

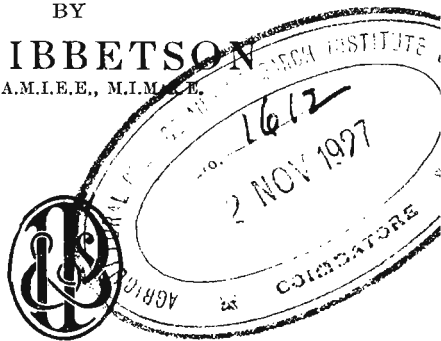
ACCUMULATOR CHARGING MAINTENANCE AND REPAIR

INTENDED FOR THE USE OF
ALL INTERESTED IN THE CHARGING AND UPKEEP
OF ACCUMULATORS FOR WIRELESS WORK,
MOTOR-CAR LIGHTING AND STARTING EQUIPMENT,
AND COUNTRY HOUSE LIGHTING PLANT

BY

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BATH, MELBOURNE, TORONTO, NEW YORK
1926

**ACCUMULATOR
CHARGING
MAINTENANCE AND REPAIR**



For Electric Lighting
Installations,
For Motor Car Starting
& Lighting,
For all Wireless Purposes.

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FOREWORD

THIS book has been written for all types of users of accumulators. It is an attempt to disperse the secrecy which surrounds this electrical device and bring about a more fair and efficient treatment of one of the most useful means of producing electricity.

The author has borne in mind throughout the work the actual requirements of both the amateur and the "Service Station" attendant, and is convinced that the knowledge gained by its perusal will be of immense benefit to both, and bring about a much greater confidence between user and provider than at present prevails.

The book is essentially of a practical nature and gives in detail all the information necessary for keeping the battery fully charged and in good condition. This, however, is not enough for the reader who wishes to thoroughly understand his battery, so just that amount of theory has been included, treated in as simple and direct a method as possible, to enable the reader to understand the principles underlying the actions of the accumulator and its treatment.

The author wishes to express his indebtedness to C. A. Vandervell & Co., and the Chloride Electrical Storage Co., for much information freely given.

W. S. I.

LONDON, 1926.

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ACCUMULATOR CHARGING

CHAPTER I INTRODUCTORY

STEAM can be observed, petrol can be poured into the tank of the car, but electricity is invisible, and an air of secrecy surrounds it, which is fostered more or less by those who have a smattering of knowledge concerning it.

But although electricity cannot be simply or satisfactorily explained, the methods of producing it, and its ordinary effects are easily understood and evident.

These effects obey definite laws, and from a knowledge of these laws it is possible to state what will happen when certain conditions hold good in the electric circuit.

• The electric circuit consists of the cables, instruments, and apparatus through which a current is made to flow.

Open Circuit.

If this circuit is broken at some part, by means of a switch, or by disconnecting a lead at a terminal, the circuit is said to be open.

Closed Circuit.

When the path is complete and the current can flow, the circuit is said to be closed.

Conductors.

Substances which allow the electric current to flow along them easily are called conductors. All pure metals are

good conductors, liquids comparatively poor, whilst gases scarcely conduct at all.

Copper is used for cables because it is one of the best conductors and is fairly cheap. Aluminium is sometimes used, but is bulky and not so flexible.

Alloys or mixtures of such metals as copper, zinc, and nickel have resistances much greater than the pure metals, and for this reason are used for resistance wires.

Insulators.

Substances through which it is difficult to pass an electric current are called insulators. They are used to cover conductors, or separate conductors, in order to prevent leakage or passage of a current from one to the other, as in the case of cables, switch bases, ceiling roses, etc.

The most commonly used insulators are rubber, paper, cotton, silk, mica, ebonite, marble, fibre, and oils.

Current.

The electric circuit can well be compared to an endless water pipe in which is a pump driven by an engine. When the pump is working, water circulates through the system. The moving water can be made to do useful work by driving a turbine, but when the pump stops the flow of water ceases.

In the electric circuit the cell or dynamo is the pump, in that it forces the current round and round the circuit. This current is not burnt up, nor in any way destroyed, as it passes through the lamps, motors, and apparatus, but immediately the generator stops, it simply ceases to flow.

According to the pressure generated by the cell or dynamo so more or less electricity is forced around the circuit.

The current flowing also depends upon the resistance, which various parts of the circuit offer to the flow of the current along them.

Amperes.

Current is measured in amperes (A. or I.).

Pressure.

Pressure, voltage, or electromotive force is measured in volts (V.).

Just as water flows from a point at high pressure to one at a lower pressure, so electricity flows from a point at high to one at a lower electrical pressure.

The positive terminal (marked +) of an accumulator is the high pressure terminal from which the current flows out; the negative terminal (marked -) is the terminal to which it returns.

Resistance.

This is measured in ohms. The resistance of a conductor depends on its length. The longer it is the greater its resistance.

It depends inversely on its area of cross section, being less the greater the cross section, as one would suppose. The resistances of different substances vary, as mentioned previously.

CONNECTION OF RESISTANCES

Resistances connected as shown in Fig. 2 are said to be in series. The total value of such a grouping is the sum of the separate resistances.

In the illustration given the total resistance

$$R = 5 + 10 + 15 + 20 = 50 \text{ ohms.}$$

Resistances connected as in Fig. 3 are said to be in parallel.

Since the current in this case has several paths to go down, the total resistance must be less than if only one such path were provided. Such a group of lamps or resistances connected in a circuit must allow a greater current to flow than one would, and for this reason parallel

grouping of lamps and resistance coils, with suitable switching arrangements, are used for charging boards. The total resistance of a parallel circuit composed of equal lamp resistances =
$$\frac{\text{Resistance of one lamp}}{\text{Number of lamps}}$$

In Fig. 3 the resistance of one lamp is taken as 25 ohms, and the total resistance of the group = $\frac{25}{5} = 5$ ohms.

AMMETERS AND VOLTMETERS

When a current is passed through a coil of wire, the ends of the coil become like the poles of a magnet. If such a coil be suspended by a controlling spring between the poles of a strong steel magnet, and a current passed through it, it will tend to turn and set with its ends or faces opposite the magnet poles. It is on this principle that the action of most ammeters and voltmeters depends.

Since ammeters are used to measure the current in a circuit, they must be connected as part of the circuit, just as a gas or water meter must form part of the supply system if it is to be of any use.

To offer as little opposition to the flow of current as possible, ammeters are made of low resistance.

An ammeter should never be connected across the terminals of a circuit, or the large current which will flow will ruin the instrument.

When large currents have to be measured, it is not convenient to allow all the current to flow through the coils of the ammeter, so only a part, say $\frac{1}{10}$ or $\frac{1}{100}$ of the total current, flows through the ammeter itself. The remaining $\frac{9}{10}$ or $\frac{99}{100}$ flows through what is called an ammeter shunt placed in the main circuit.

Voltmeters work on the same principle as ammeters, but

since the current passing through them is proportional to the pressure at their terminals, they are calibrated to indicate pressure in volts and not current. They are made of a high resistance and are always connected *across* the terminals, the pressure between which is required.

Fig. 1 illustrates the correct connections of ammeters and voltmeters in a simple circuit.

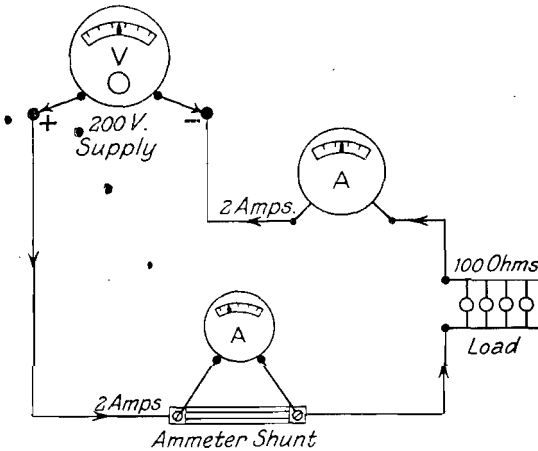


FIG. 1. CONNECTION OF AMMETERS AND VOLTMETER IN A SIMPLE CIRCUIT.

OHM'S LAW

There is a definite relation between the current, resistance, and pressure in an electric circuit.

This relationship is stated in Ohm's Law, which says that the current varies directly as the pressure, and inversely as the resistance.

Expressed algebraically,

$$\text{Current in amperes} = \frac{\text{Pressure in volts}}{\text{Resistance in ohms}}$$

If the reader will take the trouble to master the application of this law to such simple circuits as those formed by

accumulators and the apparatus in series with them, he will arrive at a far better understanding of the action taking place in such a circuit, and be able to treat scientifically a subject, the theory of which must previously have been a complete blank to him.

Ohm's Law may be applied to a whole circuit or to part of a circuit.

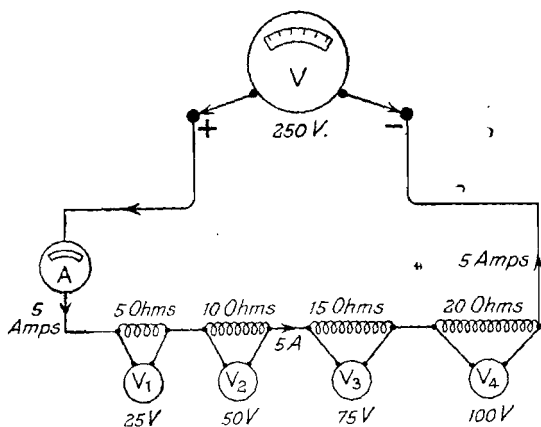


FIG. 2. RESISTANCES CONNECTED IN SERIES, SHOWING "DROP" DOWN EACH RESISTANCE.

In Fig. 2 the current flowing in *all* parts of the circuit may be found by dividing the total voltage by the total resistance = $\frac{250}{50} = 5 \text{ A.}$

Fig. 3 indicates 5 equal resistances or lamps in parallel, each of 25 ohms.

The current through each resistance

$$\begin{aligned}
 &= \frac{\text{Voltage}}{\text{Resistance}} \\
 &= \frac{100}{25} = \underline{\underline{4 \text{ A.}}}
 \end{aligned}$$

The pressure at the terminals of each is the same in every case, and is equal to the main's voltage.

Since a current of 4 A. passes through each lamp, the total current equals $4 \times 5 = 20$ A.

This result might also be calculated as follows—

Total resistance of the five lamps in parallel

$$= \frac{\text{Resistance of one lamp}}{\text{Number of lamps}}$$

$$= \frac{25}{5} = \underline{\underline{5 \text{ ohms.}}}$$

The total current,

$$= \frac{\text{Voltage of circuit}}{\text{Total resistance}}$$

$$= \frac{100}{5} = \underline{\underline{20 \text{ A.}}}$$

The currents flowing in each part of the circuit are clearly indicated in the figure and are well worthy of consideration.

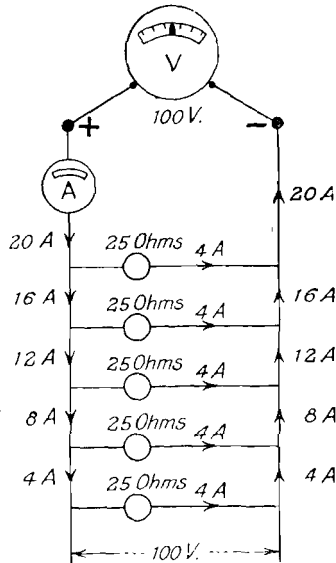


FIG. 3.
RESISTANCES CONNECTED IN PARALLEL SHOWING CURRENT VALUES IN EACH CIRCUIT.

Drop in Pressure.

This is a term used to indicate the pressure or volts utilized in sending the current from one part of a circuit to another.

It may be calculated by the equation

Drop in volts = Current in circuit \times Resistance of circuit.

In Fig. 2 the various voltmeter readings or "drops" may be calculated as follows—

$$V = \text{Total current} \times \text{Total resistance} = 5 \times 50 = 250$$

$$V_1 = 5 \times 5 = 25$$

$$V_2 = 5 \times 10 = 50$$

$$V_3 = 5 \times 15 = 75$$

$$V_4 = 5 \times 20 = 100$$

$$\text{Total drop} = \underline{\underline{250 \text{ V.}}}$$

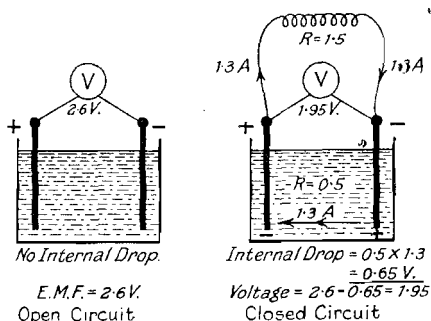


FIG. 4. SHOWING FALL IN PRESSURE OF CELL WHEN LOAD IS SWITCHED ON.

E.M.F. and Pressure.

The total pressure generated by an accumulator is called, its electromotive force (E.M.F.). This is indicated by a voltmeter connected across its terminals when no current is being taken out of the battery.

When a load is switched on the circuit, the voltmeter reading falls and less pressure is available at the terminals. This is not because the cell has become weaker, but because a certain portion of the E.M.F. is now used up in sending the current through the cell itself. The internal resistance of the cell, although small, causes a drop in voltage to take

place within it, the value of which is equal to the current in amperes \times resistance of the cell.

If more current is taken out of the cell, this internal drop will increase and still less pressure be available at the accumulator's terminals.

Example.

An accumulator has an E.M.F. of 2.6 volts on open circuit. Its internal resistance is 0.5 ohm. If connected to a lamp having a resistance of 1.5 ohms, what current will flow in the cell and lamp, and what will the voltmeter indicate ?

$$\begin{aligned} \text{Current flowing} &= \frac{\text{Total pressure}}{\text{Total resistance}} \\ &= \frac{\text{E.M.F. of cell}}{\text{Res. of cell} + \text{Res. of lamp}} \\ &= \frac{2.6}{0.5 + 1.5} = \frac{2.6}{2} = \underline{\underline{1.3 \text{ A.}}} \end{aligned}$$

$$\begin{aligned} \text{Drop of pressure in cell} &= \text{Internal res.} \times \text{Current} \\ &= 0.5 \times 1.3 \\ &= \underline{\underline{0.65 \text{ V.}}} \end{aligned}$$

$$\begin{aligned} \text{Voltage at cell terminals} &= \text{External res.} \times \text{Current} \\ &= 1.5 \times 1.3 \\ &= \underline{\underline{1.95 \text{ V.}}} \end{aligned}$$

$$\begin{aligned} \text{or} &= \text{E.M.F.} - \text{Internal drop} \\ &= 2.6 - 0.65 \\ &= \underline{\underline{1.95 \text{ V.}}} \end{aligned}$$

Fig. 4 illustrates conditions similar to those calculated in the above example.

