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PETROL MOTORS

SIMPLY EXPLAINED

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PETROL MOTORS

SIMPLY EXPLAINED

A Practical Handbook on the Construction and Working of Petrol Motors

BY

T. H. HAWLEY

FULLY ILLUSTRATED

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PREFACE

THE gigantic strides made by the Motor movement on water as well as on land during the last year or two places the Petrol Motor in the front rank, if not absolutely in the first position, of interest to scientists in mechanical matters and modern means of locomotion.

There is a peculiar fascination about the subject, appealing as it does to a wide class of thinkers and workers, for the highest art of the designer must be allied to the utmost skill of the mechanic, who in turn must be supported by the most elaborate tools and plant in order to produce the highly efficient motor vehicle with which we are familiar to-day.

The now universal system of electrical ignition opens up a field of great scope and interest to electricians; whilst it is difficult to say whether the amateur constructor or the amateur owner gets most pleasure—the one as maker and the other as user.

It is certain, however, that in the manipulation of a modern car or cycle there is ample scope for any degree of skill, and to be an expert driver demands a cool brain, good nerve, quick action and resource in emergency, and above all a complete knowledge of the function of every part of the machine he is driving.

In the few pages at disposal in a booklet of this description it is, of course, impossible to convey fully the details of more elaborate machines; and indeed the complete subject of the modern car is so complex that to attempt a brief description would merely leave the reader in a hopeless tangle of uncertainty on many points, whilst others would be quite a mystery by reason of the technical terms of necessity used but not thoroughly explained.

The object aimed at is rather a simple explanation of the principles governing the action of the petrol motor, and the manner in which the power so generated is utilised to propel the vehicle, together with a few hints on control mechanism and driving; enough, in fact, to interest the elementary reader by starting him with a clear understanding of the general subject, so that the more elaborate text-books and master works will be more easily assimilated by those wishing to probe the depths of motor car design, and also be equally useful to the embryo driver or mechanic, by enabling him to assign the proper functions of each part of the engine and the general method of construction when inspecting a cycle or car.

Chief attention has been directed to making clear the principle of the petrol motor or engine itself, for whereas transmission gearing and other outside mechanism in cars varies with every different make, the motor does not differ except in detail; hence as a study of the internal combustion motor, the model may be a mere bicycle motor of 2 horse-power or a car motor of 70 horse-power, the general principle being the same in each.

This new means of locomotion not only provides a new pleasure for the rich, but by means of the motor bicycle or tricycle new possibilities are opened to the man of most moderate means; indeed, the up-to-date motor cycle, which is capable of transporting its owner over 100 miles per day from the starting point at a cost for fuel, lubrication, etc., of some fifteenpence or so, is procurable at a price but slightly in excess of what would have been paid for the ordinary pedal-propelled machine of similar class some ten or twelve years ago.

In the compilation of this little brochure, the writer has been assisted by, and is indebted to, Messrs The Bowden Syndicate, of Baldwin's Gardens, Gray's Inn Road, London, E.C., for their permission to reproduce the sectional view of the F.N. Engine forming the frontispiece (fig. 1), they being the sole agents for this country, and to the Motor Industries Co., Great Marlboro Street, London, for the loan of the block for fig. 12.

T. H. HAWLEY.

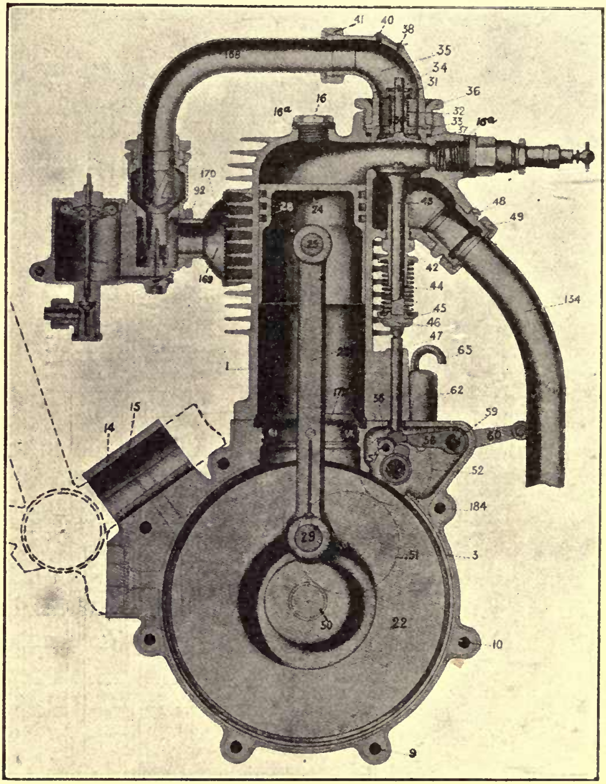

Fig. 1.—Section of "F.N." Cycle Motor.

(*For key to this illustration see page* 23.)

PETROL MOTORS

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CHAPTER I

THE PRINCIPLES ON WHICH A PETROL MOTOR WORKS

It is not at all necessary to trace the history and development of the petrol motor in order to understand the modern engine, hence this part of the subject need not be imposed on the reader; but those having knowledge of the construction and working of the ordinary "Otto" or "four-cycle" stationary gas engine start with a considerable advantage on the study of the petrol motor, because the principles are identical in each, though the outer form and most of the details have been varied and adapted to the special purposes of road locomotion; therefore those who have the opportunity of inspecting the stationary engine at work and when dismembered may learn much of use in connection with the petrol engine.

Coal gas and several other gases become explosive when mixed with certain percentages of common air, the percentage varying with the particular gas used, and in smaller degree with the character and temperature of the atmosphere, so that a certain gaseous mixture confined in a space (termed the combustion chamber) will, if ignited, exert a pressure in all directions due to the rapid rise of temperature on combustion; and at this stage it may be well to impress the fact that all internal combustion motors are heat engines, *i.e.* the power is primarily derived from the intensely rapid production of heat at the instant of explosion; and it should further be noted that the more rapid the ignition and the more complete the combustion the greater will be the power effect on the piston. To effect this complete combustion the most important factor is the correct mixture of gas and air; for if the mixture be too rich in gas the complete charge will not be consumed, or if extravagantly rich will not even be explosive; on the other hand, if the mixture should be too poor, a loss of power would be found, or again the mixture be non-explosive. A crude illustration of the basis of gas-engine or motor construction may be given if a coffee canister with tightly-fitting lid be imagined to be filled with the explosive mixture and by some means the contents ignited; the result would be that, the pressure in all directions being equal, the lid would be blown far away at the instant of explosion; but if for that loose lid we substitute the harnessed piston closely fitting the bore of a fixed cylinder, the piston and its connecting rod being coupled to a crank-axle as in ordinary steam-engine construction, then the explosion in the cylinder would drive out the piston as far as the crank-pin would allow it to go. Meanwhile the fly-wheel on the engine crank-shaft would have gained momentum enough to return the piston to its original position by reason of the rotation of the crank-pin and return movements of connecting rod, aided by the opening of the exhaust valve. This experiment would, however, merely show that power and motion had been produced; but in order that useful work may be done such motion must be continuous and as nearly as possible regular, so that we may now follow what happens on the return of the piston. In actual practice there is always a certain amount of back-pressure, due to the pressure in the cylinder of unconsumed gases and the products of combustion, which if not liberated would quickly use up the momentum stored in the fly-wheel; hence at the end of, or slightly before the completion of, the power stroke, the exhaust valve is caused to open and thus relieve the pressure on the returning piston, the fly-wheel momentum being then sufficient to return the piston to its initial position for repeating the power stroke. But it will be observed that so far we have made no provision for introducing a fresh charge of the explosive mixture, and it will therefore be necessary to introduce into the cylinder or combustion chamber another valve, termed the inlet valve; it is also obvious that both inlet and exhaust valve must be arranged to open at the correct time required to continue the progress of the piston in order to gain maximum power from the explosions.

It is at this stage that the term "four-cycle" engine may be explained; for in the description of the first impulse and return of piston making one complete revolution of crank-shaft we have the piston returned to position to perform work but no gas to continue with; if, however, the fly-wheel momentum be sufficient to continue the piston movement and the inlet valve be opened as the piston passes the dead centre after having completed the exhaust stroke (the latter valve now being closed), the cylinder will be filled with new explosive, either by suction of the piston opening the spring-controlled inlet valve, or by means of a valve mechanically operated; and the fly-wheel momentum still continuing, the piston will on its second return journey highly compress the charge of gas, as both valves now being closed there will be no outlet for the imprisoned gas.

The term "Otto cycle" or "four cycle" applies to all motors in which the engine crank makes two revolutions to one impulse or explosion or power stroke; *i.e.* the piston makes two return trips along the cylinder, each movement being termed a stroke, so that there are four strokes to complete the cycle.

These strokes of the piston are, in order, termed (1) the "suction," in which the outgoing piston sucks in the explosive mixture, and so theoretically should fill combustion chamber and cylinder with an explosive mixture of gas and air; (2) the "com-

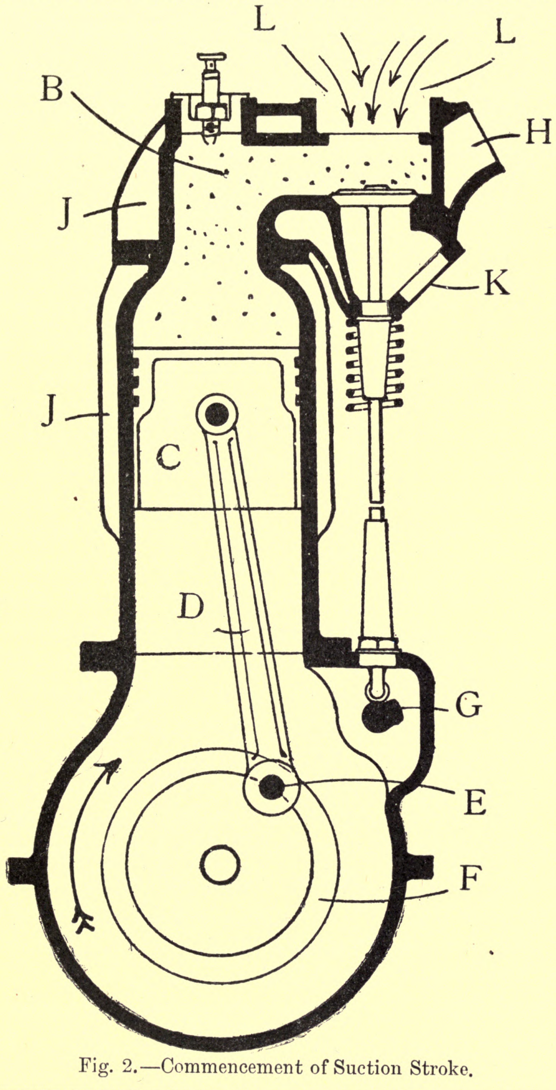

Fig. 2.—Commencement of Suction Stroke.

pression" stroke, on which the returning piston (the valves being closed) packs up the gas under considerable pressure into the small space known as the combustion chamber; (3) the firing or "explosive" stroke, on which the piston is shot forward like a bullet from a gun, and the fly-wheel absorbing the shock, its momentum continues the motion of the piston through the 4th or "exhaust" stroke, thus completing the "cycle" of events and bringing the piston back to its original position.

The four operations completing the cycle will be better understood by reference to figs. 2, 3, 4 and 5, which are diagrams showing the position of the crank-pin, piston, and exhaust valve at the four points forming the complete cycle, the inlet valve being omitted from the opening L L for clearness, but shown separately in fig. 8. In fig. 2 the piston is just commencing the suction stroke, gas is being supplied by piston suction through a pipe from the carburetter to the inlet valve, which would, in actual construction, occupy the space devoted to the arrows in fig. 2, and so to the engine as shown by the arrows, the partial vacuum thus created in the cylinder having the effect of opening the inlet valve, the exhaust valve being closed. In the white space forming the combustion chamber in fig. 2 the dots shown are rather far apart, and are intended to represent the always more or less incomplete charge of explosive mixture, due to factors which we shall explain later. Fig. 3 represents the cylinder fully charged with gas, the piston having completed the

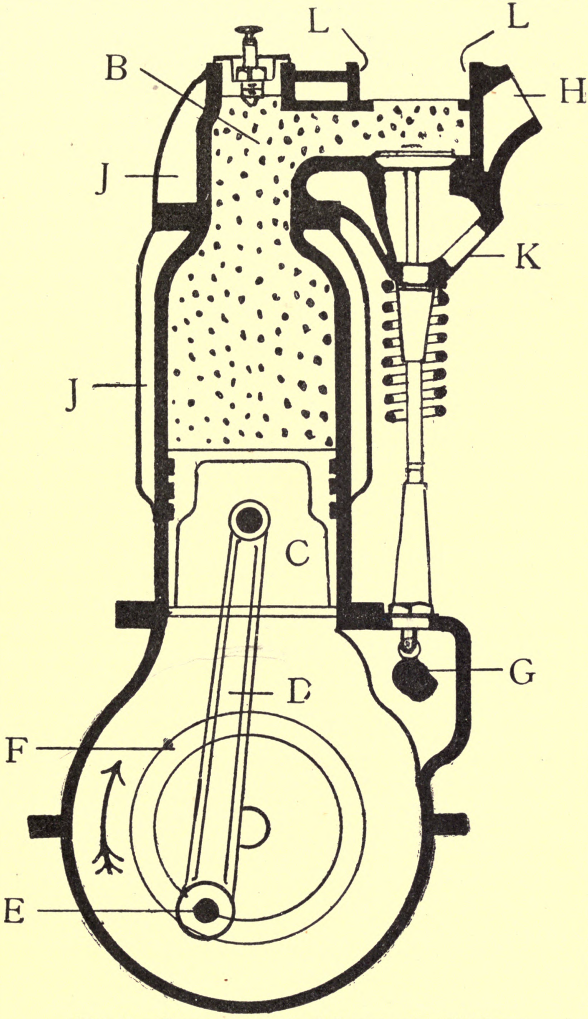

Fig. 3.—Commencement of Compression Stroke.

