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## PREFACE

IN its original form this handbook was for many years the standard guide to the making and using of small accumulators. A considerable amount of space was devoted to instructions for making small batteries; but in recent years the commercial product has been so improved in quality, in range of choice, and in price, that it pays the user better to buy his batteries than to make them. For this reason the constructional matter has been largely replaced by practical information on the charging and maintenance of batteries, and on modern types of charging equipment. It is generally conceded that a more or less interrupted or rippling current is more effective for charging than is a quite constant or straight-line current; and this, taken in conjunction with the increased use of the alternating supply for lighting and power, has extended the application of the transformer-rectifier for charging purposes. For low-voltage battery charging, methods of a much more efficient character have now replaced the chemical rectifier, in which the invention of the thermionic valve bears a part. The subject of ampere-hour capacity in relation to upkeep is now of first importance.

Thanks are due to: Messrs Economic Electric Ltd., Fitzroy Square, London, W.; The Edison-Swan Electric Co., London and Ponders End; The Grafton Electric Co., Grafton Street, London, W.; Mr M. W. Woods, of Denman Street, London Bridge; Philips Lamps Limited, Charing Cross Road, London, W.C.; and Messrs Lionel Robinson & Co., of Staple Inn, Holborn, for kindly supplying blocks, illustrations, and particulars of accumulators and various apparatus connected therewith.

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## SMALL ACCUMULATORS

### CHAPTER I

#### THE THEORY OF THE ACCUMULATOR

AN accumulator is an appliance for accumulating or storing electricity, and its working depends upon the chemical changes undergone by certain substances when subjected to the action of an electric current. Accumulators are also known as "storage" or "secondary" batteries.

Strictly speaking, it is not correct to say that electricity is stored in an accumulator, although, as far as external results are concerned, such appears to be the case. What really happens is this: the charging current, *i.e.* the current which feeds electricity into the accumulator, produces a gradual chemical change or decomposition in the active elements of which the appliance is constructed, such change continuing to take place so long as the charging current is applied. As soon as this current ceases, however, so also does the chemical decomposition of the constituents cease; and if the terminals be then connected by a wire a reversal of the process commences. That is to say, the disunited particles gradually re-form themselves into their original chemical combinations, and by so doing produce a current of electricity which flows in the opposite direction to that originally used for charging.

An early form of accumulator, though more of experimental than practical interest, was Grove's gas battery. This was composed of a series of cells, each cell comprising two tubes, closed at the upper ends, and dipping down into a glass jar containing acidulated water. Each tube had a platinum wire fused into the closed end, from which a strip of platinum foil extended downwards into the liquid. The outer ends of the platinum wires were provided with brass

terminals, by means of which several of these cells were connected together. A charging current from a primary battery was then applied, and resulted in the gradual decomposition of the water in the various glass jars. Hydrogen collected on one of the platinum plates in each of the cells and oxygen on the other. If after a short time the primary battery was disconnected from the wires joined to the outer terminals of the cells and a galvanometer substituted, it was found that a current would then flow in the reverse direction until all the separated hydrogen and oxygen gases had re-combined to form water again.

From a practical point of view, the gas battery was deficient, inasmuch as it would only supply current for a very short time, and several workers set themselves the task of contriving an arrangement to obviate this defect. The most successful of these early workers was Planté, and he found in the course of his experiments that the best results were to be obtained by using lead plates or electrodes in a dilute solution of sulphuric acid. He made a cell by taking two long strips of sheet lead, placed one over the other, and coiled these up into spiral form with pieces of insulating material between. These plates were provided with separate terminals and were placed in a jar containing a solution of sulphuric acid. The action of the charging current was to decompose the water in the solution, the oxygen combining with the metal of the positive plate and thus forming peroxide of lead, whereas the hydrogen was simply deposited on the negative plate and there retained in gaseous form. On discontinuing the charging current, the hydrogen combined with oxygen in the solution to form water again, while the peroxide of lead was deoxidised, the lead remaining on the surface of the plate as spongy lead, and the oxygen re-entered the solution to compensate for the oxygen which was extracted therefrom by the hydrogen in forming water. Planté found that this method of construction enabled him to get an electromotive force (E.M.F.) of from 2 to 2.5 volts, as against 1.47 volts given by Grove's gas battery.

Planté's experiments did not, however, terminate with this achievement, and he next introduced a method for considerably increasing the available metallic surface of the electrodes. This plan is known as "forming" the plates, and consists of repeating for a considerable time the following series of

operations: (a) charge the accumulator, (b) discharge ditto, (c) re-charge, but with the charging current entering in the reverse direction, (d) again discharge. This cycle or series of reversals in charging and discharging, if kept up for several days, has the effect of causing the lead plates to become very porous or spongy in character, and, therefore, by reason of the additional surface of contact between electrolyte and electrode thus provided, enables the cell to retain a much greater charge than it would otherwise do.

It is not difficult to see that this work of "forming" is of a somewhat tedious and expensive character, and with the object of reducing this process to a minimum, another inventor, Faure, conceived the idea of using plates coated with a paste of lead-oxide, a plan which made it possible to use an accumulator with success after being charged only two or three times. When first introduced, some difficulty was found in making the lead-oxide paste adhere properly to the plates, and various means were devised to overcome this drawback. Scratching and indenting the lead plates was tried, but this was ultimately superseded by the plan of making perforated plates in the form of grids, the paste being pressed into the perforations. With various slight modifications in the shape of the perforations this device has been found to answer exceeding well, and is now very generally adopted.

When an accumulator is freshly charged it will be found to have an E.M.F. of about 2.25 to 2.4 volts, but after being used a short time this falls to about 2 volts, at which figure it remains until the cell is nearly exhausted. For many purposes, however, a higher voltage than this is required, and it then becomes necessary to have several cells joined in series, so as to give a total voltage equal to the number of cells multiplied by 2. Thus three cells of 2 volts each if joined in series would give an E.M.F. of 6 volts, five cells would give 10 volts, and so on.

The current which a cell will accumulate or store depends upon the area of its plates—the larger the plates the greater the capacity of the cell, and, further, the higher the permissible rate of discharge. As it is not always convenient to use very large plates where great capacity is required, the same result may be obtained by using a number of small plates to increase the available plate surface, but in such cases the plates must be connected in parallel. That is, the positive plates must

all be connected to one terminal, and the negative plates all to the other terminal, thus forming practically two plates divided into a number of branches.

The capacity of an accumulator is usually measured in ampere-hours. Thus an accumulator which will discharge a current of 10 amperes for 1 hour, or of 5 amperes for 2 hours, or of 1 ampere for 10 hours, is said to have a capacity of 10 ampere-hours.

## CHAPTER II

### THE CAPACITY—RATE OF CHARGING AND RATE OF DISCHARGE

THE capacity of an accumulator varies according to its mode of construction and the size and number of the positive plates used, as also the range of voltage between which it is worked and the rate of discharge. The capacity of the cell really depends upon the size and density of the active material of the positive plate; that is to say, the quantity and nature of the pure peroxide of lead in that plate when in a charged condition. This can vary, for any one size plate, by one plate being packed more tightly with a similar porous mass, whereas yet another plate of the same size can have a much lower capacity by its contents having become hard and less porous. Much depends, therefore, upon how the grids are packed; but in commercial practice the packing of plates has become fairly standardised, and it can be taken that, if plates have a thickness of between  $\frac{5}{32}$  and  $\frac{3}{16}$  in., the following figures hold good; but in measuring a positive plate to compute its capacity it is fairer to neglect the outer frame of the positive grid and measure only the area of the active material, which may include the fine cross-lead mesh of the grid. For professionally made plates the capacity can be taken at .7 ampere-hour per sq. in. of one side positive plate working from maximum charge down to just below 1.80 volts.

This put into the shape of a formula, becomes

N=Number of positive plates.

L=Length of plates in inches.

K=Constant depending on rate of discharge and construction of plate, .7 to .5.

W=Width of plates in inches.

C=Capacity in ampere-hours.

Then

$$C=N \times L \times W \times K.$$

In the case of an accumulator with active surface  $3\frac{1}{2} \times 3\frac{1}{2}$  in., with 3 positives, then

$$C = 3 \times 3 \cdot 25 \times 3 \cdot 25 \times K \\ = 31 \cdot 7 \times K,$$

which, if we take K as equal to .6, will give a capacity of just 19 ampere-hours— $31 \cdot 7 \times .6 = 19$  ampere-hours.

#### Charging Rate

The normal charge rate for a cell is usually .08 ampere per sq. in. of positive plate, taking only one side; therefore a cell made up of four positives, each  $4 \times 3\frac{1}{2}$  in., will have a charge rate of  $4 \times 4 \times 3\frac{1}{2} = 56$  sq. in., and  $56 \times .08 = 4 \cdot 5$  amperes nearly enough. As a general thing it is advisable on a full charge, when charging a battery up from just below a working voltage of 1.8, to put in quite 25 per cent. more in ampere-hours than the reputed capacity. Worked out by the figures given above, the capacity of a battery or cell having the 4.5 ampere charge rate will be just about 40 ampere-hours. This should, at least, have a full charge of 50 ampere-hours, and therefore would have to be charged at 4.5 amperes for 11 hours or even 12 hours. The slower a battery is charged the better, and therefore it can be charged at any rate in amperes below its normal, but the time taken must be longer. It can also on occasion be charged at a higher rate than given above; that is to say, at a rate not more than half as much again—in the case given, say  $6\frac{1}{2}$  amperes. But one runs the risk of buckling the plates if this be done as a general thing, and if plates be badly buckled they are likely to shed their contents and ultimately break up.

#### Discharging Rate

The normal discharge rate of a cell has a lot to do with its capacity, and the capacity is usually gauged upon the rate of continuous discharge given in hours. The average rate of discharge is that called the 9-hour rate, so that if a cell be of reputed capacity of 40 ampere-hours its normal discharge rate in amperes is  $\frac{40}{9} = 4\frac{1}{2}$  nearly. Therefore the normal discharge rate for a given capacity is just about the same as its normal charge rate. To make this clearer, a so-called 40

ampere-hour cell if discharged continuously from top voltage to below 1.8 volts taken while discharging in 9 hours, it will be at the rate of  $4\frac{1}{2}$  amperes about, because  $9 \times 4\frac{1}{2} = 40$ . A cell can be discharged more quickly: the only point is that it will not then give 40 ampere-hours, or whatever its reputed capacity is worked out as described. The relationship on over-discharge rate and that of the 9-hour is as follows, approximately: As an example, given a 40 ampere-hour cell at the 9-hour rate. If this be discharged entirely to a working voltage of just below 1.8 in 1 hour, it will only give half capacity or 20 ampere-hours, and the discharge rate in amperes will be 20. If the same cell be discharged at about double its ampere rate, which is  $4\frac{1}{2}$ , or at 9 or 10 amperes, it will only last 3 hours and give three-fourths of its 9-hour capacity, viz., about 30 ampere-hours. If it be discharged at  $1\frac{1}{2}$  times its ampere rate of  $4\frac{1}{2}$ , or at about 6 amperes, it will only last 6 hours and give about 36 ampere-hours. The same applies the other way round for under-discharge, viz. that if a cell be continuously discharged at half the 9-hour ampere rate, or at  $2\frac{1}{2}$  amperes, it should last well over 20 hours and give more than 40 ampere-hours. But there is a limit to this discharge capacity, which limit is the total charge capacity, which as given above should be about 50 or more ampere-hours. Another point which limits the over-capacity worked out on low discharge is the leak of a cell, which even in the best cells is considerable, as, if a cell be left on no discharge or charge for some weeks, it will be found to have discharged itself practically entirely. You can never get out of any cell as much as is put into it in ampere-hours, and this plus the natural leak of a cell limits the capacity on any discharge.

#### Ignition or Intermittent Discharge Capacity

This quantity is used a good deal by accumulator makers presumably to make the cell appear of high capacity. The actual rate of discharge in ignition is not really known because it varies for different engines. The capacity in actual ampere-hours at the 9-hour rate is usually taken as half the ignition capacity; but this is quite a loose conclusion, and accumulator buyers should insist on knowing the actual capacity of a battery on continuous discharge at the 9-hour rate.