If the external resistance were made equal to 0.8 ohm,

$$\begin{aligned} \text{the current flowing would equal } & \frac{2.6}{0.5 + 0.8} \\ & = \frac{2.6}{1.3} = \underline{\underline{2 \text{ A.}}} \end{aligned}$$

The drop inside the cell would now be equal to $2 \times 0.5 = 1 \text{ V}$. This would only leave $2.6 - 1.0 = 1.6 \text{ V}$. available at the cell's terminals.

The voltage of an accumulator therefore varies according to what current is flowing. It is useless, therefore, to say that the voltage of a cell is 2.1 volts unless the value of the current flowing is also stated. Generally, the voltage stated should be that with normal charge or discharge current flowing through the cell.

CHAPTER II

ELECTRICAL POWER

ELECTRICAL power is measured in watts (W.). A *watt* is the power in a circuit when the current is 1 ampere and the pressure 1 volt. If the values of current and pressure are known, the power in a circuit may be obtained from the equation ,

$$\text{Watts} = \text{Amperes} \times \text{Volts.}$$

From this equation another is obtained by the use of which the current flowing may be found, if the power and pressure are known,

$$\text{Current in amperes} = \frac{\text{Power in watts}}{\text{Pressure in volts}}$$

The watt is rather a small unit, so a larger unit, called a kilowatt (kW.), which is equal to 1,000 watts, is used.

Wattage and Candle Power of Lamps.

Some years ago filament lamps were rated according to their candle power, instead of their wattage, or number of watts which they took when burning. Even now, *carbon* filament lamps are generally stated to be of 8, 16, 32, 50, 100 candle power, instead of 28, 56, 112, 175, 350 watts which they approximately take.

Metal lamps are nearly always rated in watts, and this together with the particular voltage for which they are made, is usually stamped on the bulb or cap.

Lamps for Charging Rheostats.

The internal resistance of a secondary cell is so small that if a battery were connected across an ordinary supply

circuit of, say, 100 volts, an enormous current would flow, and the battery, unless saved by the fuses of the circuit, would be utterly ruined. To reduce the current to the value required, resistances must be placed in series with the battery. For this purpose, lamps are very convenient and cheap.

The current required for any particular battery is known from the label, and the operator simply needs to know the number of lamps to be switched on to allow this current to flow, or switches lamps on until the ammeter in the circuit indicates the necessary current.

Such lamps must be of the correct voltage for the supply, since the filaments are only designed to carry a certain current. A 100-volt lamp, if placed on a 200-volt circuit, would have double the current forced through it for which it was made, and, not being able to carry it, the filament would fuse and probably burst the bulb.

Carbon lamps are used for charging boards because they take a much bigger current per candle power, are cheaper, and more robust than metal lamps.

In calculations referring to carbon lamps, assume that each candle power is equivalent to 3.5 W.

$$\text{Then, since amperes} = \frac{\text{Watts}}{\text{Volts}}$$

$$\text{Current taken by carbon lamps} = \frac{\text{Candle power} \times 3.5}{\text{Voltage of circuit}}$$

Example.

A 16 c.p. carbon lamp made for a 100-volt circuit would take $\frac{16 \times 3.5}{100} = \frac{56}{100} = \underline{\underline{\frac{1}{2} \text{ A. approx.}}}$

The same candle power lamp made for a 200-volt circuit would take $\frac{16 \times 3.5}{200} = \underline{\underline{\frac{1}{4} \text{ A. approx.}}}$

Half-Watt and Metal Lamps.

Ordinary metal filament lamps take 1 to 1.5 W. per c.p., hence more light is obtained for less energy than by using carbon lamps.

The huge power lamps of the gas-filled type taking 500 W. or more, only take about $\frac{1}{2}$ W. per c.p., hence their name of "half-watt" lamps.

$$\text{Current taken by metal lamps} = \frac{\text{Wattage}}{\text{Voltage}}$$

Example.

A 100-watt lamp for a 200-volt circuit would only take

$$\frac{100}{200} = \frac{1}{2} \text{ A.}$$

DESIGN OF CHARGING BOARD**LAMP RHEOSTAT.**

Lamps used for charging boards are nearly always connected in parallel, in which case the total current flowing in the battery equals the sum of the individual lamp currents.

Thus 10-16 c.p. 200-volt carbon lamps would allow $10 \times \frac{1}{2} = 2\frac{1}{2}$ A. to flow.

Example of Construction Calculations.

It is required to construct a board to supply currents varying from $\frac{1}{2}$ to 5 A. The voltage of supply is 200. What size of lamps would you employ and how would you connect them?

In all cases the lamps must be connected in parallel, a positive and negative lead being taken to each lamp.

Metal Lamps.

Since Watts = Amperes \times Volts

$$\text{Wattage of lamp for } \frac{1}{2} \text{ A. circuit} = \frac{1}{2} \times 200 = 100 \text{ W.}$$

$$\text{.. .. 1 A. circuit} = 1 \times 200 = 200 \text{ W.}$$

Carbon Lamps.

The candle power required for the $\frac{1}{2}$ A. circuit

$$= \frac{\text{Wattage required}}{\text{Watts per c.p.}} = \frac{100}{3.5} = 28.5. \quad \text{Say } \underline{\underline{32 \text{ c.p. lamp.}}}$$

The candle power required for the 1 A. circuits

$$= \frac{\text{Wattage required}}{\text{Watts per c.p.}} = \frac{200}{3.5} = 57. \quad \text{Say } \underline{\underline{50 \text{ c.p. lamp.}}}$$

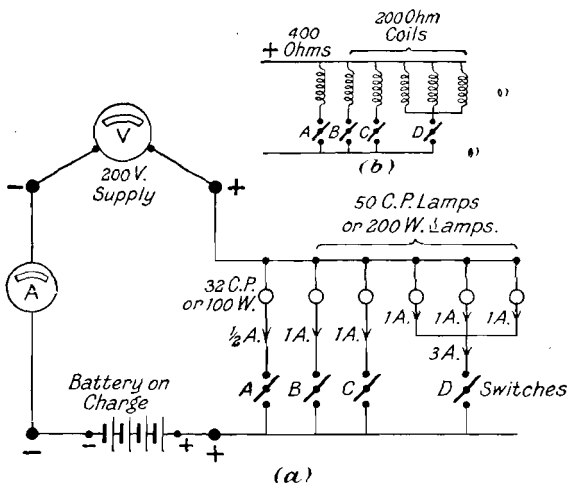


FIG. 5. PARALLEL LAMP OR WIRE RHEOSTAT ON 200 V. CIRCUIT TO GIVE CURRENTS VARYING FROM $\frac{1}{2}$ A. TO 5 A.

Fig 5a illustrates how the lamps will be connected to give the required currents.

With the various switches on, the current passing through the battery will be as follows—

SWITCH.	CURRENT FLOWING.
A	0.5 ampere
B	1.0 "
B + C	2.0 "
D	3.0 "
D + C	4.0 "
D + C + B	5.0 "

If the circuit were 100 V. the candle power and wattage of the lamps would be half the values represented in the illustration.

WATTAGE AND CURRENTS OF CARBON LAMPS

Candle Power (c.p.)	Watts (W.)	Approximate Current in Amperes.						
		100V.	110V.	120V.	200V.	210V.	220V.	240V.
8	28	0.28	0.25	0.23	0.14	0.13	0.13	0.12
16	56	0.56	0.51	0.47	0.28	0.27	0.25	0.23
32	112	1.12	1.02	0.93	0.56	0.53	0.51	0.47
50	175	1.75	1.59	1.46	0.87	0.83	0.79	0.73
100	350	3.50	3.18	2.9	1.75	1.66	1.60	1.46

N.B.—On 100-V. circuit a 16 c.p. lamp takes $\frac{1}{2}$ A. 32 c.p. takes 1 A.
 „ 200-V. „ 32 c.p. „ „ $\frac{1}{2}$ A. 50 c.p. „ 1 A.

RESISTANCE COIL RHEOSTATS

Lamps are very convenient resistances to use for charging rheostats, but wire rheostats are perhaps more permanent and to be preferred in some cases.

Resistance wires have a certain resistance per yard of length, depending upon the material. The value must be got from maker's tables. A certain size of wire will only carry a definite value of current, if more is sent through it, the wire will get red hot, there is a danger of fire, and the wire may fuse and be destroyed. The two things to note, therefore, when ordering resistance wire are the current capacity and the length to provide the resistance required.

Calculations referring to Resistance Values of Wire Rheostats.

The various resistance coils may be connected in series or parallel.

Parallel Connection.

The most suitable method is to substitute resistance wires for the lamps and connect them in exactly the same way. Taking the previous example as an illustration, the values of the resistance wires may be found as follows—

$$\text{To allow } \frac{1}{2} \text{ A. on 200-V. circuit } R = \frac{E}{I} = \frac{200}{0.5} = 400 \text{ ohms.}$$

$$\text{,, } 1 \text{ A. } \text{,, } \text{,, } R = \frac{200}{1} = 200 \text{ ,,}$$

Resistance wire of $\frac{1}{2}$ ampere capacity, and having a value of 400 ohms, will be used for the $\frac{1}{2}$ ampere coil.

The remainder of the coils must be of 1 ampere capacity and of 200 ohms resistance.

Fig. 5b illustrates the necessary connections.

Series Connection.

In the series connection the resistance coils are connected in one long length. At certain points taps are taken to contact studs by means of which a sliding contact arm can cut out or cut in the various sections, as required.

The last sections of the rheostat, which only carry the smaller currents, may be made of smaller wire, to take up less room and reduce the cost.

On 200-V. circuit the various resistances are calculated as follows—

$$\text{To allow } \frac{1}{2} \text{ A. Resistance} = \frac{200}{0.5} = 400 \text{ ohms.}$$

$$\text{,, } 1 \text{ A. } \text{,, } = \frac{200}{1} = 200 \text{ ,,}$$

$$\text{,, } 2 \text{ A. } \text{,, } = \frac{200}{2} = 100 \text{ ,,}$$

$$\text{,, } 3 \text{ A. } \text{,, } = \frac{200}{3} = 67 \text{ ,,}$$

$$\text{,, } 4 \text{ A. } \text{,, } = \frac{200}{4} = 50 \text{ ,,}$$

$$\text{,, } 5 \text{ A. } \text{,, } = \frac{200}{5} = 40 \text{ ,,}$$

			Beacon Wire	
			No.	Length yds.
The resistance in the first	step to carry $\frac{1}{2}$ A.	$= 400 - 200 = 200$ ohms	22	90
" "	second " "	$1A. = 200 - 100 = 100$ "	22	45
" "	third " "	$2A. = 100 - 67 = 33$ "	18	45
" "	fourth " "	$3A. = 67 - 50 = 17$ "	18	20
" "	ffth " "	$4A. = 50 - 40 = 10$ "	16	26
" "	sixth " "	$5A. = 40 = 40$ "	16	100

Suitable sizes of "beacon" wire to use for the various sections are given in the table.

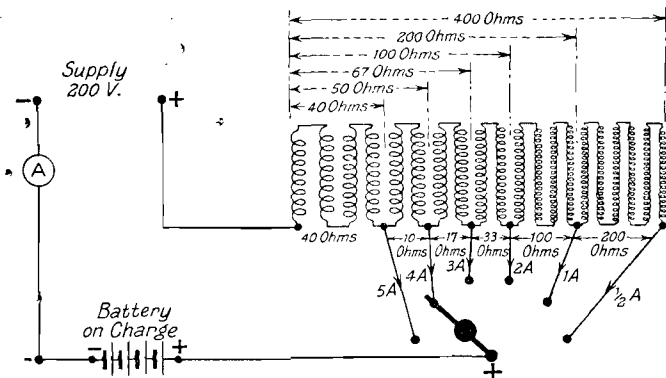


FIG. 6. SERIES RHEOSTAT TO GIVE CURRENTS VARYING FROM $\frac{1}{2}$ A. TO 5 A.

Fig. 6 illustrates the connections and the currents which would flow in the different circuits.

ELECTRICAL ENERGY

The unit of electrical energy is called the Board of Trade unit, or simply the "unit."

This is the energy in a circuit when the power is 1 kW. and the time taken 1 hr.

$$\begin{aligned} \text{Unit} &= \text{kilowatt hour (kW.h.)} \\ &= \frac{\text{Amperes} \times \text{Volts} \times \text{Hours}}{1000} \\ &= \frac{\text{Watts} \times \text{Hours}}{1000} \end{aligned}$$

Since electricity is charged for at so much per unit, the cost is calculated as follows—

$$\begin{aligned} \text{Cost in pence} &= \frac{\text{Amperes} \times \text{Volts} \times \text{Hours} \times \text{Price per unit}}{1000} \\ \text{or} &= \frac{\text{Watts} \times \text{Hours} \times \text{Price per unit}}{1000} \end{aligned}$$

Example.

A charging board consists of 10–16 c.p. carbon lamps. The voltage of the circuit is 200. What is the cost of charging for 24 hr. with energy at 4d. per unit?

The current taken by each lamp from table on p. 15 is found to be 0.28 A. Therefore the ten lamps will take $10 \times 0.28 = 2.8$ A.

$$\therefore \text{Units} = \frac{2.8 \times 200 \times 24}{1000}$$

$$\text{Cost} = \frac{2.8 \times 200 \times 24 \times 4}{1000} = \underline{\underline{4s. 6d. \text{ approx.}}}$$

Since 1 c.p. is approximately equivalent to 3.5 W., the total watts taken

$$= 10 \times 16 \times 3.5$$

$$= 560$$

$$\text{Units} = \frac{560 \times 24}{1000}$$

$$\text{Cost} = \frac{560 \times 24 \times 4}{1000} = \underline{\underline{4s. 6d. \text{ approx.}}}$$

The *actual* cost of charging a 6-V. accumulator in series with the above lamps is very small.

Units taken by accumulator

$$\begin{aligned}
 &= \frac{\text{Amperes} \times \text{Volts} \times \text{Hours}}{1000} \\
 &= \frac{2.8 \times 6 \times 24}{1000} \\
 \text{Cost} &= \frac{2.8 \times 6 \times 24 \times 4}{1000} \\
 &= \frac{1613}{1000} = \underline{\underline{1\frac{1}{2}\text{d. approx.}}}
 \end{aligned}$$

That is, out of a total cost of 4s. 6d., only 1½d. is the actual value of the energy used in charging the battery, but it has cost 4s. 6d. really, since the lighting is not of value.

Several batteries in series, however, could be charged off the above circuit and the total cost would still be only 4s. 6d. per 2.8 A. for 24 hr.

