mounted on a carrier and gear with both the other wheels. All the wheels are in one plane and form a concentric system. By locking the sun wheel, the internally-toothed wheel, or the pinion-carrier to either the driving or the driven parts, and by holding one or other of them stationary, forward and reverse motions can be obtained at different ratios. The wheels are always in mesh, and the changes of speed are brought about, in cars, by the application of brake bands, and, therefore, without shock.

Belt gearing was very largely used on early motor cars, and it had considerable advantages in the ways of silence, smoothness of working, and simplicity; but the constant stretching, slipping, and breaking of the belts, due, largely, to the use of unsuitable material and exposure to wet and mud, and some lack of efficiency, gradually led to its abandonment, though it is not done with yet and may possibly come in again for small cars. If properly carried out there is much to be said in favour of the belt drive for small low-priced cars.

The Gear Box.

The spur wheels of the variable gear are enclosed in a gear box, which serves several purposes. First, to provide a framework in which the spindles may be mounted in bearings of fixed relative position; second, to exclude dirt and wet; and third, to hold a quantity of gear-case oil for lubricating the wheel teeth. The spindle bearings are usually lubricated with oil contained within the bottom half of the casing, and splashed by the rotating pinions to the various parts. The balance gear is similarly enclosed and lubricated.

CHAPTER X.

The Frame.

THE motor and its appurtenances, the transmission gear, the springs with the axles and wheels, and the body, are all assembled upon the frame. The frame is generally rectangular in plan, but narrowed towards the front to allow of the steering wheels being deflected through a greater angle. In side elevation the main frame frequently departs from a single horizontal plane, the rear end being raised to give more play for the springs.

Varieties of Frame Construction.

The earliest frames were constructed very largely of wood, but now metal is the predominating material. When wood is employed, it is reinforced by metal " flitch plates." These should be deepest in the middle of the frame and tapered off towards the ends to prevent sagging. Frames built of weldless steel tubes were more common formerly than now, though still employed in some small cars. Channel section iron or steel was at one time very popular for frame construction, but this has now been very largely superseded by the pressed steel frame. In this last, sheet metal is pressed in powerful presses to a [section, the web being made deepest in the middle and shallower towards each end of the frame. The pressed steel frame has been very cleverly developed, and is in some cases made with an integral apron or shield to cover in the underside of the motor and gearing—to form a kind of engine room floor, in fact. These shields are a great protection to the mechanism, and save a deal of cleaning and the loss of some small parts that would otherwise be dropped; but it is more convenient to have them in detachable sections than as a permanent fixture. When a car is not made with a shield in the first place, one should be fitted as soon as possible. It may be made of leather or prepared canvas, instead of metal, if preferred.

The Question of Rigidity.

The frame should be braced transversely by cross members; and, unless naturally of girder formation, may be strengthened vertically by trussing with tension rods and king posts. It is almost hopeless, however, to attempt to build a really rigid frame of anything like reasonable weight. All four wheels have to find a footing on roads that are often uneven; and as the play of the springs is somewhat limited, one can only expect the frame to do a bit of compensating on its own account. This being so, it is important that the various elements, such as the motor, the variable-gear box, and the back axle, should be mounted and connected by means that will prevent any harm arising from moderate disalignments. The gear box often, and the motor occasionally, is supported on three points, to allow it to adapt itself to internal movements of the frame. On the other hand, the motor and gear are sometimes connected *en bloc* to prevent any disalignment. Apart from this consideration, the motor and gear box are often carried on a smaller frame—known as the sub-frame or underframe—mounted within the front portion of the main frame. Nowadays, however, it is more usual to mount these parts directly on the members of the main frame. Provided the sub-frame is well constructed and suitably carried—and it is very often wanting in the latter particular—there is not very much to choose between the two systems

CHAPTER XI.

The Axles and Bearings.

THE axles of the road wheels are often round and solid, though occasionally made hollow to decrease weight and increase strength. On the most expensive cars, non-rotating axles are usually constructed of I section nickel steel, with the flanges horizontal and the web vertical. This is a very strong form, and light at the same time.

Three kinds of bearing are open to the car designer—plain, roller, and ball. In the first the contacting surfaces are very large, and absence of friction depends upon the maintenance of a film of oil between them. A well-constructed plain bearing, comprising a steel spindle turning in well-fitted bushes of some good brass alloy, will run freely and without undue wear for a long time; but it is difficult to readjust perfectly.

The Roller Type.

In roller bearings, the sliding contact is superseded by a rolling one, a series of steel cylinders being introduced between the shaft and the bearing case. The area of contact is reduced to a series of lines, and the number of lines is less than it might be owing to the necessity of keeping the rollers out of contact with each other. If the rollers were allowed to touch, they would tend to turn each other in opposite directions, and friction would be set up by the sliding line contacts. The rollers also have a propensity for twisting out of parallel with the shaft, and this leads to further trouble. Hence the ferocity of the rollers is usually tamed by confining them solitarily in cages. When thus restrained they serve very fairly well, and were at one time quite extensively in use; but their expense and the practical impossibility of adjusting them, prevented their permanent adoption. A new type of conical roller bearing, which not only carries load, but will also take up end thrust strains, is gradually finding favour, especially in America. This form of roller bearing is adjustable, the rollers being made of conical form for the purpose.

Ball Bearing Considerations.

The ball bearing retains the advantage of the rolling contacts, and has the further great merit that it lends itself to ready adjustment; but the fact that it only provides minimum areas of contact, viz., points, makes it unsuitable for withstanding blows, as, for example, in the connecting rod bearings of the motor. Ball bearings are now employed freely in the transmission gear and wheel hubs; a well-designed front wheel hub with ball bearings is shown in fig. 65. As in the example, a separate set of bearings which solely take end thrust is advisable, in addition to the journal bearings which carry the load.

Every bearing must be lubricated in some way. A number are fed through pipes from the sight-feed lubricator on the dashboard; the steering pin bearings and a few others are generally fitted with

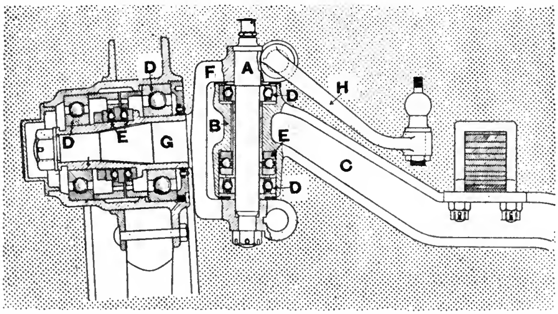


Fig. 65.—Ball Bearing Hub, Front Wheel.

A, steering spindle.
B, axle socket.
C, front axle.
D, journal bearings.
E, thrust bearings.
F, steering swivel.
G, stub axle.
H, steering pivot arm.

grease cups, the grease being forced into the bearing by a spring, the pressure of which is increased by screwing down the cap of the lubricator. The gear box may be freely treated with a grease containing a liberal admixture of finely-powdered graphite, which tends to quieten the sound of the driving pinions.

CHAPTER XII.

The Road Wheels.

THE road wheels form a very important element in a motor car. They have to support the whole vehicle, and to roll along the ground. Further, the rear wheels are responsible for the driving and breaking, while the duty of steering lies upon the front ones. The wheels bear the first brunt of the road shocks; and in turning corners they have to withstand great lateral pressure, especially if the road is banked the wrong way.

The most susceptible part of the wheel, and, indeed, of the car, is the tyre; and as the rear wheel tyres, owing to their having to transmit the driving and retarding strains, wear out more quickly than the front tyres—which have only to roll and steer—it is a convenience to have all the wheels equal in size, so that the tyres may be interchanged when required. To most people, too, we think equal wheels present a more shipshape appearance than large drivers and small steerers.

Size and Strength.

The actual diameter of the wheels will, of course, vary with the class of car, but in our opinion there is a tendency to make them too small. Not even a runabout car should have wheels less than 30in. in diameter, while 34in. makes a good size for an average. Small wheels are stronger in proportion for their weight, and the tyres cost less in the first place, but larger wheels are less subject to road shocks, and the tyres, having a larger surface, last longer.

As already indicated, the wheels must be strong vertically to carry the weight, and laterally to withstand centrifugal forces and pressure set up by running against kerbs, projecting tram lines, etc. The lateral forces generally act on the wheels from the outside towards the longitudinal centre line of the car. The driving wheels, in addition, must be strong tangentially to transmit the driving force and stand the application of the hub and gear brakes.

Wood Wheels versus Wire.

As a rule, motor car wheels are constructed of wood and without any " dish "; the artillery wheel, however, which has a metal hub or nave, and which is sometimes slightly " dished " or concavo-convex, is very largely employed. The wire wheel, especially when of the detachable type, is rapidly returning to popular favour. Its double-dished construction makes it very strong laterally, and the usual tangential arrangement of the spokes gives a high driving and braking efficiency. It is a good deal more trouble to clean than the wooden wheel, and its appearance is open to discussion ; but, on the other hand, it is much easier to replace a spoke in a wire wheel than in a wooden one, and the balance of weight is in favour of the wire wheel. As the parts of the rotating wheel move up and down as well as along, weight saved in the wheels is worth considerably more than the same weight saved in fixed parts of the car. Another point in favour of wire wheels is that owing to their lightness they ease the steering and one can also have large tyres without increasing the total rotating weights, as what one adds in the larger tyres one saves in the lighter wheels.

CHAPTER XIII.

The Tyres.

THE function of a tyre is usually to tie together the felloes of the wheel, as the more correct spelling—tire—shows. This tying duty is now generally performed by the rim, and the so-called tyre is relegated to the duty of absorbing vibration. Vibration is not only wearing to the occupants of the car, but to the car itself, and, moreover, it wastes power. True, the car jumps and jerks because of the inequalities of the road surface, but unless the motive power were sufficient to overcome them, these same inequalities would stop the car altogether. The better the tyre will swallow the projections and fill up the holes, the less vibration will be felt and the less power wasted. There is a proviso to this, however, in respect to the driving wheel tyres. The adaptability of form in the tyre must be accompanied by rapidity of restoration, otherwise the tyre will drag, and power will be lost in the deformation.

As no tyre is perfectly resilient radially, or perfectly rigid tangentially, every driving wheel turns round slightly relatively to the tread, and a lump is formed just in front of the area of contact between the tyre and the ground. This lump is constantly being ridden over, and as constantly forming. The part that has just been ridden over resumes its original shape, and so re-expands. In doing this it tends to turn the wheel forward, if it re-form quickly enough. Part of the superiority of the pneumatic tyre over the solid rubber tyre is doubtless due to the fact that in the former the re-formation at the back of the area of contact is practically simultaneous with the deformation at the front of such area, while in the latter the rubber re-forms so slowly that the action occurs too late to be of any assistance. In the pneumatic tyre, the elastic medium is operating at all points at the same time—the fluidity and elasticity of the air being practically perfect, and hindered only by the containing envelope. In the rubber tyre the movements of one part of the elastic body have little influence on other parts at only a short distance away, the material itself acting as a buffer almost as much as a transmitter.

Solid Tyre Considerations.

Solid rubber tyres present negative advantages in the way of freedom from punctures (or, rather, their results) and bursts; and if of good quality, size, and form, and securely attached, they will run a long time without giving much trouble. They seldom cause stoppages in the course of a run, and where specially flexible springs are fitted to the car, the difference in vibration, as compared with pneumatics, is not so noticeable as might be expected. Steering, however, is vastly better with pneumatics than with solids, probably because the superior elasticity of the former enables them to keep a more continuous contact with the ground than the latter. Pneumatics to the steering wheels and solids to the drivers form a good compromise, though there is generally more noise than when pneumatics are fitted throughout.

Constituent Parts.

The essential material—compressed air—of a pneumatic tyre cannot be much improved upon; but the incidental materials—the rubber and fabric of the cover and air tube—leave a good deal to be desired. The elasticity of the rubber is rather a disadvantage, in that it discounts the action of the air; but the flexibility and the waterproof quality of the rubber are good. Perfect flexibility and perfect inextensibility are what one looks for in a pneumatic tyre cover, and though one gets pretty near the latter, the flexibility is sadly lacking. Impermeability is another requisite, and non-liability to burst and slip are still others. Perhaps some day a strong thin, flexible, non-stretching, puncture-proof and water-proof material may be discovered; till then we must content ourselves with the best substitutes we know of.

The first requisite of the air tube is that it should be non-porous, so that it may fully retain the air. It should be as free as possible from seams and joins, and should fit the cover without either stretching or wrinkling.

The outer cover should be flexible, not only in material, but in design. The sides should therefore be comparatively thin, while the "tread" or running surface may be made thicker to ensure durability and resist puncture. Therubber is strengthened by several plies of fabric insertion. Two points are of great value in the design of the fabric. The first is the arrangement of the threads diagonally or obliquely to the length of the cover; this promotes flexibility without incurring either longitudinal drag or transverse instability. The other point is that the threads should not be interwoven; this gives freedom of action to each thread (and hence flexibility), and also prevents the threads chafing each other to their mutual destruction.

Methods of Attachment.

The most usual method of attaching the pneumatic tyre to the wheel consists in providing the cover without outwardly-directed edges, and the rim with inwardly-directed edges, so that the edges of the cover hook into the edges of the rim. A modification of this consists in making the rim in two parts, so that one side can be removed at will. This enables the tyre to be slid on and off the base of the rim, instead of being forced over the edges. Further, it enables one to see that the air tube does not anywhere protrude between the edges of the cover, before the tyre is put in place on the rim and inflated. With the usual single-piece rim, the nipping of the air tube between the edges of the cover is a frequent source of trouble. The means provided for releasing and securing the detachable part of the divided rim are generally rather tedious.

Tyre Strains and Sizes.

The friction between the road wheels and the ground tends to cause the tyre to "creep" round the wheel. This creeping tendency is naturally more pronounced in the case of the driving wheel tyres. To prevent the movement, a number of radial bolts, with specially-shaped heads, are passed between the edges of the cover and through the rim and felloes at intervals. By tightening flynuts on the bolts, the edges of the cover are locked firmly in position, and the injurious strain, to which the air valve would otherwise be subjected, is thereby removed.

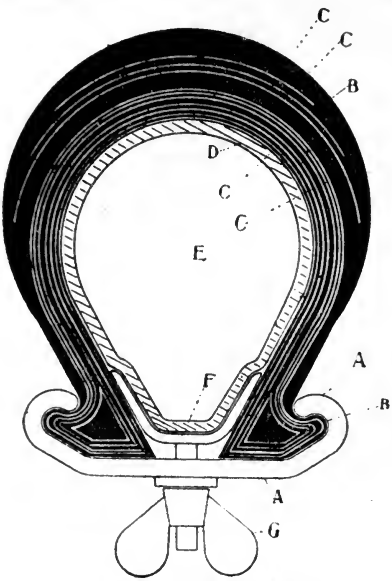


FIG. 66.—BEADED EDGE TYPE OF TYRE.

A, rim. B, outer cover. CC, fabric insertions in B. D, inner tube. E, air space. F, security bolt. G, winged nut.

The most important advice that can be given about tyres is to have the very best, and have them of extra size. The different tyre makers recommend certain minimum sizes for the carrying of certain weights of car and passenger. The car makers and retailers are too apt to cut down cost in tyres, which are always an expensive item. But the purchaser should not be content with these minimum sizes; a few more pounds laid out in "over-tyring" will be very well invested. The larger tyres will last far longer, and give greater comfort and less trouble than the smaller ones. *Verb. sap.*

Tyre Replacements.

As tyre repairing on the road is a thing to be avoided if possible, a complete spare cover and a supply of air tubes should be carried on the car. This idea can be carried out in several stages of completeness. The rims of the wheels may be made with a detachable flange, so that a damaged tyre can be quickly removed and replaced by a good one. Or the rim may be of a duplex nature, so that the spare cover and tube may be carried ready inflated on the outer rim, the whole being interchangeable with similar parts on the wheel and which can be released from the inner part of the rim, which is provided with means for securing the outer parts as required. The provision made for the accommodation of the valve and the locking bolts should be so arranged as not to entail any undue weakening of the wheel itself. The Stepney spare wheel goes rather farther than this. Here the ready inflated tyre is mounted on a rim

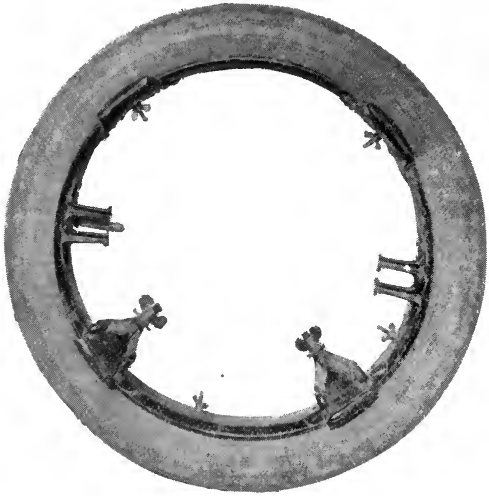


FIG. 67.—THE STEPNEY SPARE WHEEL.

which is provided with fittings whereby it may be secured to the side of the wheel. The damaged tyre need not even be removed from its place. Or, lastly, one may carry a complete road wheel. But this device is only to be recommended with a car on which all four wheels are made interchangeable.

Non-skid Devices.

In order to prevent side-slip, the tyres should have a good grip of the ground. This means that the tread of the tyre must be, more or less pronouncedly, otherwise than smooth. One of the simplest devices consists in forming the rubber tread with some form of shallow grooves at short intervals. Another arrangement is to provide the cover with a leather band having steel studs set in the tread (fig. 68). This is very effective, and the leather also serves as a powerful puncture resister. Some of these bands are made detachable, but unless very firmly secured there is a risk of grit working under them and abrading the rubber cover. One of the most successful non-slipping devices is the Parsons (fig. 69). This comprises a number of curb chains passed across the tread of the tyre and connected to other chains lying on either side of the wheel. The rings are loose enough to allow of creeping, so that the tyre and chains are always shifting their relative positions, and absolutely no damage is done to the tyres. As each chain is passed over, it secures a grip upon both the tyre and the road, and so prevents slip. These non-skidders,

FIG. 68.—STUDDED BAND NON-SKID.

FIG. 69.—PARSONS NON-SKID.

being detachable, can be carried in the car and put on when required. Some non-slipping devices doubtless deaden or slow the tyres, but that is better than the risk of an accident.

The treatment of tyres is dealt with in Chapter XVIII.

CHAPTER XIV

The Springs.

THE elastic tyres must not be expected to deal with more than the small irregularities of the road; the large inequalities must be left to the springs. These are generally introduced between the wheel axles and the frame, and are usually of the semi-elliptic type, consisting of a number of curved laminations or plates. The spring is hinged directly to the frame at one end. and is linked thereto by a shackle at the other. The "dumb irons," "hangers," or brackets by which the springs are connected to the frame should be of good design and full strength; there is often room for improvement in these respects.

The springs should be of ample length, and well up to the weight they are called upon to carry. But the laminated spring lends itself to ready adjustment of the strength by the addition or subtraction of plates. Rubber buffers may be employed to prevent closing, and checks to prevent bouncing. Spring checks or shock absorbers are better, as they control the rebound of the spring without interfering with its free compression. They add greatly to the comfort of a car if they and the springs are correctly designed and proportioned to each other. The main springs should be arranged lengthwise of the car. Transverse springs conduce to rolling, and may thus become a source of danger. Thus it is seldom a good plan to introduce a transverse spring at the front of the car, but such a spring at the back is not dangerous, and adds considerably to the comfort of the passengers. Spiral springs are often tried, but are generally superseded by laminated ones in the end Provision should be made for lubricating the plates and joints.

CHAPTER XV.

The Brakes.

MOTOR cars are required by law to have two independent brakes, and they are usually fitted to the driving wheels and to the transmission gear respectively. Some of the early cars had tyre brakes, but these are now never met with. All the brakes act, ultimately, in checking or stopping the rotation of the road wheels, and depend upon the friction between the road wheels and the ground for the retarding effect to operate upon the car.

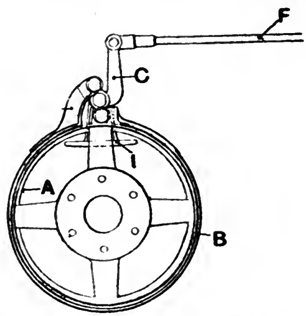


FIG. 70.—EXTERNAL BAND BRAKE.
A, brake drum. B, brake band.
C, three-arm lever connected to ends of band, and turning on a pivot.
F, brake-rod.

The gear brake usually consists of a drum, fitted to one of the rotating parts, and adapted to be gripped by a band or shaped blocks; as the brake operates through the reducing gear, it is more powerful than if fitted directly to the road wheels.

Internal and External Types.

The brakes fitted to the road wheel hubs are of the grip block, band, or internally expanding segment varieties. When employed externally the metal bands or rings are so applied that they are made to grip the brake drum from each end, thus making this description of brake effective either backwards or forwards. On long hills the friction sets up great heat, and to reduce this as much as possible brakes were at one time water-cooled. The water, a very small quantity, was admitted automatically, but is not required on modern cars owing to the general use of metal brake shoes. In internal brakes the heating difficulty is overcome by a certain amount of lubrication. All descriptions of shaft and wheel brakes require regular attention and ad-

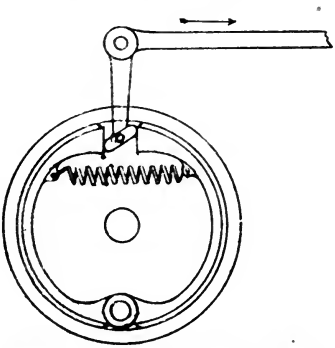


FIG. 71.—INTERNAL EXPANDING BRAKE.

justment, for unless they can be operated with the maximum effect obtainable from them they are of very little use.

Retarding with the Engine.

One of the brakes is operated by a pedal, and the other by a side lever. In some cars the brake pedal is coupled up to the clutch, so that applying the brake automatically disengages the motor from the driving gear. This is all right in the ordinary way, but in descending very steep hills it is useful to be able to let the car drive the motor through the low gear, thus obtaining additional retarding effect.

Therefore, nowadays, the fitting of an additional pedal, which acts on the brake only, is practically universal. The side lever should be, and practically always is, provided with a ratchet device, to allow of the brake being held on when the car is left standing.

As both the road wheel brakes are operated from a single lever (foot or hand), a compensating device should be introduced into the connections to ensure that each brake shall be applied equally. The compensator should be constructed on the balance beam principle, but often consists of a crude arrangement of thick wire cable bending round grooved guides of short radius. This cannot be considered satisfactory.

Front Wheel Brakes.

Several makers are now fitting brakes to the front wheels of their cars, and the improvements which have recently been made in this direction seem likely to bring this practice into general use. The use of front wheel brakes largely prevents side-slip when the brakes are applied on muddy roads, and the retarding effect is enhanced, owing to the mass of the weight of the car being naturally thrown on to the front wheels when brakes of any kind are applied.

The Sprag.

Every brake should be equally effective whichever way the drum is rotating. This is not only so that the driver can pull up after he has purposely reversed, but also when the car begins to run backwards quite independently of the driver's wishes ; as, for example, when it proves unequal to climbing an extra stiff hill. For this emergency the car may be fitted with some kind of sprag. This instrument sometimes also rejoices in the name of "devil," when it consists of a bar hinged by one end to the frame of the car and pointed at the other end. The sprag is normally held up clear of the ground by a cord, but when the car is likely to stop on a hill the driver should release the cord in good time, and let the "devil" drag on the ground. Then, directly the car stops, the pointed end of the bar digs into the ground, and an involuntary descent is avoided. Unfortunately, the driver often forgets or neglects to let down the sprag until the car has actually begun to run back. If he releases it then it may bring up the car with a severe jerk ; or the car may over-run the sprag, which is even more serious.

Another form of sprag consists of a strong pawl, which is allowed to trip over ratchet teeth cut on a revolving part of the gear. This is a good deal neater than the " devil," but, it carelessly used, it is liable to put very severe strains on the transmission gear, especially on the part to which it is fitted. Even with good brakes the one great advantage of a sprag is that it permits the car to be restarted on the steepest hill with both brakes off. This saves a lot of racing and possible stopping of the engine.

