Birla Central Library
PILANI (Rajasthan)
Class No 629.2
Book No M833.E
Accession No 55470

The Motor ELECTRICAL MANUAL

Now in its twelfth edition, this comprehensive handbook has been thoroughly revised and describes the operation and maintenance of the electrical equipment of the modern motorcar.

The text has been expanded to include descriptions of several new features such as the ignition timing necessary for higher-grade fuels, the "block-pattern" headlamp lens, flashing direction signals, electrically controlled gear shift mechanisms, electrically operated oil and petrol gauges and fuel pumps, car interior heaters and ventilators, and a chapter devoted to radio equipment has been added.

The Manual, which is well illustrated, is written in simple language and its contents are well adapted for everyday workshop and emergency use.

ALSO PUBLISHED IN ASSOCIATION WITH

The Motor

The Motor Manual
The Motor Repair Manual
The Motor Year Book
The Motor Road Tests
How to Drive a Car
The Driving Test Fully Explained

The Motor

ELECTRICAL MANUAL

Published in association with

The Motor

TEMPLE PRESS LIMITED
Bowling Green Lane, London, E.C.1.

First published 1921
12th edition published 1953
2nd impression 1956

Printed by Purnell & Sons Ltd.
Paulton (Somerset) and London

MADE IN GREAT BRITAIN

CONTENTS

I

INTRODUCTION

THE ELECTRICAL equipment of the modern car appears at first sight to be a very complex arrangement. Perhaps to the majority of car owners it is shrouded in mystery, to be left strictly alone so long as it functions satisfactorily. Since the very early days of motoring, when electricity was used only for ignition purposes, its use has spread extensively until today, instead of being a miscellaneous collection of units added when the car is all but completed, the electrical equipment has come to be looked upon as an integral part of the vehicle, playing an important role in the final standards of performance, appearance and comfort by which the car is judged.

Careful attention is paid to the choice and installation of the electrical equipment by the car manufacturer in the early design stages of a new project; and, equally important, careful attention should be paid by the car owner to the small amounts of maintenance and overhaul required to keep this vital part of the vehicle in first-class working order.

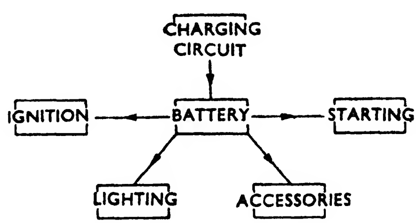
Understanding the Electrical System

Consequently, owners who take an interest in their cars find it necessary to learn something about the electrical system: a few minutes spent in the garage are greatly to be preferred to a few hours at the roadside with a breakdown. As a perusal of this handbook will show, mere maintenance routine and even minor repairs in some instances do not involve interference with the "works". The tasks are mainly of a mechanical nature and no very close acquaintance with either electrical theory or practice is needed. However, it is always helpful to understand how a particular piece of equipment functions, in order to appreciate more clearly how it may be used to best advantage. Given a fairly clear idea of that, the owner has a very good chance of discovering what is wrong in the event of trouble and of correcting the fault. Without such understanding, even the most complete fault-finding chart is likely to be quite useless. The aim of this book, therefore, is primarily to describe how the various parts operate, and secondarily to give the motorist a fair idea of the things which he ought or ought not to do to keep the electrical equipment of his car in good working order.

For both of these purposes a small amount of basic electrical knowledge is essential, and in Chapter II the fundamental principles upon which the whole of the equipment depends for its operation are described in simple, easily understandable language.

The Functions of the Equipment

Before proceeding to this, however, let us first consider the electrical equipment of the car as a whole and determine the purpose of each of the various items.



The illustration above shows how we can look upon the installation as consisting of six separate sections:

The Battery, which will be seen to be the nerve-centre of the whole installation, since it must supply electrical power to operate all the other units except the charging device.

The Charging Circuit, consisting of the dynamo and its associated control equipment, whose purpose is to generate electricity while the car is running to refill or "charge" the battery. Unless this were provided, the continual drain by the other equipment would soon cause the battery to become run down.

Ignition. The driving power of the petrol engine is derived from a rapid series of explosions of compressed gases in the engine cylinders. To ignite the gases, accurately timed high-voltage sparks are necessary and these are provided by the ignition equipment, which usually consists of an ignition coil fed from the battery, a distributor unit and sparking plugs. In a few cases, a single component known as a magneto is used; this device was very popular in the earlier days of motoring since it did not depend on the then rather unreliable battery; but with the development of the latter to its present-day dependability the magneto has been superseded by coil ignition on all engines except those used for racing, agricultural, industrial and marine purposes.

Starting, achieved by means of a high-speed motor which turns the engine over until it fires and continues to run under its own power. The elimination of the breathtaking operation of swinging the engine by hand is a boon which only those who experienced it will appreciate fully.

The Lighting Equipment, comprising head, side and rear lights, fog lamps, number-plate illumination lamps, interior lights, etc. In the early days the innumerable disadvantages of oil and acetylene lighting were accepted because there was nothing better available. It was soon realized, of course, that electricity would provide the ideal lighting system for road vehicles; but there were so many problems to be solved. Soon, however, sets of various kinds became available, and electric lighting started on its path to universal application.

At first it was usually an "extra", costing anything up to £50 if a dynamo formed part of the equipment. Progress in design and manufacture rapidly brought down the price, and eventually the system was standardized, first on the more expensive cars and later on lower-priced vehicles as well.

The Accessories. Under this heading are included direction indicators, horns, windscreen wipers, electric petrol pumps and gauges, defrosters, heaters, cigarette lighters, radio sets and so on.

Thus, what seems to the novice to be a mass of wires, switches and gadgets can readily be subdivided into quite separate channels. In this book, once we have grasped the fundamental principles of the next chapter, we shall take the sections outlined above and make a more detailed study of each device.

II

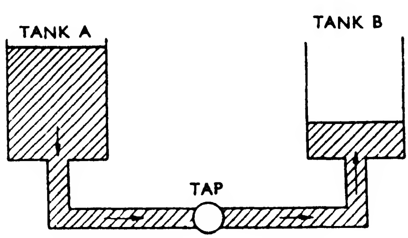
BASIC ELECTRICAL THEORY AND PRINCIPLES

ELECTRICITY CAN exist in several forms. We are concerned, however, only with what is known as "dynamic" electricity, that is, electricity in motion, the form of electricity generated by a dynamo, stored in a battery and used to operate various electrical devices.

To understand something about this form of electricity, we must ask the reader to accept certain given facts: to explain why they are facts would require several further chapters and would, in the end, probably be more confusing than helpful.

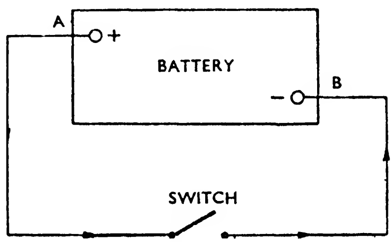
The Electrical Circuit

The most usual, and possibly the easiest, way of understanding the manner in which an electrical current is caused to flow in a circuit is to compare such a circuit with its hydraulic counterpart. In the illustration, the two tanks



A and B contain water at different levels and are joined by piping in which is positioned a tap or valve. If the tap is opened, water will flow from a tank A to tank B as long as there is a difference in their water levels, which may be termed a pressure difference between the tanks. As soon as the levels are equalized, the pressure difference is reduced to zero and no further flow takes place.

Similarly, in an electrical circuit, electricity will flow from a point at high pressure to a point at low pressure through a connecting conducting medium. For instance, in the simple circuit shown, closure of the switch results in a flow of



current from A to B through the external wiring. What is known as the positive (+) terminal of the battery is conventionally looked upon as the high-pressure terminal, the negative (−) terminal being regarded as the low-pressure side. Thus, just as in our hydraulic analogy, water flows as long as there is a pressure difference between the two tanks, so in the electrical circuit current flows from positive to negative until such time as there is no longer a pressure difference between them, when the battery is said to be discharged.

Whereas in the case of the water system pressure is measured in pounds, electrical pressure is measured in VOLTS. A 12-volt battery is so called because the pressure difference (usually known as potential difference or electromotive force) between its terminals when fully charged is 12 volts. Similarly, house lighting supplies are usually 230 volts, this being the potential difference between the feed and return wires entering the house meter. The electrical grid distribution network operates at voltages up to 132,000.

Again, water flow is measured in gallons per unit time, while electrical current is measured in coulombs per unit time, the gallon and the coulomb being units of quantity in each case. A current flow of 1 coulomb per second is known as 1 AMPERE, the ampere being the standard unit of current measurement. Hence, the statement that a wire is carrying a current of, say, 3 amperes means that 3 coulombs of electricity are passing through the wire each second.

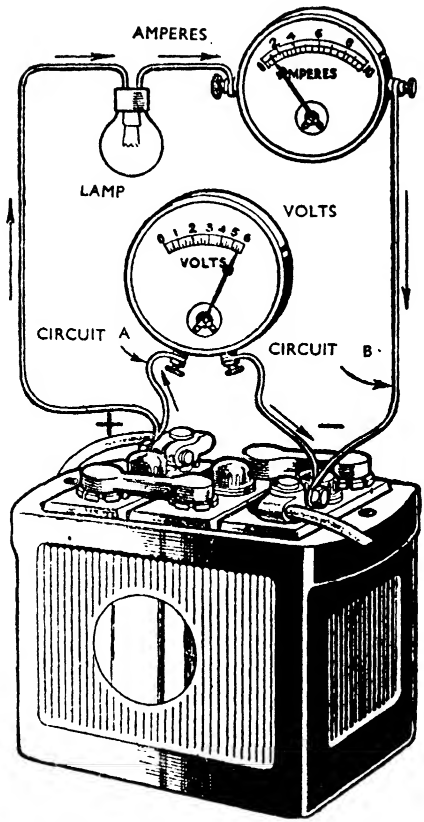
This rate of flow depends upon the characteristics of the connections between the two points across which pressure difference exists. Reverting once again to the hydraulic circuit, the length, size of bore and temperature of the connecting piping all have a bearing on the rate of water flow. Similarly, the length, area, material and temperature of the conductor joining the battery terminals all affect what is known as the "resistance" of the conductor to the flow of electrical current through it. This value of resistance increases with increased length of the conductor but decreases as its diameter, or cross-sectional area, increases. A thin wire will carry a small current, but for heavier currents a wire of larger diameter is necessary, just as a large-diameter pipe is necessary to permit large quantities of water to flow. The unit of electrical resistance is called the OHM, and a circuit or wire is said to have a resistance of 1 ohm when a current of 1 ampere flows in it with an applied potential difference of 1 volt.

Hence, to summarize thus far, we now have three fundamental units which form the basis of all our understanding of dynamic electricity:

Potential Difference, measured in volts, which is the electrical pressure necessary to cause a flow of *Current,* measured in amperes, in a wire which possesses *Resistance,* measured in ohms.

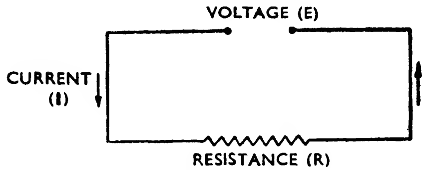
Ohm's Law

A definite relationship exists between these three fundamental units. Known as Ohm's Law, it is one of the most used relationships in electrical engineering and it can be very valuable in helping to trace many electrical troubles. The Law says that "the strength of an electrical current varies directly as the potential difference and inversely as



In an electrical circuit, it is the pressure (or volts) which causes the current (or amperes) to flow through the resistance (or ohms) offered by, say, a lamp bulb or other part of the circuit.

the resistance of the circuit". In other words, if the voltage (symbolized by the letter E) applied to the circuit is doubled, then the current I will be doubled also. On the other hand, if the voltage remains constant but the value of the resistance R be doubled, then the current will be



reduced to half of its original value. For those having a mind for formulæ, this relationship may be expressed as:

$$I=\frac{E}{R};\ E=I\times R;\ \text{or}\ R=\frac{E}{I}$$

where E is the voltage, I the current in amperes and R the resistance in ohms. Thus, by knowing two of the values, the third may be simply calculated.

The Ampere-hour

Particularly in connection with batteries, one often meets the expression "ampere-hours" which indicates a quantity of electricity because it means a current of a given strength flowing for some stated time. Although there are some complications which will be discussed in Chapter IV, the quantity of electricity which a battery is capable of storing is known as its capacity and is expressed as so many ampere-hours.

The Unit of Electrical Power

Another electrical unit must be mentioned here. This is the unit of power, or the rate at which electrical energy is consumed. The unit is the WATT, defined as the power used when a current of 1 ampere flows through a circuit having 1 volt applied to it. Expressed as a formula, power $=$voltage $\times$ current, or $P=E\times I$ where P is in watts and E and I in volts and amperes respectively as before. For example, the power required from a 12-volt battery to supply 3 amperes to a headlamp bulb would be $12\times 3=$ 36 watts.

Electrical apparatus is invariably rated in terms of wattage. An electric fire, for instance, may be rated at 1 kilowatt (which is a shortened way of saying 1,000 watts), while electric-light bulbs are listed by their wattage, this being a measure of the power which they consume and hence their respective brightness. One horsepower is the equivalent of 746 watts.

As a matter of general interest, although not strictly within the scope of our subject of automobile electrical equipment, it might be mentioned that for costing purposes the electricity supply undertaking calculates energy used in Board of Trade Units (B.O.T. Units). This unit, also often referred to as the kilowatt-hour, corresponds to a consumption of electricity of 1,000 watts for 1 hour. Thus 1 B.O.T. unit of electricity is consumed by a 1-kilowatt fire burning for 1 hour, a 100-watt lamp burning for 10 hours, and so on.

Conductors and Insulators

All materials allow the flow of electricity through them to a greater or lesser extent but, at the same time, all possess some degree of resistance to current flow. Those substances offering least resistance are known as conductors, whilst those offering so much resistance that, to all intents and purposes, current is prevented from flowing in them, are called insulators.

Most metals are conductors, silver heading the list for good conductivity, that is, the property of allowing a flow of current through it. For various reasons, chief among them being cost, silver is not generally used in the form of wire in electrical practice. Copper, which also has low resistance, is comparatively cheaper than other good conductors, has considerable mechanical strength, and is recognized as being the best all-round commercial proposition. It is used extensively in all spheres of electrical engineering, the car installation being no exception. At the lower end of the conductivity range for metals are a few which possess considerable resistance, and these are of value in certain special forms of circuit where it is necessary deliberately to restrict the amount of current which passes. Certain nickel alloys are chiefly used for the making of these "resistance wires".

Insulators include among their number such materials as glass, mica, bakelite, rubber, porcelain and fibre. Since all current-carrying wires on a car must be protected from each other and from the metal of the chassis and body, they are usually covered with either rubber or a combination of enamel and cotton, being then known as insulated conductors.

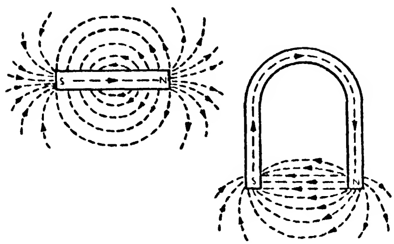
High-tension currents have a considerable tendency towards leakage, hence the thick rubber covering on the ignition cables to the sparking plugs. On the other hand, for low-voltage work there is less need for heavy insulation, even when the wires are carrying considerable current. The amount of insulation necessary is thus determined by the voltage and not by the current flowing in the conductor.

Magnetism

Before we can go any further it is necessary for us to understand something of the nature of magnetism, for it is closely connected with electricity although of an entirely different character.

Taking the case of the common horseshoe magnet with which all readers will be familiar, it will be readily agreed that some invisible force must exist between the two ends, enabling the magnet to attract other pieces of iron and steel. It is accepted that this invisible force is due to the "magnetic field" of the magnet. This magnetic field is conventionally represented by "lines of force" which flow out of the north pole of the magnet and into the south pole, forming a complete circuit through the magnet itself. The magnetic fields existing around magnets of bar and horseshoe patterns are illustrated overleaf.

There are two categories into which magnets may be placed, either "permanent" or "temporary". A bar of hardened steel, once magnetized, will retain its magnetism almost indefinitely under normal conditions, and is therefore known as a permanent magnet. Recent developments in



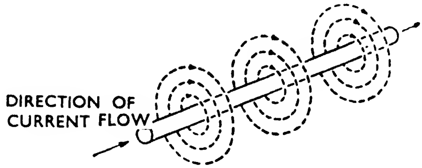
Lines of force, or magnetic flux, as indicated by the dotted lines, can be shown by sprinkling iron filings on to a sheet of paper held over the magnet.

permanent-magnet steels have resulted in considerably more powerful magnets being produced for a given size of material and hence comparatively large savings in both size and weight have been made possible. Further reference to this will be made in the chapter dealing with magneto-ignition units. The second classification applies to materials which behave as magnets only whilst a magnetizing force is applied to them. Soft iron is the chief of these materials and, as will be seen, is used often in electrical practice.

Electro-magnetism

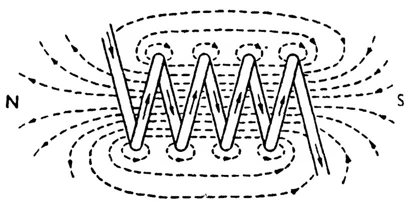
Here we begin to link up electricity and magnetism. When an electric current flows along a wire, it has the additional effect of setting up a magnetic field around the wire, the strength of the field being in proportion to the amount of current which the wire is carrying. The lines of force in this case are in the form of concentric circles around the wire and their direction is considered to be clockwise when looking along the wire in the direction of current flow.

If the conductor is wound in the form of a coil, or solenoid as it is sometimes called, then it can be shown that nearly all the lines of force will leave one end of the coil, pass round the outside circuit, enter the other end of the coil and return through it to complete the circuit. It thus



Lines of force set up around conductor carrying current.

has the same magnetic characteristics as the bar magnet which we discussed previously. If a bar of soft iron is now inserted into the coil, the magnetic strength will be increased many times, due to what is known as the permeability of the iron, that is, its ability to conduct lines of force. Thus we have now produced a strong temporary magnet: as long as current flows in the conductor, a strong

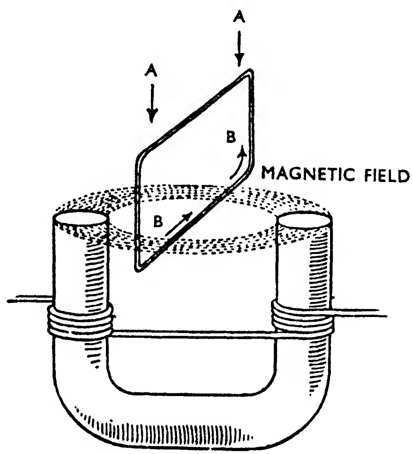


Magnetic field surrounding coil.

magnetic field will exist in the soft-iron core; but when the current is switched off, the magnetic field will collapse and disappear. This effect of electromagnetism has many applications in electrical engineering.

Electromagnetic Induction

Just as an electric current can set up a magnetic field around a conductor, so also, if suitably applied, can a magnetic field give rise to an electric current. Supposing that a conductor is moved through a magnetic field in such a way that it intersects the lines of force, then a current will be caused to flow in the conductor, the strength of the current depending upon the strength of the field and the rate at which intersections take place. The origin of the magnetic field is of no consequence. It can be provided either by a permanent magnet or by the electromagnet just described. Moreover, the same result will occur whether the conductor moves across the magnetic field or the field moves across the conductor. All that matters is the number of lines of force intersected by the wire in a given period of time.

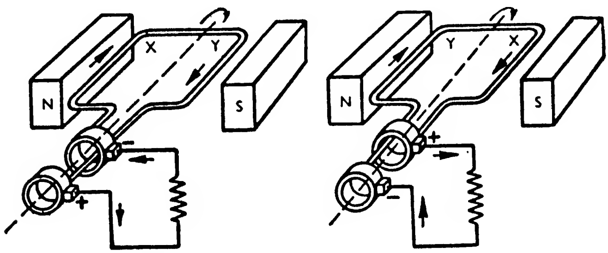


When a coil of wire is moved (as shown by arrows A, A) in a magnetic field, produced by a permanent or an electro-magnet, a current is induced in the circuit (arrows B, B).

The direction in which the current flows along the conductor depends upon the relative direction of movement between the conductor and the lines of force. If by moving the conductor in one direction we make the current travel along it from left to right, then by moving it in the opposite direction we shall also reverse the current and make it travel from right to left.

Generation of Electricity

Now let us see how these facts can be used to enable us to produce electricity for use on the motor vehicle. If a loop of wire is rotated in the magnetic field existing between the poles of a magnet, the ends of the loop being connected to two metal rings insulated from each other and rotating with the loop, then in the position shown at (a) in the illustration the wire X is cutting the lines of force in an upwards direction, causing current to flow, say, away from the observer. At the same time wire Y is cutting the lines



Simple A.C. Generator.

of force in a downwards direction, inducing a current flowing towards the observer. Thus a current will flow through the loop of wire and the external circuit, via the collector brushes of carbon or metal bearing lightly on the rotating rings.

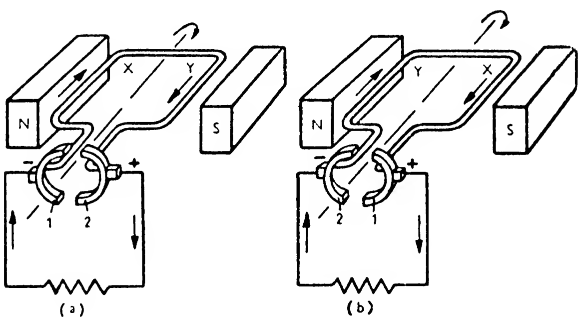
After the loop of wire has completed half a revolution the state of affairs shown at (b) is reached. Now wire X carries current flowing towards, and wire Y carries current flowing away from, the observer, with the result that the current flowing through the external circuit is reversed.

For each revolution of the coil, therefore, two surges of electrical current are produced in the loop, the surges being of opposite directions. This type of electricity is known as alternating current (A.C.), each brush being positive and negative alternately.

With various elaborations, this is the sort of machine used in the power stations which supply our homes and factories. For these purposes alternating current has certain advantages, but for the motorist it has one serious disadvantage. Battery charging requires a unidirectional current, otherwise each reversal of current would mean that whatever had just been put into the battery by one surge would be taken out again by the next, and this could serve no useful purpose in the case in which we are interested.

The Direct-current Dynamo

To obtain the constant-direction current, either the A.C. can be rectified by means of separate apparatus or certain modifications can be made to the generator itself. The latter course is the one adopted on cars as it is more convenient and cheaper. It entails replacing the collector rings by a device known as a commutator, and to understand the operation of this we will revert to our example of the simple loop rotating in the magnetic field.



Simple D.C. Generator (Dynamo).

The illustration shows that the commutator consists of two segments connected to the two ends of the loop but insulated from each other. Each collector brush bears first on one segment and then on the other, since the loop and commutator rotate together. When the commutator has turned through half a revolution, the segment which was in contact with the positive brush will now have made contact with the negative one. In the meantime, the direction of flow through the loop itself will have reversed and thus the flow of current from the dynamo through the external circuit will always be in the same direction, namely from positive to negative.

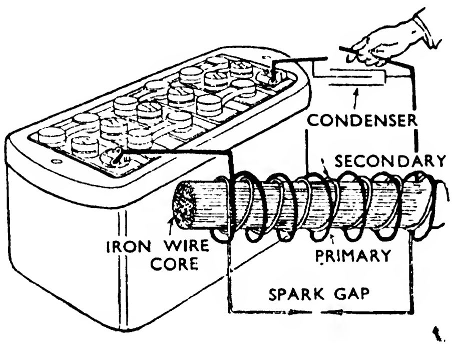
The current produced in a single loop is only small but by arranging a large number of loops or coils equally spaced on a laminated iron core, each loop being connected to a pair of segments on the commutator, a large and practically continuous steady flow of current can be obtained. Such a rotating assembly is known as an armature.

Direct-current Motor

Before leaving the subject of rotating machinery let us take a brief look at what happens if, instead of rotating the armature of our simple direct-current dynamo by mechanical means, we connect the brushes to the terminals of a battery so that current is permitted to flow through the loop via brushes and commutator. It will be remembered that a magnetic field will be set up around the wire; the effect of interaction between this magnetism and that existing between the poles of the main field magnet will be to cause the loop to rotate. Movement of the loop takes place due to the crowding of the magnetic lines on one side of the conductor more than on the other, resulting in repulsion of the conductor. The electric starter on the car works on this principle. As in the case of the dynamo, the armature employs many coils equally spaced around the iron core. Each coil carries current, the net result being a comparatively high turning power which is usefully employed in cranking the engine.

The Induction Coil

Reverting once again to our basic fundamentals, we have seen that current is generated in a conductor which intersects the lines of force of a magnetic field. This is equally true in the case of two wires laid side by side. If current is flowing in one of the wires and is suddenly interrupted, the subsequent collapse of the magnetic field about that wire will cause intersections, giving rise to a momentary current, in the second wire. This fact is made practical use of in the ignition coil and magneto, where the two wires are in coil form and are actually wound one over the other. In these cases, current flowing through a coil known as the primary,



An ignition coil is a familiar example of induction. Current is passed through a wire coiled around a soft-iron core, and when that current is interrupted, another current is induced to flow through a second wire coiled around the same core.

wound on a soft-iron core, gives rise to a strong magnetic field. Sudden interruption of the primary current causes the magnetic field to collapse, the lines of force cutting the turns of the second coil (or secondary winding) and causing a voltage to be induced in it. The value of this voltage is in proportion to the ratio of turns in the two windings. For example, if there are one thousand times more secondary turns than primary turns and the voltage impressed on the primary is 12 volts, then the induced secondary voltage be $1{,}000 \times 12 = 12{,}000$ volts. As will be explained later, this high secondary voltage is utilized in the ignition system to produce the spark at the sparking-plug points.

Self-induction

Unfortunately, when the magnetic field collapses in the induction coil not only do the lines of force intersect the turns of the secondary winding but also lines of force of one primary turn intersect other neighbouring primary turns. This gives rise to an effect known as self-induction, which can be demonstrated very well by winding an insulated wire many times around a soft-iron core, passing a current through the wire and then interrupting it. At the place and moment that the circuit is broken there will be a flash, even though the original voltage be quite small. This flash is due to the fact that when the original current ceased the magnetic field collapsed and its lines of force thus crossed the turns of the wire winding and in so doing generated another current for an instant in that winding.

In the chapter dealing with ignition, the disadvantages of self-induction will be discussed and a description given of a component known as a condenser which is designed to overcome the effects of self-induction.

III

WIRING

SINCE THE various components of the electrical system cannot function without some means of conducting current to and from them, the wiring is an extremely important part of the installation. The multiplicity of cables in the modern car, and the somewhat fearsome appearance of the wiring diagram (at first sight, at any rate) may tend to discourage the amateur from having anything to do with the wiring layout. However, it will be seen that a small amount of attention may adequately be repaid.

Unlike household and similar wiring, the cables on a car must be capable of withstanding the effects of heat, vibration, dampness, oil and, quite possibly, also of corroding gases. Cable manufacturers have succeeded in producing cables to withstand these somewhat arduous service conditions, and provided that the wiring is held securely in position, not allowed to chafe against sharp metal edges, spaced away from hot parts of the engine and not liable to become saturated with oil, it is most unlikely to give trouble during the life of the car.

The main wiring is carried out at the factory, with cables which must conform to a definite specification regarding current-carrying capacity, mechanical strength, insulation and external protection. All cables which run in the same direction for any distance are collected together in a braided protective outer covering, so that only the ends of the cables are exposed near to their positions of connection. Cables which are particularly exposed to the effects of weather, such as those to the rear lamps, are sometimes additionally protected by a spiral metal covering. The complete wiring assembly is known as the cable harness.

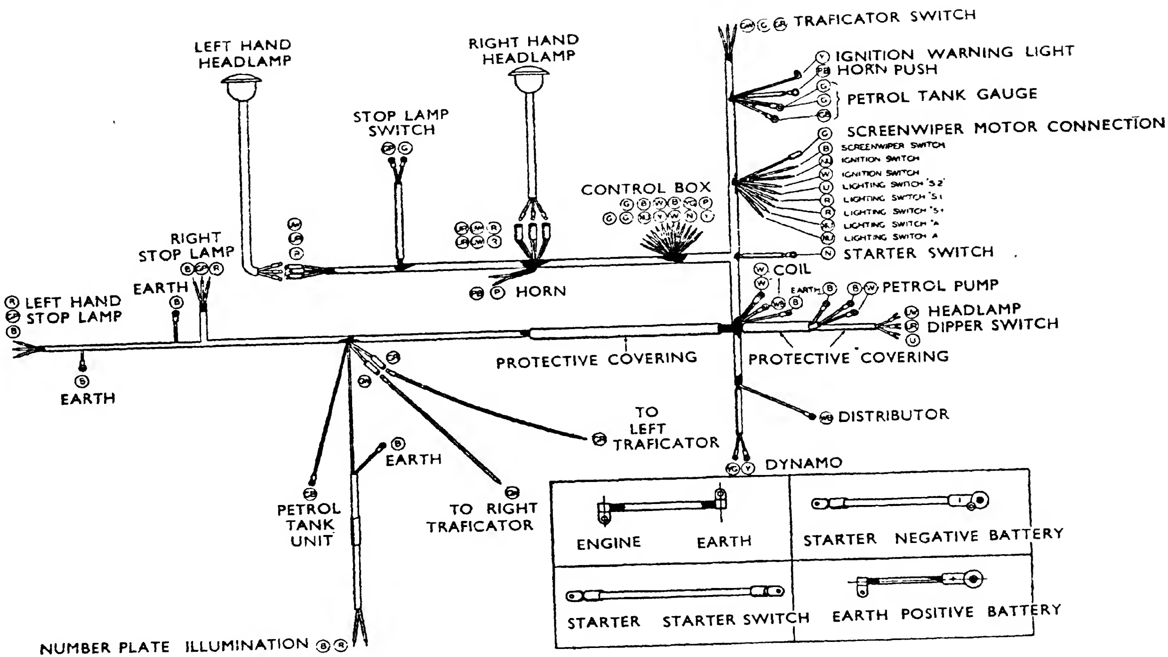


Illustration of typical Cable Harness.

Cable Sizes

The size of each of the cables used in making up the harness is carefully determined by the makers from a study of the current to be carried and the length of cable run necessary to connect to the device in question. As we have already seen, when current flows in a wire, against the resistance of that wire, a voltage drop is produced ($= I \times R$), the effect of which is to reduce the voltage available to operate the device. If this voltage drop is too great, the device will work at reduced efficiency.

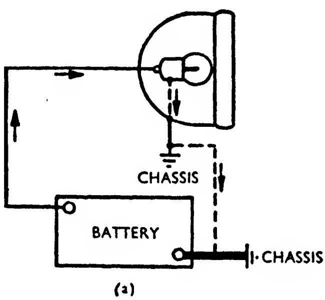
It is very important, therefore, that cable of adequate current-carrying capacity is used. A cable used for, say, a tail lamp circuit where the current to be carried may be only 1 ampere can be very much thinner than the cable used in the dynamo circuit which must carry currents of the order of 25 amperes. Similarly, if a comparatively long run of cable is necessary to connect to a particular electrical unit, then the cable must be somewhat larger in diameter than if the length was only short, because, as we know, resistance increases directly as length.

The effect of using cable of insufficient size, in addition to giving an increased voltage drop, is also to cause overheating, since the cable cannot properly handle the current. Usually, this matter does not concern the owner, unless he decides to fit some extra accessory. Even then, these are usually bought with the correct size of cable attached.

As a point of interest, however, it might be mentioned that the size of a cable is designated by the number and gauge of the wire strands forming the core. Thus a cable may be known as 35/·012, meaning that it is made up of 35 strands of wire each of ·012 in. diameter. The cables used in the car wiring harness usually vary from about 14/·012, suitable for currents up to about 7 amperes, to 45/·012, which can carry 15–20 amperes without excessive voltage drop for the lengths usually met with on the car. The cable from the battery to the starter switch and starter motor, which takes several hundred amperes for a very short time, will be noticed to be of extremely large diameter.

Earth and Insulated Return Systems

We saw in the early part of Chapter II that an essential feature for a flow of current from a point of higher to a point of lower potential is the provision of a complete conducting path between the two points. For example, taking the case of a lamp, current must flow from the positive side



(*a*) *Earth Return System*
One side of the bulb is connected internally to the lamp body, which in turn is connected to chassis.

(*b*) *Insulated Return System*
In this case, the path to and from the bulb is wired, the bulb carrying two contacts.

of the battery outwards to the lamp and then return to the negative battery terminal. The switch is merely a convenient means of interrupting that continuous path or completing it again at will.

Earlier motor vehicles were provided with cables for both the outward and return paths of every circuit. Nowadays it is the general practice on cars and many other road vehicles to use the metal of the car chassis itself in place of either the outward or return cable. This scheme has the advantage of reducing the number of individual cables required by half, and with the increasing numbers of electrical circuits on the modern vehicle, the benefits of this will be self-apparent. Such a system is known as an "earth-return" or "single-pole" installation, while the original layout with twin wires to each device is known as an "insulated-return" or "double-pole" system.

When single-pole wiring was first introduced, the normal arrangement was to use a cable from the positive battery terminal to the units, and to connect the negative battery terminal to the chassis. Hence the name earth-return, since the outward path for the current was through the cable and the return path through the chassis.

Why this arrangement was chosen is not clear, but a few years later it was shown to be much better to reverse the procedure and connect the positive terminal to the chassis, the cables being connected to the negative terminal. Thus, retaining the conventional direction of current flow from positive to negative (although later electrical knowledge tends to disprove this convention) the outward path for the current is now through the chassis, the cables forming the return path. The expression "earth-return" still remains, however. The main advantages gained from this reversal concern battery terminal corrosion, reduction of wear on the plug points and distributor electrodes in the high-tension ignition system, and the lowering of sparking-plug voltage.

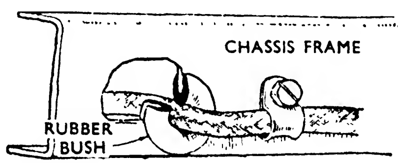
At this stage we have not advanced far enough to understand the reasons for these technical advantages, but further references will be made to positive earthing when we deal with batteries and ignition systems.

Protecting the Insulation

It will be realized that, with the earth-return system of wiring, it is extremely important that none of the wires are allowed to come into contact with the chassis unless protected by insulation. The result of such a contact occurring would be to produce what is known as a short-circuit; in other words, current would be allowed to flow unhindered from the battery through chassis and wire, and this current might reach quite a high value. In addition to discharging the battery, the heavy current flowing through the wire might lead to overheating, with its consequent risk of fire.

For this reason also, makers of electrical equipment recommend that before making any adjustments to wiring or fitting new accessories the cable to the earthed battery terminal should be disconnected at the battery. This advice is well worth following unless you have a battery master switch fitted (*see page* 33) which produces the same result but does not entail actually disconnecting the terminal.

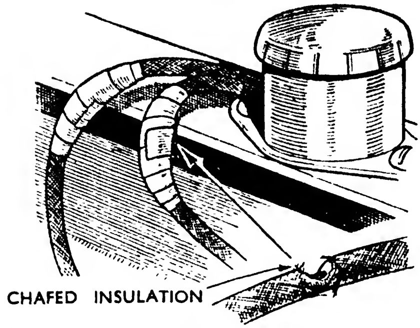
However, to dispel fears that short-circuits in the wiring are likely to cause the owner considerable trouble it must be stated here and now that the wiring of the modern car has been developed to a degree of great reliability, faults



In modern cars chafed insulation is practically abolished by such devices as this rubber bush and the bell-mouthed clip.

in the actual wiring being extremely infrequent. The possibility of chafed insulation is practically abolished by the use of bell-mouthed clips for holding the cable harness in position and rubber bushes inserted at points where cables pass through holes in the chassis.

It is advisable, nevertheless, to inspect all wiring occasionally, looking particularly for loose terminal connections or any sign of chafing, which can be remedied by the application of insulating tape, as shown in the illustration overleaf. Any wires which appear wet, oily or dirty should be wiped clean, as these factors tend to rot the insulation. Also, if any wires appear to have become trapped against metal surfaces, or to be touching hot parts of the engine, exhaust pipe, etc., they should be freed.



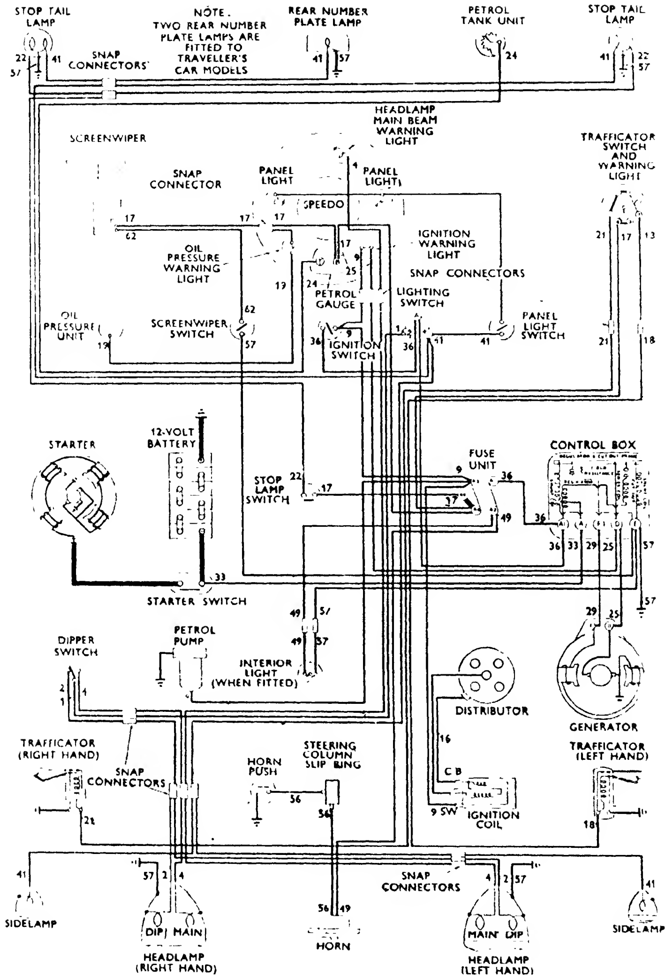
A typical insulation fault due to chafing against some other part of the car.—Insulation tape can be used to repair the defect.

Understanding the Wiring Diagram

The diagram on page 27 illustrates the complete wiring layout of a typical smaller car. Although at first sight it may appear to be a collection of wires with no planned purpose, a little study will show that quite the reverse is the case.

Since the numerous cables involved in a modern car electrical system are, as already described, braided into a single harness assembly, it is obviously necessary to provide some quick means of identification of the cable ends emerging from the braid. This is achieved by suitably colouring the outer protective surface of the cables, in either one or two colours.

In the past there has been a diversity of colour schemes by various makers, but a definite code of practice is now being established generally. It consists of allocating a basic colour to a particular group of wires and distinguishing between wires in that group by the use of a coloured tracer woven spirally into the braided insulating covering of each wire. Thus in the wiring diagram illustrated all circuits connected with the dynamo utilize the basic colour YELLOW. The lead from the D terminal on the dynamo to the control box is yellow only, while the lead from the



KEY TO CABLE COLOURS

1 BLUE	14 WHITE with PURPLE	27 YELLOW with BLUE	40 BROWN with BLACK	53 PURPLE with WHITE
2 BLUE with RED	15 WHITE with BROWN	28 YELLOW with WHITE	41 RED	54 PURPLE with GREEN
3 BLUE with YELLOW	16 WHITE with BLACK	29 YELLOW with GREEN	42 RED with YELLOW	55 PURPLE with BROWN
4 BLUE with WHITE	17 GREEN	30 YELLOW with PURPLE	43 RED with BLUE	56 PURPLE with BLACK
5 BLUE with GREEN	18 GREEN with RED	31 YELLOW with BROWN	44 RED with WHITE	57 BLACK
6 BLUE with PURPLE	19 GREEN with YELLOW	32 YELLOW with BLACK	45 RED with GREEN	58 BLACK with RED
7 BLUE with BROWN	20 GREEN with BLUE	33 BROWN	46 RED with PURPLE	59 BLACK with YELLOW
8 BLUE with BLACK	21 GREEN with WHITE	34 BROWN with RED	47 RED with BROWN	60 BLACK with BLUE
9 WHITE	22 GREEN with PURPLE	35 BROWN with YELLOW	48 RED with BLACK	61 BLACK with WHITE
10 WHITE with RED	23 GREEN with BROWN	36 BROWN with BLUE	49 PURPLE	62 BLACK with GREEN
11 WHITE with YELLOW	24 GREEN with BLACK	37 BROWN with WHITE	50 PURPLE with RED	63 BLACK with PURPLE
12 WHITE with BLUE	25 YELLOW	38 BROWN with GREEN	51 PURPLE with YELLOW	64 BLACK with BROWN
13 WHITE with GREEN	26 YELLOW with RED	39 BROWN with PURPLE	52 PURPLE with BLUE	

F terminal on the dynamo is yellow with a green tracer. Similarly, all circuits which are fed direct through the ignition switch, such as the ignition coil and electric petrol pump, have WHITE as their basic colour. Other colours, and the circuits to which they refer, are as follows:

BROWN. All unfused circuits connected direct to the battery (e.g. ammeter, cigar lighter, wind-tone horns on more recent cars.)