Table of Charges.

The tables of charges for accumulator service in vogue are as numerous as they are absurd. Some charge per volt, some per cell irrespective of size, some per ampere hour, with the result that neither customer nor service is satisfied.

There is only one correct system and that is so much per ampere hour, per volt.

The table below gives the actual cost per ampere hour for the whole circuit at different voltages. Knowing the number of cells usually on charge, the attendant can work out the actual cost per volt of cell per ampere hour, and draw up a scale of charges to give him a reasonable profit.

Voltage of Supply.	Total Cost per Ampere Hour of the Whole Charging Circuit. (Price per Unit of Supply in Pence.)					
	1	2	3	4	5	6
100	0.1	0.2	0.3	0.4	0.5	0.6
110	0.11	0.22	0.33	0.44	0.55	0.66
120	0.12	0.24	0.36	0.48	0.6	0.72
150	0.15	0.3	0.45	0.6	0.75	0.9
200	0.2	0.4	0.6	0.8	1.0	1.2
210	0.21	0.42	0.63	0.84	1.05	1.26
220	0.22	0.44	0.66	0.88	1.1	1.32
240	0.24	0.48	0.72	0.96	1.2	1.44
250	0.25	0.5	0.75	1.0	1.25	1.5

TO FIND ACTUAL COST OF CHARGING
FROM TABLE

Example.

Suppose cells having a total voltage of 20 are usually on charge, the supply circuit to be 200 V. and the price per unit 2d.

From the table the total cost of the whole circuit per ampere hour at 2d. on the 200 V. circuit = 0.4 pence.

This per volt of cell, assuming an average of 20 V. on charge = $\frac{0.4}{20} = 0.02$ pence per ampere hour per volt.

A 60 ampere hour 4 V. cell therefore actually costs

$$60 \times 4 \times 0.02 = \underline{\underline{4.8 \text{ pence.}}}$$

Add to this overhead charges and profit required, and the result equals the actual charge to be made to the customer. A little calculation at the outset would soon enable a table to be drawn up for the sizes of batteries usually charged at the station, and prevent a great deal of

the dissatisfaction which now prevails owing to obvious unfair methods in practice.

Whilst dealing with this question of charging cost, it may be as well to note that the true cost of charging a battery should be based on its actual capacity which is only half the intermittent capacity. A cell rated at 60 Ah. intermittent, should be charged for at the same rate as a cell rated at 30 Ah. actual capacity.

CHAPTER III

PRODUCTION OF ELECTRICAL ENERGY

THERMAL, mechanical, and chemical energy may, under certain conditions, be converted into electrical energy.

If one of two junctions of two dissimilar metals be heated, a current will flow down the wire, but, from a commercial point of view, the production of electricity in this way is useless.

If a coil of wire be rotated in the magnetic field which lies between the two poles of a magnet, an E.M.F. is set up in the wire, and a current will flow if it be connected to an external circuit.

This current alternates in magnitude and direction as the sides of the coil first pass the North and then the South Pole of the magnet.

If such a coil or number of coils, mounted together on an iron core to form the armature of an electric generator, have their ends connected to slip rings fixed on the shaft, an alternating current (A.C.) is available at the brushes sliding on the slip rings.

In this case the terminals of the machine become alternately positive and negative, as the current alternates in direction, with a frequency perhaps of 50 per second (represented $\sim = 50$). The frequency depends on the speed of the alternator and the number of poles.

If, instead of connecting the coils to slip rings, they be connected to the segments of a commutator, the commutator acts as a rectifier, and the A.C. which is always produced in the armature of a machine is converted to continuous current (C.C.) at the brush terminals, one brush or set of brushes always being of positive polarity (+) where the current flows outwards, and the other, where the current returns to the machine, always being negative (-).

If a battery of accumulators were connected to an A.C. supply, it would be charged in the right direction at one instant, but when the current reversed it would be excessively discharged, or charged in the opposite direction. The battery, therefore, would never receive any charge.

“ PRODUCTION OF ELECTRICITY BY CHEMICAL ACTION

The production of electrical energy from chemical energy forms the basis of the action of all types of cells.

Primary Cell.

If two dissimilar metals or conducting substances are placed in a liquid which acts chemically more upon one than the other, the resulting chemical action sets up an E.M.F. between the plates. If the two plates be connected together by a conductor of electricity so as to form a closed external circuit, a current will flow in all parts of the circuit.

Such a combination of plates and liquid forms what is called a simple voltaic cell.

The most original and simplest of all is produced by immersing a plate of copper and one of zinc in dilute sulphuric acid.

When one of the plates, usually the zinc, has dissolved, chemical action ceases and no further current is produced.

A new plate and fresh liquid have usually to be provided before the cell will “work” again.

Such a cell, in which chemical action starts immediately the plates are put in the liquid or electrolyte and connected externally, and in which some portion of the materials irrecoverably disappear, is called a primary cell.

Secondary Cell.

Under some circumstances, however, the plates are not dissolved, but simply change in composition as the chemical

action proceeds, and after all action has taken place and the current ceases to flow, the plates can be brought back to their original chemically active condition by passing an electric current in the reverse direction to the original flow through the cell.

This action is called *charging*, and the type of cell is called a secondary cell.

In the secondary cell, or accumulator, the electrical and chemical actions are reversible, whereas they are not in the primary cell.

Producing reversible cells, however, is not quite so simple as the above would make it appear to be. Many preliminary operations are necessary before plates can be got into this reversible condition. The plates have to be *formed*, as the process is termed.

EFFECTS OF THE ELECTRIC CURRENT

Thermal Effects.

An electric current passed through any kind of conductor will produce heat in it, and possibly to such an extent that light may result, as in the case of the ordinary electric bulb.

Chemical or Electrolytic Effects.

If two metal or carbon plates are placed in a vessel of water, and a current passed through the electrolytic cell, or voltameter, as such an arrangement is called, the water will be split up into its elements—oxygen and hydrogen.

The hydrogen in the form of bubbles of gas will appear at the negative plate where the current leaves the cell, and the oxygen bubbles at the positive plate where the current enters the cell.

If the plates are made of substances which are acted upon chemically by the gases liberated at them, the composition of the plates is changed.

LEAD ACID CELL

If a cell containing lead plates and an electrolyte of sulphuric acid be used, the current passing through the acid will decompose it, and the O and H resulting from this being deposited at the positive and negative plates will react upon them. The surface of the positive plate changes to peroxide of lead, and that of the negative into a porous form of pure lead.

The pure lead plates at first present in the acid, being equally acted upon by the acid, did not form a simple cell and consequently could produce no current, but by charging the cell, the composition of the plates has been altered, and if the current be now switched off and the two plates be connected together by a conductor, a current will flow around the circuit, in the *opposite* direction.

The action now is exactly the same as that taking place in any simple voltaic cell, and so long as the plates remain of different composition a current will flow. But the chemical action taking place and producing the current alters the composition of the plates again, till, finally, they are both converted into lead sulphate, and the cell, no longer acting like a primary cell, ceases to give out current.

If charged again the plates will again become dissimilar, and will again give out current, when the circuit is completed. These alternate actions of charge and discharge can theoretically, under given conditions, be repeated indefinitely.

What has been described above is in reality the action of a storage battery—but electricity is not really stored in it. What has happened is that electrical energy in the first place on charge was converted into potential chemical energy, and this chemical energy, just where and when convenient, can be re-converted, and be again utilized to produce electricity on discharge. The action certainly seems to suggest the storage of electricity.

Fig. 7 illustrates the actions and results of charging and discharging a simple lead acid cell. The reader should note the relative directions of charging and discharging currents, and that the + plate on charge is also the + plate on discharge.

Planté Plates.

Experiments similar to the above were conducted in a very crude way, about 1860, by Planté. He immersed lead plates

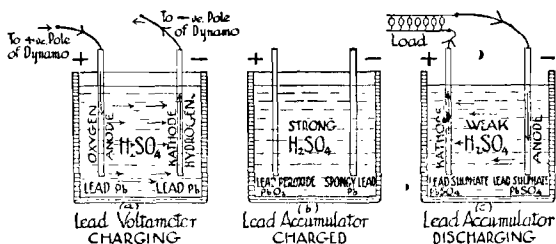


FIG. 7. CHEMICAL ACTIONS ON "CHARGE" AND "DISCHARGE" OF ACCUMULATOR.

in dilute acid and charged them from primary cells, because the dynamo as we know it was then unknown. By repeated charging and discharging, he converted quite a depth of the surface of his lead plates into lead peroxide at the positive, and into spongy lead at the negative, but the process was very tedious and expensive. It took him months and even years to form some of his plates, and the results even then were not great. Present-day batteries have, indeed, been really little altered from the original Planté cells, but the advent of the dynamo and better methods of production have made the results a successful business proposition for the production of current.

Faure or Pasted Plates.

It will have been gathered from the above that a previous forming charge is necessary before the lead plates and the

acid really produce a reversible action cell. This at once suggests that it might be possible to use lead peroxide and lead in the first case, and so do away with the long charging process necessary when pure lead plates are used.

Lead peroxide is not suitable, and spongy lead is not directly procurable, and if they were, they are not mechanically strong enough to be formed alone into plates. It is possible, however, to hasten the process by having mechanically strong grids of lead, and pasting these with litharge or red lead, which, on charging, is easily converted to peroxide and spongy lead at + and - plates respectively. For heavy traction batteries, however, Planté positives are even now often preferred to the pasted types, which are usually used in accumulators for car, wireless, and most portable batteries.

The paste for the positive grids is made from litharge or red lead, or a mixture of the two, made into a paste with dilute sulphuric acid.

Negative grids are pasted with a litharge paste made just thick enough to work easily into the interstices between the grids.

After pasting and drying, as described in detail later, the plates must be charged or formed to become active material, in which condition they will, when connected to an outside circuit, send out a current of electricity.

CHAPTER IV

THE EFFECTS OF CHARGE AND DISCHARGE

IN the last chapter it was shown how, as a result of charging, the + plate was converted into lead peroxide, and the - plate into spongy lead, both plates on discharge becoming lead sulphate.

Chemical Changes on Charge.

Electrical energy supplied is converted into potential chemical energy within the cell.

The oxygen required to form the peroxide of the + plate and the hydrogen necessary to convert the hard lead - plate into spongy lead are obtained by the decomposition of the water in the electrolyte. If some of this is thus decomposed, it follows that the acid must become more concentrated as the charge proceeds.

Chemical Changes on Discharge.

Potential chemical energy is converted into electrical energy.

The peroxide of the + plate and the spongy lead of the - plate are both converted into lead sulphate. Oxygen and hydrogen in the form of water are returned to the cell. The sulphate is derived from the sulphuric acid in the cell so that the whole tendency on discharge is to dilute the electrolyte.

Specific Gravity.

Specific gravity is the relation between the weight of an equal volume of any substance and the weight of an equal volume of water at some known temperature.

The specific gravity of liquids may be found by means of a hydrometer, which consists of a hollow glass float

weighted with lead, somewhat similar in appearance to a thermometer.

In a very dense liquid the hydrometer would not sink so deep as it would in one of less density, so the tube of the instrument may be graduated and marked in order to

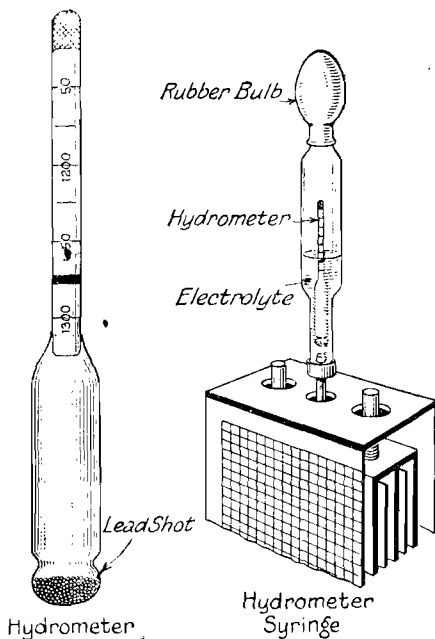


FIG. 8.

indicate the specific gravity from the height to which it sinks when immersed in any liquid.

To find the specific gravity of the acid in an open type of battery, the hydrometer is placed directly into the liquid between the plates, but for determining the specific gravity of closed-in and small batteries a hydrometer syringe is used. This is a glass tube containing a small hydrometer inside it.

Fig. 8 illustrates the hydrometer and hydrometer syringe. To use the latter, which can be bought for about 6s., the rubber tube fitted to the bottom of the glass container is placed through the vent at the top of the accumulator. The rubber ball at the top of the hydrometer syringe is squeezed and released. As the rubber bulb assumes its original shape, acid is sucked up into the tube, and the small hydrometer within it floats. The specific gravity of the acid may be read off from the level indicated on the instrument.

Relation between Specific Gravity and State of Charge and Discharge.

It has just been shown that the specific gravity diminishes on discharge and if the cell has been correctly treated from the commencement there is a certain specific gravity value at which a cell can be stated to be discharged completely.

On charge, the specific gravity increases until all the accessible sulphate at the + and - plates is converted into peroxide and spongy lead respectively. At this value the specific gravity remains a maximum. When the specific gravity ceases to rise, therefore, the cell must be fully charged, but what the actual value of this specific gravity reading will be, depends on the treatment which the battery has been previously subjected to, with regard to the addition of acid and water.

Topping Up.

To make up for evaporation, not actual spilling of acid, water should always be added, so that the electrolyte covers the plates and ensures chemical action all over the plate. It should always be added before charging by means of a long-necked glass or lead funnel or small syringe. The resulting specific gravity reading should be taken $\frac{1}{2}$ hr. after the cell has been fully charged, in order to get a true indication of the cell's specific gravity.

Colour of the Plates.

The colour of the plates is a good indication of the state of charge or discharge. Good colour indicates charge; dull, dead colour, discharge.

Charged. Lead peroxide at the + plate is deep chocolate brown. Spongy lead at the - plate is a metallic grey.

Discharged. Lead sulphate at both plates reduces the difference in the colour, but the + plate is always the darker.

Gassing.

The action in the cell on charge is primarily the production of oxygen and hydrogen gases. When these gases produce no further peroxide at the + plate and spongy lead at the - plate, they are simply given off as bubbles, which, rising to the surface of the liquid, produce the appearance called gassing.

True gassing in a cell looked at from above takes place in a clear liquid and consists of large bubbles of gas.

Sulphated cells gas at all periods of charge. This gassing is in small bubbles and the whole liquid looks milky. Such gassing, often accompanied by frothing, must not be confused with true gassing, which indicates that no further chemical action is taking place at the plates.