CHAPTER XVI.

The Steering Gear.

THE simplest form of steering gear is that which we find in the horse carriage, *viz.*, a cross axle pivoted to the carriage in the centre, and carrying a running wheel at each end; the steering lever takes the form of a pair of shafts, and the carriage follows the direction of the lever as controlled by the driver through the horse, or by the horse alone, as the case may be. No modern motor car is constructed with central pivot steering, though the lever tiller is sometimes retained, *vide* the Lanchester petrol car and some electrics.

Stud Axle Pivots.

The great objection to the central pivot is that the road wheels act at too great a leverage. Not only must the front axle be very strong if it is to support all the weight of the front part of the

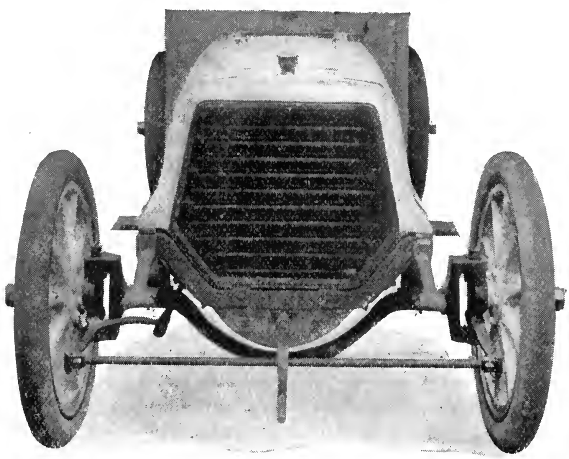


Fig. 72.—Front Elevation of an Old Type Car showing Vertical Steering Pivots.

car at its centre, but in the case of either wheel striking an obstacle, the axle is almost certain to be deflected, and the car possibly upset. These difficulties are met by providing the front axle with two pivots, one near each end. The main portion of the axle remains permanently at right angles to the length of the car. But the short end pieces—called stub axles—may be turned about their respective pivots, and the road wheels, mounted thereon, with them. If the axes of the pivots are vertical, the wheels will always have a tendency to turn outwards, though the actual movement is prevented by the steering connections, to be described later. But the tendency even may be obviated, and the deflecting influence of obstacles guarded against, by inclining the pivots so that their axes are directed to the points of contact between the wheels and the ground.

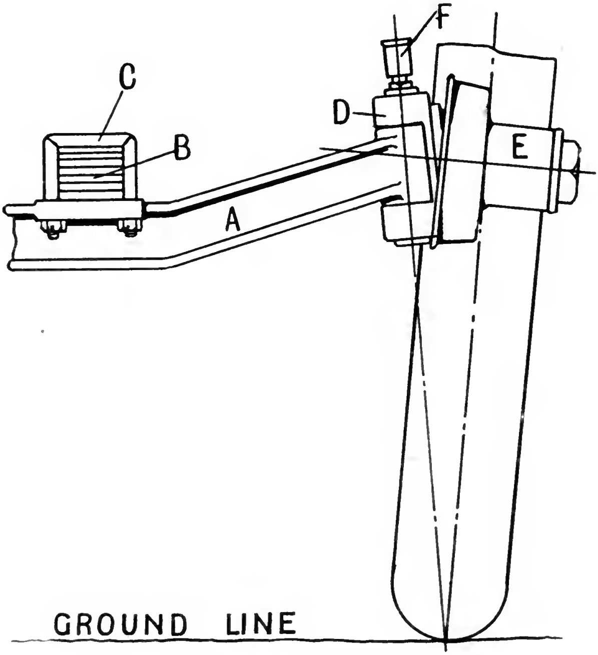


FIG. 73.—FRONT AXLE, WITH INCLINED STEERING CENTRE.

A, front axle.
B, front spring.
C, front spring clip.
D, swivel or stub axle.
E, front hub.
F, grease cap.

To ensure the wheels deflecting together in steering, each stud axle is provided with a forwardly or a rearwardly directed arm, and these arms are coupled together by a crossbar hinged to the ends thereof. Thus the deflections of one wheel are imparted to the other through the arms and crossbar.

The Ackermann System.

But unless carefully designed, stud axle steering is liable to set up lateral drag on the tyres ; and, as we have seen, the tyres have quite enough to do to manage their own business without indulging in works of supererogation. In taking a corner, all the wheels of the car should stand tangentially to curves struck from a common centre, which lies in a continuation of the back axis. The rear wheels, being at right angles to this axis, are naturally in the proper tangential positions, but the front wheels require putting there. The steering wheel nearer the common centre should describe part of a smaller circle than that described by the other wheel, which is further from the centre. Hence the inner steering

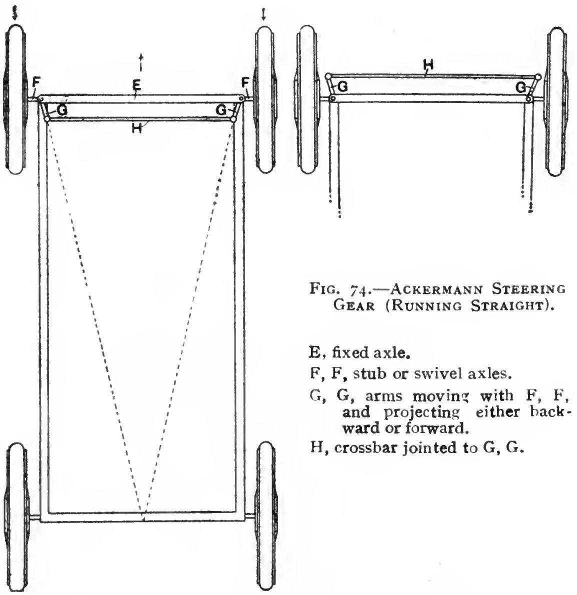


FIG. 74.—ACKERMANN STEERING GEAR (RUNNING STRAIGHT).

E, fixed axle.
F, F, stub or swivel axles.
G, G, arms moving with F, F, and projecting either backward or forward.
H, crossbar jointed to G, G.

wheel must always be turned at a sharper angle than the outer one. This may seem an awkward problem, but a simple solution is found in the so-called Ackermann system : Supposing the steering wheels to be set straight ; the arms projecting forwards or backwards from the stud axles are inclined, so that lines passing through the axis of each pivot and the axis of each crossbar hinge will, when produced, intersect at the centre of the back axle. This arrangement is found to give the requisite relative angles to the wheels when traversing curves, and should be followed carefully in the design of the steering gear.

Whether the cross bar should be in front of or behind the fixed axle is a moot question. There are points for and against both arrangements.

When the car is running straight forward, the front wheels, as well as the back wheels, should make perfectly parallel contacts with the ground. If the longitudinal axes of the contact areas converge or diverge, the wheels will scrape or "spin" as they rotate, and the tyres will wear quickly.

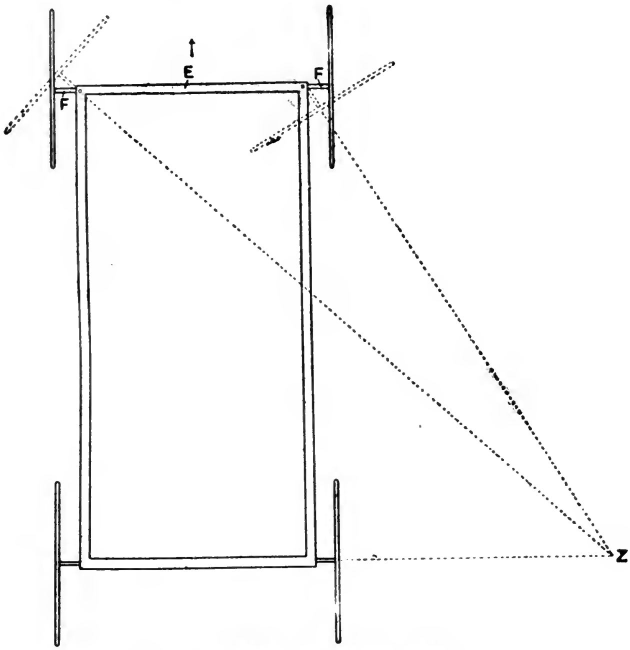


Fig. 75.—Ackermann Steering Gear.

(The dotted lines represent the wheels when diverted to negotiate a curve, the centre lines of the stub axle arms intersecting, as shown at Z, the centre of the curve.)

E, fixed axle. **F, F,** stub axles. ***Z*, centre of curve.**

Steering Wheel and Connections.

The operation of steering is now almost always performed by manipulating an article which, unfortunately, bears exactly the same name as certain other parts of the car—the steering wheel. There is virtue in this wheel, but it is no "magic circle," for a handle-bar may possess precisely the same leverage, or more. But where the benefit of the wheel comes in is that it is equally convenient to handle to whatever angle it is turned. And the convenience is considerable, in view of the fact that, in order to give the driver great control of the steering, the hand steering wheel is made to turn through a much greater angle than is imparted to the road steering wheels. Or, in other words, the steering is considerably geared down.

Not only is the driver given greater power over the steering wheels, but the connections are (or, at least, should be) so devised that the steering wheels can exert no force at all against the driver. This problem has several solutions, of which the following is an example. On the lower end of the steering column (which is surmounted by the steering wheel) is fitted a worm or coarse screw thread, which engages in the teeth of a sector, forming one arm of a bell crank. The other arm of the bell crank is coupled up by a rod to an arm on one of the

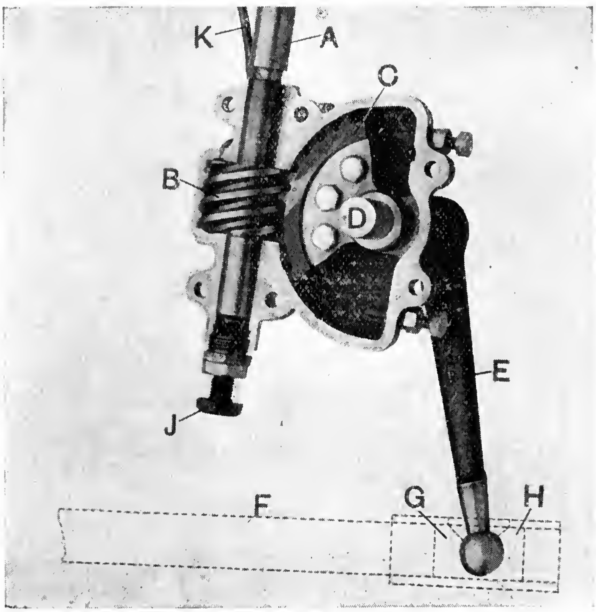


FIG. 76.—STEERING CONNECTIONS—WORM AND SECTOR.

A, steering column.
B, worm rotated by A.
C, sector engaging with B.
D, shaft carrying C.
E, steering lever connected to D.
F, steering rod.
G and H, segmental blocks embracing the ball end of B.
J, adjusting screw.
K, lubrication pipe.

stub axles. When the worm is turned by the driver, the bell crank is rocked on its pivot, and the movement is transmitted to the stud axle and its road wheel. The other road wheel follows suit by reason of the crossbar connection. The movement of the worm thus steers the car. But suppose, by running up against a "proud" tramway line or some other obstacle, the road wheel attempts to deflect; it pushes at its stud axle and arm, and the arm pushes at the bell crank, the sector teeth on which push at the threads of the worm. But these threads stand so nearly at right angles to the thrust of the sector teeth that the worm will not turn on this occasion, and so the steering wheel pusheth but in vain. The steering gear is thus said to be irreversible, and the prevalence of irreversible steering accounts for the fact that outwardly inclined steering centres are not more common. There are other ways of constructing irreversible steering gears than the worm and sector, just as there are other systems of differential steering than the Ackermann, but they or their equivalents should always be in evidence.

Points for Consideration.

There are one or two other points to look out for in the steering gear. There should be plenty of "lock" for the wheels, which, with an inconsequence not unusual in our language, means that the wheels shall be quite free to be deflected through a large angle, so that one may turn the car in an ordinary road without an inordinate number of reversings.

See also that the position of the steering wheel suits you personally. These things ought to be adjustable, but very seldom are; and it is not comforting to reflect that you are assuming the attitude of a weary woman wheeling home the washing, even if *les gamins* do not audibly remark on the fact. The joints of the steering gear should be very strong, well secured, adjustable, and enclosed against dirt and wet. They should also be provided with proper means of lubrication. The steering column is mounted in a hollow pillar projecting up from the frame. The pillar should be rigidly fixed, or it will be liable to vibrate violently while the motor is working.

CHAPTER XVII.

The Carriage Work.

IT is only comparatively recently that the body or carriage work of the car has received the attention it demands. The purchaser was always interested in the subject; in fact, he is sometimes inclined to lay more stress on the body than on the *châssis*,* while the manufacturer, having spread himself on the machinery, finds little enthusiasm left for the superstructure. Now, however, motor body building is quite a special line, and some very excellent specimens are being turned out.

The first consideration in choosing a body is the number of passengers to be carried. The number should be well within the powers of the engine, and it must be remembered that a large body weighs more than a small one, even when the extra seats are not occupied, and the difference will show itself in increased petrol consumption, tyre wear, and slower hill climbing.

Weather Protection.

If the car is to be an all-weather vehicle, it should have a good hood, a canopy, or a landaulette top; a front glass screen is practically a necessity. The hood will have to project a long way forward if it is going to shield the passengers from rain. Side doors to the footboard of the front seat contribute immensely to the comfort of the driver and his companion, and on all up-to-date cars the doors of the front seat are as high as those of the back.

Upholstery and Finish.

"Bucket" or armchair seats are sometimes fitted; but whether bucket or plain, the seat itself should slope down towards the back, the back should slant backwards, with a bulge to fit into the "small" of the occupant's back, and the footboard should be considerably sloped up in front. Beware of armrests that just reach up to the elbow; they are most tiring on a long journey.

Aluminium alloy is now very largely used in the construction of bodies; but whether the saving in weight as compared with wood and sheet steel is worth the addition to the already high cost, is a matter for each to determine according to his pocket.

The question of finish also is one for personal determination. For ourselves, we think very bright colours and a great deal of brass

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* *Châssis* strictly means frame, but as generally used it includes also the motor, gear, etc; in fact, everything but the body.

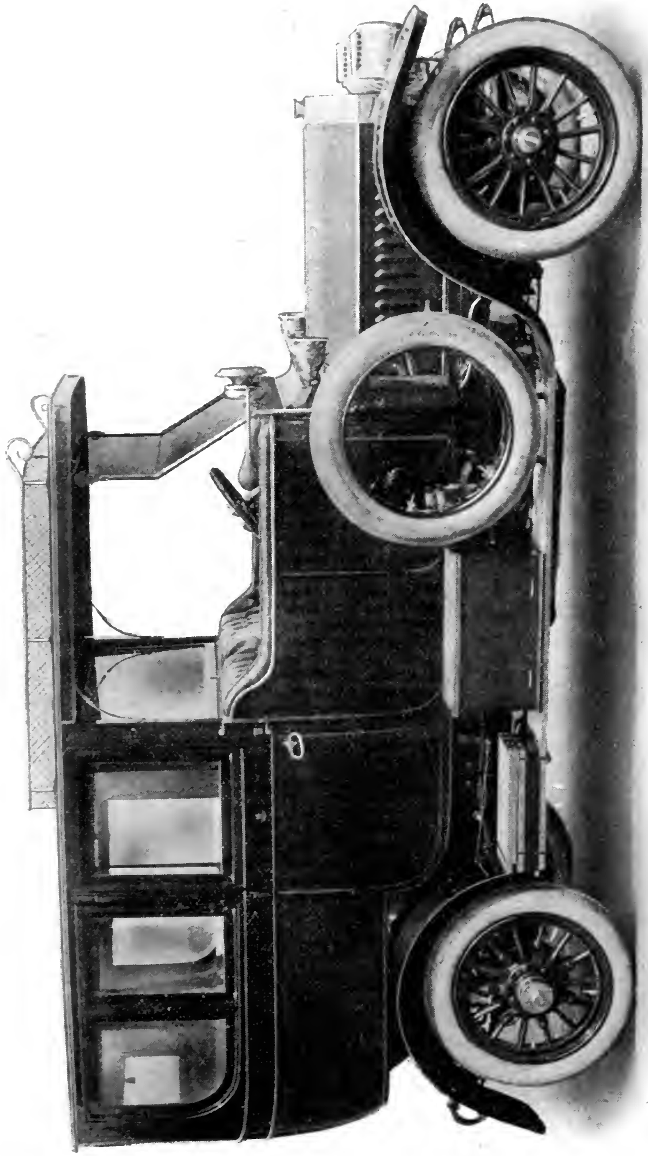

Fig. 77.—Limousine Body.

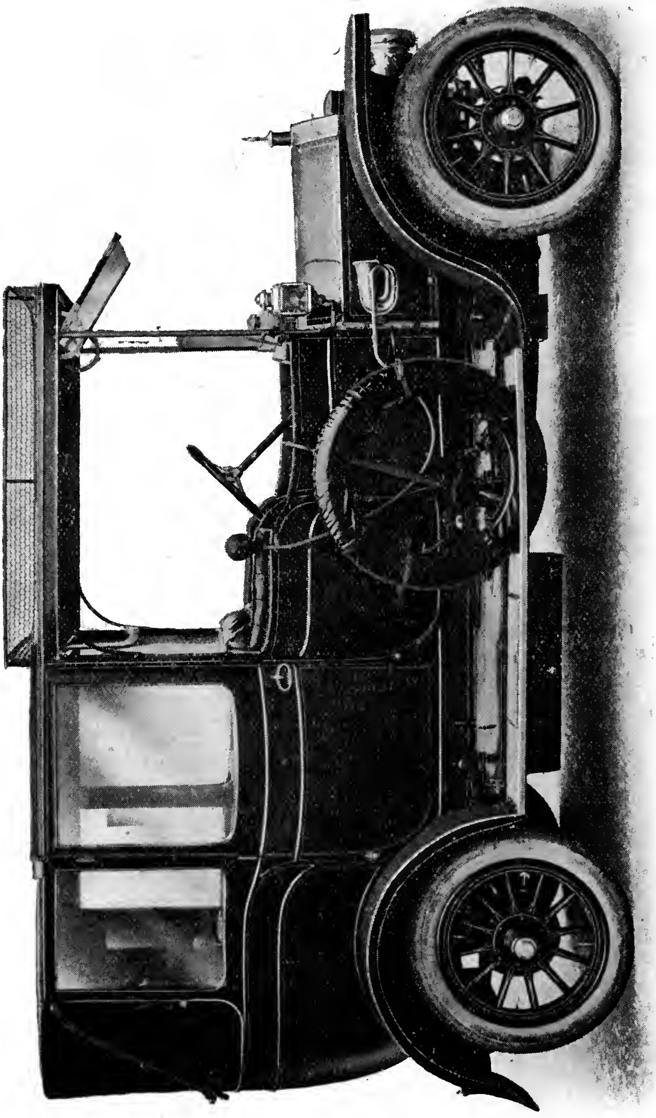

Fig. 78.—Limousine Landaulet Body.

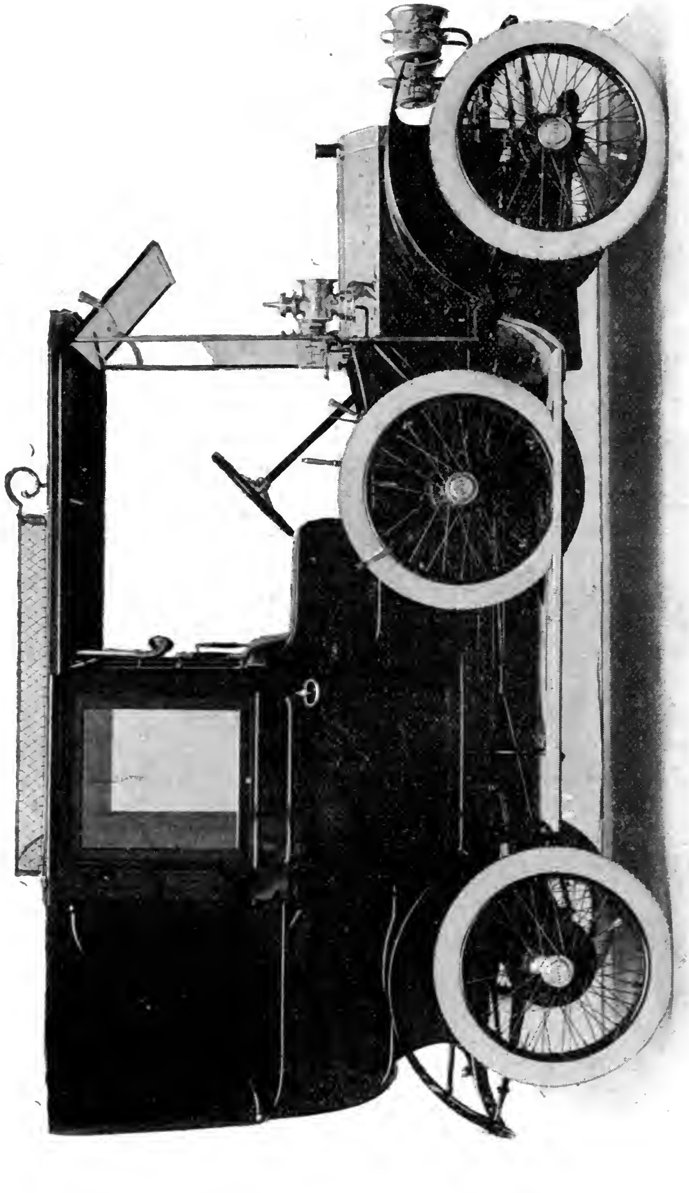

Fig. 79.—Landaulet Body.

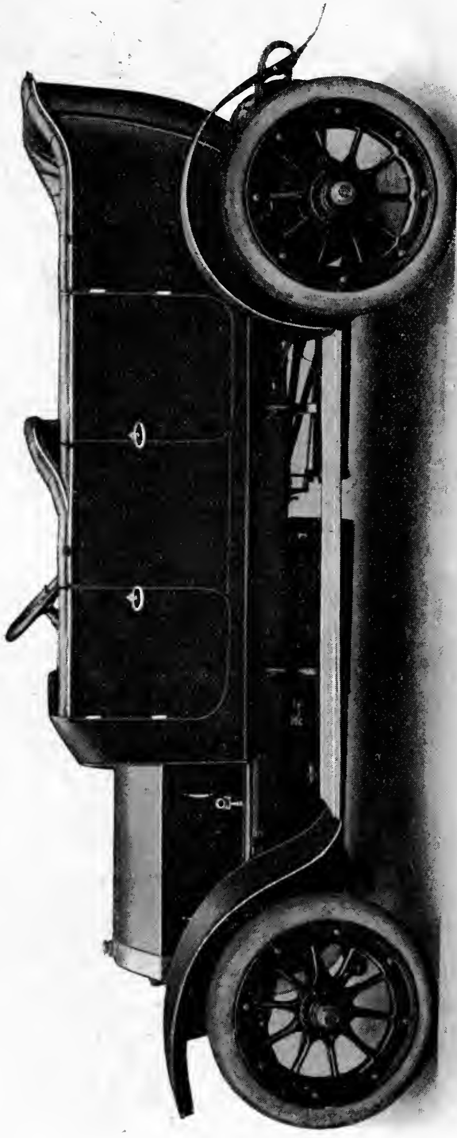

Fig. 80.—Flush-sided Body, Torpedo Type.