GREEN. All circuits of units fed through the ignition switch and fused (that is, those units operative only when the ignition is switched on, such as the windscreen wiper).

PURPLE. Circuits of units fed from the ammeter and fused (those units operative whether the ignition is on or off).

BLUE. Circuits fed through the headlamp switch.

RED. Circuits fed through the side lamp switch.

BLACK. Earth circuits.

A little practice on one's own car of identifying cables from their colours as shown on the wiring diagram usually included in the Instruction Manual will be found of use in understanding the general wiring layout.

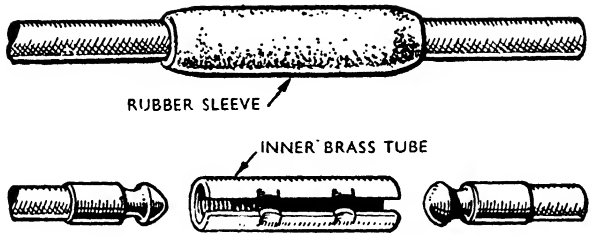
Snap Connectors

In most wiring diagrams will be found a reference to what are known as snap connectors.

These useful little devices enable various sections of a wiring harness to be joined together quickly and effectively. The connector consists of a shaped brass tube covered externally by a rubber sleeve. Waisted thimbles are soldered to the ends of the cables to be joined and, when these are pressed fully home into the brass tube, they snap into position, forming a fully insulated joint.

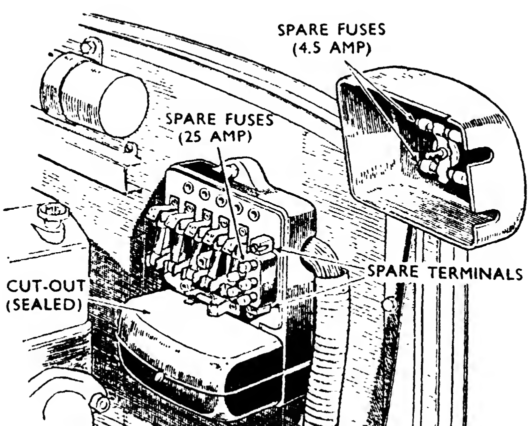
Protection by Means of Fuses

The fuses which protect the wiring system of a car are extremely important features, and no attempt should ever



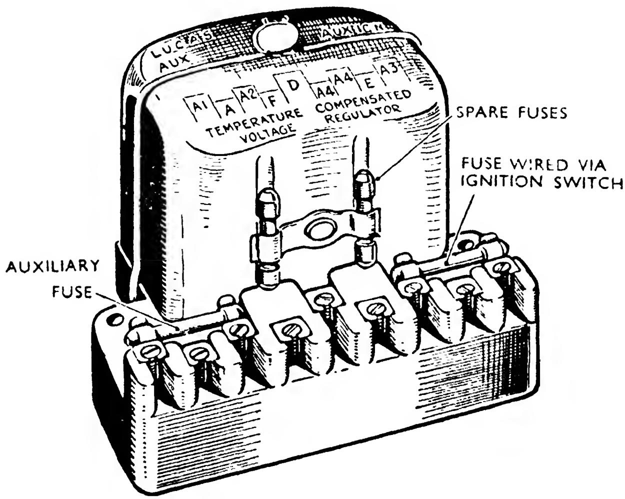
The "snap connector". The upper view shows the finished joint, whilst below are shown the component parts. Multiple combinations are also used in addition to the single unit shown.

be made to alter them in any way. On some old cars there is only one fuse, in the dynamo field circuit. Then for a time it was general practice to go to the other extreme and to include a fuse in each separate circuit. Thus, there was one for the headlamps, another for the side and tail lamps, another for the horn, and so on. More recently, the



In some earlier installations there were half a dozen separate fuses as shown in this drawing. Spare fuses were often carried in holes formed in the moulded base.

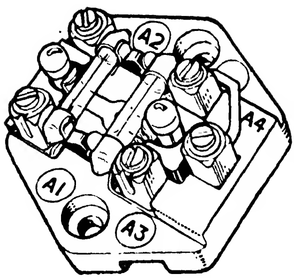
number of fuses has again been reduced, and in the modern set there are usually only two. These are housed either in a small moulded fuse unit or in the control box, which is a device containing the dynamo voltage regulator and cutout, both of which items will be described in due course. The two fuses are connected in the circuits of the accessories, one protecting those accessories which can be used only when the ignition is switched on, such as the windscreen



This control box carries only two operative fuses, and two spares clipped to the sealed cover.

wiper, direction indicators and stop lamp, while the second protects certain units which can be operated whether the ignition is on or off.

The fuses are invariably of the tubular or cartridge type, carried in brass clips. A small glass tube has brass caps at each end, the fuse wire passing through the tube and being soldered to the caps. Also contained in the tube is a slip of paper upon which is marked the current-carrying capacity of the fuse. This depends on the maximum load which may be applied with safety to the wiring of any



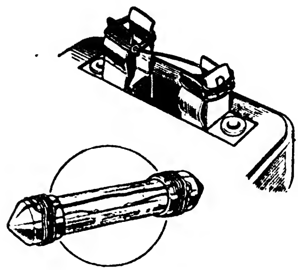
A typical fuse unit, housing two fuses and spares.

given circuit, and the fuse is arranged to blow when that particular load is reached. Generally there is an ample safety margin, so that in the case of the auxiliary circuits, several additional devices may be connected without fear of overloading the fuse. This will blow, however, in the event of a short circuit which gives rise to a heavy flow of current.

The fact that a fuse has blown is an indication of a fault in the circuit and it is inadvisable to fit a new fuse until the cause of the trouble has been located and remedied, otherwise the new fuse will probably blow immediately. Sometimes a little logical diagnosis will enable the fault to be traced very quickly. For instance, if the fuse were to fail at the moment of switching on the windscreen wiper (indicated by the failure of the other units protected by the same fuse) it is probable that the wiper or its wiring was at fault. If, however, the wiper was working steadily at the time of failure, it is less likely to be the cause of the trouble. By a similar process of elimination various other circuits can be ruled out, and the faulty one soon discovered. If the cause is not apparent, however, take the car to a service station.

Fuse Replacement

When a fuse has blown, the replacement must be of the same rating as that originally fitted. Never fit a heavier fuse in an attempt to prevent continued blowing, or the equipment and wiring will not have the degree of protection which they need. It is always advisable to use only fuses supplied by the makers of the electrical equipment. In cases of emergency, when no approved fuse may be obtainable, a suitable compromise may be arranged as described below, but no time should be lost in purchasing the proper replacement as soon as possible.



Two ways of using ordinary fuse wire if a cartridge fuse is not available.—That shown at bottom is probably the most satisfactory for it ensures good contact without difficulty.

First determine the fusing value from the slip of paper inside the fuse body. Then, with a length of ordinary fuse wire (or several strands in parallel if, as is quite likely, the fuse wire is of lower amperage than that required), make temporary connections by winding the wire either around the fuse clips or around the end of the blown fuse as illustrated. For example, if a 25-ampere fuse is needed and the only fuse wire available is of 5-ampere rating, then five strands of this wire will obviously be the equivalent of one strand of 25-ampere fuse wire.

Connecting Extra Accessories

When fitting a new accessory, such as a fog lamp, the maker's fitting instructions should be followed carefully. The feed connection should be made to either (*a*) the fuse which is permanently fed from the battery, in which case the accessory may be used at any time (and inadvertently left on when the car is parked for the night in the garage!), or (*b*) to the fuse which is energized only when the ignition is switched on, in which case the accessory can be used only whilst the engine is running, and so cannot be the source of a flat battery through being left on all night. On the majority of British cars the former circuit is supplied from terminal A2 and the latter from terminal A4 on the control box or fuse unit. Another arrangement which may be encountered is that in which the fog lamp is connected to the side-lamp terminal of the lighting switch, so that the fog lamp can be used only when the side lamps are in use, which is, of course, quite a logical arrangement.

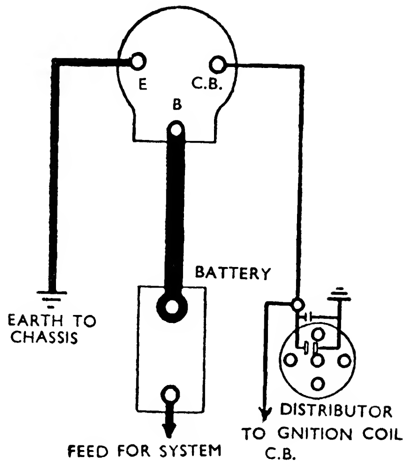
To make good connections to the brass terminals, the cable end should be bared for about $\frac{3}{8}$ in. and turned back about $\frac{1}{8}$ in. so as to form a small ball which, when the grub screw is removed, fits in the terminal post. When the grub screw is replaced and tightened up, a good connection will be made which cannot be pulled out of the terminal.

Proper care must be taken to see that the new cable is not clamped against sharp edges where there is risk of abrasion through vibration. It is a good idea to tape it to existing cables where possible. Avoid taking the cable round acute bends and also avoid, as far as possible, fixing the cable where it can be splashed by water or oil.

Battery Master Switch

Mention of the battery master switch has already been made. This switch enables the battery to be completely isolated from the remainder of the electrical equipment, so serving as a protective device when carrying out wiring alterations or in case of emergency, and as a safeguard for a parked car.

The switch is suitable only for earth-return installations, being connected between the chassis and the earthed battery terminal. When moved to the "off" position, the connection between chassis and battery is broken. If this were the sole feature of the switch, however, current would be prevented from flowing in any part of the car wiring only when the engine was stopped; if operated when the engine were running, the dynamo could still supply the other circuits, including the ignition, even though the battery were isolated, and the engine could continue to run. So that the battery master switch may be used as a safety device in the event of an accident or a short-circuit, movement of the switch to "off" also renders the ignition inoperative by a connection across the contact breaker to earth, in addition to its control of the battery supply.



Circuit diagram of battery master switch used with coil ignition.

It will have been realized that, in addition to its safety value, the battery master switch mounted in an inconspicuous position will act as a thief-deterrent device when the car is left parked. For this purpose, however, it has the disadvantage that it cannot be used in certain circumstances at night, as it would prevent the lamps from being illuminated. To make the car safe from theft, probably a better plan is to fit, in some secret or concealed position, a switch in the ignition low-tension circuit. Any prospective thief would then have to take the trouble to run an extra wire from the battery to the ignition coil before the engine could be started.

IV

BATTERIES

AS WE have noted already, the battery is really the heart of the electrical system of the vehicle; it must supply electricity to operate the various electrical devices at all times when the dynamo is not generating; that is, when the car is stationary, at starting or running slowly. The function of the battery, therefore, is to store electricity which will be immediately available when required.

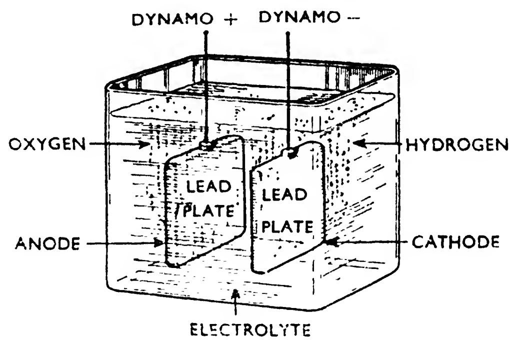
Primary and Secondary Cells

There are two main types of cells, known as primary and secondary types. The difference between the two will be well known to those having owned a battery-operated radio set in which the high-tension supply is provided by a large dry battery and the low-tension supply by a "wet" battery or accumulator as it is more often called. When the latter is discharged, it is taken to an electrical service station to be charged; that is, to have a further supply of electrical energy stored in it. In the case of the dry H.T. battery, however, once it becomes discharged it is discarded as being of no further use, and a new one must be bought.

The Primary Cell, manufactured in several forms, generates electricity by conversion from chemical energy; that is, a chemical reaction takes place in the cell resulting in an electro-motive force at the terminals. When the chemical reaction is completed, however, the cell has destroyed itself and can be put to no further use. The dry cell is best used where the requirement is for low, intermittent current—such as in electric flash-lamps, house bells, and so on—but is of little use in the motor vehicle installation.

The Secondary Cell, on the other hand, is reversible in its action. This simply means that the chemical change which occurs inside the cell when delivering current can be reversed by applying a direct current to the cell terminals. Thus there is no necessity to discard the battery when it is discharged—by passing electricity into the battery the active materials are restored to their original state, when the battery is said to be charged.

The secondary cell is a convenient means of storing electricity by converting electrical energy to chemical energy, and likewise of producing electricity by converting chemical energy to electrical energy. As in any system of storage; of course, if more is taken out than is replaced, the store



A simple electric cell can be made by immersing two plain lead plates in a solution of one part of sulphuric acid in 10 parts of water.

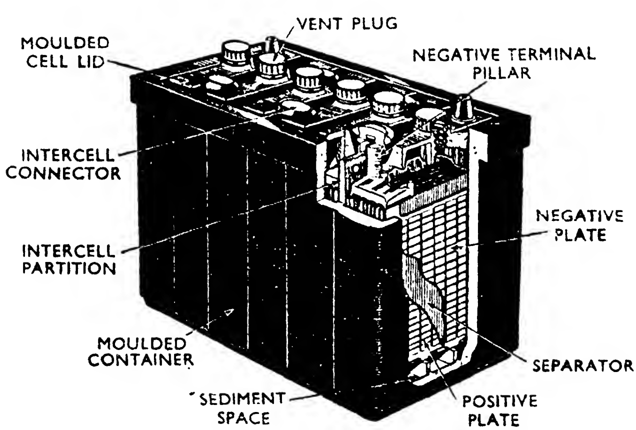
will eventually become empty. On the car, electrical energy is replaced in the battery by means of the dynamo, the output of which is arranged to be sufficiently high to keep the battery in a good state of charge under normal conditions.

Various kinds of secondary cells have been produced, but those used almost universally on motor cars are of the lead-acid variety, this name being used because the essential constituents are lead and dilute sulphuric acid. In the simplest form, two lead plates are placed in a solution of dilute sulphuric acid and a current is passed through from one plate to the other for some time, after which the positive plate (or anode) will acquire a surface of dark brown peroxide of lead, but the other (the negative plate or cathode) will remain as plain metallic lead. If the charging current is now stopped, and the terminals of the cell connected to, say, a lamp, then current will flow from the positive to the negative terminal through the external circuit until the chemical change is completely reversed and both plates are again plain metallic lead.

The Lead-acid Battery

The lead-acid battery as constructed for practical use takes the form of a moulded container, of either ebonite or some composition material having high acid-proof and insulating properties and great mechanical strength, divided into a number of compartments or cells, six for a 12-volt battery or three for a 6-volt unit.

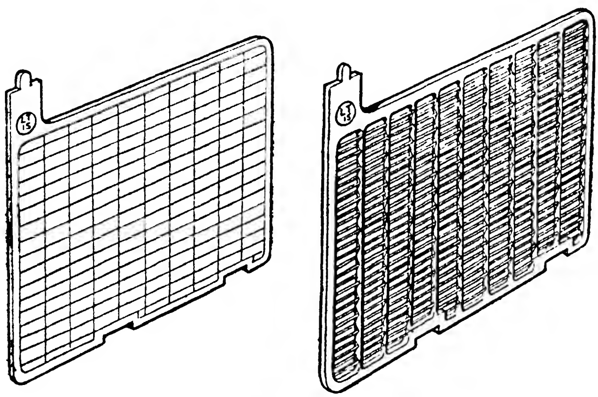
In each cell are two groups of plates, one group being positive and the other negative, the two groups being interleaved as it were in one another. The number of plates in each group depends upon the storage capacity for which the battery is designed, of which more will be said later. Separators interposed between the plates prevent adjacent plates from touching, and each group of plates is connected to a terminal pillar. Moulded lids cover each cell and are



Typical 12-volt battery, showing internal construction.

sealed to the container with a bituminous compound to make an acid-tight unit.

Cells are connected in series; that is, the negative terminal pillar of one cell is linked by means of a solid lead intercell connector to the positive terminal pillar of the next cell. A vent plug in the lid of each cell gives access for filling with acid, while small holes in the plug allow the escape of gases generated as a result of the chemical changes taking place in the cell. At the same time, the vent plugs are



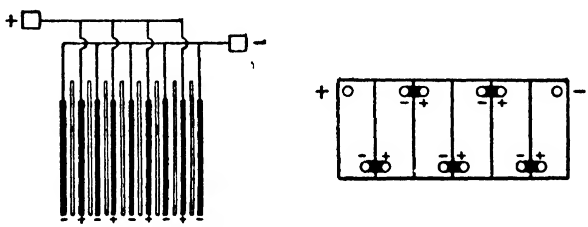
Pasted and unpasted grids.

designed to prevent acid spray from finding its way on to the top of the battery.

The Plates

The plates are not made of lead sheet as in the simple form of cell previously described. Instead, an antimonial-lead-alloy grid forms the skeleton of the plate, which is then filled with a special preparation of lead oxide paste, the design of the grid being such that the active material is held firmly in position. After a process known as forming, this paste is converted to a special spongy form of lead on the negative plate, while the positive plate is filled with a paste of lead peroxide. There is no need to discuss here the various ingenious processes used by manufacturers to produce these results; it will be sufficient to say that, by using plates which are comparatively porous, the effective surface is largely increased, and thus a given size of plate is capable of storing a greater amount of energy.

The storage capacity of a cell, as already indicated, depends upon the effective surface area of adjacent plates. As a considerable capacity is needed for such purposes as starting the engine, very large plates indeed would be necessary if there were only one positive and one negative plate in each cell. Hence the reason for dividing the large plate into a number of smaller ones is a purely practical



The internal and external connections of a 9-plate battery.

one, to enable the battery to be manufactured in a size convenient for installation on the car.

Each cell thus has a number of positive plates and a number of negative plates sandwiched together so that each positive surface is faced by a negative one. At one time there was an equal number of each kind of plate, and thus one positive surface was left unused. In present-day designs, an additional negative plate is incorporated, so avoiding the waste of positive surface.

The Separators

If there were to be direct contact between a negative and a positive plate inside the cell, the result would be much the same as a direct short-circuit outside the cell, and the cell itself would be ruined. To avoid this, a sheet of some non-conducting but porous material, arranged to interfere as little as possible with the chemical action between the plates, is interposed between each negative and positive surface.

Such sheets are known as separators, and are usually grooved on one side to allow free circulation of the electrolyte (as the acid solution is more often called). Various materials have been used, among them being special types of wood, porous rubber, ebonite and glass wool. In one current type, both a grooved wood separator and a specially impregnated sheet of glass wool are interposed between the plates. The glass wool sheet, highly porous, armours the positive plate and thus assists in retaining the active material in position on the plate.

As a further precaution against short circuits occurring internally due to active material shedding from the plates and forming a bridge across the bottom of the plates, a space is provided at the bottom of the case with moulded ribs on which the plate assembly rests, and into which such shedded material can fall.

Chemical Action of the Battery

During the process of charge and discharge, current flows through the electrolyte, and the water in it is electrolysed or split up into its two components, namely hydrogen and oxygen. While the cell is being discharged, the oxygen liberated appears at the spongy lead surface (that is, the negative plate) where it first causes the formation of lead oxide, which in turn is acted upon by the sulphuric acid to produce lead sulphate. This latter reaction also results in the formation of water, which is, as it were, a by-product left over when part of the acid has combined with the lead oxide.

At the positive plate, filled as you will remember with lead peroxide (not to be confused with the lead oxide which we have just been discussing) the liberated hydrogen reduces the lead peroxide to lead oxide by robbing it of part of its oxygen, with which it combines to form still more water.

Also, of course, the lead oxide on this plate is again converted to lead sulphate by the action of the acid, so that a third addition of water occurs.

Thus when the cell is completely discharged, both positive and negative plate surfaces consist of lead sulphate on which the acid has no further action. Also, the acid itself has been considerably weakened by the formation of water during the various chemical reactions.

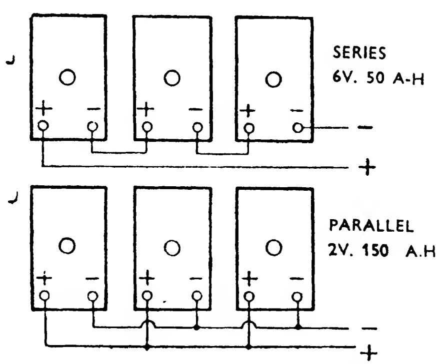
Now let us look at the charging process. Electrolysis of the water again occurs, but since the direction of current flow through the cell is reversed, hydrogen instead of oxygen now appears at the plate which originally consisted of spongy lead (that is, the negative plate). Here it reacts with the lead sulphate to form sulphuric acid, leaving the lead free by itself again. At the other plate the liberated oxygen, together with some of the water from the acid solution, combines with the lead sulphate to form lead peroxide and sulphuric acid again. Hence when the battery is fully charged, both positive and negative plates are restored to their original state and the electrolyte to its former strength.

When this state of affairs is reached it will be clear that the electrolysed oxygen and hydrogen will no longer have any effect on the plates since there is no longer any lead sulphate on them. Continued application of the charging current therefore results in the gases escaping by bubbling up through the acid and passing through the holes in the vent plugs in the cell lids to the atmosphere, with the result that some of the water from the electrolyte is permanently lost. The electrolyte thus becomes stronger and is reduced in quantity, so that it is neither of the most desirable strength nor of sufficient depth to cover the plates completely. It must be emphasized that it is only water which is lost in this way, not acid. For this reason, pure water must be added from time to time to replace that lost by the electrolyte, and details of this "topping-up" operation will be found in the section dealing with battery maintenance on page 47.

Another lesson can be learned from what has been written about the chemical action inside the battery. When the battery is discharged the plates are coated with lead sulphate, which at the time of formation is comparatively soft and porous and is readily attacked by the oxygen and hydrogen during recharging. If, however, the battery is left standing in a discharged condition for any length of time the sulphate hardens and becomes scarcely penetrable. Normal recharging then becomes almost impossible and considerable trouble is necessitated to bring the battery back to a useful condition. In extreme cases it may be quite impossible to do so and a new battery or new plates will be required. This trouble is known as sulphation and again further reference will be made in the maintenance details.

Battery Voltage

Although the number and size of the plates in each cell determines its storage capacity, the voltage of the cell is quite unaffected by these factors. A lead-acid cell in good condition and fully charged will produce a voltage across its terminals of about 2·5 volts. If the cell is put into use



If cells are connected in series the effect is to add the several voltages, but to leave the capacity unaffected. On the other hand, cells connected in parallel have the voltage of a single cell but the current capacity of the several cells is added together just as it would be if all the plates were mounted together in one large cell.

its voltage will fall fairly quickly to about 2·3 volts and then much more slowly to about 2·0 volts. Thereafter the drop is quite rapid and at 1·8–1·9 volts the cell may be regarded for practical purposes as discharged.

These facts suggest a method of discovering the state of charge of the cell by measuring its terminal voltage. In practice, however, the voltage is not a safe guide, since the reading can be affected to some extent by temperature and also by the amount of rest which a cell has had before its voltage is measured. Thus a cell which is almost discharged may, if no current has been drawn from it for some hours, show a quite misleading voltage for a short time before relapsing to something representing its true state.

For these reasons, a safer guide to the state of charge or discharge is to be found in what is known as the specific gravity, or density, of the electrolyte in the cells.

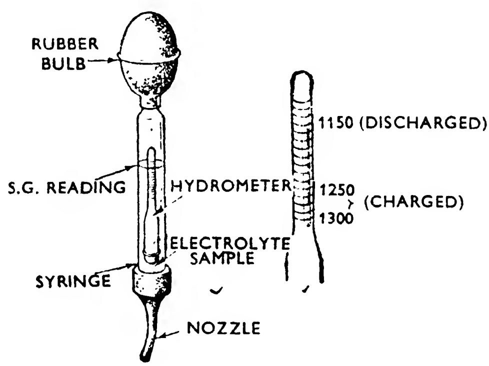
Measuring Specific Gravity

The specific gravity of the electrolyte, or indeed of any material, is the weight of that material compared with the same volume of chemically pure water. The specific gravity of the sulphuric acid used in the preparation of the electrolyte is 1·835; that is, the weight of say 1 pint of this acid would be 1·835 times that of a similar volume of pure water. The acid is mixed with water in such a proportion that when the battery is fully charged the specific gravity is between 1·280 and 1·300. We have already seen that as current is taken from the cells the chemical reaction results in the formation of more water and the acid becomes progressively diluted. Consequently the specific gravity of the electrolyte falls until, when the battery is for practical purposes completely discharged, it will have a specific gravity of only about 1·15.

Thus since the strength of the electrolyte varies with the state of charge, the specific gravity likewise varies with the state of charge, so providing a convenient method of ascertaining the condition of the battery at any time.

For the purpose of measuring the specific gravity of the electrolyte in the cells, an instrument known as a hydrometer is employed, which by a direct reading compares the weight of the acid solution with that of pure water. Hydrometers depend for their operation upon the fact that a float will stand higher in a heavy liquid than in a light one. Taking this fact to its extreme, an article which will float on the surface of one liquid may sink to the bottom of another. A solid piece of iron, for example, sinks to the bottom of water but will float on the top of mercury.

The most usual type of hydrometer is in the form of a

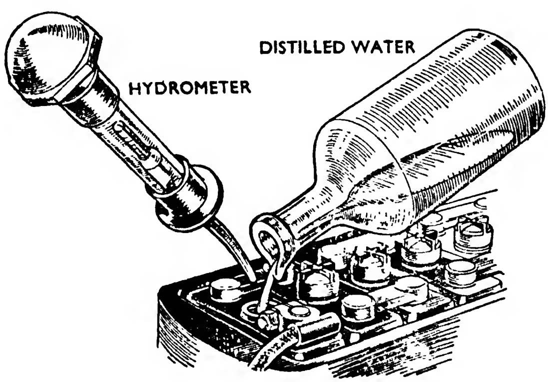


A hydrometer or calibrated float is used to measure the density of the electrolyte. For convenience it is generally contained in a syringe with which a sample of the fluid can be drawn from the cell.

syringe which contains a glass float. The latter is provided with a scale up its side so that the number on the actual surface indicates the specific gravity of the liquid. A rubber bulb at one end of the syringe and a length of rubber tubing at the other enables a sample of the electrolyte to be withdrawn from the cell into the glass body of the syringe. According to the strength of the electrolyte (that is, the state of charge of the battery) the float will assume a certain position, and the specific gravity is indicated by the reading on the scale on the float corresponding to the surface level of the liquid in the syringe.

A second type of hydrometer may be encountered. Similar in construction to that already dealt with, the float, instead of being calibrated directly in specific gravity, takes the form of several (usually three) smaller bead-like floats. These are of slightly different weights, so that one bead may just float on the surface of a liquid of 1·28 density, a second on a liquid of 1·20 density and the third when the density is 1·15. The beads are usually of different colours. A sample of electrolyte is drawn from the cell as before, and if it is fully charged then all three beads should float on the surface. When the battery is about half discharged one bead will sink to the bottom. When quite discharged there will be only one bead at the top. Some readers will have noticed that this type of indicator is used by some manufacturers of glass-cased accumulators for radio sets, the beads being inserted into the cell itself.

When using a hydrometer there is one precaution which should be taken. If the cell has been topped-up with distilled water recently, and in certain other circumstances, the electrolyte may not be of even strength. The best time to take hydrometer readings is after a run, when one may be sure that the electrolyte is thoroughly mixed. If this is not possible, however, the bulb should be released and squeezed



Topping-up with distilled water and periodical hydrometer tests are essentials of battery maintenance.

firmly several times with the rubber tube still submerged in the electrolyte. In this way currents of liquid can be squirted through the cells so as to stir the electrolyte and ensure uniform mixing.

Hydrometer readings should be taken for each cell of the battery and the specific gravity of the electrolyte in each cell should be approximately the same. If one cell gives a reading very different from the rest it is an indication that some fault has developed or possibly that acid has leaked from that particular cell and a proper examination by a service station is desirable. Sometimes the necessary correction may be made by adjustment of the specific gravity of the electrolyte, but it may be necessary to remove the plates from the cell for examination and renewal as required, and this is a task rather beyond the scope of the amateur. The hydrometer readings may be interpreted as follows:

1·280–1·300: battery fully charged.
About 1·210: battery about half discharged.
Below 1·150: battery fully discharged.

Capacity of the Battery

The voltage of a battery, then, depends, primarily, upon the number of cells in it and, secondarily, upon the state of charge of those cells. The capacity, on the other hand, depends upon the number of plates in each cell, and their size. This quantity is quoted in terms of "ampere-hours". Broadly, this means simply the number of amperes which a battery will deliver and the number of hours for which it will continue to do so. Thus a battery which will supply 10 amperes for 5 hours would be a 50-ampere-hour battery, as also would be one that supplies 2 amperes for 25 hours.

In practice a slight complication occurs, for it happens that the capacity of a battery depends to some extent on the rate at which it is discharged. Broadly, it is true that for very low rates of discharge there is practically no change in the capacity. Thus a battery which could give 1 ampere for 50 hours would probably also give 2 amperes for 25 hours, but it would almost certainly not give 10 amperes for 5 hours, and it could not maintain anything like 50 amperes for one hour, although all these various combinations are numerically equal to 50 ampere-hours. For that reason the capacity of a battery is always coupled with the discharge rate, as, for instance, "50 ampere-hours at the 10-hour rate", which means that this battery when fully charged will deliver 50 ampere-hours if discharged in 10 hours or more, but the same capacity must not be expected if the battery is discharged in less than 10 hours.

The capacity of the battery fitted to the car is determined by the car and electrical-equipment makers. One of the main factors which determines this is the ability of the starter and battery to deal successfully with the problems associated with cold-weather starting. The battery will be found to be of adequate capacity to deal with all normal requirements of the electrical system.

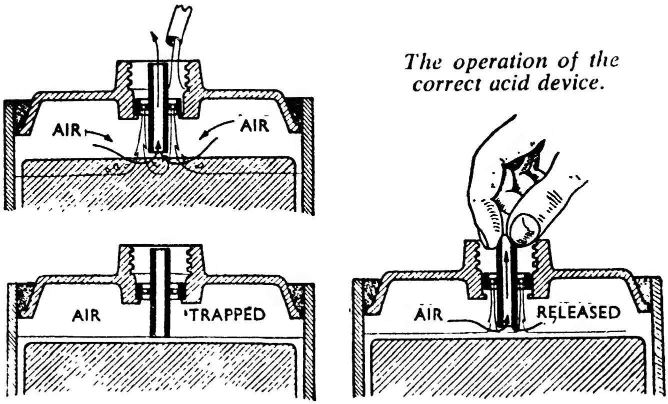
Battery Maintenance

Topping-up

We have already seen that during the chemical action which takes place inside the battery, some of the water is driven off, thus increasing the specific gravity of the electrolyte. Once every month, therefore—or more often in hot climates, or if long daily runs are made under warm conditions—the level of the electrolyte in the cells must be inspected. While doing this, never use a naked light, as a mixture of oxygen and hydrogen can be explosive.

With most makes of batteries, the correct level for the electrolyte is up to the top edges of the separators (which stand about ½ in. above the plates) and this ensures that the plates are adequately covered. If the level is low, distilled water must be added through the holes in the cell lids until the correct level is reached.

Distilled water can be obtained from chemists and garages at small cost and, while in certain districts the normal domestic supply water may safely be used, in the majority of cases it contains impurities detrimental to the battery,



The operation of the correct acid device.

and for this reason the use of distilled water is recommended on all occasions. Topping-up batteries at climatic temperatures below the freezing point of water should be done only when the cells are on charge and gassing freely, and then the water should be added in only small quantities at a time.

The volume of distilled water required for topping-up varies according to the size of cell, conditions under which the battery is being charged, and temperature.

On cars having the battery mounted on the bulkhead at the rear of the engine and an alligator-pattern bonnet fitted, visual inspection of the electrolyte level is almost an impossibility with the battery in position. A particularly useful accessory in these cases, and in fact for all batteries, is a device known as the Lucas Battery Filler, which automatically stops the flow of distilled water when the correct level is achieved. The action of resting the nozzle of the filler on the separators opens a valve and allows distilled water to flow into the cell. When the electrolyte rises level with the top edges of the separators, the flow ceases and the filler is then withdrawn.

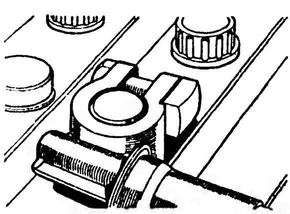
Some batteries, of Lucas manufacture, have correct-acid-level devices fitted in each cell filler hole. This takes the form of a moulded central tube held in a perforated flange which ledges in the filler hole. To top-up the cell, it is only necessary to pour distilled water into the flange (not down the central tube) until it is seen that no more drains into the cell—when the water begins to rise in the flange. This happens when the electrolyte level has risen to the bottom of the central tube, so stopping the escape of air displaced by the distilled water. If the device is now lifted slightly, the small amount of water in the flange will drain into the cell, and the electrolyte will be at its correct level. These filling devices can be lifted out when it is desired to make hydrometer tests.

It is almost equally important not to overfill. Too much electrolyte may lead to it being splashed out of the vent plugs and on to the top of the battery and the surrounding metal parts of the body, and this is extremely bad from the standpoint of corrosion.

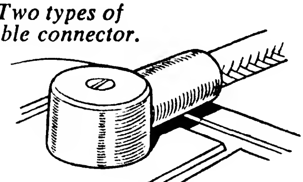
Preventing Terminal Corrosion

It is important to keep the top of the battery clean and dry, as the presence of moisture, especially if it be slightly acid, will set up terminal corrosion as well as permitting current leakage between the cells. See that the vent plugs in the cell lids are screwed well home and examine the terminals, making sure that the connections are tight. If the cable connectors are corroded, scrape them clean and coat them with petroleum jelly or anti-corrosive grease.

The reduction of battery terminal corrosion, it will be remembered, was one of the reasons for changing from negative to positive earth. Due to leakage currents, the positive terminal in the former system was apt to suffer greatly the effects of corrosion, but since the changeover



Two types of cable connector.



considerable improvement has been made. Also, improved materials used in the construction of the cable connectors have further aided reduction of corrosion, and troubles due to this factor are no longer numerous. In the latest type of connector, the cable is diecast directly into the connector, which is secured to the battery terminal post by means of a lead-plated self-tapping screw. This construction appears to have overcome corrosion troubles almost completely.

Repairing Cracked Cells

Although not a common cause of complaint, sometimes a small crack may appear on the top of a battery, allowing the escape of electrolyte or, rather, of the vapour. As a general rule it is advisable to return the battery to the makers for professional attention, but quite often a satisfactory repair can be made by first drying the top of the cell thoroughly and then melting together the edges of the crack by the application of a hot iron. Alternatively, the crack can be filed or scraped out to a V section, after which Chatterton's compound is melted into it. Care should be taken, so far as possible, to prevent the filings from falling through the crack into the cell.

These remarks apply only to the tops of the cells, as there is no satisfactory home method of repairing the moulded cases, although, as a get-you-home measure, no doubt a liberal coating of Chatterton's compound would prove satisfactory.

Incidentally, a large number of cracked battery cases have been proved to be due to excessive tightening of the battery fixing bolts which pass through holes in the lugs on the moulding. For this reason, take care to tighten these fixing bolts securely but not excessively when refitting a battery. Latest battery designs have superseded this means of holding-down by using a girdle or strap fixing.

Sulphation

If a battery is allowed to stand for some time in a discharged or even a partially discharged state the lead sulphate formed on the surface of the plates will harden and this will reduce the usefulness of the battery. Moreover, it will also increase the resistance inside the battery, and if any attempt be made to recharge at a high rate the result must be to heat the plates and possibly to buckle them. To cure this trouble the battery must be recharged very slowly, and it is probable that a single charge will not complete the cure. Therefore, after charging slowly the battery should be discharged also at a slow rate. This sequence should be repeated several times.

Even that treatment will be insufficient if sulphation has become at all bad. In such cases the first step should be to empty the electrolyte from the battery and to refill with a very much weaker solution, consisting of water with only a trace of acid in it.

Care must always be taken when dealing with sulphuric acid. Concentrated or even when considerably diluted, it causes serious burns, which are both painful and difficult to heal. In the very dilute form used for battery electrolyte there is not the same danger, but even this is unpleasant on the hands and much more so on tender skins such as parts of the face. A spot in the eye would probably be serious. Sulphuric acid attacks most metals fairly rapidly, and for that reason it should be stored even temporarily only in earthenware, glass or similar vessels. It will also quickly ruin clothing and other materials.

Batteries in Cold Weather

If a battery freezes up in cold weather it might easily result in the battery case bursting open. The possibility of such an occurrence, however, is entirely dependent on the state of charge. For instance, electrolyte of 1·3 specific gravity would not freeze at temperatures above -76 degrees Fahrenheit, or 108 degrees of frost. On the other hand, only 23 degrees of frost would freeze a cell of 1·1 specific gravity. Thus it will be seen that it is important to ensure that the battery is maintained in a reasonable state of charge during cold weather. The need for care when topping-up a battery at temperatures below freezing point has already been mentioned.

When contemplating the laying-up of a car for winter, or other reasons, a decision must be made as to what action should be taken regarding the battery. If it is aged and promises little further useful life, it may be as well to write it off and save the trouble of storing. If, on the other hand, the battery is comparatively new and in good condition, the most satisfactory way of maintaining it during an idle period is by periodical freshening charges. This should be done about every four weeks, at the normal charge rate recommended by the manufacturer, until the battery is gassing freely. Approximately four hours' charging will normally be sufficient.

An alternative method of storing the battery under these circumstances is that of washing-out. Normally, perhaps, the owner will not wish to be bothered with carrying out this procedure which can be readily done by battery service agents or garages equipped for this purpose, but details are given for those interested.

First, the battery must be thoroughly recharged from a separate source of electricity supply. Then the acid solution is emptied out and the cells washed out thoroughly with distilled water, after which the cells must be refilled with distilled water, making sure that the plates are completely covered, and the vent plugs screwed home. When the top of the battery has been wiped dry, the battery is ready for storage in a cool, dry, dust-free place, remembering that on no account must there be any risk of the water freezing in the cells, otherwise the battery case may burst open.

To prepare the battery for service again, empty out the water and drain the cells, which must then be filled to the correct level with sulphuric acid of 1·350 specific gravity (at 60 degrees Fahrenheit), and charged at half the normal rate until the specific gravity remains constant for three hours. The acid solution must then be adjusted if necessary to 1·290 specific gravity. This is done by syphoning off some of the electrolyte and replacing it with either acid of the strength used originally for filling or distilled water, according to whether the specific gravity is too low or too high respectively. Then, to ensure adequate mixing of the electrolyte, the charge must be continued at the normal rate for about two hours, after which the battery will once more be ready for service on the vehicle.

Battery Charging

When the car is in normal use the battery will be maintained in a charged condition by the dynamo. As will be clear from the succeeding chapter, there are two systems of control of the dynamo output. The one in universal use to-day, known as "compensated voltage control", ensures that the battery receives a charge best suited to its condition. For example, if the battery is discharged the dynamo gives its full output. As the battery becomes charged and its voltage rises the charging current is correspondingly reduced until, with a fully charged battery, the dynamo gives only a trickle charge.

It sometimes happens, however, that due to special circumstances the battery, whilst being in normally good condition, becomes so discharged that the dynamo cannot make good the deficiency, and when this occurs separate charging from the mains must be undertaken. This job can of course be done readily at a service station, but now that an electric supply is available in almost every household, charging can be done at home quite easily. In winter, for example, it is convenient to be able to give the battery a small boosting charge overnight, thus ensuring a lively battery for dealing with a stiff engine next morning.

A storage battery can be charged only by direct current, and care must be taken to see that the battery to be charged is properly connected; that is, the positive battery terminal must be connected to the positive supply terminal, and likewise the negative battery terminal to the negative supply terminal. If in doubt as to the polarity of the supply, connect an electric lamp in one of the supply leads (to limit the current) and then dip the two supply leads into a dilute sulphuric-acid solution or a salt-water solution. The wire around which most gassing takes place when the current is switched on will be the negative one.

A number of well-known manufacturers market charging sets suitable for home installation. The best method of using a battery-charger is to install it permanently in the garage and to provide leads sufficiently long to enable connection to be made to the battery for charging. Some cars are provided with plug-in sockets on the facia, coloured red and black (positive and negative respectively) which are connected direct to the respective battery terminals. With other models it will be necessary to make connections direct to the battery by means of battery clips. The battery maker's instructions must be followed as to the most suitable charging rates for various battery types.

In cases where the mains supply is direct current, the charging apparatus can be very simple and inexpensive, since all that is required is sufficient resistance to bring the mains voltage down to just above that of the battery while allowing the passage of the required charging current.

More elaborate apparatus is necessary for battery charging from alternating-current mains—although it is cheaper to run than is the case with direct current. The mains supply has first to be transformed down to a voltage nearly that of the battery (this being done by means of a transformer, which works on the same principle as the induction coil). This low-voltage alternating supply must now be converted to direct current, and this is achieved by means of a rectifier. The latter device acts as a valve, allowing current to flow in one direction but preventing it from flowing in the other. In most home-charging sets, this is carried out by a metal rectifier, which consists of a number of metal plates stacked together. The valve effect in this case is due to a physical property of an oxide layer formed on the surface of the metal plates. This has been found to have a low electrical resistance to the flow of current from oxide to metal, but an exceedingly high resistance to current flowing in the opposite direction, with the result that the alternating-current supply applied to the rectifier is converted into a series of unidirectional current surges.