No useful result can be obtained by prolonging the charge once the cells have been gassing for some little time.

Voltage Changes on Charge and Discharge.

Fig. 9 illustrates the changes which take place in the voltage on charge and discharge.

On charge, the voltage rises rapidly at first, especially if the cell has been left discharged for some time or been over-discharged, but after this a steady rise takes place for the greater part of the charge, until, when the charge is complete and gassing commences, a quick, final rise ensues.

On discharge, or even if left standing for a short time after charging, the voltage falls rather steeply, and then shows a slight steady decrease until about 1.8 volts is reached. If the battery is discharged below this value the voltage rapidly falls and much harm may be done to the accumulator.

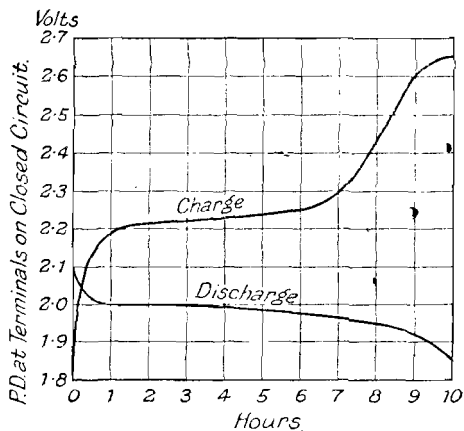


FIG. 9. VOLTAGE VARIATIONS ON CHARGE AND DISCHARGE.

E.M.F. of the Cell.

Just as the voltage of a simple cell depends upon the materials, so the E.M.F. of the lead acid cell depends on the nature of the plates and the electrolyte.

The composition of the plates is fixed respectively on charge and discharge, but the specific gravity of the electrolyte has been shown to change as the charge or discharge continues. Since the E.M.F. of the cell depends on the density of the electrolyte, the E.M.F. must change according to the state of charge or discharge.

Fig. 10 shows how the E.M.F. varies with specific gravity of the acid.

Diffusion of the Electrolyte.

It is the density of the acid in close proximity to the plates which affects the E.M.F. On charge the concentration of the acid takes place very rapidly near the plates, hence the sudden rise in the E.M.F. curve in the earlier stages of the charge.

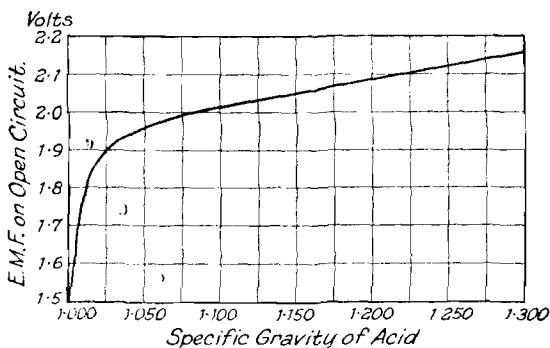


FIG. 10. RELATION BETWEEN SPECIFIC GRAVITY AND E.M.F.

When this dense acid starts to circulate or diffuse into the main body of the electrolyte, the voltage only rises slowly for the whole period of charge.

Similarly on discharge, the dilution of the acid takes place rapidly at first near the active material, and causes a sudden fall in voltage to be followed by a gradual fall as diffusion throughout the liquid sets in. Rate of diffusion of electrolyte has evidently a great deal to do with the voltage available at the cell terminals, and will be considered again in the next chapter.

CHAPTER V

CAPACITY

THE capacity of a battery is the amount of electricity which can be obtained from it. It is expressed in ampere hours (A.h.).

The capacity in ampere hours is found by multiplying the value of the *constant* current taken from the battery by the number of hours it will supply this current before its voltage drops to 1.8 volts per cell.

Thus a battery capable of supplying 6 A. for 10 hr. continuously before its voltage drops to 1.8 V. per cell has a capacity of $6 \times 10 = 60$ A.h.

This battery should give out 10 A. for 6 hr., or 3 A. for 20 hr., but, although this is true theoretically, it is not possible in practice.

Actual and Intermittent Capacity.

It is to be feared that retailers of accumulators are selling for wireless purposes batteries which have been built and labelled for intermittent work for ignition of motor-cycles and cars. There is no deception in this if the actual capacity of such batteries for constant discharge is stated and not the intermittent discharge capacity.

The actual capacity of such a battery is only half the intermittent capacity, and wireless enthusiasts should carefully note what rating the capacity is based upon. The capacity of a battery after a little experience can be judged by its size, for there is a great deal of difference between the bulk of the plates of a 30 A.h. cell and a 60 A.h. cell. A rough estimate can be formed by allowing 50 A.h. per sq. ft. of area of positive plate, counting both sides of all the + plates of *one* cell of the battery

Capacity and Discharge Rate.

Owing to the production of hard sulphate if the cell is discharged below 1.8 V., it is not advisable to exceed this limit. The voltmeter reading should always be taken with normal discharge current flowing, or the value indicated will be high and useless.

If a cell is discharged at a heavy rate, its voltage drops quickly to this minimum value, and it will be found on multiplying the amperes and hours obtained, that the capacity is less than the ampere hours available, if the cell is discharged at a lower current rate for a possible longer time.

To say that the capacity of a cell is 60 A.h. therefore is somewhat useless, unless the ampere rate or hour rate of discharge is stated. If the discharge rate of such a cell is stated to be 6 A., it is known that this cell will discharge 6 A. for 10 hr., or if it is stated that this cell has a capacity of 60 A.h. at the 10 hr. rate of discharge, it is known that 6 A. can be obtained for this length of time.

The maximum rates of charge and discharge are fixed by the makers according to the type of plate and size, considered on a basis of life and efficiency.

Capacity and Quantity of Active Material.

Since the production of electricity depends on the chemical action taking place, it follows that the capacity of a cell must depend directly upon the amount of active material on the plates, which can actually be acted upon by the acid. The size of the plates and their thickness, therefore, determine largely the capacity of the cell.

Capacity and Diffusion of the Electrolyte.

A minimum voltage of 1.8 V. is the limitation to the capacity of a cell. The sudden fall in voltage of a cell on being discharged heavily is due to the rapid dilution of the acid at the surface of the plates. Diffusion not being able to take place as rapidly as the acid weakens, a fall in

voltage results. In such a case there may be plenty of active material left unacted upon, but the acid in contact with it is weak, and further chemical action is impossible. If such a battery is allowed to rest, diffusion sets in, more acid is supplied, chemical action commences again, and a further discharge is possible.

Capacity and Porosity of Active Material.

The acid and active material must be in contact to produce electricity. Large plate areas are therefore more suitable for temporary heavy discharges, whilst thick pasted plates are more suitable for low discharges of long duration. Discharge results in the production of sulphate, and naturally this is first produced at the surface of the plates. This sulphate covers up the active material, making the plate less porous, and prevents the acid getting to the active material yet unaltered beneath. It is advisable, therefore, to have the active material in as porous a condition as possible, and various makers add graphite, magnesium sulphate, etc., to the paste to improve this quality.

Capacity and Density of the Electrolyte.

A certain quantity of acid is necessary to bring about a certain amount of chemical action.

This action takes place more vigorously, the more dense the acid. The voltage also depends upon the specific gravity of the electrolyte. Why, therefore, is the specific gravity chosen for various types of cells limited to the values given below?

<i>Type of Cell.</i>	<i>Specific Gravity when Fully Charged.</i>
Car Starting with wood separators	1.290-1.300
Batteries with threaded rubber separators	1.270-1.275
Batteries in celluloid cases	1.245-1.250

There are several reasons for these values. If the density is too high, the acid attacks the grids and separators. It

causes sulphation. Although the resistance decreases with increased density up to a certain point, beyond this it rises again. The density chosen, therefore, is a compromise which gives the best results under the conditions of voltage, capacity, resistance, and safety required for the various uses.

Capacity and Temperature.

Chemical action takes place more vigorously at higher temperatures, and the resistance also decreases with increased temperature.

Apparently it is better to work the battery at a high temperature. At high temperatures, however, the acid attacks the grids, terminal posts, and wooden separators. It changes the paste into sulphate even if the battery is not "working." This sulphation is always accompanied by expansion of the paste, especially at the + plates, and results in buckled and cracked grids. It is not advisable, therefore, to work batteries above 100° F. This temperature limits the charging rate of any battery, however large.

Capacity therefore depends chiefly on—

- Discharge rate.
- Size and type of battery.
- Amount and density of acid.
- Temperature.

CHAPTER VI

MODERN ACCUMULATORS

ALL types of batteries, whether for wireless, car starting and lighting, or vehicle work, consist of the following parts—

Plates.	Separators.	Covers.
Electrolyte.	Bottom blocks.	Connecting straps.
Containers.	Connecting bars and posts.	Case.

Plates.

These will usually be found to be of the Faure or pasted type, though occasionally Planté or solid positives are used, owing to their more robust construction.

Electrolyte.

Acid received direct from the manufacturers has a specific gravity of 1.835. This is often diluted to a value of 1.400, which value has again to be further diluted by the battery attendant to the correct density required for the particular type and condition of battery under treatment, by the addition of distilled water.

The following values of specific gravity are those used for the various purposes indicated—

	<i>Fully Charged.</i>	<i>Discharged.</i>
Wireless and portable batteries generally	1.245-1.250	1.150
Car starting and lighting	1.290-1.300	1.150
Vehicle.	1.290-1.300	1.150

Containers.

These are made of vulcanized rubber, celluloid, or glass. The former is chiefly employed for car service, whilst the transparent containers, especially of the glass type, are superior for wireless and portable types generally.

Separators.

These are made of specially treated wood, perforated rubber or celluloid, or rubber fabric made porous by the addition of cotton threads.

• The importance of easy diffusion of the electrolyte on the capacity of the battery has been emphasized. Such diffusion through the separators takes place by direct movement through the perforations, or by capillary action through the fibres of wood or cotton. In addition to separating the plates and preventing short circuits, the separators are specially designed to strengthen the plates, and especially to prevent active material falling from the positive grids.

Wooden separators must never be allowed to dry. They are always kept in water after being manufactured.

Bottom Blocks.

These are raised ribs, either fitted in the bottom of the jar or made with the jar itself. They carry the plates, hold them in position, and the pockets between them form a receptacle for the collection of the sludge produced by shedding of active material from the plates.

Connecting Bars and Posts.

A cell generally consists of several positive plates burnt together to one connecting bar, and several negative plates likewise joined together by a common bar. When the unit consists of several plates, there is always one more negative plate than positive, to produce equal working of all sides of the positive plates. The outside plates are, therefore, always negatives. An upward extension from each connecting bar forms the terminal post or pillar. This passes through the cover of the cell and enables the cell to be connected to the mains, or individual cells in series with one another, to form a battery.

External Connecting Straps.

The bars connecting the positive post of one cell to the negative of the next across the top of the cover are made of lead castings of very solid construction, especially in the case of starting batteries, which have to carry very heavy currents.

Covers.

These are generally of vulcanized rubber for sealed-in batteries. Their duty is to prevent the spilling of acid, exclusion of dirt, allow easy escape of gas, provide room for the expansion of the electrolyte, easy access for adding water or acid, and for testing purposes. They naturally vary in design according to the make of cell.

Cases.

The jars or containers for car work are carried in a case, usually of hard wood specially chosen and seasoned. After being substantially made, they are treated with acid-resisting paint, handles and lids fitted, etc., for convenience.

CAR BATTERIES

These are used for ignition, lighting and starting, and for such auxiliaries as the horn, foot-warmers, etc.

The type of battery required depends entirely on the use for which it is intended.

Starting batteries must be specially manufactured for giving excessive currents for short periods.

The voltages used are from 6 to 12 usually, and the following example of an Exide battery used for all car purposes will illustrate the possibilities of such a battery. The type of which particulars are given in the table on the next page is specially designed for Rolls-Royce cars.

The charging current may be increased to four times normal value under running conditions of car.

In ordering a battery for car use, it is advisable to give make of car, as special types of batteries have been designed to suit standard car requirements.

Voltage	Actual Capacity at 20-hr. rate of Discharge.	Normal Charging Current.	Weight in lb. with Acid.	STARTING.				LIGHTING.			
				Current given out continuously for				Discharge Current continuously for			
12	87 A. h.	7 A.	100	Min. 5 185 A.	Min. 10 130 A.	Min. 20 85 A.	Min. 30 70 A.	Hr. 7.6 10 A.	Hr. 10.6 7.5 A.	Hr. 17.2 5 A.	Hr. 31 3 A.

All such batteries, unless otherwise ordered, are sent out uncharged and unfilled with acid, and require strict adherence to the instructions issued as regards specific gravity of acid to be added, charging current, and duration of first charge, if the stated capacity of the battery is to be attained and maintained later.

GENERAL TREATMENT OF CAR BATTERY.

The battery is the most useful part of the car auxiliaries, but, owing to the quietness with which it accepts bad treatment, it rarely gets the attention it so thoroughly deserves and so adequately repays.

“What it can do depends upon what has been done to it,” is a slogan which is well worth bearing in mind with regard to the treatment of car and any other type of battery.

Starting.

Instead of being cranked by hand from the front, a battery is used to run an electric motor, which turns the engine until it runs under its own power.

Take all preliminary precautions before pushing down the starting switch, just as you would if you were going to have to crank in front of the car by hand.

Starting by battery is really so easy that no thought is

given to the battery which the switch controls. Switch off as soon as the engine starts to run, the battery is to start the engine not to propel the car.

When starting up cold, switch on petrol, flood carburettor, and do all to relieve the battery under such conditions. The battery will do its utmost to start it, but the heavy discharges required under extreme circumstances do the battery no good.

To obtain condition of battery, take voltmeter reading with lamps alight, and do not discharge below 1.8 volts per cell with battery discharging.

See that the battery case is fixed tightly, to prevent broken connections, and leaky jars due to excessive bumping. Keep battery cover, terminals and case clean by rubbing with rag dipped in soda and water. Cover terminals with vaseline to prevent corrosion.

Test depth of electrolyte by inserting a piece of glass tube through filling vent until it touches the tops of the plates. Close upper end of tube by thumb, lift out tube, and the height of liquid in it indicates the level of the electrolyte above the plates. It should be $\frac{3}{8}$ to $\frac{1}{2}$ in. If the depth is not enough, fill up with distilled water to the correct level.

If the battery discharges on open circuit, it may be due to a short circuit or earth on the system. An ammeter connected near the battery in the main circuit would indicate such a leakage.

The battery should be left fully charged after a run.

Test the voltage with lights on, and charge if necessary before switching off.

Test specific gravity once per week by syringe hydrometer half an hour after giving the battery a full charge, as indicated by voltmeter.