## CHAPTER III

HOW A LEAD CELL WORKS, GIVING SOME POINTS  
IN CONSTRUCTION OF SMALL CELLS

THERE are three kinds of lead oxide which come into lead-cell construction, but only one concerns us now, and that is lead peroxide. It contains two volumes of oxygen to one of lead, and is written  $PbO_2$ . Now, referring to fig. 1, if we have two plates as shown here, one a plate (*a*) of solid lead peroxide, and the other (*b*) a plate of solid pure lead, both having some kind of lug or connection passing upward, and both immersed in the same bulk of a solution of dilute sulphuric acid and pure water, we have a lead cell. Conditions are that the plates must not touch, and we will assume for the moment that the peroxide plate is quite impermeable, and that only

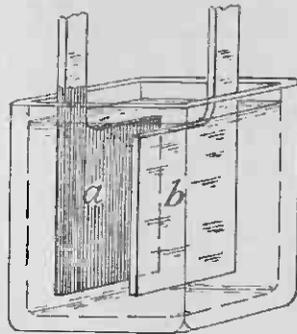


FIG. 1.—Simple arrangement of a lead acid cell.

its outer surfaces are active, the same applying to the lead plate. The vessel containing the liquid is an insulator, say, of glass, and the plates are held up away from the bottom, so that, if anything drops from them, it will not act as a junction between them. If the acid is in the proportion of one of acid to two of water by volume, having a specific gravity of about 1.28, there will be a difference of potential *inside* the cell of a little over 2 volts, the lead being positive to the peroxide. If we apply a voltmeter to the outer lugs we find this voltage, the peroxide being positive to

the lead. On joining these lugs by a conductor of such resistance that only a small current will flow, that current will flow, the cell showing during the discharge a constant voltage of about 2,

for a certain time, according to the size of the plates. At a point, when near the discharge point, the voltage will gradually drop to 1.8, the current dropping in the same proportion, at which point the cell is said to be discharged. What takes place first is that the water is split up into hydrogen and oxygen, some of which bubbles off, but the most important thing is that ultimately the sulphur and oxygen of the sulphuric acid combine *on the surface* with the lead in both plates, and covers them with an intangible film of lead sulphate, and, as soon as this film is complete, the cell has reached the point that it is said to be discharged. Sulphuric acid contains hydrogen, oxygen, and sulphur, and pure water contains hydrogen and oxygen; and as some of the sulphur and oxygen of the acid has gone to coat the plates, and some of its hydrogen and oxygen recombined to form water, at the finish there tends to be a little more water, and there actually is considerably less acid. If there is not too great a bulk of solution in the first place, the proportions of acid to water may have dropped to only 1 to 4 by volume, or about 1.17 specific gravity. Such a cell would only give a tiny current for a short time, because only the outer surfaces of the plates are active; but if the plates be made porous, so that their active surfaces include, not only the outsides but the sides of all the numerous passages of the pores, they then relatively give much more current. Taking the peroxide plate as the standard, and assuming it to be about  $\frac{3}{16}$  in. thick, properly porous, and 1 sq. in. in area at one side, it should allow of the passage of about 80 milliamperes for 9 hours, and thus have a capacity of .72 ampere-hour; that is, if the lead plate is correspondingly large and porous enough for this capacity.

It may appear that the lead sulphate could be wiped off the solid peroxide, the acid restrengthened, and the cell set to work again; but this does not commend itself as practical, because one would be using up the lead. Then again, as the lead is, in practice, all porous, the sulphate could not be so disposed of. Here comes in the reason why such cells are called storage cells. If we apply an external voltage equal to that of the cell at its best, say about 2.1 volts, against the discharged cell, or so that its positive leads into the cell by the peroxide plate, the voltage of the cell will rise almost immediately to meet it, but nothing further will take place. But if we increase the external voltage to about 2.5, which is

above the working voltage of the cell, a current is caused to flow backward through it. That is, from the peroxide to the lead. The effect of this is to split up the lead sulphate on both plates, which ultimately goes into the solution again as sulphuric acid, leaving pure lead on the surface of the lead plate and a fresh film of lead peroxide on the other plate; which, when complete, brings the cell back to the original condition with no tangible loss, excepting that some of the water has been lost as bubbles of hydrogen and oxygen.

In the commercial production of nearly all types of lead acid accumulators, the skeleton pure lead grids, upon which the plates, both positive and negative, are built up, are first of all filled tightly with a paste of lead oxide and dilute sulphuric acid. Red lead—3 volumes of lead to 4 of oxygen ( $Pb_3O_4$ )—is that used to produce the positive, and ultimate, peroxide plate; litharge—1 volume of lead to 1 of oxygen ( $PbO$ )—is used to produce the negative, which becomes ultimately porous metallic lead. How the grids are pasted does not concern us now, but later on reference will be made to a method of reconditioning peroxide plates, in which pasting and drying under pressure will be described. To produce peroxide from the one pasted plate and spongy lead from the other is carried out by a process of forming, in which the plates are charged and discharged against dummy negative and positive plates, which are a factory stock, made and maintained for the purpose. It is in this formed condition, but quite dry, that the plates in stock accumulators are sold as a general thing; in which cases, before putting the cells to regular use, they have to receive a first charge. A first charge is generally effected by charging in the usual manner, but using a much lower charging current than the normal, and carrying it on to three or four times the normal ampere-hour capacity. As an instance, suppose there be a cell requiring normally a charge of 3 amperes for 10 hours, and a certain additional time to which reference will be made, to give a capacity of 30 ampere-hours; it would probably require, on first charge, a current of  $1\frac{1}{2}$  amperes for 60 hours=90 ampere-hours, or a current of 2 amperes for 45 hours. A normal charge, which would be that used after the cell had been discharged from its first charge, should always be quite 25 per cent. over normal capacity. That is to say, in the case quoted above, of a 30 ampere-hour cell having a normal

3-ampere charge,  $12\frac{1}{2}$  hours would be the required time. It should be clear that, even under the most advantageous conditions—as when discharging in intermittent periods at a current well below the normal—one never gets from a cell as much capacity as is put into it. This statement has no direct bearing on the loss of energy in charge and discharge, because, in charging a cell, the average voltage used is  $2\frac{1}{2}$

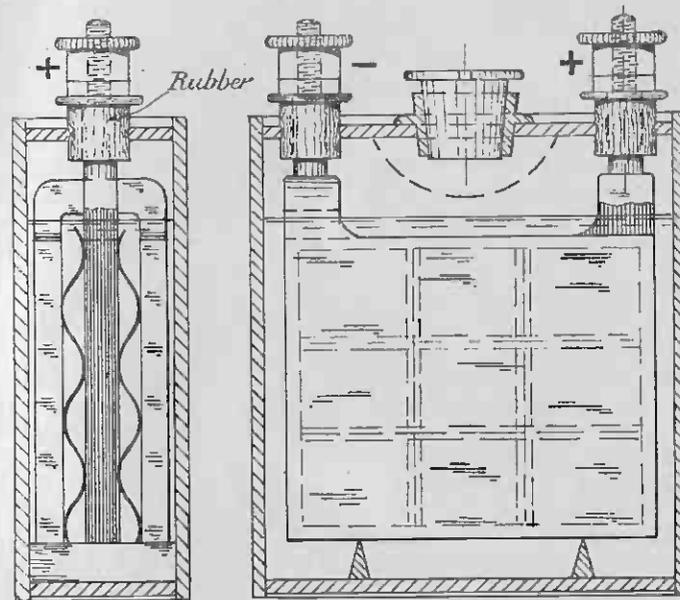


FIG. 2.—Typical construction of a 3-plate cell mounted in a celluloid case.

volts per cell, whereas the average voltage on discharge is 2; therefore, for every watt-hour put into the cell, only .8 of a watt-hour can be taken from it, even if all the ampere-hours put in are taken from it, which in practice they are not. In the most favourable circumstances no more than two-thirds the total energy (volts  $\times$  ampere-hours) put into a battery can be obtained from it by the ordinary discharge methods.

Small accumulators are usually mounted in either celluloid or glass vessels, and are practically always sealed. Fig. 2

shows the typical construction of a small 2-volt unit set up in a celluloid case. Both views are sections, and in the cross-section to the left the lead plates are shown cross shaded on the end edges, and the positive, in centre, vertically shaded over the peroxide surface. The continuation lug at the top of the latter, at a point about half-way up the top gas space, is made rounded, and passes up, a tight fit, through a rubber collar, which, acting as a cork, seals the joint in a hole made in the celluloid cover. The lead is carried above the cover to the top of the rubber, and is there fitted with a brass screwed stud which carries, first, a red washer (usually of celluloid), and then a terminal seating nut screwed down tightly to spread the rubber. The remainder is some form of knurled nut for wire or tab attachment. The negative plates are bridged across by a solid lead bridge in one with their grids, and at the opposite end of the cell from that of the positive lug. This bridge must arch over the top edge of positive plate with not less than a  $\frac{1}{4}$ -in. clearance even in quite small cells. Above the centre of bridge the terminal is carried up just as the other, excepting that the indicating washer is of black celluloid or of ebonite. The well-space at the bottom of cell must be maintained, and to this end the plates are supported on two cross bridges of celluloid fixed to the bottom, which bridges are better made with knife-edges to throw off any pieces which may lodge on them. The well is to form a clearance for any loose paste or solid white sulphate that may become detached and would act as an electrical junction to the plates if allowed to touch both. The opposite pole plates are kept separated by thin corrugated and perforated celluloid or ebonite sheets. In the better qualities of cell ebonite separators are fitted as they are not acted upon by the acid. Celluloid, although much used for cases, is ultimately partially dissolved by the acid and gives rise to one form of frothing during charging. The corrugations of the separators, which are cut to the same size or a little larger than the plates, usually run vertically, not as shown.

The usual form of vent-plug is that shown in the drawings. A taper flanged socket of celluloid is cemented by the usual medium (to be described) to a hole in the celluloid cover, into which is fitted a hollow taper stopper. This stopper has a secondary fine vent-hole at the top which ventilates during discharge. During charge the stopper itself should be removed.

In order to counteract fine spraying of acid during charging a half-looped baffle plate of thin celluloid (shown dotted), made a little wider than the vent-hole and attached to the under side of cover, is frequently fitted. It serves its purpose well but is a great nuisance when one needs to clean out a cell. Reference will be made later on how to remove and replace a case top when it is necessary to take the plates out for examination or repair.

Fig. 3 shows how multiple plates are bridged, those hatched being lead negatives, and the others the positives, which are single-bridged, just as the negatives in fig. 2. Where there are more parallel plates than shown here, as with five negatives and four positives, the vertical leads-out from the bridges are put at opposite ends of the multiple bridge, so that the leading-out terminals are at opposite diagonal corners and therefore as far apart as possible.

A multiple plate cell like this has a correspondingly low internal resistance, and it becomes a source of danger from fire (especially with celluloid cases) if the terminals are at all close together. All this bridging is done in lead right to the outside, and it is imperative that no solder be used anywhere in the gas space at top.