suction stroke, both valves now being closed, as there is no longer suction on the spring-controlled inlet valve. Fig. 4 shows, by the dots being closer together, the compression of the gases has been completed, the ignition has been made, and the piston is just starting on the power stroke. Fig. 5 shows the position of affairs with the exhaust valve open and the piston commencing its journey on the exhaust stroke, the inlet valve, of course, being still closed. In this diagram it will be noticed that the piston has not as yet operated as an expelling medium, the gathering together of the dots being due to the pressure still remaining in the cylinder after completion of power stroke being considerably above that of the outer atmosphere. The whole action, thus simply described, is that the gas formed or mixed in the carburetter is led through a pipe communicating with the inlet valve which occupies the top open space denoted at L, and admitting gas to the combustion chamber B. As the piston C moves outward by fly-wheel momentum, it draws into the cylinder a more or less full charge of gas; the outward motion of the piston then ceasing by having arrived at the turning-point, or "dead centre," of the crank-throw, the inlet valve at L closes by reason of the automatic spring and the absence of suction, and the first or charging stroke is completed. In this operation the piston C, through the medium of the connecting rod D, has driven the crank E and so communicated motion to the engine shaft, on which is mounted the fly-wheel F. In starting the

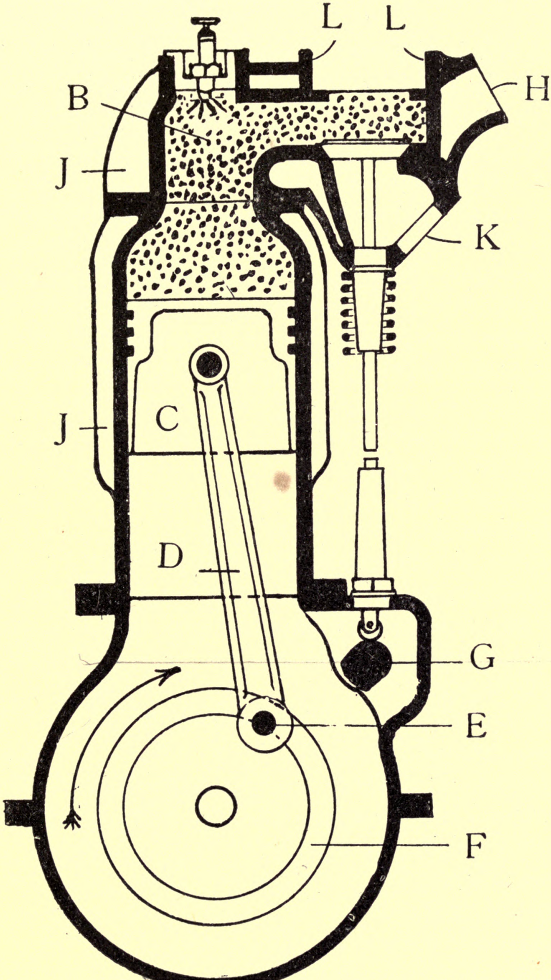

Fig. 4.—Completion of Compression Stroke.

engine it is of course necessary to complete the first cycle of operations by means of the starting handle, or, in the case of the motor bicycle, by pedalling a few turns, so that the gas shall be drawn in and the first explosion caused, after which, with all in good order, the action becomes automatic as described. The piston having completed its outward stroke, the momentum of the fly-wheel returns it and so the compression stroke is completed, the effect being that the piston C compresses the gas in B; and when this compression is fully carried out by the piston reaching the end of its return stroke, the ignition spark, electrically produced, fires the compressed charge of gas and air. The method of ignition will form subject-matter for a special chapter; in the meantime it may be said that the mechanism permits of the exact period or instant of firing the charge being varied according to the speed of the engine, and by which economy of fuel (petrol), variation of speed, and general elasticity in driving are secured.

The student of the subject should also at this stage recognise something of the importance of compression; indeed, so important is the proper compression of the gas that all four-cycle motors depend chiefly on this factor for the actual power given out, and in most cases loss of power is traceable to loss of compression. Reverting to the action of the engine after the completion of the explosion stroke, fly-wheel momentum again drives the piston to the original position; meantime opening of the

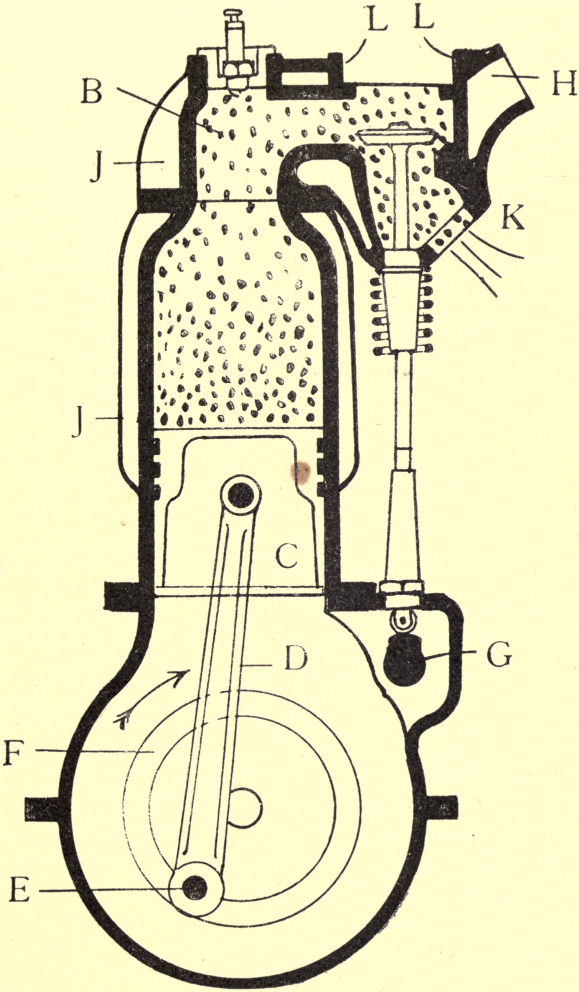

Fig. 5.—Commencement of Exhaust Stroke.

exhaust valve is effected mechanically by a cam G (fig. 5) mounted on the half-speed shaft in gear with the engine shaft in the ratio of two to one, so that the cam comes into action once to two revolutions of the engine shaft, and is so shaped and its position fixed that the exhaust valve is opened and closed at the precise moment required to ensure highest engine efficiency. Another cam, mounted on the same shaft, and in most of the more modern engines being formed in one piece with that operating the exhaust, is the ignition cam which actuates the contact breaker for opening and closing the electric circuit, a further arrangement incorporated in the contact breaker enabling the operator to "advance" or "retard" the ignition spark in relation to the piston position, as it is necessary at starting or when running slow that the spark should be "late," or should not occur until the piston has turned the dead centre on the compression stroke, otherwise the explosion would tend to drive the piston in the reverse direction. But when the motor has gained momentum and the piston is travelling at high speed, the speed of the engine and thus the machine may be further increased by "advancing" the spark—that is, producing the spark somewhat before the piston has completed the compression stroke; for although ignition by electric spark is extremely rapid, a small fraction of time is occupied in inflaming the gases, and, this being constant whilst the piston speed varies, it is necessary, in order to get the best results, that the spark may be varied at the will of the operator according to engine or piston speed.

The various mechanisms by which this and other operations are conducted will be described in due course. In the meantime, and to assist the understanding of further description of operations, the student should make himself familiar with the names and arrangements of the various parts comprising the complete engine, the frontispiece, fig. 1, being an excellent model for this purpose.

This illustration is a sectional view of the well-known F.N. bicycle motor made by the Fabrique Nationale d'Armes de Guerre, Herstal, Belgium; and though some of the details are peculiar to this engine, the design as a whole represents the best modern practice in this type of light high speed motor. The name parts also will apply to any petrol motor of whatever size or make, and in general the arrangement of essential parts does not differ.

No. 1 is the cylinder with radiating webs for air cooling, in which the piston 24 works; and at 28 are seen three spring piston rings for maintaining a gas-tight yet sliding fit to the cylinder wall. 23 is the connecting rod, the upper end being pivoted to a cross pin, termed the "gudgeon pin," at 25, the other extremity taking bearing on the crank-pin 29. The fly-wheels are two in number and connected together by the crank-pin, the illustration showing the left-hand fly-wheel 22 enclosed in the crank case 3, which, as shown, is in two halves, divided vertically in the centre, the two being connected by six bolts through lugs 9, 10, etc., the fly-wheels almost fitting the crank case in each direction, and the space between giving the merest shade of safe clearance to the connecting rod. The dotted circles 50, 51, and 52 represent the timing gear, 50 being a 17-tooth pinion on engine meshing with 51, which is a 48-tooth gear mounted on an idle spindle termed the intermediate shaft, this gear in turn being in mesh at 52, which is a 34-tooth gear mounted on the two-to-one gear shaft, and operated by 50 through the medium of 51, so that for each complete revolution of 52 the engine shaft with the pinion 50 must make two revolutions. The gear wheel 52 is mounted on cam shaft 53, with the cam shown in position just in contact with a roller 57 mounted on the end of a lever for the purpose of lifting the exhaust valve, this lever being mounted on an axle at 59, and extended through the casing at 60 for the purpose of enabling the driver to at any time raise the exhaust valve and retain it open at will when it is desired to rob the engine of power momentarily, as in driving in traffic or running down hill.

The carburetter seen on the left receives petrol from the supply tank and delivers gas already mixed with the requisite proportion of air to the inlet valve 30 by way of the top copper tube numbered 168, after performing the four operations completing the cycle of events, during the latter of which the products of combustion are passed by the exhaust valve 43.

The following is a complete key to the parts shown numbered on frontispiece :—

1 Cylinder.
3 Left crank case.
9 Crank case screws.
10 Silencer screw.
14 Motor clip.
15 Motor clip screw.
16 Cylinder top screw.
16A Cylinder top screw joint.
22 Left fly-wheel.
24 Piston.
25 Piston pin.
28 Piston rings.
29 Crank-pin.
30 Inlet valve.
31 Inlet valve cup.
32 Inlet valve cup spring.
33 Inlet valve seat.
34 Inlet valve wedge.
35 Inlet pipe.
36 Inlet pipe nut.
37 Inlet pipe washer.
38 Cover plate.
40 Cover plate screw.
41 Inlet tube nut.
42 Exhaust valve guide.
43 Exhaust valve.
44 Exhaust valve spring.
45 Exhaust valve cup.
46 Exhaust valve spring retainer.
47 Exhaust valve rod.
48 Exhaust tube joining.
49 Exhaust tube nut.
50 17-tooth gear.
51 Intermediate 48-tooth gear.
52 34-tooth gear.
53 Cam shaft.
56, 57 Valve lifter with roller.
58 Roller pin.
59 Exhaust valve raising pivot.
60 Lever for operating exhaust.
62 Crank case pressure regulator.
65 Crank case pressure regulator tube.
92 Carburetter connection.
168 Suction tube.
169 Hot air funnel.
170 Funnel sieve.
172 Crank case cup.

CHAPTER II

THE TIMING GEAR, VALVE ACTION, CYLINDER COOLING, ETC.

The correct working of the timing gear is one of the most important matters controlling the efficiency of the petrol motor; and unless well made and properly set, the engine cannot possibly give its proper power, no matter how excellent the rest of the mechanism may be, so that the student should make himself thoroughly acquainted with its construction, function, and re-setting or adjustment in case of derangement.

It was briefly described in the previous chapter as consisting of a train of gear wheels connecting the engine shaft with an auxiliary shaft in such a manner that the latter—sometimes called the half-speed or the two-to-one shaft — makes but one revolution whilst the engine shaft makes exactly two. In the most simple form of engine this half-speed shaft has keyed to it a cam suitably placed for operating the exhaust valve (see 53 in fig. 1, and G in figs. 2, 3, 4, 5). This cam is so shaped that it comes into action and commences to open the exhaust valve somewhat before the piston has reached the end of the power or explosive stroke, being so formed and placed that it goes out of action and allows the valve to return to its seat under the action of the spring shown between 42 and 45 in fig. 1 at the precise instant that the piston completes the exhaust stroke. The shape of the cam, as well as its position on the shaft, has a considerable bearing on the efficiency of the engine, for the ideal valve would open instantly, remain fully open during the whole of the exhaust stroke, and then instantly close; but in actual practice those conditions can be approximated only, the shape of the best-designed cam taking an appreciable amount of time to open the valve and corresponding time to close it. A detached diagram showing the formation and action of the exhaust cam is shown in fig. 6, which will make it clear that the valve-lifting stem S being held down to the cam face F by spring pressure, the motion of the valve itself will be controlled by the shape or outline of the cam C; and, as previously pointed out,

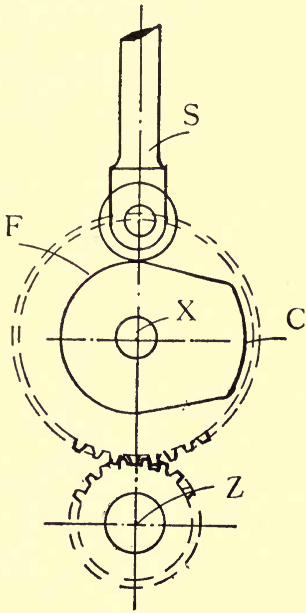

Fig. 6.—Exhaust Valve Action.

this cam being part and parcel of the secondary or half-speed shaft X, it revolves once only to two revolutions of engine shaft Z, and its periphery is so shaped that the lifting portion C is in operation through about one-half of the revolution, or one-fourth of the engine cycle of operations; this, of course, being during the period of exhaust, or the last phase completing the cycle.