The specific gravity should be	1.290-1.300	fully charged.
" " "	1.200-1.250	partly charged.
" " "	1.150 and less.	discharged.

The voltage of *each* cell of the battery should be tested

separately. A low voltage reading and the failure of the specific gravity to rise as the charge proceeds is a sign of internal short circuit. Replace all acid in the cell when taking gravity readings and do not spill on bars and cover. If acid is spilled wipe it off with a cloth dipped in soda and water or ammonia.

The temperature should not rise above 100° F. If it does the battery is being overcharged or charged at excessive rates, or is badly sulphated and needs attention.

Continual need for addition of water indicates a leaky jar. Do not add water on a cold night just before leaving the car, or, since the water is not mixed with the acid below, it might freeze and crack the jars. Water should always be added just previous to charging or during gassing to ensure diffusion. It is only after such thorough mixing that a true indication of the specific gravity can be obtained. The table below gives the temperatures at which acid of various specific gravities freezes—

<i>Specific Gravity of Acid.</i>	<i>Freezing Temperature.</i>
1.000	32° F.
1.050	26° F.
1.100	18° F.
1.140	12° F.
1.150	5° F.
1.170	0° F.
1.200	- 17° F.
1.250	- 60° F.
1.300	- 95° F.

In frosty weather keep the battery charged to maintain the density as high as possible.

Treatment of battery when car is laid up is fully described in Chapter X, page 110.

WIRELESS BATTERIES

LOW TENSION BATTERIES.

These are used on valve receiving sets to light up the filament and so maintain a constant temperature in the bulb.

Some of the latest batteries for this purpose consist of single cells having one thick positive plate and one thick negative. The cells are designed to work on low discharges for long periods and are guaranteed to stand for months when not in use, without injury.

How to Select a Low Tension Battery for a Wireless Valve Set.

The voltage required for one valve is the same as for any number of similar valves, since these are worked in parallel, and the value can only be determined from the particulars supplied with the special valve used. The voltage required varies from 0.8 to 6 volts, according to the type of valve.

The number of cells to be connected in series to give the voltage required is as follows—

Up to	2	volts per valve use	1	cell
From	2-3	„	„	2 cells
„	3-5	„	„	3 „
„	5-6	„	„	4 „

The current taken per filament also varies with the type of valve and must be obtained from the makers. It varies from 0.06 to 0.75 A. per valve.

The total current required from the battery will increase proportional to the number of valves used, being the sum of the currents taken by each valve.

Thus, three valves taking 0.8 A. per valve will require a discharge current of $3 \times 0.8 = 2.4$ A.

Capacity of Battery.

The capacity required will depend on the current necessary for the valves and the hours of use between charges.

Example of Calculations.

Suppose the set has three valves, each taking 0.7 A. at

5 V., and it is desired to recharge battery weekly, using it 4 hr. per day.

Total volts = Voltage of one valve = 5

• \therefore No. of cells in series = 3

Total current = No. of valves \times 0.7 = $3 \times 0.7 = 2.1$ A.

Total hours of discharge required between charges

$$= 4 \times 7 = 28 \text{ hr.}$$

Total capacity in ampere hours required

$$= 2.1 \times 28 = 60 \text{ A.h., approx.}$$

The capacity of each cell must be 60 A.h. and have a discharge rate of at least $2\frac{1}{2}$ A., and three such cells connected in series will be required to provide the voltage. If bought in one case, the battery would be marked—

Actual Capacity.—60 A.h. Voltage, 6–8. Discharge current (probably), 2–4 A.

HIGH TENSION BATTERIES.

- To secure successful operation of the valve, a constant high potential must be maintained between plate and filament.

Accumulators are now made to fulfil this service, which only require charging once in six months. They are contained in glass cases, which enable the plates to be readily inspected and the acid level to be checked and corrected.

The batteries are made up in 24 V. sections, with tapping connections at 12 V. points. Any desired voltage can be obtained by connecting sections in series.

The normal charging current is about $\frac{1}{4}$ A. They are sent out already charged and only require filling with acid to be ready for service, though a finishing charge should be given during the first month of use.

Care of Wireless Batteries.

Since the containers are transparent, the treatment of these high tension and low tension batteries is much more simple and satisfactory than that of the sealed in, opaque variety.

Charged conditions are shown by steady voltage readings of 2.5–2.6 V. per cell, good colour of the plates, constant specific gravity of 1.245–1.250 and free gassing.

Voltage readings must be taken with the current flowing, and should never be allowed to fall below 1.8 per cell.

CHAPTER VII

BATTERY CHARGING

THE supply from which the charging current is obtained must be direct current (D.C.) or rectified alternating current (A.C.). Alternate current direct from the mains will not charge a battery.

The polarity of the battery terminals $+$ or $-$ will be found marked on the top or the side of the container. The one

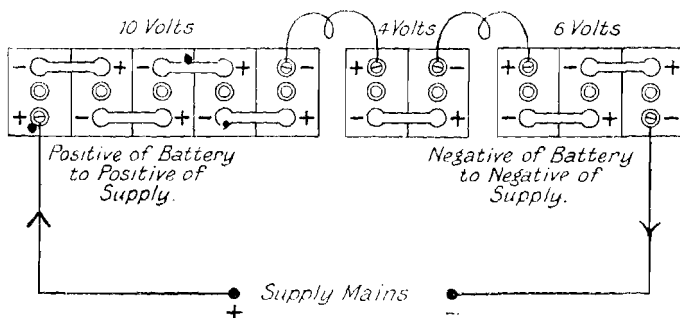


FIG. 11. CELLS CONNECTED IN SERIES FOR CHARGING.

marked $+$ must be connected to the positive terminal of the supply, and the one marked $-$ must be connected to the negative terminal of the supply.

Fig. 11 illustrates the connections necessary for correct charging.

DETERMINING POLARITY OF BATTERY TERMINALS

If by any means the determining marks of the battery have been lost or obliterated, the positive and negative plates can easily be identified and the $+$ and $-$ terminals determined by the following tests.

1. Colour of Plates.

Charged or discharged, the + plates are always much darker in colour than the - plates.

2. Number of Plates per Group.

If one set of plates contains one more plate than the other, the group having the outside plates is the negative group.

DETERMINING THE POLARITY OF SUPPLY TERMINALS

The polarity of the mains is rarely indicated in any way. The practice of using red covered wires for + mains and black for - mains used to be more or less prevalent, but at any time this indication could not be relied upon.

The following methods of determining the polarity of the supply terminals have been selected for simplicity, and, with ordinary care, can be adopted with perfect safety—

Methods.

- | | |
|--------------------|-----------------|
| 1. Voltmeter. | 4. Water test. |
| 2. Ammeter. | 5. Potato test. |
| 3. Compass needle. | |

Fig. 12 illustrates the first four of the above tests in one diagram.

Most voltmeters and ammeters for use on D.C. circuits have their terminals marked + or -. The left-hand terminal is usually +, and in any case could be marked once for all when purchasing, or at some other convenient time. If the instruments are connected up wrongly, the pointer tends to move in the wrong direction.

Voltmeter Test.

Connect the voltmeter, which should be capable of reading the full main's voltage across the supply mains,

as shown in the figure, so that it reads in the right direction. The terminal of the supply connected to the + terminal of the instrument is the + terminal of the mains.

Ammeter Test.

Connect a lamp, or group of lamps, of main's voltage in series with an ammeter across the mains. Do not omit the

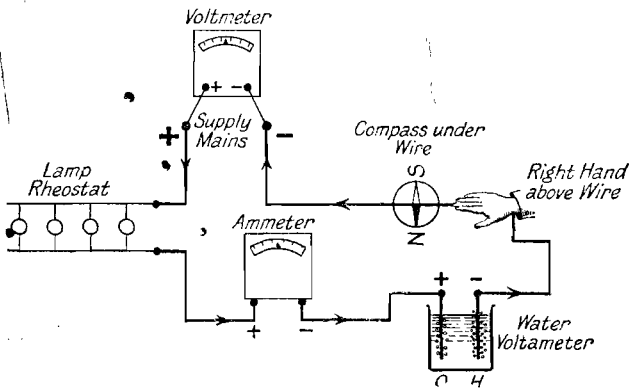


FIG. 12. TESTS FOR DETERMINING THE POLARITY OF SUPPLY MAINS.

lamps or the ammeter will be damaged. If the ammeter reads the wrong way on switching on, reverse the connections at its terminals. The main connected to the + of the instrument is the + main.

Compass Needle Test.

Obtain a small pocket compass. One can be obtained for 6d. at any of the sixpenny stores now so prevalent in large towns. Usually its North Pole is marked blue, or is pointed like the tip of an arrow, but this must be verified. Determine the true North direction from the South position of the sun at mid-day.

Note the setting of the compass needle when held in the hand. The end which points to the North is the North end of the needle.

Join up a bank of lamps by means of fairly long leads to the main supply to be tested. Place the compass needle on bench or table; hold one of the connecting wires directly above the centre of the compass. The needle will turn in a particular direction and set at right angles to the conductor. Now place the right hand flat on the wire,

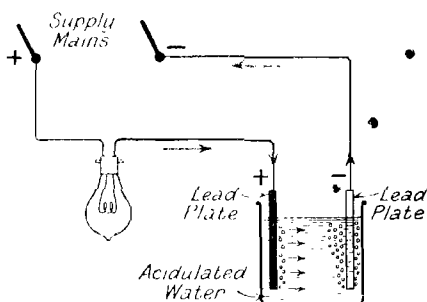


FIG. 13. TESTING POLARITY OF SUPPLY MAINS.

with the palm facing the needle, in such a way that the outstretched thumb points to the North end of the compass. The fingers will then be pointing along the wire and indicating the direction of flow of the current. The fingers therefore point to the - terminal of the supply, since the current flows out from the + terminal.

Water Test.

Fig. 13 illustrates this simple test in detail.

Wire up a lamp, or group of lamps, and connect one of the two leads to one supply terminal. Connect a separate piece of cable to the other supply terminal. To the two free ends of cable, one from the lamps and the other from a main, connect two strips of clean lead. Obtain a jar of

water, slightly acidulated by a few drops of accumulator acid. Place the two strips of lead into the jar of water. The lamps will light up and bubbles of gas will be given off from both pieces of metal, but at one the gas is produced in much greater quantities.

This strip is connected to the negative terminal of the supply. Now examine the plate at which the smaller quantity of gas is given off and it will be found to have turned dark brown, like the positive plate of a battery. This plate is connected to the positive terminal of the supply.

Potato Test.

With exactly the same connections as in the previous test, take the two *copper* cables from lamps and supply mains respectively and stick them, a small distance apart, into a raw potato. The current passing through the potato between the two ends of the wires acts electrolytically, and a green copper deposit takes place on the wire which is connected to the *positive* of the supply.

CONNECTION OF CELLS

A cell consists of one + plate or connected group of + plates, and one - plate or connected group of - plates with its electrolyte and container.

Series.

Cells are usually connected in series, as indicated in Fig. 11, forming a battery.

The total voltage of such grouping is the sum of all the voltages of the individual cells.

The same current flows through each cell or battery no matter what its voltage or its capacity in this grouping.

Parallel.

Equal voltages or numbers of cells could also be connected in parallel and the current of the circuit will split up, part

flowing through one group and part through the other, according to their size. This is useful when the charging current is too large for some cells, since two or more series groups of equal voltage can be connected in parallel, as shown in Fig. 14, and individually take a lower charging current than that flowing in the main circuit.

The sum of the currents flowing through each series group thus connected in parallel must equal the total current in the main circuit.

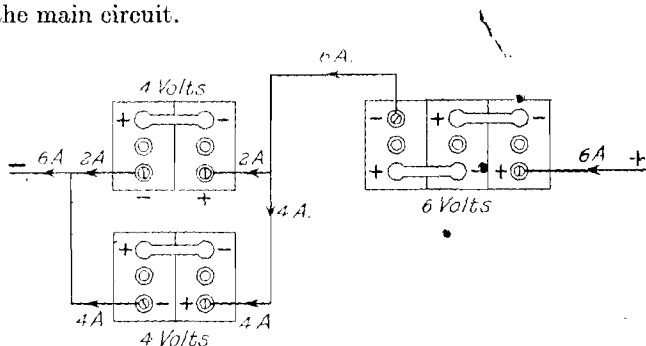


FIG. 14. EQUAL-VOLTAGE BATTERIES CONNECTED IN PARALLEL.

Such parallel grouping of cells as indicated in the figure is rarely convenient in practice. Where circuits of, say, 2, 4, and 6 A. are required, it is better to have three separate charging boards or a board as illustrated in Fig. 21, p. 66.

METHODS OF CHARGING

On first receiving a battery to charge, note its general condition if the plates are visible, and in any case top up with distilled water to about $\frac{1}{2}$ in. above the tops of the plates previous to charging.

Note the charging rate, as indicated on the maker's label, and as far as possible comply with this.

Give the customer a duplicate tag, and fix a similar one

to the - terminal of the battery. At the present time there is far too much swopping and changing of batteries at small local charging stations, often quite unconsciously on the part of the attendant, and in many cases due to the efforts of unscrupulous customers to obtain a good exchange.

General Charging Methods.

There are two principal methods adopted in charging batteries.

1. Constant potential method.
2. Constant current method.

The voltage of a fully charged cell is about 2.6 V. In the constant potential method, an average voltage of about 2.4–2.5 V. per cell is allowed, and this is applied to the battery immediately it is placed on charge.

This results in a big rush of current and charges the battery in much less time than the constant current method usually employed. It is rarely adopted except for boosting charges of large vehicle batteries, where time is of importance.

The constant current method consists in maintaining a constant current through the battery until the full charged condition is reached. This is the method considered in full in the following pages.

SERIES METHOD OF CHARGING

In the series method the current must be the *same* in all parts of the circuit. On small charging equipments where this system is used, and it is practically the only method known in such establishments, cells of all types and capacities are connected together in the same series group and charged at the same rate.

Batteries of different types and capacities require different charging currents. Maintaining the correct current for the smaller cells entails a long period of charge, perhaps useless

and even damaging undercharge for the larger cells. In the vain attempt to strike an impossible medium, the smaller cells are invariably overcharged and often ruined by being literally boiled to death.

Various types of charging equipments will be described later by means of which cells of different capacities, and in various states of charge may be treated in the manner demanded for efficient and correct service.

Principles Underlying Series Methods of Charging.

Series charging simply consists in putting a lamp, or parallel group of lamps, of the same voltage as the supply mains in series with the battery or group of batteries connected in series.