Fig. 4 shows the cell construction of a small accumulator of quite the latest type, wherein glass containers are used. The glass is internally moulded, and the three views show a part cross-section, with plates shown in edge-section, a part longitudinal section, and a part sectional plan. The inside of the glass is so moulded that it is thicker on the end sides at the bottom than at the top. This thickness is offset at a certain height above bottom so as to support the plate edges up and leave a well. Between the plates, which are relatively thicker than those usually put in celluloid cases, the glass is buttressed up the sides sloping, and forms therefore a permanent separation which will throw off any particles to the well of the cell. The plates cannot buckle on account of their thickness, otherwise they are bridged just as the others. The sealing of the cell is done at first by a thin ebonite cap holed to act as a separator or guide for the leading-out lugs and vent-plug, and otherwise fitting the case. Above this is about twice its thickness of a pitch compound in which is embedded



FIG. 3.—  
Showing how plates are bridged in parallel.

the vent-plug, usually of porcelain, fitted with a rubber plug with a glass tube gas-vent. The lead lugs passing through the solid pitch are carried up high and are there fitted with a moulded-in stud with an elevated collar and binding nut, all

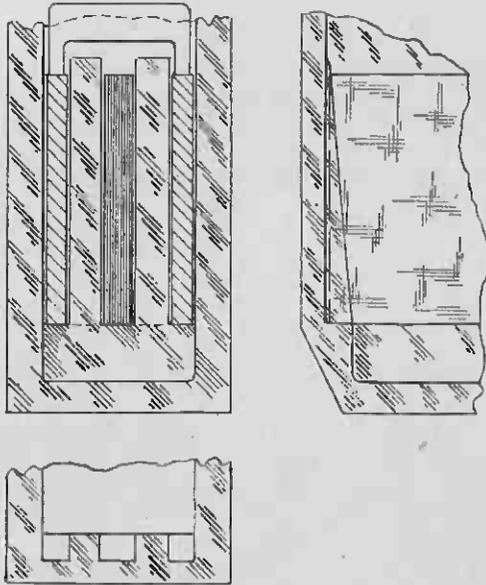


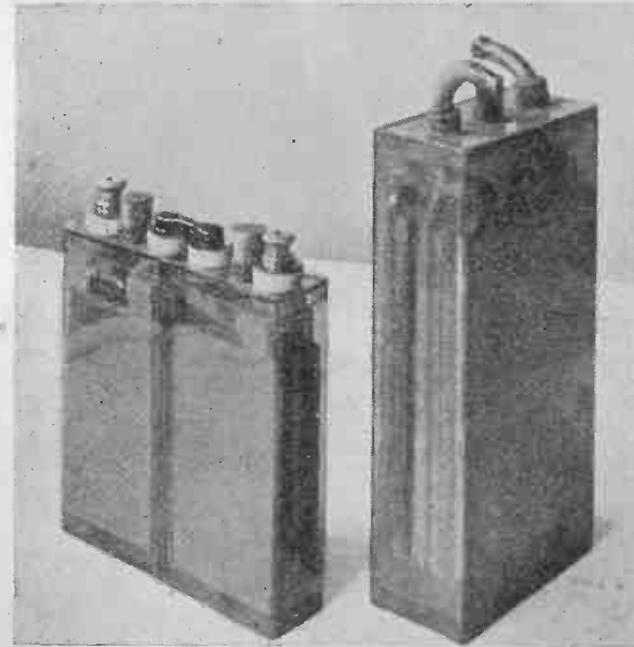
FIG. 4.—Modern method of mounting in a glass case.

lead plated. Around the shoulder, between the lead lug and stud, is cut a small annular depression, cup-shaped, into which is put a small quantity of heavy grease, as vaseline, which protects the stud joint from corrosive action.

#### CHAPTER IV

#### SOME EXAMPLES OF SMALL ACCUMULATORS AND APPARATUS CONNECTED THEREWITH

FIG. 5 is the usual form of 4-volt hand, cycle, or inspection lamp battery,  $4\frac{1}{2}$  in. high overall by 4 in. wide by 1 in. thick,



FIGS. 5 and 6.—A 4-volt hand or cycle lamp battery and a 2-volt unit used in aeroplane lighting.

made up, self-contained, as a double-cell battery, having, in each, a single positive  $2\frac{3}{4}$  in.  $\times$   $1\frac{1}{8}$  in. and two negatives. The

cases are celluloid and the construction as fig. 2. This battery will discharge about 3 ampere-hours constantly at the 9-hour rate, with a normal discharge of .33 ampere, when the discharging voltage will drop to about 3.6. A strong point in multiple-cell accumulators of this kind is to ensure absolute acid-tight conditions between the cells. If the acid can communicate at all, the double cell becomes a



FIG. 7.—Standard 6-volt battery in celluloid case used for "low-tension" radio and other general purposes.

2-volt cell in which the negative element of one is shorted to the positive of the other, and thus half the electrical contents leak away rapidly, ultimately destroying the whole cell. This point is generally well looked after by manufacturers. The battery is a useful shape for putting in a leather satchel for pocket carriage or for attaching to a cycle frame.

Fig. 6 is an example of a celluloid service battery, 2-volt unit, used on aeroplanes for lighting purposes. The cell is  $6\frac{1}{2}$  in. high overall by  $2\frac{3}{8}$  in. wide by  $1\frac{3}{8}$  in. thick, and contains two positives  $3\frac{1}{8}$  in.  $\times$   $2\frac{3}{8}$  in. and three negatives. The

strong point of these is compactness, their capacity being about 14 ampere-hours, with a normal discharge of  $1\frac{1}{2}$  amperes. They are constructed as fig. 2, but have a screw stopper to the vent, and have their series junctions made with the lead lugs burned together, and therefore have no terminals attached. They are for constant voltage, which is obtained by seven cells in series giving 14 volts.

Fig. 7 shows about the largest type of accumulator which can be called small. Self-contained multiple cells of this kind are largely used for so-called "low-tension" or valve filament work in radio reception. 2- 4- and 6-volt batteries can be obtained. The one in the picture is a three-cell 6-volt battery, 6 in. long by 4 in. wide and  $6\frac{1}{2}$  in. high overall. There are three positives per cell, each  $3\frac{3}{8}$  in.  $\times$  4 in., and it will discharge  $3\frac{3}{8}$  amperes for 9 hours, thus having a capacity of 30 ampere-hours. The normal charging current is  $3\frac{3}{8}$  amperes. Batteries of this size and type are extremely useful for a variety of purposes where current in a few amperes at a low voltage is required for a reasonable time of discharge. Their general construction is as shown in fig. 2. As a general thing the series junctions of these cells are made of lead bars burnt to the lugs which lead out. In the one in the picture, however, although this is the construction, tapped holes have been put through the series bars, to which shouldered and knurled-headed set-screws have been fitted in order to tap the battery at 2 or 4 volts; a useful and easily effected addition which enables one to take more than one different voltage circuit off the battery.

Fig. 8, which is a production of Economic Electric Ltd., is claimed to have the greatest capacity in relation to size that the type of cell admits. It is a 2- or 4-volt battery of useful shape for small boat propulsion or for model electric loco work. The smallest of these has a capacity of 2.8 ampere-hours, and occupies a space of only  $3\frac{1}{4}$  in.  $\times$   $2\frac{1}{2}$  in.  $\times$   $1\frac{3}{4}$  in. and weighs only 1 lb.

Figs. 9 and 10 show respectively two forms of unspillable flash-lamp accumulators. The first is for use with an ordinary



FIG. 8.—A suitable celluloid-cased battery for use in model boats and in model works generally.

pocket flash-lamp, for which purpose it has an advantage over the very best dry batteries, in that it can give a constant light over a period which would permanently polarize the primary cells. It is  $2\frac{1}{4}$  in. by 3 in. high overall, by  $\frac{3}{4}$  in. thick, giving a normal current of .3 ampere at 2 volts for several hours. Similar cells are made as a double-cell battery giving 4 volts. In these, as in the following one, the acid space is filled with glass wool, which absorbs the acid and holds it sufficiently by capillarity to prevent spilling. Generally it is necessary to add acid for charging, and to drain away the superfluous liquid after to prevent any leakage. The drawback of these cells being used for general purposes is that the presence of the spun glass



FIG. 9.—Unspillable flash-lamp lead acid cell.

so increases their relative internal resistance that they cannot compare with similar size wet cells for efficiency. The second one shown is a service pattern for use in a hand torch. The

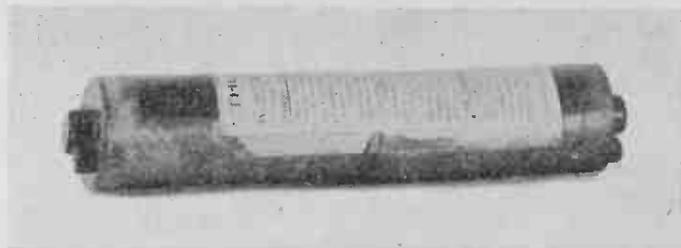


FIG. 10.—Service pattern 4-volt lead battery for use in hand torches.

sizes of it are:  $1\frac{1}{4}$  in. diameter by 7 in. long, and it has plain flat terminal plates at each end for bulb and case contacts. It is a double-cell battery working at 4 volts. In the case of fig. 9 screw terminals are fitted, with which again are supplied brass tongue-pieces for bulb and case contact.

Figs. 11 and 12 are examples of glass-cased 2-volt cells constructed on the lines of that described by fig. 4. The one to the left has but two plates, one peroxide and one lead, and is intended for radio high-tension work made up into suitable size batteries of series cells. It is only  $2\frac{1}{4}$  in.  $\times$   $1\frac{3}{8}$  in.  $\times$  5 in. high overall, and with  $1\frac{1}{2}$  in. square plates gives an actual capacity of over  $1\frac{1}{2}$  ampere-hours, or about 140 milliamperes for 11 hours. The second one has double negative plates, measures respectively  $2\frac{7}{8}$  in.  $\times$  2 in.  $\times$  6 in., and with plates  $2\frac{1}{4}$  in. square is rated at  $3\frac{3}{4}$  ampere-hours, discharging about .3 ampere. These types of glass-cell accumulators are about the last word in small acid cells, and are constructed on similar lines right up to high capacities.



FIGS. 11 and 12.—Modern glass case 2-volt units for making up batteries such as "radio" high-tension.

Fig. 13, another glass-cell accumulator, of similar construction in respect of the case, has been evolved especially for feeding some kinds of radio valves which require about  $\frac{1}{4}$  ampere for filament maintenance. The size of the case is  $2\frac{1}{4}$  in.  $\times$   $2\frac{3}{4}$  in.  $\times$   $6\frac{1}{4}$  in. high overall, and that of the electrodes (they can scarcely be called plates)  $2\frac{7}{8}$  in.  $\times$  2 in. The output for size and weight is extraordinary, being 20 ampere-hours at  $\frac{1}{4}$ -ampere intermittent discharge. This is due to the particular make of the electrodes, there being but one negative to the one positive. The first is  $\frac{5}{8}$  in. thick, and the second  $\frac{1}{2}$  in., and both are, in fact, boxes, pasted in a special way and holed to admit of internal acid circulation. The term intermittent is not that usually meant, viz. an ignition discharge, but a discharge of two or three hours and then some hours'

rest, as, no doubt, they are subject to some internal electrode polarization. Apart from their designed use, they are specially suited for electric-bell work, as, volt for volt, they are really cheaper than Leclanché cells. An almost exactly similar cell is made by the Chloride Electrical Storage Co., listed as type D.T.G.

The final small accumulators shown here are of glass.



FIG. 13.—Modern type glass case, low-current, high-capacity units for radio valve low-tension.

pegs. These cells are described as of 2 ampere-hour capacity, but this is no doubt when discharging at the 80-100 hour rate, or more slowly. In the front of the photo is seen the component details, among which are a pair of plates, their ebonite distance-piece which supports the pitch filling above and carries the ebonite filling tube, a lead series bridge with peg, and two forms of end terminal pieces, one to carry a screw terminal and the other having a terminal peg, and an ebonite end ridge piece. With an empty block and the requisite number

Fig. 14 shows a 20-volt "Monoblock" unit for a radio high-tension battery. In detail it is constructed very much like those previously described. The block of glass comprising the unit is partitioned into ten cells, each cell containing one positive and one negative plate,  $1\frac{1}{2}$  in.  $\times$   $1\frac{1}{2}$  in. The complete unit shown measures  $8\frac{1}{2}$  in. long by  $1\frac{3}{8}$  in. wide by  $3\frac{1}{2}$  in. high overall, the ten cells occupying only 7 in. of the length. The main terminals are on the projecting ends, but there are tapping pegs projecting through the compo tops from the series junctions in the cells. There are similar block units sold containing only five cells for 10 volts. These have no projecting ends for terminals, and measure therefore only  $3\frac{1}{2}$  in. in length, but are otherwise as the 20-volt unit. The 10-volt units are made with and without 2-volt tapping

of details, these cells can be readily made up, as the metal bridges and end pieces are particularly adapted for lead burning with a copper bit. We are indebted to Messrs Grafton Electric Co. for means of describing these ingeniously constructed cells, and for means of testing them.