V

THE CHARGING SYSTEM

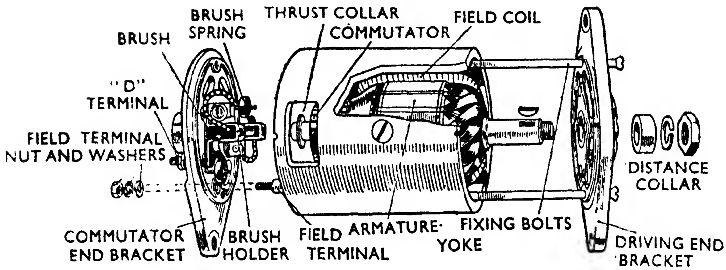
THE FUNCTION of the dynamo is to charge the battery while the engine is running and so replace the electrical energy taken from it by the starter, ignition, lighting, and so on. The general principles upon which the action of the dynamo is founded were described in chapter II, and we can therefore turn directly to a consideration of the type of machine found on the car.

The Dynamo

The dynamo is cylindrical in form, usually of 4–4½ in. in diameter. A welded steel shell, known as the yoke, contains sometimes two- and sometimes four-pole shoes, though more often the former with the modern unit. The armature is mounted centrally in the yoke, being carried in bearings which are housed in the end covers. Current practice regarding bearings is to use a ball bearing at the driving end of the machine and an oil-impregnated porous bronze bush at the other end, although some dynamos, particularly on larger and more expensive cars, incorporate ball bearings at both ends. The end cover remote from the driving end is usually referred to as the commutator end, since the armature is positioned with the actual windings between the driving pulley and the commutator.

This commutator-end cover carries the brush holders which in turn are provided with carbon brushes that bear on the commutator.

The armature core consists of a stack of soft-iron stampings known as laminations, assembled on to a steel shaft. Each lamination is slotted in such a manner that longitudinal grooves are formed around the periphery or outside edge of the core, and into these are wound the coils of insulated copper wire, the ends of each coil being connected



A typical car dynamo, shown partly dismantled to illustrate its construction and main features.

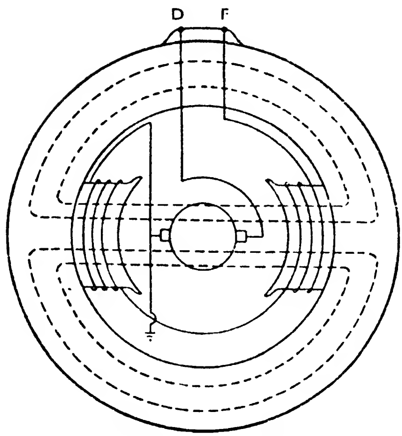
to two bars of the commutator which is also built up on the same steel shaft.

Until recently, the copper wire was insulated by means of an enamel and cotton covering, but this has now been replaced by a plastic type of insulation. This has the advantage of being much thinner, allowing more copper to be wound in the same space, resulting in greater output from the machine. Alternatively, for a given output, the size of machine may be reduced, with a consequent saving in weight.

The armature coils are fixed rigidly in position to resist the effect of centrifugal force when the armature is rotating at high speeds. This is usually accomplished by means of insulating strips of fibre or a similar material forced into the tops of the slots after winding. Furthermore, the armature must be carefully balanced so that it runs without vibration as the clearance between it and the magnet poles is very small.

The magnetic circuit of the two-pole dynamo is illustrated opposite. The lines of force are produced by current flowing in the field windings wound around each pole shoe.

The field windings consist of many turns of fairly fine wire, taped up in the form of coils which fit snugly over the steel pole shoes. The ends of the field windings are, in effect, connected directly across the brushes, or to use the technical term, the dynamo is of shunt-wound pattern. Thus, current generated in the armature has two alternative paths from the



The magnetic circuit, field windings and connections for a two-pole car dynamo.

brushes, either through the external circuit or through the field windings. The amount of current which flows through the field will depend upon the resistance of the field windings and the voltage generated by the armature. It is something in the region of 10 per cent of the dynamo output.

In order that the dynamo can begin to generate when the armature is rotated, a certain amount of residual magnetism is necessary in the field system. Then, as the speed of the dynamo is increased, the rate of intersection of the turns of the armature winding with the magnetic lines of force also increases and this, as we already know, causes the induced voltage to rise. Consequently, more current will flow through the field windings causing more magnetic flux, more intersections and still greater induced voltage. How this is controlled we shall discuss later.

The method of mounting the dynamo, and of driving it, depends to some extent on the engine design. Usually it is the practice to mount it on the side of the engine at the front, and it is driven at 1 to 1½ times engine speed by means of a belt from the crankshaft, this drive also usually being utilized to drive the cooling fan. The dynamo is most often "swung-mounted"; that is to say, it is pivoted about its mounting to permit adjustment of the tension of the driving belt.

One other feature of the car dynamo might be mentioned at this point. The output of a given size of dynamo is to no little extent affected by the temperature rise within the machine. If this factor can be kept down, considerably more output can be obtained. The dynamo is therefore ventilated, this being accomplished by drawing cooling air through the machine by means of a centrifugal fan mounted alongside or integral with the driving pulley, inlet and outlet holes for the air being provided in the end covers. This is general practice except in those cases where the dynamo is exposed to severe service conditions, such as on tractors, where excessive dirt and moisture may be encountered, when it is usual to employ totally enclosed machines. "Windows" in the yoke, at the commutator end, give access to the brush-gear and commutator for maintenance purposes. A metal cover band normally fits over the windows.

Regulating the Output

A dynamo of the shunt-wound type, although the best of the simpler arrangements for the purpose, is not ideal. In normal use on the road a car engine may run at any speeds up to say, 4,000 r.p.m., and since the dynamo is coupled directly to the engine it must also undergo similar speed variations. The dynamo voltage, without any form of control, would thus vary with every change of speed, and at the higher speed its voltage would rise to a very high value. Any such result is undesirable, since it would overload the lamps, battery and other equipment. Equally important is a consideration of the difference between summer and winter running conditions. Winter conditions call for the full complement of lamps, possibly also a fog lamp, windscreen wiper and defroster or car heater. In summer, on the other hand, the lamps may not be used at all for two or three months and the other accessories will in general be required to a much lesser extent. Thus the dynamo output must be about ten times greater during winter than summer.

It will be clear, therefore, that some form of control of the dynamo output is absolutely essential. The most obvious way to do this is by reducing the strength of the magnetic field as and when necessary. The number of intersections will thereby be reduced, and a lower output result.

Two quite distinct methods of achieving this control have been employed during the past twenty years. These are known as the "third-brush" and "compensated-voltage" control systems, and since the latter has so many advantages over the former it has been adopted as the standard method and is used without exception on all modern British cars.

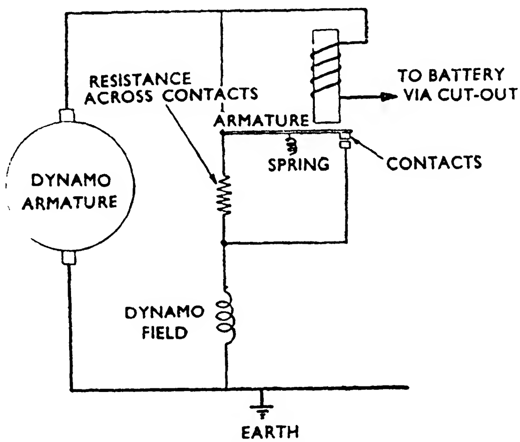
On cars manufactured in the United States of America a variation of the latter system, known as "current-voltage control", is generally employed. This is done to cope with the higher dynamo outputs and increased electrical loading necessitated by the 6-volt systems commonly used on American cars, and an extension of the use of this control to British cars is anticipated to meet the needs of the progressive adoption of more electrical units. At present, however, we shall confine our remarks to the third-brush and compensated-voltage control systems, taking the more recent type first.

Compensated-voltage Control

In this system the dynamo output is controlled by what may be simply described as an automatic vibrating switch which inserts a resistance in the dynamo field circuit. This has the effect of reducing the field current and consequently also the magnetic-field strength and voltage generated. As the speed of the engine increases the amplitude or movement of the vibrating switch becomes greater, thus causing the resistance to be inserted in the dynamo field circuit for longer periods so that the increase in speed does not cause the dynamo voltage, and therefore its output, to increase appreciably.

The charging current to the battery depends mainly on the difference between the voltage of the dynamo and that of the battery to which it is connected. When the battery is discharged the difference in voltage, with a voltage-control system, is considerable, and consequently the battery will receive a large charging current. As the battery becomes more charged its voltage increases, and thus the charging current is progressively reduced until when the battery is fully charged the difference between the two voltages is quite small, and only a trickle charge of 1 or 2 amperes passes through the battery.

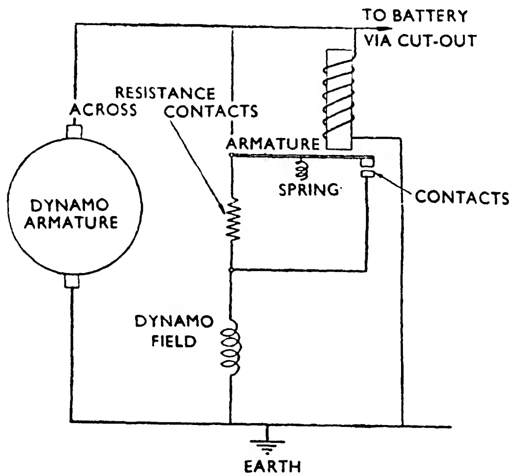
In order to understand clearly the functioning of this type of control, let us first consider a system in which the vibrating switch is operated by current variation only.



Wiring diagram of simple current-control system.

The essentials of this arrangement are an electromagnet wound with several turns of wire and connected in the dynamo charging circuit as shown, a pair of contacts, one fixed and one positioned on a soft-iron hinged armature which can be attracted by the electromagnet under certain conditions, and a resistance connected across the contacts.

Normally, the contacts are closed, and as the dynamo speed is increased so an increasing current will flow through the wire turns on the electromagnet to the battery. When the value of this current reaches a predetermined figure the magnetic pull of the electromagnet is sufficient to overcome the tension of the spring attached to the hinged armature, which is then attracted to the electromagnet. Thus the contacts are separated and the dynamo field current, which previously took the path of least resistance through the closed contacts, must now pass through the resistance connected across the contacts, with the result that the dynamo output will fall. When this occurs a stage will be reached when the magnetic pull of the electromagnet is no longer strong enough to overcome the spring tension; the hinged armature will thus spring into its original position, the con-



Wiring diagram of simple voltage-control system.

tacts will again close and short out the extra field resistance, and the dynamo output will once more commence to rise.

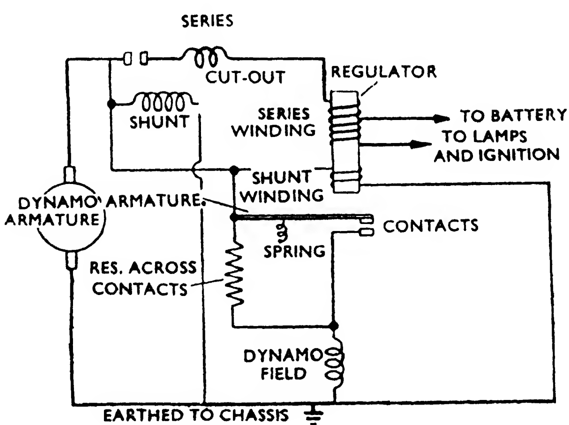
This cycle of operations will be repeated over and over again and the regulator armature will be set into vibration. While such a system as this achieves the object of keeping the dynamo output in check, it has the disadvantage that a fully charged battery would receive the same charging current as a discharged one, so that overcharging would occur.

Next, we will consider a similar type of regulator, but instead of being operated by the current given by the dynamo it will be responsive to variations in the voltage at the dynamo terminals. In this case the electromagnet is wound with very many turns of very fine wire and is connected across the dynamo terminals as shown in the illustration.

This regulator will operate in the same way as the one previously described except that the electromagnet will now attract the hinged armature when a predetermined dynamo voltage is attained. Thus the discharged battery will receive a charging current which will fall as the battery voltage rises, which is the ideal system. Moreover, when lamps or other accessories are brought into use, the consequent fall in battery terminal voltage (due to current being withdrawn from it) will cause the dynamo to give an increase of output to meet the demand for this extra current.

There is one limitation to this simple form of voltage control which prevents it being adopted by itself as the system used on the car. If the battery were fully discharged and the lights or some other accessories were in use, the dynamo, ever willing to attempt to cope with all possibilities, would run a serious risk of giving a current far greater than it is capable of doing, and overloading might occur, leading to a burnt-out dynamo.

The compensated-voltage-control system is, however, one



Wiring diagram of compensated-voltage-control regulator.

depending on both current and voltage variations. This gives all the advantages of the voltage-control system and is "compensated" by the addition of the current regulator to prevent the dynamo being called upon to give currents beyond its capacity. The type of regulator in common use has a voltage winding connected directly across the dynamo terminals and two current windings, one of which carries the full current from the dynamo to the battery, while the other carries the current of the lighting, ignition and accessory loads.

As the dynamo speed increases and its voltage rises, the magnetic field of the electromagnet increases in strength due to the greater current flowing through the voltage winding, and when the voltage is in the region of 16 volts the regulator armature is attracted against its spring tension, the contacts separate and the additional resistance is inserted into the field circuit. Thus the armature is set into vibration as previously described.

If the battery is completely discharged, a large current will flow through the current winding in the battery circuit. The effect of this current will be to assist the voltage winding in building up the magnetic field of the regulator, and thus the contacts will open rather sooner than would be the case with a fully charged battery. If, with the battery discharged, the lamps are switched on, then the current flowing through the second current winding of the regulator electromagnet will provide additional assistance to the voltage winding, thus exerting a control which prevents the dynamo from being overloaded.

In brief, therefore, the regulator unit gives an ideal method of control, since it allows a large current to flow to a discharged battery but causes this current to be reduced as the battery becomes charged. Moreover, it provides for an increase of current if the lamps or other accessories are switched on, but at the same time it prevents the dynamo from being overloaded. Control of the dynamo output is quite automatic and, under normal running conditions, the motorist can be sure that his battery is being well looked after.

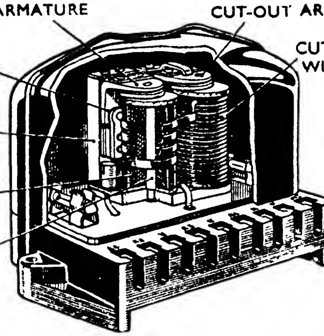
An additional feature incorporated in most regulators is a means of compensating for temperature changes. A characteristic of a battery is that the voltage required to charge it is higher in cold weather than in warm, and without temperature compensation this would mean a lower charging current to the battery during winter and a higher rate during summer, which is usually the reverse of what is needed. In order that the battery shall be charged at the rate best suited to it at any temperature, it is obvious that the setting of the regulator must be caused to vary accordingly, being raised under cold conditions and reduced when warm.

This is done by using a strip of thermostatic metal in conjunction with the regulator armature spring. This thermostatic metal strip is composed of two metals which expand to different extents with an increase in temperature, so that the strip bends when subjected to temperature changes. The bending of the strip causes the spring tension of the armature to alter with changes in temperature and consequently the value of dynamo voltage at which the magnetic field is strong enough to overcome this spring tension will also vary. Under cold conditions the voltage setting is raised to compensate for the increased battery voltage, while under warm conditions the voltage setting is lowered to correspond to the lower battery voltage.

Temperature compensation also causes the dynamo to give an increased charge to the battery during the first half-hour after the car has been started (when the dynamo is cold and therefore capable of giving a somewhat larger output). This quickly restores to the battery the energy that has been used in the operation of starting the engine.

The regulator unit is carefully set during manufacture to meet the requirements of the vehicle to which it is to be fitted. It is combined structurally with the cut-out (*see page 70*) and is housed in the control box, usually mounted on the
fitted. It is combined structurally with the cut-out (*see page*
a sealed cover protects the regulator and cutout assembly.

An earlier type of regulator, known as the "barrel" by virtue of its physical shape, works on similar principles but



Control box, showing cut-out and regulator.

is of different construction and employs two sets of contacts.

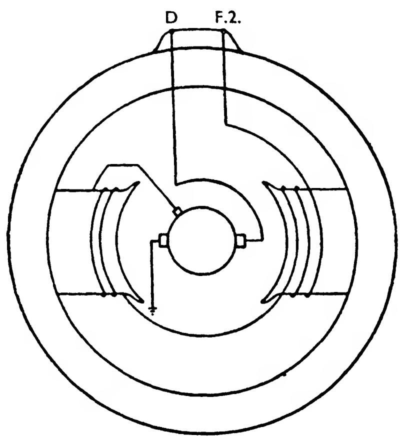
A cylindrical steel armature is held suspended through the centre core of the windings and oscillates to and fro endwise. Contacts at one end perform similar functions to the open type described above. When the armature vibrations are at maximum amplitude the field circuit is short-circuited entirely by the second pair of contacts. The action then is first to open and close the field resistance contacts at one end on high load or slow running, and secondly to short-circuit the field at the other end on light load or fast running.

The Third-brush Dynamo

The dynamo used in this system is similar to that used for the C.V.C system in external appearance, but internally, three brushes are used instead of two, the third and smaller brush being placed between the two main ones and connected to one end of the field winding as illustrated overleaf.

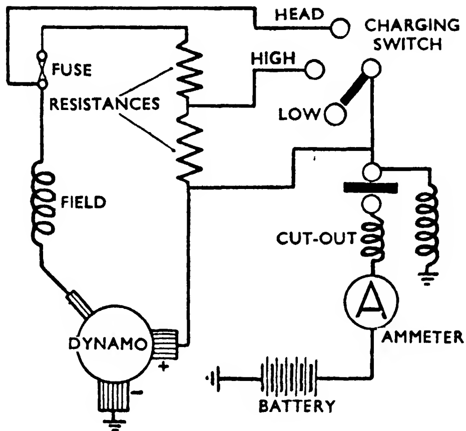
Without going into the somewhat involved details of what actually takes place inside the machine, it can be said that this type of control depends for its operation on a peculiarity known as cross-magnetism, which distorts the shape of the magnetic field, and of which the effect varies as the speed increases. Thus at low speeds the field receives a proportionate amount of the main voltage across the brushes while at higher speeds distortion of the field causes a reduced voltage to be applied to the field winding. In this way it is possible to obtain a dynamo output rising fairly steeply at first as the engine speed rises, remaining fairly constant over the next portion of speed range and finally falling off as higher speeds are reached.

As a method of dynamo output control purely as a function of the speed, this arrangement is fairly satisfactory. Unfortunately, however, there is one very great disadvantage: the current which the dynamo gives is a function of



The internal connections of a typical third-brush dynamo.

the voltage of the system. Simply, this means that as the voltage of the system becomes higher (that is, as the battery becomes charged) the current which the dynamo will give before the distortion effect of the field exerts its control also becomes higher. Such a machine will, therefore, deliver a heavier current to a fully charged battery during a daylight run than to a partially discharged battery with the lamps in use. This would result in overcharging of the battery during long daylight running periods, while if the car is used for long night runs without corresponding periods of daylight running the battery would tend to become discharged. In



Resistance added to the dynamo field circuit reduces the current output of the dynamo. By moving the charging switch to the other extreme from the position illustrated, both resistances are removed and the full charging rate is attained.

other words, the dynamo gives more current to a full battery than it does to an empty one, which as we have seen is the reverse of the result obtained from the compensated-voltage-control system.

In order to minimize overcharging, a so-called two- or three-charge-rate system is usually utilized with third-brush dynamos. This is achieved by means of a resistance which is automatically inserted in the dynamo field circuit when the lights are switched off to reduce the dynamo output from its maximum value. Moreover, there are two alternative positions of the charging switch, one (usually marked Summer—High Charge) giving the maximum reduction in charging rate for summer running and the other (Winter—Full Charge) a small reduction in charge for daylight running during winter.

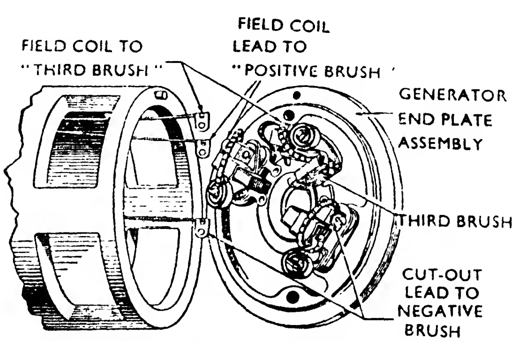
Whilst this system is reasonably successful in meeting the needs of the average motorist, the fact still remains that the output of the dynamo increases with the voltage. In addition, the insertion of the resistance in the dynamo field circuit increases the speed at which the dynamo commences to charge the battery (since the dynamo will, with a weaker field, need to be driven faster to attain the same voltage), with the result that when the car is driven under traffic conditions and at low speed, the output tends to be insufficient.

The third-brush dynamo has given satisfactory service for several years, but the real need for an alternative method which would overcome the disadvantages which we have described led to the general introduction of the C.V.C. system.

Third-brush Setting

With this system there is an adjustment which can be made by a service station, or, if this is not possible, by the owner, either to increase or decrease the output, and this is done by moving the third brush, since the output depends very largely upon the position of this brush with relation to the two others. There is, of course, a limit to the amount of current which the windings can safely carry and for that reason it is certainly not advisable to push up the output beyond the maker's recommendations. If the dynamo appears to be doing less than its full duties, adjustments should be made. A fairly safe method of carrying this out is as follows:

With the engine and, therefore, the dynamo at normal



The third-brush system of output control, showing relation of the third brush to the main brushes.

running temperature, open the throttle, with the gear in neutral, to a point where the engine revolutions represent about 30 m.p.h. The dynamo should then be generating its full output. If it is not, open the throttle a little more.

Switch on all the lights—head, side and tail—and note the reading of the ammeter; it should show a small amount of charge—about 2 amperes, or a little less. If the needle is on the discharge side of zero, move the third (regulating) brush of the dynamo in the direction of rotation of the armature until the ammeter is showing 2 amperes charge. Alternatively, if a charge of rather more than 2 amperes is shown in this test the output must be reduced as it will be too great when the lamp load is removed.

It is assumed, of course, that bulbs of standard wattage are used. If "oversize" headlamp bulbs are fitted—taking, say, 2 amperes more than normal—one should be content with a zero ammeter reading on full load, i.e. no "charge" and no "discharge", otherwise during daylight running the battery will receive an excess charge.

The method of arranging for brush movement varies with different dynamos. Sometimes there is a locking screw (or two screws) working in a curved slot in the end cover. The brush can be moved after slackening the screw (or screws) very slightly.

In another design, part of the brush carrier is formed as a toothed segment with which meshes a small pinion. A hexagon on the pinion enables it to be rotated with a spanner, thus moving the brush. A locking screw in the end cover prevents movement at the wrong time. There is a further scheme in which the brush carrier is frictionally held, so that only a fairly hard push is needed to move the brush.

The Field-circuit Fuse

In the case of a broken connection or similar occurrence causing an open circuit in the battery circuit with third-brush equipment, an excessive voltage will build up across the field coils. To guard against burnt-out field windings a fuse is usually interposed in the field circuit, sometimes being located with the accessory and lighting fuses. This fuse will blow only if a fault develops in the main circuit, and in the event of it blowing the cause must be found before the fuse is renewed. Any attempt to increase the "strength" of the fuse may lead to serious trouble.

The Cutout

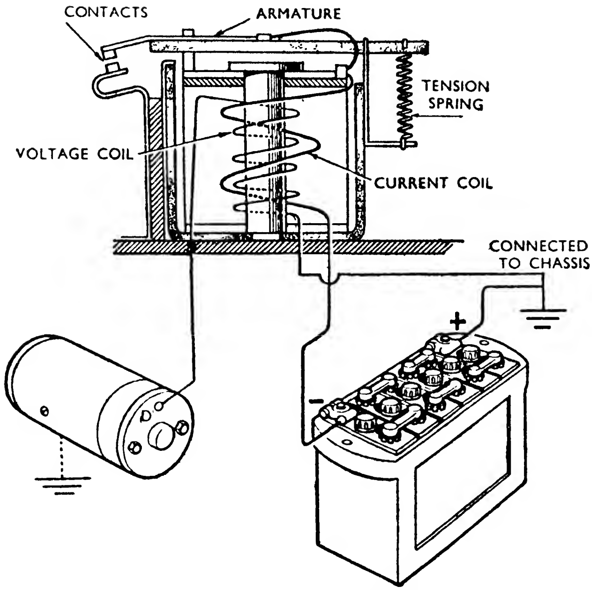
We have already mentioned this unit, but so far have not described either its purpose or construction. In fact, it is an automatic switch connected between the dynamo and battery. When the engine is not running, or is running only very slowly, the dynamo voltage will not, of course, be equal to that of the battery and thus current would flow from the battery through the dynamo windings. Since this is obviously not desirable, the cutout is arranged to connect the dynamo to the battery when the speed of the former is such that its voltage exceeds that of the battery, or in other words, when charging current will flow.

So long as the dynamo is running at charging speed the automatic switch will remain closed, but as soon as the generated voltage falls below that of the battery, the switch opens and disconnects the two units.

The switch consists of a pair of contacts which are held open by a spring and closed magnetically. When the engine is stationary or running very slowly the contacts should be open.

There are two windings on the cutout core—a shunt winding of many turns of fine wire and a series winding of a comparatively few turns of thicker wire. The shunt winding is connected across the dynamo terminals, whilst the series winding has one end connected to a battery terminal. The other end is led out to a hinged soft-iron armature which passes across the top of the core and carries a contact on its free end. The opposite, or fixed, contact is connected to the dynamo terminal.

When the car is starting, the dynamo voltage rises with engine speed until the current flowing through the shunt winding produces sufficient magnetic flux in the core to



A normal type of cutout, showing the various connections to the dynamo and the battery.

overcome the spring tension holding the contacts open. Thus the contacts close and allow current from the dynamo to flow through the series coil to the battery. The series coil also causes a magnetic pull, which adds to that of the shunt coil, so that the contacts are firmly closed and cannot be separated by vibration. When the car slows down, the dynamo voltage decreases until it is lower than that of the battery, and when this point is reached current will now pass through the series winding in the reverse direction. This will cause partial demagnetization of the cutout core, allowing the spring to separate the contacts and so open the charging circuit.

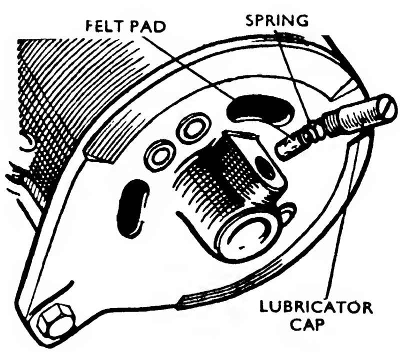
As is the case with the regulator unit, with which the cutout is usually mounted, it is carefully set during manufacture, and is often protected by a sealed cover. Any adjustments to the cutout need special instruments and tools, and are best left to an electrical service station.

Maintenance

The charging system of the modern vehicle is quite reliable normally, and only a small amount of attention is necessary in service to ensure that it continues to do its job satisfactorily.

From time to time the terminal connections throughout the circuit should be checked for tightness. Never change over the original connections or wire any additional lead directly to the dynamo terminals: a wrong connection might easily cause a short-circuit which may burn out the windings. Another point for occasional inspection is the driving belt. Any undue slackness must be taken up by moving the dynamo on its pivoted mounting, but care must also be taken against overtightening. The belt should have just sufficient tension to drive the dynamo without slipping.

The ball bearings fitted at the driving end of nearly all dynamos (and also at the commutator end on some



The lubricator on the commutator-end cover.

machines) are packed with high-melting-point grease at the time of manufacture, and this supply is sufficient to last for a very long time. It is suggested that when the car undergoes a general overhaul (say after about 50,000 miles) the dynamo should be stripped down for examination by an accredited service station, when one of the things to be done to it will be the repacking with grease of the ball bearings.

Some earlier types of dynamos were fitted with screw-down grease cups at the commutator end to lubricate the porous-bronze bearing bush and a single turn of the greaser should be given about every 1,000 miles, refilling the cup when empty with high-melting-point grease. On many more recent dynamos there is a lubricator consisting of a grease cup and a felt pad. With this type, once a year unscrew the lubricator, lift out the felt pad and spring and about half-fill the lubricator with high-melting-point grease. Then replace the spring and felt pad and screw the lubricator back into position.

It is important not to overdo the lubrication—too much grease or oil at the commutator end will certainly cause trouble if it gets on to the brushgear or commutator.

Also once each year take off the cover band which gives access to the commutator and carbon brushes and examine the condition of the commutator. It should be clean and have a highly polished appearance. Any dirt or oil on the commutator should be removed and this is best done by holding a dry cloth on a suitably shaped piece of wood against the commutator surface while the engine is slowly turned by hand. For very dirty commutators, the cloth can be moistened with petrol.

At the same time check that the brushes move freely in their holders by holding back the brush tension springs and pulling gently on the flexible connections to the brushes. If a brush appears to be sticking, remove it from its holder and clean its sides with a petrol-moistened cloth. Be careful to replace brushes in their original positions in order to retain the "bedding"; that is, the shaping of the brush face which bears on the commutator. If a brush is badly worn it will not bear against the commutator properly and so will cause excessive sparking at the commutator, and under these circumstances it must be renewed. Here again, however, this is usually necessary only at very long intervals, and is one of the checks which should be made during the general overhaul of the car. At the same time, the tension of the brush springs will also be measured and the condition of the commutator examined and remedied if undue wear or burning appears to have taken place. Dynamo brushes are made of a special form of carbon and the material and brush size vary with each different type of machine. The hardness of the carbon varies according to the special requirements, so that harm can be done by using replacement brushes of the wrong grade. When brush replacement is necessary, therefore, the correct type for that particular machine must always be used. Whilst brush replacement is a comparatively simple operation, it is probably as well to have it done at a service station, where they will "bed" the brush properly to the commutator after fitment.

The cutout, in the case of third-brush systems, or the combined regulator and cutout in the case of compensated voltage-control systems, is, as we have already said, usually protected by a sealed cover and it is inadvisable for the amateur to attempt to adjust these components.

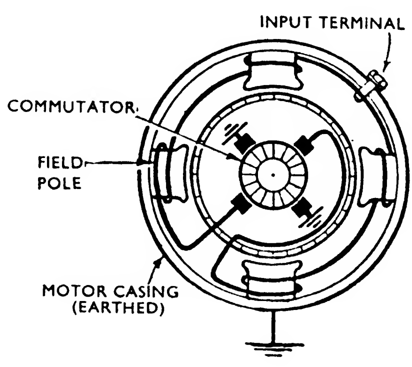
VI

STARTERS

In order that an engine may start satisfactorily it must be turned at such a speed as to draw in a mixture which is capable of being exploded by the sparks produced by the ignition system. The power required to turn the engine is surprisingly high, particularly under cold conditions, and thus the starter motor, although of necessarily limited dimensions, must be capable of a power output of 1–1½ b.h.p.

The Starter Motor

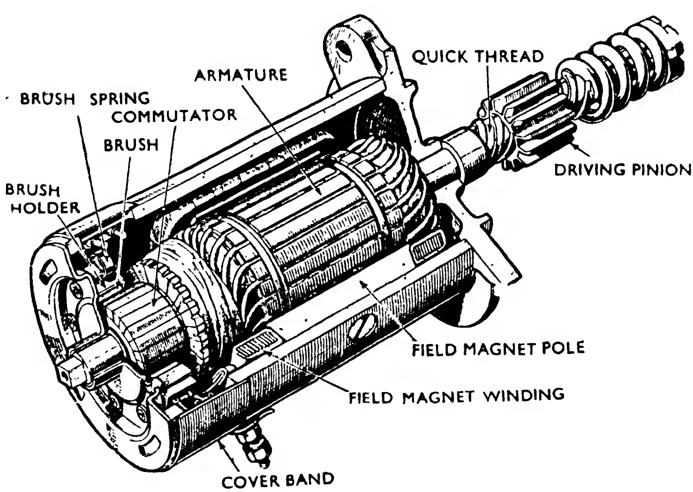
A starter motor is very similar to the dynamo in general construction, having field windings, an armature, a commutator and brushes. There are, however, four poles in the starter whereas the dynamo usually has only two, and instead of the field windings being connected directly across the brushes they are connected in series or series-parallel



A starter motor differs notably from a car dynamo, in having series-parallel instead of shunt winding and four poles instead of two as in most dynamos.

with the armature. In order to cope with the very heavy starting current the brushes are usually duplicated, so that the current is divided between them. Also, because of the heavy current involved, copper strip is used instead of wire for the windings of both the armature and the field coils. The strip is, of course, insulated in much the same way as is the wire used in a dynamo, but the cross-section of copper is greater in relation to the space occupied by the insulation and thus a larger amount of conducting material can be built into a motor of given size. Much the same result could be obtained with large-gauge wire, but it would not be so easy to wind into shape. A series or series-parallel motor of this type has the property of giving its maximum turning effort immediately after starting from rest, and this is just what is required when a sluggish engine has to be rotated.

As the speed of the motor rises further its torque or turning effort is reduced, with corresponding reduction in current demand; thus, whereas at the instant of closing the switch there may be a drain on the battery to the extent



The construction of a typical starter.

of perhaps 300–400 amperes or more, the current will drop by half within a second and the motor will continue to rotate the engine at a speed which depends upon bearing stiffness, oil viscosity, and so on.

When the starter switch is closed the rush of current from the battery to the motor causes an appreciable voltage drop, so that a normal 12-volt battery may show only about 8 volts at the instant of discharge.

Heavy Cables Needed

In view of the large amount of current to be dealt with, heavy cables and connections are used between the battery and the starter to avoid reduction in voltage as much as possible. It will also be noticed that the heavy discharge from the battery when the starter is operated does not register on the ammeter—a very heavy type of instrument would be necessary to carry currents of this value.

Using the Starter

It is appropriate to mention here that every effort should always be made to use the starter sparingly. This does not mean that the engine should be cranked by hand, because starting systems are designed for use under all conditions, and if the battery, starter and engine be in proper working order there should be no need to crank by hand.

If the engine does not fire within a second or two after pressing the starter button it is a mistake to keep the starter engaged; rather, one should release the button and wait a few seconds, then try again. This gives the battery a chance to recover its voltage, whilst, at the same time, the mixture drawn into the cylinders will have had a chance to vaporize under the effect of the slight warmth set up by compressing the charges, even though they may not have fired.

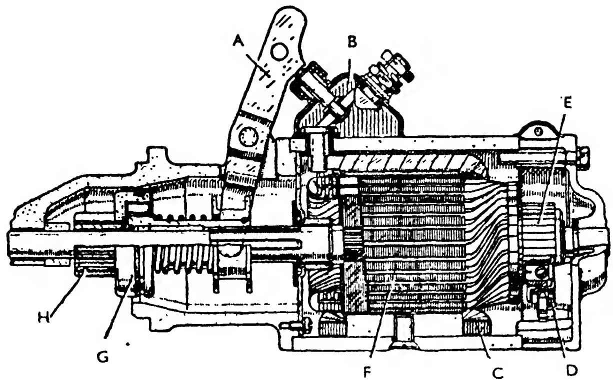
If, after making several attempts to start, the engine still will not fire and run, although the starter is heard to be turning the engine, it is best to look for the reason elsewhere. Further operation of the starter push can only result in discharging the battery even more and, possibly, unnecessarily.

The Starter Drive

The main problems in starter design are centred around the method of connecting the drive to the engine flywheel and of disconnecting it again when the engine has fired. Although friction drives of various types have been tried from time to time, a gear-reduction system is the only method which has survived and, despite a few disadvantages such as noise and a certain amount of wear, is giving very good service on cars in use at present.

Since the starter gives its maximum horsepower at something of the order of 1,500 r.p.m., while an engine usually needs turning at up to about 100 r.p.m. in order to start, then obviously a gear reduction of the order of 15 to 1 is most suitable to produce the most efficient working conditions. This is achieved by the use of a pinion on the starter shaft which moves into engagement with the flywheel when the starter is operated. On the other hand, once the engine has fired and commenced to run under its own power, then unless the starter armature is disconnected from the flywheel it will be driven at fifteen times the engine speed, with consequent disastrous results. There are, however, several ways of bringing this engagement and disengagement about.

Possibly the most obvious is what is known as the pre-engaged or positively engaged pattern often encountered on American cars. A system of linked levers controlled from a floorboard pedal operates a forked arm which slides the pinion into mesh, at the same time closing a switch mounted on the body of the starter. This system makes for quickness of operation, and is kinder to the flywheel gear teeth, but it necessitates the complication of an inbuilt freewheel so that when the engine fires the armature will not be revolved at excessive speed. Another variation of the pre-engaged starter is that in which manual movement of the pinion is replaced by electrical means, a solenoid on the starter yoke supplying the moving power for the forked lever.



A typical pedal-operated starter with positive engagement of pinion.
(a) Pedal-operated lever. (b) Starter switch. (c) Field windings. (d) Brushes. (e) Commutator. (f) Armature. (g) Roller-type freewheel. (h) Flywheel pinion.

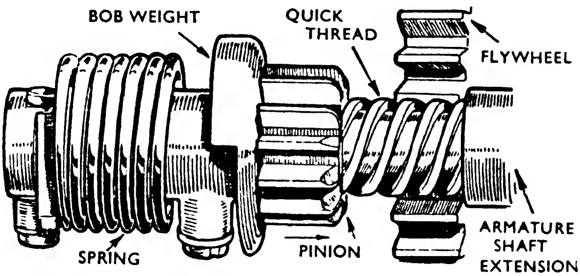
The pre-engaged starter has not found much favour in the United Kingdom, and a succession of inertia-engaged drives have been developed to meet this particular problem.

Bendix Drive

In this type, used quite extensively at one time, an extension of the starter armature shaft carries a sleeve in which is cut a coarse-pitch thread. A pinion, internally screwed to slide on the sleeve, is connected to the starter shaft through a stiff helical spring. As a rule, the pinion has a small bobweight formed upon it so that it is slightly out of balance.

When the starter button is pressed the armature instantly commences to rotate at a very high speed, but since the small pinion is slightly out of balance it does not at once rotate with the armature but instead lags momentarily behind, with the result that it is moved axially along the screwed sleeve towards the flywheel ring. The pinion then engages with the flywheel, the spring drive relieving the shock of the engagement. As soon as the pinion is fully home, the starter rotates the engine until either the engine starts or the starter circuit is opened.

With the engine running, the flywheel will now be driven faster by the engine than it was by the starter, with the

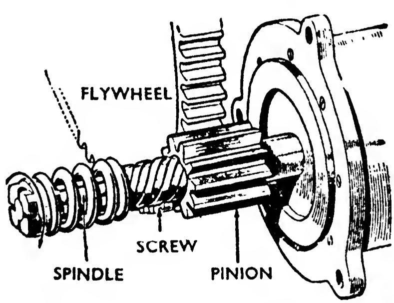


The Bendix starter drive has an out-of-balance pinion to ensure rapid engagement; the drive is transmitted through, and cushioned by, the spring.

result that again, due to inertia, the pinion will lag behind the shaft and so will be withdrawn out of mesh with the flywheel, automatically effecting disengagement.

Other Drives

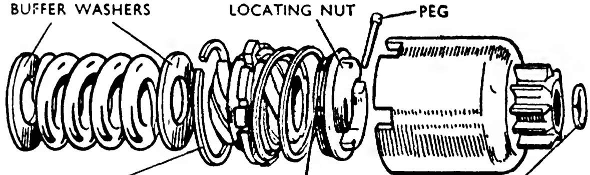
One very usual drive fitted to many cars nowadays is known as the Lucas "S" type. The pinion is mounted on a screwed sleeve which is carried on splines on the armature



In this starter drive a threaded sleeve slides on the splined armature shaft and is cushioned by a spring.

shaft, the sleeve being arranged so that it can move along the shaft against a compression spring so as to reduce the shock loading at the moment engagement takes place. The sequence of operations when the starter switch is pushed is similar to that in the case of the Bendix drive, the inertia of the pinion causing it to move along the sleeve into engagement, or out of engagement when the engine commences to run. The drive is taken direct from armature shaft to pinion via the screwed sleeve, the compression spring acting as a cushion to absorb the shock of pinion teeth meeting flywheel teeth. A light spring is often fitted on this type of drive to prevent the pinion from being vibrated into contact with the flywheel while the engine is running.

Another drive, similar in principle to the "S" type, will often be found on smaller engines which employ a smaller diameter starter. In this case, however, the pinion is carried on a barrel-type assembly and is considerably smaller, riding directly on the armature shaft. By this means, a larger gear ratio between starter and engine is made possible.