An ammeter in the return main indicates the current taken by each and all of the cells. This current is varied by switching on or off the lamps in the circuit. Any number of batteries may thus be charged, so long as the total voltage of the cells does not exceed the main's voltage, in which case the batteries would discharge into the mains.

Effect of the Number of Batteries on the Current Allowed to Pass Through the Lamps.

A 32 c.p. carbon lamp on a 100 V. circuit allows about 1 A. to flow.

If 10 cells, each having a voltage of 2.5, and therefore a total voltage of 25, were put in series with such a lamp, the voltage at the lamp's terminals would only be $100 - 25 = 75$ V. Naturally, this would not send 1 A. through the lamp, but probably only $\frac{3}{4}$ A.

If 20 cells, having a total voltage of 50, were connected in series with such a lamp, the lamp would only get $100 - 50 = 50$ V. of the 100 V. of the supply, and about $\frac{1}{2}$ A. would flow through the circuit.

It is not correct, therefore, to say that one 32 c.p. lamp allows 1 A. to flow in a charging circuit of 100 V. The actual current depends on the number of cells in series with the lamp.

In this system of charging, however, the required value of the charging current is known, the ammeter indicates the actual current flowing, and the operator simply switches on more lamps at the charging board, until he gets the desired current.

There is no need, therefore, to dwell further upon the question as to how much current really would flow with 6, 12, 18, or any other number of cells in the circuit.

Charging Table.

The table below gives the approximate currents which the lamps of various wattages and candle powers allow to flow at the voltages indicated.

Increased current is obtained by switching on more lamps.

The current values given may be taken as being approximately correct when the total voltage of the batteries in series equals $\frac{1}{2}$ of the main's voltage. The values given must be halved if the total battery voltage equals $\frac{1}{4}$ of the main's voltage.

If the battery voltages approximately equal $\frac{3}{4}$ of the main's voltage, the current will only be about $\frac{1}{4}$ the values given in the table.

CURRENT.	CARBON LAMPS.				METAL LAMPS.			
	25V.	50V.	100-120V.	200-230V.	25 V.	50 V.	100-120V.	200-230V.
$\frac{1}{2}$			8 c.p.	16 c.p.		15 W.	25 W.	50 W.
$\frac{1}{4}$		8 c.p.	16 c.p.	32 c.p.		25 W.	50 W.	100 W.
1	6 c.p.	16 c.p.	32 c.p.	60 c.p.	25 W.	60 W.	100 W.	200 W.

ACCUMULATOR CHARGING

VALUE OF RESISTANCE COILS TO BE PUT IN PLACE OF THE LAMPS

CURRENT.	25 V.	50 V.	100-120 V.	200-230 V.
Ampere.	Ohms.	Ohms.	Ohms.	Ohms.
$\frac{1}{4}$	100	200	400-480	800-920
$\frac{1}{2}$	50	100	200-240	400-460
1	25	50	100-120	200-230

CHARGING BATTERIES AT HOME

The insertion of a small battery in any lighting circuit makes practically no difference to the current passing, and consequently the illumination is in no way altered. The cost of charging a battery under such conditions therefore is nil, if such lamps are used for illuminating purposes whilst the battery is being charged. Since a battery can be charged for a time and then switched off, and the charge completed later when convenient, wireless amateurs naturally wish to charge their own batteries from the home mains if electricity is installed.

This is not always with an idea to economy, but is often caused by many useless visits to the charging station, and the disappointing results which frequently are produced there.

There is far more knowledge required, however, to charge a battery correctly than simply connecting it in the right way to the mains, and the self-charger should study the information given in other parts of the book on upkeep and maintenance; provide himself with a hydrometer, thermometer, and voltmeter if he desires to keep his battery in a good and efficient condition.

Connection to Ordinary Lighting Circuit.

The simplest position in a house for connecting the battery to the supply is at a switch.

BATTERY CHARGING

The first thing to do is to find the polarity of the terminal at the switch. This is done by switching off, removing the cover of switch, and fastening two wires either beneath

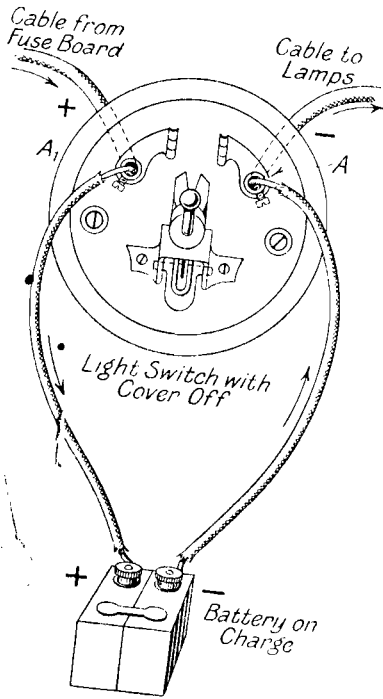


FIG. 15. CONNECTION OF BATTERY TO ORDINARY LIGHTING SWITCH FOR CHARGING

the screws in the socket contacts of the switch to which the main cables are connected, or to the switch contacts.

Place the ends of these wires into a tumbler of acidulated water an inch or so apart. The lamps will at once light. The wire at which the bubbles come off most readily connects to the - terminal of the switch.

for future reference the + and - terminals of the switch. They will never change.

The battery may now be connected to the same two wires as were used for the polarity test, the + of the battery being connected to the + of the supply, and the negative to the negative. The lamps will light up as soon as the battery is connected, as the latter really takes the place of the switch itself. Fig. 15 illustrates the arrangement described.

The danger of such a connection lies in the fact that someone may close the switch as usual, with the battery

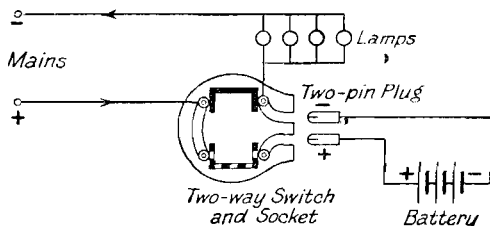


FIG. 16. SAFETY CHARGING DEVICE FOR "HOME" USE

on charge. This would immediately short circuit the battery through the switch, and probably ruin it.

A much safer method of charging small batteries from the home supply is to disconnect an ordinary switch and replace it by a "two-way and socket" arrangement of switch, as illustrated in Fig. 16.

The battery in this case is connected to the two pins or plugs, one of which is larger than the other, to ensure correct connection at the socket.

When fitting this switch and socket arrangement, the polarity of the mains must be tested, and the mains so connected to the switch terminals that the larger socket is made the + terminal.

With the switch in the top contacts, the lights only are in circuit; with the switch in the bottom contacts, the

battery is in series with the lights. The lights can only be switched off with the battery plugs withdrawn and the switch in the bottom contacts.

This arrangement prevents all danger of short circuiting the battery, whilst the connection of battery to the switch is simple, easy, and not detrimental to the normal operation of the switch.

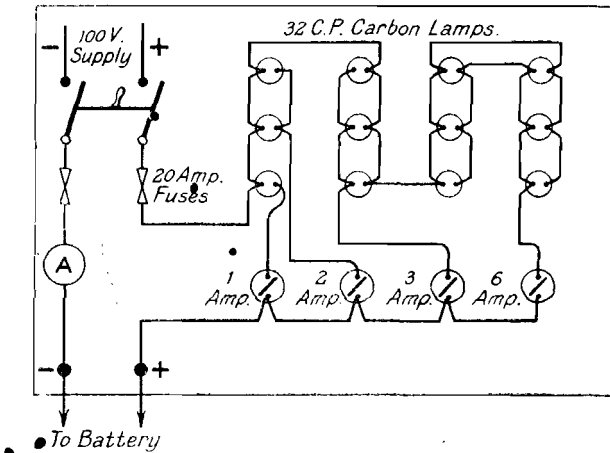


FIG. 17. SIMPLE LAMP RHEOSTAT CHARGING BOARD

The current taken by the battery will be that taken by the lamps which are illuminated when the battery is connected in the circuit. Its value can be found by adding up the wattages of these lamps, as indicated on the bulbs, and dividing by the supply pressure in volts.

SIMPLE CHARGING BOARD FOR SERIES CIRCUIT

Parallel Grouping of Lamps.

Fig. 17 illustrates the actual wiring of lamps and switches for a charging board which will give currents varying from

1 A. to 12 A., in steps of 1 A. for several batteries connected in series.

The current available from any particular lamp circuit would decrease as the number of batteries was increased, but instead of the 32 c.p. lamps used, which normally allow 1 A. to flow on 100 V. circuit, larger candle-power lamps

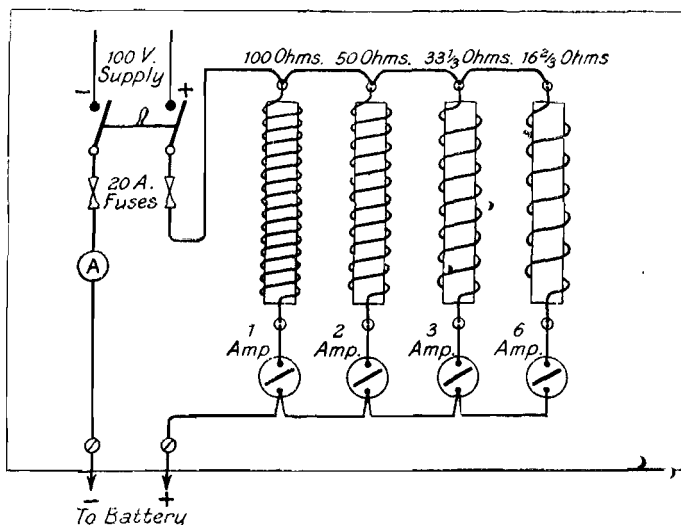


FIG. 18. WIRE RHEOSTAT CHARGING BOARD

could be inserted if desired to maintain the current with a large number of batteries in circuit.

The ammeter would in any case indicate the charging current, and this is the indication which would be noted, and not the number of lamps or switches which were on.

Parallel Grouping of Wire Rheostats.

Fig. 18 illustrates a group of resistance coils used instead of the lamps in the previous diagram.

The resistance of each coil is found by dividing the supply voltage by the current required in each case.

Resistance of coil 1 to allow 1 A. to flow	=	$\frac{100}{1}$	=	100 ohms
" " 2 " 2 A. "	=	$\frac{100}{2}$	=	50 "
" " 3 " 3 A. "	=	$\frac{100}{3}$	=	33 $\frac{1}{3}$ "
" " 6 " 6 A. "	=	$\frac{100}{6}$	=	16 $\frac{2}{3}$ "

These coils must be of sufficient length to give the required resistance and of sufficient cross-section to carry the current which will flow through them without overheating.

From manufacturers' tables, the size and length of Beacon resistance wire required has been found to be—

No. 1 coil	.	.	.	45 yd.	No. 22
" 2	"	"	"	50 "	" 19
" 3	"	"	"	45 "	" 18
" 6	"	"	"	50 "	" 15

• The connecting wires to switches, coils, main supply, and battery terminals should be big enough to carry, say, 20 A. No. 7/22 S.W.G. will do for this.

• Fuses should always be inserted in the battery circuit of, say, 150 per cent full-load value. They should be connected on the battery side of the main switch, so that, with the switch out, the terminals will be dead and safe to touch in case the fuses blow and need replacing.

Series Wire Rheostat.

Fig. 19 illustrates the connection of a rheostat in which all the coils are in circuit to give the lowest current. Higher values are obtained by cutting out coils, thus decreasing

the resistance in the mains. The calculations necessary for the design of such a board are illustrated on p. 16. The illustration here shown gives the actual values of the resistance coils and the currents which would flow with the sliding contact on the different studs and a few cells in circuit. The rheostat would work quite as satisfactorily

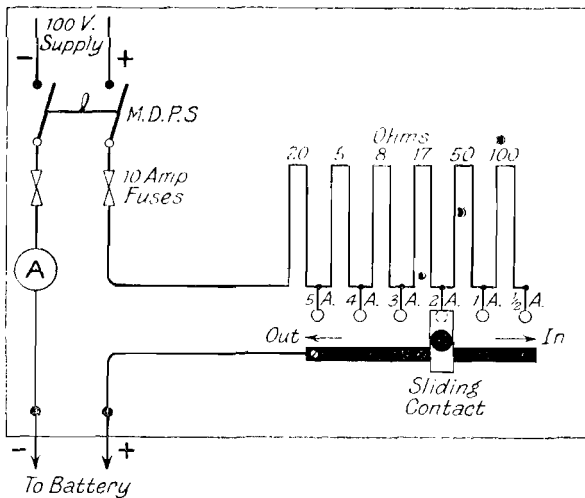


FIG. 19. SERIES WIRE RHEOSTAT CHARGING BOARD

with several cells or batteries in series as with a few, but the currents would be less than indicated.

The sizes of wire would vary, since the currents to be carried vary. The coil connected to the last stud can never have more than $\frac{1}{2}$ A. passing through it. Intermediate coils will carry greater currents, and the first coil should be large enough to carry 5 A.

These would be selected, therefore, of such a size and resistance as are most suitable. Using Beacon wire, the following table gives particulars.

Coil No. 1.	To Carry.	Size.	Length.
20 ohms	5 A.	No. 16 S.W.G.	50 yd.
5 ..	4 A.	.. 17 ..	10 ..
8 ..	3 A.	.. 18 ..	11 ..
17 ..	2 A.	.. 19 ..	16 ..
50 ..	1 A.	.. 22 ..	25 ..
100 ..	0.5 A.	.. 22 ..	50 ..

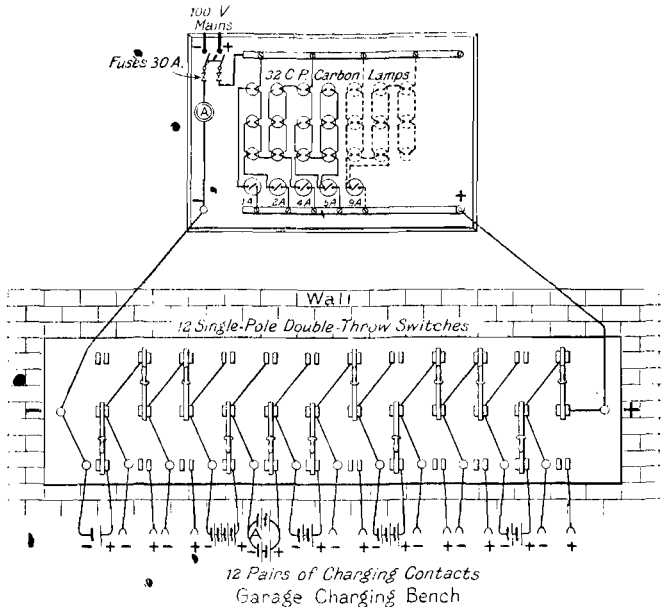


FIG. 20

Garage Series Charging Bench.