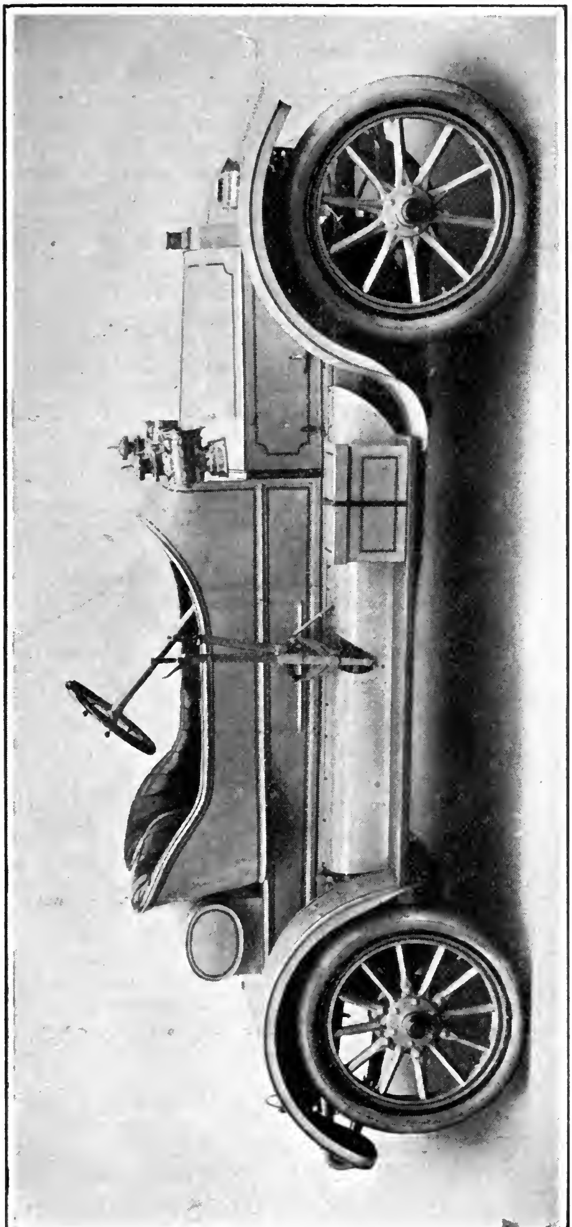

Fig. 81.—Two-seated Body, with Semi Bucket Seats.

in very poor taste. Natural wood finish often looks smart and businesslike without being too showy.

As to the upholstering, leather wears best, while some of the substitutes are highly inflammable. The lighter coloured materials very soon look soiled. Corduroy wears well, but is rather clinging for the seats.

The wings or mudguards should be of ample dimensions, and should be very strongly mounted, as they are liable to vibrate a great deal; this point hardly receives enough attention. The guards should keep the mud off the car as well as off the occupants; on the other hand, if extended too near the ground, they raise a great deal more dust than necessary. The front ones should be easily detachable.

CHAPTER XVIII.

Care and Management.

Housing.

THE motor house should, if possible, be constructed of brick, though where cost is a prime consideration, some very serviceable wooden and corrugated iron houses can be procured at low prices, and have the advantage that they can easily be erected so as not to become landlords' fixtures. The house should be large enough to provide a space of at least four feet all round the car. If a glass-covered yard can be arranged as an addition to the house, it will prove a great convenience.

There should be large doors at each end of the house if space permits, so that the car may be run in one way and out the other. This will save a lot of time and trouble in reversing.

The floor should be of concrete, and care should be taken to avoid nooks and crannies, into which small parts can run and hide, if accidentally dropped. In the middle of the floor a pit should be dug. This should measure about 3ft. 6in. wide, 4ft. deep, and 6ft. or more long, according to the size of the car. Steps should lead down into it at each end, and a strong cover must be provided. The edge of the pit should have a projecting ridge to prevent the wheels of the car being accidentally moved over the pit, and also to prevent other things running into it. The pit, as well as the floor of the house, should be drained.

Light and Warmth.

Light is best admitted through windows in the roof, and these should be made to open and close, or other ample means of ventilation should be provided. If a current of electricity can be laid on to the motor house, it will be found a great advantage in several ways. In the first place it affords a very convenient and safe means of lighting at night. Besides handlights that can be carried about, a number of fixed sockets for the electric lamps should be provided on the walls, and also in the pit. The electric current will also be useful in charging the accumulators, especially if the car is an electric one. Naked lights should never be used about a motor car, when it is confined in a building. Of course, we are here speaking particularly of petrol cars. Several buckets of sand, and some *extincteurs*, should be placed about the house ready to be thrown on and stifle any fire that may begin. As already mentioned, water should not be thrown on burning oil or spirit.

A good supply of water should be laid on for cleaning purposes, and the soft rain water falling on the roof should be collected in a covered tank, as soft water should always be used in the radiator, if possible. The water should be drawn off as clear as possible, and passed through a fine strainer into the radiator.

The warming of the house requires careful attention. It is not advisable to use a coal fire or oilstove inside the house on account of the flame. A hot-air or hot-water system, heated by an outside furnace, is much better. A very high temperature is not desirable; provided it is well above freezing that is enough, though it is always safest to run off the circulating water, in case the heating apparatus break down. So far as the tyres are concerned, the atmosphere of the house should be neither too hot nor too dry; nor, for that matter, too light.

A workbench should be erected near one corner of the house, and if it can be supplemented by a small lathe so much the better. If the car is provided with a detachable top for the body, a pulley should be hung from the middle of the roof, so that the top may be manipulated easily, and suspended clear when out of use.

Cleaning.

On returning from a dirty run the mud may be washed off the car by turning the hose on it. The painted work may be afterwards dried with a soft clean sponge, and be polished with a leather in the usual way. In using the hose, care should be taken to keep the water and grit out of the bearings and other working parts as much as possible. The tyres should be wiped clean and dried. See that they are well inflated, and that no water gets in to rust the rims and rot the canvas. The exterior of the engine, gear, etc., may best be cleaned by a good-sized paint brush dipped in paraffin. If the leathers of the clutch, brakes or pump get too greasy, they may be cleansed by washing with waste petrol. The clutch leather should not be allowed to get dry; on the contrary, it should be kept moist with collan oil, evenly applied, and preferably allowed to soak in over-night.

The silencer should be cleaned out occasionally to prevent the deposits therein accumulating to such an extent as to choke the passages, and so put back pressure on the motor.

Care of the Hands.

While on the subject of cleaning it may be as well to give one or two hints as to cleaning the hands. Before starting to do anything to a motor car, it is a good plan to fill the nails and the crevices around the same with soap, and the fingers also may be rubbed over with the same material. This prevents the dirt securing positions from which it is most difficult to dislodge it. A great deal of the dirt that does adhere may be removed by rinsing the hands in paraffin or stale petrol. To rub the hands in vaseline and put a few drops of ammonia into the hot washing water, is a useful plan. We have also found soft soap, pumicestone soap, and some of the advertised preparations useful for cleaning the hands. Petrol, even if stale, comes in handy for removing grease spots from the clothes.

A piece of flannel should be moistened with the petrol, and a ring described with it round the spot, to prevent the latter spreading. Then a second application of the liquid should be made, first holding the moistened flannel on the spot for a few moments and then rubbing it vigorously. The odour very quickly passes off.

Lubricating.

All the rotating and rubbing surfaces on the motor require lubrication, except leather brake bands (now rarely used), and the stems of the inlet and exhaust valves. Besides the motor itself, the steering sockets, connections, worm and column bearings require attention; also the bearings of the road wheels, the transmission gearing and levers, the balance gear, and the starting apparatus. The pump and radiator fan bearings must not be overlooked. A new car requires more lubricating during the first 200 or 300 miles, while it is settling down, than it does afterwards. If the engine appears sluggish, it is sometimes due to lack of lubrication; and a little extra oil will often help in hill-climbing. The dirty oil which accumulates in the crank case should be run off occasionally, and about every thousand miles the oil pipes and bearings should be cleansed out with paraffin, the engine run for half a minute or so in this way, and then the paraffin run off and full doses of proper lubricating oil administered. When using the paraffin, make sure that it runs through. If a pipe get choked it should be blown clear, or a wire pushed through it.

While it is bad economy to stint the lubricating oil, it is a very common fault to use a great deal too much. This is not only wasteful, but tends to foul the valves, sparking plugs, and platinum contacts. Further, it has a prejudicial effect in creating a cloud of evil blue smoke. The driver should keep a look-out to see that he is not thus polluting the atmosphere and bringing motoring into evil repute.

Adjusting.

"Little and often" is an excellent motto in the care of motor cars, the "little" being a consequence of the "often." The great thing is to give the attention regularly. All working parts should be adjusted to move freely but without shake. This ensures the highest efficiency and absence of noise. Spring washers are often useful in attaining these results where proper means are not provided for adjustment. All nuts used for positive gripping purposes should be secured by castle locknuts, with split pins passing through a hole in the bolt and through the slots in the nut.

Adjusting Bearings.

As a rule, the owner will do well not to attempt the adjustment of plain, roller or ball bearings.

A scrunching noise in a ball bearing should receive immediate attention, the bearing being taken apart in order to discover the cause. It may be found to be due merely to the presence of some grit, though that is bad enough. In this case a thorough cleansing of the bearing and lubrication will cure the trouble. If one of the balls is found to be broken, all the bits must be removed, and a new ball inserted. But unless a new one of exactly the right size can be procured, it is best to run the bearing with a ball short for the time being; as, should the new ball be a shade too large, it will almost certainly cause trouble. When the bearing is apart the cones and cups should be carefully examined for scores and cracks, as if these are found, the parts affected should be renewed at the earliest opportunity. In some cases, where the damage to the bearing parts is serious, it is best to remove the balls and let the bearing run on the plain surfaces as far as the nearest point available for repairs. If a wheel spindle has been cut into so as to weaken it materially, the load should be lightened as much as possible, or the run discontinued entirely, pending repairs.

A car should not be run with either the wheel bearings or the steering crossbar joints very slack, as the wheels will wobble under these conditions, and the bearings and tyres will get badly worn.

Brake Treatment.

The adjustment of the brakes is even more important than that of the bearings. They require treating according to their individual construction. Two points, however, should be borne in mind. First, that the pedal or hand lever should not be at the limit of its stroke, even when the brake is hard on; and second, that the braking surfaces should not rub anywhere when the brake is off.

Charging Accumulators.

As there are many depots where one can get accumulators charged for a few pence each, it seems hardly worth while troubling to do one's own charging if this involves putting down a plant for the purpose. But where a suitable source of electricity is available, it is a great thing to keep the voltage of each pair well over 4; and where no charging station is at hand, it may be almost necessary to do the work one's self. And here the reader may be reminded that if he finds himself in a strange place where no one undertakes recharging, and where no accumulators are to be bought, dry batteries can often be purchased at the local ironmonger's: and one or two of these may be coupled in series with the expiring accumulators on the car, or a complete set may be secured to do the work alone. Failing this, you may have the good luck, as we once had, to get recharged from the generating plant of a large private installation.

The current for recharging may be obtained from a suitable continuous current dynamo (either directly or through an electric lighting system) or from a primary battery.

From a Strange Supply.

If the recharging is to be done from a dynamo constructed for the purpose, or from a specially-designed switchboard worked on the local electric lighting system, the job will be simple enough.

But if you want to charge up from a strange supply, the first thing to do is to enquire whether it is a continuous or an alternating current, and what is the voltage. We will suppose the current to be continuous, and of 110 volts.

The charging rate should be marked on the battery case. Usually it will not be over two ampères, but this may generally be exceeded by fifty per cent. if time is short. A safe charging rate may generally be found by dividing the ampère hourage of the battery by 10. A 16 c.p. (candle power) lamp will pass about half an ampère, and a 32 c.p. lamp will pass about one ampère, so a switch controlling four of the former or two of the latter lamps should be found. Two of the former or one of the latter will be better if the time can be afforded, as slow charging at a low ampèrage is best for the battery, and conduces to long running. A six 16 c.p. or three 32 c.p. lamp switch may be used if one is in a hurry. The lamps are generally marked with their candle-power, and can be disconnected from their sockets by a simple twisting and withdrawing action.

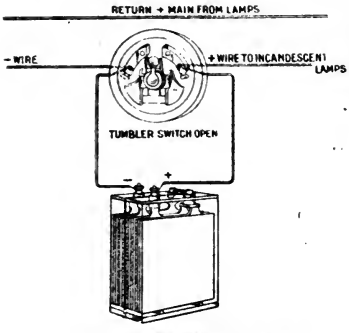

Fig. 82.—Charging Accumulator from Ordinary Switch, Open.

The switch must be put into the off position (which will put the lamps out, so have another light handy), and must be kept in this position during the whole process. (Fig. 82.) If the switch were closed it would short circuit the battery.

Pole Finding.

As charging is opposite to working, the positive pole of the charging apparatus must be coupled up to the positive pole of the accumulator, during charging. To find which pole is which in the switch, unscrew the cover, and connect separate wires to the terminals. Now take a slip of your pole-finding paper, wet it thoroughly, and lay the free ends of the two wires on it, about half an inch apart. The paper will usually turn red around the end of the negative wire, but read the directions on the packet of papers, as they do not all work alike.

If you have no pole-finding paper, drop a little vinegar into a glass of water, and hold the ends of the wires about ¼in. apart in the water thus acidulated. Bubbles will be seen rising from the end of the negative wire. Bubbles may come from both wires, but if so, they will come faster from one (the negative) than from the other.

The two wires can now be coupled up to the terminals of similar polarity respectively on the battery; and as soon as the circuit is completed by so doing, the lamps will light up again.

Or one of the wires leading to the switch may be severed, and the ends thus made be connected to the terminals, positive to positive and negative to negative, as before. (Fig. 83.) This allows the switch to be used in the ordinary way; but, of course, the battery will not be charging when the switch is "off."

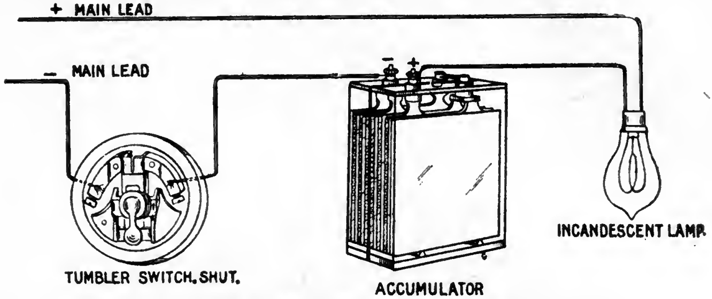

FIG. 83.—CHARGING ACCUMULATORS FROM ORDINARY SWITCH, SHUT.

Instead of coupling up to a switch, one may employ an adapter. This is a fitting for attaching to a lamp socket in place of the lamp. The displaced lamp should be fitted into a socket comprised in the adapter, and the polarity of the wires having been ascertained, the positive wire is coupled to the positive terminal of the accumulator, and the negative to the negative, as before.

With a current of more than 110 volts, the number of 16 c.p. lamps should be increased, about in the proportion of one lamp to thirty volts. If the lighting system is worked on an alternating current, it will be necessary to employ a rectifier to transform the current into a continuous one. Some of the charging dynamos are made to be driven by water pressure from the house supply.

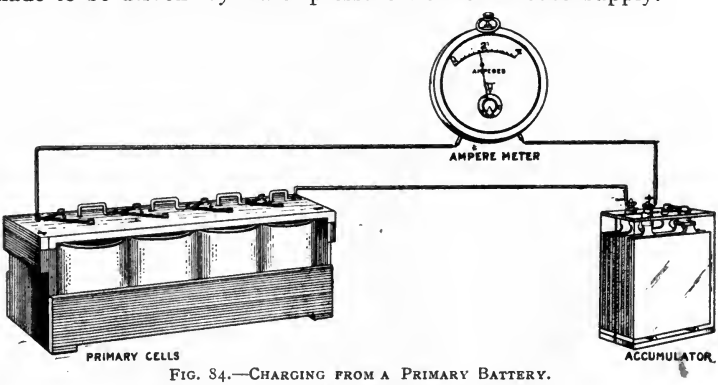

FIG. 84.—CHARGING FROM A PRIMARY BATTERY.

Charging from a Primary Battery.

But where neither electric lighting nor water is laid on to the house, one can use a large primary battery. When employing this system an ammeter should be introduced into the circuit; and the zincs should be let down into the liquid just so far that the required number of ampères is shown on the meter. The zincs should be lowered from time to time to keep up the number of ampères. Instead of moving the zincs, a small resistance may be introduced into the circuit and adjusted as required. Some of these primary batteries should be very carefully handled, as the liquids employed therein are highly corrosive. They require replenishing from time to time, and the zincs should be entirely withdrawn while the battery is not in use.

Whatever system of charging is adopted, the vent plugs should be removed from the accumulators, to allow free escape of the generated gases, during the process. The time occupied in charging naturally varies, but six hours to eight hours may be taken as an average. The battery should be disconnected soon after the electrolyte begins to bubble, and the voltmeter should then show a reading of at least 4.4. Sometimes it may show as much as 5.0, but the pressure will soon drop to an orthodox level when the accumulator is put to work. Wipe the case quite dry, vaseline the terminals, and replace the vent plugs before returning the battery to its position in the car.

Water Circulation.

A few further hints may be given on this subject. If a pump be employed and it be suspected that the water is not circulating properly, one of the upper connections may be opened, when, if the water spurts out, it may be concluded that the circulation is in action. Some cars are fitted with a manometer or gauge, which indicates the circulation of the water visibly. When one has become accustomed to a particular car, the condition of the circulation can be inferred from the temperatures of the inlet and outlet water pipes, as tested by the hand. If the water is not circulating satisfactorily the trouble will almost certainly arise from the pump. This should be taken to pieces and thoroughly cleaned, and any defect that may be found should be remedied as far as possible.

If the water is boiling, and one wishes to replace it with cold, the operation should be performed gradually. Do not simply run off the boiling water and then fill up with cold. but make the change in easy stages. The advice to empty the circulating tank after each run in cold weather, will bear repeating, but the risk of freezing may be reduced by mixing glycerine with the water in the proportion of one of the former to two or three of the latter. Sometimes the pipes will become furred, and the cooling effect of the water thereby reduced, by reason both of the diminished capacity for water and the increased thickness of the containing walls. The fur may be dissolved by introducing a quantity of some strong alkali, such as caustic soda, into the cooling water. Two or three applications may be made until the water comes away practically clean, after the water jackets, etc., have been repeatedly rinsed with fresh water to remove the alkali.

If one of the pipes break, a temporary repair may be effected by slipping a length of rubber tubing over the broken ends, and binding tightly with wire. If the pipe has broken off close to one end, a reunion can sometimes be effected by tapering down the end of the pipe and somewhat enlarging the hole it ought to communicate with. The end of the pipe is then forced into the hole and tied in position, and the joint completed with red lead and insulating tape. This is a rather difficult repair, and should be superseded by a workshop job as soon as possible.

The Care of Tyres.

One of the great advantages of pneumatic tyres is that their strength of spring can be adjusted to the work they have to do, and they should be inflated to such a pressure that they will give only slightly when they rest under the weight of the car and passengers. So long as these conditions continue all is well. Occasional reinflation may be necessary. A speedy deflation demands instant attention. Pneumatic tyres cost quite enough while doing their work, but to drive a car with a deflated tyre is ruinous.

Directly a tyre goes down the car should be stopped, and the cause ascertained. In case of doubt, the first thing to do is to reinflate, and then ascertain if the valve is leaking, by placing a film of moisture over the orifice at the exposed end. If this is found to be the seat of the trouble, the valve should be tightened up or repaired, as the case may require. But unless the valve can be dealt with from the outside, the next step is to jack up the wheel and clean the outside of the tyre cover. Then the tyre must be completely deflated, when it may be opened.

Removing the Cover.

The nuts holding down the valve, and the security bolts, must be screwed nearly off, and the valve and bolts pushed well back into the tyre. The side of the cover nearer to you should then be pressed away from you all round the wheel, so as to unstick the edge, "bead," or "rib" of the cover from the edge of the rim. Now take two tyre levers, and thrust them down between the edges of the cover and rim, about nine inches apart. Do not push the levers too far in or they may damage the air tube. Press down the outer ends of the levers, so as to raise the edge of the cover above the edge of the rim. If you have a helper, let him insert a third lever, about nine inches beyond the second, and pull it down like the others. But if you are alone on the job, pull the first lever down to the vertical and secure it by a loop to one of the spokes. The loop should be put round the spoke before pulling the lever down. Having secured the first lever, move the second further along and pull it down again. Quite a number of special tyre levers have been introduced, some of which are much easier to manipulate than the ordinary bar levers. Repeat the levering until a good portion of the cover has been prised over the edge of the rim; the rest can be worked out by hand. The valve may now be completely removed from the rim, and the air tube withdrawn from the cover.

It may be that there is a leak between the head of the valve and the air tube, and this may generally be cured by tightening the nut which secures the valve to the tube.

In cleaning the cover, however, one may have come across a cut, or the head of a nail, or other interesting object, indicating a puncture, and the interior of the cover should be carefully examined to see if any nails or the like are projecting through the inner surface, and also to see whether any parts of the lining are discoloured by the penetration of wet through cuts in the rubber. Wet rots the canvas very quickly, and such spots should be treated both from without and from within.

Advantage of Spare Tubes.

Repairing a puncture in a motor car tyre is a much more serious affair than dealing with a similar trouble in a cycle tyre; and, even with light car tyres, unless the patching process is very carefully and patiently carried out, the result will not be satisfactory. Hence it is much better to carry one or two spare tubes, and insert one of these, than to attempt to execute a repair by the roadside.

Vulcanised Tyre Repairs.

The unsatisfactory results too frequently attaching to attempts to repair motor car tyres by the ordinary patching system have led to the introduction of small vulcanising plants, some of which are portable enough to be carried on a car, and indeed are specially constructed with a view to this. The system differs essentially from patching, in that the damaged part is remade instead of merely repaired. In the case of a punctured air tube, the rubber round the hole is cut away so as to form a bevelled or concave seating extending right through the wall of the tube. This gives a fresh surface of large area. The cutting may be effected by gouging, or by folding the tube so as to bring the puncture to a corner, and then snipping off the corner with a pair of sharp scissors. The tool should be wetted, as rubber cuts much more easily when wet than when dry. The fresh surface is then roughened by rubbing with sand-paper or a small rasp to facilitate penetration by the flux which is next applied thereto. This flux is a solution of raw rubber mixed with sulphur and other ingredients. When the first coat of flux becomes sticky, a second may be applied, and this should also be allowed to reach the "tacky" stage before the next operation is proceeded with. It is convenient while doing this part of the work to tie the air tube down flat, as, for example, across the top of a wheel with a sound tyre. The next thing to do is to fill up the enlarged hole with rubber compound, which is a similar material to the flux, but in a plastic or putty-like state. It is well to warm the compound, as by dabbing it on the vulcaniser, before kneading it into place. The compound should be pressed well in, and rather more than enough applied. The surplus should be trimmed off with a wet, sharp knife, great care being taken not to cut the tube in so doing.

The apparatus itself consists of a small brass boiler with vertical fire tubes. One side of the boiler is made flat to adapt it to the vulcanising of air tubes; the opposite side is concaved to suit the contour of the outer surface of the purchaser's tyre covers. The water is filled into the boiler through an orifice at the top until it runs out at the blow-off cock, which also forms part of the steam pressure gauge on the boiler. The furnace consists of a cylindrical methylated spirit lamp. The spirit is soaked up by cotton-wool

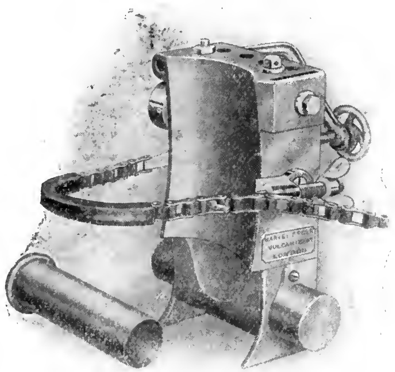

FIG. 85.—THE H.F. CAR VULCANISER.

located in the cylinder under a wire gauze burning surface. The lamp telescopes into the lower part of the boiler, and the heat can be regulated by pushing in and drawing out a sliding sleeve or extinguisher to a greater or less extent. A detachable metal arm is secured to the upper part of the boiler, and forms a handle by which the vulcaniser can be moved about. The bent outer end of the arm forms a bracket, and carries a screw between the end of which and the flat surface of the boiler the air tube is gripped during the vulcanising process. A metal plate and a block of wood or vulcanised fibre are introduced between the point of the screw and the air tube. The vulcaniser is fitted with a socket whereby it can be mounted on the rear light lamp-bracket when repairing air tubes, and with a detachable chain device whereby it may be secured directly to the wheel in the case of repairing a cut cover.