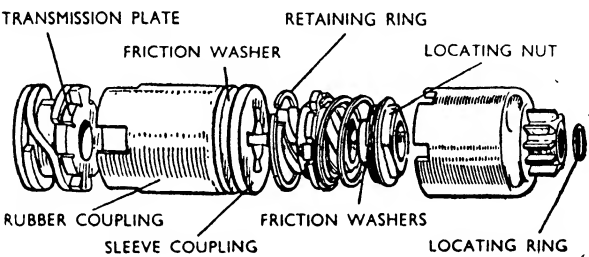


In this drive the pinion is attached to a barrel assembly which moves along the screwed sleeve.

Lucas "Rubber" Drive

There are several different designs of this type of drive, in which a rubber coupling is used to transmit the drive from the starter shaft to the engine, but the basic principle of operation is the same in each case.

The drive embodies a combination of rubber torsion member and friction clutch in order to control the torque transmitted from the starter to the engine flywheel and to dissipate the energy in the rotating armature of the starter at the moment when the pinion engages with the flywheel. It also embodies an overload release mechanism which functions in the event of extreme stress, such as may occur in the event of a very heavy backfire, or if the starter is



The construction of the drive employing a rubber shock-absorbing coupling.

inadvertently meshed into a flywheel rotating in the reverse direction due to rocking back off compression.

When the starter is energized the torque is transmitted by two paths, one via the outer sleeve of the rubber coupling and through the friction washer to the screwed sleeve, while the other path is from the outer to the inner sleeve through the rubber coupling and then directly to the screwed sleeve. The torque through the rubber limits the total torque which the drive transmits, and since the rubber is bonded to the inner sleeve, under overload conditions slipping will occur between the rubber bush and the outer sleeve of the coupling. Slipping does not take place under normal engagement conditions, when the rubber acts merely as a spring with a limiting relative twist on the two members of approximately 30 degrees. Under conditions of unduly severe overload which might cause damage to the drive or its mounting, however, the rubber slips in its housing so that a definite upper limit is set to the torque transmitted and to the stresses which may occur. The bonding of the rubber to the inner sleeve is a recent design alteration, as a result of which the drive is capable of absorbing a torque 50 per cent in excess of the non-bonded unit.

The advantages of such a drive may thus be summed up as quieter and safer starting, since the flexibility of the rubber coupling considerably relieves the shock of pinion engagement with the flywheel, and its ability to slip eliminates the possibility of a bent starter shaft or damaged pinion in the event of engagement with a back-running engine.

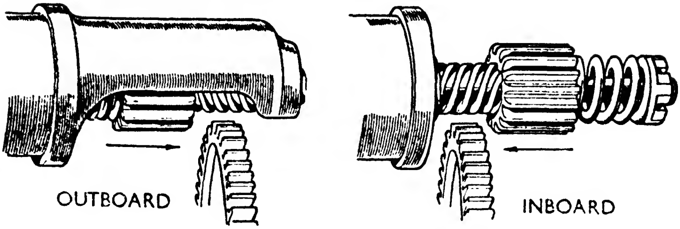
Axial Engagement

Although not strictly applicable to motor cars, another method of engagement normally fitted to heavy engines such as Diesel or petrol lorries and buses may be of interest to complete this story of starter engagement. In this starter the armature when stationary is not lying in line axially with the field poles. On closing the starter switch, usually solenoid-operated inside the starter-end cover, the field poles pull the armature axially into line whilst at the same time applying a small turning force on the armature. The pinion, being fixed to the armature shaft, is thus thrust into mesh with the flywheel, the slight twist ensuring engagement. As engagement is achieved a trip mechanism in the starter applies full electrical load on the windings and the engine is turned. A clutch is interposed between armature and pinion to prevent overdrive.

Inboard and Outboard Drives

Starters are known as inboard or outboard according to the direction in which the pinion moves into engagement with the flywheel. If the pinion moves towards the main body of the starter, then the drive is an inboard one, while if it moves along the shaft away from the starter, then it is an outboard unit.

In the latter case, an extension of the starter-drive end casting houses an additional bearing for the end of the shaft.



Showing inboard and outboard starter drives. The outboard type has an extra bearing in the nose to steady the pinion shaft.

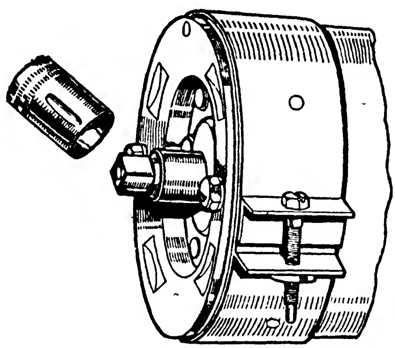
Maintenance

When everything is in order, the starter motor should behave in a perfectly reliable manner and should be good for some thousands of starts.

From time to time, make sure that all terminal connections in the starting circuit are tight and making good electrical contact. The method of making an occasional check of brushgear and commutator is similar to that already described for the dynamo. Again, it is to be recommended that the starter be stripped down for examination by a service station when the car is in for a general overhaul. The bearings (usually porous-bronze bushes at either end) can then be checked for wear, and brushes and brush tension springs renewed if necessary. Because of the heavy current which they must carry, the brushes are made of a special grade of copper-carbon to ensure that the voltage drop shall be a minimum, and, as in the case of the dynamo, it is of the utmost importance that only the correct replacement brushes are used.

If on pressing the starter switch the starter armature is heard to rotate but the familiar noise made by the pinion engaging with the flywheel is absent, it is an indication that the pinion is being prevented from moving along the screwed sleeve and this is usually caused by dirt having collected on the sleeve. Should this happen, clean the sleeve carefully with paraffin. A very small quantity of light machine oil can be applied to the sleeve to lubricate the threads, but an excess of oil might only encourage a further accumulation of dirt.

Another possible occurrence, though by no means a common one, is that of the starter-drive pinion jamming in mesh with the flywheel. This would have the effect of rotating the armature at very high speeds while the engine is running, and would be indicated by failure of the starter to rotate when the starter switch is operated. In order to allow the pinion to be disengaged there is usually an extension of the armature shaft through the commutator-end cover, this



Most starters have a square-ended armature shaft. covered by a cap. Should the drive jam in engagement it may be freed by turning the shaft with a spanner.

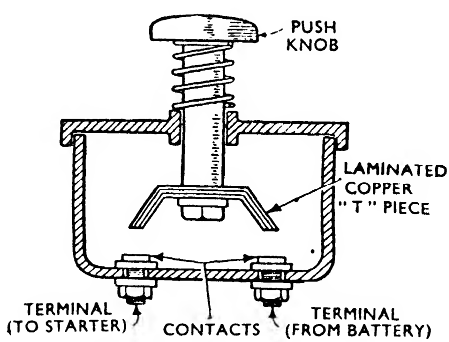
extension being squared to enable the shaft to be rotated by means of a spanner. The squared end is usually covered by a small metal cap, which is either a push fit or is secured by two small screws.

The Dynamotor

Many attempts have been made to design successfully a dynamotor; that is, a dynamo which would operate also as a starter motor and which could be either directly coupled to the engine crankshaft or geared to it with a comparatively low ratio. Such machines were manufactured and, indeed, fitted to certain makes of cars prior to about 1931, but in view of certain difficulties which arise with this type of unit, they have been abandoned since this date in favour of the separate dynamo and starter. The apparent economy of using one machine to do two jobs is not realized because of the complication necessary to make it do both of them effectively.

One of the main difficulties was that of choosing the correct gear ratio. To obtain sufficient torque for starting, when the machine is used as a motor, the gear ratio should of course be of the order of 10 to 1, but this would mean that when working as a dynamo the ratio might be too high.

Consider a ratio of 3 to 1; this would be scarcely high enough for maximum starting torque, but it would mean that with the engine running at 4,000 r.p.m. the dynamotor armature would rotate at 12,000 r.p.m. Suitable compromises were adopted by manufacturers so that the machine did not have to be geared too low as a starter or too high as a dynamo.

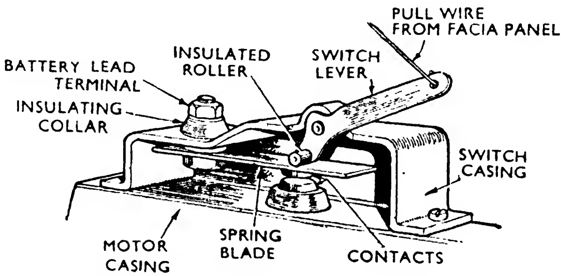


A foot-operated starter switch.

A refinement of the system consisted in providing a variable gear ratio, by means of suitable sliding pinions. With the pinions in mesh the motor can be geared down to 7 to 1 or even more, but when working as a dynamo a direct coupling comes into action so that the machine runs only at crankshaft speed.

Starter Switchgear

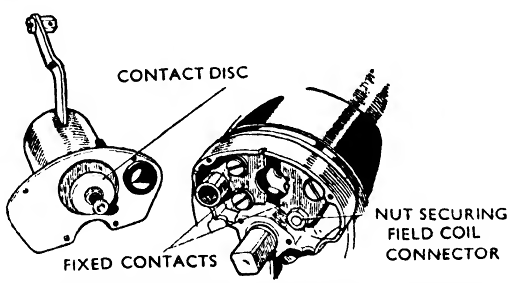
A starter switch must be of robust construction with heavy contacts, since it is called upon to make and break a current of several hundred amperes. There are two main ways of operating the starter switch, either mechanically



Hand-operated switch, mounted on starter.

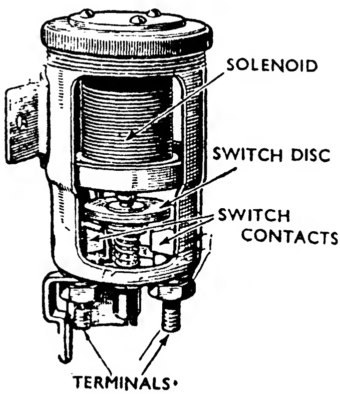
by means of a foot or hand control or electrically through a solenoid controlled by a push button on the facia.

The former pattern may be directly operated or controlled through a linkage or flexible cable. In some cases the starter switch may be mounted directly on the starter yoke or commutator-end cover, thus making the cable run considerably shorter and keeping voltage drop down to a minimum.



The starter switch is often mounted on the motor, and is operated by wire control from the facia.

The solenoid switch is, in effect, a remote-control device. Operation of the starter push on the facia energizes a solenoid mounted either on or near the starter motor. The magnetic field so produced in the solenoid attracts a soft-iron plunger which is free to move inside the winding, and this has the effect of closing the contacts in the main starter circuit, which will then function in the normal manner.



A switch mounted on the starter may be operated by a solenoid controlled by a simple press button on the facia.

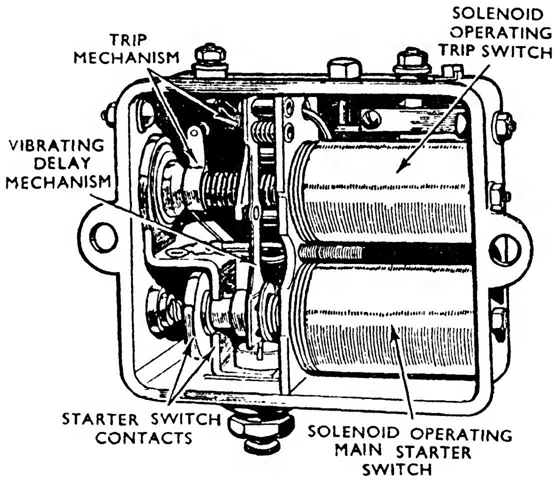
With the present-day tendency to mount the battery under the bonnet on the engine bulkhead, a number of advantages are gained. The heavy starter-cable length is reduced to a minimum, with consequent reduction of voltage drop and less possibility of damage and short circuits. Also, a hand-operated starter switch is feasible without sacrifice of cable or the expense and complication of a solenoid.

Automatic Switches

From time to time devices have been introduced for starting the engine almost automatically. In each case, some simple and natural action by the driver was caused to operate the starter in addition to performing its own primary function. Changes of design and practice elsewhere in the modern car have, however, obviated the need for anything of this sort and we will, therefore, only briefly describe two of the devices, known as Lucas Startix and Lucas Pedomatic which may be found on some elderly vehicles still in use.

Lucas Startix

In the former, the act of switching on the ignition also controls the starter, but in addition, has several other features.



General arrangement of the Startix automatic-control mechanism.

The equipment consists of a sealed box which houses two solenoids; one of them operates the main starter switch, whilst the other acts as a trip-switch for cutting out the starter. There is a single winding on the main solenoid and two windings on that of the trip-switch, the connections being so arranged that when the ignition-switch key is turned to the "auto" position current passes through the main solenoid and moves the plunger.

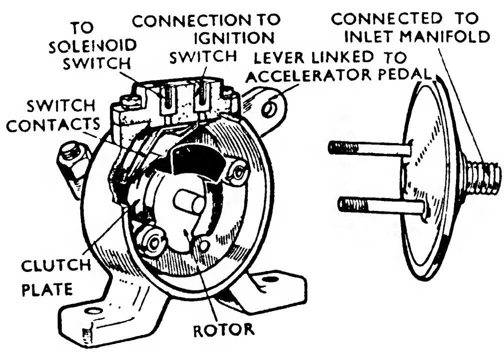
This operates the starter switch and also sends current to the outer of the two windings of the trip-switch solenoid. When the engine starts and the pinion is disengaged the reduction in current causes this solenoid to be pulled in.

Its movement opens a pair of tungsten contacts. This breaks the circuit in the main switch solenoid and cuts off the current to the starter.

When this happens the outer trip-switch winding is isolated, but the inner one is now energized by current from the dynamo so that the plunger remains in its outward position. At full charging speed, with the main cut-out contacts closed, the "auto" contacts open and insert a resistance in the winding circuit so that only a very small current flows.

If the engine stops, the dynamo naturally ceases generating, thus causing the trip plunger to be released. The main starter switch is not, however, closed immediately, because the movement of the trip plunger flicks a spring-mounted contact arm, the vibration of which prevents full contact being made for one second.

This allows the engine to come to rest before the starter pinion is re-engaged. A similar delay-action contact in the outer winding circuit of the trip coil prevents its immediate



The Lucas Pedomatic automatic starting device.

energizing. By this means time is allowed for the starter pinion to engage the flywheel ring before the trip mechanism opens the switch.

The Pedomatic Switch

In this device the starter switch is incorporated with the accelerator pedal. The mechanism consists of a casing which contains the switch contacts and a clutch controlled by a vacuum-operated diaphragm, the necessary suction being obtained by a connection to the inlet manifold.

When the engine is stationary a spring stop keeps the clutch engaged, so that a slight pressure on the accelerator pedal will close the switch. So soon as the engine starts, the induction vacuum, operating on the diaphragm, causes the clutch to disengage, thus opening the switch and allowing the accelerator to be used in the ordinary way.

The clutch is so designed that the pedal must be in the idle position before the starter can be switched on. This ensures that there shall be no risk of the motor being cut in when, with a wide throttle opening, the induction vacuum may be so low that normally the diaphragm would allow the switch to close.

VII

COIL-IGNITION SYSTEMS

THE PURPOSE of the ignition equipment is to provide a succession of accurately-timed high-voltage sparks to ignite the explosive mixture in the engine cylinders. In a four-cylinder engine, two sparks are necessary for each revolution of the engine so that if the maximum engine speed is 4,000 r.p.m. then the ignition equipment is called upon to supply anything up to 8,000 sparks per minute, each of which must be carefully timed to less than one-thousandth part of a second—a very exacting requirement. Moreover, the timing of the spark is not constant since to obtain maximum power output from the engine it is necessary that under certain running conditions the spark should occur at differing positions of the piston in the cylinder.

There are two main systems of providing ignition. Coil-ignition equipment is the one fitted to practically all cars nowadays, while magneto ignition is usually only used on sports and racing cars, aircraft engines, tractors and industrial engines. Both systems work on the same principle, namely that of electro-magnetic induction to give a high voltage from a low one, the equivalent of a small transformer being incorporated. They differ essentially in the source of the low-tension current feeding the primary winding of this transformer, the battery being used in the case of coil-ignition and a self-generated current in magneto ignition. Since there is little difference in the performance of the two systems, wherever a battery has to be carried for other purposes, such as lighting, the simpler coil-ignition arrangement is now invariably utilized but if a battery is otherwise unnecessary, the magneto is fitted.

Main Features of Coil-ignition Equipment

Coil-ignition equipment consists essentially of:

The Battery, which supplies the electrical energy.

The Ignition Coil, which transforms the battery voltage of 6 or 12 volts into a high voltage of at least 6,000 volts to produce a spark across the gaps of the sparking plugs in the engine cylinders.

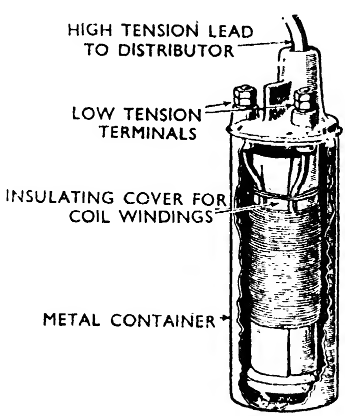
The Contact Breaker, driven by the engine, which opens and closes the circuit through the coil.

The Distributor, which delivers the spark to the correct cylinder.

The Ignition Switch, for disconnecting the battery when it is desired to stop the engine.

The Ignition Coil

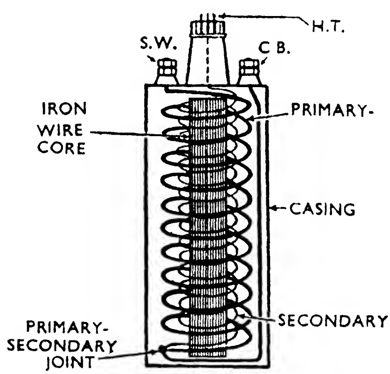
The ignition coil has a laminated soft-iron core around which are two windings; the secondary winding, consisting of many thousands of turns of very fine wire, and, usually on top of this, the primary winding of a few hundred turns of comparatively thick wire. The actual number of turns



The two windings of an ignition coil, heavily insulated, are housed in a protective container.

in the two windings determines to a great extent the value of the induced secondary voltage, as explained in chapter II, the ratio varying in different makes or different types of coil.

For example, in addition to the standard Lucas coil as fitted to very many cars, there is also a Lucas Sports coil, having a different ratio of primary to secondary turns and producing an extra high voltage suitable for certain special purposes. The secondary winding—about three-quarters of a mile of wire in each coil—is wound with wire about the thickness of a human hair, insulated with an enamel covering about two ten-thousandths of an inch in thickness. In addition to the insulation provided by the enamel, layers of varnished paper separate the layers of wire and the whole assembly, consisting of core and windings, is wax impregnated and is housed in a cylindrical container filled with an insulating compound which seals the coil winding and prevents moisture from entering.



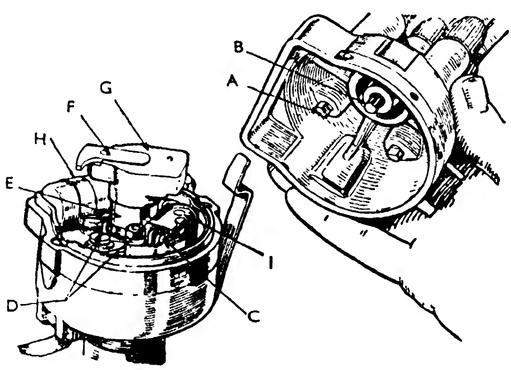
The internal connections of the ignition coil.

The winding of the primary outside the secondary is an arrangement which possesses certain advantages, such as greater mechanical strength and improved dispersion of the heat produced when the coil is operating.

Connections to the windings are made through terminals on the moulded coil cover. One end of the secondary winding is led out to the high-tension terminal and the other end is connected internally to one end of the primary winding, to which also is joined a wire leading to the terminal marked "CB" on the cover. This denotes the connection which must be made to the contact breaker. The remaining end of the primary winding is attached to the second terminal (marked "SW") on the cover, which is connected to the ignition switch. There are no moving parts to the coil, and of course no attempt should ever be made to remove the windings from the coil case.

The Contact Breaker and Distributor

The contact breaker and distributor are mounted together in what has become known simply as the distributor unit. The distributor spindle, driven from the engine at camshaft speed (that is, half crankshaft speed), carries at its upper end a cam having as many lobes as there are cylinders in the engine.



A—electrodes in moulded cap
B—carbon brush
C—contacts
D—screws securing fixed contact plate
E—cam
F—rotating electrode
G—moulded rotor arm
H—condenser
I—contact-breaker pivot

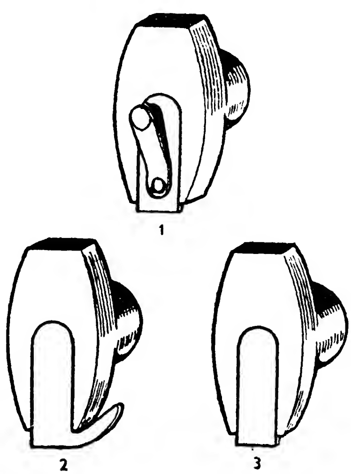
A typical distributor unit illustrating the main construction features.

Bearing on the cam is a heel piece, usually of bakelized fabric, secured to a rocker arm which in turn is carried on a pivot pin. The other end of the rocker arm carries a contact, usually of tungsten, whilst a second contact is fixed to the contact breaker base in the distributor casing.

A spring acting on the rocker arm causes the first contact (known as the moving contact) to bear against the second (known as the fixed contact). The latter contact is adjustable in order to control the size of the gap. The spring is made from austenitic stainless steel on modern distributors, and is rustless and not affected by the oxide of nitrogen produced inside the cap by the spark discharge.

A condenser, also usually mounted on the contact breaker base, although sometimes fitted outside the distributor body, is connected directly across the contacts. When the distributor spindle is rotated the contacts are made to separate at the appropriate instant by the cam lobes lifting the heel on the contact breaker lever.

An extension of the main spindle above the cam carries a

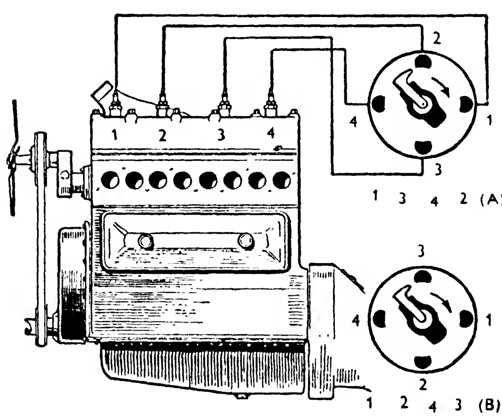


Distributor rotors. The spring-contact type (1) *has now given place to the plain type* (3), *whilst* (2) *is designed to prevent backfiring on* 4-*cylinder engines when starting.*

rotor arm, moulded from a plastic insulating material. The rotor is readily detachable and, to ensure its replacement in the correct position, it is slotted to engage with a projection on the spindle. Alternatively, the spindle has a slot or keyway and the rotor arm has a projection to fit it. Moulded into the top of the rotor arm is a metal strip.

The distributor cover, also a plastic moulding, is held in position by means of two spring clips, and carries as many terminals as there are cylinders. In addition, a centre terminal accommodates the main high-tension lead from the coil. Inside the moulding the plug lead terminals are provided with metal electrodes arranged in a circle. When the cover is in place the metal arm on the rotor clears the electrodes in the cover by about ·01 inch but this dimension is not exceedingly important.

The centre electrode (that is, the one connected to the ignition coil) usually takes the form of a small carbon brush, spring-loaded so as to press lightly on the metal strip on the rotor arm, so that the high-voltage current from the coil can travel to the end of the rotor arm electrode and jump the gap to the nearest cylinder electrode inside the



In the distributor, the fixed electrodes are connected one to each plug. For a 4-cylinder engine two different firing sequences are possible, as shown at (A) and (B).

distributor cover. Sometimes, particularly on older distributors, instead of the carbon brush the cover moulding carries a metal stud, against which presses a bronze button on the end of a springy arm riveted to the rotor electrode.

The Cycle of Operations

When the ignition is switched on, current flows from the battery through the ignition switch, the primary winding of the coil and so on to the contact breaker. On pressing the starter switch the engine rotates, so driving the distributor spindle carrying the cam and causing the contacts to make and break alternately. Each time the contacts open, the subsequent collapse of the electromagnetic field set up by the primary winding in the coil gives rise to a high induced voltage in the secondary winding, and current passes along the high-tension lead from the coil to the centre distributor electrode.

From here, as we have already seen, connection is made to the metal strip on the rotor arm, which at that instant will be opposite one of the terminal electrodes leading to a sparking plug. The current jumps the gap between the rotating and fixed electrodes and then sparks across the sparking-plug gap to earth. The provision of the gap in the distributor has the effect of intensifying the discharge at the plug gap.

Immediately after the spark occurs the contact breaker closes, current again flows in the primary winding of the coil and the cycle of operations will be repeated for the spark to occur in the cylinder next in the firing order.

The Condenser

The function of the condenser is to overcome the harmful effects of self-induction. The interruption of the primary current each time the contacts open causes an induced current to flow in that circuit as well as in the secondary winding. This self-induced current, at quite a high voltage, tends to jump across the gap between the contacts, and

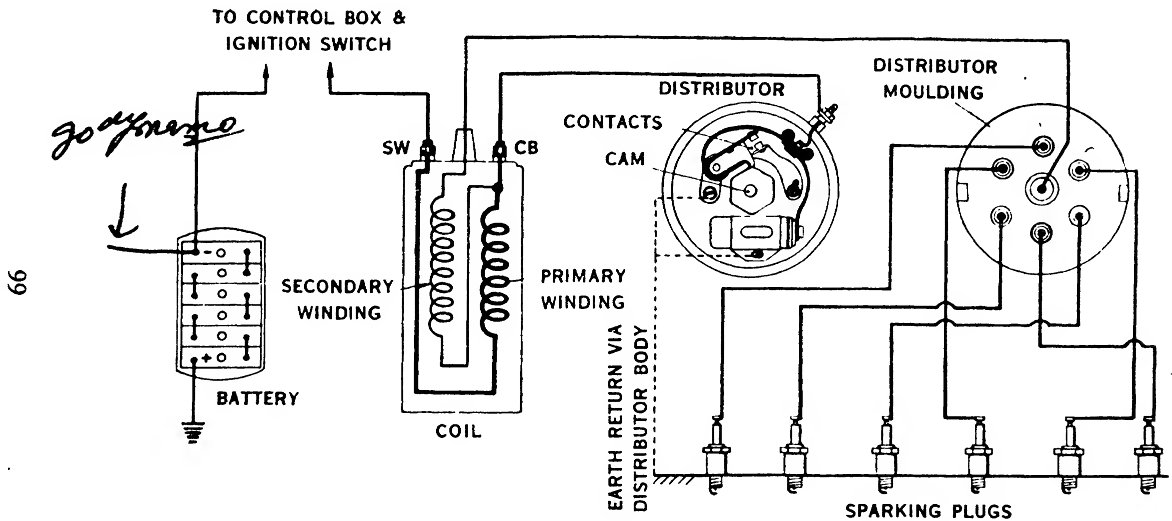


Diagram of the complete layout for the coil ignition system of a 6-cylinder car.

unless precautions are taken would lead to excessive burning and consequently short life of the contacts. Some device which will absorb part of the self-induced current is therefore necessary and the condenser is used for this purpose.

The condenser consists either of strips of thin tin foil separated by very thin paper, or of strips of metallised paper, that is, paper having a very thin metal coating deposited on it. These strips are rolled up tightly and impregnated with an insulating compound. The roll is then hermetically sealed in a cylindrical container which is fitted in the distributor and connected directly across the contacts. Without probing deeply into why it works, it can be said simply that when the self-induced primary current surges to the gap it is diverted by this obstacle and is momentarily partly absorbed in the condenser, to the relief of the contacts. In the next instant, however, the self-induced current having ceased to flow, the condenser discharges itself and a current now flows momentarily in the opposite direction through the primary circuit. This has the additional advantage of producing a magnetic field of opposite direction, thus assisting in the complete collapse of the magnetic flux in the coil.

The condenser, therefore, is a means of obtaining a quick break of current and a reduction of sparking at the contacts.

The unit of electrical capacity, by which condensers are measured, is the farad, but as this is much too large for practical purposes, another unit, the micro-farad—one-millionth of a farad—has been adopted. The average capacity of a magneto condenser is 0·01 micro-farad, whilst 0·2 micro-farad is usual in a coil-ignition circuit.

The Choice of Contact Material

It is not possible, however, to eliminate sparking at the contacts completely and a certain degree of transference of metal from one contact to the other (known as "pitting-and-piling") will usually be found to take place. If on examining the contact surfaces a small pit is visible on one contact and a corresponding pile on the other contact, this is quite a normal condition which will in no way effect the performance of the ignition system, provided of course that the gap can be adjusted to the correct setting (*see page 112*).

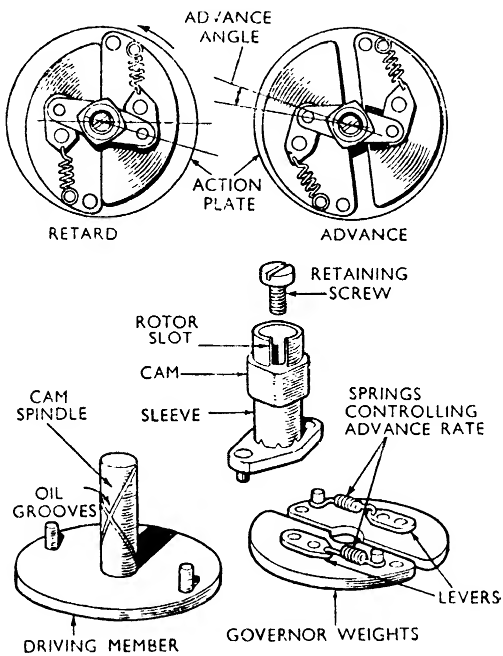
All metals which are suitable as contact materials are acted upon in the manner described. Where the current is unidirectional (that is, current flows through the contacts in the same direction all the time the equipment is operating) the tendency to transference is naturally increased, since one contact is always positive and the other negative. It is on this account that tungsten is invariably used nowadays in coil-ignition equipment; other metals, such as platinum and its alloys for example, are superior to tungsten from the standpoint of oxidation (that is, the formation of an oxide film on the contact surface when the equipment is left idle for a long period, especially under hot and humid climatic conditions) but are very susceptible to transference and are suitable for use only when the current reverses, as is the case with the magneto.

Automatic-timing Control

In order to obtain maximum power output from an engine running on full throttle, the ignition timing must be advanced in relation to engine speed. In other words, whereas when the engine is running slowly at a few hundred r.p.m. the spark occurs when the piston is at the top of its stroke ("top dead centre"), as it speeds up the spark must occur a fraction of a second before this, while the piston is still on its compression stroke. Further, the timing must vary by differing amounts, increasing with the speed of the engine.

In the earlier days of coil-ignition equipment, this effect was achieved manually by the driver by means of a wire control conveniently situated near the steering wheel, and timing control was thus dependent for its effectiveness on correct operation by the driver. Incorrect usage would prevent the engine from running at its maximum efficiency and might even lead to damage to the engine, and so for the last 20 years an automatic control has been incorporated in the distributor unit.

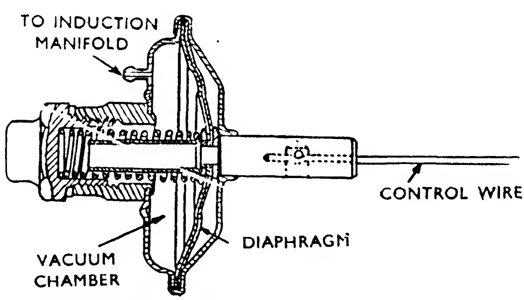
This mechanism is housed beneath the contact breaker and takes the form of a centrifugal governor which alters the position of the cam with relation to the driving shaft. Two weights tend to move outwards against the tension of springs as the engine speed increases, causing the cam to move in the direction of the drive and so causing the sparks to occur earlier. With falling speed there is precisely the opposite effect and the ignition is retarded.



Working principles and details of automatic centrifugal ignition control. The weights fit over pegs on the action plate, the cam sleeve fits over the driving spindle and its pegs engage with the levers.

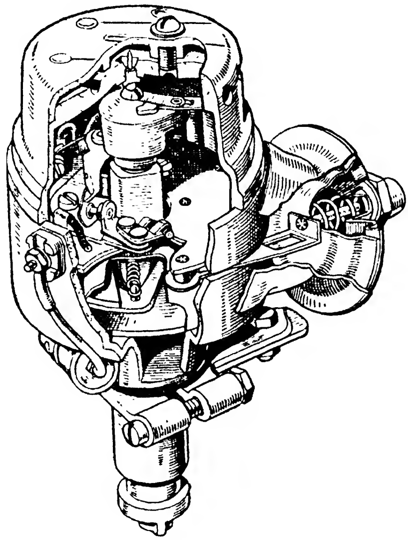
It should be mentioned here that the control springs are carefully chosen by the equipment manufacturers to give the correct rate of advance for the engine to which the distributor is fitted, and any unauthorized alteration to the spring tension can only result in a loss of performance.

A further refinement is incorporated on many types of distributor. Experiment has shown that the correct timing of the ignition depends not only on the speed at which the engine is running but also on the load, a greater degree of advance being necessary under conditions of light load (that is during part throttle and cruising conditions) than with a larger throttle opening. Advantage is taken of the fact that at any fixed engine speed the intake manifold suction is roughly inversely proportional to the engine load; that is to say, with a light load the suction in the intake is of a comparatively high order, whilst on full load it is of low value. This variation of pressure is utilized in what is known as vacuum-operated timing control, in which a spring-loaded flexible diaphragm is enclosed in a metal housing and is connected to the induction pipe of the engine. Variations in inlet suction cause the diaphragm to move, and this motion is conveyed in some suitable way to vary the timing.



Ignition timing control by engine suction is possible by means of this vacuum unit. It may be used together with centrifugal control.

In its earlier form, the vacuum-control unit was a separate device attached to the distributor and effecting rotation of the complete distributor body with relation to the driving spindle, but later versions are actually built in to the distributor casing and variation of suction causes rotation of the contact breaker base only, the latter being carried on some form of bearing for this purpose. This combination of centrifugal and vacuum-operated timing controls gives ideal ignition timing under all conditions.

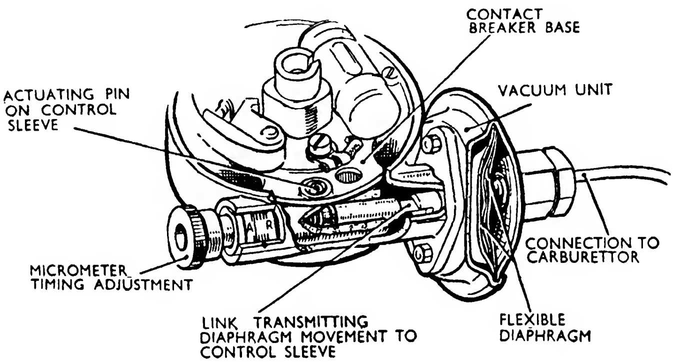


This Delco-Remy distributor unit incorporates centrifugal timing control in the base and vacuum control on to the side.

Micrometer Adjustment

Yet another form of control is provided on some distributors, either alone or combined with the vacuum-control unit. This is known as a micrometer adjustment, and its purpose is to enable small variations in timing to be made to allow for altered engine conditions, such as change of fuel, state of carbonization of the engine, and so on. It is mounted just beneath the distributor or is combined with the built-in vacuum control unit, and by means of a knurled knob the distributor body or the contact breaker base may be rotated slightly.

A mark on the micrometer spindle traverses a scale having divisions equivalent to two distributor degrees, thus providing a precise indication of the amount of advance or retard given. Assuming the distributor to be set normally so that the scale reading is at zero, a range of eight degrees retard and two degrees advance is provided. This adjustment, of course, is independent of the automatic control.

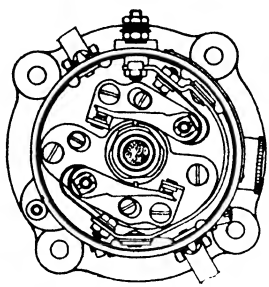


Distributor having micrometer adjustment for fine variation of ignition timing.

Distributors with Double Contact Breakers

During the closed period of the contact breaker the coil must store up enough energy to ensure a good spark at the plug gap, otherwise misfiring may occur. The amount of energy stored is a function of the time for which current flows in the primary winding, and, as we have seen, this factor is governed by the speed at which the contact breaker opens and closes. The latter, in turn, depends upon the speed of the engine and the number of lobes on the cam; that is, the number of cylinders in the engine.

On multi-cylinder high-speed engines it has been found that the contact-breaker rate does not allow sufficient time during the closed period to enable the primary current to build up to its correct value, and for this reason double contact breakers are often employed, the arrangement being that on a 6-cylinder distributor a three-lobe cam is employed and a four-lobe cam on an 8-cylinder unit. Each contact breaker then operates for half the engine cylinders, so doubling the closed period. Actually, double contact breakers on 6-cylinder engines are not often encountered nowadays as, due to improved coil designs, a single contact breaker can quite adequately cope at all speeds usually met with in service, but 8-cylinder distributors invariably have the double arrangement.



For high-speed ignition. The Delco-Remy double-break distributor unit for a 6-cylinder engine.

An alternative scheme, sometimes employed for racing purposes, is to use two separate coils and single contact-breaker distributors, each serving half of the engine cylinders. This of course can be carried a stage further, and a 16-cylinder engine could be provided with four coils and four 4-cylinder distributor units.

Safeguarding the Ignition Coil

If the engine is stalled with the ignition switched on there is quite a possibility that this will occur with the contacts closed, in which case there will be a continual flow of current from the battery through the coil and this may result in the coil heating up sufficiently to burn out or, at least, to melt its insulation. As a warning to the driver, it is the usual practice on modern cars to fit an ignition warning light in the instrument panel. This causes a red light to show when the ignition is on and the engine is either stationary or running very slowly. It goes out automatically as soon as the dynamo begins to charge, but if the engine is stopped accidentally the red light gives an indication that the ignition is still switched on and the battery may be being discharged through the coil windings, and thus reminds the driver to switch off if he is leaving the car. Should the bulb of the warning lamp burn out, it will not effect the functioning of the ignition system in any way, but it is well worth while replacing it as soon as possible so as to retain its safeguarding effect.

Earlier designs of ignition coil may be found to have what is known as a ballast resistance designed to protect the coil and connected in series with the primary winding. As a rule the resistance consists of a small helix or spiral of wire mounted under a protective cover on the coil casing. The wire is of a special nickel alloy, which has the property of increasing its resistance with the rise in temperature; thus, during normal running it remains comparatively cool and does not limit the flow of current to the coil. On continual discharge, however, the resistance heats up, and this has the effect of limiting considerably the current which can pass. By this means the coil is protected and the battery is prevented from discharging rapidly.

Checking the Firing Order

If the plug leads of an engine become detached and "mixed up", it will be necessary to trace the firing order when replacing them. To do this, turn the engine by hand until the position of No. 1 cylinder is at T.D.C. on the firing stroke—as indicated by both valves being fully closed. At that point the rotor in the distributor will be adjacent to one of the cover electrodes. Connect a plug lead from that terminal to No. 1 plug.

Again turn the engine and watch the valve movement. If it be a 4-cylinder unit firing 1,3,4,2, the valves of No. 3 cylinder will be the next to reach the "both closed" position. The rotor will have moved round to the next electrode.

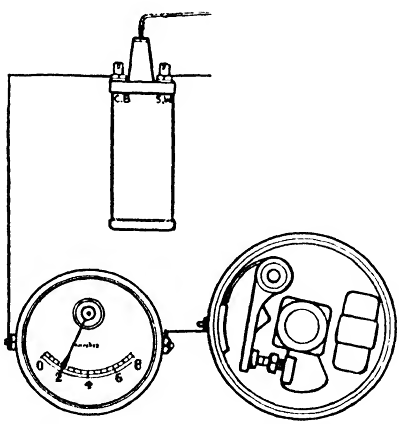
Connect its terminal with the H.T. lead to No. 3 cylinder. Having found the sequence of two cylinders, it then becomes only a matter of connecting the two remaining leads in the order of distributor rotation. The third electrode must belong to No. 4 cylinder and the fourth to No. 2.

On some 4-cylinder engines the firing order is 1,2,4,3, in which case positions 1 and 2 are traced by valve movement and the remaining two follow in sequence. Six-cylinder engines fire 1,5,3,6,2,4, or 1,4,2,6,3,5; again only two positions need be found for the others to follow according to the direction of rotation of the distributor rotor.

Resetting the Timing

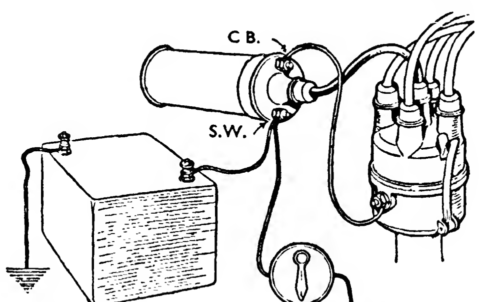
The actual timing of the distributor is, in the case of practically all makes of distributors used with coil-ignition systems, quite a straightforward matter.