Figs. 1, 2, 3, 4, and 5 should also be studied in this connection, and the action will be made clearer still by fig. 7, in which the cam is seen at Y, the half-speed shaft K, the exhaust valve stem at C and the lifter at C^2, guides at *a* and *b*, and the control spring at V.

The correct time for the exhaust valve to open is when the piston has completed from seven-eighths to nine-tenths of the explosive stroke, and it should *close exactly* the piston reaches the end of the exhaust stroke, otherwise the charge of gas for the following power stroke would be deficient in quantity. Mounted on the same half-speed shaft as the exhaust cam is another cam, termed the ignition cam, whose function it is to close the electric circuit at the proper moment to fire the charge.

This cam comes into action once in every four reciprocations of the piston, but whereas the exhaust cam does its work during the fourth movement, the ignition cam operates during the third; but by suitable mechanism to be described, the exact time of closing the circuit in relation to piston position may be varied. It will now be seen that the two cams

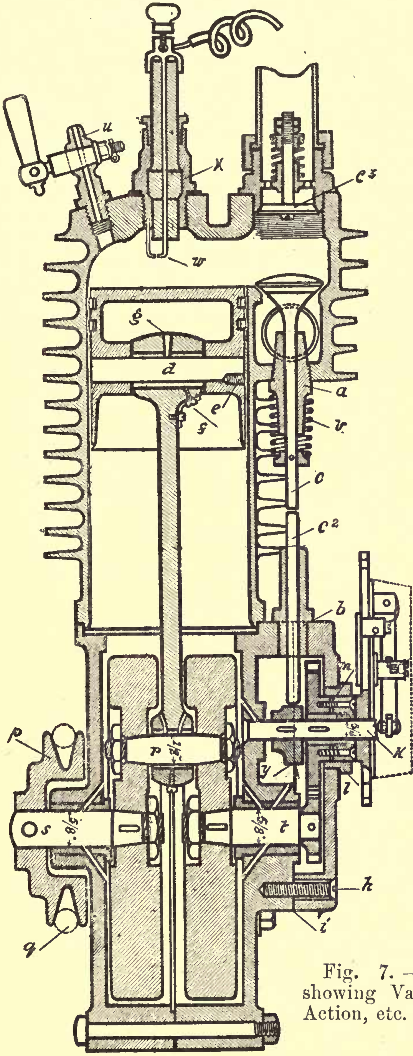

Fig. 7. — Section showing Valve Cam Action, etc.

on the half-speed shaft provide (if the connecting gear wheels are meshed together in proper position) for the correct period of firing the charge or third operation, and exhausting products of combustion on fourth operation. Let us, then, investigate first and second operations.

The first or charging, or, as sometimes termed, the suction stroke, may be automatic as to the entry of

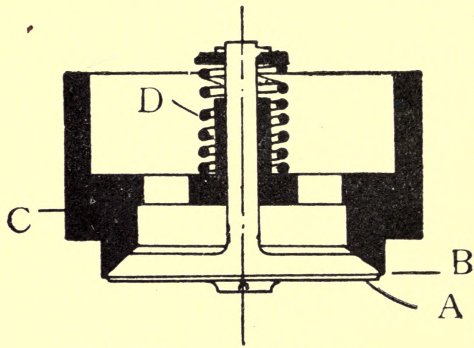

Fig. 8.—Automatic Inlet Valve.

gas by suction of piston, or it may be mechanically controlled by a cam and spring in the same manner as the exhaust valve. The former, or automatic suction valve, is shown in fig. 8, in which A is the valve proper, B the seating, C the outside cage or body, and D a very flexible spring in compression with just power enough to close the valve firmly when there is no suction action from the piston, as during the compression, power, and exhaust strokes, yet opening quickly to the piston suction and pressure of outer atmosphere on its active or charging stroke.

Theoretically, this valve, like the exhaust, should open wide immediately its period for opening is reached, which is, when the piston commences the suction stroke to draw in gas, and should remain fully open until the piston stroke is completed; but there are various causes preventing this ideal action.

In the first place, a spring too strong will make the valve open late and close too soon, or a spring too weak may not close properly at all, or rather not until a serious proportion of the gas drawn in has been driven back by the piston on commencing its compression stroke.

Another point urged against this form of valve is that when the combustion chamber gets very hot, and the valve opens, the first rush of gas instantly expands to such an extent that the back-pressure tends to completely stop or seriously throttle the further inflow of gas, with the result that by the time the piston commences the return or compression stroke there is little gas to compress, and the following working or power stroke is correspondingly weak by reason of the double loss due to loss of fuel and ratio of compression.

The mechanically-controlled inlet valve is bound to open and close at a definite time, and remain open for a certain period, this being its greatest advantage over the automatic or spring-controlled valve; but this, of course, does not prevent back-pressure in the cylinder, due either to overheating or unexpelled pressure of incomplete combustion, or to premature closing of the exhaust valve. The M O V makes its best point when the engine is running slowly. In the case of the suction valve, when the piston drops below a certain speed the suction is insufficient to open the valve wide enough to take in a working charge of gas, and if there should be any leakage at either valve, inlet, or exhaust, or past the piston itself, this fault is aggravated; so that on the whole the mechanical inlet is, in the writer's opinion, preferable, especially on single-cylinder engines and such machines as motor bicycles not fitted with change-speed gearing.

The action of the mechanical inlet valve will be readily understood by reference to fig. 9, in which *b* is the inlet valve and *h* the exhaust. This also makes clear one very simple arrangement of the gear wheels working the half-speed shafts, though the cams are not shown. P is a pinion fixed to the engine shaft and in engagement with the two gears S and S′, which have double the number of teeth on P. So that whilst P is making two revolutions, S and S′ make one only. On the spindle S the inlet cam is shaped and disposed so that the valve opens quickly at the *same instant that the exhaust closes*, and remains open until the charging stroke is completed; and it should be emphasised that the slightest deviation from this will mean loss of power, for if the valve should open *before* the piston has completed the exhaust stroke, there would be a back-pressure retarding the inflow of gas; whilst if the inlet valve

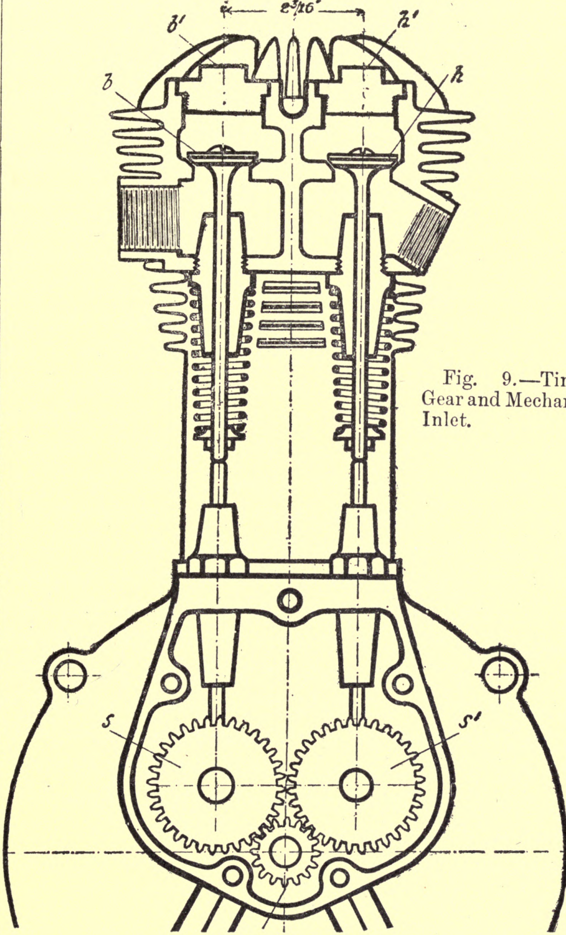

Fig. 9.—Timing Gear and Mechanical Inlet.

should *close too early*, the charge in the cylinder would be robbed of quantity; or again, if it closed *too late*, there would be a loss of power due to loss of compression, because a portion of the charge would be forced back through the inlet. In any case, but especially where both valves are mechanically operated, it will be seen that it is of the utmost importance that the timing gear should not only be originally correctly set, but afterwards maintained; for after considerable service it will be found that the valve gearing is slightly out of time through general wear and tear of the parts, especially of the working surfaces of the cams and the lifting rods, also by alteration in length of valve stems due to grinding in the valves repeatedly, so that to maintain full efficiency of the engine this timing of the valves must be tested at suitable intervals; and particularly it should be noted that there is at all times a clearance of about $\frac{1}{32}$nd of an inch between valve lifter and valve stem C^2 and C in fig. 7.

Cylinder cooling is another matter of great importance to the proper working of the engine. When the engine is run at its maximum speed and on a full charge of gas, heat would be produced much more rapidly than it could be dissipated by the mere expansion and exhaust, until a stage would be quickly arrived at where the cylinder would be all but red-hot and any known lubricant would be burnt up, thus adding the heat of friction to the heat generated by combustion.

The internal combustion motor has been described as a heat engine, from which the novice might be excused for assuming that the greater the heat the greater the power. On paper this is so, but in practice it has so far been found impossible to utilise or dissipate the whole of the heat of combustion in the small time between one explosion and another—*i.e.* that whilst the heat is generated practically instantaneously on ignition of the gas, its diffusion takes up some time; and as working conditions do not permit us to utilise the whole of the heat of combustion, we have to waste a considerable amount of energy in order to keep the cylinder walls down to a temperature at which lubrication is possible. If all the heat of combustion could be extracted in the shape of useful work on the piston, the loud noise made on exhaust to which we are accustomed would not exist, because this noise is caused by the sudden liberation of unused force when the exhaust valve is opened, the noise being really caused by the difference between the pressure remaining in the cylinder at the end of the working stroke and that of the outer atmosphere. Consequently, as all the heat value and resulting pressure cannot be utilised on actual work, it makes little matter if we cool the cylinder down to a workable condition as to lubrication, for any heat loss in this direction is merely deducted from the pressure of exhaust, the initial temperature at the moment of ignition being quick enough to look after itself. The method of cooling may be by air or water, and air-cooling may be by simple radiation or by a forced draught from a fan or scoop or other contrivance arranged to supply a current of cold air to the outside of the cylinder and combustion chamber.

Water-cooling is effected by causing a constantly moving or circulating body of water to flow through an outer chamber or "jacket" surrounding the cylinder and combustion chamber.

In the simple form of air-cooled motor as used on bicycles the cooling effect is obtained by casting the cylinder and head with radiating webs or fins, which by conduction draw away the heat from the cylinder proper. These radiating webs are seen projecting from the cylinder sides in figs. 1, 7 and 9.

The drawback to air-cooling for an engine of considerable power is that under normal conditions the heat is generated and piled up quicker than it can be dissipated by conduction through air contact alone, and this state of affairs is rapidly aggravated whenever the machine is called upon to climb a rather steep hill, because then it is necessary to give the engine more gas, which means more heat; and at the same time the progression through the surrounding air being slower, the cooling effect is vastly diminished.

Thus for big-powered engines to take all kinds of roads, water cooling is a necessity; and water-cooling, to be effective, must be continually circulating, though this does not mean that the cylinder is to be always surrounded by *cold* water, for as a matter of fact, if the cylinder is *always* jacketed with water, it cannot overheat, because experience has taught us that the boiling point of water is a cool, comfortable temperature for the working parts of the internal combustion motor. The general arrangement of the water-jacket will be seen in the sectional drawings figs. 2, 3, 4, 5, in which the white space J J surrounding the thick black lines is the water-jacket—formed either by a separate casing of copper, or other metal, but more generally being cast in one with the cylinder, the advantage of the one-piece casting being absence of leakage, whilst for the separate casing may be claimed higher cooling efficiency, lighter weight, and lower cost of renewal should it be found necessary to fit a new cylinder.

In big cars fitted with high-powered multi-cylinder engines the weight of water for cooling purposes which must be carried on the car is an item of importance, hence the *radiator* is extensively employed, not only to merely lower the temperature of the circulating water, but to reduce the quantity and weight of water necessary to be carried.

The radiator consists generally of a number of copper pipes made up into one continuous length and placed in circuit with water tank and engine, the cooling effect being increased by the fitting to the whole length of the radiating piping a closely-assembled series of fins of corrugated form calculated to catch the maximum amount of air, and by conduction carry off the heat of the water flowing through the radiating pipes.