Fig. 15 indicates one cell of an "Ediswan" standard 20-volt unit. These are remarkable for their extreme simplicity of construction. They have glass tops to the cells, which are secured by a joint made with an acid-resisting enamel. The

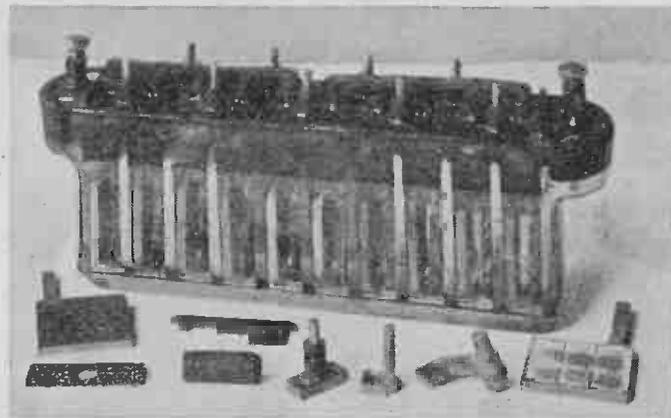


FIG. 14.—A "Monoblock" multiple cell 20-volt unit in glass for high-tension work.

lugs lead loosely through holes in the glass, and although each cell is otherwise separate, the units are supplied bridged with burnt-on joints, and each bridge carries a wander-plug hole. Glass cells are  $2\frac{1}{8}$  in.  $\times$   $1\frac{1}{4}$  in.  $\times$   $3\frac{3}{4}$  in. high overall, and the plates are  $1\frac{1}{8}$  in. square. At the usual long-discharge rate common to most high-tension batteries, these come out at 4 ampere-hours. They are supplied dry charged, and almost immediately after filling show full open-circuit voltage.

There are other types of high-tension accumulator batteries set up in open glass tubes sealed by a layer of oil on the acid, and these with the types shown constitute most of the forms of small accumulator likely to come into the reader's use.

A few instances are shown of apparatus connected with

small accumulators for their application. For flash-lamp purposes the use of dry cells has been made so general by improvements in their construction that they are certainly more convenient where only short lighting periods are necessary. For instance, in short-distance pedal-cycle riding, where some form of front light is imperative, they will answer well. In a case, however, where longer distance night-riding is usual

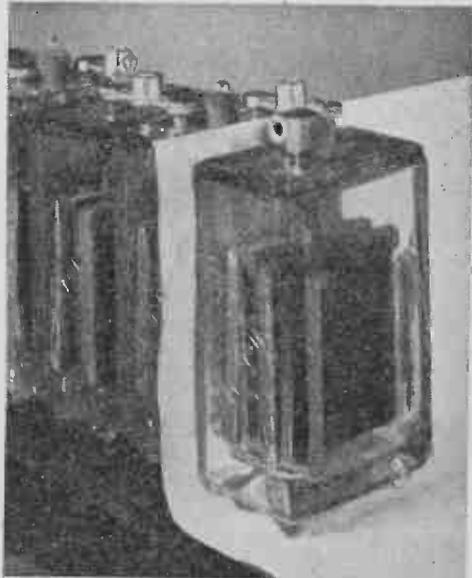


FIG. 15.—One cell, in glass, of an "Ediswan" 20-volt high-tension unit.

and a headlight a necessity, either acetylene or the accumulator-driven electric headlight are more to the purpose, and under bad weather conditions electricity stands alone. Fig. 16 shows a light type of electric bulb headlight fitted with a paraboloid projecting reflector and plain glass front, 3 in. in diameter. This has a telescope adjustment to the lampholder to put the light point into the parabolic focus, and the whole thing weighs less than 7 oz. This, together with a suitable small accumulator in a handle-bar hanging case will weigh

well under 2 lb. For exactly this purpose, taking the bad weather factor into consideration, only the "dynamite" and "votalite" types of electric lighting appear to compare, and with these, the rider has to do the work of generating current, which is only operative while riding.

Fig. 17 illustrates a useful type of small accumulator-driven shaded reading lamp, fitted with 4 volt 4-c.p. metallic filament bulb, and driven by a 20 ampere-hour accumulator, with switch complete. The lamp is on a universal ball joint for projection of the light upon books or papers. This contrivance can be run with maximum light efficiency for hours at a stretch. Fig. 18 shows the lighting contrivance attached to a bedpost, or, by a slightly different form of ball socket, the same can be screwed to a panel or wooden bedpost. The accumulators are then put on the floor, and only a longer flex required to obtain effective reading light.



FIG. 16.—A light type of cycle head-lamp suitable for use with an accumulator.

Fig. 19 shows a useful inspection lamp with small accumulator. This is intended to be worn on the person and used for inspection of tickets, passes, and the like. The accumulator battery of the non-spillable variety can be carried in a case in a pocket. Fig. 20 is a very strongly made special hand-lamp, service pattern and ex-government stock, which carries an unspillable accumulator. These lamps are particularly adapted for use where a long interval of light may be required in a dangerous situation, where inflammable gas or liquids may be stored. It is  $3\frac{1}{2}$  in. in diameter by  $6\frac{3}{4}$  in. high, and will be found quite the thing for rough usage in damp situations and under weather conditions where other kinds of hand-lamps would be put out of action.

In spite of the vogue of the dry battery for flashlight

purposes, the usefulness of small accumulators on the testing table of a laboratory far outclasses any kind of primary cell,

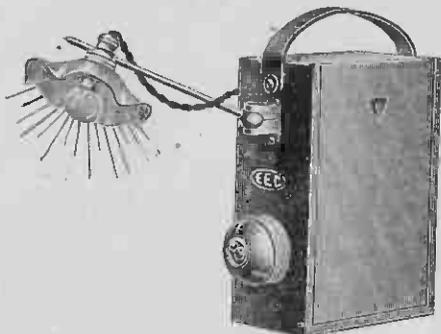


FIG. 17.—Small accumulator with shaded reading lamp.

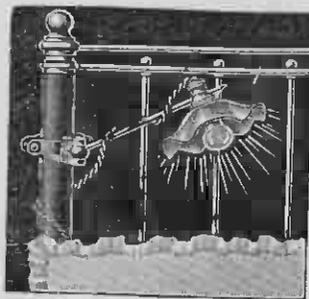


FIG. 18.—An accumulator lighted reading lamp attached to bedstead.

either wet or dry. For computing resistances without the aid of a bridge, the constant voltage on discharge and negligible internal resistance of a lead cell places it far ahead of any



FIG. 19.—An inspection lamp with accumulator in case worn by the inspector.



FIG. 20.—Service pattern weather- and gas-proof inspection hand-lamp.

primary battery for these and similar purposes. As a matter of fact, size for size, the lead cell is the only battery that will give for a definite time a straight-line current.

## CHAPTER V

### APPARATUS FOR CHARGING SMALL ACCUMULATORS

THERE is not the least doubt that small lead cells will give constant results over a long period if their users will take the trouble to understand them sufficiently to pay strict attention to their upkeep. The most important thing in the upkeep is that of their charging, its periodicity, extent, and rate being everything in the life and use of a lead cell. It is not too much to say that, if it is a good make, users can become so accustomed to the appearance of the cell only as to know within quite reasonable limits the state of its charge and what it is likely to do. This cannot be said of any primary battery that the writer knows of, more particularly of so-called dry cells. For these reasons, lead cells should always have some sort of transparent case within which the plates are so placed that they can readily be seen on the negative faces, the positive edges, above and below them, and as far as possible between them if they have no separators.

There are three main methods of charging: by other cells, primary or secondary; by direct-current dynamo; and directly from the mains.

#### Charging by Cells

Of the first method, if other accumulators be used, they should have at least double the capacity of the cells to be charged. There should at least be one cell more in the charging series when charging up to 8 volts. That is, when charging up to four cells in series. Thus, to charge one cell use two; two cells, three; and so on up to four cells, five. After this two extra cells must be used, as five cells require seven; six, eight; and so on up to eight cells, ten. Nine cells require twelve, and so on. To get the normal charging current requires an average of  $2\frac{1}{2}$  volts per 2-volt cell to be charged. And it will be seen that in charging an 8-volt battery with

10 volts, and in charging a 16-volt battery with 20 volts, it is just right. The greatest out-of-balance voltage is when we charge one cell with two, five cells with seven, and so on. Take the first case, one cell requires  $2\frac{1}{2}$  volts, and we apply 4 volts, having too much by  $1\frac{1}{2}$  volts. Take the second, five cells require  $5 \times 2\frac{1}{2} = 12\frac{1}{2}$  volts, and we apply  $7 \times 2 = 14$ , again  $1\frac{1}{2}$  too much. This extra voltage, or part of it, is sometimes useful for dealing with badly sulphated cells, which may have a higher resistance, or sometimes in charging unspillable spun-glass-filled cells, which, especially small ones, also have a high internal resistance. As a general thing, however, an artificial adjustable resistance, capable of carrying the highest charging current likely to be used, is necessary, upon which to drop the out-of-balance voltage. For small accumulators a resistance made to carry up to 4 amperes is a good thing, and as this has to drop on occasion  $1\frac{1}{2}$  volts, it should have a resistance of at least  $4 \times 1\frac{1}{2} = 6$  ohms. It can be made of No. 19 wire gauge high-resistance wire (uncovered), of which 12 yards would be required. Get a piece of hard wood about 8 in. long, turned a shade under 3 in. diameter, and sheathe it with sheet asbestos. Put the butt joint of the asbestos along the cylinder and pin it with fine brads to the wood with their heads sunk into the asbestos. Wind on this tightly and evenly, the wire not touching per turn, but otherwise fairly close. It must be tight to sink into the asbestos. Anchor one end to a terminal screwed to the wood, and anchor the finishing end with a staple, also to the wood. Mount the cylinder between two end wooden uprights on a wooden base with a space between the bottom of coil and the base, and equip it with a sliding contact, just as is used on the original types of adjustable inductance coils in wireless. As is usual, the second terminal will be attached to the square metal runner of the sliding contact. This resistance, if made to carry 4 amperes, will get too hot to touch, but otherwise will serve the purpose well of adjusting the out-of-balance voltage up to a charging current of 4 amperes. Take the positive lead from the charging battery, put it to one terminal of the resistance (either will do). From the other terminal of resistance take a lead to the positive terminal of a directional ammeter reading at least to 5 amperes. Attach the other side of ammeter to *positive* of battery or cell to be charged, and return from the negative of the latter to the negative of

the charging battery. Start with the resistance all in, and cut out till the required amperage is shown on the ammeter.

In charging with primary cells, the same procedure is necessary. Fig. 20A is a primary battery charging set supplied by Economic Electric Ltd. This is a battery of three 2-volt bichromate cells set up with a charging board carrying an ammeter, switch, and fuse, the current of which is regulated by raising or lowering the zinc poles of the battery into or from the acid bichromate solution. Other numbers of cells are supplied, and the contrivance is certainly a good application of the primary cell for these purposes. Leclanché cells, although having a better voltage increment for small lead cell charging, are really useless for the purpose, unless relatively very large and set to charge at a very small current.

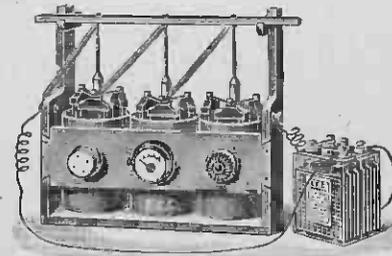


FIG. 20A.—A primary battery charging set operated by bichromate cells.

#### Charging by Direct-current Dynamo

Fig. 21 shows a double pole, ring-type field, shunt-wound dynamo, which, running at 2200 r.p.m., will generate up to 6 amperes at 6 volts. This little machine is supplied by Economic Electric Ltd. and is called the "Dreadnought." It is admirably adapted for charging small accumulators up to 4 volts, and should be used in conjunction with a charging board, as seen in fig. 22. It is equipped with a volt and ammeter, a special automatic cut-in and cut-out, the former being accomplished by the shunt-field current of the dynamo, and the latter taking place when the voltages of the accumulator and dynamo balance. There being no load either way at this point, the cut-out operates by a no-load release, and saves the cells from either shorting through the dynamo or motoring it. As an additional security, a single-pole fuse is added, and two circuits lead out from the board, one with a switch, the charging circuit, and the other, also with switch, the discharging circuit from the cells to their apparatus.