Assuming for example, that the spark is to occur at T.D.C. with the control fully retarded, the process consists of turning the engine until the piston in No. 1 cylinder is at



An ammeter, or a lamp bulb, wired in the circuit as shown, will aid accurate timing. The instant that the contacts separate the needle will drop to zero or the lamp will go out.

the precise top centre on the compression stroke. The clamping bracket on the distributor body is then slackened; this allows the head to be rotated by hand. If the timing is merely being checked or slightly adjusted, it will be found upon removing the distributor cover that the rotor electrode is in a position adjacent to the terminal electrode of No. 1 cylinder plug. A lobe on the cam will be just bearing on the heel piece of the rocker arm and the points should be just separating. If they are fully open the timing is too far advanced for the required setting, and the distributor must be rotated forward slightly; that is, in the direction of rotation of the cam. Move it backwards to advance.



Coil ignition can be operated by using a temporary battery when the main battery is out of action.

As it is almost impossible to see precisely when the points open, a test lamp or an ammeter should be wired in the ignition circuit at the distributor "CB" terminal. That is, the lamp or ammeter is put in series with the lead from the coil to the distributor. With the ignition switch "on" the lamp will light or the ammeter will show a reading so long as the points are closed. The instant that they separate, however, the lamp will go out or the ammeter hand will drop back to zero. That is the moment of ignition.

Although the foregoing is the accepted and conventional method of using a lamp to indicate the precise moment at which the contacts separate, there is another and rather more convenient method which does not involve disconnecting any of the normal wiring. If a lamp of battery voltage be connected simply across the two terminals "SW" and "CB" on the coil, it will behave in precisely the same manner as it would when wired in series with the coil, except that it will burn with normal (instead of diminished) brilliance. It will usually be found that temporary wires can be wound around the terminals so as to connect the test lamp. If retiming is a frequent occurrence in any establishment, it is easy to make up a lamp holder with a pair of short stiff wires which will clip on to the terminals. This arrangement, unlike the other, must not be used with an ammeter instead of a lamp unless some suitable resistance also is placed in series with the ammeter.

Alteration of Timing to Suit Higher-grade Petrol

With the re-introduction of branded higher grade fuels in 1953, and the retention also of lower grade fuels roughly equivalent to Pool, it was made necessary to retime the ignition according to the particular fuel in use in order to obtain optimum performance. The premier grade petrols differ from Pool and pre-war petrols in a way which cannot be described only by octane number; they are less prone to pinking at lower engine speeds, but may cause pinking at higher speeds in some engines if the ignition timing is not set carefully.

On many engines, the ignition timing must be retarded at lower speeds to avoid heavy pinking on Pool—and consequently there is some loss of power. Centrifugal timing controls on distributors fitted to engines during the Pool era were arranged to give this retarded timing at lower speeds, but maximum power at higher speeds. With pre-war engines, the ignition setting had to be retarded by a few degrees to prevent excessive pinking when Pool became the only available fuel.

The tendency to pink at low speeds is reduced or eliminated when premier grade petrol is used, and some improvement in performance may be obtained by advancing the ignition timing slightly. Most o.h.v. engines give an improved performance on premier grade petrol—generally, the higher the compression ratio, the greater the improvement. Side valve engines, on the other hand, may not derive so much improvement by the use of higher grade fuel. The manufacturers of the ignition equipment, and the petrol companies, have stressed that the amount by which the ignition may be advanced with advantage and safety is limited. If the ignition be over-advanced, no advantage will be gained, and there is danger of blown gaskets and risk of backrunning during starting.

With pre-war cars it is usually only necessary to revert to the original ignition timing, quoted in the manufacturer's handbook, to give best performance with higher grade fuel. Engines produced during the Pool era, however, should have the normal static setting advanced by an amount specified by the engine manufacturer, usually not more than 6 degrees (flywheel) for o.h.v. engines or 4 degrees (flywheel) for s.v. engines. This is done by turning the distributor body in its housing in a direction opposite to that of shaft rotation, noting that a movement of about $\frac{1}{16}$ in. of the distributor shank is equivalent to 6 degrees (flywheel) advance. When a micrometer adjustment is incorporated with the distributor (*see page 104*), timing advance can be made simply by turning the knurled knob.

Maintenance

Having now examined the construction and operation of the coil-ignition system, the reader will be in a position to appreciate the necessity for the small amount of maintenance which it is recommended should be carried out from time to time. The ignition coil requires no attention apart from seeing that the terminal connections are tight and occasionally wiping over the cover moulding. Distributors of different makes, types and production dates will naturally vary slightly from one another in detail, but in general the procedure outlined below should be followed.

Lubrication

Some older distributors are provided with screw-down greasers or oilers on the shank from which lubricant passes to the spindle bearings. A turn of the grease cap every 500 miles (refilling when empty with a good-grade high-melting-point grease) or a few drops of thin machine oil added to the oiler every 1,000 miles will be all that is required.

About every 3,000 miles the cam upon which the fibre heel bears must be given a light smear of a light grease, or clean engine oil may be used. Some distributors will be found to have a felt cam lubricator to which the lubricant should be applied. Guard against overlubrication of the cam; the presence of oil or grease on the contacts will quickly give rise to trouble.

To lubricate the cam bearing, every 3,000 miles lift the moulded rotor arm off the top of the spindle and add a few drops of thin machine oil inside the top of the spindle. The screw which is exposed to view must not be undone; it is either drilled or there is a clearance between the screw and the inner face of the spindle through which the oil passes. Then replace the rotor arm correctly.

If the distributor is mounted horizontally it will usually be found that the automatic timing mechanism is amply lubricated by oil which finds its way along the spindle from the engine. With the more usual vertically mounted types, however, the automatic timing control must be lubricated every 3,000 miles with thin machine oil. Some distributors have an oil well or hole marked "OIL" in the contact-breaker base through which the oil should be added. With other types, a few drops must be added through the hole in the contact-breaker base through which the cam passes, again taking care that no oil gets on or near the contacts.

Some older cars still in service may have the distributor mounted on the dynamo and driven from the dynamo shaft through gears. In these instances the gear drive should be lubricated with high-melting-point grease, but only a very small amount is needed, as any excess may find its way either into the dynamo or into the distributor head, where it will cause trouble.

The only other lubrication point on the distributor is the pivot on which the contact-breaker rocker arm works, and to which a spot of clean engine oil or a touch of light grease should be added occasionally.

Cleaning

With regard to cleaning, it is advisable about every 6,000 miles to remove the distributor cover and to wipe the electrodes with a cloth, at the same time taking care to remove any dust which may be present on the under face of the moulding. A certain amount of pitting on the faces of the electrodes is to be expected, but it will do no harm. See that the central carbon brush is clean and moving freely in its holder against the pressure of the light spring, if the distributor be of that type. If it be of the metal-button type, make sure that the contacting face of the button is clean and smooth.

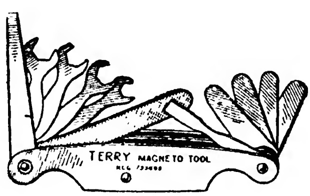
The need for keeping the contact points free from grease or oil has already been mentioned, but if they are burnt or blackened they can be cleaned with a piece of very fine emery cloth or, better still, with one of the thin carborundum slips sold specially for this purpose. All dust, whether from the metal or from the abrasive, must be cleaned away, of course. Excessive pitting or burning of the points, especially if accompanied by a falling off in ignition performance after the engine has been running for half an hour or so, is usually an indication that the condenser is breaking down. It is best to have this checked at a service station, however, so as to avoid unnecessary replacement. Condensers made from metallised paper (*see page 100*) have the additional property of being self-healing, and trouble with this type will rarely be encountered.

When the distributor has been in use for a long time the edge of the rotor electrode will be found to be burnt away somewhat; the effect of this is to increase the gap between it and the electrodes in the distributor cover. A small increase due to burning is of no importance, but when it becomes excessive it is advisable to renew the rotor.

Occasionally, uneven running of the engine is experienced owing to the earth-return circuit of the distributor body to the engine being faulty due to excessive clearance and oiliness in the housing-bore. A short flexible lead between the distributor body and some convenient earthing screw or bolt head on the engine will obviate this.

Contact-breaker Gap Setting

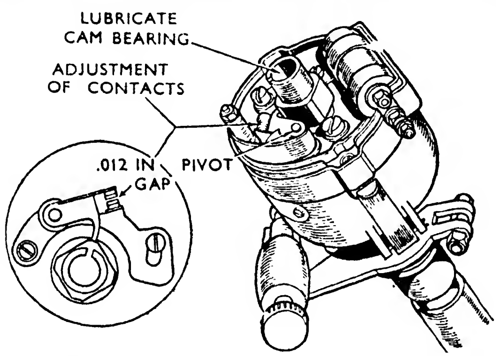
It is important that the setting of the contact-breaker gap is maintained to the correct value. For many years the standard setting on most distributors was ·010–·012 in., but from 1952 onwards this setting was increased on many distributors to ·014–·016 in. Generally the correct figure is stated in the instruction book supplied with the car, and a gauge of the correct thickness is often provided in the tool kit. If not, it will be necessary to buy from an ironmonger or tool merchant a set of feeler gauges. These are put up rather in the form of a pocket knife with a number of blades, each one being of a different thickness, which is marked on the side of the blade. To check the gap,



This Terry tool combines the essential equipment for distributor or magneto maintenance.

first turn the engine by hand until the contacts are seen to be fully opened, that is, when the fibre heel is at the very peak of one of the lobes on the cam. Then insert the gauge between the contacts. The correct gauge should just slide comfortably into the gap; if it does not, then the necessary adjustment must be made.

In early models there was a screwed stem carrying the fixed contact, and this, by rotation with a small spanner, could be moved endwise in its supporting bracket. A lock-nut fixed it firmly in the chosen position. A few years ago a rather simpler design was introduced in which the tungsten is attached directly to a small pressed bracket, which itself is held by two screws. One of these passes through a slotted hole in the bracket. After it has been slackened the bracket can be pivoted about the other screw, which also should be undone half a turn for the purpose. In this way the gap between the two tungsten surfaces (when they are separated) can be adjusted easily without affecting the relative positions of any points on the two surfaces when they are in contact. Consequently, if there should be a small pit in one surface mating with a high spot on the other, these two irregularities will continue to mate after



Illustrating points mentioned in the text in relation to distributor lubrication and contact setting. A gauge must be used for measuring the gap.

adjustment—a desirable state of affairs which does not occur with the earlier form of contact breaker.

The importance of maintaining the correct gap is threefold. A moment's consideration will show that the larger the gap the shorter must be the time during which it is closed, assuming for the moment a constant engine speed. Thus the gap width has a very direct bearing on the time available for the coil to build up the energy of its field. In short, too large a gap must reduce the speed at which misfiring may set in, and the 4,000 r.p.m. mentioned by way of example earlier in this chapter may become 3,000 r.p.m. or 2,000 r.p.m., or even less in extreme cases. That is one effect. The second is that for the same basic reason the gap width affects the actual ignition timing. A small gap means a late opening, and vice versa. This is not merely a theoretical point. By increasing the gap only a few thousandths of an inch it is quite possible to turn a well-behaved engine into one that pinks or knocks unpleasantly. Particularly for this reason it is especially important to maintain very close equality between the gaps of a double contact-breaker set.

Finally, the contact gap setting has an important bearing on contact wear. As the gap becomes reduced, burning of the points increases; neglect in maintaining the setting may lead to the necessity for early replacement of the contact set. It is particularly important on a new car, or with a new distributor, to check and readjust the gap after the first 500 miles, since most of the wear of the fibre heel takes place during this period, so affecting the setting.

High-tension cables

The distributor high-tension terminals are connected to the plugs and the coil by means of special rubber-covered ignition cables. From time to time each lead should be examined for perishing or cracking of the rubber insulation which might allow sparking to take place elsewhere than at the plugs. Any defective cable must be replaced by a new length. Connecting the cable to plugs and distributor terminals is a comparatively simple task, details of which are usually to be found in the car instruction book.

The Effect of Positive Earth

The question of which battery terminal should be earthed, as affecting the ignition system, can be considered under two headings: firstly, burning of the plug points and distributor electrodes, and, secondly, sparking-plug voltage.

Generally speaking, it is the positive electrode which burns most rapidly. If, therefore, the high-tension terminal of the coil is made positive, then both the central electrode of the sparking plug and the rotating electrode of the distributor will also be positive, and will burn more rapidly than if the reverse is the case. In most plugs the area of the central electrode is less than that of the earthed electrode, while in the case of the distributor the burning of the rotating electrode is concentrated on the single metal strip. By earthing the positive battery terminal, however, thus making the high-tension terminal of the coil negative, the burning can spread over the larger earthed electrodes of the sparking plugs and over the four, six or eight metal electrodes in the distributor cover.

In connection with sparking voltage, this is to a great extent dependent on the temperature of the negative electrode, falling as the electrode becomes hotter. As the central electrode of the sparking plug is generally hotter than the earthed electrode, positive earthing of the battery, resulting in the central plug electrode being negative, makes for lower sparking-plug voltages, with consequently less strain on the ignition equipment.

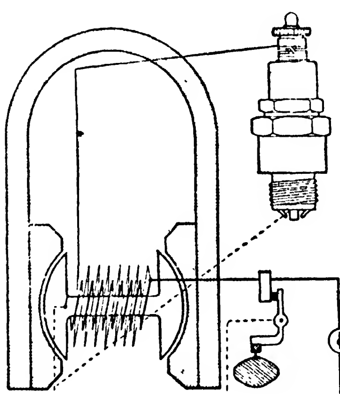
VIII

MAGNETO IGNITION

TURNING NOW to the subject of magneto ignition, in view of the comparatively little use made of this component on ordinary cars for many years now, we shall limit this chapter to a brief explanation of the construction and operation of some typical designs. As has already been stated, whereas in the coil system the primary winding is fed from the battery, the primary current of the magneto is generated in the machine itself.

Rotating-armature Magnetos

In Chapter II there was mentioned a simple type of dynamo using a permanent magnet for its field; this is done



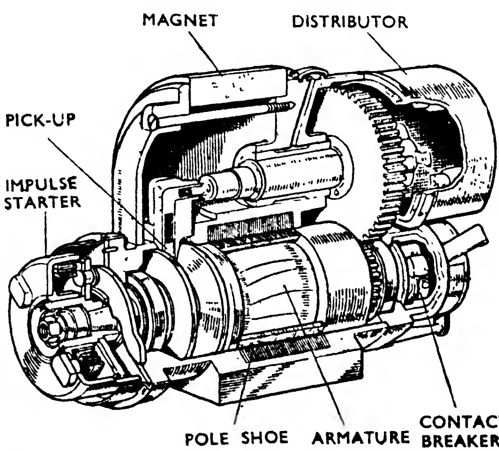
Armature windings and circuit of a normal magneto. The dotted lines indicate "earth."

in the magneto, except that the armature has two windings, corresponding exactly to those of an ignition coil, rotating between the poles of the magnet.

In the more usual design of rotating-armature magneto, an armature core of H section, built up from soft-iron laminations, is wound with primary and secondary coils and is mounted on a spindle. The latter is carried in ball bearings, so that it can rotate within the magnetic field provided by a permanent magnet. One end of the spindle has a coupling through which the armature is driven by the engine, whilst on the other end is mounted the contact breaker, employing either tungsten or platinum-alloy contact points. A condenser is carried in a casing behind the contact breaker, and the whole assembly rotates as a single unit. Surrounding the contact breaker is a cam ring, so called because it carries two fixed cams against which the fibre heel of the contact-breaker rocker arm bears during rotation.

The primary connection to the contact breaker is made through its centre fixing screw, the head of which fits a tapered hole in the metal block which carries one of the contact points. This block is insulated from the plate upon which the rocker arm is mounted and thus the primary current flows only when the contacts are closed.

To ensure proper earthing of the contact-breaker plate



The construction of a typical Lucas rotating armature pattern magneto.

a carbon brush is fitted in a boss on its reverse side, and is arranged to bear upon a circular track on the cover in which the armature ball bearing at that end is mounted.

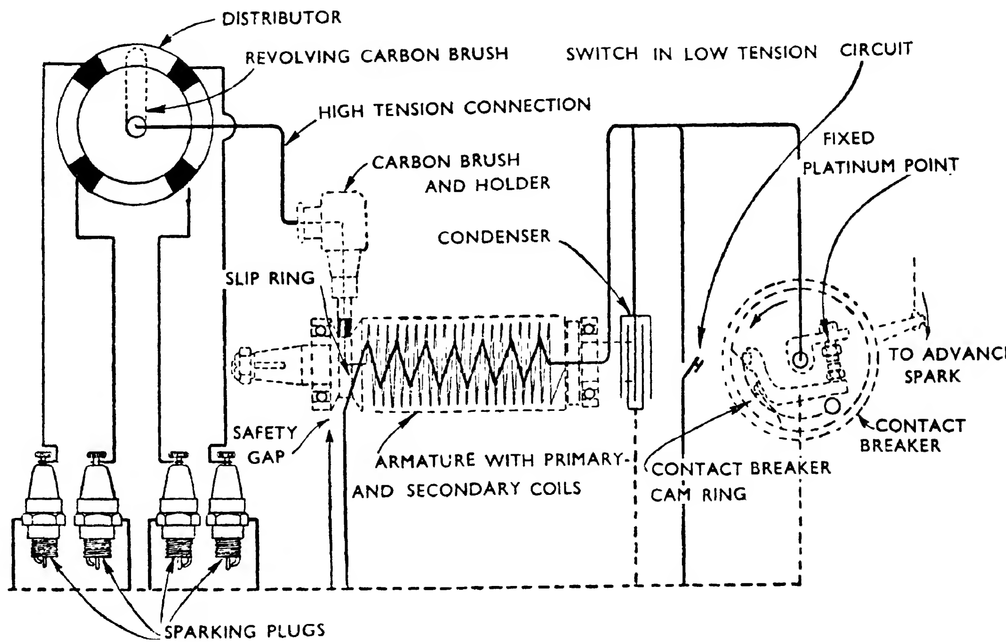
One end of the secondary winding on the armature is led out to a slip ring carried on the spindle. It is heavily insulated by means of ebonite flanges, and has bearing upon it a spring-loaded carbon brush, to which in turn connection is made to the rotating electrode of the distributor portion of the magneto.

This simple type of magneto, with its H-shaped armature, can produce only two sparks per revolution, the sparks being equally spaced. If the magneto is intended for use on a four-cylinder engine, therefore, the magneto must be driven at engine speed. Nevertheless, each cylinder requires its spark only once every two revolutions of the engine and thus the distributor rotor must run at half-engine speed, this being achieved by means of gearing between the magneto spindle and distributor rotor.

The distributor in modern machines usually is similar in general form to what has been described for coil use, except that the rotor arm electrode is connected to the high-tension collector brush instead of direct to the secondary winding. At one time a different form of distributor was common. Instead of requiring the spark to jump across from the rotor to the fixed electrodes, it embodied a spring-loaded carbon brush which slid round against an insulator surface in which were embedded bronze segments connected to the high-tension plug leads.

The Safety Gap

If the high-tension circuit of the magneto should be interrupted at any time, due perhaps to one of the plug leads becoming detached, the magneto will continue to produce a high voltage, and if no escape path for this were provided there would be a risk of the armature windings breaking down due to the severe electrical strain on the insulation. To prevent this a safety spark gap is incorporated in the magneto, usually carried on the holder of the main collector brush, through which the high-tension current can escape to

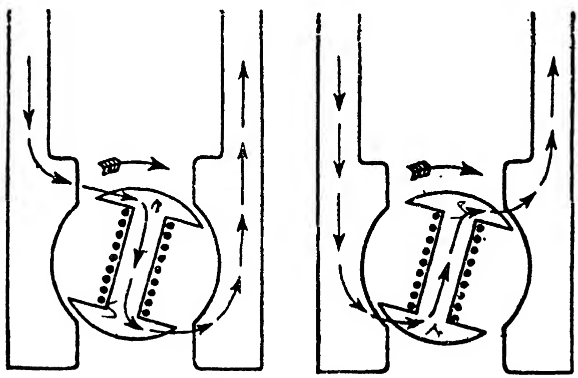


Complete circuit diagram of a 4-cylinder rotating armature magneto. The primary winding is that shown in heavy line.

earth should the resistance in its normal path to the plug become too high.

How the Magneto Works✓

The operation of any magneto is based on the same general principle as that of the coil, namely the rapid change of magnetic flux in a laminated iron core carrying a suitable winding. In the rotating-armature-pattern magneto, the reversal of flux relative to the core is caused by the rotation of the armature between the pole pieces of the magnet. As the engine drives the armature, voltages will be induced in the primary and secondary windings, just as they are in the dynamo. Current flowing in the primary winding through the normally closed contacts of the contact breaker has the effect of distorting the magnetic field as shown in the illustration above. At a predetermined instant, one of the lobes on the cam raises the fibre heel of the contact breaker and separates the contacts, so interrupting the primary current. The magnetic field now undergoes a rapid reversal, giving rise to a high voltage induced in the



CONTACTS CLOSED CONTACTS OPEN

The diagram on the left shows how the low-tension current in a magneto holds the lines of force in the armature after they would otherwise have broken away. When that current is interrupted (right) the lines promptly reverse through the armature.

secondary winding, which passes to the distributor and so on to the sparking plugs.

As a magneto generates H.T. current all the time it is running, some means must be provided for stopping the engine when required. This is done very simply by the provision of a switch which when in the closed position connects the primary winding of the armature to earth, so that the contact breaker cannot interrupt the circuit.

Timing Adjustment

As with the coil-ignition system, some means of altering the ignition timing to allow for variations in engine speed and running conditions is necessary, and this is usually provided by a wire control attached to the cam ring. The latter can be partially rotated, thus producing an earlier or later opening of the contacts, according to the position to which the driver has set the hand control.

Impulse Starter

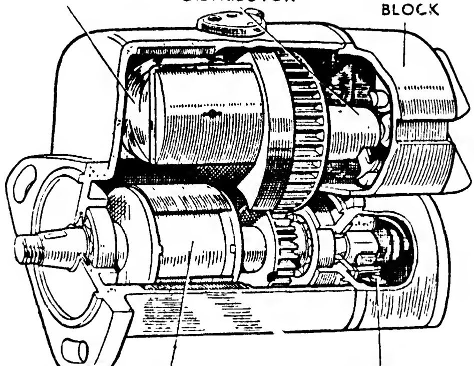
Sometimes the magneto is fitted with an impulse starter, which is a device intended to retard the ignition when starting the engine and also to ensure a good slow-speed performance from the magneto, so assisting in obtaining an easy start, particularly since in the majority of cases where a magneto is fitted no battery is provided so that electric starting must be replaced by hand cranking. A coupling on the magneto spindle is flexibly connected through a coil spring to a second coupling on the driving shaft.

As the engine is slowly rotated, a pawl prevents movement of the magneto spindle and thus the coupling spring is "wound up". At a certain instant the pawl is tripped by means of a cam, with the result that the armature flicks rapidly through the sparking position and a powerful retarded spark results. The sequence is repeated until the engine fires and commences to run under its own power, when the pawls are held out of engagement by centrifugal force at a comparatively low speed.

Rotating-magnet Magneto

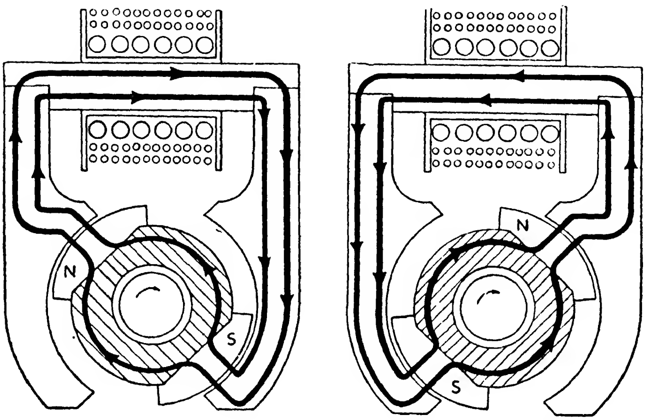
The rotating-armature magneto has the disadvantage that the less robust parts, such as the windings, condenser and contact breaker, revolve. With higher speeds of present-day engines, a considerable amount of mechanical strain is imposed on these parts.

Since in the generation of electric current it does not matter whether the armature windings move in the magnetic field or the magnetic field moves in relation to the windings, another possible construction for a magneto suggests itself, in which the windings remain stationary and the magnet system rotates.



A typical magneto of the rotating-magnet pattern.

The magnet, with laminated pole shoes attached, forms the rotor and carries at one end a cam which operates a contact breaker similar to that used in the coil system, the other end being coupled to the engine drive as before. Primary and secondary windings are mounted on a limb of a laminated magnetic-field system, one end of the secondary being connected to the rotating distributor electrode through a carbon brush. Thus, what might be termed the weaker parts of the magneto remain stationary, and there is no necessity for a slip ring and pick-up as in the former case. Also, since the windings can be more heavily insulated, the risk of them breaking down under open-circuit conditions is minimized, and thus the safety spark gap is often omitted. The magneto is thus more reliable as a result of its improved mechanical construction, and incidentally usually requires less maintenance.

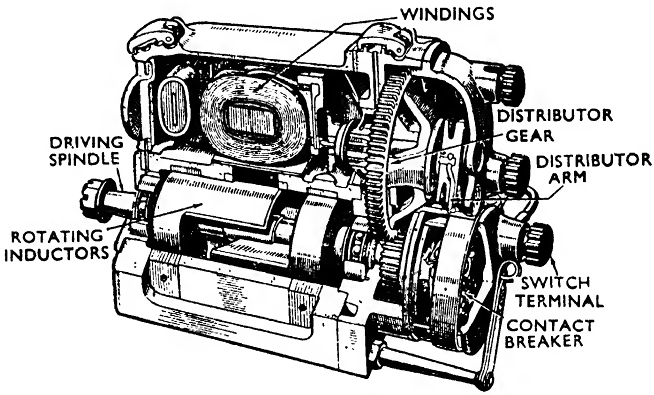


Showing how rotation of the magnet rotor causes flux reversal through the windings.

In operation the magneto is similar to the rotating-armature type. Again the current generated in the primary winding constrains the main magnetic field until the contact breaker opens, when the rapid flux reversal, linking with the turns of the secondary winding, induces a high voltage in that winding.

The development of magnet steels over the past few years has been taken advantage of by magneto designers. Where originally it was necessary to utilize a large horseshoe pattern magnet of cobalt steel, only quite a comparatively small size of the latest materials (such as Nifal, containing nickel, iron and aluminium) is required to produce the same amount of magnetic flux, making possible a considerable saving in size and weight of the completed magneto.

Another type of stationary-winding magneto is known as the polar inductor machine, in which the magnet also is fixed. The windings are mounted above the rotor, which



The B.T.-H. polar inductor type of magneto in which soft-iron inductors revolve and the windings and magnets remain stationary.

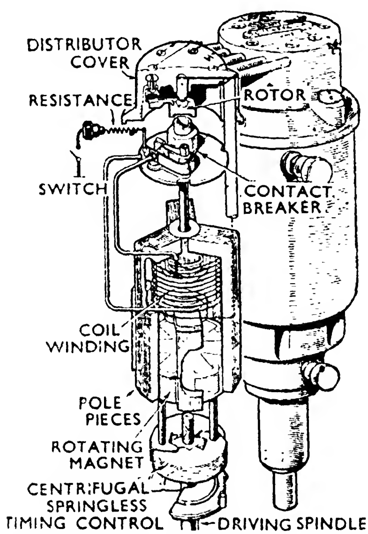
consists of soft-iron inductor bars. These rotate in the stationary-magnetic-field system provided by bar magnets having end cheeks in the form of laminated iron rings. The distributor is gear-coupled in the same way as the revolving-armature type, whilst the contact breaker is operated from a cam on the end of the rotor spindle as in a coil distributor.

Camshaft-speed Magneto

A rather special form of rotating-magnet magneto is designed to run at camshaft speed (that is, half engine speed) and is arranged to replace the coil-ignition distributor unit on any engine with the minimum of trouble. It is usually mounted vertically or at a slight angle in the same way as the distributor, and for this reason is sometimes also known as a vertical magneto. As a result of running at camshaft speed, no gear drive to the distributor is necessary.

Several manufacturers produce magnetos of this type, but essentially all are constructed on similar lines, differing only in certain design details.

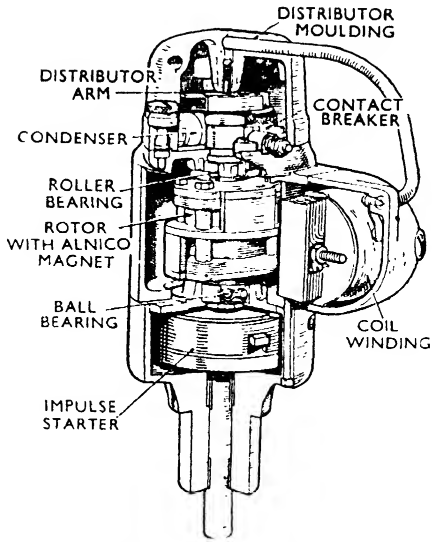
A single circular magnet (of cobalt steel, or one of the newer permanent magnet materials) is fitted with laminated pole shoes of alternate polarity; in a magneto for a 4-cylinder engine there will be four pole shoes, and six in a 6-cylinder unit. The rotor spindle is carried in ball or



The Scintilla Vertex camshaft-speed magneto.

roller bearings and at its upper end is fitted a four- or six-lobe cam operating a standard type of contact breaker. Above this is the usual type of coil-ignition distributor rotor arm and jump-spark arrangement to the electrodes in the moulded cap.

Below the magnet rotor, in the lower part of the cylindrical metal body which encloses the assembly, is fitted either a centrifugally operated automatic timing control or an impulse starter device. Primary and secondary windings are mounted on a laminated iron core, which in some designs is actually inside the main cylindrical casing. In



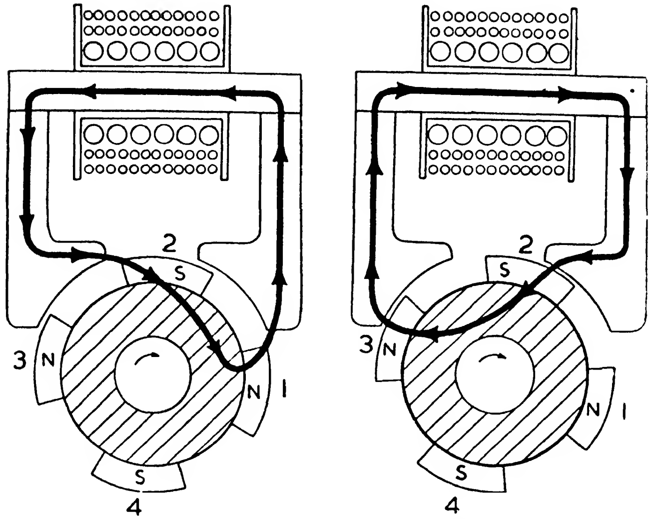
Internal construction of Lucas camshaft-speed magneto with impulse starter.

other types the coils are mounted externally on the side of the main housing.

As will be clear from the illustration of the magnetic circuit of the magneto, there will be as many flux reversals in one revolution of the rotor as there are pole shoes on the rotor. Thus, the number of sparks produced for each revolution will be equal to the number of engine cylinders, as in the case of coil ignition.

Timing

The general principle of timing is, of course, the same as in the case of coil ignition, namely that the spark shall occur at the top of the compression stroke when the engine is running slowly. It is, however, not possible to generalize as to the particular method to adopt with magnetos, amongst which there is much greater variance in design than is the case with distributors.



Flux reversal in a 4-cylinder camshaft-speed magneto.

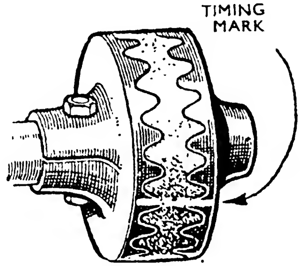
Before attempting to carry out timing, therefore, the manufacturer's instruction book must always be referred to for the recommended procedure to adopt.

Magneto Maintenance

Several of the maintenance points described in the previous chapter are applicable also to the magneto. The contact breaker, distributor moulding and electrodes must be kept clean and dry. Rotating-armature magnetos usually allow access to be obtained to the slip-ring track which must occasionally be cleaned by inserting a soft cloth against the slip ring and at the same time slowly turning the engine. Carbon pick-up brushes must slide freely in their holders, and must be replaced when worn.

Correct adjustment of the contact-breaker gap is just as important on the magneto, and usually this is carried out in a manner similar to that described on page 114. With magnetos employing a rotating contact-breaker assembly, make sure that the cam ring, if it be of the movable type, is properly in place on its spigot. If it is twisted slightly, as may easily happen, it may affect the gap setting and the timing.

Lubrication of the distributor gear calls for the addition of two or three drops of thin machine oil from time to time. The ball or roller bearings in which the rotor spindle is carried are packed with high-melting-point grease when the magneto is being assembled and, as in the case of the dynamo, should not require further attention until the



By marking the three parts of a Vernier coupling with a streak of paint correct assembly is assured. A coupling of this kind allows a timing variation of less than one degree.

engine is undergoing overhaul. Cam rings are usually lubricated from a length of felt contained in a pocket in the contact-breaker housing; the oil finds its way on to the cam surface through a small hole drilled in the cam ring and fitted with a wick. The felt is accessible when the cam ring is withdrawn, when two or three drops of thin machine oil can be placed on it. In magnetos where the cam is mounted on the rotor spindle, it should have a light smear of grease or clean engine oil occasionally, and a spot of oil should be placed on the pivot bearing of the contact-breaker rocker arm.

While the above hints are applicable to all magnetos, it is advisable before doing anything beyond cleaning to consult the maker's own instruction book, as there may be some important part which requires special treatment.

Retaining the Magnetism

Whatever type the magneto may be, reduced sparking efficiency may be due to loss of magnetism; that is, to the magnets becoming weak. Full strength can be restored by remagnetizing and all electrical service stations are equipped with the necessary plant. The magneto must, of course, be removed from the engine to be remagnetized, but it is not always necessary to dismantle it, the complete machine being mounted on the magnetizing apparatus, and only a few seconds are necessary for doing the job.

Magnets have somewhat peculiar properties, and it should be borne in mind that all magnetism can be lost if they receive a sudden blow or if they become unduly hot.

For this reason, also, no attempt should ever be made to dismantle the magneto, as with most types removal of the rotor from the machine results in demagnetization of the magnets unless special precautions are taken.

IX

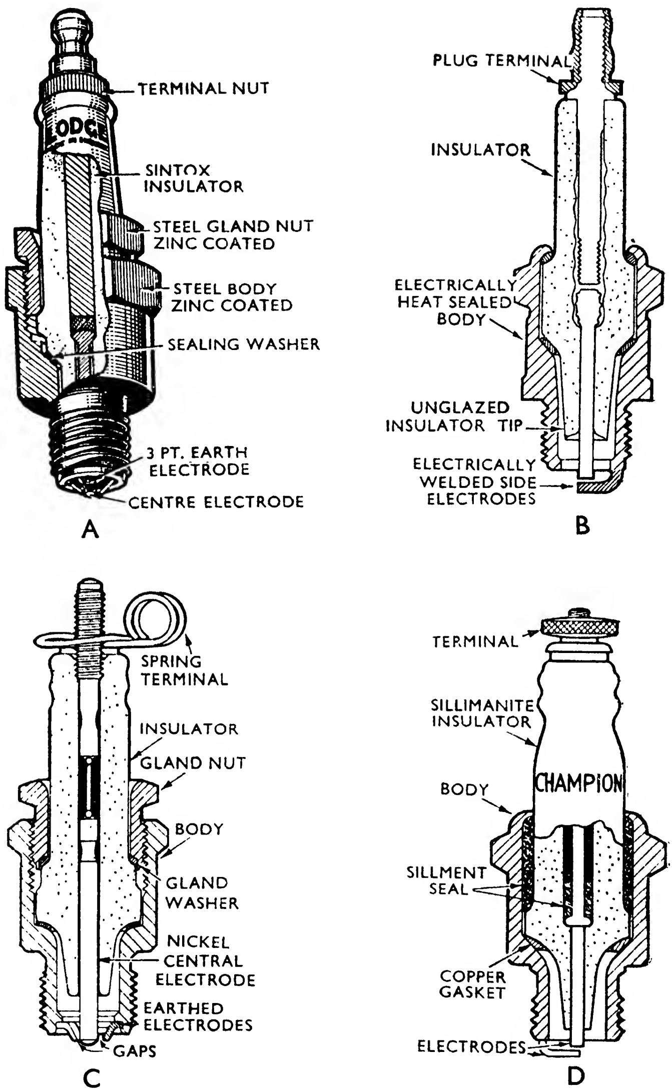
SPARKING PLUGS

THE PURPOSE of a sparking plug is to provide a gap across which the current generated in the secondary winding of a coil or magneto can jump. In jumping, this current makes a spark—a miniature lightning flash—which sets fire to the mixture of air and petrol vapour compressed within the cylinder. To force this current to take the somewhat difficult path through the air, it must be deprived of all other possible paths. In short, one side of the gap must be very thoroughly insulated from the other. Moreover, this insulation must be maintained under working conditions, which include quite high temperatures and pressures as well as the presence of oil and carbon which is apt to form on all surfaces inside a cylinder and which is itself quite a fair conductor of electricity.

Practically all plugs are of the same general construction. There are two main parts—a steel body, which screws into the cylinder, and an insulated centre piece carrying a rod or electrode. This is arranged in such a manner that there is a small air gap between it and the earthed body, and it is across this gap that the spark jumps.

The insulator may be of mica or of some ceramic material. Porcelain was the earliest of these to be used and "Sintox" is probably the latest; it consists of aluminium oxide, which is finely ground, made into a stiff paste and then sintered or fused at a very high temperature. Other well-tried ceramic insulators such as steatite and sillimanite are used by different makers. The essential requirements are electrical insulation at all temperatures, ability to withstand heat, and mechanical strength.

Various metal alloys are used for the central electrode, which is an equally vital part of a plug. Usually, nickel is a prominent component, but recently platinum has come into great favour despite its high cost. Resistance to oxid-



Some typical, famous makes of sparking plugs.

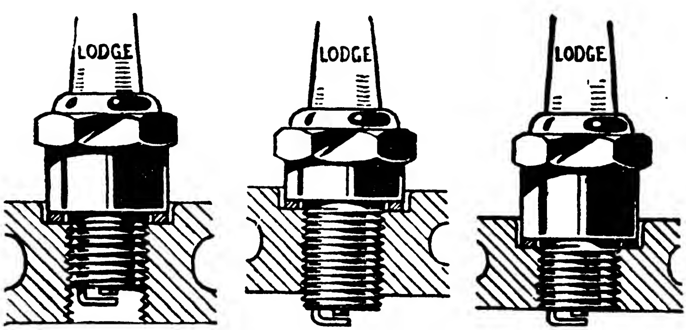
A. Lodge. B. AC-Spinx. C. KLG. D. Champion.

ation and to electrical "burning" are the essentials here, but the nature of the electrode material also has a marked influence on the sparking efficiency of the plug.

Some plugs have three earthed electrodes or "points", whilst others have only one; again, there are plugs in which an earthed ring is formed around the central electrode so that the spark jumps the annular gap.

The two usual plug sizes used on British cars are known as 14 mm. and 18 mm., this being the metric diameter of the thread. The length of the thread varies, according to whether the plug is of the short-reach or long-reach type.

The smaller of these has been standardized in most British and American cars built in the last few years. Its principal merit is that the hot patch, inseparable from any plug and its boss, is naturally smaller than in the case of the 18 mm. size. This does actually permit the use of higher compression ratios so that greater efficiency is obtained. There is, incidentally, some advantage due to the fact that the smaller boss causes less obstruction in the water passages. In the case of overhead-valve engines, too, a little more freedom is left to the designer in the disposition of the valves because the small plug takes up less space. It will be well understood from what has here been said that, although a 14 mm. plug has merit if used in an engine designed to take advantage of its special properties, there



Too long a reach (centre) may cause pre-ignition, and too short (left) spoils starting and slow running. The plug on the right is of correct length.

is no advantage whatsoever in fitting a 14 mm. plug with an adaptor in an 18 mm. hole.

Still smaller metric sizes also are available, a 12 mm. plug being used in some cars, while plugs of 10 mm. size are being used by a few American car makers. Certain other American engines use plugs with $\frac{7}{8}$ in. S.A.E. thread.

Length of Reach

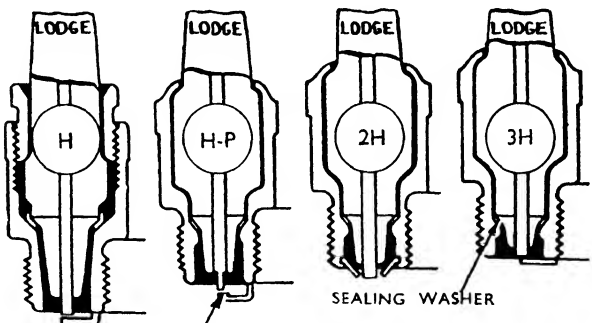
Quite apart from this matter of the size of the thread, there are differences between various plugs according to the engine in which they are intended to be used. Brief reference has already been made to the fact that the length of reach varies. This dimension is very much the same thing as the length of the threaded part of the plug. It varies because the thickness of the water jackets (or some other complication of design in an engine) may necessitate a plug hole which is longer than usual.