The circulation of the cooling water is generally ensured by using some form of pump—centrifugal, rotary, or direct-acting; though in some small voiturettes and in most water-cooled motor tricycles or tri-cars, thermo-syphon or self-acting circulation is relied on, the water tank being placed well above the engine level to ensure a gravity feed, and the return flow being due to the known fact that the hottest water will rise to the top. The object, in any case, is to supply the water-jacket with a constantly changing body of moderately-cooled water, as should the circulation cease, the heat of combustion would quickly empty the water-jacket by turning the water into steam at considerable pressure. In a well-designed water-cooling system the water tank is carried well above the level of the engine, the radiators being arranged preferably below the tank, the chief object, however, being to place the radiator where it will receive the maximum cooling effect from the rush of air due to the motion of the car.

The simple gravity or thermo-syphon water circulation works on the principle that hot water always rises to the top. Thus if a closed circuit is established with the feed tank above the level of the engine, and the whole system is filled up with water, the hot water rises up one pipe and the cylinder is cooled by the cold flow from the tank. The point of greatest heat in a petrol motor is the vicinity of the exhaust valve, so that the cold flow is generally arranged to enter somewhere near that point, or to pass that point before it becomes highly heated, the positions of inlet and outlet where the circulation is on the thermo system being somewhat exacting.

The flow would be from bottom of water tank to bottom of engine casing or water-jacket, and the return flow from top of engine to a point nearly at top of water tank, it being important, however, that this return pipe should at all times deliver under the surface of the water in the tank, or that the level of the water in the tank should never fall below a point at which the return flow pipe is fully covered. With forced circulation by pump the arrangements may be varied somewhat to suit convenience, but the best position for the pump is the point in the circuit where the water is coolest, which would be on the supply pipe to engine, the water at this stage having been returned to the tank and cooled by passing through the radiators or coolers.

It is highly important that circulation should be maintained, or the piston may seize through imperfect lubrication, due to overheating; and on some of the big cars gauges are carried on the dashboard to show whether the water is circulating properly or not.

Water-cooling has not yet been successfully applied to the motor bicycle by reason of the difficulty of finding room for the apparatus, and the disadvantages due to the added weight of the water and its containing tank; nothing less than two gallons being of use in the absence of assistance from elaborate radiators, for which there is no accommodation on the bicycle.

CHAPTER III.

THE CARBURATION OF PETROL.

PETROL spirit as used for motor car work is a double distilled deodorised spirit of ·680 specific gravity, derived from petroleum.

Petrol at this specific gravity is a very pure hydrocarbon, and will volatise very readily, leaving no gummy deposit in the cylinders or valves; latterly, however, there has been some difficulty in procuring spirit of this specific gravity, and many dealers have been unable to supply anything lighter than ·700 specific gravity, which does not so readily vaporise at ordinary temperatures as the lighter spirit, so that for efficiency and certainty of action it is preferable to procure the lighter spirit whenever possible, even at a slightly higher price.

The greatest care should be exercised in the storage of petrol, not only because of the danger of approaching an open can with a naked light, but because if a can be left with the stopper out, the rapid evaporation quickly deteriorates the explosive value of the contents of the vessel.

There is no more danger in storing a large quantity of petrol than a small quantity if kept in a suitable place, and for private owners the sealed gallon or two-gallon cans form the most suitable means of storage.

On the motor car or cycle the petrol is carried in a tank of suitable size, usually capable of carrying the vehicle from 100 miles to 200 miles on one charge, a rough calculation for the motor bicycle being 100 miles to the gallon, though it is obvious that this is dependent on the state of the roads, hilly nature of the country, etc., also on the skill of the driver; but under test trial conditions as much as 160 miles on a bicycle have been covered on one gallon of petrol costing a shilling.. In small car work, say from 5 to 8 horse-power, about 45 to 50 miles per gallon is considered a good average in ordinary running, though here again on special tests these figures have been badly beaten.

We may now proceed to the practical method of utilising this petrol spirit, which is the motive power operating the engine and propelling the vehicle. Petrol in itself is not explosive, nor even inflammable, until it comes in contact and mixes with air or with oxygen. Thus if it were possible to introduce a light or electric spark into a tin full up to the bung with petrol, nothing would happen except that the light would be put out. If, however, the can should be three parts empty and a lighted match be applied to the bung-hole, the contents would be instantly ignited, by reason of the three parts of air contained in the tin; but with this proportion of air it is unlikely that an explosion would occur, as the proportion of air would be insufficient and constantly getting less as ignition consumed the air in the can.

The explosive range is something like from 8 parts of air to 1 of gas up to 12 or 13 of air, but this depends on the state of the atmosphere and the density of the petrol, about 9 of air to 1 of gas giving the best general average at normal temperature.

The carburetter or mixer, sometimes termed the vapouriser, is the arrangement for mixing the gas vapour with the required quantity of air and delivering the proper quantity of correct explosive mixture to the engine according to the speed and power called for. The complete list of requirements in an up-to-date carburetter would be as follows:—1st, An automatic petrol feed in which the quantity of petrol supplied is neither more nor less than the engine calls for at the moment; 2nd, the conversion of the liquid petrol into a rich gaseous vapour and a mixture of gas and common air; 3rd, to thoroughly mix or "pulverise" this vapour with the requisite quantity of pure air to form the most effective explosive; 4th, to automatically regulate the supply of free air according to the temperature of the atmosphere and the speed of the engine piston; 5th, should also be fitted with a tap or throttle valve operated by hand from the steering wheel, and acting exactly as an ordinary house gas-tap, so that a mere whiff of explosive may be sent into the engine when running on easy down-grades, or the full gas given when climbing steep hills ; this throttle may, however, be a separate device placed anywhere between the carburetter and the engine inlet valve; 6th, the carburetter should be provided with an extra air inlet controlled by the driver, the object of this being that after the engine gets warmed up, and in hot summer weather, an economy of petrol may be effected by giving the mixture more air than is supplied by the automatic mixing valve; 7th, in very cold weather it is sometimes difficult to set the engines running, and to aid this, a pipe should be fitted from the engine exhaust pipe or silencer to supply heat to the carburetter, such pipe being fitted with a tap enabling the driver to shut off the hot air when the engine has picked up power.

The modern carburetter, in which all these functions are combined, is a somewhat intricate thing for the beginner to thoroughly understand, unless he works up gradually from the simple devices to get a grip of the principle. Once that is obtained he will be able to follow the action of the more intricate affairs, for although their number is legion and impossible of description individually, it will be found that in each the inventor has sought to attain more or less of the objects enumerated.

A crude form of carburetter would be any kind of closed vessel with three openings into it each controlled by a tap or valve—No. 1 to admit a variable flow of petrol, No. 2 a variable quantity of air, No. 3 to pass on to engine a variable quantity of gas and air mixture. A tank so made and with petrol enough to occupy one-eighth of its cubic capacity would, if well agitated, have the remainder of its capacity filled with a fairly correct explosive mixture which would work all right so long as it lasted and with the air inlet closed, but as the engine uses up the tank of gas it is necessary to provide a constant new supply.

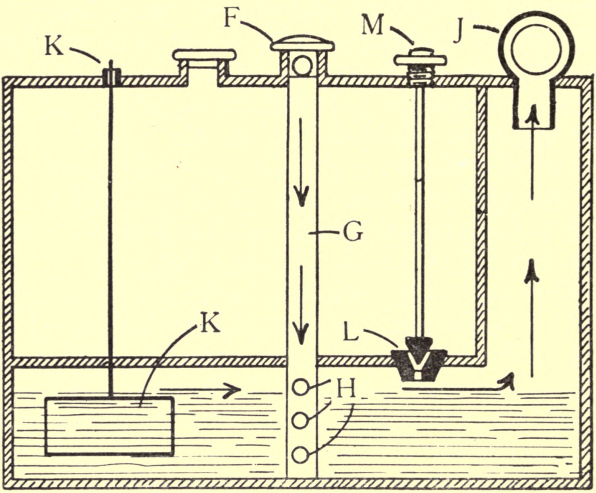

Fig. 10.—Surface Carburetter.

What is known as a "surface" carburetter is simply a tank as described, but in which arrangement is made for drawing the incoming air either over or through the petrol. Fig. 10 shows about the most simple form of surface carburetter; the diagram is a section of a tank such as might be found on a motor bicycle. It will be seen to be divided by an inner partition; this upper and inner portion provides the petrol storage, the under part being the carburetter proper.

Petrol is admitted from upper to lower compartment at intervals as required by turning the milled nut M, which actuates the conical valve L, which is shown open, the carburetter working best when the petrol is about the level shown, at which point the valve should be closed until the float rod K shows that more petrol is required.

The air supply comes in through holes F in the air-shaft which passes through the petrol tank and to the bottom of the carburetter, a series of holes H H H being drilled at the lower end. The air admitted at F may be controlled by a revolving cap more or less covering up the holes.

As the engine suction draws in air it flows out of the holes H H H and bubbles up to the surface of the petrol highly charged with vapour, passing along the surface of the petrol up the side shaft to the mixing chamber J.

It should also be observed that the whole of the petrol surface is covered by air which becomes richly charged with vapour by the time it reaches J, which is a double cylinder with closed ends but communicating in the centre, one cylinder communicating with outer air and the other with the supply pipe to engine. Holes cut in the top of the tank and in the outer casing of the twin tap or mixing chamber J, afford communication through the two cylinders, actuated by small levers. The first of these may be termed the "quality" chamber, and at opposite diameters holes are drilled at the top of the tank and the top of the casing, in which the cylinder is movable. At the portion of the cylinder surface covering these holes a slot as wide as the holes is cut away through nearly half the diameter of the cylinder, so that when in one position the slot in cylinder coinciding communicates with the outer atmosphere and the maximum quantity of air would be drawn in, at the same time the gas outlet from carburetter would be almost closed, giving the minimum amount of gas. By drawing back the lever the air-hole is decreased in area and at the same time the gas outlet is enlarged; thus a fine regulation of the proportion of gas and air is obtained.

The other half of the cylinder is in communication with the tank by means of holes corresponding in size, so that by a forward or backward motion of the controlling lever these holes may be made to more or less coincide or be shut off from communication altogether. This is best described as the "quantity" tap, dealing as it does with the quantity of already correctly-mixed explosive which is allowed to pass onward to the engine.

It is not intended to elaborate the description of the various forms of surface carburetters, as except for a few makes of motor bicycles the type has no champions and is generally considered already obsolete, but it nevertheless acts as an excellent stepping-stone to the study of the more intricate but more efficient "spray" carburetter.

Some of the reasons which may be advanced against the surface type are: It is wasteful of petrol when not in use, as any petrol left in the lower portion or carburetter proper quickly deteriorates and has to be thrown away; in travelling over rough road the petrol is flung about and seriously interferes with regular carburation; the needle valve is liable to leak and so flood the carburetter from the tank above, in which case the surface exposure to air is lost and insufficient gas formed; these conditions call for a constant variation of the position of the mixture and quantity levers. Unless the correct mixture and quantity can be maintained, the engine is almost sure to suffer from overheating with all its attendant troubles; at the same time an extravagant consumption of petrol is going on.

The "spray" carburetter, as the name would suggest, sprays the liquid petrol through a small hole or minute slits into an air chamber or mixing chamber, where the mixture is perfected before passing through the throttle valve on its way to the valve by which it is admitted to the combustion chamber of the engine. In these few words we have the basis of the spray type of carburetter, and the student need only imagine an ordinary scent spray with its nozzle connected to a small chamber filled with air to at once grasp the idea in crude form.

The spray type of carburetter is quite a small affair in itself, the petrol being carried in a separate tank and conducted to the carburetter through a small tube, the tank being fitted with a stop-cock for shutting off the supply when the vehicle is not in use. The tank being made airtight by closing the air inlet, the petrol is preserved against loss by evaporisation.

"Spray" carburetters are sometimes spoken of as "Float feed," or again as "Atomisers," but the various terms will apply to most makes as to general principles, for most "sprays" are "float" fed, and all are atomisers.

Fig. 11 will make clear the principle on which most carburetters of this class work, the drawing being a simplified diagram of the F.N., as shown to the left of fig. 1. The petrol is fed from the tank above by gravity to the orifice A and to the float chamber B, until the spirit reaches a level which closes the needle valve V, as shown by raising the float F, which is a light brass box or cylinder connected to the needle valve through the medium of the weighted lever arms P P with weighted ends W W working on a collar C, so that when the float is raised to the height shown the petrol supply is cut off until, the engine having used up some of the petrol, the float falls, the weights W follow the float, and so open the needle valve admitting more petrol. This action continues automatically, so that whether the engine is making 1000 or 2000 revolutions the float continues to admit just as much petrol as is required to maintain the feed. From the float chamber the petrol is drawn through a passage E by engine suction into the spray tube S, which in this case is a single-hole spray which breaks up or sprays the spirit into the mixing chamber M, which is open at the bottom end, and so sucks in air at R, connected to a gauze-covered funnel or scoop placed near the engine in order to warm the incoming air; this will be seen at 169 in fig. 1. An extra air

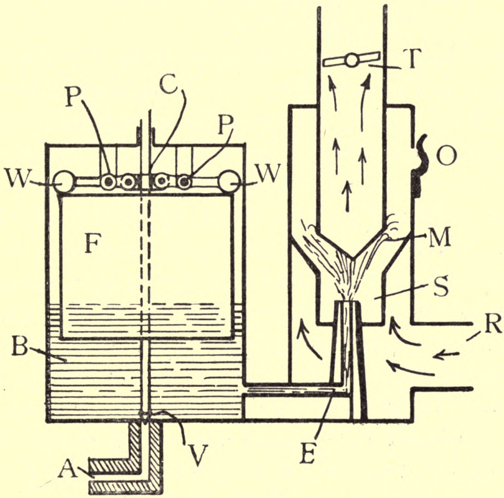

Fig. 11.—Float Feed Spray Carburetter.

inlet is provided at O, but except in very hot weather it is not necessary to open this.