It should be clearly understood that the boiler is employed simply because it provides the most convenient method for securing the necessary heat. There is no magic in the heat being produced by steam. Further, the steam pressure has nothing to do with the pressure exerted on the tube or cover under repair. The pressure of the steam is merely useful as indicating in a convenient manner certain temperatures corresponding thereto. As it takes some ten or fifteen minutes to raise cold water to the necessary steam pressure of 50 lbs. to the square inch (corresponding to a good vulcanising temperature of about 281° F.), it is advisable to start the boiler before preparing the punctured part of the air tube, and also to use warm water (as from the radiator) instead of cold.

The injured tube having been treated as above described, and the indicator on the boiler showing 50 lbs. pressure, a piece of tissue paper or linen, rather larger than the flat surface of the boiler, is laid on the part of the tube, which is then pressed flat against the boiler by means of the screw and plates. The screw should be turned by the fingers only; this will give sufficient pressure. The paper or linen prevents the rubber compound sticking to the surface of the boiler. The wood or fibre plate should not be so large as to reach and pinch the edges of the air tube. If the wound is a large one, instead of a mere puncture, it should be treated in a similar way; but it is then as well to insert a piece of tissue paper in the air tube, so that the repaired part shall not stick to the opposite wall when vulcanised. After about a quarter of an hour the sulphur will be thoroughly melted, and the raw rubber compound thereby vulcanised.

The tube may now be removed from the vulcaniser, and if the thumb-nail be dug into the repaired part, the impression should quickly disappear when the nail is removed, otherwise the vulcanising should be carried on for a few minutes longer. The time varies with the thickness of the article being treated, not with the size of the surface. A gash will take no longer to vulcanise than a puncture, but a thick tube should be given about twenty minutes instead of fifteen.

Cuts in the cover are treated substantially in the same way. The rubber should be cut away around the injury right down to the first canvas, and at such an angle as to expose a large surface of fresh rubber around it. It is then rasped and treated with one or two coats of flux, and after the last of these has become tacky, the hole is filled up with compound, well pressed in with a roller tool provided for the purpose, and pared off flush with the surface of the cover. Meanwhile the vulcaniser has been getting up steam on the bracket. The damaged portion of the cover is brought to the back or front of the wheel. The injury is covered with paper or linen, and the vulcaniser is secured to the wheel, with the concave side to the injury, by means of a chain which should be screwed up fairly tight, but not so as to indent the cover materially. Owing to the greater thickness of the material, the heat will have some difficulty in penetrating it. A pressure of 60 lbs. may be used for about fifteen minutes, twenty minutes being necessary for 50 lbs. The cover should be perfectly dry, and the dryness may generally be obtained by putting the vulcaniser in position before the required pressure has been obtained, so that the moisture may be evaporated before the 50 lbs. or 60 lbs. has been reached, and before the vulcanising has commenced. A pad of cloth should be placed temporarily between the cover and vulcaniser to let the damp vapour escape. Special adapters can be obtained for covers of special formation.

The above vulcaniser weighs about 10 lbs. More elaborate ones are made for garage use, and are provided with means for repairing burst covers. In the case of an ordinary burst, the cover should be turned inside out, and a large piece of the lining should be cut away right across the inside of the cover. Then the material should be cut away in layers extending to the depth of one canvas each. The portions of canvas cut away should be of rectangular form with rounded corners, and each layer should measure about one and a half to two inches less in length and breadth than the one previously removed. The last layer of canvas should not be cut out, but should be left bare to the extent of about one inch all round the burst. During this operation the portions of fresh canvas should be cut to the shapes of those detached, and saturated with the flux, successive coats being applied and allowed to get "tacky" until a substantial film of rubber is left on both the surfaces. The steps cut in the cover should be coated with flux in the same way. The cover is now turned back again outside out. The wound in the tread is treated as before described, and the patches of canvas are laid in position, and pressed down with the roller. The last piece should be considerably larger than the others, and as it is to replace the damaged portion of the lining, it should be solutioned on the back only. When this is in place, the cover is put in the vulcaniser between two properly shaped steam containers, one inside and the other out, and it is bound down tightly to the inner container by a strip of webbing wound on spirally. The parts are gripped thus, and a pressure of 60 lbs. is kept up for about twenty-five minutes, or longer if necessary.

Air tubes may be joined, and other jobs done in a substantially similar manner, but we have not room to go into further details here. There are now several designs of small vulcanisers for car use; some employed steam pressure, others being electrically heated, but the method of making a repair is practically the same with all patterns.

Repairs by Patching.

In the absence of a sound spare tube and of a vulcaniser, the patching process will have to be resorted to. The air tube should be examined for one or more punctures. If the trouble cannot be ascertained by mere inspection, the tube should be reinflated lightly, and immersed and stretched, bit by bit, in a large bowl of water, when the seat of the injury will be discovered by a stream of bubbles issuing from the puncture.

Draw a ring on the tube, concentrically with the puncture, with an indelible ink pencil. As this is to serve as a guide to the position of the hole during the subsequent operations, it should be rather larger than the patch to be applied. The surface around the puncture and within the ring must be thoroughly cleaned. Petrol is very useful for cleaning off the sulphur and preparing the rubber for the solution. A block of sulphur is also handy; but the usual process is to wrap a piece of glass paper round something hard, such as the chalk case, and rub the tube clean around the seat of the injury. When all the sulphur has been removed, a thin film of indiarubber solution should be spread on the prepared surface. The area of the film should be sufficient to extend well beyond the edges of the patch to be applied. This film should be allowed five or ten minutes to dry, and another spread over it, and subsequently a third. If the films of solution are exposed to the direct rays of the sun they will dry quickly.

One of the rubber patches in the repair outfit should be chosen according to its size, and this also should be cleaned and given three coats of solution, each being thoroughly dry before the next is applied. If the patch shows an irresistible desire to curl up, encourage it to embrace a fixed rod of suitable diameter, so that it shall not roll about and get covered with dust, etc. The patch should then be carefully laid on the solutioned part of the tube, which should be quite empty of air at the time. The patch should be firmly pressed down on the tube, the pressure being applied from the centre outwards, so as to drive out any bubbles of air that may have been caught between the patch and the tube. The patched portion of the tube may be laid between two flat plates and moderate pressure applied, as by a vice or a weight.

If the puncturing object has penetrated right through the tube, of course both holes will require mending; and a second hole should always be carefully looked for. Sometimes one puncture fiend will make quite a lot of holes close together. Try to cover them all with one big patch.

Treating the Cover.

Outwardly, the hole in the rubber should be carefully probed and freed from grit, and then cleaned with petrol, benzine, or the like solvent. The surfaces of the hole should next be solutioned with two or three coats, and the wound bound up until the solution has set. If the hole gapes, it should be plugged with some of the stopping preparations sold for the purpose. Inwardly, the weak place in the fabric should be reinforced by a piece of prepared canvas extending not only the full width of the cover, but a short distance up the outside as well, so as to be gripped by the rim. This should be carefully solutioned in place. The canvas should be cleaned with petrol before applying the coats of solution, plenty of which will be necessary. The cover ought not really to be used for some twelve hours or more, hence the advantage of carrying a spare cover; but if none has been brought, the damaged part should be relieved from strain either by lacing a gaiter round the cover and felloe of the wheel; or, if this cannot be done, a short canvas sleeve may be sewn around the air tube. This sleeve should be large enough to allow the tube to assume its ordinary diameter, but small enough to relieve the cover from strain. Care must be taken not to prick the tube when sewing the sleeve. Actual bursts in the cover must be treated in the same way, but on a larger scale. If a gaiter is employed, it should be laced on while the tyre is only lightly inflated. When the inflation is completed, the extra pressure will cause the gaiter to set very closely, as it should do.

Many excellent devices are now sold for reinforcing weak or damaged outer covers. A liner formed to fit inside the whole circumference of the cover is one example; winged patches which fit inside the cover at a weak spot, of such a width that the "winged" edges pass round the bead and are clinched between the tyre and the hooked edges of the rim, form another example. The life and service of a weak cover may be considerably prolonged by the use of one of the many of these reinforcing appliances.

Stripping the Wheel.

In case the cover has to be completely detached from the wheel, pull down the bolts near the top of the wheel, and insert two levers, about nine inches apart, under the remaining edge of the cover. Press on the outer ends of the levers, and then push them forward, so that they bridge across the rim, resting on both edges thereof. The edge of the cover at the top of the wheel will now lie on the levers, and may be drawn along them across, and over the edge of, the rim. Pressing down the handles of the levers will assist the operation. When the cover is thus released from the top of the rim, it may be easily withdrawn from the rest thereof.

Before reinstating the tyre, the interior of the cover should be liberally dusted with powdered talc, generally called French chalk. Blacklead or grate polish (or, more properly, graphite) forms an efficient, though dirty, substitute for the chalk. All solutioned parts in the cover and on the tube should receive special allowances. Sometimes a quantity of grit and dirt will accumulate in the cover; this may be picked up with a small lump of soft clay or putty.

While the rim is bare, take the opportunity of seeing that it is clean, free from dents and rust, and well covered with enamel. If there are any bare or rusty patches, and it is not convenient to enamel them at the moment, give them a wipe with a greasy cloth, as rust rots canvas quickly. The grease must be cleaned off thoroughly before applying the enamel.

Replacing the Tyre.

If the bed of the rim is uneven, and it is pretty sure to be if the wheel is wire spoked, see that it is covered with an evenly-laid tight tape. Straighten or replace any security bolts that have got bent, and push them up from the bed. Put a few pumpfuls of air into the inner tube, and place in position in the cover, while the cover is still off the rim. Be very careful to get the valve stem comfortably into the notches in the cover. Turn the wheel round until the valve hole is at the top. Now very carefully place the tyre on the upper part of the wheel, so that the further edge goes into the rim, and the valve can be put into its hole without straining to right or left. Work the further edge of the cover into place under the edge of the rim and under the heads of the bolts. Much of this can be done by hand; the levers must be used for the rest.

The parts are now in the position they occupy when the cover has been opened merely, not entirely detached from the wheel. Supposing the air tube has been withdrawn, and is to be replaced, the stem of the valve should be passed into its hole and the valve completed, except for tightening the outside locknut; and the heads of the bolts should be pressed down into the bed of the rim. The tube should be slightly inflated and tucked into the cover, care being taken not to twist it, or to disturb any of the patches. Pass the hand round between the air tube and the rim to make sure that the tube is not caught by any of the bolt heads.

The valve and bolts are next pushed up again, and the other edge of the cover is got back into the rim like the first. The bead may be helped under the edge of the rim by prodding it with the end of the tyre lever; but if it is very obstinate it probably means that the air tube has got down between the edges of the cover. If this is suspected, it is much the best to open the tyre again, and then reinsert the second edge of the cover, as a nipped tube spells disaster, none the less deadly because deferred. A little judgment is required to pump the air tube tight enough to prevent nipping in this way, and yet not so tight as to prevent the second edge of the cover being got back into place. If the security bolts can be moved up and down in their holes without difficulty, it generally shows that the tube is not being nipped. When satisfied on this point, you may tighten up the nuts of the valve and bolts, and put a little more air into the tyre.

The wheel should now be slowly rotated, and the tyre pulled and pushed laterally, and pommelled well with the fist. This encourages the parts to assume their proper positions. After a due amount of exercise of this sort, the tyre may be fully inflated, and the nuts of the valve and security bolts given a final turn.

Miscellaneous Hints.

After running a few miles, go over these nuts again. It is important to have them tight to prevent the tyre creeping or wrenching or blowing off, and to prevent water getting in. Turning corners too fast is a frequent cause of the tyres coming off if the bolts are loose; and if the tyres are too weak or the speed too high, the cover may split along at the edge of the rim. Under such circumstances a temporary repair may perhaps be made with a gaiter, but a permanent repair is often impossible. Tyres stand best when the inflation is kept well up to the mark. If the tyre gets flabby it will get pinched between the rim and the ground, will let the water in, will wear out rapidly, will be more likely to side-slip, and will waste power.

Cheeseparing does not pay with tyres. Have the covers retreaded as soon as they are worn enough to show the first ply of canvas.

In case a tyre is damaged beyond repair, one may remove the air tube and stuff the cover with hay or any other suitable material that may be at hand; or one may lay some thick coils of rope round the rim. But these are expedients only to be resorted to when *in extremis.*

If the car is to be put away for any length of time, it is best to jack up all the wheels and to inflate the tyres only hard enough to keep them in shape. They should be wiped over occasionally with a rag dipped in warm water, and should be kneaded to maintain their suppleness.

As to solid tyres, little advice can be given, except that they should be examined with a view to ascertain that their means of attachment are secure. Any large cuts should be picked out and mended as above described in relation to the covers of pneumatic tyres.

CHAPTER XIX.

Driving.

Learning the Steering and Control.

IT is well in the first place to study the construction and working of the car, as far as possible, while it is stationary. As part of this course, one should spend some time in the driver's seat, and accustom oneself to the positions of the steering wheel and the various levers. Then the novice may venture out on the road with an experienced driver, and by first resting his right hand lightly on the steering wheel, learn the effect of the different movements of the wheel on the course taken by the car. Gradually he will be able to take charge of the steering entirely from the left-hand seat, and then, occupying the driver's seat, may learn to steer the car on its first speed.

We will now suppose that you are able to steer the car, and have a general acquaintance with its various features, but otherwise are very much left to your own resources. Naturally, you are anxious to go for a drive; and here we may give a hint as to the route to be pursued on this occasion. Let it be a circular tour of short radius, and with home as centre. In this way the risk of an expensive return in case of a breakdown is greatly reduced, and you will have the advantage, in all probability, of being well acquainted with the whole of the road traversed.

Preliminary Attentions.

Before starting out, the various nuts and bolts should be looked over, especially on a new car, and the brakes and steering gear connections should receive particular attention. The quantity of petrol in the tank should be ascertained. If no gauge glass is fitted, a celluloid or glass tube should be inserted, a finger placed on the top, and the tube lifted out. The height of the petrol in the tube will indicate the quantity in the tank. Or a clean white stick or paper spill will serve as a guide by discolouring the portion moistened. If more petrol is required, it should be poured in through a funnel or tundish having a fine wire gauze strainer. This strainer should be supplemented by a piece of fine white cambric, as this, when saturated with petrol, resists the passage of any water that may happen to be in the can. Any water collecting in the cambric should be thrown away. See that the spout of the funnel is clean outside and in. A little petrol or paraffin may be injected into each cylinder to free the piston rings and (in the case of the petrol) to facilitate the obtaining of the first explosion. The lubricators or oil sump should be filled, and the grease cups given a turn—

in fact, the car should be lubricated throughout. After having seen that the gear lever is in the out-of-gear position, the carburetter should receive attention. It may be emptied of any stale petrol it may contain. The mixture regulator may be set to cut down the quantity of air; and, the petrol tap having been turned on, the float may be agitated so as to flood the carburetter. The throttle valve should be opened. The electric current should be switched on; and be careful to see that the timing lever is set well back. The next thing to do is to release the compression, if means for so doing are provided, but this is only usually necessary with large engines.

Starting the Engine.

The starting handle should be turned round clockwise (in most cars) until the resistance of the compression is felt. If this occurs as the handle is going downwards, turn the handle back half a turn or so, and then try again until the compression is felt as the handle is beginning to come upwards. The handle should be held with the fingers of the right hand under it, and the thumb not over it. When the compression is felt, give a strong and continuing pull upwards, when, if all is in order, the motor will start. If the ignition were too far advanced, the explosion would drive the handle backwards; and if you were pushing the handle down at the time, the chances are your wrist would be broken or so severely sprained as to be useless for some time to come. But if you are pulling up, the back fire simply unbends the fingers; and though you may be a bit scared, you are not likely to be hurt. If the motor will not start after a few attempts, the ignition may be slightly advanced, and different mixtures may be tried for the gas. If this will not do, try further injections of petrol into the cylinders. Test the ignition to see that it is sparking properly. Sometimes it will be found that the valves having become dirty do not move freely; and if they remain open when they ought to close, the engine cannot work.

As soon as the engine starts, the ignition may be advanced somewhat, and the throttle partly closed. Your passengers having got aboard, you are ready to start. Hold the clutch out by the foot, and move the change gear lever into the first speed notch. If it will not enter easily, allow the clutch to engage slightly for a moment, and then try to get in gear again. As soon as the gear is engaged, the clutch should be let in very gradually, the throttle being opened to provide plenty of power. As the clutch engages, the car will move off, and the run will be begun. In starting, changing speed, etc., the finger catch (if any) must be grasped with the handle of the lever, but the catch should be released when it is clear of its notch, so that it may be ready to drop into the fresh notch as soon as the lever brings it opposite thereto.

Changing Speed.

After the car has got into its stride on its first speed, the gear may be raised to the next speed. To effect this, the throttle should be opened so as to bustle up the motor, the clutch taken well out, and the gear lever moved, with as much decision and promptitude as possible, into the next higher notch. The clutch is let in again quickly, but gradually, and the whole operation should be performed with address, so that the speed of the car may not be sensibly diminished during the operation. Never put in a higher gear until you have become perfectly acquainted with the next lower one. It is very tempting to see how fast the car can go, or how fast you dare let it go, but the temptation should be sternly resisted during your novitiate, otherwise you may never become an expert! The throttle should be opened only so far as will allow of the car being driven at the desired speed with the ignition well advanced. When changing gear the throttle, having been opened, as suggested above, to accelerate the car on the lower ratio, should be almost closed so as to prevent the engine racing when the load on it is removed by the depressing of the clutch pedal.

On reaching a hill, the speed of the car should be kept up at first by opening the throttle further and further as required. When the limit of this adjustment has been reached, the ignition should be gradually retarded, especially if the engine sets up a knocking noise. Some drivers are very skilful at coaxing cars uphill without lowering the gear, but this practice is not to be commended. If the engine begins to labour or the speed of the car has fallen to that of the next lower gear, that gear should be brought into operation. The motor should not be allowed to run too fast during the change; and the change should be effected quickly, as the speed of the car will fall very rapidly while the motive power is cut off. The directions for changing speed are soon given, but the amount of success with which the driver carries them out depends upon practice and skill.

Coasting, Braking, and Reversing.

Down grades will call for different treatment of the engine, according to their steepness and length. If the hill is only a short one, the engine may be left running at a slow speed and the clutch disengaged. If the hill is a long one, the motor may be stopped altogether, and the car allowed to run down by gravity; the quiet running will be found a welcome change. On nearing the bottom of a hill, the clutch should be gradually let in so as to start up the motor again. If the hill is very steep, the car should be kept well in hand from the very top. The first (lowest) speed should be put in and the current switched off; thus the engine will be converted into a pump, and will serve as an auxiliary brake, though this is not possible, of course, where the application of the pedal brake throws out the clutch.

Both the foot and the hand brakes should be tested soon after starting out on a run. If the car shows a disposition to get away down a hill, the clutch should be let in gently with the ignition switched off or the throttle quite closed. This will serve to limit the speed of the car. Broadly speaking, and in a general way, the brakes should be applied as little as possible. One sometimes sees a car come dashing up to its destination, and pull up in a few yards. This only shows that the driver has more control over the machine than he has over himself. Smart, no doubt, especially for the tyres. Nothing is gained, but rather the contrary, by applying the brakes so hard as to skid the wheels. It is really much more clever to throttle down gradually and let the car arrive at the desired point upon momentum only. On reaching one's destination, the current should be switched off and the petrol tap closed.

If it is desired to reverse the car, it must first be brought to a dead stop, the engine of course being left running, and the clutch disengaged. The reverse gear is now put in, and the clutch very gradually re-engaged. It is as well to practise reversing in a wide space at first, as the steering will be found somewhat awkward. Remember that if you encounter a hill that your car cannot climb, even on the first speed, it may be able to get up on the reverse, being driven backwards, of course, for the purpose.

As a general rule, do not advance either the timing of the sparking or the opening of the throttle, suddenly. The changes effected by these means should always be made gradually. And, finally, practise with your car until the control of it becomes perfectly automatic. Until then you can never trust yourself to do the right thing in an emergency.

Sources of Sideslip.

One of the worst evils the driver has to contend with is that of sideslip, and it is not to be surprised at if he loses his head somewhat on the first two or three occasions that this diversion occurs. The accident is nearly always compound—that is to say, the slipping in itself is not dangerous; but if the car strikes anything else, that thing will be damaged as well as the car.

It is a well-known fact in mechanics, that if a sliding movement occurs between two contacting bodies, the one that is in motion may be moved at an angle to its path with comparative ease. In driving, therefore, on slippery surfaces, great care should be taken to avoid any variation from the true rolling motion of the wheels on the road. The variation may occur in several ways. For instance, if the engine be suddenly accelerated, the driving wheels will tend to spin round instead of merely rolling forward. Again, if the brakes be suddenly applied, the road wheels may rotate slower than the progress of the car corresponds to, and, indeed, they may cease to rotate at all, merely sliding along. Further, in passing over an uneven road the car may bounce, so that the wheels at times are actually out of contact with the road surface. Under any of these conditions, a very slight disturbing force will be enough to deflect the car from its straight course, and cause sideslip.

So long as the road is hard and dry, the friction between the tyres and the road surface will be ample to prevent skidding; but if the hard smooth surface be covered with thin mud, or if a comparatively soft surface be covered with thick mud, the car will be prevented from obtaining a firm grip, and may begin to slide at any moment. The same thing may, or will, happen on roads that are deep in dust; but the worst surface is undoubtedly ice that has begun to thaw.

Another source of sideslip is found in connection with tramlines. The lines themselves, or the tracks in which they are laid, generally project above the general level of the road, or sometimes are depressed below the same, in either case forming ridges which tend to prevent the car travelling at an angle thereto. The disturbing effect is greatest when the lines are wet. Probably the fact that cars are driven from the back and steered by the front contributes to their tendency to slip, as the rear part has a disposition to push round the front, on one side or the other. Of course, the greatest tendency to sideslip occurs when the car is being driven round a corner, as the centrifugal force then exerts a considerable lateral pressure upon the vehicle.

To Avoid Skidding.

To avoid sideslip our novice may take certain precautions. We will not say, do not take the car out when the roads are slippery, because it may not always be possible to follow that advice; and, further, though the roads may be perfectly safe as a rule, you may find that the water-cart has made them quite the reverse over more or less restricted sections. But when a greasy stretch is encountered, proceed slowly, especially in making turns. If the car begins to slip, keep your wits about you and begin to steer in the direction of the slip. This may be exactly contrary to your inclination, but it will tend to restore the grip of the wheels on the road; and as soon as this result is attained, you may begin carefully to steer again in the direction you wish to follow. As the camber or transverse curve of the road surface helps to promote sideslip, one should drive as much on the crown of the road as consideration for other traffic will allow.

In turning corners to the left, take the left side of the road; but in turning corners to the right, only take the right side of the road if you can see that the course is clear. If you keep on the inside of the corner, the transverse inclination of the road will help to get the car round. In taking corners, it is a good plan to declutch. and also to abstain from putting on the brakes; the chances of getting round safely are much increased if the car simply rolls round the curve. Tramlines should be crossed at as nearly a right angle as possible. But if you are running along a crowded road laid with tramlines, and wish to get on to, or off from, the track, the steering should be as gradual as possible, so that if the wheels refuse to take the ridges, the disturbing effect will be very small. One grain of comfort we can give: Sideslip is practically never accompanied by over-turning, unless the car catch against some low object.

Non-slip Devices.

Prevention, however, is better than cure, and it is well to adopt some form of non-slipping device. Nearly all of these devices consist of some apparatus fitted to the tyres and designed to cut through the grease, and so obtain a hold on the firm surface below.

A fairly effective non-slipper may be improvised by winding strong cord round the tyre and felloes in spiral form. The ends of the cord must be carefully secured, and the cord itself examined frequently, and renewed as required. But this plan should only be adopted as a temporary expedient, for the cord or rope tends to wear the rubber tread of the tyre excessively at those points with which it makes contact.

Choice of Track.

Too many drivers simply take the road as it comes without troubling to select the best path. Possibly they are not aware that every bump means waste of power and increased wear to the car. But such is undoubtedly the case. One can often detect the fact that the driver is an experienced cyclist from the way in which he picks his course. We do not mean, of course, that the driver should keep the car perpetually on the wriggle, but simply that where he has the choice to make, he should take the line which will be best for the vehicle and most comfortable for the passengers. Thus a smooth surface is to be preferred to a rough one ; dry ground is better than wet ; the crown of the road gives better running than the sloping sides ; and all reasonable care should be taken to avoid holes and loose stones. If a patch of new metal cannot be avoided, it is best to drive up to it at a good speed and then declutch, so that the wheels merely roll over the stones, without being subjected to the additional strain set up by driving. If the momentum is not sufficient to carry the car the full length of the patch, the remainder should be driven over quietly at slow speed.