Experience has shown that, apart from special circumstances, the best position for the spark gap is flush with the wall of the combustion chamber. If the reach be too short the gap (and therefore the spark) will be pocketed. This will result in difficult starting and in uneven firing at low speeds. On the other hand, if the reach be too long, the plug protrudes into the combustion chamber and thus becomes overheated so that there is pre-ignition and loss of power. The importance of using plugs of the correct reach is therefore fairly clear, and it is fortunate that most cars need a plug of standard reach. When buying new plugs the owner will be well advised to make certain of getting the correct reach.

Types of Plugs

There is another very important factor in which one plug may differ from another, despite great similarity in external appearance. This is known as the heat characteristic. Every engine has its own peculiarities, and some of these react on the sparking plug. Thus one may cause its plugs to become very hot when the engine is running normally, although in another unit the plugs may keep comparatively cool. One induction system may keep a plug dry internally, but another may drench it with fuel, especially when starting. Then again, some piston designs permit a great deal of oil to reach the plugs, whereas others are free from this occurrence.

For such reasons it is not possible to design one plug to suit all engines. Consequently, there are three general classes of plug: cold, normal and soft. A cold plug is for a hot-running engine, and a soft plug is for a unit that does not overheat its plugs or for one that is subject to a good deal of oil in its combustion chamber. Normal plugs come in between these two. Particularly in the cold category,



The nose of the insulator, i.e. that portion from the sealing washer to the firing points, controls the operating temperature of the plug. A long nose means a hot plug, where the heat takes a longer time to disperse to the cylinder head; a short nose means a cold plug—the heat disperses more quickly. The only contact the insulator has with the cylinder head is through the sealing washer and the plug body.

which has to cover the entire range of racing engines with their varying demands, there are sub-divisions to suit almost every conceivable set of conditions.

Although in many makes there is not much difference externally between the appearance of a cold plug and of a soft one, internally there are important differences. In a cold plug (that is one for use in hot engines) only a very small area of the insulator is exposed to the heat of combustion. Quite close to the central electrode, the insulator is connected to the metal body so that heat can escape speedily. The gap is set back slightly into the body so that the electrodes are shielded from the worst of the heat. In a soft plug, on the other hand, the points are more prominent and a comparatively great length of the insulator is exposed. Thus heat can reach the insulator in larger quantity and must travel further before it can escape; the surface is therefore maintained at a higher temperature than would otherwise be reached. This helps to ensure that carbon, if it should form on the insulator surface, will soon be burnt away. Further, owing to the length of the surface from the central electrode to the earthed body of the plug, any thin film of carbon formed on it will have a corresponding length and therefore its resistance will be greater than if the same film were to be formed on a short insulator.

In view of these facts, it should not be necessary to emphasize that the wise owner fits only a type of plug which is known to suit his engine. The maker of the car conducts extensive tests before adopting a particular plug for standardization. It is therefore usually safest to replace these, when their day is done, with others not merely of the same make, but also of the same type. This course, however, is not essential. If for any reason it is desired to try some different make, a suitable type in that range can usually be found. To assist in finding it, most sparking-plug manufacturers provide agents and garages that sell their products with a reference book or chart which indicates precisely which particular model of plug should be used in any given motor car. This should invariably be consulted.

Theory of Spark Discharge

There are, as it were, two stages in the formation of the spark, but together they occupy only so infinitesimal a fraction of a second that they may be regarded as occurring simultaneously. Let us see exactly what happens.

For all practical purposes a gas is an insulator, that is to say, a non-conductor of electricity, but by a process known as ionization it can become a conductor. Ions are molecules changed from their neutral state, and they may be positive or negative, according to whether they have lost an electron in the process or gained one.

These phenomena are, of course, connected with the electronic theory of matter and do not particularly concern us here. We must know, however, that under the influence of an electric field such as will exist at the plug points at the moment of discharge, the electrons and ions will be busily rearranging themselves, and a condition will arise when the ions will bridge the gap between the two electrodes and the spark will pass.

With a three-point plug ionization occurs at all three gaps, but the formation of the bridge of ions may be more rapid at one gap than at the other two, therefore the spark will pass across the bridge which is first formed.

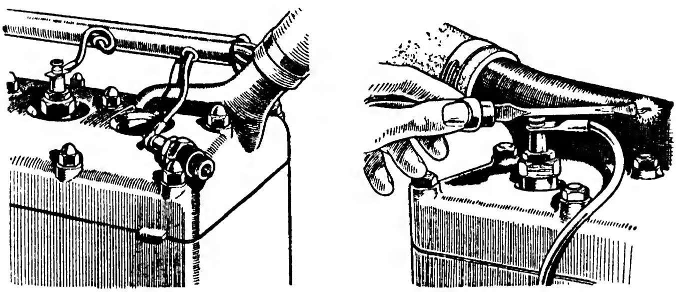
In a single-point plug ionization occurs in just the same way, but with either type the shape and size of the electrodes has a very great influence on sparking efficiency; so, also, has the size of the gap.

Various Plug Faults

No matter what type of plug be used, there will be no spark if carbon forms on the points and bridges the gap. It is easy to see why this should be so with a single-point plug, and a little thought will show that if one gap of a three-point plug be "shorted" the current will pass across to earth rather than jump one of the remaining gaps.

A coating of soot, carbon or oil on the insulation inside the plug body may also give rise to misfiring by allowing the current to leak over the coating to earth. The leakage can be direct or, possibly, the current will spark across, but, owing to the pocketing effect of the plug body, it is unlikely that the spark will fire the mixture.

Some types of plugs are provided with stepped or skirted insulators. The effect of this may be twofold; the irregular surface does not lend itself readily to the formation of carbon deposits, whilst, furthermore, the stepping or skirting increases the length of the path along which the current must travel from the electrode to the body. The chances are, therefore, that unless the plug be badly fouled the ionized



Testing a plug in free air (left) may mislead. By earthing it (right) one can note whether the engine loses speed. If it does not, the plug is evidently defective.

gap will offer a lower resistance to the current than that presented by tortuous insulator paths. Hence misfiring is avoided.

Plug-cleaning Precautions

In some types of plug the centre part is detachable from the body. This simplifies cleaning the insulator, but introduces some problems of its own. Other types cannot be separated, but two methods of cleaning them have been evolved.

When cleaning plugs it is very important to avoid scratching the insulation material. When the centre part is detached from the body, the insulator can be wiped with a petrol-damped rag. Judicious scraping is, perhaps, allowable in bad cases, but care must be taken with mica insulators to avoid flaking. A smooth and polished surface is the finish at which to aim.

Scratched insulators are not necessarily impaired electrically, but the rough surface encourages the formation of carbon deposits by enabling them to key on readily.

The electrode itself may be rubbed with very fine glass paper, but remember that, being made of fairly soft metal, it is easily bent. No attempt should ever be made to alter its shape by filing.

A stiff wire brush can be recommended for cleaning the end of the plug body and the attached electrodes. These, like the central electrode, should never be filed.

When reassembling a plug, see that the seating within the body against which the flange on the centre part abuts is clean and free from grit. As a rule, a plain copper washer is interposed between the seating and the flange; this must be in good condition.

The gland nut should be tightened down fully, preferably by the use of a box spanner, so that risk of distortion is avoided.

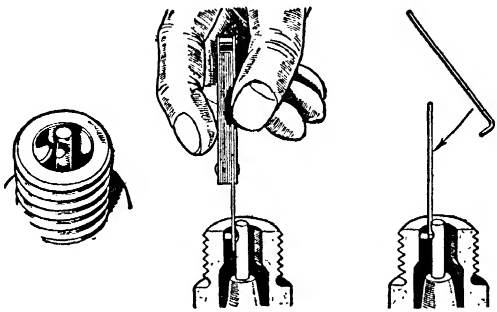
Naturally, the upper part of the insulation between the terminal and the body must be clean. If it be cracked or, in the case of mica, distorted, there is considerable risk of current leakage; in fact, the plug will probably have to be discarded.

Setting the Gap

The final job after cleaning a plug is to set the gap or gaps. A feeler gauge should be used, as an exact setting cannot be obtained by guessing.

As a general rule, a gap of ·02 in.—or ·5 mm.—is correct for all normal plugs with either coil or magneto ignition apparatus. A variation from this setting, however, is to be found, to mention only one instance, in the case of the Delco-Remy equipment, where a gap of ·028–·030 in. is recommended.

Recently it has been established that an exceptionally wide plug gap has a beneficial effect on combustion, particularly on small throttle openings. It seems that a wide gap permits the burning of unusually weak mixtures without any sign of erratic running such as would usually be experienced in these circumstances. Gaps up to ·050 in. have been recommended by some authorities, but others are of the opinion that little or nothing is to be gained by using gaps wider than ·035 in. Even this, it must be emphasized, is not simply a matter of widening the plug gap to the desired extent, and leaving it at that; there must be sufficient voltage to persuade a spark to jump across this wide gap. For that reason it is necessary to use special equipment such as the Lucas Sports coil or the Delco-Remy set.



A badly pitted or burnt electrode (extreme left) will not give a correct gap reading with a feeler gauge (centre). It is then preferable to use a round wire (right) of known diameter as a gauge.

Before leaving the question of plug cleaning and setting, it may be mentioned that owners who do not care to clean their own plugs may have the work done very efficiently and inexpensively at a garage, where, as a rule, a plug-cleaning machine will be installed. The service usually includes resetting of the gaps and, in some cases, the plugs are tested under pressure.

Many garages are equipped with a plug-cleaning machine which is rather like a small sand-blasting plant, except that the abrasive powder is rather more gentle than sand in its effect. Even so, it is liable to damage a plug with mica insulation, and therefore it should never be used on plugs of this type. These machines are reasonably safe for ceramic insulators, however, but if no such equipment is available and the plug to be cleaned is not of the detachable type, a good job can be made of it with the aid of a stiff bristle brush soaked in petrol and used with care and patience.

Cold-starting Troubles

When an engine is first started from cold in very damp weather, sparks can often be seen or heard jumping from the H.T. terminal to the body of the plug. This is because the insulator has on it a very thin coating of moisture down which the current leaks in preference to jumping the gap at the points.

A cold plug requires a much higher sparking voltage than a hot one, owing to the fact that at low temperatures the electron emission at the gap is reduced. If, therefore, no bridge of ions be formed over which the spark can pass, the current will find an easier path, and this may well be across the damp insulator.

A warm rag will prove effective for wiping the insulators dry, but in cases of really obstinate starting a good plan is to remove the plugs from the engine and to heat them on a gas ring or before a fire. If, then, they be replaced in the engine before they have time to cool the effect will be two-fold. The moisture will have been evaporated and the electrodes will have attained a temperature at which there will be efficient ionization at the gap.

Where obstinate starting is due to spark inefficiency, such as might be caused by a weak magneto, or a partially discharged battery in the case of coil ignition, it is advisable to see that the plugs are perfectly clean, especially with regard to the internal insulated portions, and that the points are set as closely as possible. It will sometimes be found that rubbing the electrodes with a lead pencil will aid "cold" sparking.

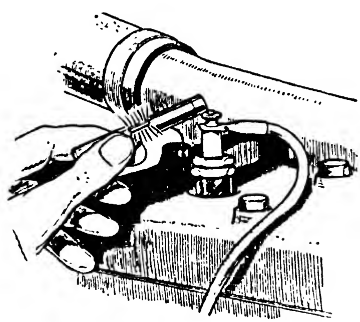
When doubt exists regarding the condition of a plug, no accurate idea of its efficiency can be obtained by removing it from the engine and watching it spark whilst lying on the cylinder head. In these circumstances, the plug is not working under normal conditions, and if a spark occurs regularly at the points, it by no means follows that it will do so when the plug is in the engine and subjected to the compression pressure.

It makes no difference whether the fault lies in the plug or in the coil or magneto. No true idea of performance can be gained by testing under atmospheric pressure. Most garages and service stations have special appliances where the plugs can be tested under high pressure.

Neon-tube Testers

A very good idea of how a plug is behaving in the cylinder can be gained by the use of a neon tester. This consists of an insulated holder in which is inserted a sealed glass tube containing neon gas. The tube is connected at one end to a piece of metal, which may take the form of a cap on the end of the insulated holder.

In use, the tester is brought against each plug in turn so that the metal part touches the plug terminal. The test is made, of course, with the engine running, and if a plug is sparking properly there will be a series of bright flashes in the neon tube, whilst faulty sparking is indicated by the dullness or irregularity of the flashes.



A neon plug tester in use. Its indications are a useful guide to sparking efficiency.

A neon tester is useful also in tracing leakage of high-tension current along the cables connecting the plugs to the distributor. The tube will glow when brought near the cables, even when the insulation is perfectly good, but if the rubber be cracked or perished the glow at that point will be very much brighter.

X

LIGHTING EQUIPMENT

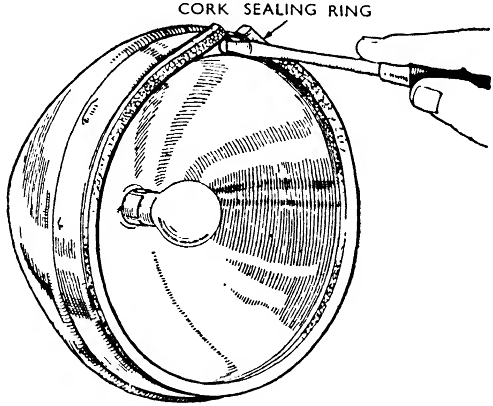
WHAT IS the law regarding lighting equipment fitted to a vehicle? First, every vehicle on the road during the hours of darkness must display two white lights showing forward, each of a power not exceeding 7 watts and fitted with frosted glass or other diffusing material. In addition, a red light must be carried at the rear of the vehicle, either on the centre line or the off side, and visible from a reasonable distance. The height and spacing of these lamps are subject to statutory regulations. Also, the rear number plate must be illuminated so that every letter and figure is "easily distinguishable" at a distance up to 60 feet.

These are the only lights which are obligatory, but driving at night would be something of a trial unless headlamps were fitted, and these again must conform to definite rules. The Lighting Regulations state that a lighting system must be arranged so that it can give a light which is "incapable of dazzling any person standing on the same horizontal plane as the vehicle at a greater distance than 25 feet from the lamp, whose eye level is not less than 3 feet 6 inches above that plane". This means that headlamps must either be permanently deflected downwards or provided with some anti-dazzle device, either by dipping the beam or beams, or by arranging a third lamp with a permanently deflected beam to be switched on when the headlamps are extinguished. A third lamp used for driving must be mounted more than 2 feet 2 inches from the ground (measured to the centre of the lamp). Any lamp mounted below this height can be used only in fog or when snow is falling. There are no restrictions as to the wattage of headlamps.

Various other lights may be fitted as aids to driving and comfort, such as panel lights, roof lamps, stop lamps, reverse lamps, oil-pressure warning lights and so on. Generally the side and headlamp switches are mounted on the facia or in the centre of the steering wheel, whilst the switches which control the auxiliary lights are placed in various convenient positions. The headlamp dipper switch is very often of the foot-operated pattern.

Headlamps

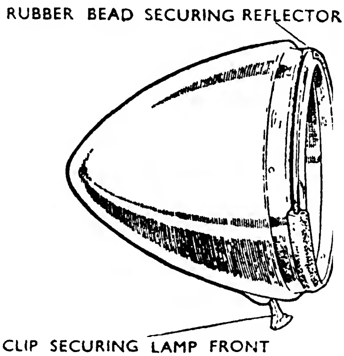
Until the recent alterations in styling, with their attendant "all-flush" external appearance, headlamps were almost invariably of the externally mounted stem-fitting type. With these types, the front rim which carries the glass is usually retained in the lamp body by a locating tongue at the top of the rim and a hook or spring catch at the bottom, there being a thin rubber seal between the rim and the glass.



Headlamp with cork sealing ring, showing screw securing reflector to lamp body.

Removal of the front rim exposes to view the reflector and a second sealing ring, either of cork or rubber. The purpose of these seals is to prevent dust and moisture from reaching the reflector surface and so spoiling its effectiveness. In the older method, a strip of cork is retained in a flange on the reflector by means of small pointed tongues. The removal of the cork will uncover a small screw which secures the reflector to the lamp body, although occasionally with this type of lamp the reflector is retained by a screw at the extreme back of the lamp body, the front of the reflector being positioned by tongues engaging slots in the body.

In the second case, a moulded rubber beading serves the dual purpose of sealing the rim joint and holding the reflector in the lamp body. The flanges of the reflector and lamp body are placed together, a projection on the reflector engaging a location at the top of the body, and the rubber bead is fitted.



The rubber bead acts both as a seal and a means of securing the reflector.

The lamp body itself is usually either chromium plated or black. When cleaning, it is important to note that metal polish must not be used for chromium-plated surfaces or the surface may become scratched. Wash the lamp with plenty of water and, when all the dirt has been removed, polish with a chamois leather or a soft dry cloth. Black or coloured lamp bodies can be cleaned with a good car polish.

The Reflector

The greatest single factor in headlamp efficiency is undoubtedly the shape and condition of the reflector. It is usually of parabolic shape and formed from thin sheet brass, and at its centre is mounted the bulb holder. The reflecting surface is silver-plated and then polished to give a very bright finish, which is usually covered with a special form of lacquer to protect and preserve the surface. For this reason, great care must be taken when handling reflectors to see that they do not become fingermarked, and of course metal polish must never be used in an attempt to brighten up a reflector surface. It is permissible to wipe them over very occasionally with a piece of very soft material.

Unfortunately, however adequate the sealing arrangements between lamp front and reflector in this type of lamp, climatic conditions affect the polished surface, giving rise to a certain amount of tarnishing after two years or more of service. This will often be noticed earlier with a vehicle used mostly in industrial areas than with those remote from so many impurities in the air. Since a dull reflecting surface will absorb a considerable amount of light, one should have no hesitation in sending the reflector away for replating; this is a comparatively inexpensive job and is essential if maximum efficiency is to be obtained from the lamps.

For the same reason, if a headlamp glass becomes cracked or broken, no time should be lost in obtaining a new one. Complete exposure of the reflector to the air will, of course, hasten the tarnishing of the surface.

Headlamp Glasses

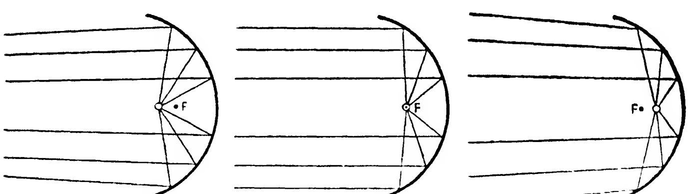
In most cases, special forms of glass are used in headlamps, for the purpose of distributing the beam in such a manner as to produce the most useful driving light. The main requirements for night driving are a long-range beam for early detection of obstacles, coupled with sufficient illumination at the roadside some distance ahead which will pick out pedestrians stepping from the kerb, will indicate to the driver his position on the road and also provide some useful light for cornering.

To achieve this from what would otherwise be a parallel beam of light produced by the parabolic reflector, the glass (or lens, to use its more accurate description) may be domed and moulded into a series of vertical ribs or flutes, the design of which has been carefully determined to give the effect required.

It will be clear from this that in the event of a lamp glass being broken an ordinary piece of glass will not be a satisfactory substitute, although there is every reason for fitting it temporarily in order to protect the reflector whilst the proper lens is being obtained. Any glazier will cut the necessary disc of plain glass for a small charge.

Getting the Best Light by Focusing

Focusing a headlamp means the positioning of the bulb filament in relation to the physical construction of the reflector to give the best possible illumination from the lamp. If the filament is too far forward, the beam will be convergent, with a dark spot in its centre; if, on the other hand, the bulb is too far back, the beam will be divergent, that is, it will spread out. A badly focused bulb will cause the lamp to have a poor range and to give excessive dazzle.

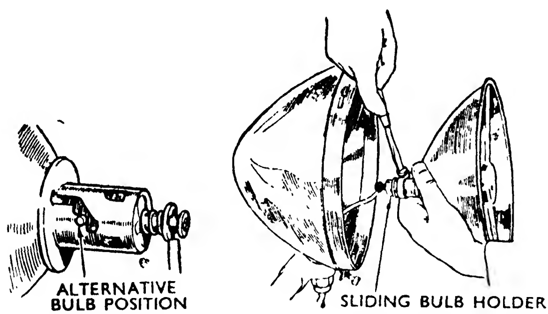


This illustrates the effect on the lamp beam of the position of the bulb filament.

This is quite a different problem from lamp setting, which is the adjustment of the complete lamp on the vehicle to give a correctly set driving beam in relation to the direction of travel.

As will be seen from the illustration, there can only be one absolutely correct position to which the headlamp bulb should be focused. Any diffusion or refraction of light is achieved by means of the front lens as already explained. Since the latter disperses the light too much to permit accurate focusing, it must be removed before making the adjustment.

The most popular form of focusing adjustment is that of the sliding bulb-holder. First remove the front rim and glass and then take the reflector out of the lamp body and, with the main driving beam switched on, project the beam on to a flat surface at a reasonable distance, say 25 feet. Cover up one headlamp while testing the other, and remember that the reflector has to be "earthed" for the bulb to light. If no separate earth wire is connected between the reflector and body, the reflector can be held against the lamp whilst focusing, remembering to keep the live terminal away from "earth".



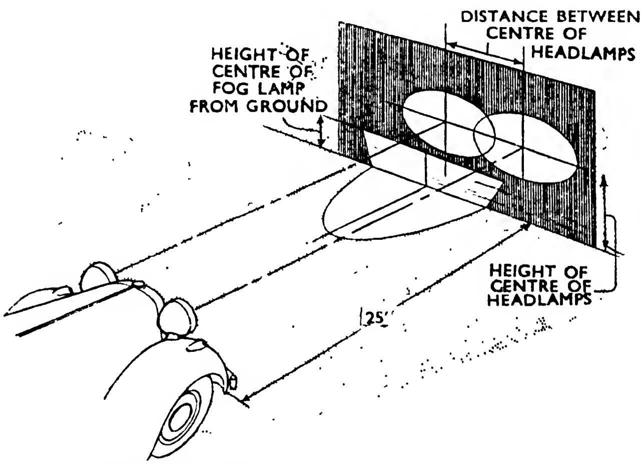
Lamp bulbs are focused by the use of a three-notched bayonet catch (left) or a sliding holder.

If the lamp does not give a uniform long-range beam without any dark centre, slacken the clamping clip at the back of the reflector, when the bulb-holder may be moved backwards or forwards until the best result is obtained. Then retighten the clamping clip, reassemble the reflector into the lamp body and fit the front rim.

Another type of bulb adjustment is that in which alternative locations (usually three) are provided for the bulb in its holder, and each position should be tried for the best result.

Setting the Lamp Beams

Having found the correct position for the bulb in the reflector, we are now ready for the second step—lamp setting. The correct setting for the main driving beams is straight ahead, parallel with the road and with each other. In practice a compromise must be made here, since the addition of passengers to the rear seats (if any) will depress the springs and so tilt the lamps upward. The



Method of setting headlamps and a fog lamp.

lamps should, therefore, be adjusted with the normal rear load carried, or slightly tilted downward with no rear load.

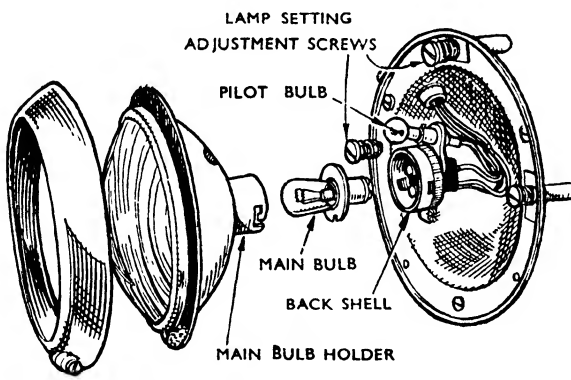
To set the lamps the car should stand on a flat surface, facing squarely and at 25 feet from a flat vertical surface, such as a wall or garage doors. The centres of the two discs of light projected should now be exactly the same width apart and the same height as the lamps. The fixing nuts of the lamps must be slackened for corrections to be made, always remembering to tighten the nuts fully and re-check the light-pattern afterwards.

This method, if carefully carried out, provides a reasonably accurate setting of the headlamps, which will now operate with maximum efficiency.

The foregoing remarks on construction and focusing are intended to apply in the main to what were conventional headlamp patterns before the general advent of the flush-fitting unit, in which the sealing and focusing problems are tackled in a novel manner.

Flush-fitting Lamps with a Light Unit

The essential features of this new design are the use of a combined reflector and front-lens assembly, known as a "light unit", and a "pre-focus"-type bulb, which ensures that the filament is always positioned correctly with respect to the focal point of the reflector.



The flush-fitting pre-focus-bulb-type headlamp. The reflector and lens are permanently sealed at the front joint.

The construction of the light unit, in which the reflector is permanently spun over the glass lens, the joint being sealed with an internal rubber ring, ensures that the reflector is permanently protected, with obvious advantage to its efficiency. Moreover, at the back of the reflector is formed a cup into which the flange of the pre-focus bulb fits exactly, so making the light unit almost proof against dust, moisture and other climatic conditions.

The pre-focus bulb does away with the necessity for providing a means of focusing within the lamp. The bulb is cylindrical in shape so as to reduce its overall diameter, and hence the aperture in the rear of the reflector, to a minimum, and has a large cap on which is carried a flange, accurately positioned in relation to the filament during manufacture. It can only be fitted in the bulb holder in one position, and is secured by means of a bayonet-fitting cap or back-shell with spring-loaded contacts which carry the supply to the bulb. On cars with no separate side lamps, a bracket attached to the back-shell carries a small pilot bulb, giving illumination through a small window, covered with a diffuser material, in the reflector.

A decorative front rim is held in position by means of a screw fixing at the bottom. Removal of this exposes to view a dust-excluding rubber ring, behind which will be seen three spring-loaded adjustment screws which also serve to hold the light unit in position through keyhole-type slots in the flange in which the unit is mounted. To obtain access to the rear of the reflector for bulb removal, it is only necessary to press the light unit in against the tension of these springs and turn it to disengage it from the screws.

Since the correct focus of this type of lamp is arranged by the maker, it remains for the owner only to set the lamps. The same rules apply as for the earlier external types, the only difference being that, in this case, adjustment is made by means of the spring-loaded screws to give horizontal and vertical movement of the light unit.

In America, "sealed-beam" headlamps have been in use on all cars for some time. In this design the bulb filaments also are sealed in the permanently enclosed light source, so that should a bulb filament burn out the lens and reflector unit must be replaced complete. Whilst this may be an economic proposition in America where such large numbers of vehicles are involved, it would certainly not be so in the case of the United Kingdom manufacturer who must export a considerable proportion of his far smaller output (by comparison) to many countries with widely different lighting requirements. For this reason, the unit with replaceable bulb has been standardized in this country.

Anti-dazzle Schemes

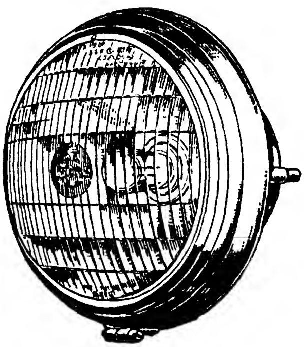
Since it is impracticable to produce a lamp in which the main driving beam is both suitable for reasonably fast driving at night and at the same time is below the eye level of the oncoming driver, all countries have accepted the necessity for having two types of headlamp beam, one for driving and the other for passing. The three main methods of achieving this are:

(*a*) by switching off the headlights and at the same time bringing into operation a third lamp with a permanently deflected beam to meet the anti-dazzle requirement;
(*b*) by the use of double-filament bulbs, one filament being displaced in relation to the focal point of the reflector, so that changeover from one filament to the other causes a change of light distribution;
(*c*) by means of a movable reflector which can be made to tilt the headlamp beam downwards and usually also towards the near side.

Method (*a*) is not met with so often nowadays, although many motorists at one time used a combined fog lamp and pass light, mounted low down on the front bumper, as a driving light. It was a common failing with this arrangement to tilt the lamp upwards slightly to gain increased range, and this, of course, resulted in excessive dazzle. An order has been made, therefore, restricting the use of lamps having a centre height of less than 2 feet 2 inches from the ground; they may now only be used in fog or falling snow.

Methods (*b*) and (*c*) have been the general practice of recent years. Until 1951, the "dip-and-switch" system was the recognised fitment in this country—this being the name given to the arrangement whereby the nearside beam is deflected downwards and the offside beam extinguished on operation of the dip switch. This system had been adopted to give the low dazzle limit considered desirable in the

United Kingdom, in spite of the fact that illumination of the road at any distance ahead of the car was reduced very considerably. In other parts of the world, however, it had for many years been the custom—in some instances even the legal requirement—to dip *both* headlamp beams: and, in general, the degree of dazzle was much greater than with the "dip-and-switch" system.



The block-lens headlamp unit.

In 1951 a new design of headlamp lens, known as the "block-pattern" lens, was introduced by the Lucas concern. The main feature of this lens is the reduction of top light from the dipped beam to about half that of former pattern lamps; thus both headlamps can be used for dipped lighting with no increase in dazzle over the earlier system, but since two lights are on instead of one, much better illumination is provided for the road ahead. Consequently, "double-dipping" has replaced the "dip-and-switch" system on modern British cars, bringing them into conformity with the practice generally in use throughout the world.

This "block-pattern" lens is divided into a large number of small rectangular zones, each formed optically in the shape of a flute, or a combination of flute and prism, by means of which each part of the beam is dispersed or deflected to play its designed part in the final beam pattern. It depends for its efficiency on a correctly-focused light source, and is therefore incorporated in the light unit with pre-focus bulb.

Incidentally, conversion sets incorporating these new lenses are available for the majority of earlier headlamps, and it is well worth considering whether it would not be wise to fit such a set and bring the lighting up to date, particularly if, for example, the existing reflectors are badly tarnished and in need of replacement. The conversion set usually consists of a pair of Light Units, in rims which readily replace the original ones, together with the necessary pre-focus bulbs and adaptors. Some wiring alterations will need to be made, but these are not usually very extensive.

When the driving light has been correctly set, it is worth while to operate the dip switch in order to be sure that the deflected beam also points in the appropriate direction. The impression may be gained that there is too much dip, and it is not unknown for drivers to tip the whole lamp up a bit in order to rectify the supposed fault when dipped. This is not commendable. If the lamps are correctly set on the main driving beams, the amount of dip is controlled by the lamp design to give an adequate dipped beam with the minimum of dazzle.

The Dipping Reflector

With electrically operated dipping control the mechanism is carried within the body of the near-side lamp. It takes the form of a solenoid, the plunger of which pushes a bracket on the under-side of the bulb-holder, thus tilting the reflector to the dipped position. This position is determined by another bracket carrying a rubber buffer which stops further movement of the reflector. Upon reaching the end of its travel the plunger opens a pair of contacts, thereby bringing into circuit a high-resistance winding, which limits the amount of current flowing to a fraction of an ampere. When the current is switched off the reflector is returned to its normal position by means of a spring. The dipping mechanism gives very little trouble in practice, but should it show sluggishness in operation or should the off-side headlamp fail to cut in or out when the control switch is moved an examination of the dipping mechanism will be necessary.

It can be exposed by removing the lamp front and taking out the reflector in the manner described earlier in this chapter. The solenoid and its contacts will be found mounted on the reflector frame, and it will be noticed that there is a small cartridge fuse placed across the windings, and that there is a spare fuse mounted in clips near by. Make sure that the working fuse is held firmly in its clips.

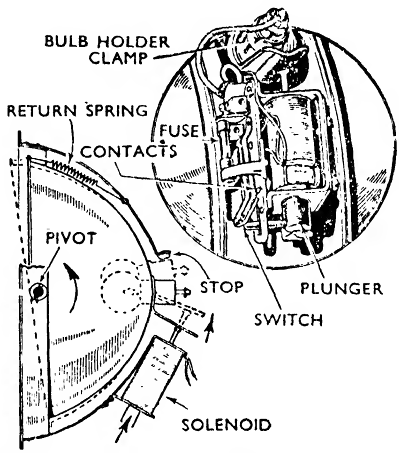


Diagram of the Lucas dipping device operated by a solenoid.

If the fuse has "blown" the spare fuse can be inserted, but it is wise to look for the cause of the overload which brought the trouble. Three points merit inspection. It is possible, if the reflector has been moved previously, that one of the cables gets in the way of the reflector and prevents it from dipping. Another possibility is that the reflector pivot bearings have become tight through lack of lubrication. If there seems to be any stiffness, the remedy is to apply one drop of thin machine oil to each of the two bearings on which the reflector rocks. A third possibility is that the solenoid plunger is inclined to stick. This can be cured by a light smear of thin machine oil on the side of the plunger.

Apart from such possible faults as these, it may happen that the wiring behind the reflector has developed a short-circuit owing, perhaps, to its insulation being chafed. A search should be made for any sign of that. If found, it can be cured either by fitting a new piece of wire of the same length, so as to leave full freedom for the motion of the reflector, or the chafed patch may be re-insulated with the aid of a short piece of insulating tape wound securely round it.

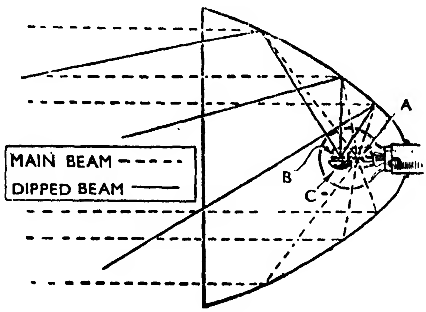
Another fault which can develop in the dipping mechanism causes the reflector to oscillate and the lamp beam to dither; this is due to maladjustment of the contacts which bring the high resistance into circuit. These contacts will usually be found near the fuse. When the reflector is fully dipped, the gap should be between ·010 in. and ·018 in. It can be set by means of the pin at the end of the plunger. If all these things are in order, and the amount of dip is found to be really too great, it can be remedied by a slight alteration of the stop. This is not truly adjustable, and it should never need alteration, but in the case of a second-hand car some previous owner may have tampered with it. If that appears to be so, the bracket can be bent very slightly in the desired direction so that it stops the reflector in the correct position.

Double-filament Bulbs

Some years ago, British cars quite commonly were equipped with double-filament bulbs, the main filament being positioned at the focal point of the reflector and the auxiliary filament being forward of the focal point, resulting in a dipped beam. A small cup or shield was fitted below the dip filament to prevent light from this filament from striking the lower half of the reflector. This construction was known as the Graves-type bulb.

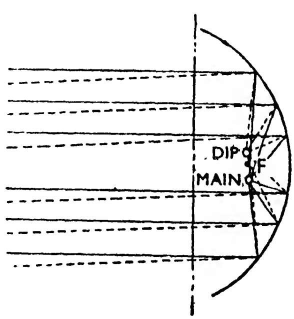
This system was gradually superseded on the majority of cars by the solenoid dipping device already described; recently, however, with the general adoption of the flush-fitting pre-focus lamp, a return has been made to the double-filament bulb, which of course makes for a simpler lamp construction and eliminates a moving part—and hence a possible source of trouble.

There are two types of double-filament bulbs in use. One has both filaments offset slightly from the focal point. This has the effect of producing main and dipped beams of about



The Graves-type bulb. The rear filament (A) gives the main beam shown dotted. When the current is diverted to the forward filament (B) a dipped beam is obtained, the lower half of the reflector being screened by the shield (C).

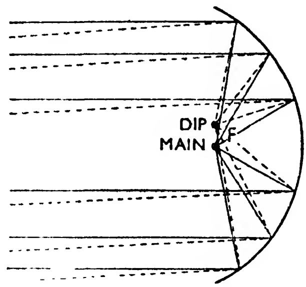
equal intensity. As will be seen from the illustration, just as the light beam from the dip filament is directed downwards, so that from the main filament will be directed slightly upwards by virtue of its not being positioned absolutely at the focal point of the reflector. This, of course, is corrected for when setting the lamp by the method



When both filaments are offset from the focal points, the lamp must be set down to give a horizontal main beam.

described, the lamp being actually tilted a very small amount downwards.

In the second type of bulb, the main filament is positioned at the focal point as was the case with the Graves bulb, but the dip filament, instead of being forward of the

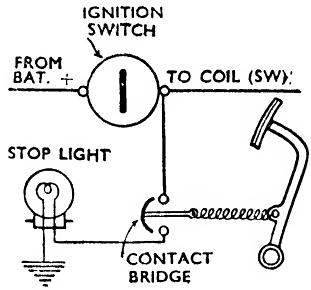


The beam distribution of a double-filament bulb having the main filament at the focal point of the reflector and the dip filament offset above it to produce a dipped beam for anti-dazzle purposes.

focal point, is displaced above it. From this arrangement, therefore, the main filament produces the best possible driving light, while the dip filament, being out of focus, gives a downward but somewhat distorted beam which, however, is redispersed by the front lens to form an adequate passing beam. Bulbs of this type usually are marked "Top" on the metal cap to ensure replacement in the correct position.

Side and Rear Lamps

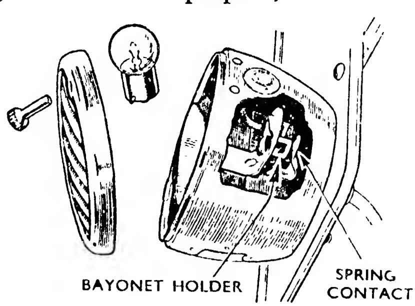
These may be of external or flush-mounting pattern and there is a great variety of shapes and sizes. Although only one tail lamp is obligatory, it is quite common practice for two to be fitted, one on each side of the car, and usually it is combined also with the stop lamp. The latter is provided to give an indication to following vehicles that the brakes are being applied, and is operated automatically when the brake pedal is depressed, the switch being located on the chassis close to the pedal anchorage. On cars where the brake pedal and lever are interconnected, the stop light is wired in series with the ignition switch. This arrangement allows the stop light to be switched off when the engine is stopped, otherwise it would remain alight whenever the car was parked with the hand brake on.



The stop light at the rear of the car is controlled by a switch operated by the brake pedal. Usually this circuit is fed through the ignition switch as indicated in this diagram.

With the increasing use of hydraulic braking systems, a hydraulically-operated stop-light switch fitted in the master cylinder is becoming popular.

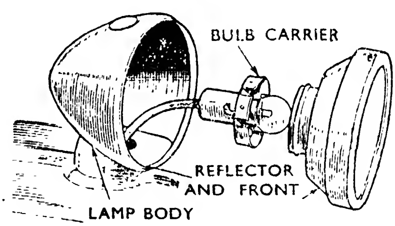
Earlier stop tail lamps were fitted with two separate 6-watt bulbs, one for each purpose, but on later models,



A Lucas combined tail and stop lamp cut away to show the simple form of bayonet holder.

particularly the flush-fitting types, a double-filament bulb is usually employed, the tail light being of 6 watts and the stop-light filament of 18 watts. This arrangement enables a much more distinct indication to be given of braking, particularly in conditions of bright daylight or night driving when the tail light is already on. When replacing one of these composite bulbs, care must be taken, of course, to ensure that it is fitted correctly so that operation of the tail-light switch illuminates the lower-wattage filament. On the very latest types, however, the locating pins on the bulb cap and the corresponding location slots in the bulb-holder are at different heights instead of being diametrically opposite, so that it is possible to fit the bulb only in one position.

Some cars include a reversing light at the rear of the body, commonly controlled by means of a switch associated with the gear lever, giving automatic operation when the lever is moved to engage "reverse". This is a very convenient arrangement when a car has to be manœuvred in the dark. The bulb employed is usually of 24-watt rating.



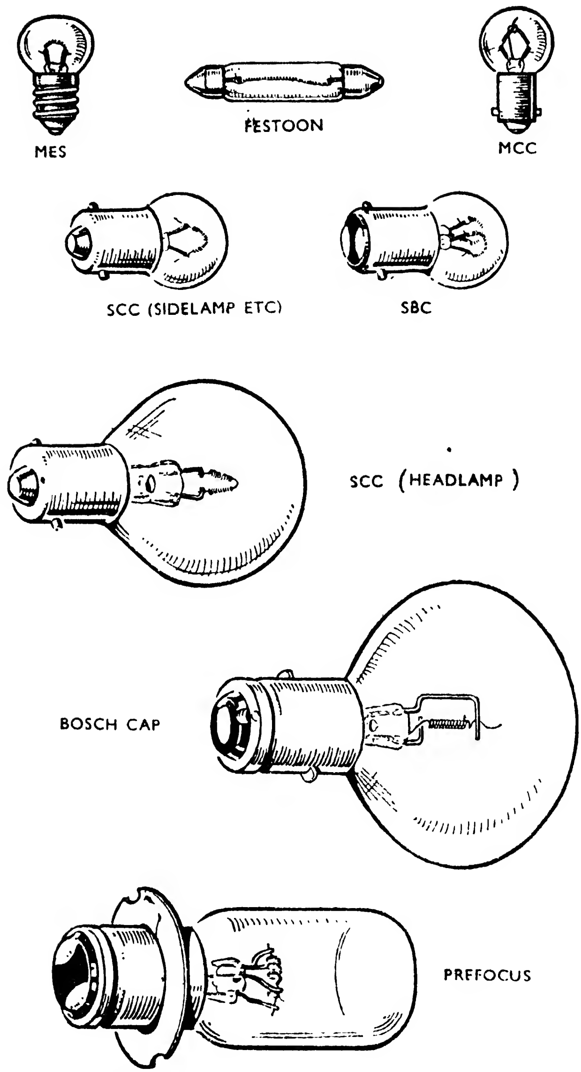
In some side lamps the bulb carrier comes away with the front and can then be separated from the reflector to reveal the bulb.