The spray from S impinges on an inverted cone, not shown in this diagram but clearly traceable in fig. 1, the object of this being to further break up the liquid particles by the baffle plate action deflecting the upward tendency of the spray and throwing it down to meet the rush of incoming air from R, so that the atomising is complete by the time the mixture reaches the upper end of M. The flap T is the throttle operated from the handle-bar or steering wheel, and simply regulates the amount of gas passing to the engine; it consists of a disc pivoted at the centre at opposite sides, and is shown about a quarter open.

The Longuemare carburetter is by far the most popular, and in extensive use throughout the whole automobile world. It is made in various patterns and sizes to suit anything from a 1½ horse-power motor bicycle to a 100 horse-power racing car.

The principle is the same as described above. There is the float feed ensuring automatic petrol supply and a spray action into the mixing chamber; but whereas the F.N. spray is a single jet, the Longuemare spray is through a series of slits formed on the outer surface of a cone, the spray being heated and deflected from the straight onward path by a combined baffle plate and chamber with lower end open, compelling the uprising gas to descend and proceed on its way through the mixing chamber proper and through a perforated disc, which further assists the breaking-up of liquid petrol and the completion of the pulverising process. This carburetter as described is of the most advanced type, and provides for the following: 1st, An automatic supply of petrol controlled by float feed; 2nd, a variable supply of gas due to (*a*) the number of slits in the spray chimney, and (*b*) the carburation or mixture key; 3rd, variable expansion of gases by controlled hot-air jacket; 4th, an automatic supply of air to accord with the gas supply and so feed the engine whatever the speed; 5th, the further refinement of a secondary or auxiliary air supply for reducing the

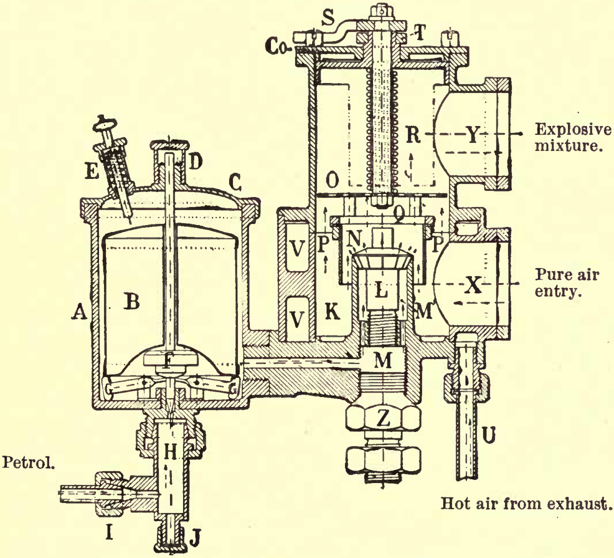

Fig. 12.—Section of new pattern Longuemare Carburetter.

richness of the mixture to the lowest explosive point when necessary.

This carburetter is shown in section in fig. 12, the petrol entering at I, proceeding by piston suction through H to the float chamber A, and lifting the float B, which in turn shuts the needle valve F when the supply of petrol is sufficient to provide for the needs of the engine at the time.

From the float chamber the petrol, still in liquid form, is sucked through a narrow passage to M, and is then drawn through the slits between L and N, where it is intimately mixed with the warm air and further amalgamated by passage through a perforated disc.

The upper chamber R delivers explosive mixture direct to the cylinder through the passage Y, the mixture being regulated by the spring-controlled disc S, and the quantity admitted to the engine by the perforated disc T, which is operated by the driver.

The following is a full description of the parts of the Longuemare carburetter as illustrated, and this type is what would be employed on tri-cars, etc., but with minor variations serves equally the motor bicycle or car.

KEY TO FIG. 12.

A Outside shell of constant level.
B Float.
C Cover of constant level.
D Plug of constant level.
E Piston spring.
F Inlet plug for spirit.
GG Balance levers.
H Coned filter joint.
I Coned joint conducting spirit.
J Outlet plug.
K Air chamber.
L Spray chimney.
MM Spirit chamber.
N Throttle tube.
R Gas chamber.
Co Cover of carburator.
S Spring controlled variable air inlet.
T Regulating disc for quantity.
U Joint in communication with the exhaust.
VV Heating chamber.
X Inlet for pure air.
Y Outlet for explosive mixture.
Z Plug support.

To the student who wishes to become an expert driver, the study of carburetter action is of vital importance, because in great measure not only the economy but the efficiency is largely dependent on the proper manipulation of the carburetter.

CHAPTER IV

IGNITION METHODS

HAVING arranged by means of the apparatus called the carburetter for an adequate supply of explosive mixture of gas and common air, we must next deal with the problem of firing or igniting this compressed charge of gas boxed up in the combustion chamber of the engine.

In earlier patterns of stationary gas engines, and also in road vehicles, the ignition was by flame or live tube, but as this method of ignition is now obsolete it is useless discussing the pros and cons. Motor car ignition to-day is exclusively electric, but there are one or two, or even three, ways of employing electricity as the firing agent.

The magneto method is entirely mechanical, and may be briefly described as consisting of a small dynamo with fixed magnetic field or permanent magnets, the current being generated by power from the motor itself.

In the original magneto method the current was a low-tension one, and called for special adaptations in the engine to suit this method of ignition, the make and break of circuit necessary to produce the firing spark being a trigger-like action between two points, one of which was insulated from the metal of the engine, the movement being mechanical and operated from the main engine shaft.

The magneto or dynamo method of ignition is now arranged to give a high-tension current and utilising the ordinary sparking plug, consequently no special engine construction is called for, and existing vehicles may be fitted with this system without expensive alterations. The best known and most successful apparatus for this form of ignition are the magnetos of Simms - Bosch and the Eisemann, the latter requiring the services of the induction coil.

By far the most popular, however, is the high-tension or battery method, in which a low-tension current generated by a chemical battery, or stored and drawn from an accumulator or storage battery, is transformed by means of an induction coil into a current of extremely high voltage, and consequently possessing the power to overcome high resistances such as that formed by the air-gap at the sparking plug points.

The whole object of the ignition system is of course the firing of the compressed charge at the exact moment when the power generated by the explosion has the greatest value, and this moment is not a constant one, for it varies with the engine speed, the road gradient, and in a lesser degree with the state of the atmosphere.

Perhaps the quickest way to make the matter clear to the lay mind will be to work backward from the sparking plug, the usual construction of which is made clear in the sectional illustration fig. 13, in which the outer body is of steel and the inner body of porcelain or other high insulating medium.

Through the centre of the porcelain is seen the positive wire, which by the wing nut is connected to the discharging point of the induction coil; the other wire seen fixed in the outer body forms the

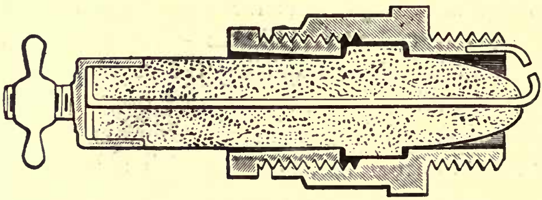

Fig. 13.—Sparking Plug (De Dion type).

"earth" or return circuit for the current on discharge, the metal of the engine and the vehicle being employed in place of a return wire.

The gap between the two wires is the spark gap, the air resistance causing the electric current, when of sufficient strength to overcome this resistance, to give forth a brilliant flaming spark, and so igniting the charge in the combustion chamber of the engine into which the sparking plug is screwed.

The unfailing production of this firing spark, which may be called for as many as 2000 times per minute, is one of the chief troubles of the practical motorist; for shortage of current, an irregularity in adjustment here and there, will cause certain failure. The distance apart of the spark plug points is a matter of importance, as although with an induction coil which gives a half-inch spark in open air no spark may occur in the presence of highly compressed gases, if the points are further than $\frac{1}{32}$ inch apart; indeed, the safest adjustment is about the thickness of an ordinary visiting card.

Now let us see how this spark is produced. First of all we must have some source of electrical energy on the vehicle, and in the system now being described this usually consists of one or more sets of accumulators or storage batteries. Two cells usually form one ignition set, and two cells of whatever size give approximately two volts per cell, or a pressure or E.M.F. (electro-motive force) of four volts when coupled, spare cells usually being carried and so connected that one set may be switched off and another on in case of failure.

The low-tension current given off by these accumulators is caused to circulate through the primary winding of an induction coil whenever the circuit is closed by action of the engine cam, which is every other revolution, or once in the four motions of the piston. At the time this primary circuit is closed a current flows through the primary winding of the induction coil, which in turn builds up a powerful current by inductive action in the secondary of the coil; and on the mechanical *break* of the primary circuit occurring, this piled-up force of the secondary or induced current is discharged by way of the sparking plug, and the gaseous mixture is ignited. It is not here proposed to enter into the principle or construction of either accumulators or induction coils, and readers not already acquainted with this branch of the subject would do well to study the special handbooks in the same series devoted to this branch of electrics: in a later chapter, however, will be found some useful hints on maintaining the electrical apparatus of a car in efficient condition.

The contact breaker, as already mentioned, is a mechanical device for closing and opening the electric circuit at the required time. It may be a direct momentary contact of two points insulated the one from the other, or a sliding or rubbing contact between two conducting surfaces, as in a disc of vulcanite or slate on the face of which a segment of brass or copper is inserted, so that a circuit is established whenever this segment comes into contact with the shoe or brush forming the other contact point.

The complete ignition mechanism on the high-tension or induced current principle will then consist of the following:—

1st. The accumulator or storage battery from which the vital current is obtained.

2nd. The induction coil by which the low-tension current at four volts is transformed into a high-tension current of some hundreds of volts.

3rd. The contact breaker, which at every other revolution of the engine shaft completes the primary circuit and so brings the coil into action.

4th. The sparking plug inserted in the engine cylinder top or combustion chamber, by which the gas is ignited from the secondary discharge of the coil.

In addition there are switch cutouts and plug switch cutouts, the first for switching off the current in driving, the second for preventing any leakage of current when the machine is not in use.

No effect is to be obtained from electricity unless the conducting path is complete, forming an endless circuit from the positive terminal of the battery or accumulator back to the negative of same.

Electricity demands a good conductor, which in general is a copper wire, and for road motor purposes this usually takes the form of a flexible cable composed of a number of strands of fine wire encased in an outer insulating covering of cotton, rubber, etc.; but the whole of the circuit need not necessarily be insulated, the important section being from the source of supply to the point of work to be done; the return path may then be through the metallic framing of the vehicle, commonly termed "earth" return.

There are several methods or variations in the manner of wiring up a motor vehicle according as one, two, or more cylinders are employed, the situation of the switches and operating levers, etc., but usually the connections are as follows:—

Starting from the positive terminal of the accumulator (the one coloured red), the current runs directly to the low-tension or primary winding of the induction coil, the terminal being in general the one marked P +, signifying positive of battery. The current then flows through the inner winding of the coil and emerges at the terminal usually marked C, signifying connection for contact breaker, to the insulated portion of which the conducting wire is connected. The path is then by way of the vehicle frame to the handle-bar or steering-wheel cutout switch, one terminal of which is insulated, and an insulated wire completes the circuit through a plug switch or intercepter to negative terminal of accumulator.

In some cases this plan is slightly varied, the negative of battery being connected direct to some metallic point on the framing, the current in this instance being sent around an insulated path through the switches before reaching the contact breaker, from which it travels by the common earth formed by the frame to the accumulator negative. The high-tension or induced current must also be provided with a complete circuit, except for the small air-gap at the sparking points. A highly-insulated cable carries the induced current from the induction coil terminal—generally marked B for the French word "Bougie"—direct to the central wire of the sparking plug. This wire being insulated from the outer body of the plug, as already described, by porcelain or other material, the outer wire is fixed into the metal shell of the plug, which in turn is screwed into the combustion chamber, and so affords a path through the vehicle framing back to coil terminal M—"Masse" or earth.

It should be understood that no current flows in either primary or secondary circuit except during the brief period of time the contact make and break is in a certain position to close the primary circuit. The diagram fig. 16 shows the more usual method of wiring up a two-cylinder car, using separate induction coils for each cylinder. This system shows the type of wipe contact (fig. 15) in conjunction with trembler coils, P being the terminal connecting battery with coil primary, C^1 C^2 the respective coil terminals connecting to contact breaker, and B^1 B^2 the high-tension terminals for spark plugs.

Fig. 14 shows the F.N. contact breaker, which is one of a type known as positive make and break, *i.e.* there is no spring-trembling device, though this form may be used in conjunction with a "trembler" coil, the object being to secure a succession of sparks at the plug points in place of one single spark.