Emergencies, and General Conduct.

As a rule, the steering of the car, like the manipulation of the throttle and spark timing, should be performed gradually. It is very bad for the tyres and most provocative of sideslip, to swing the steering wheel suddenly from one position to another. Perhaps the only times when this may be excused is when accidents would otherwise occur ; as, for instance, when people, especially children, rush across in front of one without looking. Again, if a car begins to run back down a hill, the steering wheel should be promptly rotated so as to change the course of the car to a transverse direction. The brakes should be applied at the same time to prevent, if possible, charging into the bank or other side of the road. It is much better to collide with the bank at the top of the hill than at the bottom—we mean, stop the car before it has gathered speed.

The motorist's reputation being at the present time none of the best, it is most important to drive as inoffensively as possible. It is not enough merely to have regard to the safety of other road users. One must avoid driving in such a way as to let them *think* that they have been in danger. It is almost, if not quite, as bad to offend a man's dignity by running him fine (as he imagines), as to knock him down. As a general rule, it is far safer to pass behind people than in front of them, when their path intersects your own. The horn or gong should be used fairly freely, though in blasts of short duration, the idea being rather to comply with the law than directly to profit by the signalling.

Never drive so fast that you cannot come to a dead stop within the length of road for the time being seen to be clear. Do not incommode or endanger other users of the road or the inhabitants of roadside houses by raising an excessive amount of dust, and do not bespatter pedestrians with mud. These things may seem a lot to ask, but not too much, we think, to require from one who is, after all, merely taking his pleasure in public.

Speed limits are misguiding. There can be no harm morally in disregarding them where the road and its approaches can be seen to be clear; and they do not license one to travel up to them, where to do so would be to endanger the public. With the best intentions in the world, one is liable to travel too fast unwittingly at times. Thus, after a clear run at a good speed in the open, the pace is reduced to what seems a mere crawl on reaching a village. The driver contrasts his crawl with the speed he has just been running at; the villager, on the contrary, compares it with the rate of progress of the local Dobbins—and the resulting impressions are naturally somewhat different. A speedometer has its uses.

Do not confine your attention to the road merely; have an eye open for somnambulistic pedestrians with a weakness for leaving one path for the other with no regard for the traffic on the roadway. Treat them gently; it spoils their temper, to wake them suddenly. Do not be satisfied with being in the right; keep out of scrimmages at all costs, for the motorist cannot reckon on justice in these days. May they be few and short, for it is an unfortunate thing for any section of the public to distrust the law. Observe the rules of the road, *i.e.*, keep to the left when meeting other vehicles, and to the right when overtaking them. But these rules must be disobeyed, if necessary to avoid an accident.

Negotiating Town Traffic.

In driving through towns one should be careful to see that the course is clear before attempting to overtake vehicles in front. It is not always necessary to swing round to the off side in order to ascertain the possibility of getting by, as many vehicles can be seen right through from end to end. When about to turn off to the right or left, the driver should hold out one hand to that side; and for stopping he should hold one hand straight up. Of course, drivers of all vehicles should observe these rules, but a good many do not, cabmen plying for hire being the worst offenders. As you approach a cross street, the windows you see in that street reflect what is coming up to your road; and by looking at the windows at your side, you can see reflected the traffic that is coming behind you.

Pedestrians are allowed to walk where they like on a road provided they do not unreasonably obstruct other traffic. A led horse should be passed (in either direction) on the side of the man leading it; but this is convention rather than law. Tramcars should be met and overtaken on the near side.

Horses, Cattle, and Cyclists.

Horses are now fairly well accustomed to motor cars in most districts; but in remote places the owners have taken little or no trouble to educate their animals to the new method of locomotion, and special care must be exercised in dealing with them. In meeting a doubtful horse, it is best to proceed slowly and be ready to stop at any moment, whether the driver holds up his hand or not. Some horses have an unpleasant trick of looking perfectly unconcerned until almost up to the car, and then suddenly backing right across the road. Under these circumstances, the motorist will have to act very promptly if a collision is to be avoided. In overtaking nervous horses, it is best to drive quickly and quietly, so as to shorten the incident as much as possible. Unless time is precious, one should always offer to spend a few minutes in improving a badly trained horse's acquaintance with motor cars. The horse owner's opinions on the subject are generally as much improved as those of his animal. Great care should be exercised in overtaking carts carrying poles and other long burdens; as, if the carter draws his horse over to the near side, the tail of the load swings across the road, and momentarily obstructs the off side.

The perfect control one has over a car tempts one to assume that all other road users are in equal command of their steeds, whether cars, horses, or cycles. But this is a very unsafe assumption. Every rider and driver has a period of inexperience; and even those who have got over their novitiate are liable to lose their heads at times, as, *e.g.*, on hearing a car coming up behind them. The only safe course, therefore, is to see how much, not how little, space one can give cyclists, horsemen, and others. Remember especially that a cyclist's position is always more or less dangerous when the road is wet and slopes to the gutters.

As cyclists and most vehicles show no back light at night, great care must be used to avoid running them down from behind. Generally, one can see a faint gleam of light on the road; but, unless carefully looked for, it may easily escape notice. Horses and cattle, of course, show no light at all, and take plenty of watching for in consequence. In meeting vehicles at night, do not be in too much of a hurry to resume the centre of the road. Sometimes a cart carrying lights is followed by one or more without any illumination, and these latter are very liable to be crashed into. Motorists will always do well to use lamps which will not only serve as a signal to other vehicles, but will give enough light to show up the road for a long distance ahead. In fact, one should never drive so fast at any time that one cannot pull up well within the stretch illuminated by the lamps.

CHAPTER XX.

Involuntary Stops.

OF course, the car may pull up for defects other than those connected with the engine, but the most frequent causes of stoppages (with the exception of tyre troubles) are due to failures of the motor. With a little experience one can often guess the cause of the trouble from the way in which the stoppages occur. Thus, if the firing cease suddenly, it is probably due to a breakage in the electric system, or to the seizing of one of the pistons, or to one of the valves sticking or breaking, or, lastly, to stricture of the carburetter. On the other hand, if the engine expires gradually, the trouble probably arises from failure of the water circulation, or the supply of petrol or lubricating oil, or to the choking of the gauzes in the carburetter by dust or ice, or to the leakage of the float or of the compression. Thirdly, if the firing is intermittent, it indicates a discharged battery, a loose electrical connection, or a cracked sparking plug. We do not mean to say that this analysis is exhaustive, but it is a guide which will generally be found correct.

Failure of Petrol.

We will now consider some of the defects to which the various elements of a car are subject. If the petrol is fed from the tank by gravity, the supply may cease owing to the fact that air is unable to enter the tank. The remedy is to unscrew the cap and let more air in. The cap should have a small air-hole in it. Some tanks are provided with two caps, one having an air-hole and the other not. The former is used during running; and evaporation is prevented by using the latter at other times. If the petrol be fed under pressure, failure of the pressure will, of course, cause failure of supply. The most common cause of failure of supply is that the stock is exhausted. This generally means negligence, and it is always a good plan to carry one or two spare cans of petrol, to be used in case of emergency. If petrol cannot be obtained, one can sometimes get along with benzolene, or even naphtha, especially if introduced while the engine is still warm. And one can warm the engine by filling the water system with hot water. A broken feed pipe may be mended in the ways already described with reference to a broken circulating water pipe.

Carburetter Complaints.

The carburetter's most usual complaint consists in stoppage of the jet by some solid particle carried into it by the petrol. If this be suspected while the car is running, the air supply may be reduced suddenly, so as to cause increased suction at the jet. If this does not remove the obstacle, one should agitate the float. If the carburetter floods and overflows from the jet chamber, the trouble has probably been got over; if it does not, the passage to the jet should be opened, and a fine wire pushed through. Do not use a needle or other hard wire for this purpose, as it may break off in the jet. A piece of flowerseller's wire, or wire off a soda water bottle, if not too thick, will serve very well. If the carburetter is provided with a well or filter, this should be opened, so that the precipitate may be removed. The tap in the petrol supply pipe should be turned off first, otherwise a quantity of petrol will be wasted. Or it may be found that water has collected in the carburetter; this may be removed in the same way by emptying the well.

Float and Needle Defects.

A more awkward situation is created when the float leaks; this, of course, upsets the balance of the carburetter, and prevents the petrol standing at the right height in the jet. One can easily tell if there is petrol in the float by taking it out and shaking it. To cure the trouble, warm the float and apply a light to it; the petrol will be vaporised, and will catch light at the hole by which it entered. Put out the flame, mark the hole, and, if it is not large enough to pour out the petrol through, make another hole in the top of the float and pour it out through that. When the float is empty, re-solder both holes, using as little solder as possible, so as not to alter the weight of float. On one occasion we emptied a float entirely by the warming and lighting process, and a very long time it took to burn out! This method should only be resorted to in an emergency, as it might result in much more harm than good.

A defective needle valve will upset the working of the carburetter. If it arise from bending of the needle, it may be remedied by straightening the needle, and, if necessary, regrinding-in the valve. This grinding operation is similar to that of grinding-in the motor valves, as described later on. Sometimes the gauze screens through which the air and petrol are admitted get so clogged up with dirt that the supply of these two items becomes insufficient. A little careful cleaning is all that is required. In cold, damp weather a block of ice will sometimes form on the gauze screen at the carburetter end of the inlet pipe, and the simplest way to deal with this is to remove the screen; it is not really necessary in a spray carburetter. Many carburetters are provided with heating arrangements, and if these are fitted with a tap, the tap should be opened on such occasions.

Ignition Troubles.

The ignition is a most fruitful source of stoppages, especially the accumulator system. First inspect the sparking plugs; detach the high-tension wire from one plug and hold the end about a quarter of an inch from any metallic part of the engine. Hold the wire by the insulation, and, better still, wrap a thick cloth round this; then turn the starting handle, and see whether a good spark passes from the end of the wire. If it does, unscrew the plug from the cylinder, and probably you will find that the points, and very likely the end of the porcelain also, are covered with a carbon deposit. Clean this off with petrol and an old toothbrush, and polish up the faces of the points with fine emery cloth. See that the points are in line, and about a millimetre (or $^1/_{25}$in. to $^1/_{26}$in.) apart. Examine the porcelain to see that it is not broken, cracked, or loose. Also make sure that the central wire is properly secured. The porcelain may be tightened by carefully screwing in the gland nut.

Now reconnect the wire to the plug, and lay the plug on the motor, so that only the metal body thereof is in contact therewith. Turn the starting handle again, and see whether a good spark occurs at the points of the plug; if it does not, try another plug. Do not forget to switch the current on while testing. It should be remembered that water is a good conductor, and that if the exposed part of the porcelain is wet, the current will pass therethrough instead of across the points. Drying the porcelain will suffice in this case.

It may be, however, that no spark passes from the end of the high-tension wire, or that, though a spark is obtained, it will not continue for any length of time; and the test should always be continued for, say, five or ten seconds. If the sparking gets weaker and perhaps expires during this time, it shows that the battery is run down, and such current as it gives is only due to temporary recuperation. This should be remembered when testing the high-tension wire or the plug. The condition of the battery, if of the primary or dry type, may be tested by an ampèremeter (or "ammeter"). which should read at least six ampères. If it is a wet or secondary battery, a voltmeter should be employed, and should show over 3.8 volts. In each case the test should be made quickly. Some voltmeters are so constructed that their indexes come to rest promptly, and they are to be preferred for this reason. Instead of using a voltmeter, one may employ a four-volt test lamp. If this glows, and continues to glow brightly for some five or ten seconds, it may be gathered that the battery contains a sufficient charge, but not otherwise. Use the devices by applying their terminals to those terminals of the battery to which the low-tension wires are connected. If the meter shows nothing at all, reverse the application of its terminals.

If the battery is down, it must either be supplemented by another or recharged, if capable of recharging. The right plan is to carry spare batteries, so that when one gives out the other may be brought into use. It is just as well to switch over on to the spare accumulator now and again to make sure that it is in good order, but most of the running should be done on one accumulator, and then when that is exhausted it can be recharged while the spare is in use. By having a third battery, one can be on charge without depriving the car of its reserve.

Accumulator Defects.

Sometimes it is found that batteries, instead of holding their charges for the proper time, will run down very quickly. This may be due to the primary circuit being left complete accidentally —the driver forgets to switch off after a run. Or it may be due to a short circuit in the wiring ; or, again, to some of the paste dropping out of the grids and touching both a positive and a negative plate, thus forming an internal short circuit. Or it may be caused by a leak past the partition between the two cells. If the accumulator has a transparent celluloid case, one can see whether any loose paste is causing a short circuit. To test for a leak past the partition, some of the acid should be poured out of one cell ; then, if there is a leak, the acid in the other cell will pass through, and the levels of acid in the two cells will be restored. A leaking partition should receive immediate attention.

Detecting Short Circuits.

Where a short circuit is suspected, it may often be discovered by testing the ignition in the dark, as a spark will be noticed as passing from the defective point. The "short" is most liable to occur in the high-tension circuit, that is, in connection with the wire leading from the coil to the sparking plug ; and the short should be looked for while the wire is in the position it generally occupies on the car, as the mere act of moving it in order to make the test above described may prevent the occurrence of the short circuit from which it suffers. It is a great mistake to purchase cheap insulating wire, as a few dischargings of the battery will more than make up the difference between the costs of the cheap and best quality wire. If, on examining the wire, one finds parts that are chafed, they should be carefully bound with insulating tape, and steps should be taken to secure the wire so that further rubbing will be prevented. A better plan is to slip a length of rubber tubing over the wire, or to replace the wire with a new length.

The wires should be kept as free from oil as possible, as oil rots the insulation, and thus invites short circuiting. If the insulation appears to be quite sound, the trouble may arise from breakage of the wire itself. If the wire be passed through the fingers with a bending movement, the break will probably be easily felt ; but if not, it may be detected in the case of the primary wire by the voltmeter. The battery, suspected wire, and voltmeter, should be formed into a circuit for the purpose ; some tension and twisting movement should be put on the wire during the test. If there is current in the battery, but none can be detected through the wire by the voltmeter, there is evidently a break. The wire should be replaced by another if possible, but if no spare wire is available, the defective one should be cut through at the fault, the insulation slit lengthwise and peeled back for about one inch on each part, and the ends thus bared should be twisted together. The insulation may then be turned back over the joint and the whole bound with insulating tape.

Terminals and Connections.

Though the electricity is willing to adopt all sorts of channels in order to shirk its work, all contacts through which it is intended to pass should be thoroughly clean, and should be scraped with an old knife for this purpose. Avoid using a knife on which you set any value for scraping the terminals of the battery, as you will be very likely to make contact accidentally with both terminals at once, to the great detriment of the blade, not to mention the battery. In order to avoid corrosion, the battery terminals should be anointed with a mixture of vaseline and ammonia.

There are many different devices (also going by the name of terminals) for connecting the wires to the different screws, etc. These are generally more satisfactory than making loops on the ends of the wires themselves, though one has to take care that the attached terminals do not project and touch each other or other metal parts, and so cause short circuits. It is perhaps easier to tell what to avoid than what to do in making terminals out of the ends of the wires themselves. Thus the wire should not be twisted up into an eye of which one part is thicker than another; nor should the eye, when made, be soldered with acid flux, as this brings about corrosion and fracture. If the eye is soldered at all, resin should be used, but the sudden stiffening of the wire by any soldering is also liable to cause breakage.

Probably the simplest way to make an eye is to untwist the wire at a short distance from the end, and then to separate the straightened strands equally by pushing a sharp instrument in between, forming a hole sufficiently large to receive the screw terminal. A stronger eye may be made by baring a good inch of the wire and bending it into a simple loop, and then binding together with fine wire the two parts lying in parallel contact, leaving an eye of suitable size, as before. In securing the one terminal to the other, be careful that no part of the insulation is pinched, as this would tend to prevent perfect contact between the metallic surfaces; at the same time, the insulation should be continued as nearly up to the connection as possible; and for further security, the whole connection may be wrapped with insulating tape.

Care of Trembler Points.

Another cause of intermittent firing is looseness of the platinum point on the trembler blade of the contact breaker. The presence of dirty oil on the back of the blade round the platinum is ground for suspecting that the point is loose. Under these circumstances the blade should be detached and laid face downwards on a hard surface while the back of the point is riveted over with a light hammer. The faces of the platinum points should make contact squarely with each other; but the passage of the current and the tapping of the one point on the other spoil the surfaces in course of time, and the usual remedy is to file them flat with a thin, watch-maker's file. As platinum, however, is somewhat more expensive than gold, it seems a pity to waste it by filing, and the better plan is to hammer it smooth with a few light and carefully-applied blows. In some cases, too, the distortion of the surfaces can be corrected from time to time by changing over the wires on the battery terminals so as to send the current the reverse way through the points. But if the reversal of the wires is accompanied by the failure of the ignition, or excessive sparking at the contact-breaker, they must, of course, be replaced. In any case, no dirt should be allowed to remain between the platinum points, though a drop of oil there is sometimes found to be an advantage rather than otherwise. The points may be cleaned by inserting a thin card or a slip of strong paper between them, and then withdrawing the card while the points are pressed together. Be careful that no particles of paper are left behind, as they will be as bad as, or worse than, the dirt.

Adjusting Contact Breakers.

In adjusting a make-and-break contact breaker one has to see that the cam projection lifts the blade into contact with the screw, and that when the projection has passed, the points are out of contact. Provided the points make a good firm contact, nothing is gained by the excessive bending of the blade, but rather the reverse as current is wasted by the prolonged contact.

Unscrew the sparking plug and lay it on part of the metal work so that one can see the spark, and so that the terminal end of the plug lies clear of the metal work. Then fix the contact screw at that position which corresponds with the best spark at the plug. Notwithstanding the action of the condenser, a small spark will be noticed as the points at the contact breaker separate. In fact, if no spark shows here it is a pretty sure sign that either the battery is run down or there is a fault in the primary circuit.

Wipe contact breakers are generally self-adjusting by means of a spring. They should, of course, be kept clean, but they should be freely oiled ; the reason for this being that if they are run dry the wipe tends to scrape particles off the metallic segment and embed them in the fibre cam, thus constructing a path through which the current will continue to pass after it should be broken, and disturbing the timing of the sparking and wasting the current. Any such particles should be removed; and the metal and fibre surfaces should be kept even with one another, as inequalities frequently cause the wiper to jump, with irregular firing as a result.

Coil Troubles.

When every other part of the ignition system has been proved to be in order, one can only conclude that the trouble is in the coil. This may be due to failure of the insulation. If, on the system being connected up and the contact breaker being worked, a ticking noise be heard in the coil, this is a pretty sure sign of defective insulation. The only remedy is to get the coil repaired by an electrician, preferably the coil-maker himself. The trouble, however, may arise from loose connections at the coil, or from loose strands of wire causing a " short " from one coil terminal to another. These troubles can, of course, be easily remedied if they occur at the exposed ends of the terminals; but if the shorting is between the inside connections, the cover must be carefully removed so as not to break the wires, and as carefully replaced in its proper position after correcting the fault.

If the coil trembler suddenly stops work, it is probably because it has stuck. Should this happen, the trembler may be set in motion again temporarily by unsticking it, but the platinum-pointed screw should be readjusted as soon as possible. The platinum points should be inspected, and, if necessary, cleaned and reshaped ; they should stand normally about half a millimetre apart, but it is best to effect the adjustment with the sparking plug where the points can be seen, so that the platinum-pointed screw can be locked at the position which shows the best spark. The tightening of the locknut on the screw will generally upset the adjustment somewhat, and this must be allowed for by setting the points a little too close together before finally tightening up. If this adjustment will not cure the trouble, the defect may lie in the loss of elasticity in the spring blades ; if so, they must be replaced by new ones.

Magneto Management.

Magnetos should be handled carefully, not only for the sake of their internal economy, but shocks and vibration are detrimental to the maintenance of the magnetism. Most magnetos are constructed to run in only one direction, which is indicated by an arrow marked thereon. The driving connections should be free, in such a way as to avoid putting any cross strain on the armature-shaft, but should not allow of any backlash, as that would involve wear and interfere with the timing. A slight buffer action may be introduced into the drive of very high-speed magnetos, with advantage.

If it should become necessary to retime the magneto with the engine, the procedure is as follows : Bring the front piston to the top of its compression stroke, and set the timing lever in the middle of its range. Then turn the armature shaft until the distributer is in position for serving the front cylinder plug and the points of the contact breaker are just beginning to separate. Now secure the transmission mechanism by tightening the nut holding the wheel or other connection on the taper part of the armature spindle. As the points of the contact breaker separate just when the armature is passing through its maximum positions, care must be taken not to let the armature slip, as the magnetism acts strongly upon it, and tends to pull it back or shoot it forward from these positions. If the relative arrangement of the parts described is not quite satisfactory in running, the nut on the armature spindle should be loosened, and the armature turned round forward (or the wheel or the like thereon turned backward) relatively to the direction of the armature's rotation, in order to advance the ignition more. If, on the other hand, the ignition is too far advanced, as indicated by the engine knocking even with the timing lever retarded, the parts should be moved in the opposite direction—that is, the armature shaft should be turned backward, or the wheel or the like forward, a few degrees. When the right positions have been found, lines should be scribed, or points dotted, on the wheel and spindle, so that they may be readily replaced in their proper positions if occasion should arise to disturb them in future.

Beyond lubrication and cleaning, it is neither desirable nor easy to give a magneto much useful attention. Some lubricators are constructed with overflow pipes, and should be filled up until the escape of the oil shows that the containers are full. Generally, however, the bearings should be oiled with three or four drops of oil about twice a week; say one drop per day as an average. The bearings of the distributer spindle should be oiled as well as those of the armature. Take care to see that the contact breaker lever works freely, and that the platinum points are clean, and fit squarely together. They may be trimmed with fine emery-cloth or a very small file. All particles of emery, etc., should be cleaned off before using the magneto. The points should separate by only a very short distance, about one-third to one-half of a millimetre, when the contact is broken.

The distributer should be kept clean and free from oil, especially if it comprises a carbon pencil or "brush," as oil is liable to disintegrate the carbon. See that the brush works freely in its container, and is pressed well out by its spring.

The sparking plugs used with magnetos require to withstand a higher temperature than those employed in accumulator and coil ignition, and should, therefore, have points of good quality refractory metal, preferably platinum. The points should be set close together, not more than half a millimetre apart. If of inferior material, they may become bridged across by a globule of metal, which will, of course, stop the firing, and should be removed forthwith. Similar results will ensue if the switch wire short-circuits to the frame or other metalwork of the car, or if the magneto is exposed to the wet. In this case it may take some time to dry enough to restore the insulation. Hence it should be well protected by a patent leather or other waterproof cover, unless properly shielded by the bonnet.

If the failure of a magneto cannot be traced to any of the defects above mentioned, it is probably due to more serious trouble, and will require the attention of the manufacturer. Never neglect misfiring if the magneto is being used, and never fail to short-circuit the magneto by the switch when an alternative ignition is brought into operation, unless the two systems are entirely separate.

Loss of Compression.

After running a car for a while, one sometimes finds that it will not climb hills or attain the speed that it would at first. This is probably due to loss of compression, which may arise from several causes. The first thing to do is to switch off the current and pull the starting handle round with the compression closed. If it is found that the handle comes round with comparatively little effort, the next step is to find where the leakage takes place. If you put your ear close to the cylinder head while someone else turns the starting handle, you may be able to hear where the air gets out; or by wiping the various joints and connections about the motor head with soapsuds or oil, you may observe the air forming bubbles. It may be that the sparking plug wants screwing in tighter, but more likely the valves require grinding-in, or one of them may merely have stuck in its guide; or again something may have lodged between the head of the valve and its seating, so that it cannot close. On one occasion some friends found that the very poor running of their car was merely due to the fact that they had inadvisedly left the compression taps open very slightly! When the leak does not betray itself by any outward and visible sign, it may arise from the fact that the slots in the piston rings have got into line, or that one of the rings is broken.

