



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.

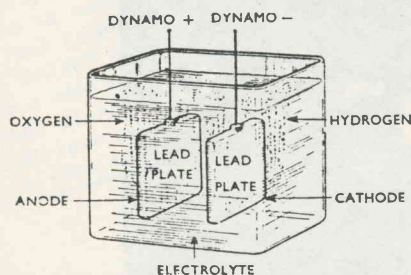
Primary and Secondary Cells

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 will eventually become empty. On the car, electrical energy



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.

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.

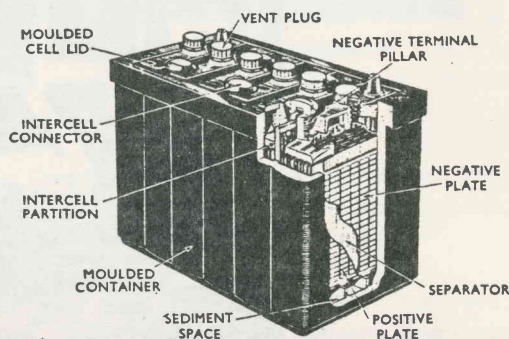
Various kinds of secondary cells have been produced, but those used almost universally on motor cars are of the lead-acid variety, this name being used because the essential constituents are lead and dilute sulphuric acid. In the simplest form, two lead plates are placed in a solution of dilute sulphuric 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

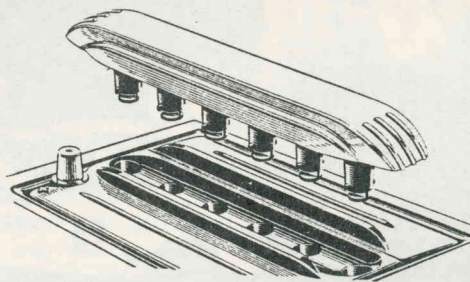
The lead-acid battery as constructed for practical use takes the form of a moulded container, of either ebonite or some composition material having high acid-proof and insulating properties and great mechanical strength, divided into a number of compartments or cells, six for a 12-volt battery or three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



Typical 12-volt battery, showing internal construction.

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, either individually for each cell or of one-piece pattern covering the entire top, are sealed to the container with a bituminous compound to make an acid-tight unit.

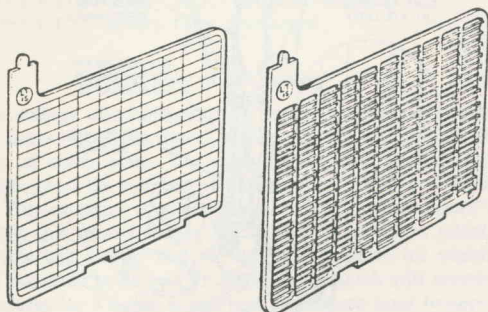


A battery having the vent plugs carried in the moulded cover.

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 designed to prevent acid spray from finding its way on to the top of the battery. In one design, the vent plugs are all carried in a moulded cover, and are taper fitting into the holes in the cell lids. Instead of unscrewing each vent plug, as is the usual necessity, lifting the moulded cover gives immediate access to all the cells. The cover is also designed to return any acid spray to the cells.

The Plates

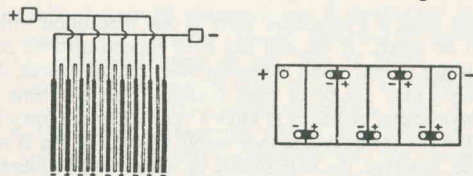
The plates are not made of lead sheet as in the simple form of cell previously described. Instead, an antimonial-lead-alloy grid forms the skeleton of the plate, which is then filled with a special preparation of lead oxide paste, the design of the grid being such that the active material is held firmly 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



Pasted and unpasted grids.

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



The internal connections of a 9-plate cell (left) and the external connections of a 12-volt battery.

plate into a number of smaller ones is a purely practical one, to enable the battery to be manufactured in a size convenient for installation in 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 much of the development work of recent years has been devoted to the provision of highly porous separator materials of improved mechanical strength, which will 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 some current types, both a porous rubber separ-

ator 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.

Some batteries are provided with a separator guard which takes the form of a strip of perforated material laid across the top edges of the separators in each cell. Its purpose is to protect the separators from damage due to careless use of a battery filler, and also to help in reduction of electrolyte splashing.

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.

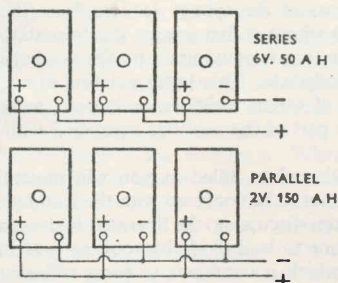
When this state of affairs is reached it will be clear that the electrolysed oxygen and hydrogen will no longer have any effect on the plates since there is no longer any lead sulphate on them. Continued application of the charging current therefore results in the gases escaping by bubbling up through 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 49.