In fig. 14 the outer casing 1, which contains the device shown with the cover removed, is fixed by a bayonet joint to the crank-case of engine. C is a cam mounted on the two-to-one or half-speed shaft; enclosing this cam, and eccentric to it, is a cage 2 pivoted at 3, this cage being in metallic contact with crank chamber and carrying one of the platinum contact points P, the other point mounted on the end of the adjustable screw 4 being insulated from the outer body or any other part of the machine by passing it through a vulcanite bush. S is a plunger controlled by a coil spring in compression which pushes at the base of the cage, and brings the contact

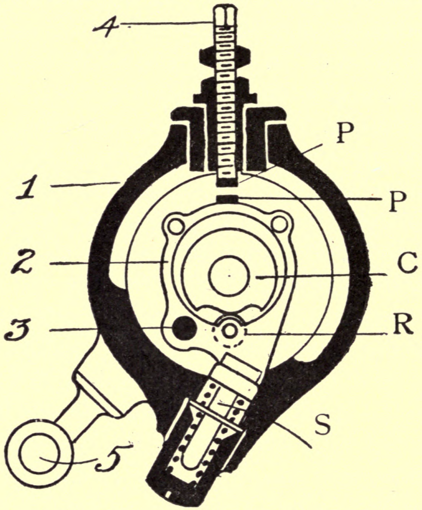

Fig. 14.—F.N. Contact Breaker.

points together whenever the cam allows the small roller R to drop into the recess cut in the cam, the continued rotation of the cam separating the points again as the high portion of the cam comes into operation by overcoming the resistance of the spring and swivelling the contact cage bodily over to the left by reason of its being pivoted at 3. The projecting arm 5 is attached to the outer casing 1 and to a connecting rod and lever operated by the driver. This provides the means for advancing or retarding the spark by moving the whole body of the contact breaker in a rotary direction backward or forward.

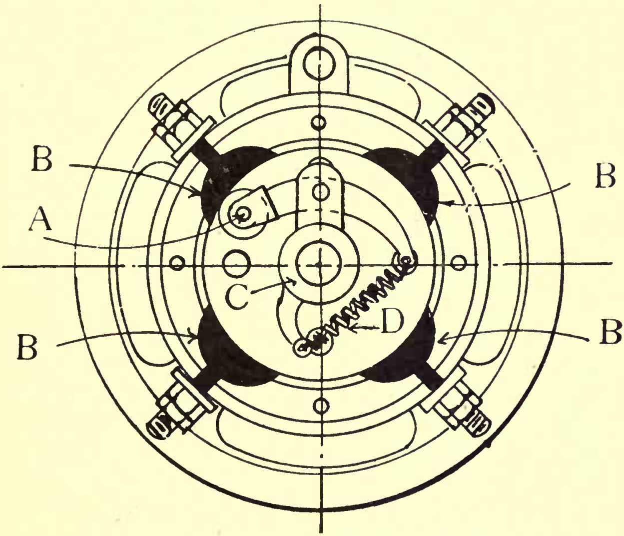

Fig. 15.—Four-point Wipe Contact Breaker.

Now it will be noticed that this rotary movement does not disturb the relative positions of any part of the mechanism so moved, though it does alter position with relation to the cam C on the engine half-speed shaft, and consequently the circuit may be established at variable periods in relation to position of engine piston.

In fig. 15 we have what is known as a "wipe" contact, the one shown being a four-point contact

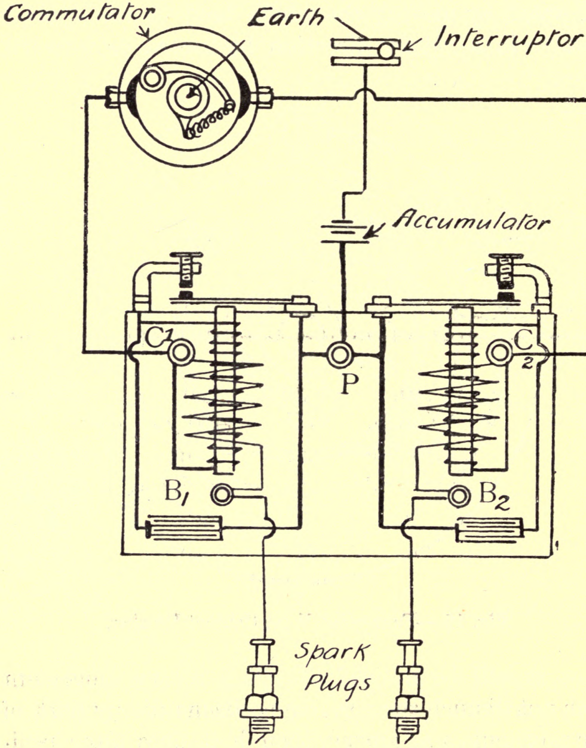

Fig. 16.—Diagram of Wiring for Two-Cylinder Engine.

for a four-cylinder engine. The four insulated contact blocks are shown in heavy black at B B B B in one piece with the screws for attaching the conducting wires, but insulated from the main body. The circuit is in this case closed by the roller A, which is mounted as shown on a pivoted arm carried by the rotating centrepiece C, which, as before, is keyed to the half-speed shaft, a spring D in tension serving to keep the roller in firm contact with the interior surface of the outer casing, the body of which, carrying the conducting blocks, is of vulcanite, so that current can circulate only during the time the roller is in contact with one of the blocks B.

The engine crank-shaft has crank-pins similarly arranged at angles of 90 degrees, so that ignition takes place in each cylinder at an equal period of advance sparking or retarding by rotating the outer casing or body of the contact breaker in the manner previously described.

This control of the period of ignition by advancing the spark is of vital importance, and the mechanism should provide for ignition occurring when fully retarded just after the piston has passed the dead centre on commencing the explosion stroke, this being the position for starting the engine.

As the engine gathers speed it will be found that the sparking may be slowly advanced until at high piston speeds the spark may be produced considerably in advance of the piston completing the compression stroke, as a minute fraction of time is occupied by the electric spark in igniting the gas.

CHAPTER V

TRANSMISSION AND MANIPULATION GEARING: GENERAL ARRANGEMENT, ETC.

THIS portion of the subject is extremely difficult to deal with briefly by reason of the infinite variety of cars and cycles, scarcely any two of which correspond throughout in the general arrangement of the parts, and even greater variety is found in the control mechanism or manipulation gearing, so that it is possible only to attempt to convey a general outline of the principles on which the various systems are built up.

The first problem the designer has to solve is the method of transmitting the engine power to the road wheels, or, as it is termed, the transmission gear. The most simple form of transmission is the direct belt drive as seen on motor bicycles, though the chain drive is equally simple and direct; but it is found in practice that the sudden jerks at starting render necessary some form of relief spring or clutch which will take up the drive gently. In the bicycle belt drive this starting shock is prevented by a certain amount of slip between engine pulley and belt, the tension being so arranged that this slip is not sufficient to allow the engine to "race" when going uphill.

Belt drives were also much used on cars in the earlier patterns, but have latterly been superseded by gear and chain drives, in consequence of the difficulty of maintaining the flat belts at proper tension under various atmospheric conditions, a continual and troublesome tightening up being called for. In one way the belt drive made for simplicity, as by having three sets of belts on pulleys differing in size it was possible to get three speeds by merely striking one belt out of action and another one in; moreover, this form of change speed was a gradual one, by reason of slip, and did not unduly strain the engine or other working parts. The older pattern "Benz" cars are good examples of the belt drive, but, as already stated, belts have practically disappeared from the modern car, though for a beginner a good deal of pleasure and a good grounding of motor knowledge may be got out of driving one of this belt-driven type, such as may now be picked up second-hand for £30 to £40.

In the modern motor car we have two well-defined systems of conveying the motion from the engine, which is usually placed in front of a car, to the driving wheels, which are invariably the rear wheels, so that the power has to be transmitted through the whole length of the vehicle. In the one system power is conveyed by a longitudinal shaft and bevel gearing to a transverse or cross shaft, and at each end of this shaft chain wheels are fitted, the drive then being by chain to another and larger chain wheel bolted to the driving wheel, each driving wheel being so fitted, the wheels being independent of each other and free to revolve on the *stationary* axle, this type of transmission being commonly spoken of as the "Panhard" type. In the other system, what is termed a "live" axle is used; *i.e.* the axle and two driving wheels all revolve together, the motion from engine being obtained as before by a longitudinal shaft and a bevel gear. This type is frequently termed the "De Dion" system, having been first perfected on cars of that make.

We need not enter into the relative merits of the two systems, as each has good points not possessed by the other; also to avoid confusion and because the Panhard type is most commonly met with, and may almost be termed the standard transmission gear, further remarks are confined to that type.

In the crude description given above no mention has been made of the method of changing speed, or of the "differential," or of the functions of the "clutch"; all three are, however, necessary incorporations in any modern system of car transmission.

Referring now to fig. 17. This is a "Chassis," or the whole of the mechanism ready to receive the car body. It is a good modern example of the Panhard type fitted with a two-cylinder engine, a lot of the minor fittings, of course, having been omitted from the drawing in order to make the general arrangement clear.

The complete transmission system consists of (*a*) the clutch, (*b*) the connecting shaft, (*c*) the counter-shaft, (*d*) the change speed gearing, (*e*) the differen-

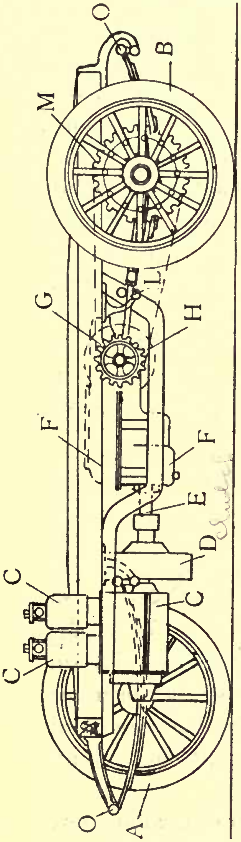

Fig. 17.

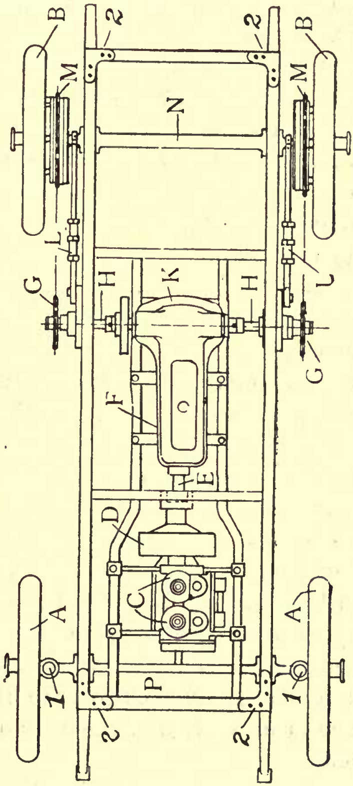

Fig. 18.

Plan and Elevation of Chassis, Two-Cylinder "Panhard" type.

tial gear, and (*f*) either chain drive or other means of conveying motion to road wheels.

Fig. 18 is a plan or top view of the same Chassis as fig. 17, and the lettering in each is the same.

The whole mechanism and the body of the vehicle is carried on springs as shown, and jointed at O. The front road wheels A A are the steering wheels mounted on short axles pivoted at 1 1 to the fixed main axle P by a connecting rod coupling the two steering sockets (not shown). The wheels may be turned in unison and in such a manner that the one describing the outer circle in making a curve will assume an angle which allows it to conform with the path of the inner wheel. The driving wheels B B are also mounted on a fixed axle N, but here there is no pivot, and the wheels remain at right angles with the axle, the wheels and axle, however, being arranged to move bodily along the main framing in order that the chain may be adjusted by the nuts L L.

The entire frame is a rigid structure of channel steel, riveted together at jointed parts and reinforced at several points by steel angle plates as shown at the four corners in fig. 18 at 2 2 2 2. Power is developed by the two-cylinder engine C C, the crank-shaft of which is connected to one half of the clutch D, the other half of the clutch being connected to the transmission shaft E, and the two halves of the clutch being made to withdraw or more or less engage with each other by a pedal lever worked by the driver's foot.

This clutch usually takes the form of a coned male and female clutch, with one of the surfaces leather or fibre lined, the drive being by the friction of the two surfaces, the clutch being normally held in engagement by a powerful coil spring and being withdrawn by the pedal mentioned, or a certain amount of slip may be given at starting by judiciously using the clutch pedal.

The clutch being in engagement the power is transmitted by the shaft E to the change-gear mechanism enclosed in the casing F.

This gear somewhat resembles the back gear of a lathe, though varied in many ways, but in the Panhard type it is known as the sliding gear, the teeth engaging end-wise. Other gears, such as the De Dion, are on the epicyclic principle, but the Panhard type prevails, and the object in each is to gain an instant drop or rise of gear according to the gradient of the country being passed over. In the particular design shown in figs. 17 and 18 the differential gear is enclosed in the same oil-tight metal casing as the change-speed gear, and is situated at K, or in line with the centre of the counter-shaft H.

The function of this differential gear must now be explained.

If reference is made to the elementary description of the way the wheels are mounted on the back axle, it will be seen that it would be impossible to steer the machine with the two rear driving wheels driving equally, for in order to turn a corner the outer wheel must run faster than the inner one, and at times the inner one all but stands still, as when turning in the width of the road, yet it is equally necessary that both rear wheels should drive, and take equal share of the working when running in a straight line.