Removal procedure of side- and rear-lamp fronts to gain access to the bulbs varies from lamp to lamp, but it will generally be found that the slackening of a screw or movement of a hinged clip is all that is necessary.

Lamp Bulbs

There are several sizes and shapes of bulbs in common use apart from wattage variations, and they may be listed as follows:

Festoon: The glass envelope is of tubular shape with



This illustration shows most of the bulbs to be found on British cars.

the filament stretched between brass caps cemented to the tube ends. This type is commonly used in roof lamps, direction-indicator arms, etc.

MES (Miniature Edison Screw): The well-known flash-lamp bulb with screw cap. This type is popular in warning-lights, usually with ballast resistance wound round the body of the lamp.

MCC (Miniature Centre Contact): The bayonet cap is of about $\frac{3}{8}$ inch diameter, single contact, and has been used in panel and warning lights. It is now coming into popular use in external obligatory lamps.

SBC: Small Bayonet Cap.

SCC: Single Centre Contact.

Both these types have a bayonet cap of about $\frac{5}{8}$ in. diameter and cover a variety of bulbs, the SBC invariably being double contact and the SCC, as its name implies, single contact.

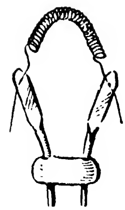
They are supplied both as low-wattage bulbs suitable for side lamps, etc., and the larger types as used in headlamps and fog lamps.

Bosch Cap: This is of Continental origin, and is usually associated with the higher wattage bulbs as used in certain high-powered headlamps. It is also used for special anti-dazzle bulbs such as "Lucas Graves". It is of larger diameter, and has non-reversible bayonet tongues.

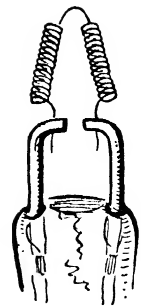
Pre-focus: This is the modern type of bulb specially developed for use in lamps employing the light-unit construction, already referred to earlier in this chapter.

The smaller ranges of bulbs are usually of the vacuum type, whilst the SBC and SCC varieties are almost invariably gas-filled. Gas-filled car-type bulbs usually consume, roughly, $\frac{3}{4}$–1 watt per candle-power, a consumption only about half that of the vacuum type.

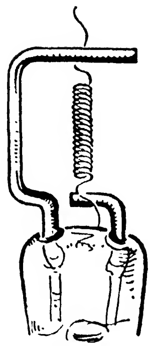
The constant vibration to which the bulb filaments are subjected in service makes robustness one of the primary considerations in the construction of the filament. In the case of bulbs used in non-critical applications such as side and rear lights, panel lamps, etc., it is really the only consideration—accuracy of filament shape is relatively unim-



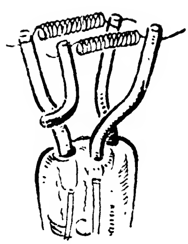
BOW
(LOW WATTAGE)



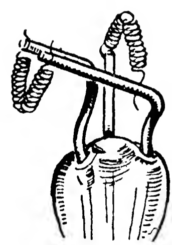
VEE



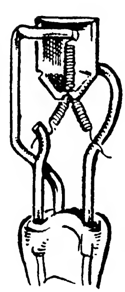
LINE



BI-FOCAL
(PARALLEL)



BI-FOCAL
(CENTRAL FOR NORMAL
OFF-CENTRE FOR DIP)



BI-FOCAL (LUCAS-GRAVES ETC)

These pictures illustrate the filament constructions used in bulb making.

portant. When considering bulbs intended to be used in a reflector, however, such as in head and fog lamps, a second main factor is present. The filament must not only be robust but must also be extremely accurately positioned and of the correct shape to achieve the optical results for which the lamp has been designed. A common fault of cheap bulbs lies in the failure to maintain accuracy of dimensions and shape.

The actual shape of the filament will have an important effect on the light pattern projected from the lamp. A pin-point light-source would, when in correct focus in a parabolic reflector, give a dead parallel beam with no spread. However, this is not possible, as a wire filament must have area, and when this "area" of light-source is averaged around the focal point, a useful beam with some degree of spread is achieved. In fact, headlamp filaments are usually either "straight" or "vee", and the design of the front lens is arranged to deal effectively with the light pattern produced by the type of bulb filament originally fitted in the lamp.

For this reason, only the correct replacement bulb must be used if the efficiency of the lamp is to be maintained.

The general arrangement on modern cars with flush-fitting lamps and pre-focus bulbs is to use double parallel filaments in each headlamp for "double-dipping" systems; for "dip-and-switch" systems, the bulb in the offside lamp has a single line filament.

Correct reflection in a lamp is of the utmost importance, both from driving and anti-dazzle viewpoints. Cover the reflector of the headlamp in the dark and see how much light is present from the bulb only at 300 feet. The bulb itself contributes only a small part in direct rays to the effect.

Whilst when new a bulb should give a very close approximation to its rated candle-power at the rated wattage, conditions can arise which will cause a big drop in efficiency. Chief amongst them is the ageing of the bulb. After a considerable period of use, the inner surface of the glass becomes blackened, due to emission from the filament. This generally indicates that the end of that bulb is near. Inevitably, the light emitted by a bulb in that condition is much below normal, and the wise owner will throw it away and fit a new one. The increased driving comfort at night is well worth the cost.

Avoid Cheap Bulbs

One other point in connection with bulb efficiency. It is seldom worth while to buy very cheap bulbs. Some of them are good and will stand the most exacting candle-power consumption tests; their effective life also is reasonable. Others, however, may be heavy in their current demands or badly made in that the glass is not properly cemented to the cap; the two may part company when the force necessary to engage the pins with the bayonet joint is applied.

When dealing with unbranded bulbs one should beware of super-brilliance. It may seem very attractive to have additional candle-power, but as this result is achieved, as a rule, only by shortening the life of the bulb, it is not so good as it seems.

The scheme adopted is to overrun the filament; that is to make it somewhat smaller than normal. This causes it to glow more brightly, but it will not last so long. Another serious snag in most cheap bulbs is that the filament is neither accurately placed with respect to the bayonet cap nor formed compactly. In consequence, although the bulb may seem very bright it can never be focused properly in the lamp and thus the driving light is likely to be inferior.

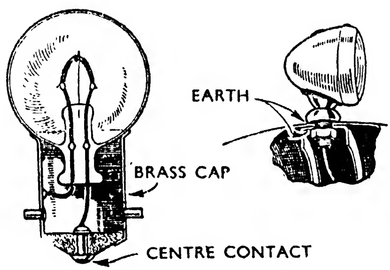
Single- and Double-contact Bulbs

Car bulbs normally have either one or two soldered "pips" in the end caps, being known as single contact and double contact respectively. Single-contact bulbs are "earth return", in other words the bulb filament is connected between the centre contact and the cap itself, the circuit being completed from the cap through the lamp body and car chassis frame, which is connected to the "earthed" side of the battery.

Two types of double-contact bulb may be met, the first being that used in the now rare instance of insulated return systems. A single filament is connected between two contacts, which are both insulated from the cap, and two insulated wires from the battery are required to operate the bulb.

The second type of double-contact bulb is the double filament for use with earth-return systems. Two separate filaments are connected, one from each contact, across to the metal cap, the common circuit back to the battery again being via the car frame.

As we have already seen, earth-return wiring is very conveniently simple, but it is important that all the earthed connections shall be perfectly clean. The formation of a film of rust, for instance, on a lamp mounting can easily set up so high a resistance to the current flow that the bulb will do no more than glow dimly, or even refuse to light at all.



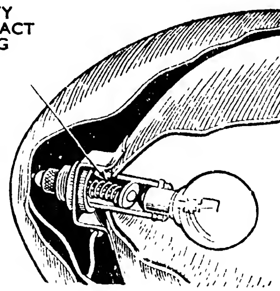
A single-pole bulb (left) uses the lamp body as part of its circuit and therefore there must be good electrical contact between the lamp and the wing or other part on which it is mounted.

When such a fault exists the lamp must be unbolted and the contact faces scraped bright. Further rusting can be prevented by applying paint, enamel or cellulose around the edges of the joint after it has been fully tightened, but not on the contact surfaces themselves, of course.

Bulb-Holder Faults

Connection to the bulb contacts is achieved by means of spring-loaded plungers in the bulb-holder in the case of bayonet-cap bulbs or in the back shell with pre-focus types. The wire from the lighting control switch is connected to the back of the plunger which presses against the contact in the bulb cap.

Although faults in the bulb-holder are not frequent, a few possibilities are mentioned here.



A somewhat unusual but very perplexing fault occurs if the contact spring breaks, softens or is wedged back so that it does not meet the bulb contact.

If the spring in the plunger should become weak, or if the plunger itself should stick, faulty contact will be made with the bulb, and the lamp either will not light at all or will flicker. This trouble is very rare, but it has been known to occur. There is a possibility also of the plunger tip becoming corroded, so that an insulating film is formed between it and the bulb contact; this can well result in a lighting failure.

When fitting a new bulb difficulty is sometimes experienced in pushing it in far enough to engage the bayonet joint. The trouble is due, as a rule, to an excessive amount of solder having been applied on the contacts, and the cure is to file away some of it. Care must be taken to clean away all particles of solder from the surrounding insulation, otherwise a short-circuit may occur. This point is particularly important with double-contact bulbs, because there is, as a rule, only a small gap between the two contacts.

One other point in connection with bulb fitting: in some types of lamp there is a sleeve outside the bulb-holder, and if the two pins which project from the cap are too long they will foul the sleeve and prevent the bulb from being inserted. Here, again, matters can be put right by the judicious use of a small file, with which the length of the pins can be reduced slightly. Do not, of course, clamp the bulb in a vice, as this would be sure to damage it; all the necessary filing can be done with the bulb held gently with the fingers of the left hand.

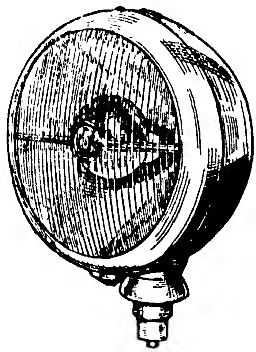
When dealing with the wires leading to the bulb-holders it is important to see that there are no loose strands which might set up a short-circuit by touching an adjacent earthed part. As a rule, in the case of double-contact bulb-holders, there is a small piece of insulating material between the two terminals. If this be missing a piece of cardboard or a short length of insulating tape, folded over, can be inserted.

Driving in Fog

Fog is a nuisance by day, but it is doubly so at night; what, during daylight, may be looked upon as merely a heavy mist can become a very unpleasant condition in the darkness. Fog consists of innumerable particles of moisture suspended in the air and the beam from the car headlamps is reflected back by these water drops so that the driver is dazzled by his own lights. Thus his vision is to a great extent impaired, while the objects which he wishes to see are illuminated less than they would be in normal circumstances. That, in simple terms, is recognized to be the cause of difficulty of driving in fog at night, and in the case of a really dense fog, no satisfactory solution exists.

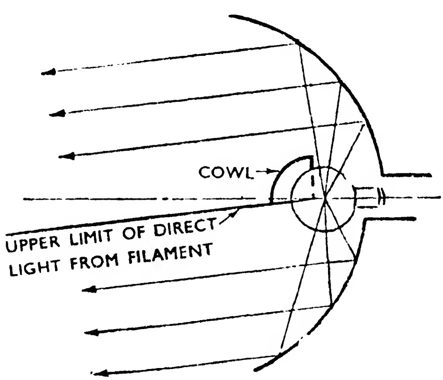
From time to time, amber or yellow glasses have been fitted to lamps used for driving in fog and many motorists consider them to be a greater aid to easier vision. On the other hand, this supposed improvement may be due only to the fact that the reduced illumination intensity due to the colouring of the glass results in a lessening in the back-glare dazzling the driver. There will, of course, also be a reduction in the illumination of objects.

The basic principle underlying the design of the various makes of fog lamps obtainable is that of providing a sharp upper cut-off, resulting in a flat-topped beam located well below the driver's line of vision. Any light reflected by



A hooded bulb and split reflector are used in some Lucas fog lamps to provide a flat-topped beam which prevents dazzle.

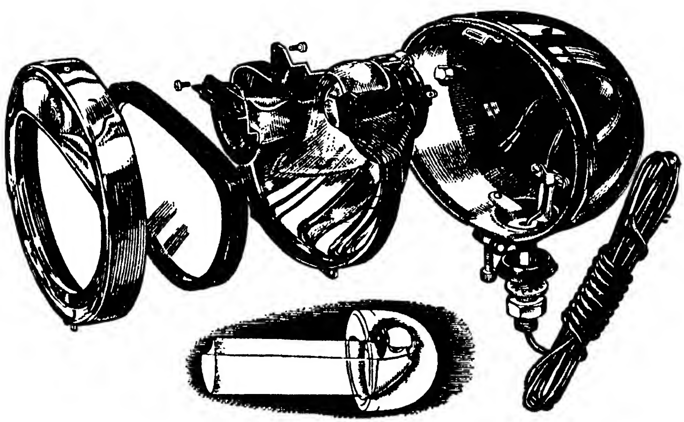
the fog particles is then less likely to reach his eyes. This result is achieved in several different ways in the various lamps, and the differing constructions produce their own characteristic beam patterns. Individual preference also



The principle of the stepped reflector as used in some fog lamps. The filament is slightly out of focus with both halves of the reflector. The bulb cowl prevents exit of direct upward rays.

enters into the problem of beam spread in fog, some drivers preferring a wide-angle spread while others find a pencil beam of light more suitable.

In some Lucas fog lamps, the flat-topped beam effect is achieved by displacing one half of the reflector axially with respect to the other, this arrangement being known as a stepped reflector. The bulb filament is then disposed so that it is in front of the focal point of the upper half of the reflector but behind the focal point of the lower half, and



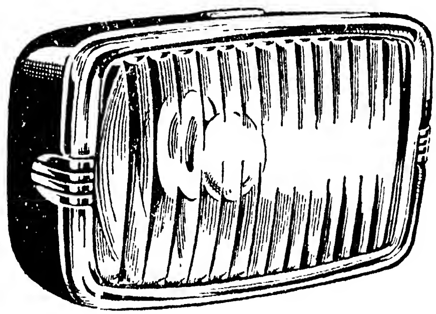
The construction of the Butler "Fogbeta" lamp.

consequently all issuing rays of light are deflected downwards. In effect, the half-circle of light produced by the upper half of the reflector is inverted and superimposed on the light from the lower half, resulting in an intense semicircular light pattern with a sharp upper cut-off. A cupped shield over the bulb prevents any direct rays from the bulb from issuing in an upwards direction. In other types of lamp, a specially designed front lens is used to control the beam dispersion from a conventional light source with prefocus bulb.

The Butler "Fogbeta" lamp is of different construction, and throws a powerful, concentrated non-spreading beam, again with a complete absence of reflected light. The Delco

"Flatray" lamp, on the other hand, projects a wide beam of light with a sharp cut-off at top and bottom; the Notek "Fogmaster" is also a lamp with a wide-angle beam which is most effective under these conditions.

In addition there are several other well-known makes, each of which produces its concentrated light beam with the sharp cut-off necessary to reduce stray rays and back-glare to a minimum.



The Delco "Flat-Ray" lamp.

As was the case with headlamps, the bulb must be correctly focused and the lamp properly set if the fog lamp is to give its designed performance. At the risk of repetition, it might again be mentioned that a lamp of this pattern must be used only in fog or snow if its centre height is less than 2 feet 2 inches from the ground. If it is mounted higher than this, there is no objection to its use as a passing light.

XI

ELECTRICAL AUXILIARIES

So far we have dealt only with what might be termed the essential items of the electrical installation. There are, of course, certain other components which are rather in the nature of auxiliary fittings, although they generally make a big contribution to either comfort or safety. Among these devices are horns, windscreen wipers, direction indicators, petrol pumps and gauges, car heaters and so on, and in this chapter we will briefly review the accessories found on the more popular cars.

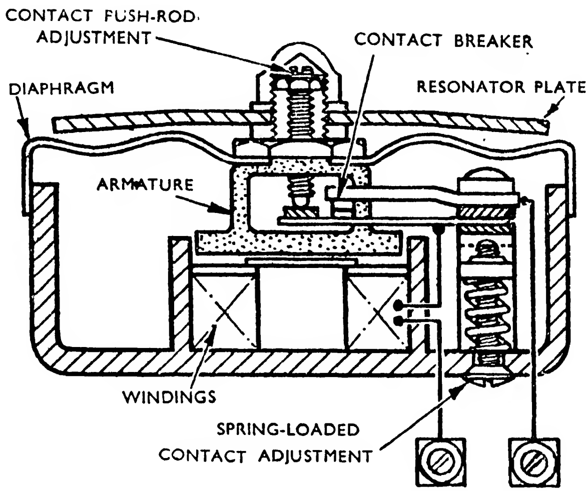
Electric Horns

The law requires that all cars shall be provided with "audible and sufficient" warning signals, and the recognized method of producing such a signal is by means of an electric horn. On the other hand, a horn must not be sounded between the hours of 11.30 p.m. and 7 a.m. in a "built-up" area, nor must it be sounded when the car is stationary.

So far as modern cars are concerned, there are two distinct types of horns in general use. One is the high-frequency pattern, which is gradually being superseded, even on smaller cars, by the wind-tone horn, although there are many hundreds of thousands still in use.

The High-frequency Horn

In this type of horn an electromagnet attracts an armature to which is secured a circular sheet-metal diaphragm, usually of corrugated design, held rigidly around its circumference. Also secured to the armature, in front of this diaphragm, is a tone disc or resonator plate made of very light metal such as a magnesium alloy. Unlike the diaphragm, its outer edge is free. There is an airgap between the armature and the pole around which the coil is fitted. The contact breaker is operated by movement of the armature and sometimes has a condenser or resistance connected across the contacts to prevent excessive sparking.



Details of a typical high-frequency horn.

The operation of the horn is as follows: When the horn button is pressed, current flowing through the coil winding causes the pole to become magnetized, whereupon the armature is pulled downwards and impacts on the pole face. This sets up vibration of a comparatively low frequency in the diaphragm, while a violent vibration is set up in the resonator plate which emits a correspondingly high-frequency note which is superimposed on the note given by the diaphragm. The contact breaker opens each time the armature is pulled down to the pole, de-energizing the magnet system and causing the cycle to be repeated at a frequency determined by the characteristics of the diaphragm.

High-frequency horns are often fitted in matched pairs; that is, two horns with notes of different pitch having a definite musical interval between them, so producing a blended tone.

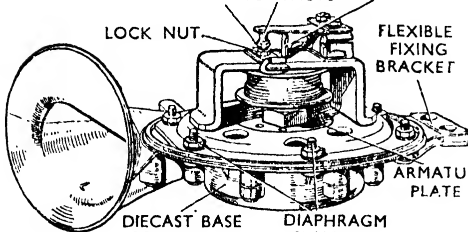
Most high-frequency horns have an adjustment for the contact breaker, for diaphragm movement, or for both. The latter is best left alone by the amateur, but the contact adjustment on horns of recent manufacture is fairly simple (not that adjustment should be found necessary for a very long period—after all, the blowing time of a horn is very short in comparison to the running time of the car). A serrated screw will be seen at the back of many high-frequency horns and a partial turn of this will often liven up a dull horn.

Wind-tone Horns

The second type of electric horn has become exceedingly popular during the last few years and is rapidly replacing the high-frequency pattern on the majority of new vehicles. The wind-tone horn is designed on the principle of an orchestral wind instrument, vibration of a diaphragm (by electromagnetic means) setting up resonance in an air column. The latter is in the form of a passage in the die-cast base of the horn which terminates at its outer end in a flared trumpet. The length of the air passage determines the pitch of the horn, being somewhat longer in the case of a low-note horn than in the high note. This difference in pitch represents a definite musical interval, usually a major third; the horns are invariably supplied in pairs, one high and one low note, resulting in a pleasing, blended musical signal.

With wind-tone horns designed for external fitting (although the modern tendency is to put them out of sight under the bonnet), a bright metal flare is usually fitted with metal gauze to prevent the entry of mud and snow into the air column, and slots are provided through which any water can drain away.

An early horn of this type, known as the Lucas Mellotone, utilized a two-way switch instead of a simple horn button. This took the form of a rectangular push which could be pressed down at either end to operate a relay or



Construction of a typical wind-tone horn.

remote-control unit. When one end of the push was pressed, the full voltage was supplied to the horns which thus operated at full strength for use in the open country. To produce a gentle sound for town use, however, the other end of the push was pressed, which resulted in a resistance being inserted in the circuit, so reducing the voltage available to operate the horns. With more modern horns, however, the value of the voltage is fairly critical if the horn performance is to be maintained, and no attempts should be made to soften the horn note by the addition of an extra resistance.

Wind-tone horns require considerably higher operating currents than do high-frequency types. The current consumption of a 12-volt horn is of the order of 5 amperes (that is, 10 amperes for the pair), while on a 6-volt system it is double this value. In the latter case, it is usual to wire the horns through a relay switch, in which case the wiring and push button usually embodied in the steering column carry only a small current and do not create excessive voltage drop. For the same reason, 12-volt models must be supplied by cables of adequate size (at least 44/·012) if they are to be wired direct and not through a relay unit.

This type of horn is sometimes connected direct to the battery, usually through a fuse of 35 amperes fusing value, and thus the current consumed by the horns is not registered on the ammeter.

Here again, adjustment of the contact breaker is provided for, but it should not be necessary until the horns have been in service for a very considerable period. Adjustment does not alter the pitch of the note which, as we have already seen, is determined by the length of the air column, but simply takes up wear of the moving parts. Contact breaker adjustment is quite a simple procedure, but as there are several different arrangements on various horn types it is recommended always to follow the makers' instructions for the pattern actually fitted to your car.

Horn Mounting

Whatever the design of horn, it is very sensitive to the rigidity of its mounting. Special spring brackets are often provided with the horns, and it is important that a very firm mounting for this must be found. A fixing bolt working loose may cause the horn to cease to function or give a very poor performance.

The same is true if any looseness occurs in the part to which the horn is attached, and even if the mounting appears to be firm it may yet be the cause of the trouble if it vibrates in such a way as to counteract the vibration of the horn. If a horn is mounted on a cross-bar which is attached to the mudwings or which carries headlamps or a spot light, vibration of any of these things (due possibly to one of them becoming a trifle loose) may put the horn out of action. This can be tested by detaching the horn from its mounting, holding it firmly in the hand (with a wire to take the place of the earth, if necessary) and pressing the horn button.

Tracing Faults

If a horn should fail to operate, or should give only a choking sound, it does not necessarily follow that the horn itself is faulty. A discharged battery will be indicated by the horn before any other component except the starter, and so the state of charge of the battery should be ascertained. Similarly a poor connection will seriously affect the performance of the horn and the terminal connections of wires in the horn circuit should be examined.

When two horns are fitted, if both fail at the same time, or become uncertain in their action, it will almost certainly be due to some external fault, such as a blown fuse (when fitted), or a discharged battery. If the fuse has blown, the wiring must be examined for faults before a new fuse is fitted.

If no apparent cause can be found, then adjustment of the horn contact breaker as previously described may be attempted. If this does not restore the original performance of the horn, the wisest plan is to send it to the makers or a qualified service station for inspection and repair if necessary.

Horn-button Faults

Whatever type of electrically-operated horn is used, it is almost sure to be controlled by a press button or, on some recent cars, by means of a ring mounted slightly above and central with the steering wheel. The average button consists of a moving contact, moulded into the base of the "press" portion, and a stationary contact to which the horn wire is attached. When the button is pressed the moving contact touches the stationary contact, and so completes the circuit to earth. A spring returns the button to the "off" position.

As a certain amount of sparking at the contacts is unavoidable, it follows that the metal surfaces become pitted and oxidized in time. When this happens the current will be unable to pass and the horn will not sound.

A temporary cure can sometimes be affected by rotating the button slightly to bring fresh surfaces of the contacts into use. As soon as convenient, however, the complete button should be dismantled for cleaning. A fine file or a piece of glasspaper will remove the oxide from the surfaces. If there be excessive pitting it is a sign that rather bad sparking has been going on. In cases where one of the button wires is earthed it is important to see that effective contact is being made.

Fitting New Horns

When fitting new horns to a car, the first important point to remember is the need for rigid mounting to a substantial member of the car. The next is to be sure to use cables of adequate size to carry the horn current without excessive voltage drop. Undersized cables may easily result in a very poor note being given by the horn. Fortunately, the majority of horns on the market include a length of cable with which to make the necessary connections.

If an earth-return system is used, the earth wires from the horn must make good contact with the chassis. Any paint, enamel or oil must be removed from the points to which earth wires are connected. If the horn should be of the type which is earthed internally, the same remarks apply to the cleanliness of the horn bracket fixing.

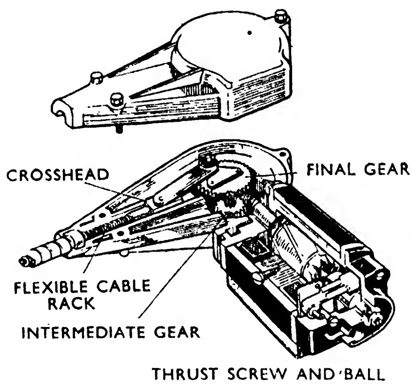
Electric Windscreen Wipers

An automatic wiping device must be fitted to any car on which the windscreen is not capable of being folded completely out of the line of vision, and to meet this requirement an electrically operated device is usually fitted, although in some countries a suction-operated windscreen wiper is still very popular.

Before the electrical installation became an integral part of the car, the windscreen wiper was attached to the top of the screen. Consequently limitations in size meant limitation in the power available to deal with bad weather conditions, the mounting of the motor was such that any noise was amplified, and of course the whole of the installation was always visible. Since those days, considerable progress has been made with this problem of keeping as much of the windscreen as possible clear at all times. Many different designs have been evolved, tried out and superseded, until today even the smallest cars are usually fitted with a powerful motor mounted on the engine bulkhead and driving two arms and blades by means of either a flexible cable rack mechanism or connecting links. Moreover, when not in use the arms are parked unobtrusively along the lower edge of the screen rail.

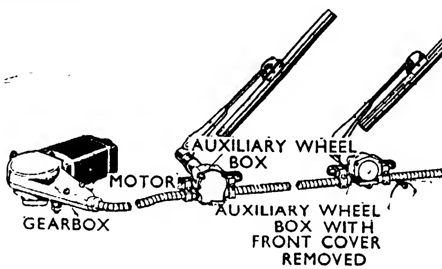
Cable Rack Windscreen Wiper

The driving motor is a comparatively small but powerful shunt-wound unit, having field coils, armature, commutator and brushgear similar to the dynamo and starter. It is flexibly mounted on a rubber cushioning pad or by means of bonded-rubber fixing studs on the engine side of the dash, being accessible when the bonnet is lifted.



The motor and gearbox used in the cable rack type windscreen wiper.

A gearbox casting attached to the motor contains a two-stage reduction gear, the final gear being fitted with a connecting rod which operates a crosshead arranged in a slide in the casting. The rotation of the armature, which runs at a speed of roughly 2,000 r.p.m., is then converted into a push-pull movement of the crosshead at a rate of about 35 strokes per minute. To the crosshead is secured one end of the cable rack, this being in the form of a flexible cable around which is formed a helix constituting the rack. The other end of this cable is passed through two wheelboxes, these containing toothed wheels with which the rack meshes. The toothed wheels are integral with the wiper-arm spindles, carried in bearings in the wheelbox castings. As the crosshead moves up and down in its slide, a reciprocating motion is imparted to the toothed wheels, and so the arms and blades are moved backwards and forwards across the screen. The angle of wipe is, of course, a function of the design of the gearbox. A thick-walled flexible metal outer casing protects the cable rack throughout its entire length, the ends of each section being secured by means of clips in the wheelboxes.



The general arrangement of the cable rack windscreen wiper.

When the windscreen wiper is not in operation, the blades are parked unobtrusively along the lower edge of the screen. This may be accomplished in different ways. Some installations have knobs fitted on the facia on extensions of the wiper-arm spindles, by means of which the toothed wheel can be disengaged from the cable rack mechanism, so enabling the arms to be moved by hand to the parked position. In these instances the switch controlling the motor is combined with the knob on the driver's side, so that the action of bringing the arm on to the windscreen also switches on the motor.

More often, however, a separate switch is fitted in a convenient position on the facia, and parking of the blades is achieved by switching off at the end of the stroke when, due to the provision of specially shaped (or cranked) arms, the blades will again be parked out of the line of vision.

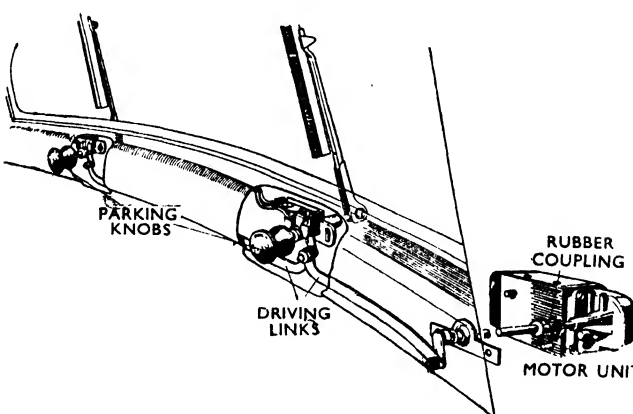
This method has the advantage of no protruding knobs, giving a somewhat cleaner appearance to the facia.

On some cars the blades are arranged to move first towards and then away from each other, instead of in the more usual tandem manner. This is arranged for by reversing one of the wheelboxes in such a way that the rack engages with the top side of one toothed wheel and the underside of the second.

The gearbox on the wiper motor is packed with a special grease during assembly and requires no further lubrication. Similarly, the armature spindle bearings are soaked in oil before they are fitted to the motor and will need no additional lubricant. Indeed, the only attention likely to be necessary in normal service will be the occasional replacement of the blade. The rubber wiping edges tend to become worn or perished after a period of use, and when this occurs they will not clean the windscreen so effectively. Replacement can be made easily and at small cost.

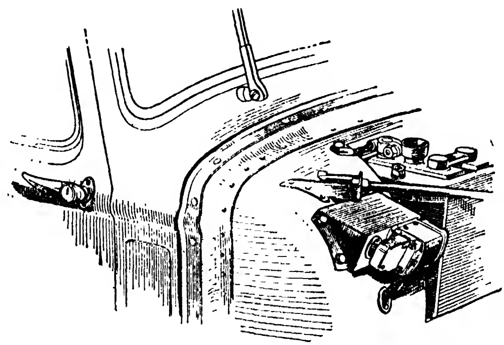
Link-operated Wiper

In this type of wiper a similar driving motor is again fitted to the bulkhead, but in this case the reduction gear-



The scuttle mounted wiper in which links transmit motion to the arm spindles.

box converts armature rotation into a much slower rotation of a driving shaft which, through a rubber coupling, drives a crank mounted behind the facia panel. The crank is connected by links to two clutch-boxes on the screen rail which transmit motion to the wiper-arm spindles. The action of pulling out and turning the knobs brings the blades on to the screen and, again, the switch for the motor is incorporated in the clutch-box on the driver's side.

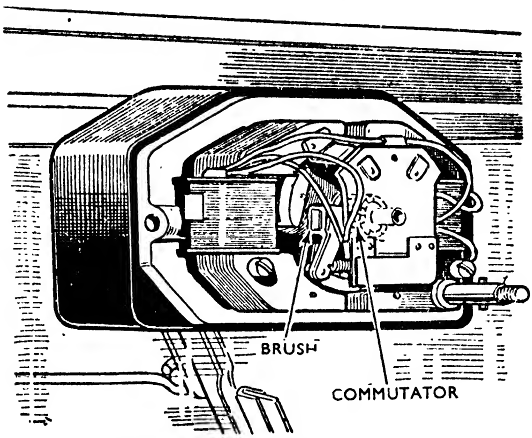


Showing how the wiper motor is mounted on the engine bulkhead.

As before, all moving parts are thoroughly lubricated during manufacture and no further attention should normally be necessary.

Externally-fitted Wipers

Although now only fitted as initial equipment to certain sports cars with folding screens, light vans and similar vehicles, there are very many externally-mounted windscreen wipers still in service. They consist of an electric motor fitted on the screen rail and containing gearing which converts armature rotation to a reciprocating motion of the wiper-arm spindle. In some cases a second arm is fitted, driven from the first by means of a coupling rod linking the arms. The switch is mounted on the motor cover, and a



A typical externally fitted wiper with its cover removed.

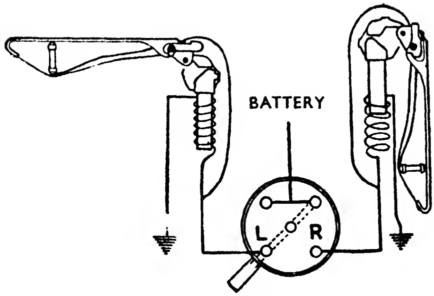
parking handle enables the arm to be moved by hand and to be locked out of the line of vision when not in use.

Direction Indicators

Direction indicators are now in almost universal use. In the semaphore pattern, an arm lifts and a bulb lights to give illumination of the arm, whereas in the flashing light system, lamps at the front and rear of the vehicle, on the side corresponding to the proposed turn, flash on and off about 30 times per minute. Each system has its own merits and each, properly installed, gives effective warning of the driver's intention.

Semaphore Indicators

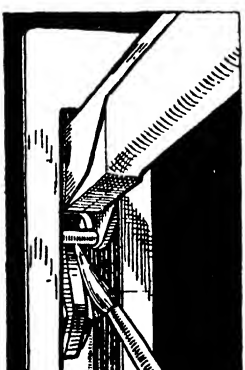
Semaphore pattern indicators are usually built into the centre pillar. The hinged arms are lifted electromagnetically by the attraction of an iron core by a solenoid when the current is switched on. The bulbs in the arm's are wired in parallel with the solenoid windings. A catch mechanism is provided which locks the arm in the off position to prevent it swinging in and out with movement of the car.

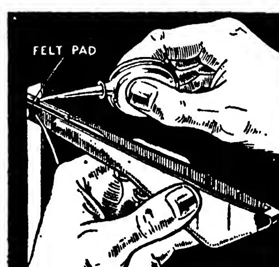


The essentials of a Lucas Trafficator set.

Occasional lubrication of the arm hinge bearing and the catchpin between the arm and the operating mechanism, together with replacement of bulbs as necessary, is all the attention likely to be required by these units. To lift the arm, switch the indicator on and then switch off again while holding the arm in the raised position.

Bulb replacement is a simple matter, although the method varies with different types. The most usual way of gaining access to the bulb involves removal of the metal arm cover

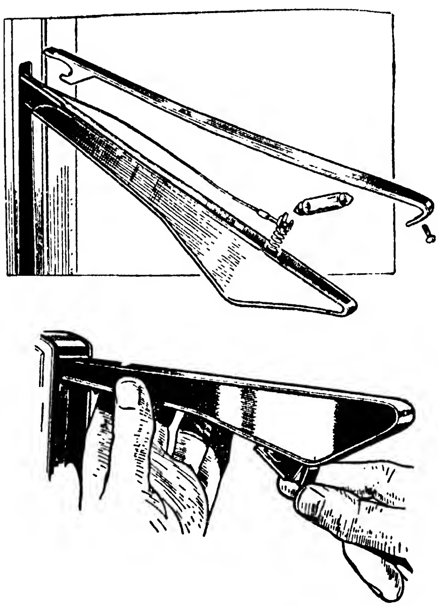




Thin machine oil applied at the points illustrated will ensure smooth working of the signals.

which is retained by a single screw in the outer end of the arm. The bulb is of 3-watt festoon type on both 12- and 6-volt systems. When refitting the arm cover, make sure that its inner end hooks properly into its seating before replacing the screw.

On some external-type indicators, where the arm and the operating solenoid are housed in a rectangular metal case attached to a door pillar or other convenient member, the



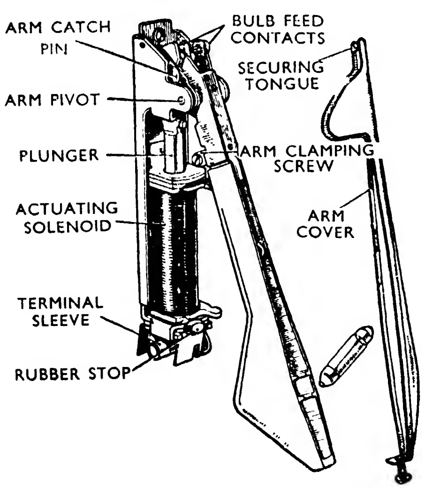
How access to the bulbs is obtained on some flush-fitting and externally mounted Lucas Trafficators.

bulb is carried in a small metal tongue clipped into the underside of the arm.

If, after ascertaining that the bulb is not faulty, the signal fails to light up when the arm lifts, it is possible that the thin flexible wire connecting the bulb to the solenoid-coil terminal has fractured. This wire is, however, specially chosen for its flexibility, and it would be wasted time to attempt to join a fracture or make a replacement with ordinary wire, as a further early failure would be inevitable. Moreover, replacement of the wire involves removal of the unit from inside the car on all but the latest inbuilt types; this in turn will involve disturbance of the pillar trim, and it will be found best to leave this job to a service station.

If the arm does not lift when the indicator is switched on, check the wiring between the switch and the unit. Another possible source of trouble may lie in the earthing of the indicators; make sure that the unit is really efficiently earthed. The signals should be wired through a fuse, preferably controlled from the ignition switch.

Also make sure that the arm is not being prevented from lifting by fouling the sides of the aperture in the door pillar. If the arm is not lying centrally in the aperture, adjustment is necessary. This should be done by moving the complete unit on its back plate (also usually best left to a service station) and not by attempting to bend the arm, which might crack in the process. A broken arm moulding necessitates replacement of arm and hinge complete, except on the latest models which have a readily replaceable arm moulding. On these types, it is only necessary to remove the arm cover, slacken the arm clamping screw, lift out the bulb and its contact spring and withdraw the damaged moulding. Fit the new arm in its place, retighten the clamping screw, and finally replace the spring, bulb and cover.



Construction of the semaphore-type direction indicator.

If the arm, after being raised, does not drop back properly into its casing, examine the inside of the case for obstructions, such as disarranged cable ends. The arms drop of their own weight—they are not pulled down—and, being purposely made very light, they will not "shut up" fully if bent slightly or if the hinges are stiff.

Direction indicators are usually controlled by means of a self-cancelling switch. This may be of the time-delay pattern, the indicators being switched off after say 15 seconds; more often, however, it is operated by the return of the steering wheel to its normal straight-ahead position after the turn has been made.

On some cars with semaphore indicators, the direction-indicator switch will be found to include a small warning light, when not of the self-cancelling pattern. This provides a ready reminder to the driver that one of the indicator arms is "out".

Flashing Light Indicators

There are two alternative circuit arrangements for use when direction indication is achieved by flashing light signals. For front indication, both employ either the second filaments of double-filament bulbs in the sidelamps or, if this is not possible, separate indicating lamps. Rear indication in the simpler circuit is given by lamps which are quite independent of the normal stop-tail lamps; in the other installation, however, the stop lamp filaments are used also as direction indicators. This necessitates the use of a relay unit which, in the event of the brakes being applied at the same time as the direction indicator is in operation, arranges for the stop lamp on the side of the proposed turn to continue flashing, and that on the other side to give braking indication in the normal manner.

A warning lamp is usually fitted on the dash; this lamp flashes at the same frequency as the indicator lamps and often also gives warning of failure of one or more of the indicator lamp filaments. If, therefore, the warning lamp does not light when the direction indicator switch is operated, or if the frequency of flashing is very greatly reduced, it is possible that the cause is a burnt-out bulb filament.

The flasher unit itself is contained in a sealed metal case. Although all flashers are not identical in construction or method of operation, they usually rely on the same basic principle, namely the linear expansion of a hot wire carrying an electric current. When current flows through the wire, the latter expands in length, allowing a spring blade to snap into an alternative position. In one make of flasher, this movement breaks the circuit to the indicator lamps, so stopping the flow of current through the hot wire which, on cooling, decreases in length and so restores the spring blade to its original position. Thus the lamps are made to switch on and off under the influence of the changes of length of the hot wire. In another type of unit, movement of the spring arm completes the circuit to the indicator lamps, at the same time shorting out the hot wire, and again setting the flasher into operation.

The Ammeter

Most cars include an ammeter among the instruments on the panel, and this is usually a centre-zero meter by means of which either the discharge from the battery or the charging current to the battery is indicated. References to ammeter readings with compensated voltage control and third-brush dynamo equipment have already been made.

The Ignition Warning Light

As we have already seen in Chapter VII, the ignition warning light plays a dual role. It indicates whether the ignition switch is on or off and at the same time provides some information as to the functioning of the dynamo. The light is connected between the ignition switch and the dynamo armature terminal, so that when the engine is stationary and the ignition on, current flows from the battery through the ignition switch, warning bulb and dynamo armature to earth. The bulb is thus alight with normal brilliance. When the engine is started, voltage is built up in the dynamo in accordance with its speed, so that a voltage of like polarity is offered to each side of the bulb. The bulb will, therefore, dim down to a brilliance commensurate with the difference between dynamo and battery voltage; when they become the same at higher engine speed the cutout will close and the bulb will go out completely. Some cars utilize this function instead of fitting an ammeter in the charging system. Again no maintenance other than bulb replacement is normally required. The bulbs in these warning lights are often of the flash-lamp type, the difference in voltage being made up by the inclusion of a ballast resistance, usually wound around the carcase of the bulb-holder. If the ignition light stays on under all conditions, a fault in the dynamo or its wiring should be looked for.