The dynamo shown is suitable for use in country districts where no electric supply is available, and the best method of driving it is by a small petrol engine that will give  $\frac{1}{4}$ th horse-power or larger. The simplest form of drive is by direct belt, geared to give the correct speed. A similar machine to this is suitable to form one unit of a rotary or motor converter,

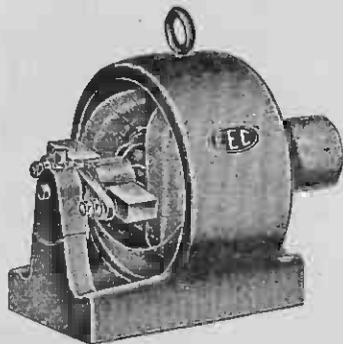


FIG. 21.—A 36-watt double-pole dynamo suitable for charging small accumulators.



FIG. 22.—A charging board for use with the dynamo in fig. 21.

which is really a method of charging from the mains, where such exist. The machine is set on a foundation board and directly geared by a coupling (preferably a flexible coupling) to a similar speeded motor, either direct or alternating, according to the supply; which motor must of course have a power factor higher than the total dynamo output.

#### Charging from the Mains

This method is the one most convenient for dealing with small accumulators as a general thing. In all towns of any reasonable size there are now electric-lighting undertakings, and as all modern houses are generally wired ready for lighting installations, it is likely that most small accumulator users will be able to apply such methods. Charging from the mains can be done directly or by some form of voltage conversion, and these two methods apply to either where there is direct or alternating current.

#### Charging from Direct-current Mains

The effect on a cell by charging from a direct-current main is exactly similar to charging from a direct-current dynamo, whereas in charging from cells or any battery, primary or secondary, the current given is quite even and in a more or less straight line; but when taking current from a dynamo or from a generating station, which produces direct current by dynamos, the current given is in the nature of a fine ripple (all in the same direction). This rippling current, for reasons not necessary to explain, is really more thorough in its action on a lead cell.



FIG. 23.—A four-lamp charging board for use on direct-current house supply.

The simplest method, and really

the most wasteful, for charging low-voltage small accumulators, is carried out by attaching the cells to be charged directly to the mains, positive to positive and negative to negative, and disposing of the extra voltage not required by introducing some form of high resistance into the charging circuit. Most of the energy absorbed by this arrangement is lost over the resistances. The most convenient form of resistance is an ordinary incandescent bulb or a number of bulbs put in parallel according to the current required. Fig. 23 is an illustration of a lamp-charging board carrying four lampholders, volt- and ammeters, double-pole switch, double-pole fuses, and a single-pole voltmeter switch. Fig. 24 is a simple contrivance for plugging into a lampholder for charging a small cell through one lamp. In this a directional meter is included in the arrangement, and the lead from the + side goes to the positive of the cell.

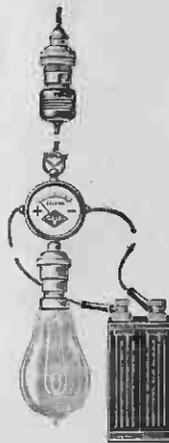


FIG. 24.—Single lamp-charging appliance to use in a lampholder.

If then the meter does not register it is only necessary to give the plug a half-turn in the holder, and what current is passing

will be registered by the meter, the direction for charging then being correct. It is usual if a current of from  $\frac{1}{2}$  to 1 ampere be required to use carbon-filament lamps, because such lamps take relatively more current for a given candle-power. Thus a 32-c.p. lamp passes 112 watts, and that quantity corresponds at 220 volts to about  $\frac{1}{2}$  ampere; and again a 50-c.p. lamp takes 175 watts, and that at 220 volts is a little over  $\frac{3}{4}$  ampere. When smaller currents are wanted metallic-filament lamps will do (not gas-filled lamps). These usually take about 1 watt per candle-power and are registered in watts. Thus a 20-watt lamp at 200 volts =  $\frac{1}{10}$  ampere; a 40-watt, same voltage,  $\frac{2}{10}$  ampere; a 60-watt  $\frac{3}{10}$  ampere, and so on.

These currents are the case nearly enough when charging only low-voltage cells as 2 to 8 volts, and if it is required to get higher currents a multiple board is required, as shown in fig. 23. Here if one lamp of a type gives  $\frac{3}{4}$  ampere as above worked out, two lamps will give  $1\frac{1}{4}$  amperes, and four lamps 3 amperes, the lamps being put in parallel.

When charging high-tension batteries directly from the main, the question of wastage of energy scarcely comes in, in some cases, but the calculation relating to lamps and the possibility of charging in the wrong direction are now of some importance. To compute the necessary lamp or lamps, add 25 per cent. to the normal battery voltage and deduct it from the main voltage. That gives the voltage to drop over the lamps. Then the lamp required should be a full-voltage lamp that allows of the passage of the necessary current at the lower voltage. Here is a case. It is required to charge a 60-volt H.T. battery off a 200-volt main at 70 milliamperes. 25 per cent. on 60 = 75 volts, and this taken from 200 leaves 125 volts drop on the lamp. Then  $125 : 200 :: 70 : 112$ . That is, a 200-volt lamp that takes normally 112 ampere. A  $22\frac{1}{2}$ -watt lamp would be necessary, and the nearest obtainable would be a 20-watt lamp giving about 64 milliamperes instead of 70. Again, suppose on the same main it is required to charge a 120-volt battery at 100 milliamperes. The voltage drop on the battery will be 150, and on the lamp 50 volts. A lamp that passes at 50 volts 100 milliamperes will pass, at 200, 400 milliamperes. Therefore an 80-watt lamp will be required. It will be seen that in either of the above cases, if by accident the current was put through in the discharge

direction, the voltage put on the lamp in the first case would be 260 volts, and in the second 320 volts. The second, at any rate, would blow the lamp filament, and in either case would not be good for the battery. In order to ensure polarity small books of pole-finding paper, costing a few pence, are procurable. With this the ends of the circuit, before attaching to the accumulator, are tested according to instructions. Fig. 25, however, shows a type of lampboard which acts as a safeguard. It is fitted with a directional milliampmeter.

With this set up, and two high-resistance lamps in series, the direction of the current can be tested before putting in the battery. If the meter does not read, a half-turn is given to the plug, and then the direction is correct. The correct lamp is put in one holder and a shorted plug, as shown, in the other, and the battery connected correctly. Fig. 26 shows another simple arrangement sold by Messrs The Grafton Electric Co. In this a small controlled magnet galvo is deflected by the current passing through a coil beneath it, and so indicates the correct polarity before putting on the battery.

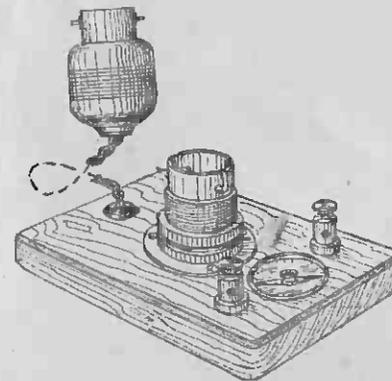


FIG. 26.—Sketch of small charging lampboard with directional galvo.

The final charging arrangement shown here to use directly on direct-current mains is called the "NoKost." Fig. 27 shows it. This is put on to a house main at its lead-in, so that a low-voltage battery can be switched into the house-lighting

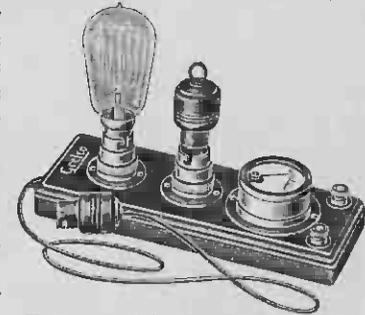


FIG. 25.—A lamp-charging board with directional ammeter or milliampmeter.

circuit and receive a charge according to the current which is passing to light the house. It costs nothing, therefore, to use it. The charge, of course, varies according to the number of lights on, and when all lights are off there is no charge going on. It cannot be used for high-tension charging, because the back voltage of such a battery would dim the house lights too much. Anything up to 8 volts on a 200-volt circuit, however, has no appreciable effect in this respect; although it does, of course, cut down the lighting current slightly. This appliance is supplied by the last-mentioned firm.

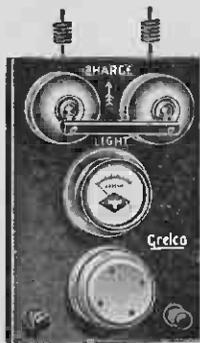


FIG. 27.—A small charging board to put cells in series with the house supply.

dynamo has already been referred to. Fig. 28 shows a small machine which is a combined motor and dynamo. It has a commutator and brush gear at one end of the spindle, to be connected to direct voltages 100 to 110, 200 to 220, 230 to 250, and gives from brushes at the opposite spindle end 5 amperes at 9 volts. A shunt field excited by the main voltage operates both sides of the machine, and there are double windings on the armature. The small charging board attached has an ammeter and regulating resistance for the charging circuit, and the whole apparatus is an ideal thing for charging low-voltage accumulator batteries from direct-current mains in the cheapest possible manner. Other machines are made giving higher voltages and outputs, particulars of which can be obtained from Messrs Lionel Robinson & Co., of 3 Staple Inn, Holborn, W.C. 1.

#### *Charging directly from Alternating-current Mains*

If one were to try to charge a cell really directly with alternating current nothing would take place, because at the same rate that charge took place, so would discharge. To

actually charge, therefore, directly from mains supplied alternately, some apparatus must be included in the circuit which, while retaining the current in the charge direction, cuts out or reverses the current in the discharge direction. Such an apparatus is called a rectifier. It will be seen that when the discharge direction is cut right out, that the appliance

is really an interrupter, and that a rectifier proper does not cut out the discharge direction but retains it and reverses it. There are mechanical devices for the purpose, electrolytic or electro-chemical, metallic, vapour arc, and oscillating valve. They cannot all be described here, but reference will be made to such appliances as will be useful for dealing with small accumulators. It should be clear to the reader that the periodicity or cycle of an alternating current is the number of times in a second that it goes in the one direction, and reverses and goes in the other. If (what is called) a single-phase alternating current has a periodicity of 50, it means that in  $\frac{1}{50}$ th of a second it passes in the one direction for  $\frac{1}{100}$ th of a second, reverses, and passes in the opposite direction for another  $\frac{1}{100}$ th of a second. If an interrupter rectifier be used with the above, the current will go in the one or charge direction for  $\frac{1}{100}$ th of a second, and then for the other  $\frac{1}{100}$ th there will be an open circuit and no current. If a rectifier proper be used, the current passes in the charge direction for  $\frac{1}{100}$ th of a second and again passes in the charge direction for the other  $\frac{1}{100}$ th. Both halves are a kind of ripple, which differs slightly, but the circuit is not broken. It is considered that this ripple current is better for charging purposes, and there are some scientific men who state that the interrupted current is better still.

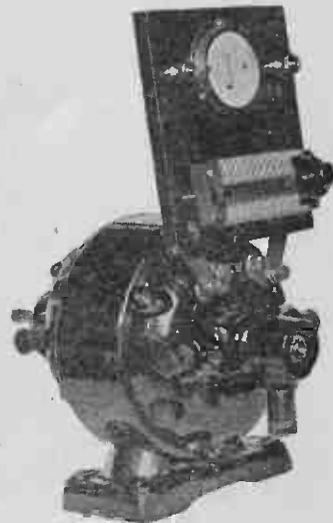


FIG. 28.—A dynamotor or single-voltage converter for direct current.