Valve Grinding.

First let us deal with an exhaust valve that requires grinding-in. To remove the valve, the spring must be held up by a screwdriver, or, better, by an instrument specially provided for the purpose. The cup-like washer below the spring must be held up at the same time, and this will allow the little cotter or key passing through the valve stem and supporting the spring to be removed. The plug above the valve must be detached, and then the exhaust valve can be lifted out by raising the stem with a screwdriver. Even when all is clear it is not always easy to prevail upon the exhaust valve to leave its seating. It may generally be got out, however, by lifting it a little way and then passing a loop of string under its head. The valve is then drawn out by pulling at the ends of the string. If there is a saw-cut across the head of the valve, well and good; but if not, such a cut should be made, so that the valve can be rotated by a screwdriver.

A mixture of the finest emery powder and oil should then be prepared, and a lump of wadding or the like thrust into the exhaust port of the motor to prevent any emery getting into the cylinder. Some of the emery and oil should be smeared on the bevelled surfaces of the valve and its seating, and the valve replaced in position. Next, the valve should be rotated by means of the screwdriver. At every few turns the valve should be raised and let down again in a different position, and the turning repeated. This process should be continued, applying more of the emery and oil as required, until the surfaces are both clean and bright. When this result has been obtained, all traces of the emery and oil should be wiped away, finishing off with a swilling of paraffin or petrol.

The lump of waste may now be withdrawn from the exhaust port and the valve reinstated; the spring and washer are first placed in position and the stem of the valve lowered into them. They are then forced up until the cotter can be pushed into the slot in the stem. The projection on the cotter should be uppermost, so that when the washer bears on the cotter the former will prevent the latter moving out of position lengthwise. Compressing the valve springs is an awkward job, but some irritation may be saved as follows. Before replacing a spring, put it in a vice so that one side projects a little above the jaws. Screw up the vice so as to contract the spring somewhat; thread a string through and tie it tight so as to hold that side of the spring compressed. Repeat the process on the opposite side. The parts can be easily replaced with the springs thus contracted, and when all are in place, the strings are cut and the spring expands ready to do its duty.

The opportunity should be taken to see that the end of the valve stem clears the plunger by about $\frac{1}{32}$ of an inch. If the clearance is less than this, the valve stem may expand so much when hot that it will always bear on the plunger, and so prevent the valve closing properly. On the other hand, if the clearance is more than a $\frac{1}{32}$ in., the plunger will strike the stem late and leave it early, so that the valve will not be held open during its full period, and the escape of the products of combustion will be restricted. It is easy enough to shorten the valve by filing, but lengthening is a job which the ordinary amateur will not be wise to attempt. A small cap fitted under the end of the stem, or over the top of the plunger, is one remedy for a short valve stem. Restricted opening of the exhaust valve may be due to wear of the cam projection, which should be renewed as occasion requires, though if well made in the first place it should last a very long time.

The inlet valves, not being subject to the passage of the hot waste gases, do not require grinding-in as often as the exhaust valves; and when they do have to be done the operation is easier if the seating, as well as the valve itself, is detachable.

Timing.

As a rule, it is a bad plan to take a motor to pieces; the parts work best in the positions to which they have become accustomed, and the chances are they will not be restored to their relative places exactly, if once disturbed. Where a mistake is most likely to be made is in the timing; unless the wheels of the half-speed gear are engaged in the proper positions, the motor will either not drive at all or only inefficiently. If you have to set the timing, remember that if there is only one half-speed shaft, the cams actuating the ignition and the exhaust (and the inlet, unless automatic) have their relative positions permanently fixed, and by setting the exhaust valve gear correctly, one can trust the others to look after themselves. If the wheels of the half-speed gear be examined carefully, one will probably find a mark on each, indicating, respectively, a tooth on one and a tooth-space on the other. If the gear wheels be re-engaged so that that tooth enters that space, one may fairly conclude that the timing is right, as these marks are put on at the works after the best positions of the wheels have been found by experiment. Sometimes, however, the wheels are not marked, and sometimes they are marked incorrectly !

The way to proceed then is to pass a stiff wire down the compression tap on the piston, and mark it with a file when the piston is at its highest and lowest positions. Below the upper mark make a third, about one-sixth of the way down. Thus, if the piston has a 4½in. stroke, the third mark will be ¾in. below the top mark. Move the piston until it is five-sixths of the way down, that is, until the mark last made on the wire is just showing at the compression tap. Now turn the half-speed shaft round until the cam is just ready to begin lifting the exhaust valve plunger. Gear the wheels together at this position, and turn the crank shaft in the direction in which it runs in driving; the valve will lift as the shaft turns, and should close at the moment the piston reaches its highest position. If the valve remains closed instead of opening as the crankshaft is turned, it will be because you have forgotten that the half-speed shaft and crankshaft turn in opposite directions, and have brought the cam up to the wrong side of the plunger. If the gearing will not allow of the exhaust valve opening and closing at the periods mentioned, get the closing right, and the opening as near as you can. Of course the valve stem must be just the right length, if it is too long or too short, it should be put right before timing the valve.

If the exhaust valve of one cylinder be correctly timed, the timing will be right for the whole engine, however many cylinders it may have—provided the valve stems, plungers, and cams are not worn unequally. If there is no compression tap in the top of the cylinder head, there will probably be a screw plug, which can be withdrawn for the purpose of inserting the testing wire. But in the absence of both tap and plug, one will have to expose the crankshaft, or, better, the top of the piston itself.

If the inlet valve is operated by an independent camshaft, it should be timed to open at the moment when the exhaust valve has just closed.

The firing mechanism should be set so that, when the adjustment provides equal ranges of advance and retard, the spark occurs on the completion of the compression stroke.

In a four-cylinder motor the sequence of cycles should not be 1, 2, 3, 4, but 1, 2, 4, 3 or 4, 3, 1, 2. That is to say, the firing or impulse stroke in the first cylinder should be accompanied by compression in the second cylinder, exhaust in the third, and suction in the fourth, thus—

Cylinder 1.	*Cylinder* 2.	*Cylinder* 3.	*Cylinder* 4.
1. Firing	1. Compression	1. Exhaust	1. Suction
2. Exhaust	**2.** Firing	2. Suction	2. Compression
3. Suction	3. Exhaust	3. Compression	**3.** Firing
4. Compression	4. Suction	**4.** Firing	4. Exhaust

Piston Ring Vagaries.

If the piston rings have worked round so that their joints are in line, or if they are broken, or a bad fit, the gas will leak past them during compression and combustion, the power of the engine will be decreased, and the crank case will become heated. Sometimes the utility of the rings will be impaired by their becoming stuck in their grooves with carbonised oil. They should fit the grooves so that they have no play up and down, but they should be free expansively. The slots should be practically closed when the rings are in the cylinder, but they are usually slightly open to allow for expansion caused by the heat generated by the engine when running.

If the joints are in line the rings should be turned round until the joints are as far as possible from being in line. Dark marks on the rings and in the cylinder show that they do not fit, and that the burning gases have leaked by. In this case, or if the rings are broken, new ones should be fitted. It does not matter much about breaking the old ones, but the new ones will require careful handling, as, being made of cast iron, they are extremely brittle. The best dodge is to take three strips of thin metal and arrange them equidistantly around the upper part of the piston, and parallel to its length. The ring to be put on is slipped over the ends of the strips, which should reach from just above the groove to beyond the top of the piston. By these means each ring may be easily got past the upper grooves into position, the lowest one first and the highest one last.

CHAPTER XXI.

Accessories, Tools, and Spare Parts.

IT is easy to spend quite a lot of money under this head, and the motorist requires to exercise judgment as to what is, and is not, worth his while to purchase. Some articles may pay for themselves, in one way or another, in a very short time; others will be more trouble than they are worth.

One soon discovers that very different prices are asked for the same things by different houses. Car manufacturers almost invariably charge more for accessories than firms whose principal business consists in dealing in such articles. Get the catalogues of a few such firms, and, having decided which you like best, deal as far as possible with that one. Regular customers receive better attention than casuals. Before starting on a tour, arrange with the chosen firm and the makers of your car as to the forwarding of anything you may require while away. If necessary, open a deposit account. Of course, a good many things one can buy satisfactorily at local motor depots, but it is a great convenience to be able to wire for any special article and receive it by train within a few hours. Where no arrangement has been made, it is best to wire the money with the order, and thus avoid any reason for delay. Take a catalogue with you so that you may know how much to remit, including carriage, if necessary.

Some things—sparking plugs, for example—can be bought at all sorts of prices. While the best is the cheapest, the highest-priced are not always the best, though the lowest price are seldom satisfactory. A fair price and a good name may be relied on as guarantees, in the ordinary way. Never buy imitation things which look as good as the original but which cost less. Remember that business is not philanthropy.

The motorist's outfit should include the following articles, apart from clothing, which is dealt with separately. It is a good plan to write out a list like the following, making such alterations as circumstances may direct, and hang it up in the motor house:

Accessories, Tools, and Spares.

To be taken on Ordinary Runs.

Accumulator (spare).
Aprons and rugs.
Asbestos packing and string.
Burner for acetylene lamp.
Carbide.
Card (thin).
Cold chisel.
Contact breaker, cam, blade, and screw.
Emery cloth (fine).

Accessories, etc.—(Continued).

Files (half round, round, and flat small).
Funnels (petrol, water, and lubricating oil).
Goggles.
Grease and injector.
Hammer.
Horn.
Inflator.
Inner tubes (two in bags).
Insulating tape.
Jack.
Knife, fitted with pricker and scissors.
Lamps. Leather laces.
Magneto platinum contacts and brushes if no accumulator ignition is fitted.
Metal clips and screws for rubber water connections.
Motor watch.
Nuts, bolts, and washers (various).
Oils (paraffin, cylinder, lubricating, Collan oil for leather clutch).
Oilcans (three) for above.
Petrol in spare tin (two gallons).
Pliers (large and small).
Repair tyre outfit, with chalk and solution.
Rubber tube, spare lengths for water connections, and to repair petrol or lubricating pipes.
Spanners (box and tubular) to fit all nuts.
Sparking plugs.
Split pins.
Spring washers. Straps.
Screwdrivers (large and small).
Terminal screws.
Twine and cord.
Tyre valve parts.
Tyre levers (special lever for valve insertion).
Vaseline. Hand vice.
Voltmeter (if batteries are carried
Washers, metal, and copper asbestos.
Wire, copper 16 g., iron 20 g. and 30 g., and high tension and low tension insulated wire.
Wrenches (large and small).

Additional for Long Runs and Touring.

Accumulators (three sets in all).
Ammonia.
Blowpipe, solder and flux.
Breast drill.
Cleaning brushes, gloves, leathers, cloths, and waste.
Dividers for map measurement.
Foot muffs (for winter use).
Hack saw and blades.
Lamp parts.
Maps and road books.
Overalls. Reamers.
Springs (various).
Trembler for coil.
Tyre cover and three inner tubes
Vulcaniser.

For Garage Use.

Bench.
Blowpipe and bellows.
Brace and bits.
Breast drill.
Cleaning: Metal polish, plate polish, chamois leathers, sponges, bass broom, mop, spoke brush, bucket, cloths, and waste.
Drills.
Emery powder and crocus powder
Enamel (quick drying).
Files (various).
Fire extinguisher.
Hose, water.
Lathe (not essential).
Paint (aluminium and black).
Stock, dies, and taps.
Vice (fixed)

Some of the things to be taken on tour will usually form part of the motor house equipment.

A few remarks on some of the articles in the above lists may be of service here; a number of them are dealt with in other parts of the book.

If the driver uses an *apron* or *rug* at all—and many prefer to depend entirely on their clothing—it should be cut of a special shape, so as to leave plenty of clearance for the steering column. Passenger aprons and rugs should be provided with a flap at the middle, near the top, either inside or out, the flap being secured along both the upper and lower edges so as to form a kind of sleeve or muff. If the hands be thrust into this sleeve, they will not only be kept warm, but they will help to hold the rug up in place. The lower part of the apron should be of some material that will stand being trodden upon; the rest of it should be rain and wind-proof and a bad heat conductor. Mackintosh lined with fur meets most requirements. Fur foot muffs are a great comfort to those troubled with chilly feet.

Accumulator.—Provision for the third accumulator is best made in the accumulator box, now found in most cars placed upon and secured to the forward portion of the offside running footboard. Even if not used occasionally for an electric incandescent on the dashboard or in the tail lamp, this third standby should not be forgotten; it should have a refreshing charge from time to time, when on a long tour, in case it should be required.

Asbestos is useful for packing (as between the shoulders of the porcelain and the metal work of sparking plugs), and for making joints (as between the head and the cylinder of the motor). In making water joints the asbestos should be impregnated with oil or with rubber solution. Thinner joints can be made with good brown paper saturated with a mixture of graphite and black treacle; but asbestos has the advantage that it is unaffected by heat.

Ammonia is useful in several ways. It may be applied to the battery compartment and also to one's clothes to neutralise the effects of acid splashes. Mixed with vaseline, it forms a good preventive of corrosion when rubbed on the battery terminals. It is also a good thing to relieve the bites and stings of insects.

The *blow pipe* if taken on tour should be for use with the mouth and a spirit lamp; but in the motor house there should also be a large one burning gas and having foot bellows. Neither should be used close to the car or elsewhere in the presence of petrol vapour.

Cleaning brushes are now procurable in which the stock is hollow and perforated. They are meant to be coupled up to the hose pipe, so that a constant stream of water flows out of them, and hastens the removal of the mud. Chamois leather will dry supple if washed with plenty of soap, which should not be rinsed out. The leather should be thoroughly dried before being used for polishing purposes. Cotton waste is good for sopping up oil and grease, but its propensities for catching and for leaving bits behind are tiresome.

Miscellaneous.

Thin *card*, such as is used for visiting-cards, is useful for cleaning the points of some contact breakers, and may also be used instead of metal in manipulating piston rings.

Dust screens are usually made of canvas mounted on a light folding frame, and are extended behind the upper part of the car body to prevent the eddying air currents carrying the dust into the back of the car and on to the occupants thereof. They should be arranged so as not to interfere with ingress and egress to and from the car.

The *drill* for carrying on the car should have an ample breast-piece, and preferably a two-speed gear. With this breast drill, a brace with a good assortment of bits, and a bench drill for home use, quite a lot of handy jobs can be done.

Crocus powder may be used instead of emery for valve grinding, either entirely or for the "last lap."

Some quick-drying *enamel* should be kept for touching up black parts, but it is difficult to use it without producing the effect of a newly-tarred fence. First, smooth down the part to be treated, then work the brush in one direction only, using a small quantity of the enamel, and avoiding touching any part a second time until the first coat is quite set. Where one has a choice, small rough surfaces look better painted with aluminium than if blacked.

It is said, and we can well believe, that soda-water ejected from a syphon is very fairly effective in extinguishing burning petrol, the carbonic acid gas being non-combustible. The idea seems to have been elaborated in certain *fire extinguishers*, in which a liquid chemical is stored at high pressure in cylinders provided with suitable valves and nozzles. These may be more convenient than sand to carry on a car; but both together are better than either alone, whether on the car or in the motor house.

The *petrol funnel* should have a finer gauze strainer than the water funnel. Both should have non-circular spouts, so as to leave a passage by which the air may escape from the tank as the liquid flows in; and the spouts should have removable caps or covers to keep them clean when not in use. Where space is precious, a flattened funnel is to be preferred to one having a full circular dish. Funnels are called tundishes in some parts.

Goggles and Horn.

Goggles are not only useful for keeping dust out of the eyes. Stray winged insects, often encountered in large numbers in the neighbourhood of streams and other waters, are even more objectionable intruders than dust. To many people the rush of air and the glare of the sun are painful, and to such goggles offer protection, provided in the latter case the glasses are tinted. In choosing goggles, be careful to see that they do not distort the sight. We came across one pair that made us feel about fifty per cent. taller than our proper height. If one has to wear glasses in the ordinary way, the goggles should be preferably worn over them. Do not let a misguided vanity beguile you into purchasing any unnecessarily hideous affairs. They should be as light as possible, and should not confine the vision more than can be helped. A strong, but not too tight, elastic is preferable to the usual wire hooks. The edges of the frame should be covered with chenille, or have margins of kid or silk, to make a dustproof contact with the face.

The *horn* should be of ample dimensions, and should give a good deep note. Some horns will not sound unless the bulb is squeezed with a particular pressure, so test with squeezes differing in speed and intensity. Fix the horn itself well in front, directed forward. The bulb should be located where it can be squeezed with a minimum diminution of control of the car and with a minimum loss of time. The electric buzzers present a considerable advantage in this respect; and the buzzer may be used to replace a broken down coil trembler, at a pinch. If the horn loses its voice, unscrew the bulb or the flexible tube, as the case may be, from the horn, and flick the reed, when it will probably be found that the trouble has been overcome. Be careful not to bend the reed, as it is not an easy thing to reset. Unfortunately, the law and good driving dictate different practices in the use of the horn. One must use one's discretion, remembering that in these days it is good policy to keep the right side of the law. As much as possible, avoid tootling when passing places of worship during service, hospitals, etc.

Inflators, Spare Tubes, and Jacks.

The *inflator* or tyre pump should be provided with footpieces, so that both hands may be left free to work the plunger. The connecting pipe should be of good length, firmly secured, and provided with a swivel valve connection and nipples adapted to suit different valves. A large diameter barrel allows of the tyre being filled quickly; a small one enables a high pressure to be attained without undue exertion. To meet these conflicting conditions, some pumps are in duplex form, having two barrels and pistons of different diameters, mounted on one footpiece. A pressure gauge is a useful guide in pumping up a tyre. Power pumps worked by the motor, and "sparklets" or bottles of compressed gas save much labour in tyre inflation.

Spare inner tubes should be carried in separate bags sold for the purpose, and a liberal supply of French chalk should be put in each bag. If the air tubes are left loose among the other impedimenta, they are liable to get cut by the tools and rotted by oil. Oil and grease should always be kept away from insulated wire and other rubber-containing goods, or they will very soon be irretrievably damaged.

The *jack*, in the motor world (every industry seems to comprise some article of this name), is a pillar, the height of which can be extended by some device giving great leverage in favour of the operator. It is used principally for lifting the wheel while its tyre is being repaired or during cleaning operations. The jack should have a base of ample dimensions, and the rising platform should be placed under the axle near to, but clear of, the wheel. Scotch one or more of the other wheels while using the jack, otherwise the car may move and bring down the wheel with a bang, at an awkward moment. In choosing a jack, be careful to see that its range is great enough to lift the wheels of your particular car.

Lamps.

The *lamps* serve the dual purpose of illuminating the way and acting as a signal to others on the road—indeed, in the latter connection, the law requires that a red light shall be shown behind and the rear number-plate shall be illuminated. Several methods of lighting are available—acetylene gas, electric incandescence, and light or heavy oil. On some cars all these systems are employed—acetylene for the head lights, oil for the side lights, and electric for the rear number-plate.

In acetylene lamps the gas is generated by the application of water to calcium carbide. The combined lamps and generators are very heavy, and put a severe strain on the brackets carrying them. A separate generator is to be preferred on this account, and especially where there are two lamps, as they can both be supplied from the one source. A good supply of carbide should be carried on the car, in view of possible night repairs ; and one or two spare burners, in case the one in use should become choked. Acetylene lamps are a necessity for night driving. Some of the most recently designed electric head lights are, however, a distinct advance, and nearly approach the acetylene variety in the range of their beam. The installation of batteries and dynamos (both of which are required) is an expensive item, so that to many this method of illumination is barred on the score of initial outlay.

Paraffin lamps light easily, give a fairly strong light, and if well constructed will stand a pretty rough wind. Do not attempt to burn paraffin in a lamp constructed for colza. The greater temperature will start the soldered joints ; but a proportion, not more than fifty per cent. of paraffin, may be mixed with the colza to facilitate lighting. If no colza can be obtained, put some cotton-wool, rag, or other absorbent material in the oil well, pour in some paraffin, and pour out again all, or nearly all, that has not been absorbed. One can sometimes use petrol in a similar way ; but in this case be sure to pour off *all* that is not soaked up by the absorbent material. The wick should be of close texture for paraffin, and open for colza. Avoid cutting the wick. To trim it, pinch off the charred part, and pat it smooth. A drop of paraffin on the wick will ensure a colza lamp lighting quickly. All wick should be thoroughly dried before being used, and fresh wicks should be inserted every month. Keep the lamps thoroughly clean, and see that all the ventilation holes are clear. It is best to remove the lamps to a safe distance from the car before lighting them, and be sure that the set screws or other locking devices are quite tight before starting.

A much less powerful rear light is sufficient to show up a transparency number-plate and the red light behind, so electricity may be employed for back and side lamps. As a rule, however, a paraffin lamp is employed. In any case, keep a watch on the back lamp, as the police are down on those who allow it to expire; possibly because a motor car, being the fastest thing on the road, is the least likely to be a source of danger to any vehicle following it.

The choice of the *lathe* will depend a good deal upon the kind of person who is to operate it. It is no use going to the expense of an elaborate tool if one is not skilful enough to profit by its capabilities. 5in. centres, gap bed, back-geared, and screw-cutting, may be taken as a rough specification.

A small horseshoe *magnet* is handy for picking up balls, split pins, etc., from inaccessible positions; and a small *mirror* is very useful for inspecting, or reflecting light upon, parts that cannot be readily seen otherwise.

Lubricating Oil, etc.

It is very difficult for the amateur to judge the qualities of *oil* correctly, and the only safe course is to purchase a reputable make. Cylinder oil is subjected to a very high temperature, and only mineral oils will stand it. As air-cooled cylinders get hotter than water-cooled, they require a thicker oil, so that they may retain sufficient viscosity in use; but best gas engine oil may be used for a water-cooled motor, at a pinch. A less expensive oil may be used for lubricating other parts of the car, as they are not subjected to high temperatures. The *oilcans* used on the car should be of different patterns or colours, so that they may be readily distinguished, and attempts to lubricate with paraffin, and other such little mistakes, avoided.

Two pairs of *pliers* should be carried—one, a small pair of watchmakers' pliers, for electrical work and other light jobs; the other, a good sized pair of parallel action pliers with wire cutter. for general use.

The tyre *repair outfit* should include prepared patches of various sizes, sheet rubber, ditto backed with thin canvas, rubber solution, solutioned canvas, French chalk, three tyre levers, two or three security bolts with nuts, spare valve parts, glass paper, wire scratch brush, valve rubbers, an indelible ink pencil, and a pair of scissors. In addition, one should carry spare tins of solution and French chalk.

The tubular *spanner* is a very handy instrument for turning awkwardly placed nuts. The ends of the tube are made hexagonal, so as to slide on to the nut from the top, and holes are pierced in the tube to receive a cross bar, by which it and the nut can be turned. The "Auto-clef" acts in a similar way, and is provided with a universal joint, which makes it all the more convenient.

The *spare sparking plugs* should be protected by wooden caps screwed on over the business end; or, better, by being enclosed entirely in boxes made for the purpose.

Speed Indicators and Spare Parts.

Speed and distance indicators are both interesting and useful instruments to have fitted to a car. The former help one to avoid exceeding the legal limit, and, especially if fitted with a maximum index, are useful in controverting police evidence, or rather allegations, as to speed. The driving mechanism should be positive—not merely frictional. The cyclometer, distance indicator, or odometer, is not only useful in showing the distance piled up by the car, but it also enables one to compare the wear of various tyres, and so forth. It is also handy in exploring new country, as one can identify turnings by their distance from ascertained points. Some distance indicators have two sets of figures, one for the grand total and the other for measuring individual trips.

The small *screwdriver* may conveniently be of the ratchet pattern; this action saves a lot of time in light work. See that the end of the blade of the large turnscrew is not too fat to enter the screwhead slots properly—grind it down to a reasonable shape if necessary. Sometimes it is necessary to put a spanner on the screwdriver blade and use it as a lever, in order to start a screw.

A hand *vice* is a very convenient instrument on a car; but a small parallel action vice, which can be fixed to a gate, or even to part of the car, is still more useful. It is often half the battle to get a firm hold of the article one is dealing with. The motor house vice should also be of the parallel type, and should have a quick grip.