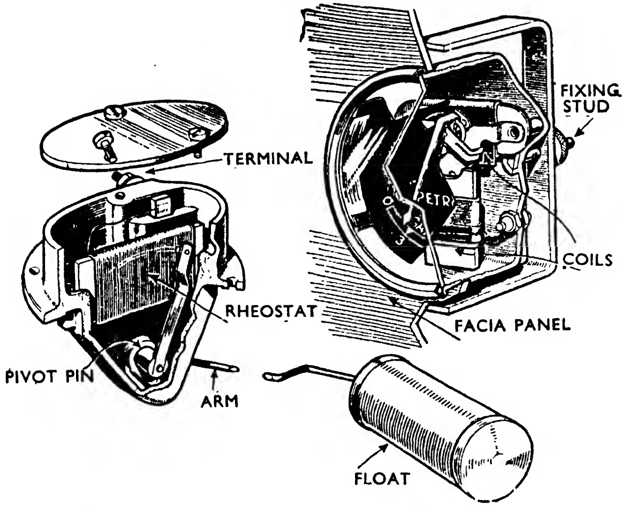
Oil-pressure Indicators

Cars not fitted with an engine oil-pressure gauge are usually provided with an indicator light which glows when pressure falls below the safe minimum. The switch actuating this light is screwed into some point in the engine lubricating system and completes to earth the warning-bulb circuit when pressure falls. The light is usually fed from the ignition switch, normally via a fuse. No maintenance is required other than replacement of the bulb if this should fail.

Electric Petrol Gauges

Some form of remotely-operated petrol gauge is of course an essential rather than an auxiliary device, and this is invariably of electrically operated pattern. The gauge consists of two units, a transmitter mounted in the petrol tank connected by a wire to an indicating instrument on the dash which shows the state of affairs at the transmitter.

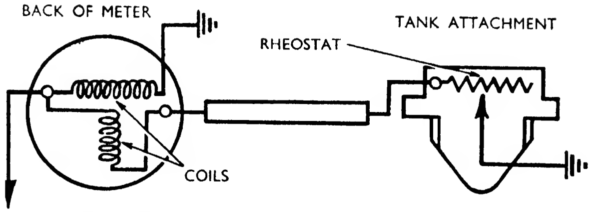
The transmitter is, in effect, a rheostat or variable resistance, the amount of resistance in the circuit being determined by a slider controlled by the position of a float on



Details of the Smith electric petrol gauge. The tank component which carries the float is shown at the left with the panel instrument top right.

the surface of the petrol. The simplest form of indicating instrument would, of course, be an ammeter measuring the current flowing in the circuit, representing a given position of the slider on the rheostat and hence a certain fuel level in the tank. A moment's thought, however, will show that the measurements given by a system such as this would be to a great extent dependent on the state of charge of the battery, and this would be most undesirable.

The indicating instrument is thus provided with two coils, one connected in the circuit to the transmitter and a second "control" coil permanently connected across the battery. The needle of the dial gauge is carried on an armature free to swing between the two coils according to the combined magnetic effect produced by the current flowing in them. Thus, as the level of fuel in the tank varies, the float, in rising or falling, will cause the slider to move across the rheostat, so altering the value of resistance in the circuit and consequently varying the magnetic effect due to the deflecting coil in series with it. The position which the armature



Wiring diagram of a typical electric petrol gauge.

will take up will therefore be dependent on the resultant magnetic field produced by this coil and the control coil connected across the battery. A reading of fuel level will thus be given which is quite independent of the battery voltage, and can be relied upon as showing a true measurement of the tank contents.

The presence of electrical mechanism practically inside the petrol tank gives rise to no risk of fire as the unit is sealed in a corrosion-proof casing and the float spindle passes through a close-fitting hole.

Diagnosing Gauge Faults

Although neither the dash nor tank units are liable to give trouble—and, in any case, are not repairable by amateurs —external wiring faults can put the gauge out of action.

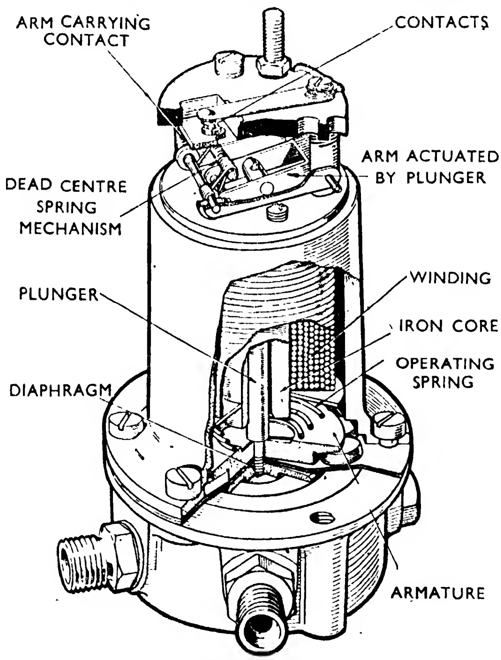
For instance, if the needle does not move when the ignition is switched on it is possible that the wire between the gauge and the switch is disconnected. If the gauge shows "empty" under all conditions, look for a break in the wire between the dash unit and the tank unit, or a bad earth at the tank unit. If the needle shows "full" under all conditions, it is likely that the wiring somewhere between the dash unit and the tank unit has chafed to earth. If the reading stays at an intermediate position, the float is probably sticking and removal of the tank unit will be necessary.

Some cars are fitted with a level indicator in the oil sump, often with a changeover switch so that a common instrument dial is used; the principle of operation is, however, exactly similar.

Electric Fuel Pumps

Fuel pumps for transferring petrol from the tank to the carburetter fall into two categories, those operated mechanically by a drive from the camshaft and those operated by electrical means. Of the latter there have been two patterns, the gravity type having now given place entirely to the pressure type. The S.U. pressure-type electric fuel pump will be found to be fitted on many cars; it comprises three main parts: the body, the magnet assembly and the contact breaker.

The magnet assembly consists of an iron core on which is wound a coil of copper wire which, when carrying current, energizes the iron core magnetically. An armature, to which is connected a flexible diaphragm, is located centrally within

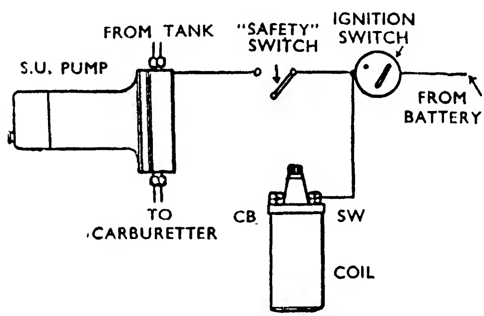


An S.U. pressure type pump in part section to show its general construction.

the magnet by eleven spherically-edged rollers. A bronze plunger, secured to the centre of the diaphragm and armature assembly, passes through the magnet core to the contact breaker which is located at the opposite end. An operating spring is interposed between the armature and the end plate of the coil.

Inlet and outlet valves, together with a filter, are housed in the base of the pump.

The contact-breaker mechanism consists of two rockers, the inner of which has screwed to it the bronze plunger attached to the armature. The outer rocker carries a tungsten contact which normally bears against a second contact



Typical wiring arrangement of an electric fuel pump.

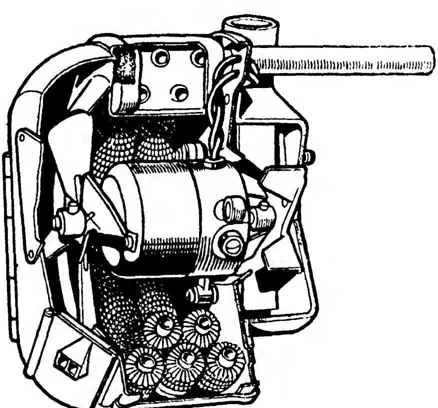
carried on a spring blade. One end of the coil winding is connected to the blade and the other end is connected to a screw terminal. The circuit is completed to earth via a short flexible wire connected between the outer rocker and one of the screws in the moulding of the contact-breaker housing. When the pump is at rest, the contacts are closed. As soon as the ignition is switched on, current flows in the coil winding, thereby energising the magnet system, and the armature is attracted to it against the tension of the operating spring. This movement deflects the pump diaphragm, causing petrol to be sucked through the inlet valve into the pumping chamber. When the armature has advanced nearly to the end of its stroke, the bronze plunger trips the contact-breaker mechanism, so separating the contacts and breaking the current supply to the coil.

Spring tension now pushes armature and diaphragm back, forcing petrol through the delivery valve to the carburetter —it should be noted that the pressure is determined by the spring and is independent of battery voltage. Again, as soon as the armature nears the end of the return stroke, the contacts are closed and the cycle of operation is repeated.

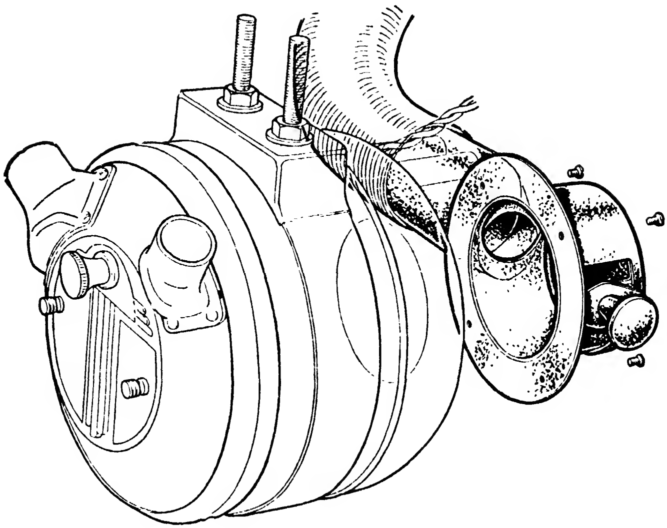
Electrical troubles are unlikely to develop, and no maintenance is necessary apart from the usual checking of connections from time to time. Any difficulty in obtaining a supply of petrol to the carburetter should be investigated by a service station.

Car Interior Heaters and Ventilators

Many modern cars incorporate, or have provision made for the easy later fitment of, heating units designed to circulate heated air into the car interior, to provide both for comfort of the passengers and windscreen demisting and defrosting. In many cases, the same unit provides an adjustable ventilating system for use in summer, controls



The Clayton heater unit.



Delaney-Galley heater with fresh-air intake and control for regulating air discharge rate.

being fitted by means of which incoming air can enter the car at outside temperature or be progressively diverted over heated elements of the engine cooling system. The temperature of the car interior can thereby be varied to suit individual requirements.

With these types, the forward motion of the car drives air into the heater unit, but several makes employ in addition a small series-wound electric motor fitted with a fan which increases the rate of air flow when it is desired to obtain more rapid demisting of the windscreen or heating of the car interior—and supplements the ram effect of the incoming air when the vehicle is travelling only slowly.

Other heaters, known as recirculating types, heat and recirculate air already in the car interior, and in these types a fan motor is an essential. The consumption of these motors is approximately 24 watts, and their speed is controlled by means of a rheostat incorporated with the switch, allowing the quantity of heated or ventilating air to be controlled to suit conditions.

The fan motor is usually totally enclosed and requires no maintenance in normal service, apart from checking occasionally that the wiring is in good order.

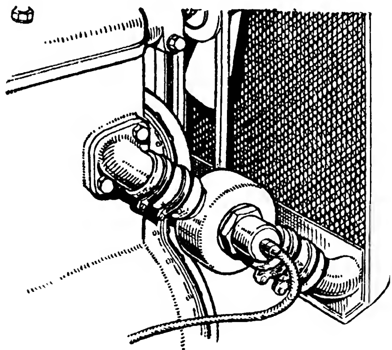
Windscreen Demisters and Defrosters

Several electric windscreen demisters and defrosters are available on the market, most of them arranged to be attached to the windscreen by means of rubber suction cups. A single- or double-heating element of resistance wire of about 36 watts consumption is usually stretched between the ends of a trough-like metal reflector or plastic body. Another design consists of a piece of safety glass across which run two or four heating elements. A rubber sealing strip between the safety glass and windscreen eliminates misting up, the heating elements being switched on only when defrosting is necessary.

When connecting a defroster, see that it is controlled by the ignition switch—it is very easy to forget to switch the unit off when garaging the car.

Although strictly not part of the car's electrical installation, mention might be made of these engine-heating units, designed to keep an engine comfortably above freezing point while it is garaged in cold weather and so making the job of the battery and starter easier when starting up next morning. They may be of the lamp resistance type for external use, or of the immersion type.

The last-named are very convenient, as they are permanently fitted either in the base of the radiator or in the lower water pipe. A plug and socket connection for the mains supply is provided. By maintaining the water at a reasonable temperature a rapid start from "cold" is ensured. Heaters of this kind consume only about 150 watts. The elements are fully enclosed, and there is no obstruction to the normal flow of water.



The Bray engine heater fits into the lower waterpipe and is run from the mains.

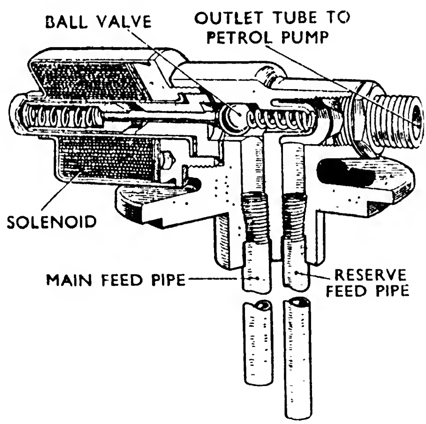
Other Devices.

There are other auxiliaries which may be met with on some cars, such as rear-blind lifting motors, electrically operated lowering and raising of windows, door-operated switches for lighting the car interior, automatically operated luggage-boot lights, petrol reserve valves, and so on.

Recent further applications of the uses of electricity in the car are to be found on certain of the higher-priced classes—and no doubt in time will be extended also to some of the more popular models. One such example is the electrically controlled overdrive mechanism in which a centrifugal switch is set to operate at a given road speed and, provided the car is in the appropriate gear and other switch controls are correctly set, completes the circuit to a solenoid unit. When the latter is energised, transition into overdrive is effected by movement of a plunger within the solenoid.

Another instance is to be found in the electrically controlled gear-shift mechanism. A gear-selector switch takes the place of the normal gear lever and contains a series of contacts by means of which electrical connection is made to any one of five solenoid units mounted on the gearbox (assuming there to be four forward gears and reverse). When it is desired to change to the pre-selected gear it is only necessary to operate a foot switch, when a relay closes and allows current to flow through the appropriate gear shift solenoid, thus effecting the gear change.

An "anti-creep" braking system for cars with automatic fluid transmission is a third example. This system is designed to hold the car stationary during temporary halts, without the necessity for the driver to keep the brake pedal depressed to counter the motion-imparting drag which is an inherent feature of this type of transmission. It achieves this by means of a solenoid-operated valve, a pressure switch (operated by transmission oil pressure) and a throttle switch, associated with the accelerator mechanism. When the car is almost stationary and the engine idling, these switches are closed, so energising the solenoid. A single depression of the brake pedal now builds up brake fluid pressure which, on releasing the pedal, remains trapped by the solenoid valve mechanism to hold the car stationary until such time as the throttle is once more opened.



An electrically operated reserve petrol tap. Normally both pipes are in use, but when the level falls to uncover the main pipe only air is drawn. A switch on the facia operates the solenoid to close the top of the main pipe, fuel then being drawn through the longer reserve pipe.

XII

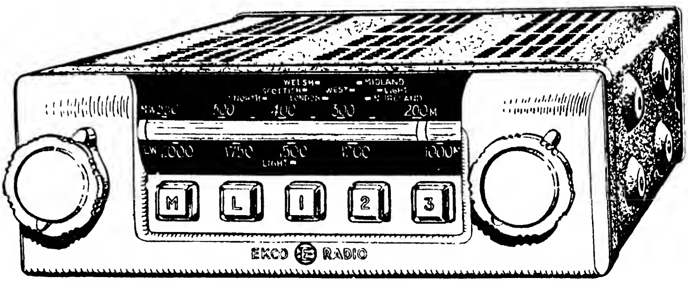
CAR RADIO EQUIPMENT

ALTHOUGH THERE still exists a body of opinion amongst some motorists that a radio set in the car is a serious source of distraction from the job of driving, there is no doubt that a good set, properly installed, can add considerably to the pleasures of motoring and can be a boon when long solo journeys have to be undertaken by the driver for, say, business reasons.

The modern set is self-contained and often has both push-button and manual tuning. It draws its power from the car battery, the low-tension supply being fed direct to the valve filaments. High tension is obtained by the use of a vibrator, which is a device which "chops" the direct-current battery supply, the resulting rapid succession of voltage surges being converted to a high voltage by means of a transformer in the normal manner. The overall drain from the battery is about 6 amperes for a 6-volt system and 3 amperes from a 12-volt system; that is, a total consumption of the order of 36 watts.

A variety of proprietary makes of set are available. The facias of some cars are now being designed to house a set, in which case one particular make is usually recommended to fit exactly into the space provided, if the set is not part of the initial equipment. On those cars not designed to take an inbuilt set, a suitable mounting position must be found; usually the footwell, glove box or cubby hole in front of the front passenger is most convenient.

Many sets consist of three or four separate units (e.g. power unit, receiver, loudspeaker and remote control unit) which can be fitted as a combined unit if space permits, or can be individually positioned when necessary. The superhet receivers employed vary in the number of stages just as do domestic sets, the more expensive models having up to eight



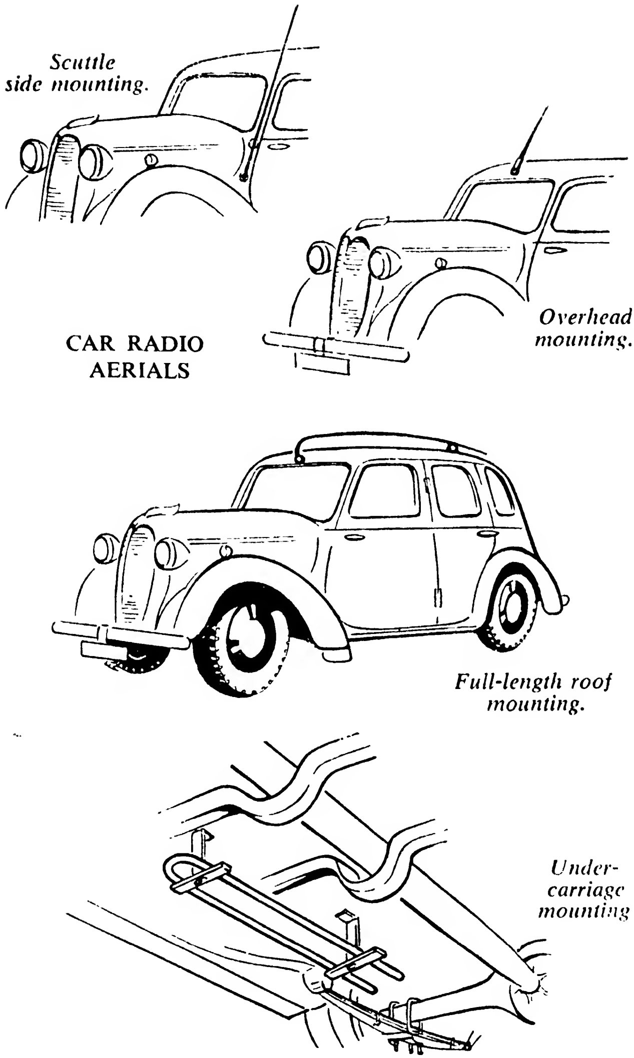
Ekco car radio model CR117 showing pre-set push-button tuning.

valves, with various waveband coverages from about 19 to 2000 metres. Loudspeakers are invariably of permanent magnet type.

The necessarily limited size of the car radio set, and the adverse conditions of signal reception under which it must work, mean that the receiver must be highly sensitive. The higher the sensitivity, the more likely it is to pick up electrical interference from other electrical components of the car, and precautions must be taken to reduce such interference to a minimum. For this reason, car radio sets are completely screened and incorporate filters to eliminate as much interference as possible, reducing the need for further suppression of other items of the electrical equipment. Often, however, the kit does contain condensers for attachment to the dynamo and ignition coil, and suppressors for the high tension ignition circuit (*see page* 204). In addition care must be taken to obtain the best signal strength possible, a factor upon which the aerial has considerable bearing.

The Aerial

The strength of the signal picked up by the aerial depends primarily on its position with relation to the bulk of the car body. The further away from the body the aerial is mounted, the stronger will be the signal picked up. Naturally, a strong signal means that the volume control



Scuttle side mounting.
CAR RADIO AERIALS
Overhead mounting.
Full-length roof mounting.
Under-carriage mounting

can be turned down, reducing amplification of the unwanted noise due to interference pick-up.

Two fundamental types of aerial are available, the first and most popular being the plated mast or roof aerial, and the second the unobtrusive under-carriage type. The latter, mounted beneath the car floor, has the advantage of being invisible, but is not usually so efficient as the external type mounted on roof or scuttle. There is not really much to choose between the two latter aerials, and personal preference may be indulged. The external aerial is often telescopic and can be extended to improve reception from distant stations or when parked in an area of poor reception.

It is important, when installing car radio, to consider the relative positions of aerial and receiver, since for best results the lead-in should be as short as possible. For this reason, the method sometimes observed of mounting the aerial on the rear bumper is not normally to be recommended.

The Sources of Interference

Interference is produced by the sparking between two electrical conductors or whenever current flowing in a circuit is interrupted. The main source of interference is the ignition system, each spark producing a series of current oscillations of radio frequency. Other items, such as dynamos, windscreen wipers and switches, also give rise to interference to a lesser extent. The noise from the latter components is more apparent on the longer wave bands, while that from the ignition circuit will be very pronounced on the short-wave bands and is particularly severe at the frequencies chosen for television and other short-wave radio devices. More will be said in connection with this later.

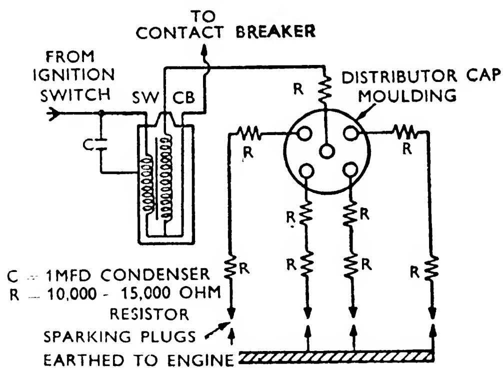
Ignition equipment produces interference in the form of regular clicks at a rate varying with engine speed. The interference from dynamos takes the form of a medium-pitched whine which varies in pitch as engine speed changes, whilst the voltage regulator produces a continuous crackle. Windscreen wipers give a low-to-medium-pitched whine, and switches, direction indicators and so on give interference in the form of clicks. The latter are usually unimportant because they are operated only infrequently.

Interference Suppression

The precautions to be taken vary from car to car, and it is not possible to lay down any hard and fast rules regarding the methods to be adopted or the degree of suppression necessary.

Internal filtering arrangements incorporated with the receiver itself will in some cases be found largely to overcome the interference problem. In other instances, however, it will be necessary to take further steps.

Dealing with the main offender first, the ignition circuit, maximum suppression is obtained by the use of resistors, of



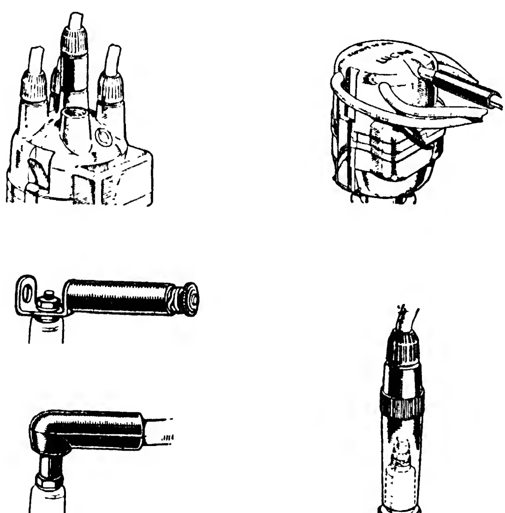
Arrangement of condensor and resistors to give maximum suppression of interference due to the coil ignition equipment.

10,000–15,000 ohms value, inserted in the high-tension cables as near as possible to the points at which sparks occur (that is the distributor-cap terminals and the sparking plugs), whilst a condenser of about 1 microfarad capacity connected between the SW terminal of the coil and earth is often found useful. Suitable proprietary resistors and condensers are available at quite small cost.

In very few cases, however, will maximum suppression be required, and when carrying out an installation the following procedure is recommended, with tests after each stage to determine if the desired signal-to-noise ratio has been achieved.

(i) Insert a resistor in the high-tension cable at the centre distributor terminal (that is, in the cable from the ignition coil high-tension terminal).
(ii) Connect a 1 microfarad condenser between the SW terminal and earth.
(iii) Connect resistors in each of the high-tension cables at the sparking plugs.
(iv) If further suppression is still required, insert resistors at each of the remaining distributor high-tension terminals.

It may be mentioned here that the fitting of suppressor resistances into the H.T. circuit usually causes no deleterious effects on performance of a normal engine operating under normal conditions.



Some typical ignition interference suppressors for use at distributors and sparking plugs.

As a rule, the fitting of one or more of these anti-interference devices will have sufficed to give satisfactory performance from radio equipment. If trouble is experienced from other devices, however, such as the dynamo or windscreen wiper motor, it will be necessary to fit further condensers between the insulated output or supply terminal and earth, and again such condensers are readily available with suitable easy means of attachment.

Voltage regulator interference presents a rather different problem. Condensers must not be fitted across the regulator contacts or the latter will quickly become damaged and cause failure of the regulator. If the internal filtering arrangement of the set is not adequate, a voltage regulator unit containing a suitable filter circuit should be fitted, and it is recommended that expert advice be obtained.

Prevention of Television Interference

With the extension of the television service and the increasing use of certain other short-wave radio devices, the suppression of interference from automobile electrical equipment (the ignition circuit in particular) has become of some importance, even though the car itself is not equipped with radio. In November 1952, the Postmaster General announced that from July 1953, the ignition systems of all new vehicles were to be suppressed to an extent ensuring non-interference. No compulsion was placed on owners of older vehicles to take the same steps, it being hoped that most owners would do this voluntarily.

It is probable that, in some cases, the single suppressor in the coil-distributor high-tension cable will be all that is required to comply with the regulations, although in certain installations sparking plug suppressors may be necessary in addition.

XIII

GENERAL INFORMATION

THE FOLLOWING brief explanations, alphabetically arranged, of some of the more important terms and expressions used in the foregoing chapters will be found convenient for quick reference purposes.

Alternating Current or A.C. This is the name given to current which flows first one way and then the other, reversing many times in one second (compare with Direct Current).

Ammeter. An instrument for measuring current in amperes. On a car it is usually of the central-zero type, so that the hand can show "charge" or "discharge".

Ampere. The practical unit of current. In a circuit having a resistance of 1 ohm a pressure of 1 volt will cause a current of 1 ampere to flow.

Armature. The rotating part of a car dynamo or starter which is built up from soft-iron laminations and wound with insulated wire. This term is also used to denote a piece of soft iron acted upon by a magnetic field as in the regulator, petrol pump, etc.

Battery. A number of cells, generally connected in series, which may be said to store the current generated by a dynamo. Car batteries consist of three or six cells, according to whether they are of the 6-volt or 12-volt type.

Brushes. Carbon blocks used to transfer current from a rotating part to an external circuit. Used mainly on dynamos, starters, distributors and magnetos.

Charge Rate. The amount of current in amperes which is fed to a battery when it is being charged.

Charging. The action of supplying current to a battery. This may be done by the dynamo on the car or by an external source of supply. When the action is complete the battery is said to be fully charged.

Circuit. A conductor or series of conductors passing from one side of a source of electricity (e.g., a dynamo or a battery) and back again to the other side or terminal of that same source. The word is used at times in conjunction with certain others. A *closed circuit* is one in which all the connections are complete, a true circuit, in fact. An *open circuit* is an interrupted one, and is really no circuit at all. A *short circuit* occurs when some unintended conductor provides a short cut for the current, which thus returns to its source without passing through the lamp or machine which it was intended to operate.

Commutator. A device secured to the armature shaft of a dynamo to which the armature windings are connected. Its purpose is to enable a unidirectional current to be collected by the brushes which bear on it. In the case of the starter to which it is also fitted, it converts the unidirectional current to a reversing one.

Condenser. A form of electrical buffer or reservoir connected across the contacts of a coil or a magneto contact breaker. It absorbs the follow-on current in the primary winding and, when the voltage ceases to rise, discharges itself by sending a reversed current through the coil. This action prevents sparking at the contact-breaker gap and, in addition, intensifies the secondary, or high-tension, discharge.

Conductor. A substance which provides an easy path for the flow of electric current.

Contact Breaker. A device which automatically opens and closes a circuit. In ignition systems, either coil or magneto, the contact breaker, by interrupting the flow of current in primary windings, causes a high voltage to be induced in the secondary coil.

Cut-out. An automatic switch which disconnects the battery from the dynamo when the voltage of the latter falls to that of the battery. Similarly, the cut-out closes the circuit, that is, connects the battery, when the dynamo voltage exceeds that of the battery.

Dielectric. Almost any insulator or non-conductor can be a dielectric, but the term is commonly reserved for special applications, e.g., the insulation between the two sides of a condenser.

Direct Current or D.C. Current which flows in only one direction in a circuit.

Distributor. A form of rotary switch by which the high-tension current of a coil or magneto is conveyed, in correct sequence, to the sparking plugs.

Dynamo. A machine for converting mechanical energy into electrical energy.

Earth Circuit. Actually, a circuit in which the earth forms the return path for the current. In cars the chassis as a whole is regarded as the earth, and it is to this that in single-pole wiring systems one terminal of the battery—usually the positive—is connected.

Eddy Current. Internal currents circulating locally in a mass of metal, particularly in such a part as an armature or the core of a coil. Motion between this metal and the surrounding magnetic field generates a current in the metal just as it does in the wires of the winding upon the armature. To resist this effect, which may cause overheating, a laminated construction is common.

Electrode. A general term applied to such parts as the points of a sparking plug; that is, the central electrode or the earthed electrodes. The metal segments in a distributor cap, to which the sparks jump from the rotor, are also known as electrodes.

Electrolyte. The liquid which supports chemical action in a cell. In the normal lead-acid car battery the electrolyte consists of a sulphuric-acid solution having an average specific gravity of about 1.250.

Electromagnetism. The production of magnetic effects by an electric current flowing in a conductor.

Farad. The electrical unit of capacity. It is far too large for any normal purpose, so that a much smaller unit, the microfarad (one-millionth of a farad) is used. The capacity of a condenser is expressed in microfarads or in decimals thereof.

Fuse Wire. A piece of wire of some alloy that melts at a comparatively low temperature, placed in safe surroundings in a circuit so that, if an unduly high current should flow, this particular piece of the circuit will be the first to suffer, and will thus save the rest of the circuit from damage. The thickness of a fuse is suited to the circuit in which it is to be used, so that it will carry the normal current and a safe overload without melting. The current in amperes at which a wire will fuse depends upon the metal of which it is made and its gauge. The following table forms a useful guide:

Diameter		Current in amperes		
S.W.G.	In.	Copper	Tin	Lead
34	.0092	9.04	1.44	1.21
32	.0108	11.50	1.84	1.55
30	.0124	14.15	2.27	1.90
28	.0148	18.44	2.96	2.48
26	.018	24.75	3.96	3.33
24	.022	33.43	5.36	4.50
22	.028	48.00	7.69	6.46
20	.036	70.00	11.22	9.41

Hydrometer. An instrument for testing the specific gravity of the electrolyte in a cell. It consists of a glass float with a graduated stem and a syringe for drawing a small amount of liquid from the cell. The specific gravity is indicated by the height at which the float rides in the liquid.

Induction Coil. Two sets of windings, primary and secondary, encircling an iron core. Interruption of a low-voltage current passed through the primary coil causes a high voltage to be induced in the secondary winding.

Insulator. A substance offering very great resistance to the flow of electricity through it.

Interference. Extraneous noises in a radio receiver caused by various other components of the car electrical installation.

Magnetism. The property of certain materials that enables them to attract iron. Such materials are surrounded by what is known as a magnetic field, composed of lines of magnetic force.

Motor. A device for converting electrical energy to mechanical energy in the form of a rotating shaft.

Ohm. The practical unit of electrical resistance. 1 ampere will be passed through a circuit of 1 ohm resistance when a pressure of 1 volt is applied.

Pole Pieces. In a dynamo, a magneto or a motor, the shaped bodies of the field magnets between which the armature rotates.

Potential Difference. The difference in electrical pressure existing between two points, such as the terminals of a battery, by virtue of which a current is forced to flow from the point of higher to the point of lower potential.

Rectifier. A device for converting alternating current into direct current. It is used when charging batteries from A.C. mains.

Relay. A device which enables a weak current to cause a stronger one to be switched on. In cars a relay is sometimes used to operate the starter switch.

Resistance. The obstruction offered to the passage of a current. It is measured in ohms.

Rotor. The revolving member of an electrical machine.

Solenoid. Strictly, a coil of wire creating a magnetic field but commonly a coil of wire arranged round a loosely-mounted iron core. A flow of current causes the core to move inwards. The principle is used in automatic switches and similar devices.

Specific Gravity. The ratio of the weight of any material to that of the same volume of chemically pure water. The specific gravity of the battery electrolyte provides a means of determining the state of charge.

Stator. The stationary member of an electrical machine.

Timing. Adjustment of the ignition system to ensure that the spark occurs at the correct instant in relation to the position of the piston in the engine cylinder.

Transformer. Apparatus used to change the voltage (either up or down) of alternating current. Similar in principle to an induction coil but different in construction.

Usually consists of two windings, primary and secondary, on a former consisting of soft-iron laminations. Used in mains-charging equipment for batteries and in radio sets.

Trickle Charge. Strictly speaking, this denotes a continuous charge passed through a battery at a rate just sufficient to balance the open circuit leakage losses; this is provided in many large battery installations for emergency use in the case of failure of the mains. In motoring circles the term is used to describe intermittent charging at a low rate, such as about an ampere. A better term for this would be a boosting charge, but the other is now so firmly established that it must be accepted.

Volt. The unit of electromotive force or pressure.

Volt Drop. The loss of voltage in a circuit, or part of a circuit, due to the current flowing and the resistance of the conductor, as stated in Ohm's Law.

Watt. A measure of electrical power; the product of volts × amps. 1 electrical horse-power equals 746 watts. There is also the kilowatt (1,000 watts). Domestic electricity is charged for in terms of kilowatt hours or Board of Trade units.

Useful Facts and Formulae

Prefixes

Meg(a) = one million; as megohm = 1,000,000 ohms.
Micr(o) = one millionth; as microfarad = $\frac{1}{1000000}$ farad.
Kilo = one thousand; as kilowatt = 1,000 watts.
Milli = one thousandth; as milliampere = $\frac{1}{1000}$ amp.

Units of Energy

A British Thermal Unit is the amount of heat required to raise 1 lb. of water through 1 Fahrenheit degree. Abbreviated commonly in speech to " B.T.U.", but in writing to " B.Th.U." to distinguish it from:

A Board of Trade Unit, which is a kilowatt-hour, or 1,000 watt-hours, and is the measure by which electricity is generally sold in this country. It is sometimes abbreviated to " B.O.T. unit", rarely to " B.T.U.", and commonly to nothing more than " unit ", the context usually showing what unit is meant. Approximately 3,400 B.Th.U. = 1 B.O.T. unit.

Soldering Fluxes

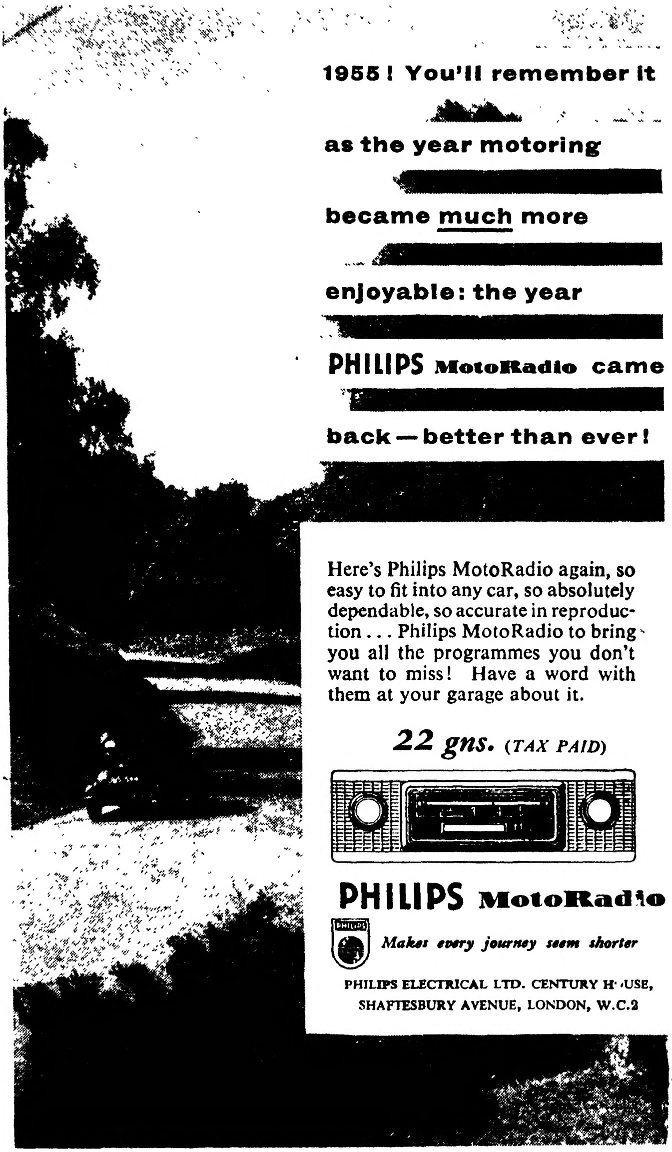
A non-acid flux must always be used for electrical work. Failing one of the special proprietary fluxes, use ordinary resin. Where risk of corrosion is unimportant, " killed spirits", that is, chloride of zinc, made by dissolving zinc in spirits of salts (hydrochloric acid), is effective with practically all metals save aluminium and cast iron.

An Insulating Varnish

Dissolve flake shellac in methylated spirit or spirits of wine. This varnish, which is obtainable " ready made ", besides being an insulator, will protect electrical fittings from the weather.

INDEX


Long Life Lithanode
Lithanode
Batteries for all purposes
FIRST IN 1881
FOREMOST EVER SINCE
The LITHANODE Co. LTD.
★ 190, QUEENSTOWN ROAD, LONDON, S.W.8 ★
Phone: MACAULAY 4541* Grams: LITHANODE. CLAPROAD. LONDON


1955 ! You'll remember it
as the year motoring
became much more
enjoyable: the year
PHILIPS MotoRadio came
back — better than ever !
Here's Philips MotoRadio again, so easy to fit into any car, so absolutely dependable, so accurate in reproduction . . . Philips MotoRadio to bring you all the programmes you don't want to miss! Have a word with them at your garage about it.
22 gns. (TAX PAID)
PHILIPS MotoRadio
PHILIPS
Makes every journey seem shorter
PHILIPS ELECTRICAL LTD. CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

(P43C)

MORE and MORE MOTORISTS

are switching to

"SUPER SERVICE"

FITTED WITH MICROPOROUS RUBBER SEPARATORS

FOR
MORE SUSTAINED POWER
AND LONGER LIFE

Every Park Super Service Car Battery has a 2 years unconditional guarantee

PARK BATTERIES

MANUFACTURERS OF PARK AUTO ELECTRICAL COMPONENTS

PARK BROTHERS LIMITED · BLACKBURN · LANCS.

WRITE FOR ILLUSTRATED BROCHURE GIVING ALL DETAILS

The Motor Repair Manual

By the Staff of the "The Motor"

An increasing number of private car owners today are undertaking repair and maintenance work on their own vehicles. In this eleventh edition of *"The Motor" Repair Manual* they will find much useful information and practical advice to help them in their work.

Starting with a survey of the range of workshop equipment required, the Manual goes on to describe how such tools as cold chisels, scrapers and special spanners may be made or adapted. Other chapters are devoted to such practical subjects as soldering, brazing and case-hardening, engine overhauls, repairs to clutch, gearbox and rear-axle. Brake adjustment and electrical equipment problems are also fully dealt with.

Another valuable feature of the Manual is an appendix listing symptoms and causes of engine trouble together with details of the appropriate remedies.

11th Edition Crown 8vo (Laminated Paper Boards) Illustrated

Available from all booksellers 6s. net or direct from the publishers 6s. 6d.

TEMPLE PRESS LIMITED, Bowling Green Lane, London, E.C.1