Fig. 29 shows a small and inexpensive apparatus to use for charging high-tension accumulator batteries directly on the main, a lamp being used as a controlling resistance. It is particularly adapted for charging the glass monoblock cells shown in fig. 14. The plug in lead to the left is put into (and either way) a lampholder on an alternating circuit of the correct periodicity for which it is made, and the other plug on lead, to the right, which can only be attached one way,

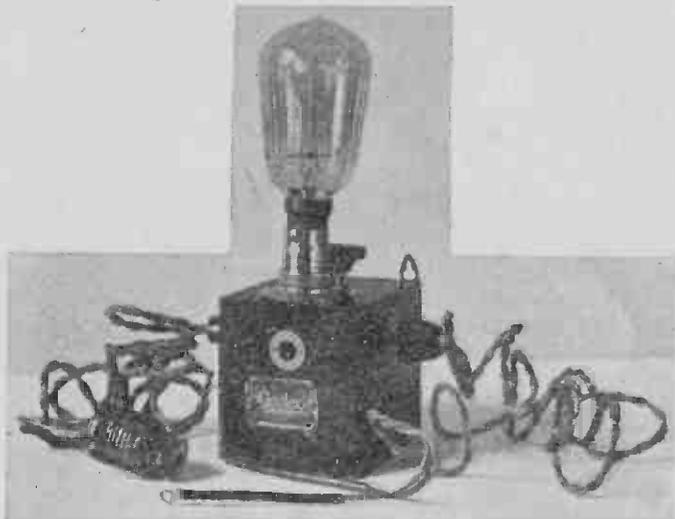


FIG. 29.—A single-lamp alternating charging half-cycle rectifier.

has its red-covered end put to the battery positive and the other (black) to the negative. When properly adjusted by the milled handle behind the lamp, the lamp glows with a red vibratory glow, and steady otherwise. Then it is charging. It provides an interrupted current by means of a vibrating arm set to vibrate at the correct periodicity. The lamp is worked out just in the same manner as given for high-tension charging off direct-current mains, excepting that, as half the cycle is cut out, the resulting current (given in terms of energy) is only half. A directional milliammeter, reading at least to 100 milliamperes, should be connected as follows: Put the positive or red lead from the rectifier to the positive of the

meter, and from the negative of the meter run a wire to the positive of the battery. When the lamp glows evenly (not with a bright scintillation), the meter will record the correct current, with a nearly steady indication.

A method of high-tension rectification is that known as the Noden valve, which is a form of electro-chemical rectifier. A lead and aluminium plate, externally insulated, and immersed in a solution of ammonium phosphate, will admit of the passage of a current from the lead to the aluminium, but not the other way. An arrangement like this, put in an alternating charging circuit with the aluminium pole joined to the positive of a cell to be charged acts as an interrupter to the discharge half of the cycle. This, however, appears only to act with any degree of certainty at voltages above 100 up to 150, or thereabouts, and even then the contrivance must be run for some

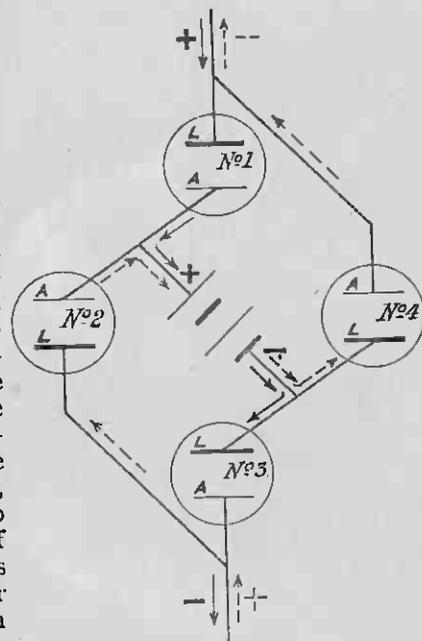


FIG. 30.—Method of connecting four half-cycle electro-chemical rectifiers to give whole-cycle rectification.

“form” the plates. It is said to act at as low a voltage as 40, but the writer has found that at such low voltages as in charging 6 to 8 volts it “lets back” quite a considerable proportion of the discharge half. A point necessary to proper working, under the best conditions, is to avoid any appreciable rise of temperature in the solution. It ceases to work altogether at a temperature half-way up to the boiling-point of water. Fig. 30 shows an arrangement of four cells of this character, wherein the lead is marked L and the aluminium A, which

converts the contrivance into a true rectifier, always supposing it is working satisfactorily per cell. The cell to be charged is put across the centre with its high potential side at the top. The four cells are numbered. Taking the first half-cycle shown by the full arrows, and plus at the top: Cell No. 4 baffles it, its aluminium plate remaining at high potential. Cell No. 1 passes it, while cell No. 2 baffles it again, its A plate remaining at high potential. It therefore must go through the battery from plus to minus. Then, although Cell 4 would pass it, its potential is lower than A of that cell. It must then go down and through Cell 3 to the negative. It cannot pass Cell 2 because the plate A of it is at high potential. The next half-cycle shown by the dotted arrows is similarly baffled by Cell 3, passed by Cell 2, baffled by Cell 1, and hence through the battery from plus to minus. It therefore finally passes Cell 4, and thence to the negative at top.

Metallic or dry rectifiers have recently been developed upon commercial lines. They consist of a number of plates or discs set up in the form of unit couples. Each couple is a flat plate of copper oxidized on one side, bearing, by that side, on a plate of lead. Units are clamped tightly together by an insulated bolt, and have insulated separators, and some form of thin metal disc of larger dimensions to act as a heat dissipator. The couple acts somewhat in the manner of a radio crystal, passing current against low resistance in one direction and introducing a high resistance in the other. Units are clamped in series to work against volts and are connected in parallel to give higher current. Little information is available on the construction and manufacture of these, but it appears that they are more sure in action than electrolytic rectifiers, but are limited in output, unless very large, and therefore costly. It is stated that if current be forced through in the wrong direction they tend to break down.

#### *Charging from Alternating-current Mains by Conversion*

Conversion of voltage in alternating-current mains is conveniently carried out by means of step-down transformers. Fig. 31 shows a modern type of mechanical transformer rectifier, which in this case provides an interrupted current. The transformer is in the lower half of the case, working directly from the mains by the plug flex to the left. The current from it is then half-cycle, rectified by the vibrating finger, or reed, at

the top of the case, which arrangement is designed to vibrate at 50 periods. The vibrator is worked by the back voltage of the battery to be charged, which may be from 6 to 8 volts. It is connected by the spring-clip terminals of the right-hand flex and has the directional ammeter and plug-in tubular fuse in series with the battery. To operate it, the main plug is put to any lampholder of an alternating main, 200 to 240

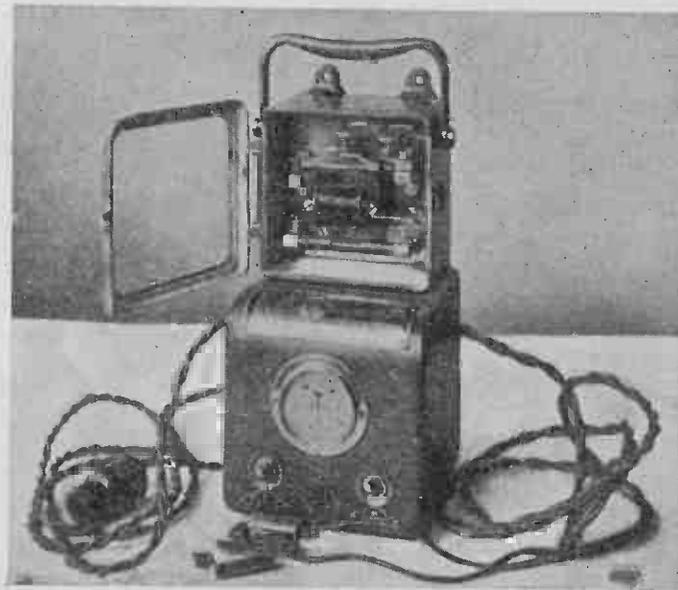


FIG. 31.—A transformer rectifier for charging from 200 volts, 50 cycles, down to 6 volts direct. Half-cycle rectification.

volts, 50 periods, either way round. The clips are clipped to plus and minus terminals of the battery either way round. The battery switch (at bottom right hand) is closed, and the vibrating finger touched down on to the contact lightly to show the discharge direction of ammeter, which has a centre zero. Then, if, when the left-hand or alternating-current switch is closed, the vibrator starts and the ammeter needle swings to the charge direction, the contrivance is charging at the current indicated. Adjustment for sparkless working is made by the

right-hand knurled screw at top. The maximum charge current is 5 amperes, and the apparatus will give an input of 10 ampere-hours to a 6-volt battery, at about its normal charge rate, for 1d., paying for current at 9d. per unit (slot meter rate). There does not seem any necessity to provide for double rectification, as it would appear that the loss (which is very small) on the high-tension side at the break, is made up for by the advantage of charging with an interrupted current. Apparatus of this kind, however, is made to give complete rectification if required.



FIG. 32.—The Philips transformer valve rectifier. External view.

former valve rectifiers. external appearance, and the second the workings with the cover removed. It is a complete cycle valve rectifier called the Philips Rectifier, made by Messrs Philips Lamps Ltd., of 145 Charing Cross Road, W.C. 2. The plug lead goes to the main, which may have any voltage from 100 to 260, and any periodicity between 25 and 100, and is plugged either way. The tabbed leads are marked plus and minus, and go respectively to those terminals of the charge battery. It gives a charge up to 1.3 amperes on 2-, 4-, or 6-volt batteries. As seen in fig. 33, there is a transformer wound to step down to about 19 volts. There are three sections to its secondary wind-

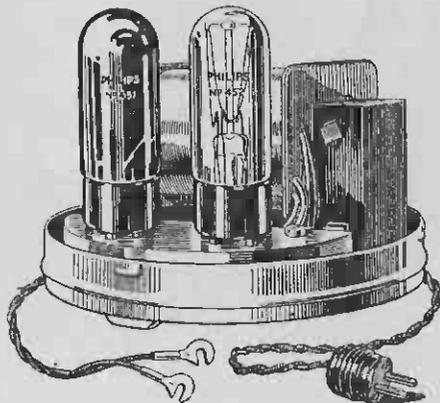


FIG. 33.—The Philips valve rectifier. Internal view.

ing, two of which are in one, with a centre tapping, which is connected through the special resistance lamp on right to the minus terminal of battery. Each end of the two sections go, one each, to a plate of the valve. The filament of the valve is lighted by the third section of the secondary, and at the resistance junction of the filament ends a lead goes to the plus of battery. Each alternation goes from its plate to the valve filament and hence to the plus terminal of the cell. The current is controlled by using different resistance lamps. It works silently and can be used for any purpose where direct current within its limits is essential and only alternating available. There are other sizes which charge up to 12 volts with the same current, and up to 8 volts, 6 amperes, or 10 to 14 volts, 3 amperes.

The Mercury Vapour Arc Rectifier, which is a vacuum lamp rectifier, works similarly to the above valve, passing each alternate half-cycle by an electrode to one end of the arc. But this contrivance is generally constructed to give large currents far beyond those required for small accumulators.

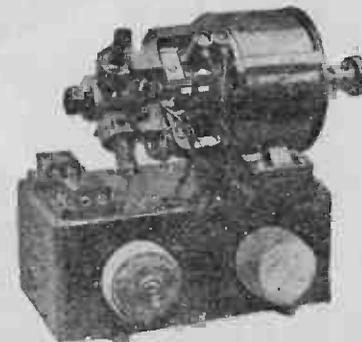


FIG. 34.—A double-wave rotary commutator rectifier for charging and other purposes.

The subject of alternating rectification is closed with fig. 34, which shows a Rotary Rectifier mounted on a transformer for purposes of double-wave rectification. It is a machine made by Messrs M. W. Woods, of 3 Denman Street, London Bridge. The motor is operated by the alternating supply, and the rectification is effected by a four-brush interrupting commutator. Machines of this type can be obtained for supply voltages of from 100 to 250 volts, 50 to 60 periods, and transform and rectify, giving various outputs, the smallest of which series gives 15 volts, 4 amperes. Machines can be obtained from this firm, similar to fig. 28, giving 8 volts, 3 amperes, and 6 volts, 4 amperes, but for rotary conversion of direct current.

Measure :—

A glass graduate-marked in fluid ounces and drams as used for photographic purposes.

(8 drams to 1 oz.)

## CHAPTER VI

### THE TREATMENT OF SMALL ACCUMULATORS

ON purchasing an accumulator cell or battery it will be found that it bears a card or ticket giving particulars of treatment. In the first place, it will state whether it is "dry charged" (*i.e.* having received its first charge and dried off), or it will give its first charge rate in amperes, and its normal charge rate, showing it has not received its first charge and that the plates are only in the formed condition and dried off. Beyond this it should give, beside the voltage, the maximum charge and discharge in amperes, and the capacity in ampere-hours. If the latter is called "ignition capacity," one really needs to neglect it, but is on the safe side to assume that the ordinary capacity, on constant discharge, at the nine-hour rate, down to a working voltage of 1.8 on discharge, to be at least half the ignition capacity. Further to this, it may give particulars of the acid charge, which is the first thing to consider.