For convenience in charging many batteries there could be no better equipment than that illustrated in Fig. 20.

The size and number of lamps, and number of switch controls, would be varied to suit the requirements.

The board selected shows the arrangements suitable for a maximum charging current of 12 A., but more lamps could be added as suggested, if a larger current was required than the 12 lamps allowed.

All cables used must be adequate for the full current value required. Switches and fuses must be also of full charging current capacity.

It is suggested that the charging switches be built up on a long board fixed to the wall of the garage. In front of this a bench should be built about 1 ft. 6 in. from the ground, and of ample width to accommodate the batteries to be charged.

The switches, each mounted on its own base plate, and fastened to the long board suggested, are of the single pole, double-throw type. The top contact of each is permanently connected by a piece of cable to the hinge contact of the next switch, and thence to the - terminal of the preceding pair of charging contacts.

The bottom contact of each switch, together with one of the - contacts just named, form the two charging terminals for each switch arrangement. These terminals have pieces of flexible cable of about 18 in. long connected permanently to them. The free ends of these connecting wires are fitted with some type of clip, for easy fixing to the posts or terminals of the battery.

As many switches are provided as it is thought likely there will be batteries on charge at the same time. Such an arrangement is neat, simple, and efficient. There are no loose connecting wires about. With a switch on the bottom contact, the battery connected to the corresponding leads is put in circuit and on charge. With a switch on the top contact, the current passes directly to the next switch, the hanging cables are not in circuit, and any battery connected to them is simply disconnected. Once

a battery is fixed to a pair of clips therefore, it can be charged for any length of time, and disconnected by the throw of a switch at any time, without any interference with the rest of the circuit. The arrangement therefore gives individual control of all batteries on the charging bench at any time.

The initial cost of the arrangement may be great, but the gain in efficiency and general result will amply return the outlay in a very short time.

All the batteries in such an arrangement, however, are charged at the *same* rate, depending on the number of lamps in circuit at the charging board. This disadvantage has existed on all the charging arrangements described up to the present, and is inevitable in a single-series arrangement. It is advisable, therefore, to have at least two such charging boards, so that two charging rates may be maintained. Although not all that could be desired, the variations in current value on two such series arrangements would be far superior to the single system so often adopted with all types and sizes of batteries.

The board would be best placed at one end of the bench. In the figure, 12 switching arrangements are shown. With only a few occupied, the current flowing would be as indicated, but with 12 - 4 V. batteries on charge, taking 50 V. or more of the supply, the charging current at each switch control would only be about half that indicated in the figure—but the current would be increased as desired and the ammeter would indicate what was flowing.

At *A* two batteries are shown connected in parallel in order to reduce the current flowing through each. The voltage of each battery in such a series parallel arrangement must be the same and the current will divide somewhat according to the size of the battery in each circuit. The sum of the two currents will equal the total current in the circuit.

ACCUMULATOR CHARGING

SEPARATE CHARGING CIRCUITS
ARRANGEMENT

Fig. 21 illustrates a parallel charging arrangement very similar in construction and connection to those just described, but superior to them in that the switching

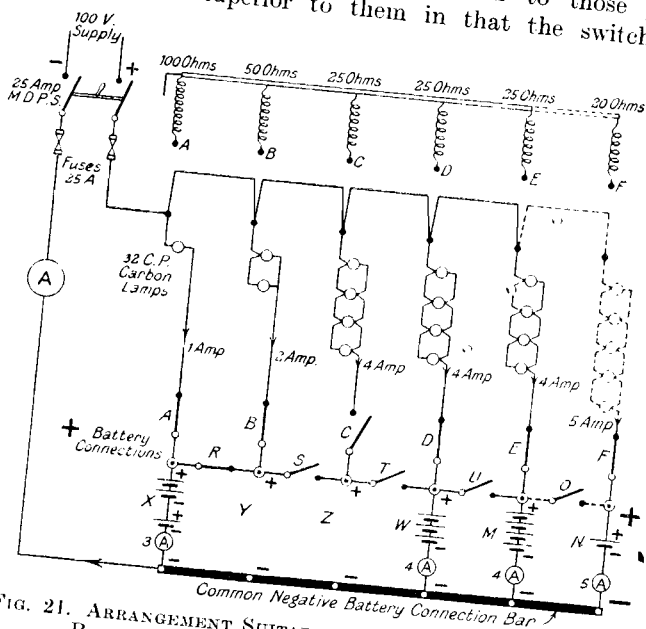


FIG. 21. ARRANGEMENT SUITABLE FOR CHARGING SEVERAL BATTERIES AT DIFFERENT CURRENT RATES

arrangements allow batteries of different capacities to be charged at correct rates.

Numerous combinations of switching circuits can be obtained, with corresponding variation of currents. With switches *RSTUO* open, the arrangement simply resolves itself into six separate charging equipments, controlled by switches *A, B, C, D, E,* and *F* supplying 1, 2, 4, 4, 4, and 5 respectively to batteries or small groups of batteries

connected across X , Y , Z , W , M , and N and the common negative terminal bar.

By closing switches A , B , and R , and connecting the one battery as shown in the circuit at X , a current of 3 A. would flow. The further closing of switches C and S would increase this by 4 A., making a total current through the battery of 7 A.

At the same time, batteries connected as shown at W , M , and N , with switches T , U , O open, and D , E , F closed, would be charged at rates of 4, 4, and 5 A. respectively.

The maximum number of charging circuits is evidently six, but others could be added, and the current values increased by connecting a larger number of lamps in the circuits. The large ammeter, as shown, indicates the total charging current of all the circuits and is of little use. To calculate the current in any particular circuit, either this should be judged roughly from the number of lamps in that particular circuit, or an ammeter should be connected between the battery on charge and the common terminal bar, as shown in the figure.

Above the lamp diagrams are shown values of resistance coils which, at the main's voltage indicated, would allow the current shown to pass, if substituted for the group of lamps in each lamp circuit respectively.

EARTHED CIRCUITS

Relative Positions of Charging Board and Battery with Respect to Supply Terminals.

Generally the lamp board should be connected between the + supply terminal and the battery, the - terminal of the battery being connected directly to the - terminal of the supply. Fig. 22a illustrates this clearly.

If one of the mains is earthed, it is desirable to connect the lamp rheostat to the unearthed main, in order to

prevent danger of shock when connecting and disconnecting the battery.

Fig. 22*b* represents the correct connection in the case of a 2-wire circuit with - main earthed.

Fig. 22*c* represents the connection with + main earthed.

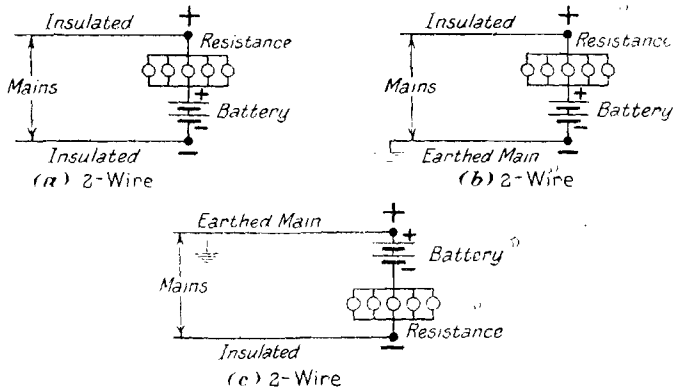


FIG. 22. CORRECT RELATIVE POSITIONS OF BATTERY AND RHEOSTAT ON "EARTHED" SUPPLY SYSTEMS

Three-Wire Systems with Middle Wire Earthed.

Many lighting and power systems are supplied on what is called the 3-wire system of distribution.

Fig. 23*a* illustrates this kind of supply. There are two "outer" mains, both insulated, the one called the positive outer and the other the negative outer. Between these, perhaps 400 V. is maintained.

This pressure is too high for lighting and is dangerous, so a third or middle wire is put in, between which and the two outers a voltage of 200 is maintained by a special machine at the central station called a balancer. This middle wire is usually connected to earth, so the + outer is 200 V. above earth potential, and the - outer is 200 V. below earth potential.

The + outer is positive with respect to the middle wire, but the middle wire is positive with respect to the - outer.

Three-wire systems are generally split up so as to supply

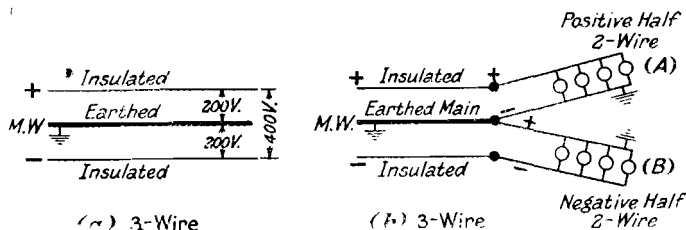


FIG. 23. 3-WIRE SYSTEM OF DISTRIBUTION

districts on the 2-wire system, and customers may be unaware that they are on a 3-wire system, their supply being for all intents and purposes just like a 2-wire system.

The resulting supply and polarity of such an arrangement into positive and negative halves of the system, are shown in Fig. 23b.

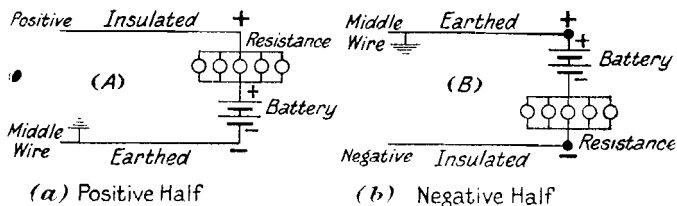


FIG. 24. CORRECT CONNECTION OF BATTERY ON "EARTHED" 3-WIRE SYSTEM

Figs. 24a and 24b show the correct connection of a battery on either the + or the - half.

Testing for the Earthed Main.

If an earthed supply is suspected or known, the earthed main can easily be detected by wiring up a single

ACCUMULATOR CHARGING

lamp-holder to a length of double flexible cord in ordinary manner.

Connect either of the free ends to one "supply" terminal and the other to a water tap.

If the lamp lights up, the main terminal to which it is connected is the *unearthed* main.

If the lamp does not light up, the terminal to which it is connected is the earthed main.

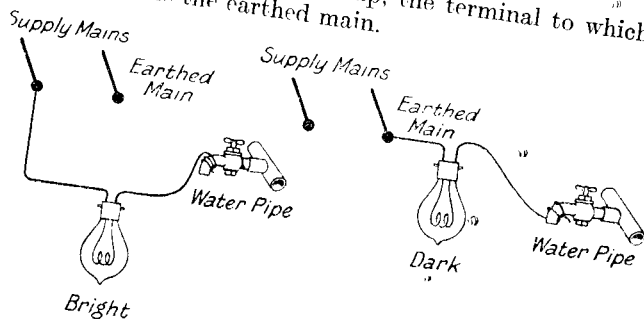


FIG. 25. TESTING FOR "EARTHED" MAIN

If the lamp appears to glow about equally, when connected between either terminal and the tap, the system is not an earthed system.

This test and the results are illustrated in Fig. 25. After the earthed main is determined, it is still necessary to determine the + main in the ordinary way before connecting up the battery between lamps and earthed main, as illustrated in Figs. 22 and 24.

CHARGING HINTS

Charging Rates for Normal Charging.

1. Read the maker's instructions and follow them.
2. If these are not available, calculate the rate approximately as below—
- 3) If the capacity at the 10 hr. rate of discharge is

given, divide the capacity by 6 to get the normal rate of charge. If the capacity at the 20 hr. rate of discharge is given, divide the capacity by 12 to get the normal rate of charge.

(b) If the capacity only is given and there is no indication of the hour rate at which this is correct, divide this by 12 to get an approximate charging rate.

(c) If there is no indication, then the charging rate must be approximately obtained from the area of the plates, as follows—

Measure the length and breadth of one of the + plates of *one* group or of *one* cell, in inches, multiply these together to get the area of one side of a plate in square inches. From this find the total area of all sides of the positive plates of one group by multiplying by 2, and again by the number of plates. Divide this value by 3 to get the ampere hour capacity, and again by 12 to get an approximate charging rate.

Note that the capacity of a battery is the capacity of one group of plates or of one cell, no matter how many cells are connected in series to form the battery. It is only the voltage which is varied by connecting a number of cells in series.

Example.

A battery has 4 positive plates per cell or group. These are each 6 in. by 5 in. Calculate the ampere hour capacity and the approximate charging rate.

$$\text{Area of one side of one plate} = 6 \times 5 = 30 \text{ sq. in.}$$

$$\text{Area of both sides of one plate} = 30 \times 2 = 60 \text{ sq. in.}$$

$$\text{Total area of four plates} = 4 \times 60 = 240 \text{ sq. in.}$$

$$\text{Capacity} = \frac{240}{1} \times \frac{1}{3} = 80 \text{ A. h.}$$

To find the charging rate, divide the calculated ampere hour capacity by 12.

$$\therefore \text{Charging rate} = \frac{80}{12} = \underline{\underline{6\frac{2}{3} \text{ A. approx.}}}$$

The above calculations are based on a capacity of 50 A.h. per sq. ft. of positive plate area, and a 20 hr. rate of discharge.

Minimum Charging Rates.

With so many different types of batteries on charge at the same time, the little man is apt to charge some at a very low rate. It is very detrimental to charge Planté positives at a rate below about 60 per cent of the normal rate. Pasted positives do not appear to be injuriously effected by such low rates, but the time taken to charge a 60 A.h. battery on a quarter ampere circuit, as the author has seen attempted, appears to be bordering on the ridiculous.

INDICATIONS OF COMPLETION OF CHARGE

1. Voltage of each cell.
2. Specific gravity of the electrolyte.
3. Gassing.
4. Colour of the plates.

The reasons for the variation of these have been treated theoretically in Chapter IV.

1. When the voltage of each cell reaches 2.6 the battery is fully charged.

The total voltage of a battery fully charged, therefore,

$$= \text{Number of cells} \times 2.6.$$

All voltage readings must be taken with charging current flowing. Continue the charge for some time after full voltage has been reached to reduce any sulphate which may be present, but at a reduced rate, according to

circumstances respecting gassing, state of plates, and maker's instructions.

2. If the specific gravity readings remain stationary for some considerable time with the charging current flowing, it is an indication of full charge condition.

The readings observed are no real indication of the actual state of the plates unless the previous condition and attention to the cell and its specific gravity are known.

It is necessary to adjust the specific gravity of each cell to give an actual value to the readings obtained.