The differential gear fulfils these conditions by a combination of two bevel gears face to face and engaging with two or more spur wheels, the bevel gears being each keyed to the inner ends of the shaft H at the centre point K, so that when all are in mesh the spur wheels merely act as a coupling together of the gears on the divided axle so long as the machine runs in a straight line; but whenever a curve is made and one driving wheel runs faster than the other, the spur wheels alter their position to accommodate the relative position of one bevel gear with the other, at the same time maintaining the requisite amount of forward drive on each road wheel. To those readers who are totally ignorant of motor car construction, this portion of the mechanism will be most difficult to understand from mere word description; but if fig. 18 is studied, and the axle H H is stated to be divided at the centre line, the most simple explanation is that the differential couples up and enables the two chain wheels G G to revolve at varying speeds, and so give varying speeds to the road driving wheels B B.

Having now outlined something of the method of arranging the parts of a car and explained the means of transmitting the power, we may briefly refer to the arrangement of the accessory apparatus necessary to supply the engine with fuel, etc., and the means by which the mechanism is controlled.

For the former purpose a more compact system, as found on a motor tricycle, has been selected for illustration, because here the principle may be grasped from the compact arrangement shown in

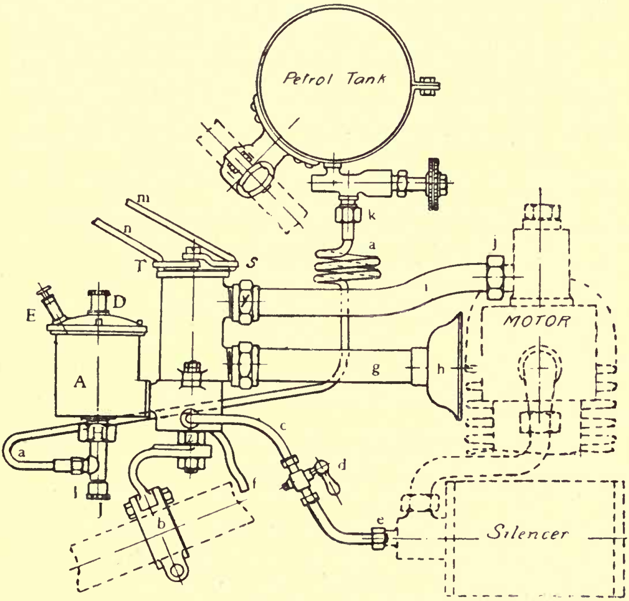

Fig. 19.—General Arrangement as Applied to Motor Tricycle.

fig. 19, whereas in a large car the same components would be widely distributed.

The illustration fig. 19 refers to an air-cooled system, but with this exception and the relative position of the parts, it will apply to any kind of petrol road vehicle fitted with the spray type of carburetter which is now quite general, and reference should be made to fig. 12 in Chapter IV. for details of this carburetter (Longuemare).

The petrol tank as seen is elevated some distance above the inlet to the carburetter at I, the feed being by gravity through the valve K controlled by the milled nut, round the spiral (which is merely to check vibration), and along the pipe *a*, rising through H to the float chamber A, thence to the spray chamber, where it is vaporised by warm air entering at the gauze-covered funnel *h* through the pipe *g*, the vaporisation being assisted in cold weather by a bye-pass from the silencer conducting hot products of exhaust through *c d c* to the base of the warming jacket at *z*, this heat supply being controlled by the stop-tap *d*.

The properly proportioned mixture of gas and air is then passed on to the engine by the sucking action of the piston through the pipe Y J. At the conclusion of one cycle of operations the exhausted products of combustion are carried through a pipe, shown in dotted lines, to the silencer.

The silencer is merely a cylinder or box, or rather a series of cylinders, one within another, with communications between each, but arranged in such a way that the gases are split up into innumerable particles generally by passing through small holes and a maze-like path, so that by the time the exhaust reaches the outer atmosphere it has been cooled down sufficiently to considerably modify the Gatling gun effect of the direct exhaust.

J at base of float chamber is a screwed cap which may be removed either to test the petrol flow or clean the orifice; H a connection between pipe and carburetter; E is a spring-controlled plunger used for flooding the carburetter before starting; D is a cover giving access to the interior of the carburetter. M and N are rods in connection with the driver's control levers and operating the "quantity" or supply of gas, and the "mixture" or fine graduation of gas to air. The ordinary facilities afforded the driver of either car or cycle consist of a number of levers, or it may be circular motions, all within reach of either hand or foot, but so arranged that whatever control in driving may be required is attainable without the driver moving his position or taking his eye from the road in front.

Methods of carrying out these requirements vary indefinitely, but the chief functions found provided for in all modern cars and some cycles are—

1st. Regulation of the proportion of gas and air required to form explosive mixture.

2nd. Regulation of quantity of explosive mixture admitted to cylinder.

3rd. Mechanism for advancing or retarding the firing spark.

4th. Electric cutout for shutting off the supply of electric current.

5th. Clutch for engaging the engine with the transmission gear.

6th. Change-speed gear.

7th. Brakes, anything from one to five in number.

In addition, there are other control devices in some special mechanisms for regulating the amount of lift given to the exhaust valve, a medium of governing the engine on the exhaust. In other engines the governing is done on the inlet by either (*a*) regulating the opening of valve, or (*b*) regulating the explosive by the throttle valve; and again, there are "cutouts" for silencers, where in open country and on climbing steep hills extra power may be gained and no one inconvenienced.

A number of other ingenious devices and combinations come under this heading, but the above are the principal ones, and whatever the make of car the mechanism for control transmission is placed conveniently to the driver's reach.

CHAPTER VI

HINTS ON OVERHAULING, AND CARE OF MOTOR

A FIRST-CLASS motor is, or should be, turned out by the maker ready for the road, but no new mechanism can give such good results as will be obtainable after a certain amount of actual practical service, so that most motors, if properly handled and cared for from the first, will give better results in every way after a few hundred miles of running.

The points to be attended to, to ensure this increase of efficiency, are attention to lubrication, cleanliness, general adjustment of working parts, and of engine and transmission gear in particular. These are the points to be watched keenly in driving a new car, and in addition a sharp eye must be kept on nuts, bolts, and other fitments inclined to work loose under constant vibration.

Lubrication of the cylinder is of vital importance, and the class of oil used equally so, as at the high temperatures attained — particularly in the air-cooled variety of engine — nothing but a specially prepared thick oil can remain liquid; and if the oil should be burnt up there is first the danger of the piston seizing and a smash-up of the internal parts; or failing this, the minor evil of badly-corroded valves and consequent loss of power through leakage. The student should grasp the fact that the petrol motor cannot give its best driving power unless the temperature at the moment of combustion is enormously greater than that of high-pressure steam. The petrol motor is essentially a heat engine, and the lubricant used must be able to "live" at the greatest heat likely to be attained, several brands of special oil being on the market for both air- and water-cooled engines.

These remarks are necessary as an introduction to the subject of overhauling in the sense that prevention is better than cure, and with a well-made motor complete overhauling should be seldom necessary if the driving and general treatment have been good; yet there are minor points requiring constant attention, as, for example, the electric circuit, to see that all connections are sound and clean, and that the conduction or insulation is at no part interrupted. The contact breaker, if of the "trembling" or "positive" type, requires constant attention in the way of verifying the cleanliness of the contacts, though the actual readjustment required may not be frequent; and with the "wipe" contact there is really little trouble, as the oil which at times stops the action of the plain make and break is found really beneficial to the wipe form, some systems, indeed, running the contact mechanism in a bath of oil.

When it becomes necessary to make a more thorough overhaul of the engine, the cylinder cover should be removed and both piston and valves closely inspected. The piston rings should be evenly, highly polished, and if black streaks are found here and there they denote an escape of the explosive gas past the piston, with consequent loss of power by leakage.

Similarly with the valves, especially the exhaust valve, the face of which will denote its condition. If it is found badly corroded or pitted, it must be re-ground or re-turned until a perfectly bright smooth surface is obtained on both valve and seating.

The valves are ground in with the finest emery powder and oil until the surfaces are flat and clean; but if the defect is only slight it is better to use crocus powder; and where emery is used it is important that none should be allowed to find its way into the cylinder, or inevitable scoring of the cylinder walls and piston rings would result. The same remarks apply to the valves themselves: all traces of emery should be washed away with some stale petrol. With regard to piston rings, if the faults are not very numerous or deep they may be corrected with an emery stick—a piece of planed wood with a strip of No. 00 emery cloth glued on—care being taken to preserve the circular shape. Piston rings in very bad condition should be renewed with new ones a shade larger, to compensate for slight wear on cylinder walls, and in replacing rings the slits where they are cut through should be arranged at different positions to prevent leakage of gas through these slits.

This process of replacing piston rings calls for not a little care and some skill, as the rings are easily broken, so that they should be gradually wound screw-like outside the piston until the leading end enters the groove it is intended for, when the remainder will easily follow.

Most pistons have three rings, in which case it is necessary to first place the ring in the centre groove, and in order to pass it over the first groove a slip or two of thin steel or whalebone will be found useful as a bridge or guide across the piston groove to prevent the ring from entering the first groove.

Whilst the engine is taken apart, other portions to be examined are the top and bottom bearings of the connecting rod, as if there is much lost motion at these points the engine will "knock" badly and the timing will be seriously disturbed, which, as already explained, vitally affects the running of the engine, and may, in the case of a single-cylinder machine, reduce the power by more than one-half. As the driver gains experience by practice, the various faults due to wear and tear or other unusual causes, and which call for a thorough overhaul, will be made manifest through the ear; so whenever anything of a grinding or squeaking nature is heard it will be known that something is wrong. As to overhauling the entire mechanism of a car, that is altogether beyond the scope of this little handbook, and the subject must be passed over with a warning as to general lubrication and adjustment of all working parts. Tyres, however, are worth more than passing mention, and should indeed take first place, just as if neglected they take first place in the cost of upkeep of a car. Whether running or standing idle, pneumatic tyres should be pumped up hard, and on heavy vehicles they can hardly be too hard. A soft tyre is liable to be damaged by being nipped between the rim and the road.

When a car or cycle has to be put aside for some time it is wisdom to change the position of the tyre at the point resting on the ground, though the very best method is to sling the car clear off the ground and so take all weight off the tyres.

Tyres last longest when kept in a moderate temperature and away from the light.

Punctures cannot be prevented, and gashes in the outer cover must occur. The former will demand immediate repair in order to continue the journey, but the latter are apt to get neglected, and this is a fatal policy; for directly wet gets into these outer gashes a rotting of the fabric sets up, and if still further neglected a burst is the result, and probably a new cover required.

So that with pneumatic tyres on any type of motor vehicle it is necessary to keep a sharp eye for defects, and repair immediately.

One of the most important points in overhauling a vehicle in the sense of merely preparing it for a run is the washing out of the engine crank chamber. The drain tap should first be opened and all the black oil drawn off, then the tap being closed a quantity of paraffin should be poured into the crank chamber and the whole well churned up by a few revolutions of the starting handle, the drain tap being again opened and the residue discharged.

This treatment not only clears away all objectionable matter, but leaves the motor in better condition to receive new lubricating oil, and also considerably assists starting the engine, especially if a little stale petrol has been injected to follow the paraffin, though this should be in very small quantity.

CHAPTER VII

MAINTAINING EFFICIENCY

THE keynote to efficiency in the petrol motor is compression.

Some engines are designed to attain a compression of as much as six atmospheres or 90 lb. to the square inch, others are designed for about four atmospheres or about 60 lb., the difference being chiefly due to proportion of stroke and bore and as to whether the engine is a single-cylinder high-speed engine or a multi-cylinder low-speed engine; but whatever the original design, the motor cannot give its full power unless the compression is maintained.

This question of maintaining the compression is one of the least understood factors in the working of the petrol motor; *i.e.* that although all practical motorists know that in the absence of good compression they do not get power enough, they do not sufficiently appreciate the value of even a small loss in compression.

Loss of compression can occur only when there is a leakage from the combustion chamber at the completion of the compression stroke, or at some point in the period of compression. The sources of leakage are several, and may be classified in the following order as to probability:—

1st, and by far the most frequent cause of loss of compression, is leaky exhaust valve, which through not closing properly allows the gas to escape during the compression stroke, and also robs the following incoming charge of gas by destroying the vacuum and consequently the suction power of the piston; for it will be seen that as the piston descends on the suction or charging stroke instead of drawing full measure of correctly-mixed explosive through the inlet valve, it will suck back some of the products of combustion of the former stroke through the leaky exhaust.

2nd. Leaky inlet valve; here the argument is much the same as with the exhaust, only that the loss does not occur on suction but on compression only, a portion of the gas sucked in being returned along the carburetter supply pipe, with the further danger of back-firing into the carburetter, though serious results are prevented by a system of superposed wire-gauze shields which prevent the passage of flame but not the passage of gas.