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 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.



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.

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

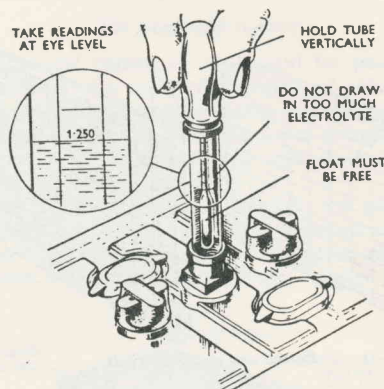
The specific gravity of the electrolyte, or indeed of any material, is the weight of that material compared with the same volume of chemically pure water. The specific gravity of the sulphuric acid used in the preparation of the electrolyte is 1.835; that is, the weight of say 1 pint of this acid would 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 1.270 and 1.290. 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 1.13.

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:

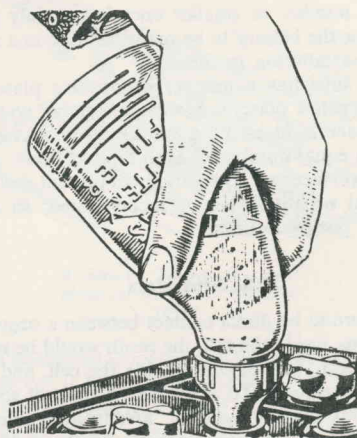
The most usual type of hydrometer is in the form of a syringe which contains a glass float. The latter is provided with a scale up its side so that the number on the actual surface indicates the specific gravity of the liquid. A rubber



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.

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.

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 firmly several times with the rubber tube still submerged in the electrolyte. In this way currents of liquid can be



Topping-up with distilled water is an essential battery maintenance task. It can be simplified by the use of a battery filler which automatically stops the flow of water into the cell when the correct level has been reached.

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:

- 1-270-1-290: battery fully charged.
- About 1-210: battery about half discharged.
- Below 1-130: 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 $\frac{1}{4}$ in. above the plates) or to the top of the separator guard when fitted, 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, 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.

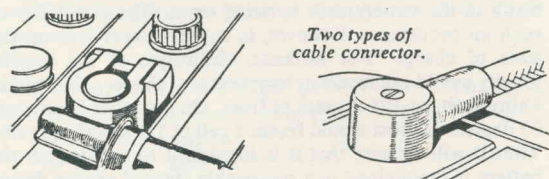
The volume of distilled water required for topping-up varies according to the size of cell, conditions under which the battery is being charged, and temperature.

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.

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 is 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.



Improved materials used in the manufacture of battery cable connectors have considerably reduced the prominence of terminal corrosion which at one time was a continual source of trouble. This is particularly true of the latest type having the cable diecast directly into the thimble-shaped lead connector, which is secured to the battery terminal post by means of a lead-plated self-tapping screw.

When fitting this type of connector to the terminal post, a few precautions must be taken. First, smear the terminal post and the inside of the tapered recess with petroleum jelly. Then push the connector by hand on to the post as far as it will go, and finally give it a light tap with the handle of a medium-sized screwdriver. Insert the self-tapping screw and screw home only sufficiently to maintain a tight joint. Fill the recess above the screw head with petroleum jelly. If the connector is fitted dry, if it is hammered on to the terminal post too tightly, or if the screw is screwed too far home, extreme difficulty may be experienced when next it is desired to remove the connector.

On some cars with connectors of this pattern, a small tapered peg fits into a hole provided on the negative connector. This peg has a cable attached, and forms the main feed from the battery to the electrical system. Again, care must be taken to see that this peg is securely, but not over-tightly, fitted into the hole.

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.

Some batteries are secured to the car by means of fixing bolts passing through holes in the case moulding at each end; excessive tightening of these bolts is sometimes a cause of cracked battery cases, and once again secure but not excessive tightening is called for. On the greater majority of cars, however, the battery is held in position by means of a strap or girdle, so that this potential cause of cracking has been eliminated.

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 is 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.

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.

Precautions with Sulphuric Acid

Care must always be taken when dealing with sulphuric acid. Concentrated or even when considerably diluted, it causes serious burns, which are painful and do not heal easily. 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.

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 alternative systems of control of the dynamo output. Those in practically universal use today, known as "compensated voltage control" and "current voltage control", ensure that under normal running conditions 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 or unusual running conditions 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 with the relatively inexpensive apparatus now available, 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 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 fascia, 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.

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.

In the few remaining areas 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.

Source: The Motor Electrical Manual.
Temple Press Ltd. 1960.