#### Charging with Acid

The specific gravity of the dilute acid is usually given as between the numbers 1.17 and 1.28. This really means 1.17 and 1.28. As it constitutes an admixture of commercially pure sulphuric acid and commercially pure water, the following table will give approximately the quantities corresponding to given specific gravities (sometimes called the "density").

#### Table for diluting Sulphuric Acid

*Giving quantities by volume to be added together to produce a given specific gravity.*

Materials :—

Commercially pure brimstone sulphuric acid sp.g. 1.85

" " water (distilled) " 1.00

(Add acid slowly to the water and stir with glass or ebonite rod.)

Sp.g. when mixed and cold.	Ratio acid to water by volume.	Proportions of 1 oz. acid to water.	Total volume in oz. and drams.
1.17	1 to 4	1 oz. to 4 oz.	5 oz. 0 drams
1.18	4 " 15	1 " " 3 $\frac{3}{4}$ " "	4 " 6 " "
1.19	2 " 7	1 " " 3 $\frac{1}{2}$ " "	4 " 4 " "
1.2	4 " 13	1 " " 3 $\frac{1}{4}$ " "	4 " 2 " "
1.21	1 " 3	1 " " 3 " "	4 " 0 " "
1.22	8 " 23	1 " " 2 $\frac{7}{8}$ " "	3 " 7 " "
1.23	4 " 11	1 " " 2 $\frac{3}{4}$ " "	3 " 6 " "
1.24	2 " 5 full	1 " " 2 $\frac{1}{2}$ " "	3 " 4 " "
1.25	8 " 19	1 " " 2 $\frac{1}{4}$ " "	3 " 3 " "
1.26	4 " 9	1 " " 2 $\frac{1}{8}$ " "	3 " 2 " "
1.27	8 " 17	1 " " 2 $\frac{1}{8}$ " "	3 " 1 " "
1.28	1 " 2	1 " " 2 " "	3 " 0 " "
1.29	8 " 15 full	1 " " 1 $\frac{7}{8}$ " "	2 " 7 " "
1.3	4 " 7	1 " " 1 $\frac{1}{2}$ " "	2 " 6 " "

When mixed the solution will get hot, and must be allowed to stand till at normal temperature, which may take an hour or more. When cold test with hydrometer and correct if necessary by adding acid (if not up to density) or water (if above density) and test again.

To test specific gravity a small hydrometer can be purchased. (Cost about 2s.) Fig. 35 shows a typical hydrometer (sometimes called an "acidometer") and how it works. It is a small sealed glass tube about 3 in. long, bulbous at the bottom, wherein it is weighted by a few shot in wax, and fitted with a paper scale inside the top tube. When put in any liquid of density between its range, it floats, bulb downward, and indicates the specific gravity at the level of the liquid. The one in the sketch is indicating a density of 1.2 specific gravity, and therefore would correspond to about 4 volumes of acid put to 13 volumes of water. There is a thin form of hydrometer specially made for testing between the plates of large lead cells after they have been charged. These are not practicable for small cells, but a type of suction-pump with hydrometer

similar to fig. 36 can be purchased for a few shillings. This is a glass syringe tube, fitted with a rubber suction-bulb at top, and a short length of rubber tube at the bottom.

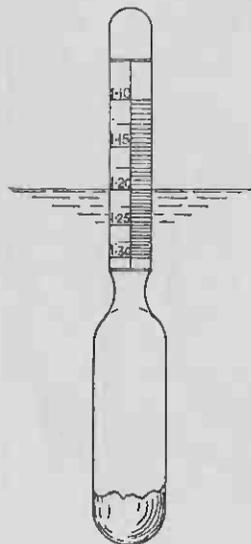


FIG. 35.—An acidometer or form of hydrometer for acid testing.

The lower portion of the syringe tube holds an hydrometer, and by compressing the bulb and introducing the rubber tube into an acid cell, sufficient liquid is withdrawn and held by vacuum in the tube to float the hydrometer and take a reading. By removing the hydrometer, the syringe forms an excellent filler for small accumulators. In filling any covered accumulator trouble may occur due to electrical leakage from spilling acid on the top. The smaller the accumulator cell the more marked relatively is the question of a moist or wet top. In the case of very small cells, such as in fig. 14, it is almost an absolute necessity to avoid any spilling of acid. Owing to the air-locking effect in filling, even with one of the above-mentioned syringes, trouble may occur in this respect. The cells mentioned hold only 3 fluid drams of dilute acid, and the vent to fill is less than  $\frac{1}{4}$ -in. bore. A certain kind of fountain-pen filler has been found to effect the filling of these and other small cells quite cleanly. It is made up of about 3 in. of ebonite tube, less than  $\frac{1}{8}$  in. outside, and  $\frac{1}{16}$ -in. bore, headed with a 1-inch rubber bulb, of capacity about  $1\frac{1}{2}$  fluid drams. It costs less than one shilling. Two charges of acid made with this inserted to the lower part of cell just fills the cell to the correct level, which may require "topping up" with a few drops to bring the acid about  $\frac{1}{8}$  in. above the plates. The difference in the life of a battery of this kind with perfectly dry tops, and with the acid not touching the underside of the seal, is very marked. A filler like this should not be used between whiles for filling pens, as traces of the ink affect the contents of the cells, but used only for filling small cells, and for topping up any small accumulator.

Topping up accumulators is done with the standard filling acid only when putting in the first acid charge, such acid that sinks into the plates being made up thereby. Afterward only distilled water should be used, as it is the water which evaporates and not acid. Never use tap water on any account for filling or topping up. Tap water can be used for washing out a cell, but in that case every vestige must be drained off before replacing or recharging with acid. At a pinch, the use of rain-water has been found to have no great ill effect. Collect the water in clean vessels, let it stand a little for heavy carbon deposit to settle, take of it from the top, bring it to the boil and allow to cool right down, and filter through clean white blotting-paper. Rain-water treated in this manner can be used for topping up, and should be used for cleaning out in preference to tap water. It is better, however, to dilute the acid in the first place with distilled water only.



FIG. 36.—A glass tube suction-pump fitted with hydrometer for acid testing.

The only impurity likely to get into bottled acid—which by the way is better kept air-tight in a stoppered bottle—is the cork, if it happens to be in a corked bottle. It should be understood that the bulk of stock acid should be kept in the concentrated form, because in that form it is less active than diluted. If, however, the cork goes down under its action, the effect will be to carbonise the acid. If this should happen, make up the acid with distilled water to the density required when required. When the heat of combination has subsided, and the solution has stood long enough for the more solid carbon to fall to the bottom, dilute acid of density up to 1.3 can be filtered by means of clean white blotting-paper held in a glass funnel. Apparently the presence of the slight discoloration probably left in the filtrate will pass off in use, and no ill effect will result. Do not try to filter dilute acid above 1.3 or any dilute acid while hot, as the blotting-paper will break down.

### Hints on Appearance of Cells during Charge and Discharge

If a cell during use shows the following appearance, and gives the following results to tests, it is certainly in a discharged state. The assumption is that the cell was originally properly acid-charged and is not sulphated abnormally. If the positive plates appear of dull red colour with palish patches (not with any white deposit), and the negative plates are dark grey and likewise patchy so that it is difficult to distinguish them at a short distance away; combined with the fact that, on test, and with the cell discharging its normal current, the voltage is down to 1.8, and at the same time the tested density of the acid is below 1.9—are in combination evidence that the cell is down. The colour indication, especially of the positive plate alone, is almost sure indication that the cell is far from a charged state, but the other three indications are not alone a great deal of evidence that the cell is down. Should, however, a test show the density of acid to be as low as anything below 1.2, when all other indications are that the cell is in a charged state, then the acid must be corrected and brought up to density of at least 1.24.

If, on the other hand, while the cell is charging the following combination is indicated, then it can be taken that the cell is fully charged. If the positive plate is so dark a chocolate colour that it appears, at a little distance, almost black and glistening, and if the negative plates are evenly light grey, giving an impression of grey chalk colour, but not so patchy; at the same time the voltage taken across the terminals of the cell with the normal charge current on is 2.6 or above, and the tested density of the acid is in the neighbourhood of 1.25, and the cell gassing freely (to be explained)—it may be taken that the cell is fully charged. The colour of the plates should be relatively dark and light; so that they are readily distinguished at some distance away. This, however, in the absence of gassing at both plates, or at so low a cell voltage while on charge as 2.2 or less, is no sure indication of a full charge. When a cell shows all the above indications of a full charge it should be taken off, and then it will be found that after standing some little time, and even after a small discharge at normal rates is taken, that the positive plate will lose its black look and show a distinct chocolate-red or dark plum colour, the negative plates will darken to slate grey and

lose their chalky look, the voltage on open circuit will be about 2.15, and the density of acid about 1.26. This is quite normal, and the voltage on normal discharge will be at about 2 exactly.

### Sulphation

If the chemistry of the lead cell be only casually examined, and it contains only the original elements—hydrogen, oxygen, lead, and sulphur—under normal charged conditions the only solid materials it should contain are metallic lead and lead peroxide. Also the only other solid material it can form is lead sulphate. Lead sulphate exists in three forms: (1) normal surface sulphation due to discharge; (2) excessive or abnormal sulphation which can be reduced by prolonged charging at a low rate; (3) the aggressive form of sulphation which may be either in white spots on the otherwise healthy plates, or it may be all over the plates in white crystalline curtains, the presence of which renders the cell useless, as it is not possible to reduce it by ordinary electrical charging.

The first form of sulphation is that which occurs on normal discharge and alters the healthy colour of the plates. The second is that which corresponds somewhat to the condition of the cell before it receives its first charge. During a low-rate long charge to remove it, the gassing of the cell is fairly continuous in fine globules, which make the liquid in the cell look milky, and gradually adds to the density of the acid without a corresponding rise in charge voltage. Of the third, which in its spot form is the commencement of the other, it can be removed by prolonged charging, wherein the action on the healthy lead or lead peroxide beneath it causes it to fall off the plates into the well of the cell. The presence of any white sulphate in a cell has the effect of adding to it, and further reducing the specific gravity of the contents. It is often noticed that during the removal by prolonged charging of white sulphate that the acid drops considerably in density. The white loose sulphate should be soon removed and the acid corrected to normal. If the white sulphate covers everything, there appears to be only one thing to do if the cell is otherwise worth it—take it down and remove as much of the hard white deposit as can be rasped away, and then, if the positives show up with a reasonable peroxide colour, but very pale, and the lead plates show a fair metallic surface,

the cell can be reset up with 1.2 acid and prolonged charging resorted to, which may bring back some of the capacity. It must be remembered, however, that in removing white sulphate from a cell lead is taken out of it thereby and that the plates will never again give full capacity. The formation of white sulphate results from a discharged cell standing without use in its low gravity acid, and, if in excess, is generally considered to be equivalent to scrapping the plates and fitting new ones—in small cells as costly an undertaking as buying a new one altogether. Users of cells should watch carefully for any tendency to deposit white sulphate, and set to work to recharge it off immediately it shows.

#### Gassing

The evolution of hydrogen and oxygen gases gives rise to this, and generally speaking if a cell is down in charge, but is otherwise healthy, gassing should not occur immediately upon being put on charge. Immediately on acid-charging any new cell, either dry-charged or only formed, gassing takes place, especially with dry-charged cells, and continues till the acid has soaked right in. The evolution is evidenced by the formation of small bubbles of gas on the surfaces of plates, which small bubbles if held down coagulate with others and form large bubbles which rise rapidly. It should be realised that this gas collection in the upper portion of a covered cell may be easily of an inflammable or explosive nature, and that lighted matches, lamps, or even live cigarettes, should not be brought near the vents of small accumulators at any time. On charging a healthy cell the positive plate generally gasses first, and finally both plates, the bubbles being clear and well defined in the clear liquid. If the gassing is general from both plates and extremely fine during all parts of the charge and is still a good deal in evidence when standing idle, it indicates an excess of the active form of sulphation. It is so bad sometimes and so fine as to render the liquid cloudy and also to form a thin foam at the top, but can generally be cured by prolonged charging and use of the cell. Excessive foaming of celluloid cells is more often due to the effect on the acid by its effect on the celluloid. There are said to be cures for it, but it is very much modified by throwing out the acid contents, washing out and draining the cell, and putting in

a new acid charge, exactly as described in the next chapter, especially if the foaming is heavy and yeasty, which is a sure indication of an excess of free sulphate in the acid.