The *voltmeter* consists partly of a coil of long, thin, insulated wire. When the terminals of the instrument are put in contact with the terminals of the battery, a current passes through the wire and deflects a needle more or less, according to the intensity of the current. It is best to test each cell separately, and to do this part of the bridge connecting them must be scraped clean and one of the voltmeter terminals pressed thereon, while the other is applied to the screw terminal of the cell. A considerable difference in the readings should direct one to look for defects in the cell having the lower voltage. Do not forget that a practically exhausted battery will often show quite a good reading for a short time, but if tested while at work its true condition will be revealed. Dry or primary cells should be tested with an ammeter, but this instrument should never be applied to the poles of an accumulator.

Vulcanisers are constructed of several patterns, and are used for making repaired parts of covers and tubes homogeneous by the action of steam heat.

Warmers and Wrenches.

Warmers. Whether it is due to enthusiasm or to some other action of the mind on the body we cannot say, but we always find it easier to keep warm when driving than when playing passenger. Passengers are often glad of some artificial means of maintaining their temperature. In a few cars the exhaust gases have been led through a footwarmer. Indiarubber hot water bottles, Instra warmers, and the Everlasting warmers are all serviceable. The last is a sealed tank containing a chemical preparation. It is heated by boiling for a comparatively short time, and keeps hot for several hours, and may be used over and over again. It can be had in a variety of sizes.

A *wrench*, to be satisfactory, must be well made and of good material, and it is worth while to pay a little extra to ensure these qualities. The cardinal sin of wrenches is gaping. Therefore the steel should be fairly hard, the shaft of good depth, and the jaws massive at the roots. The corner where the fixed jaw joins the shaft should be well rounded, and the sliding jaw should have a long bearing on the shaft. The screw adjustment should be well fitted, so that there will be very little backlash and very little tendency for the adjustment to alter. Further, the screw and nut should be located where the finger and thumb of the hand holding the wrench can readily reach them. The ordinary screw hammer or coach wrench is not an ideal implement. For small hexagon nuts, a wrench having notched jaws that will grip four sides of the hexagon is a good tool to have. Another wrench may be of the Clyburn pattern, with the jaws at an angle to the shaft. This is very useful where there is only room for a small movement of the wrench, as it can be put on first one way and then the other. The third (and largest) wrench may be of the simple type first described. The wrench should be applied to the nut with the jaws at right angles to the bolt, not parallel to it. Nuts that are milled or knurled or provided with wings should be tightened by the fingers only, though a wrench or pliers may have to be used to slacken them.

CHAPTER XXII.

Clothing.

SPECIAL clothes are not absolutely necessary for motoring; neither is it absolutely necessary that special motor clothes should be hideous. In due time, doubtless, the budding motorist will get over his vanity, and be content to appear as rational on his car as off it. But, unless some equally irrational legislators have their way, the fact will remain that motoring is, to all intents and purposes, sitting still in a wind, averaging about thirty miles per hour. Nothing makes one feel the cold like a wind (except hunger), and in order to keep warm it is necessary to prevent the wind penetrating one's garments. While the clothes should not confine the movements of the body, there should be nothing to flap about. This applies more particularly to capes, soft brimmed hats, and anything that can obscure the driver's vision, whether worn by himself or by anyone near him. His own handkerchief and his companion's furbelows may be equally responsible for a nasty smash, by being blown for a moment across his eyes. Warmth should not be sought in mere bulk, for a heavy garment is tiring to wear, even though one do not walk about in it. For the sake of appearance, the cut and colour should be as unobtrusive as possible; indeed, the colour should be rather governed by the liability or otherwise, to show up dust and grease stains, than by anything else.

For the most part an ordinary lounge suit will do very well; it is the outer garments that demand most consideration. Shiny black leather is no longer "the thing," and tan leather is not much better. But the windproof quality of leather may be availed of in the form of a tan leather waistcoat, or, perhaps better still, a detachable "breastplate" of the same material. As one is always facing the wind, the leather need only cover the front, the woollen back being left free for exhalation purposes. If a leather waistcoat be chosen, it may be provided with leather sleeves, lined with silk.

Overcoat Design.

The overcoat is the *pièce de résistance.* It is the sort of thing upon which one acquires ideas of one's own. Ours materialised as follows: A rather dark drab waterproof cloth, cut double-breasted, and with a serviceable turn-up collar, with tab to button across the throat. Straps to the sleeves, so that they could be folded and secured around the wrists. Lined with chamois leather throughout, and the sleeves lined again with Italian cloth to prevent the leather clinging in putting the coat on. Usual four pockets outside, and inside a breast pocket and two large "poachers'" pockets. It answered very fairly well, but was neither quite as warm nor quite as waterproof as we had hoped. A second lining of wool would be an improvement in the first respect; and as to the second, it is useless to expect too much. The penetrating powers of rain are greatly accentuated by the speed of the car, and leather itself will let the wet through in the course of a long drive. There is nothing for it but oilskins or indiarubber, and, for real use, there is probably nothing better than the "parapluie" or umbrella coat. This differs from an ordinary mackintosh in that, instead of the usual button fastenings, the neck and wristbands are made of indiarubber, and are stretched open to admit the head and hands. It is not the sort of garment to take violent exercise in, and should not be worn longer than necessary at a time. Fur is beautifully warm, especially when made up with the skin inwards, as the fur itself then holds a thick layer of warm air outside the skin; but it is apt to hold dust as well as air, and the wearer runs the risk of being taken for a "specimen" escaped from a menagerie.

FIG. 86.
THE "PARAPLUIE" COAT.

The skirt of the overcoat should be cut much fuller than for walking, so that there may be ample material to cover the legs when seated. The motoring tailors have various dodges in the way of concealed folds, which let out automatically when wanted in this way. The cuffs can be fitted with short false linings gathered into elastic bands to stop the draught up the sleeves; but a cuff folded and held by a strap, fits into the gauntlet of the glove better. For very cold weather nothing is so good as a fur-lined coat. A fur-lined coat is better than a coat with the fur outside, as it is less cumbersome and certainly less pretentious.

As to the headgear, nothing sticks on better than a well fitted cloth cap; and if this be provided with a shield that can be turned down to cover the ears and neck in bad weather, it will serve for all ordinary occasions. For night work it may be supplemented by a Jaeger fleecy wool cap; this has a kind of telescopic shield, which can be let down to enclose the whole of the head and neck, leaving only the eyes and nose exposed. For rain, one can invest in a waterproof cap cover or a genuine "sou'-wester."

For warmth, mits are to be preferred to gloves; the fingers keep each other warm better when all are ensconced in one compartment. The gauntlets may be in one with the gloves, when the latter will have no fastenings. If the gauntlets are separate (and they last much longer than one pair of gloves, as a rule), the wrists of the gloves should be contracted with elastic, or should be made of a knitted material which will contract on its own account. The gauntlets should be so stiff that they will not pucker into folds around the wrist. Here, again, fur is capital for warmth, and rubber for keeping out the wet. Never drive far in the rain without gloves if the wet coat sleeve rests on the wrist, as the cloth edge may soon chafe a very sore wound. It should be understood that these hints refer in the main to clothing suitable for open cars. With a wind shield and a Cape cart hood no rubber or mackintosh coats are necessary, as the combination of screen and hood keeps out all the worst of the weather. At the same time it is as well to have a light mackintosh on the car, so that if one wants to do anything with it on the open road in the rain one can do so without getting one's driving coat soddened with wet.

Leather gaiters form an excellent protection for the legs. They should extend well over the boot uppers, and the extensions should be flexible, to allow of freedom in walking; if too stiff, they and the instep will war against each other with almost certain damage to both. The passengers can tuck their feet into footsacks in cold weather, but the driver should avail himself of thick socks and snow boots, and these, like the gloves, must not be so clumsy as to interfere with the proper control of the car. For country driving, two small footsacks may be fixed to the footboard, so that the feet may be slipped into them when not wanted on the pedals.

In view of possible roadside repairs, a suit of engineers' overalls should be carried on the car. Do not hesitate to use them. One can work much more freely with them on, and so save time, as well as the cost of a new suit in the end. The kind in which the trousers and jacket are cut as a single garment is perhaps the handiest. A big apron with bib is better than nothing. As has been already mentioned, petrol and ammonia are capital for removing grease and acid stains respectively, from the clothes.

Ladies (as well as men) should wear small hats when motoring, as too much topsail is apt to induce headache. And head and hat together should be enveloped in some sort of veil to keep the hat on and the dust off. For the rest, we must leave the fair sex to utilise the intuitive judgment with which they are so liberally endowed.

CHAPTER XXIII.

Touring.

PARTICULARS of the R.A.C. and other leading institutions will be found in the chapter devoted to that subject. The great delight of touring by motor car is the gratifying sense of independence; there is no train to be caught—or missed; there is no restriction of route, as on the railway or the waterway. You can start this way or that, can go as far as you please or dawdle at your will, and here and there you can put in a sprint, "if so dispoged." But this last touches the limit. Do not confuse the tour and the speed trial, they are essentially different. The former is pleasure reckoned in terms of nature multiplied by time; the latter is pleasure, partly scientific, partly sporting, in terms of miles divided by time. For the former one carries all sorts of conveniences; the latter is a matter of bare necessities. A record run is a grand thing in its way, but it is quite foreign to touring.

The enjoyment of a tour is threefold—anticipation, realisation, and recollection. In planning the tour, do not attempt too much. Do not try either to cram too much into the time at your disposal, or too many people into the car. Let the party be a congenial one—jolly but not vulgar, good-hearted but not crotchety. With a view to complete independence, let all the impedimenta be carried on board, even though this may mean sacrificing one or two seats.

Route Maps and Guide Books.

The route should be chosen through diversified country, and should be planned out in advance. This means selecting some maps and road books as a preliminary step. As to the former, we have found nothing to beat Bartholomew's, on the scale of half-an-inch to the mile. They are a very correct reduction from the ordnance survey, and the elevations are shown by different shades of colour. This is a very interesting and useful feature, but would be even better if the colours employed were more numerous and distinctive; some of the shades display very little contrast, especially by artificial light. As you value your future, never buy an unmounted map! A paper map in a wind is —— !

As regards route books the "Autocar Road Book," volumes of which are now being published, contains full and lucid descriptions of all the main routes of England and Wales, and the Lowlands of Scotland, in addition to a large number of cross and branch roads. Not only are the roads dealt with as such, but the points of interest *en route* are described, even including those contiguous to the main roads on either side. Intermediate and full mileages, gradients, dangerous points, and many other essential and interesting matters are given.

Luggage and Impedimenta.

We have already given a list of tools, etc., that should be taken on a touring car, but there are sure to be lots of other things that will occur to one from time to time, and these should be jotted down on a paper kept for the purpose.

The personal luggage to be taken will depend upon the tastes of the tourists, subject to the accommodation of the automobile. Those who have had experience of touring by cycle will find the space at their disposal quite luxurious, but to others the case may appear differently. Still, it is wonderful how many things can be done without, if one makes up one's mind to it. If each article be rolled up tightly, a great deal can be packed into a small space. That hint, we humbly admit, is of limited application to ladies' gear; if they "really can't" do without a lot of things, such impedimenta had better be sent on by train, but essentials for one night at least should be taken on the car.

A camera is a capital companion on a motor tour. The pictures help to recall in the most vivid way the incidents of the excursion. Space may also be found for a favourite rod, racket, or other implement of sport. One enjoys the tour all the more if the car occasionally gives way to some other form of amusement.

The Preliminary Overhaul.

In anticipation of the journey, the car must receive a thorough overhaul. Plenty of time should be devoted to the job, so that nothing need be hurried or scamped. The tyres and brakes should receive special attention. When all is ready, put the car through a sharp test, including one or two stiff rises, to make sure that everything is up to the mark. Fill up with petrol, grease, oil, and water the day before the start; the batteries should all have been fully charged before. Leave everything ready for the morning. The "everything" should include something in the way of food. Be it only chocolate, chocolate biscuits, or bananas, never omit to have rations of some sort aboard Much money and time may be saved and pleasure gained by taking lunch and tea *al fresco.* A fitted basket and spirit stove should be carried if this course be decided on. Forced draught paraffin stoves, like the Primus, are very effective; and the little methylated spirit stoves are good in their way—they give quite an alarming flame if fed with petrol instead of alcohol. A fine day, a pretty view, and a picnic luncheon form a combination not to be despised. Another point among many in favour of the roadside lunch and tea is that these two meals are almost invariably the least appetising and relatively the most expensive of those supplied by the majority of hotels. Hotels can manage breakfast or dinner, but the less said about their luncheons and teas the better.

En Route.

En route too much should not be exacted from the driver; if he keeps the car going well, that is as much as should be expected of him. One of the party may be appointed "personal conductor," and he will see that the right course is followed, and call attention to the objects of interest as they are reached. Another, a lady for choice, may have charge of the commissariat, and so on.

A high speed is even less desirable on tour than at other times.

Finally, remember that in outlying districts you will be something of a missionary. Treat the "natives" kindly, though, if need be, firmly, not only for your own sake, but because the way the next exploring motorist will be received will largely depend upon the kind of impression you leave behind. If you can give a few local worthies a pleasant run on the car, you may reckon conversions to your credit quite in orthodox missionary style.

CHAPTER XXIV.

Institutions.

EXPERIENTIA DOCET, and next to personal trial, there is nothing to beat the instructiveness of the experiences of one's fellows. Therefore, join a motoring club, using due care in selecting one of congenial membership. Provincial clubs are decidedly numerous, and one that is affiliated to the Royal Automobile Club or to the Motor Union is to be preferred to an independent club. Suburban clubs are much fewer than provincial, and Londoners should become direct members of the R.A.C. or the Motor Union. The advantages of membership of the R.A.C. include those of an ordinary Piccadilly social club, in addition to the use of the club motor houses (about two minutes' walk), and special rates at various hotels and "garages" (motor stables) throughout the country; the services of the club engineer; the training of motor servants, and access to a register of the same; the granting of driving certificates and facilitation of passing cars through foreign customs. The club publishes a weekly journal and annual handbook, both of which are valuable. Members touring abroad are admitted as temporary honorary members of a number of leading automobile clubs on the Continent.

The R.A.C. has rendered immense service to the industry and motoring, by the organisation of trials, mostly on a large scale. The membership is about 6,000. The club is the property of the Automobile Proprietary, Limited, which consists of the members themselves. The liability is limited to £1, and this is set aside out of the first year's subscription. The annual subscriptions for town and country members respectively are £8 8s. and £5 5s.; entrance fee, £6 6s. Members of most of the best clubs require only one proposer when joining the R.A.C., otherwise two are necessary. The existence of the following committees will give an idea of the scope of the club's work. Besides the general and executive committees, there are others denominated Foreign Relations, House, Legal Cases, Competitions, Public Policy, Inconsiderate Driving, Expert and Technical, Dust, Training School, Motor House, Touring, and Auto Cycle Union. The secretary's present address is 119, Piccadilly, London, W., but the club intends moving into its new premises in Pall Mall in February, 1911.

The Motor Union.

The Motor Union of Great Britain and Ireland (M.U.) has partly the same objects as the R.A.C. The Motor Union offers its members advice and assistance in respect of civil and criminal proceedings in connection with the use of motor vehicles; information as to touring routes, hotels, motor repairers, customs; a copy of *The Autocar* every week to each member; the M.U. Handbook annually; motor car insurance; and generally, the protection and extension of the rights and privileges of automobilists. Anyone may become a member on payment of an annual subscription of one guinea.

The M.U. is strongly established and has accomplished some excellent results, not only for its members, but for motorists generally. The secretary's office is at Caxton House, Westminster, S.W.

The Automobile Association.

The original object of this Association was the discovery and exposure of "police traps" in places where, owing to the open nature of the country and the absence of traffic, motorists might be tempted to commit technical breaches of the law by exceeding the arbitrary speed limit of twenty miles an hour. But the Association now does much more. Indeed, its original purpose has become quite a secondary matter. It discourages every kind of furious and inconsiderate driving, and helps the authorities to maintain the safety of the highways. The Association employs a number of agents, consisting principally of cycle-mounted scouts, whose presence on the highway may be interpreted as an injunction to proceed with special caution. In addition to this their services may be requisitioned to assist in tyre repairing and the execution of other roadside jobs, or to give information respecting local repair shops, doctors, state of the roads, etc. While many of the benefits necessarily extend to motorists in general, the personal advantages (amongst which is free legal representation in police court cases) are confined to members, as it is only reasonable they should be. The liability of members is limited to the amount of the annual subscription, which is two guineas, apart from a deposit of five shillings repayable on the return of the official badge, by which members' cars are recognisable on the road, Looked upon merely in the light of a premium paid for insurance against unjustly inflicted and exorbitant fines, the amount cannot be considered excessive. The Association is economically managed by a committee including a number of motorists of high standing, and the Secretary, Mr. Stenson Cooke, has offices at 1, Whitcomb Street, Leicester Square, W.C., adjacent to the premises of the Motor Club, which is a comparatively new institution.

CHAPTER XXV.

Law.

AS there is not space here to set out the Motor Car Acts of 1896 and 1903, and otherwise deal at length with the subject of motor car law, we must confine ourselves to indicating, first, what the motorist must do; and second, what he must not do, leaving the reader to refer to the Acts and Regulations for himself.

Licensing and Registration.

The following are the formalities to be observed on commencing motoring:

	FEES. £	s.	d.
1. First obtain from the County Borough or County Council within whose district you reside a driving licence. (Usually the Chief Constable issues these licences)		5	0
2. Ditto for driver (if any), unless he has one already		5	0
3. Apply to any County Borough or County Council for registration of your motor car	1	0	0
4. Get your number-plates prepared and fitted in accordance with the regulations (which are known as "The Motor Car Registration and Licensing Order, 1903")			
5. Within twenty-one days of coming into possession of car, obtain from any Post Office an Inland Revenue licence to keep a motor car.			

Under the Finance Act of 1910 these excise duties are increased as compared with what they were formerly, and instead of being charged according to the weight of the car, are levied upon the horse-power of the engine. The new rates are as follow:

	DUTY. £	s.	d.
Motor bicycles and motor tricycles, of whatever h.p.	1	0	0
Motor cars—			
Not exceeding 6½ h.p.	2	2	0
Exceeding 6½ h.p., but not exceeding 12 h.p. ..	3	3	0
,, 12 h.p. ,, ,, 16 h.p. ..	4	4	0
,, 16 h.p. ,, ,, 26 h.p. ..	6	6	0
,, 26 h.p. ,, ,, 33 h.p. ..	8	8	0
,, 33 h.p. ,, ,, 40 h.p. ..	10	10	0
,, 40 h.p. ,, ,, 60 h.p. ..	21	0	0
,, 60 h.p.	42	0	0

(These excise duties need not be paid on a motor car which is kept but not used. If commenced to be used on or after 1st October in any year, the duties are halved.)

6. Within twenty-one days of driver commencing his duties, obtain from Post Office an Inland Revenue licence to keep male servant	s.	d.
	15	0

Driving licences should be renewed annually, from the dates on which they are expressed to come into force. A duplicate licence can be obtained for 1s. if the original one be defaced or destroyed. Registration of the car does not require renewal, and a note of any material alterations in appearance or construction will be entered without charge; but if the car be sold, the registration may be either cancelled or transferred to the new owner. In the latter case a fee of 5s. is charged. In either case notice must be given to the registration authority of the change of ownership. The excise duties Nos. 5 and 6 above must be renewed during the month of January in each year.

Acts and Offences.

The diversity of the laws to which the automobilist is subject in one way or another makes the compiling of a complete table of offences and penalties well nigh impossible. The list here given relates only to the Motor Car Acts of 1896 and 1903; to the Local Government Board Regulations dated 19th November, 1903 (Registration and Licensing of Motor Cars); 9th March, 1904 (Use and Construction of Motor Cars); and 27th December, 1904 (Heavy Motor Cars); and to the Secretary of State's Regulations dated 31st July, 1907 (Petroleum). The following particulars are based on a circular issued by the Local Government Board:

Section 11 of the Act of 1903 provides that "a person guilty of an offence under the Act for which no special penalty is imposed, shall be liable on summary conviction in respect of each offence to a fine not exceeding £20, or in case of a second or subsequent conviction to a fine not exceeding £50, or, in the discretion of the Court, to imprisonment for a period not exceeding three months."

The following are the offences to which the foregoing provision applies:

1. Reckless, negligent, or dangerous driving within the meaning of Section 1 (1).
2. Refusal on the part of a driver who commits an offence under Section 1, (1), to give his name or address, or the giving of a false name and address [Section 1, (3)].
3. Failure on the part of the owner of a car to give information within his power leading to the identification and apprehension of the driver, if required to do so [Section 1 (3)].
4. Subject to the exceptions and provisions stated in Section 2, driving a car on a public highway without it being registered or without having the identification mark properly fixed or with the mark in any way obscured or rendered or allowed to become not easily distinguishable [Section 2 (4)].

5. Driving a motor car without being licensed under the Act or employing an unlicensed person to drive [Section 3 (1)].

6. Failure of a licence holder on conviction for offences as specified in the section to produce the licence within a reasonable time for the purposes of endorsement [Section 4, (2)]. (The question as to what particular offences are endorsable is at the time of writing occupying the attention of the courts upon a case taken up by the R.A.C. The contention being that some offences that Motorists commit—allowing a tail lamp to be extinguished, for example—are not endorsable, being neither "offences under the Act" nor yet in connection with the "driving" or manipulation of a car.)

7. Applying for or obtaining a licence while disqualified, or applying for or obtaining a licence without giving particulars of endorsements on a previous licence [Section 4 (5)].

8. Forging or fraudulently altering or using or fraudulently lending or allowing to be used by any other person any identifying mark or any licence under the Act [Section 5].

Special Motor Act Penalties.

Other offences, for which special penalties are prescribed by the Act, are set out below. It must be noted that these particular offences are not in terms expressed to be "offences under the Act," and the contention is that none of them are endorsable, though, as a matter of fact, they are usually endorsed upon licences:

1. Failure by the driver of a motor car to produce a licence when demanded by a police constable renders him liable to a fine not exceeding £5 [Section 3 (4)].

2. A person driving a motor car, if an accident occurs to any person, whether on foot or horseback or in a vehicle or to any horse or vehicle, in charge of any person, owing to the presence of the motor car on the road, is bound to stop, and, if required, give his name and address, and also the name and address of the owner, and the registration mark and the number of the car; and if any person knowingly acts in contravention of this provision he becomes liable on summary conviction in respect of the first offence to a fine not exceeding £10; in respect of the second offence to a fine not exceeding £20; and in respect of any subsequent offence to a fine not exceeding £20, or, in the discretion of the Court, to a term of imprisonment not exceeding one month [Section 6].

3. Infringement of any speed limits imposed by or under Section 9 of the Act (twenty miles per hour on any public highway and ten miles per hour in places prescribed by the Local Government Board) renders the person convicted liable in respect of the first offence to a fine not exceeding £10; in respect of the second offence to a fine not exceeding £20; and in respect of any subsequent offence to a fine not exceeding £50 [Section 9]. In proceedings under this section a person cannot be convicted unless he is warned of the intended prosecution at the time the offence is committed or notice of the intended prosecution is sent to him or to the registered owner of the car within such time after the offence is committed, not exceeding twenty-one days, as the Court think reasonable, nor can he be convicted for exceeding the limit of speed of twenty miles per hour merely on the opinion of one witness as to the rate of speed.
4. The infringement of regulations made by the Commissioners of Works respecting the use of motor cars on Menai Bridge renders the offender subject to penalties similar to those for offences against speed limits [Section 17].
5. Regulations made by the Board in pursuance of Sections 7 (identification marks, licences), 8 (prohibiting cars on special roads), and 12 (maximum weight of cars) of the Act are declared to be made under Section 6 of the Locomotives on Highways Act, 1896, and consequently Section 7 of that Act, which provides that a breach of any regulation made under it may on summary conviction be punished by a fine not exceeding £10, will apply to them.

Endorsement of Licence.

Not only are offenders liable to the penalties specified, but, as already intimated, Section 4 provides for the endorsement of particulars of offences upon the offenders' licences, and for the disqualification of offenders by suspension or otherwise for holding a licence for such time as the Court think fit. This penalty attaches to any "offence under the Act" or any offence in connection with the "driving" of a motor car other than a first or second offence consisting solely of exceeding any limit of speed fixed under the Act [Section 4].