3rd. Leakage past the piston. This may be due to a variety of causes. In the first place, the original workmanship may have been wrong, and so rapid deterioration in compression occurs through either (*a*) taper-bored cylinder; (*b*) cylinder wall left rough; (*c*) imperfect fit of piston rings to piston; (*d*) irregularity of shape of cylinder walls and outer surface of piston rings. The leakage past piston is not necessarily a direct blow-through between cylinder wall and ring, but may take a zigzag path either through the slots coming in line where the piston rings are cut through, or it may be by way of the groove in piston through ring not being a good enough fit to its groove, in which case the gas would pass into the groove; and if a similar fault occurred in the other piston rings there would be a clear path capable of considerably lowering the total compression. The symptoms denoting loss of compression through leaky piston are a hot crank chamber and the appearance of an undue quantity of oil on top side of piston, or about valves and sparking plug. Whatever the cause, loss of compression must be attended to directly suspected; for the direct loss due to compression alone is not the only loss — there is the added loss due to imperfect combustion of an insufficient charge of explosive mixture of gas and air, with a further loss due to the loss of heat generated in the process of compression; *i.e.* that with a cylinder fully charged with the explosive and the compression carried to a high degree, a considerable amount of heat is generated by the mere act of compression, and on explosion this heat is added to the heat of combustion, and also assists in the rapidity of ignition, which in turn gives high temperature and quick combustion with more rapid drop as the piston proceeds on the power stroke. The ideal engine would be one attaining a very high initial temperature, in combination with an exhaust at atmospheric pressure, but this we know is impossible in the light of present knowledge. There are, of course, many other parts in a fully-fledged motor car coming under the heading of maintaining efficiency, but they are most of them mere matters of adjustment such as any ordinary mechanic would readily understand, so that these may be passed by and the whole subject dismissed with a few words on ignition. Granted that the engine compression and other accompanying mechanism such as the timing gear and valve action (see Chapter III.) are correct, the remaining principal cause of breakdown will be ignition. Accumulators are now generally used in combination with an induction coil and sparking plug, the system being known as the "high-tension" one, in which a low-tension current is transformed into a high-tension current by the action of the coil, as explained in a previous chapter.

Of the group of parts forming such an ignition system, two require pretty frequent attention, and these are (1st) accumulator, (2nd) contact breaker, the coil, if of good make, looking after itself; *i.e.* there is no wearing-away action in the coil, but accumulators run down and require re-charging, and contact breakers burn away or get pitted and require refitting with new platinum tips, or the old ones dressing up with a file.

In dressing up platinum contacts, care should be taken to ensure the contact surfaces coming squarely together, and in fitting new contact points care should be exercised in purchase, as a good deal of fictitious metal is passed off on the unwary as platinum, but nothing else than pure platinum will long stand the rapid and continuous make and break.

Just as compression is the key to getting full power from the engine, so is the accumulator to the ignition system. Everything else may be first-class, but if the current should fail or fall below a certain point, the engine will cease to work or will misfire frequently; consequently it is necessary to maintain a good supply of electricity on the vehicle. Accumulators for motor ignition work are almost universally made up of two cells giving two volts E. M. F. each, the pair giving four volts when connected in series, the different sizes used simply being according to requirements of distance or capacity; *i.e.* small cells give the same voltage and will work the same induction coil, but for a shorter period.

The capacity is expressed in ampère hours, denoting the number of hours the cells can maintain a continuous discharge of one ampère.

The proper understanding of accumulator action is certainly not one of the least important points in maintaining the efficiency of the motor, but to deal anything like thoroughly with the subject would demand another handbook fully as large as this one which is supposed to cover so many subjects.

Briefly explained, the accumulator is able to supply for a certain time sufficient current at a voltage or pressure equal to igniting the gases for, say, 600 to 800 miles running of the vehicle; but where the trouble comes in and care is required is in seeing that the discharge is not prolonged beyond a certain point, though the cells may still give enough current for ignition. Experience has fixed this limit at 3·6 volts, and to let the cells run lower than that means semi-destruction of the plates, preventing on the next re-charge the cells receiving, or at any rate retaining for any period the full charge. Amateurs who do not really understand accumulators should not tamper with them, but take them for re-charging purposes to some reliable firm or to the local electric light station. One golden rule, however, is easily remembered: charge your cells often and at something less than the normal charging rate stated by the makers; in this way the cells never get run down. For instance, fully-charged cells will read 4·6 volts, and after 100 miles running will drop to about four volts; now, although the battery might run other 500 miles before dropping to the safe limit of 3·6 volts, it is better to put it on charging again, *i.e.* instead of using one accumulator through the full range of its capacity, substitute another, as in this way the cells are never strained either on charging or discharging.

Most vehicles and even motor cycles are nowadays fitted with two sets of ignition accumulators and a two-way switch, so that in the event of one accumulator running down the other may be instantly switched on.

CHAPTER VIII

SOME HINTS ON DRIVING

This booklet is written in the interests of those who know little or nothing of the complete petrol motor vehicle, which may be a 40 horse-power car, or a modest 2 horse-power bicycle. The principle, however, is the same in all types, and the student who realises this makes a good start on the way to grasping the details of all.

Perhaps the best manner of conveying in a simple way the instructions necessary to the driving of a motor will be, to take the whole of the operations necessary before starting for a drive and follow on with the method of manipulation whilst driving.

For this purpose, and to simplify matters for the absolute novice, we will take a motor cycle of the single-cylinder type, and air-cooled, though there is really nothing more in driving a 40 horse-power car except understanding the additional control mechanism relating chiefly to change-speed gears, accelerator, etc.

Before taking out a machine see that all bearings on the machine itself have been lubricated. Next, see that the engine crank chamber has its dose of oil. Then be sure to fill up with petrol, and also with reserve lubricating oil. Test the accumulators by a volt-meter and see that they register something over four volts at the terminals. Test again at the contact breaker, which will show you whether the conduction is complete or whether there is a breakdown in the insulation, though it should be noted that the volt-meter reading at the contact breaker will not be quite so high as from the terminals direct by reason of the resistance of the induction coil primary and the rest of the circuit.

The sparking plug should next be tried by laying it in metallic connection with some part of the engine and operating the contact by hand, with the outer body of the plug in contact with engine or frame; a brilliant shower of sparks should pass between the points. Another test, not including the plug itself, is to detach the high-tension wire from the plug terminal and hold its end within about $\frac{3}{8}$ inch of any portion of the engine, when if the circuit is complete and the current strength right the $\frac{3}{8}$-inch air-gap will be bridged over by the spark.

Now all being ready, the actual start in a car would be made by a winding handle in order to gain the first compression and following explosion, when the clutch would be gently worked into contact and motion be conveyed to the road wheels.

In the case of a motor cycle not fitted with clutch and starting handle the initial engine revolution must be got by the rider pedalling the machine or running alongside, the exhaust valve meantime being lifted or held open to release the compression until it is heard that the spark is firing the charge; the exhaust is then dropped, and the machine quickly picks up speed. Immediately a start has been made the levers controlling the "throttle" or supply of gas, the "advance" sparking, and that regulating the "mixture" of gas and air, should be adjusted to the requirements of the road as to gradient, and to the atmosphere as to temperature. The quantity or throttle lever should be wide open for starting in order to pass plenty of gas. The mixture lever must be guessed at until experience teaches. The advance spark mechanism must be retarded to the utmost.

Under these conditions, immediately the exhaust valve is allowed free play we have in the engine an ample supply of gas being exploded late; but the mixture is an unknown factor, so in systems not fitted with automatic carburetters the mixture lever should be the first one to be operated on, the speed of the machine and the beat of the engine being the best guide.

Following on this, the throttle should be gradually closed down until the engine is running on but a breath of gas, and of course much slower.

Then the mixture lever should again be manipulated to get a fine adjustment, noting the speed of the engine beat until at a certain position of this lever the highest speed is attained with the minimum supply of gas and with the speed or advance spark lever still at the retard or slow position.

Having got thus far, the advance may be made very gradually, and if all is correct the machine should respond until the speed is almost doubled.

The levers are now in the position in which the engine is doing its best work, not only in petrol consumption, but in keeping the valves and other parts in order, for it should be known that in the case of an air-cooled engine to run it on full advance spark and full gas supply, *i.e.* full power, for any length of time, would mean overheating and the machine being pulled up to a standstill, as when a cylinder gets very hot the new gas cannot enter in sufficient quantity, because it expands instantly on entering the cylinder, and quantity is deficient.

This teaches us that when running on level road the gas lever should be shut down to the lowest point and the speed be extracted from advancing the spark, the mixture lever also being manipulated to run on the biggest proportion of air the engine will take.

In going up-hill all these adjustments suitable for level going must be altered if the hill is a long one; but if it is a mere sprint up a short hill, opening the throttle wide and passing more gas will send the machine bounding up it at top speed, when having attained the summit the gas is again cut down to the lowest point necessary for the speed required.

In tackling a long hill, however, the manipulation is different.

The mixture lever remains constant. The advance sparking is full on and the throttle almost closed as in running on the level.

Now as the long hill is approached, note how the gradient affects the speed of the machine; and as the speed falls, slightly and gradually open the throttle just sufficiently to maintain a speed at which the engine appears to be working comfortably. Nurse it at this with the least gas possible until the steepest portion is approached, and then, if the gradient calls for it, give the engine all the gas by opening the throttle wide, and follow this quickly by a very gradual retarding of the advance spark lever, but hold the speed due to this advance lever as long as possible. Considerable judgment is required in the treatment of hills, and this can be obtained only by experience; but in general the above gives a good idea, the basis of which is to at all times work on the smallest amount of gas possible and make the greatest possible use of the advance, the whole, of course, being controlled by the correct mixture of gas and air, though in some of the modern spray carburetters this point is looked after automatically, others are semi-automatic and a further fine adjustment is left for the rider to make. After a stop, and on re-starting, a little paraffin should always be injected into the cylinder, as this thins down the thick oil and also fills the combustion chamber with explosive mixture if the cylinder is hot enough, so that the engine starts at the first time of asking.

In running downhill, if the hill is short and not steep, it is sufficient to simply lift the exhaust valve, with the benefit to the engine that it gets cool.

If the hill is steep, merely cutting off the current and leaving the exhaust valve closed makes an excellent brake.

If the car or cycle is fitted with a clutch, throwing the clutch out and stopping the ignition to engine allows the vehicle to run down on the brakes; meanwhile the engine is being cooled and refreshed.

Whenever a re-start is made, the carburetter, if of the float-feed type, should be flooded to make sure of a supply of petrol; and whenever a long trip is contemplated, all the items mentioned should receive doubly careful attention, as it is far easier to adjust faulty mechanism at home than on the roadside.

Specially—always carry a good supply of tools and spare parts.

Spare parts are difficult to enumerate unless the type of car is known; but whether car or cycle, such parts as spare exhaust and inlet valves complete, with three or four spare sparking plugs and a good assortment of screws, washers, nuts, insulated and bare copper wire, etc., should be carried.

The great thing in motoring is to take matters quietly; don't be discouraged by a breakdown, but deliberately settle down to find out what is the matter, always remembering that what a machine or motor has once done it can do again when the requisite conditions are restored.

The trouble, whatever its nature may be, is always magnified when it occurs out in the open country, perhaps miles away from any town or repair assistance; thus the careful owner or driver will endeavour to do all his overhauling and repairs at home, and never take out the car otherwise than in the pink of condition. Notwithstanding every care, however, there will be times when a whole series of misfortunes will overtake the driver, and it is on these occasions that his skill and knowledge may be taxed to the utmost. Roadside troubles are of a very varied character, and consequently difficult to foresee or anticipate, but some of the leading ones may be enumerated. As previously stated, the ignition system is the section most likely to cause stoppage or indifferent working, though latterly great advances have been made in the direction of perfecting the apparatus employed. Wrong mixture, or too much of it, can hardly be set down as a fault of the car mechanism, but is clearly the fault of the operator; and in similar manner faulty ignition, due to lack of attention to the accumulators at home, cannot be put down to the account of the accumulators. There are times, however, when the best precautions avail not, as when short circuiting occurs through long-continued wet weather, the obvious remedy being to get the vehicle under cover for examination in the first place, then dry all the parts, and examine the entire circuit for (1st) conductivity, (2nd) insulation.

A very common source of ignition failure in wet weather is direct leakage from the positive terminal of the accumulator to the metal tank in which it is contained, which is in the case of the motor bicycle and other cycles in the return circuit and in direct contact with the negative of the battery, so that not only is failure to ignite the charge experienced, but the plates of the accumulator are or may be seriously damaged. This statement clearly proves that every precaution should be taken to prevent short circuits occurring, and to this end the accumulators should be so cased in with insulating material that, even in the event of a torrent of rain continuing for hours, there can be no chance of water acting as a conducting medium between the two terminals of the accumulator or between any two conductors of opposite sign, always bearing in mind that water is an excellent conductor, a mere film of it serving to rob the sparking plug of the necessary spark, particularly if the leakage should occur in the high-tension or secondary circuit; and as this portion of the wiring is of necessity exposed more or less, the terminals such as the connection from high-tension wire to spark plug are better protected by a covering of gutta-percha tissue or thin sheet rubber solutioned on.

The careful driver will never venture out without a trustworthy volt-meter, for this instrument will tell him many things. Its reading will determine the condition of his accumulators, and give an approximate idea of the distance the cells are good for without further charging; or, if a short circuit or breakage in the conductor is suspected, it will help him to quickly locate the fault.

The induction coil is another delicate instrument in wet weather, though ordinarily it will give no trouble whatever when of good make. If exposed to the wet, the secondary or high-tension discharge will certainly not bridge the air cap at the sparking plug points, but will find a return path by the easiest way home across the watery surface.

On no account should the accumulator terminals be directly connected even for an instant, and neither should an "ampere-meter" be used for testing the current, as this instrument offers little resistance and practically short circuits the cells. A dead-beat volt-meter of about 15 ohms resistance is the proper thing to use.

Finally, the novice should be extremely chary of meddling with electrical fittings or engine parts, or indeed anything else about the vehicle, unless he has grasped something of the function of the part or parts concerned.

Better let a small defect alone than make a big one of it; but all the same, let every defect and failure be an object lesson to be thoroughly learnt and sifted for future reference.

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