#### Dealing with Dry-charged Cells

With these, as with all accumulators, the instructions should be followed exactly. It has been found, however, that dry-charged cells rarely hold a full charge, but have sufficient in this respect to put on discharge in an emergency. It is usual to put in an acid charge of the strength indicated, and leave them standing to soak for some hours before discharging. They generally show then full-open circuit voltage, but, nevertheless, give better first discharge results if they are subjected to a half-normal charge before putting into use. The effect may be to overcharge them, but this does not matter in any case. An overcharge in point of time does no cell any harm, only resulting in the loss of water. An overcharge in point of current is wrong always. It tends to heat the contents of the cell and thus to buckle the plates, principally the positives. For the latter reason hot acid should never be put into any cell at any time, and should any heating become apparent during an ordinary charge, always modify the charge current to avoid it, or stop charging altogether till the cell is again cool.

## CHAPTER VII

## REPAIRING SMALL CELLS

If a cell shows a fair collection of white substance, with or without some loose red peroxide in the well, especially if it is so heaped that it may form a plate junction, wash the cell out. Remove the vent stopper, and pour out the acid into a clean glass vessel. Then thoroughly wash out and rinse the cell with water (as before described) and get rid of every vestige of loose material that can be got out. If tap water be used, it should be drained right off, and can generally only be so disposed of by drilling a small hole in each cell cover at one extreme corner. The cells are then drained upside down and the resultant water poured right off through these corner holes. Meanwhile the acid, having its solid contents settled and become clear, should be poured off the precipitate, corrected if necessary for density, and put back. The density of acid used depends upon the charge condition of the cell, and, in round figures, the following densities can be employed. If the cell is discharged, use 1.16 or 1.17; if about half-discharged, 1.2 or higher; when fully charged, 1.25 or 1.26. In any case, after washing out, give the cell a charge at normal rate till the gassing, conditions of colour, and charge voltage are in accordance with a full charge. Then test the acid again and correct it to about 1.26 if necessary.

If such a cell originally had a fair proportion of the white deposit, which means sulphate, the acid is sure to be down, because it has been used up by the sulphating, and further, as stated before, the presence of the sulphate in excess is found practically to tend to its greater accumulation.

## Taking down a Cell for Plate Repairs

Should it be necessary to remove the plates from a cell for repairs the cover will have to be removed. In this, dealing with celluloid cells is rather easier than with glass. In any

case empty the cell first, wash it out, and drain it. The celluloid cover is usually cemented to a rebate formed by strips of celluloid first cemented to the inside edges of the case, near the top. The cement used is made by dissolving celluloid in amyl-acetate, or in acetone. By running the thin sharp point of a penknife blade round the joint, between the cover and sides, the top piece can usually be loosened. If this can be done, and the cover, together with the plates, lifted out, so much the better; but cells of this sort are usually made so close a fit that the strips have also to be removed, which is a little more difficult and entails replacing them. Sometimes it is better to cut away gaps in the strips to allow the edges of the plates to pass through, and otherwise leave the strips. It may not be necessary to remove the cover from the plate lugs, but if any lead-burning is necessary at the top, it must certainly be taken off to avoid fire. To do it, remove the top terminals and washer, when the lugs can be pulled back through the rubber plugs. When the repair is finished, whatever it may be, the plates are put back into place in the rubber plugs, and the whole thing into the case. Here the retention of the strips comes in as an advantage, because it is better to set up and test the cell with a loose cover, and not cement it down till one is sure that all is going well.

When this is certain, a better cementing job can be done by running off the acid, washing out the cell, and thoroughly cleaning and drying the joint. The joint is remade by running in the cement mentioned, which can quite easily be made by a reader, and allowing it to dry hard before re-charging the cell with acid. In taking down multiple cells attention is called to the preservation of the partition joints particularly.

To deal the same with glass cells requires the application of an old knife-blade heated sufficiently to cut through the pitch cement, a good deal of care being necessary to avoid cracking the glass by the heat applied either with the blade or, on remaking the seal, by melting together the pitch at the joint, which can be done with a bit of thick hot copper wire or the point of a small soldering bit when hot enough.

Repairs likely to be necessary are to straighten buckled plates. Buckled plates—usually the peroxide plate—will work, and quite satisfactorily, in their buckled form, but often present a likelihood of short circuiting. If this is imminent, they can be flattened by means of pressure applied with a

flat board when on a flat board. If multiple plates are concerned, flat boards must be put between them. When applying the pressure watch out for any likelihood, or start, of a fracture to the grid frame, which is put into considerable tension. If any tendency shows up, desist, and let the job go at that, when dealing with positives. A fracture to the frame of a negative is not so serious a matter. In all cases if plates be successfully flattened, they will most likely not clear the cell in width. If this be so, file the edges till they do, with a bit to spare, using a coarse-cut file or a fine-cut rasp. In this, however, one must see that the filing is not carried right through the grid framing.

During the work of dealing with plates when free of the acid, attention must be paid particularly to the negatives when they are dry. If the latter are healthy and well up in charge, they are nothing but pure lead, and this element, when in contact with air in volume, is liable to rapidly oxidise. That is, form superficially the monoxide of lead (litharge), the material from which they were originally formed. The action is so rapid that they heat up and will buckle and otherwise deform. They must be kept cool if this occurs, and should be protected from air in the bulk, as draughts of air. Keeping them covered with distilled water will help. If they become coated all over with the green-grey film, a sort of secondary forming has to be gone through before they will work satisfactorily.

If any lead-burning is wanted it can be quite well done with a soldering bit. File away all the solder tinning of the bit and retin with pure lead, using chloride of zinc as a flux. Tallow is the usual flux to use for lead, but in small jobs chloride of zinc or "fluxite" will do. The stick used must be pure lead, and no tin should be allowed in the jointing. Joining up negatives by this means is not difficult, but working on positives, with a junction to the peroxide, is, as the leading will not amalgamate with the oxide, and there is too much of it to be reduced by any flux. Generally it is best to work the lead round the peroxide filling, and so lock it in.

Positive plates can be repaired and even entirely replaced by pasting a new grid with peroxide. Old peroxide plates free from white sulphate can be employed as follows: Smash up the grid by knocking out the oxide pellets and freeing them from bits of grid. Pound up the oxide by hammering

between several thicknesses of thick brown paper, and sift it through a fine sieve, and only use the flour form of oxide without lumps. Follow by desulphating the powder. Get a wide-mouth glass jar, and put in the bottom of it a lead plate, having the edges turned up by flanging, a strip or lug burnt on and coming up the side of jar and out at the top. Put a heap of the powder—enough and a bit more for the job—on this improvised dish, and fill the jar slowly, to avoid disturbing the powder, with dilute acid of about 1.15 density. Place a stick of wood across the top, and from it hang a piece of clean lead grid by means of some thick lead fuse wire to the wood. This grid may be a bundle of fuse wire, but is better if a piece of old clean negative, cut to about the circle of the dish, and hung horizontally over the powder as low down as possible in the acid, not touching the powder, the dish, or its leading-out strip. Apply about 3 volts, positive to the dish, and negative to the hanging wires of the grid. This will set up a charge and reduce the sulphate in the powder. If the ebullition is too great it will spread the powder off the dish where it will get out of circuit. To avoid it, cut down the current. Keep it on for several hours, and use the paste as soon as possible after finishing. Draw off the acid, and drain off as much as possible, and allow the paste to dry—in a dry air or it will gather moisture—to a stiffish consistency. Either repair or paste a grid with this. Lay the grid on a flat board and apply the paste with a wooden spatula like a paper-knife. Press it in tightly on both sides, and keep on, using an excess of paste, till it dries sufficiently not to sag out when lifted from the board. When so far finished, set plate vertical in a dry current of air till it sets sufficiently to hold up when held horizontally for some little time. Meanwhile prepare two flat hardwood boards, and cut two pieces of asbestos about  $\frac{1}{8}$  in. thick the same size and shape as plates. Put one board down, make pieces of asbestos red hot, lay one on the board, then the plate exactly on it, then the other sheet of asbestos made red hot, and finally the other board. Put this sandwich under a letter-press, apply a good pressure, and leave all night or longer to dry. When taken from the press the asbestos should be retained, and wedged tightly between the positive and a pair of negatives, so that, when set up, and with an acid charge, the plate can receive its first charge and discharge before removing the asbestos. The effect of drying the plate

under pressure and in the neighbourhood of the hot asbestos, coats it with a porous, hardened skin that helps to retain it in the grid. Further, if a first charge can be put in without disturbing the inner contents of the grid, it helps to cement it by contact peroxidation of the grid, and plates made in this way have been used to great advantage.

#### Making New Plates

New plates are made in the way described above, but the pasting of the positive, in the first place, is done with an admixture of red lead with some litharge mixed to a paste with dilute acid. The paste of the negative is litharge only, similarly mixed with acid. The method of pasting both is as described, but no hot sheets of asbestos are necessary. An excess of paste is used, and after the plates have set a little they are put between boards and under a screw-press with pressure applied and so left to harden under pressure.

The subsequent process, that of forming, is rather long and tedious. In an accumulator factory the plates would be formed before they were mounted in batteries by sandwiching the plates between dummies and passing the current through them whilst immersed in dilute sulphuric acid of 1.10 specific gravity, the positive and negative plates being treated separately, as the positive plate only requires about three-quarters of the time necessary to form the negative. For the amateur, however, this is an unnecessary complication, as the plates can be formed both together in the same bath; but it is important to fix two thin lead plates in such a manner that they will act as temporary positives to the outer side of the two outside negative plates: otherwise these plates would only be formed on the inner side, which would be liable to cause the plates to "buckle." In forming the plates only about half the regular charging rate, or two amperes, should be employed, and this continued till the negative plates become thoroughly converted to porous lead—which can be judged by the colour. This should be a good slate grey, and should penetrate right through the paste. This can be tested by scraping the paste out of one of the partitions in the grid of one of the outside negative plates. When the negative plates are formed the positive are certain to be—which will be indicated by their changing to a rich chocolate-brown colour.

The charge must be continued till the plates—both positive and negative—have gassed for two or three hours; then the battery should be given a rest for, say, twenty-four hours and again charged till the plates have gassed for, say, one hour.

After this the forming acid should be poured away and new acid of 1.200 specific gravity poured in, the extra plain lead temporary positive plates removed, and the battery put to regular work.

There is no apparent reason why an amateur accumulator should not give as good results and have as great a capacity for its active surface as a professionally made battery, as the materials used (at any rate by some firms) are similar and the manner of construction practically identical; but home-made plates are never up to the commercial article either in capacity or endurance, and for this reason they (home-made accumulators) should never be taxed by over-quick charging or discharging.

#### Storing Accumulators

If accumulators are to be put out of commission for a short period, charge them up fully and put away in a dry place, occasionally examining them to ensure that no white sulphate forms. If the positives lose colour, put on charge again and bring them back to normal charge appearance.

If they are to be stored indefinitely, discharge them slowly right down, empty out the acid, and store it in stoppered bottles. Thoroughly wash out the cells with distilled or rain water, and follow by filling with the water and letting them soak for an hour or so. Empty out the water, and allow the cells to drain quite dry, and as far free from moisture as possible. Put in all stoppers and plugs and close all air holes, and put them away in a dry place out of any draught. This procedure must not be carried out with cells in a charged condition.

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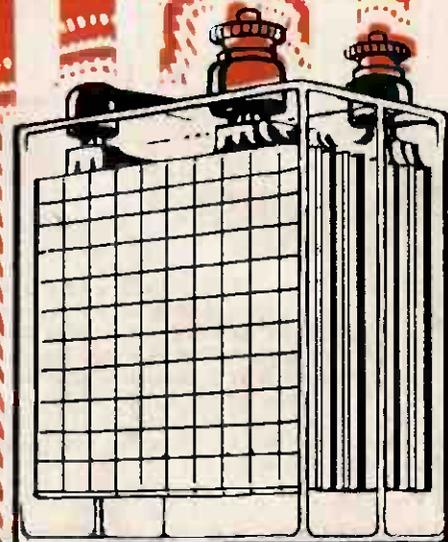
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