Section 15 of the Act further provides that nothing in it shall affect any liability of the driver or owner of a motor car by virtue of any statute or at common law.

Offences under the Act or Regulations are punishable on summary conviction. Any person adjudged to pay a fine exceeding 20s. under the Act or who is by virtue of an order of the Court under Section 4 disqualified for obtaining a licence may appeal against the conviction or the order as the case may be in the same manner as a person may appeal who is ordered to be imprisoned without the option of a fine. In this connection reference may be made to Sections 19 and 31 of the Summary Jurisdiction Act, 1879.

The new petrol regulations, while repeating the requirements as to storing not more than 60 gallons of petrol in strongly made and properly marked cans of not more than two gallons capacity, in a suitably constructed, isolated, and ventilated storehouse, as to not exposing petrol in proximity to naked lights, and as to other points, also prescribe that—

> "14. In the storehouse or in any place where a light locomotive is kept or is present, petroleum spirit shall not be used for the purpose of cleaning or lighting, or as a solvent or for any purpose other than as fuel for the engine of a light locomotive.
>
> "Provided that where due precaution is taken to prevent petroleum spirit from escaping into a sewer or drain and provision made for disposing safely of any surplus petroleum spirit and where no fire or naked light is present, quantities not exceeding one gill may be used for the cleaning of a light locomotive at a safe distance from any building, place of storage of inflammable goods, or much frequented highway, or for the repair of tyres, under suitable precautions.
>
> "This regulation shall apply to premises on which petroleum spirit is kept for the purpose of, or is being used on, light locomotives, whether such premises are licensed or not, unless the local authority see fit, in the case of licensed premises, to grant an exemption by a special term of the licence.
>
> "15. Petroleum shall not be allowed to escape into any inlet or drain communicating with a sewer."

Miscellaneous Tables, etc.

Alphabetical List of Index Marks.

A, L C, L N, L B, or L D, London

A A	Hampshire.
A B	Worcestershire.
A C	Warwickshire.
A D	Gloucestershire.
A E	Bristol.
A F	Cornwall.
A H	Norfolk.
A I	Meath.
A J	Yorkshire (North Riding).
A K	Bradford (Yorks).
A L	Nottinghamshire.
A M	Wilts.
A N	West Ham.
A O	Cumberland.
A P	East Sussex.
A R	Hertfordshire.
A S	Nairn.
A T	Kingston-upon-Hull.
A U	Nottingham (Borough).
A W	Salop.
A X	Monmouthshire.
A Y	Leicestershire.
B	Lancashire.
B A	Salford.
B B	Newcastle-upon-Tyne.
B C	Leicester (Borough).
B D	Northamptonshire.
B E	Lincolnshire (Lindsey)
B H	Bucks.
B I	Monaghan.
B J	East Suffolk.
B K	Portsmouth.
B L	Berks.
B M	Bedfordshire.
B N	Bolton.
B O	Cardiff.
B P	West Sussex.
B R	Sunderland.
B S	Orkney.
B T	Yorkshire (East Riding).
B U	Oldham.
B W	Oxfordshire.
B X	Carmarthenshire.
B Y	Croydon.
C	Yorkshire (West Riding).
C A	Denbighshire.
C B	Blackburn.
C C	Carnarvonshire.
C D	Brighton.
C E	Cambridgeshire.
C F	West Suffolk.
C H	Derby (Borough).
C I	Queen's County.
C J	Herefordshire.
C K	Preston.
C L	Norwich.
C M	Birkenhead.
C N	Gateshead.
C O	Plymouth.
C P	Halifax.
C R	Southampton.
C T	Lincolnshire (Kesteven).
C U	South Shields.
C W	Burnley.
C X	Huddersfield.
C Y	Swansea.
D	Kent.
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D H	Walsall.
D I	Roscommon.
D J	St. Helens.
D K	Rochdale.
D L	Isle of Wight.
D M	Flintshire.
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D O	Lincolnshire (Holland).
D P	Reading.
D R	Devonport.
D S	Peebles.
D U	Coventry.
D W	Newport (Mon.)
D X	Ipswich.
D Y	Hastings.
E	Staffordshire
E A	West Bromwich.
E B	Isle of Ely.
E C	Westmorland.
E D	Warrington.
E E	Grimsby.
E F	West Hartlepool.
E H	Hanley.
E I	Sligo.
E J	Cardiganshire.
E K	Wigan.
E L	Bournemouth.
E M	Bootle.
E N	Bury.
E O	Barrow-in-Furness.
E P	Montgomeryshire.
E S	Perth.
E T	Rotherham.
E U	Breconshire.
E W	Huntingdonshire.
E X	Great Yarmouth.

Index Marks (continued).

E Y	Anglesey.
F	Essex.
F A	Burton-upon-Trent.
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F C	Oxford (Borough).
F D	Dudley.
F E	Lincoln (Borough).
F F	Merionethshire.
F H	Gloucester (Borough).
F I	Tipperary (North Riding).
F J	Exeter.
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F L	Soke of Peterborough.
F M	Chester.
F N	Canterbury.
F O	Radnorshire.
F P	Rutland.
F R	Blackpool.
F T	Tynemouth.
F X	Dorset.
F Y	Southport.
G	Glasgow.
H	Middlesex.
H A	Smethwick
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H I	Tipperary (South Riding)
H S	Renfrew.
I A	Antrim
I B	Armagh.
I C	Carlow.
I D	Cavan.
I E	Clare.
I F	Cork (County).
I H	Donegal.
I J	Down.
I K	Dublin (County).
I L	Fermanagh.
I M	Galway.
I N	Kerry.
I O	Kildare.
I P	Kilkenny.
I R	King's County.
I T	Leitrim.
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L C	London.
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S U	Kincardine.
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S W	Kirkcudbright.
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S Y	Midlothian.
T	Devon.
T I	Limerick (Borough).
T S	Dundee.
U	Leeds.
U I	Londonderry (Borough).
U S	Govan.
V	Lanark.
V S	Greenock.
W	Sheffield.
W I	Waterford (Borough).
W S	Leith.
X	Northumberland.
X S	Paisley.
Y	Somerset.
Y S	Partick.

English—French Dictionary.

English.	French.
Admission pipe.	Tuyau d'admission.
Air tube.	Chambre (*f.*) à air.
Axle.	Essieu (*m.*)
Back wheel.	Roue (*f.*) d'arrière.
Balance gear.	Différentiel.
Ball bearings.	Coussinets (*m.*) à billes (*f.*)
Battery (dry).	Pile sèche (*f.*)
Battery (electric).	Batterie (*f.*) electrique.
Bearing.	Coussinet (*m.*) palier (*m.*)
Belt.	Courroie (*f.*)
Bevel wheel.	Roue conique (*f.*)
Boiler.	Chaudière (*f.*)
Bolt.	Boulon (*m.*)
Bonnet.	Capot (*m.*)
Bore (of the cylinder).	Alésage (*m.*) du cylindre.
Brake.	Frein (*m.*)
Brass.	Cuivre jaune (*m.*)
Breakdown.	Panne (*f.*)
Bridge.	Pont (*m.*)
Cam, exhaust.	Came (*f.*) d'echappement.
Camshaft.	Arbre à came (*f.*)
Carriage work.	Carrosserie (*f.*)
Case (tor chain or gear).	Carter (*m.*)
Casting.	Moulage (*m.*)
Chain.	Chaîne (*f.*)
Change speed lever.	Levier (*m*) de changement de vitesse (*f.*)
Clutch.	Embrayage (*m.*)
Clutch pedal.	Pédale (*f.*) de débrayage (*m.*)
Coil.	Bobine (*f.*)
Combustion chamber.	Culasse (*f.*)
Contact breaker.	Interrupteur (*m.*)
Copper.	Cuivre (*m.*) rouge.
Countershaft.	Contre-arbre (*m.*)
Crank.	Manivelle (*f.*)
Crank axle.	Arbre des manivelles.
Crank chamber.	Carter (*m.*)
Crank pin.	Boulon (*m.*) de manivelle.
Current.	Courant (*m.*)
Discharged.	Déchargé.
Driver.	Chauffeur (*m.*)
Dust.	Poussière (*m.*)
Earth (electrical).	Masse (*f.*)
Exhaust.	Echappement (*m.*)
Exhaust port.	Lumière (*f.*) d'echappement (*m.*) de la vapeur.
Exhaust valve.	Soupape (*f.*) d'echappement.
File.	Lime (*f.*)
Flange.	Bride (*f.*)
Flaw.	Paille (*f.*)
Float.	Flotteur (*m.*)
Flywheel.	Volant (*m.*)
Frame.	Châssis (*m.*)
French chalk.	Talc (*m.*)
Friction.	Frottement (*m.*)

Dictionary—(continued).

English.	French.
Front wheel.	Roue (*f.*) d'avant.
Funnel.	Entonnoir (*m.*)
Gauze (wire).	Tissu (*m.*) métallique.
Gear.	Engrenage (*m.*)
Gear (to throw into).	Mettre en marche.
Goggles.	Lunettes (*f.*)
Governor.	Régulateur (*m.*)
Gudgeon pin.	Goujon (*m.*)
Hammer.	Marteau (*m.*)
Handle.	Manette (*f.*), poignée (*f.*)
Horn.	Corne (*f.*) trompe.
Hub.	Moyeu (*m.*)
Ignition.	Allumage (*m.*)
Indiarubber.	Caoutchouc (*m.*)
Inlet valve.	Soupape (*m.*) d'admission (*f.*)
Inlet valve (mechanically operated).	Soupape d'admission commandée.
Insulation.	Isolation (*f.*)
Iron.	Fer (*m.*)
Jack.	Cric (*m.*)
Jet (carburetter).	Gicleur (*m.*)
Lathe.	Tour (*m.*)
Lead.	Plomb (*m.*)
Lead (red).	Minium (*m.*)
Lead (white).	Ceruse (*f.*)
Leakage.	Fuite (*f.*)
Leather.	Cuir (*m.*)
Licence.	Permis (*m.*)
Lug.	Raccord.
Manufactory.	Fabrique (*f.*), usine (*f.*)
Mixture.	Mélange (*m.*)
Motor car.	Automobile (*m.* or *f.*)
Nut.	Ecrou (*m.*)
Oil.	Huile (*f.*)
Oilcan.	Burette (*f.*)
Outer cover (tyre).	Enveloppe (*f.*)
Paraffin.	Huile de pétrole.
Petrol.	Essence (*f.*)
Pipe.	Tuyau (*m.*)
Piston ring.	Segment du piston. (*m.*)
Platinum.	Platine (*m.*)
Pump.	Pompe (*f*).
Reversing gear.	Mécanisme de marche (*m.*)
Rim	Jante (*f.*)
Screw.	Vis (*f.*)
Shaft.	Arbre (*m.*)
Side-slip.	Dérapage (*m.*)
Silencer.	Silencieux (*m.*)
Sleeve.	Manchon (*m.*)
Solution (rubber).	Caoutchouc (*m.*) plein.
Spanner.	Clef (*f.*)
Spark.	Etincelle (*f.*)
Sparking plug.	Bougie (*f.*)
Split pin.	Goupille (*f*) fendue.
Spoke.	Rayon (*m.*)
Sprag.	Requille (*f.*)

Dictionary—(continued).

ENGLISH.	FRENCH
Spring.	Ressort (*m.*)
Sprocket wheel.	Roue (*f*) à chaîne (*f.*)
Starting handle.	Manivelle de mise en marche.
Steam.	Vapeur (*f.*)
Steel.	Acier (*m.*)
Steering.	Direction (*f.*)
Steering wheel.	Roue (*f.*) directrice.
Supply pipe.	Tube (*m.*) alimentaire.
Switch.	Interrupteur (*m.*)
Tap.	Robinet (*m.*)
Terminal.	Borne (*f.*)
Throttle.	Rélage (*m.*) à main.
Tube.	Tube (*m.*)
Universal joint.	Cardan (*m.*)
Valve.	Soupape (*f.*)
Washer.	Rondelle (*f.*)
Water, cooling.	Eau (*f.*) de refroidissement.
Water tank.	Réservoir (*m.*) d'eau.
Weight.	Poids (*m.*)
Weldless.	Sans soudure.
Wheel.	Roue (*f.*)
Wire.	Fil (*m.*)
Wood.	Bois (*m.*)

ENGLISH AND METRIC WEIGHTS AND MEASURES.

1 kilogramme	=	2.2 lbs. approx.
1 lb.	=	453.6 grammes.
1 lb.	=	.4536 kilogramme.
1 cwt.	=	50.8 kilogrammes.
1 ton	=	1,016 kilogrammes.
1 litre	=	1.75 pints, approx.
1 pint	=	.568 litre.
1 quart	=	1.135 litres.
1 gallon	=	4.543 litres.
1 cubic foot	=	28.3 litres.
1 cubic metre	=	35.3 cubic feet.

MEASURES OF LENGTH.

1 kilometre	=	0.6214 mile, $\frac{5}{8}$ mile approx.
1 metre	=	39.3701in.
1 centimetre	=	0.3937in.
1 millimetre	=	0.0394in., $\frac{2}{51}$in. approx.
1 inch	=	25.4 millimetres.
1 foot	=	30.48 centimetres.
1 mile	=	1,609.315 metres.

DENSIMETER READINGS.

The following table shows what the densimeter should read at various temperatures with good petrol:

Fahr.	Densimeter reading.	Fahr.	Densimeter reading.
32°	.694	64°	.678
40°	.690	66°	.677
50°	.685	68°	.676
60°	.680	70°	.675
62°	.679		

and so on, .001 point less for every 2° more in temperature, but the spirit sold is generally some .03 or .04 heavier than this and is quite serviceable.

Tables, etc.—(continued).

Table of Speeds per Hour.

Time. m.	s.	Speed. miles.	yards.	Time. m.	s.	Speed. miles.	yards.
6	0	10	0	1	30	40	0
5	0	12	0	1	20	45	0
4	0	15	0	1	15	48	0
3	45	16	0	1	12	50	0
3	20	18	0	1	6	54	960
3	0	20	0	1	0	60	0
2	45	21	1440	0	50	72	0
2	30	24	0	0	48	75	0
2	15	26	1173	0	45	80	0
2	0	30	0	0	40	90	0
1	45	34	503	0	36	100	0
1	40	36	0				

Revolutions of Wheels per Mile.

(In practice, pneumatic-tyred wheels travel one or two per cent. more revolutions than those given.)

Diameter of wheels.	Revolutions per mile.	Diameter of wheels.	Revolutions per mile.
26in.	775½	34in.	593
28in.	720	36in.	560
30in.	672	38in.	530½
32in.	630	40in.	504

Lamp-lighting Table.

The times here given are calculated from sunset at Greenwich, and are therefore practically right for London, but in other places lamps must be lit earlier or later, firstly, according as they are east or west of Greenwich at all times of the year; and secondly, according as they are south or north thereof (in summer), or north or south thereof (in winter). As these factors influence each other, it is best to obtain an official table for one's district, and, failing that, to keep well within the mark. The times vary very slightly from year to year:

Jan.	p.m.	Feb.	p.m.	March	p.m.	April	p.m.
1	4.58	2	5.48	1	6.37	3	7.33
4	5.2	5	5.53	4	6.41	6	7.38
7	5.6	8	5.58	7	6.46	9	7.43
10	5.10	11	6.4	10	6.53	12	7.47
13	5.14	14	6.9	13	6.58	15	7.53
16	5.19	17	6.15	16	7.3	18	7.57
19	5.24	20	6.20	19	7.8	21	8.3
22	5.29	23	6.27	22	7.13	24	8.8
25	5.33	26	6.32	25	7.18	27	8.13
28	5.39			28	7.23	30	8.18
31	5.44			31	7.28		

Lamp-lighting Table—(continued).

MAY	P.M.	JUNE	P.M.	JULY	P.M.	AUG.	P.M.
3	8.23	2	9.6	2	9.18	1	8.48
6	8.28	5	9.9	5	9.17	4	8.43
9	8.32	8	9.11	8	9.16	7	8.38
12	8.37	11	9.13	11	9.13	10	8.33
15	8.41	14	9.16	14	9.11	13	8.27
18	8.45	17	9.17	17	9.8	16	8.21
21	8.49	20	9.18	20	9.5	19	8.15
24	8.54	23	9.19	23	9.1	22	8.9
27	8.58	26	9.19	26	8.57	25	8.2
30	9.2	29	9.19	29	8.52	28	7.56
						31	7.49

SEPT.	P.M.	OCT.	P.M.	NOV.	P.M.	DEC.	P.M.
3	7.42	3	6.35	2	5.31	2	4.53
6	7.36	6	6.27	5	5.26	5	4.51
9	7.30	9	6.21	8	5.22	8	4.50
12	7.22	12	6.14	11	5.16	11	4.49
15	7.16	15	6.7	14	5.11	14	4.49
18	7.9	18	6.1	17	5.8	17	4.49
21	7.2	21	5.55	20	5.4	20	4.51
24	6.55	24	5.48	23	5.1	23	4.52
27	6.48	27	5.43	26	4.58	26	4.53
30	6.41	30	5.37	29	4.55	29	4.56

RAILWAY RATES.

The charges for conveying motor cars by train vary somewhat on different lines, but the usual charge for conveyance on a truck attached to a passenger train is 6d. per mile at owner's risk, and at the company's risk the charge is 7½d. per mile. The minimum charge is generally 7s. 6d. Reductions are sometimes made where the owner sends two or three cars on the same truck, or where an old car is sent in part exchange for a new one. The passenger train rates apply to cars of any ordinary weight; but by goods, if the car exceeds one ton, about one-third extra is added to the ordinary rate for each extra 5 cwts. The goods rate varies from about 9d. per mile for ten miles down to about 3½d. per mile for 400 miles; up to fifty or sixty miles it is cheaper to send a light car by passenger train. An extra charge of 5s. or 10s. is made for covered trucks. The companies generally stipulate that the car shall be discharged of electricity, petrol, etc. It should be remembered that an ordinary insurance policy does not cover a car while in transit, otherwise than under its own power.

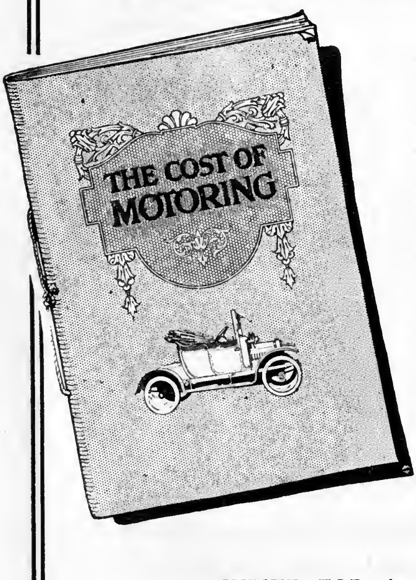
INDEX.

INDEX TO ADVERTISERS.

First cost or total cost—which do you consider ?

When purchasing a motor car you should carefully consider the relationship between first cost and future expenses, that is total cost, if economy is an important matter. Low first cost suggests economy to those who have little experience, but, particularly in motor cars, low price means inferior quality, unreliability, dissatisfaction, loss of use, repair bills, and loss by depreciation. It will pay you to look to the future and to buy only what has been proved to be the best. The first cost of a

De Dion Bouton



car, owing to its proved and acknowledged superiority in design, materials, workmanship, and the experience of its manufacturers, is higher than other makes, some of which are claimed to be "just as good," but a De Dion Bouton is undoubtedly cheaper in total cost. It will be always ready for service and will give you great and sustained satisfaction by reason of its efficiency, simplicity, great reliability, and durability. Finally, owing to its low cost of running, small expense for repairs, and the high price it will fetch when second-hand, your actual saving will be much greater than the comparatively small saving which you may effect in first cost by buying any other make of car. In "The Cost of Motoring" will be found the records of a number of De Dion Bouton owners, who furnish accurate details of the cost of running their cars for varying periods. You can get this book free on application.

WRITE FOR A COPY TO-DAY.

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De Dion Bouton

cars each of which has run upwards of

100,000 miles.

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"I have taken her over places that car never went before......her mileage is certainly well over 100,000. she is to-day going as well as ever."

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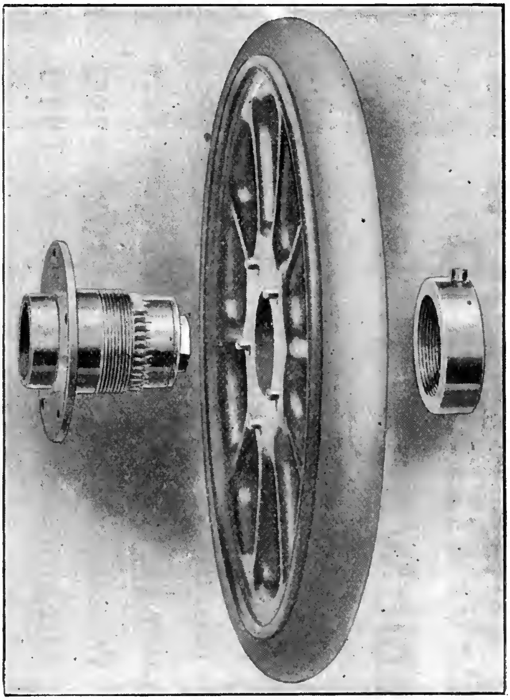

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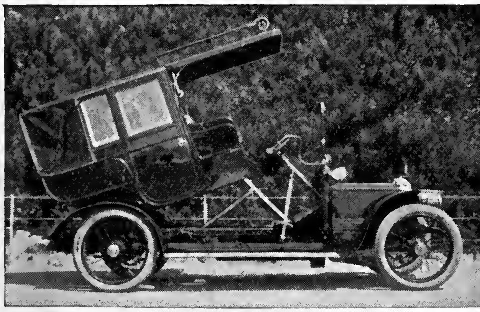

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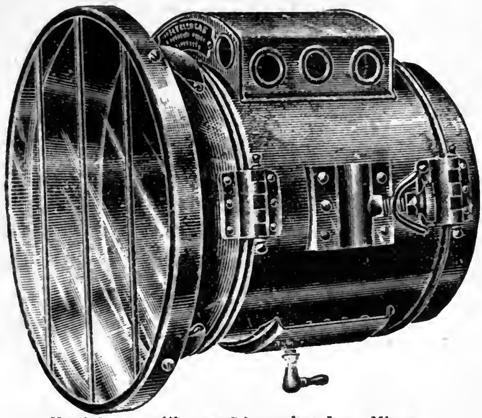

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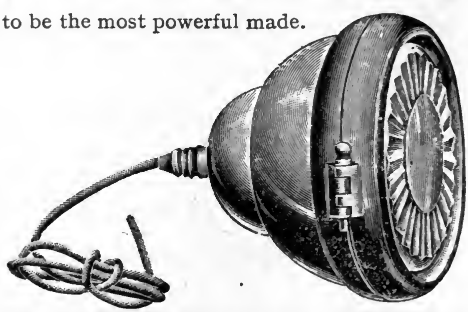

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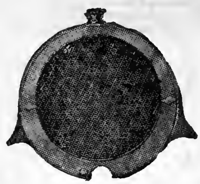

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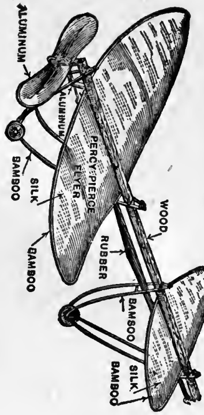

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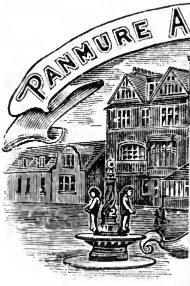

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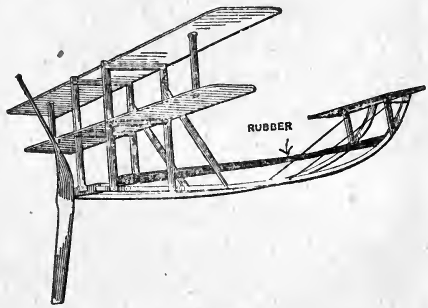

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