If the gravity has been correctly adjusted previously, the specific gravity after full charge should equal 1.290 to 1.300 for car starting batteries and 1.240 to 1.250 for celluloid cased batteries.

The gravity readings should be taken $\frac{1}{2}$ hr. after the charge has been switched off to get the true reading.

Gassing.

A sulphated cell gasses at all times of charge, but the true gassing which indicates the cessation of chemical action at the plates, and that the conversion of the electrical energy solely in the production of oxygen and hydrogen is general throughout the cell, is in large bubbles and is in an approximately clear liquid.

After gassing has fully developed, reduce the charging rate, so that it does not proceed vigorously but steadily. Continue the charge for an hour or so at this reduced rate, according to the condition of the cell and the previous treatment to which it has been subjected.

Colour of Plates.

When fully charged, the + plate is a rich chocolate brown, and the - plate is grey; the liquid is sparkling and the plates look alive.

When discharged, the positives are much darker than the grey negatives, but the plates appear inert and lifeless.

Length of Charge.

Follow the instructions given and after the full charge conditions are indicated reduce the charge to 60 per cent of the normal value and continue for $\frac{1}{2}$ or 1 hr., according to the state of the cell.

The length of time required to charge a battery fully and satisfactorily from the customer's point of view, and consequently from a business point of view, depends entirely on the state of the battery when received.

To charge a battery for a certain number of hours according to its rated capacity, irrespective of its condition of charge or discharge when received, and then consider it, and return it, as fully charged is as absurd as it is unfair.

Overcharging.

An occasional slight overcharge is beneficial, but excessive gassing and temperatures above 100° F. or 38° C. must not be allowed to develop.

Batteries charged weekly should have $\frac{1}{2}$ hr. overcharge at 40 per cent normal rate once per fortnight.

Undercharging.

It is bad business to get as much out of a battery as possible. Repeated discharges, with insufficient charges, gradually undermine the efficiency of any battery, just as overwork and insufficient food undermine the constitution of a human being.

THE ELECTROLYTE

Topping with Water.

Use pure *distilled* water and fill to about $\frac{3}{8}$ or $\frac{1}{2}$ in. above the tops of the plates previous to charging.

Obviously, specific gravity readings are useless unless this level is maintained.

Ordinary tap water contains many impurities, whose presence in the cell cause chemical and electrical reactions which are very detrimental to the working of the battery.

Tap water is never used for mixing with acid, or for topping by anyone, whose object is to treat the batteries under his care fairly and reasonably.

Distilled water is perfectly pure water, and is only obtained by the condensation of steam.

This water may be obtained from a still, or by fixing a coil of lead piping partly immersed in cold water to any supply in which steam is being produced. Distilled water will emerge from the open end of the coil.

Rain water obtained in the country, if free from dust and dirt, may be used instead of distilled water. Its purity in the town is usually very doubtful, but it is far better than tap water.

To Correct the Specific Gravity.

If acid has been spilled and if the specific gravity must be corrected, because it will not rise to the best and correct value after the cells have been fully charged, withdraw as many syringefuls of electrolyte from the cell as is roughly judged to be necessary, and replace with acid of 1.400 specific gravity.

Charge again until the cell gases freely. Half an hour or so after the completion of the charge test the specific gravity again. Correct the reading for temperature value at 70° F. It should be 1.290–1.300 for car batteries, and 1.245–1.250 for celluloid batteries. If it has not risen to this value, repeat the above operation until the required result is obtained.

If the specific gravity is too high, withdraw some of the acid and replace with water, and treat as described above until the value desired is obtained.

If at the end of a charge the specific gravity is below 1.265 and 1.210 respectively in car and celluloid batteries,

entirely replace the electrolyte with new acid of 1.300 and 1.250 respectively. Charge and adjust as directed above. It is no use taking specific gravity readings directly after adding liquid. The added water or acid must be mixed with the body of the electrolyte, and the best way to do this is to steadily gas the cell for a short period.

Mixing Electrolyte in Bulk.

When dealing with acid only use glass or earthenware jugs and funnels, and a wooden or ebonite rod for mixing purposes.

Never use metal utensils for any operations involving acid.

Form an idea as to how much electrolyte is required, then, from the tables of volumes, judge how much acid and water respectively will be necessary to make the amount of approximately the correct specific gravity. Pour the quantity of water required into a jar and add the acid to it slowly, stirring all the time. Never add water to acid, or the great heat produced at the junction of the acid and water may produce steam, which, exploding through the mass, may scatter acid into the eyes and result in serious injury.

Allow the mixture to cool. Take the specific gravity reading and the temperature. Correct the specific gravity reading at this temperature to what it would be at 70° F. as follows--

Correction for Temperature Effect on Specific Gravity.

The specific gravity values given as correct for various kinds of batteries are estimated for a working temperature of 70° F.

Fig. 26 gives an illustration of a thermometer calibrated to indicate points to be deducted from, or added to, the actual hydrometer reading of newly mixed acid, or the

electrolyte in a cell, to give the corresponding value of the specific gravity at 70° F.

The reader could easily rule out such a scale and fix it along the tube of his thermometer.

A *point* in specific gravity readings = 0.001 and 1 point has to be added for every 3° F. above 70° F., since the liquid, in cooling, will contract and become more dense.

For every 3° F. below 70° F., subtract 1 point from the observed reading of the hydrometer to get the reading at 70° F.

The two specific gravity scales shown to the right of the thermometer scale in the diagram give the required specific gravity reading, at the corresponding temperature, which is necessary to produce a specific gravity of 1.300 and 1.250 respectively at 70° F.

Example.

(a) At 85° F. the specific gravity for car batteries is given as 1.295, and for celluloid batteries 1.245. These are the necessary specific gravity readings of electrolyte at a temperature of 85° F. to produce 1.300 and 1.250 respectively, when the liquid has cooled to 70° F.

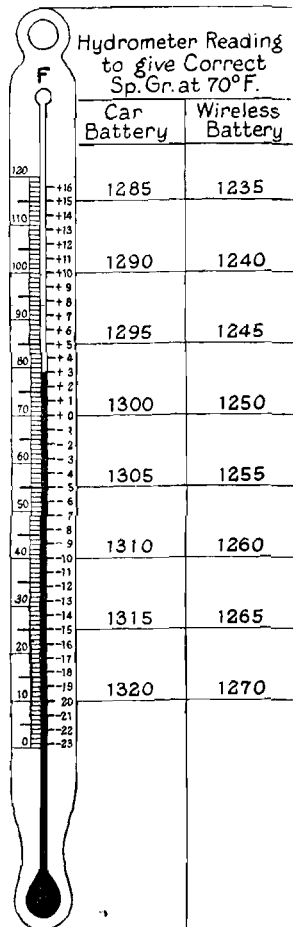


FIG. 26. HYDROMETER-THERMOMETER

(b) The specific gravity of some acid at 85° F. is 1.290. What would it be at 70° F. ?

Since 1 point must be added for every 3° F. above 70° F., 5 points must be added to the reading, making a specific gravity of $1.290 + 0.005 = 1.295$ at 70° F.

QUANTITIES OF WATER AND ACID TO BE MIXED
TOGETHER TO PRODUCE AN ELECTROLYTE OF
DEFINITE SPECIFIC GRAVITY
USING ACID OF 1.400 SPECIFIC GRAVITY

Required Specific Gravity at 70° F.	Water, Parts by Volume.	Acid, 1.400 Specific Gravity. Parts by Volume.
1.300	4.5	" 10
1.280	5.5	" 10
1.275	6.25	" 10
1.260	6.5	" 10
1.250	6.75	" 10

USING ACID OF 1.835 SPECIFIC GRAVITY

Required Specific Gravity at 70° F.	Water, Parts by Volume.	Acid, 1.835 Specific Gravity. Parts by Volume.
1.400	15.6	10
1.350	19.5	10
1.300	24.7	10
1.290	26.0	10
1.280	27.5	10
1.270	29.0	10
1.260	30.0	" 10
1.250	32.2	" 10
1.240	34.0	10
1.230	36.0	10
1.225	37.2	10

Emptying Acid from Carboy.

Fig. 27 illustrates an arrangement for emptying acid with ease and safety from the carboys.

The mouth of the carboy is fitted with a rubber stopper through which are fitted two lead tubes as shown. The shorter tube has a T-piece, one end of which is connected to an air foot pump, and the other is closed or opened as required by the finger or thumb. The longer tube reaches into the liquid and is connected to jar or filling jug by a rubber tube.

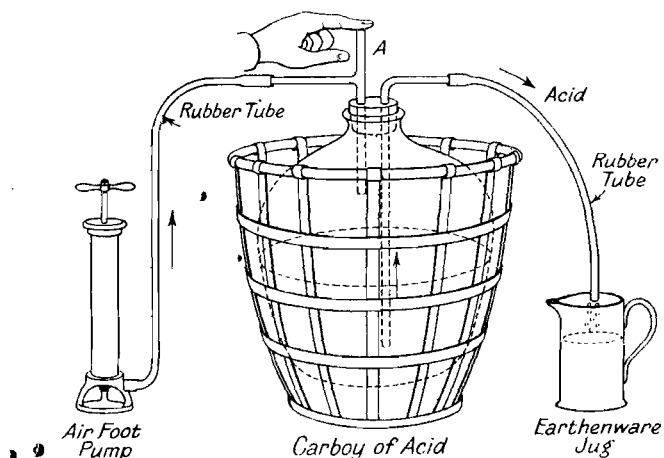


FIG. 27. SIMPLE METHOD OF EMPTYING CARBOY OF ACID

To obtain acid the finger is put so as to close the vent of the T-piece at A, the foot pump is worked, and the air forced in the space above the liquid causes it to rise in the delivery tube and emerge as shown.

The flow is immediately stopped on releasing the air pressure, by removing the finger from the T-piece.

FIRST CHARGE

If this is not carried out properly, the battery will never give out its full capacity; it will not be efficient, and its useful life will be shortened.

Filling the Jars with Electrolyte.

Have an ample quantity of electrolyte ready mixed and cooled.

The specific gravity of acid to be used, corrected for temperature, should be 1.245 for celluloid batteries and 1.290 for car batteries.

Fill the jars holding the plates to $\frac{1}{2}$ in. above the tops of the plates. Allow to stand for 1 hr. During this time the acid is absorbed into the pores of the separators and plates, and the level sinks.

Fill up again with acid, and allow to stand for about 11 hr. At the end of this time level up again and place on charge, after making certain that the connections are correct as regards polarity of main and battery.

Charging Current.

Switch on and adjust current to normal charging rate. This is given on the maker's instruction chart affixed to the battery, or can be found approximately by dividing the ampere-hour capacity by 12.

Duration of First Charge.

Once the charge has been started it is imperative that it be kept continuous for at least 12 hr. Altogether, the length of time should be 40 to 50 hr., depending upon the rate at which the plates develop. It is better if the whole charge can be given continuously without break, but charging periods of 12 hr., with 12 hr. intermission between each charge, will be satisfactory if it cannot be arranged as advised.

Completion of Charge.

Continue the charge irrespective of the actual period of time, until every plate of every cell is gassing or bubbling freely, and the specific gravity and voltage of each cell tested separately, cease to rise for a period of 4 hr.

To obtain this information, tests should be taken at half-hour intervals towards the end of the approximate time required for the complete charge. These tests should be taken from each individual cell of the battery.

Precautions.

Thermometer tests should be taken frequently towards the end of charge, and in fact at intervals during the whole period of charge. If the temperature exceeds 100° F. or 38° C., the current should be reduced or switched off entirely before resuming the charge at a reduced rate.

Excessive rise in temperature or excessive gassing are indications of too high a charging current, and it is very important that this first charge especially should not be excessive.

Emptying the Electrolyte.

Now empty out the electrolyte and fill with new acid having specific gravity of 1.300 for car batteries and 1.250 for celluloid batteries, corrected for a temperature of 70° F.

When this is done, place on charge again until gassing proceeds freely in all cells. Switch off current. After 1 hr. rest take specific gravity readings and temperature of each cell. Correct the readings for 70° F. specific gravity values and add water or acid as indicated on p. 78, until the specific gravity of the cells can be guaranteed to be correct.

Specific gravity readings of such cells during subsequent charges and discharges will be honest indications of the actual state of the cells. After this add only water, previous to charging, to maintain the level of the electrolyte $\frac{1}{8}$ in. above the plates at all times.

Once per year fully charge, empty out the electrolyte, add new electrolyte, and proceed just as if each cell were at the end of its first charge to adjust the specific gravity, in order to get a further year's service out of the battery.

CHARGING HIGH-TENSION BATTERIES

Accumulators are now being manufactured for use on wireless sets to replace the high-tension dry-cell batteries previously employed. Their high initial cost is soon recompensed by the longer service and more efficient behaviour. They only take a charging current of $\frac{1}{4}$ A., and only need recharging about once every six months.

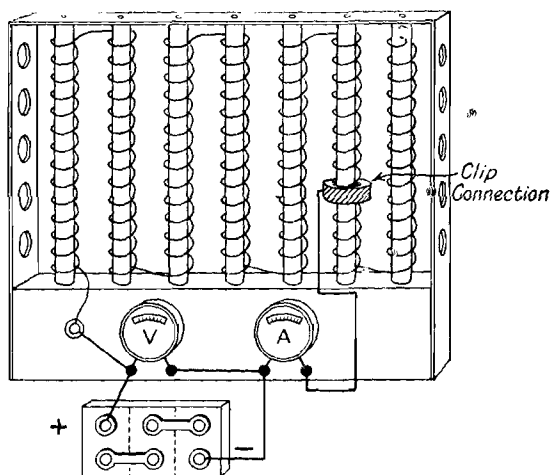


FIG. 28. BATTERY DISCHARGE BOARD

A metallic filament lamp would be best to use for charging such a battery. Assuming a 50 V. battery, the voltage at the terminals of the lamp would only be about 50 V., on a 100 V. circuit. For the purpose, therefore, a 50 W. 100 V. lamp would do admirably.

On circuits of 200 V. or more, a wattage of about 50 would also be found satisfactory for charging purposes.

DISCHARGE BOARD

When removing sulphate it is often necessary to charge and discharge repeatedly. For this purpose a discharge

frame is required. Coils of iron wire can be hung on a wooden frame or wound on wooden rollers covered with asbestos to form rheostats. Contact at any point by means of a clip can be arranged to regulate the discharge current, which will be indicated on the ammeter.

The voltmeter, as connected in the figure, will indicate the value to which the cells are discharged.

Fig. 28 illustrates such an arrangement, suitable for a discharge board.

The wire is made of No. 10 iron wire, which will carry above 30 A., and has a resistance of about 4 ohms per 1,000 ft. Allowing a maximum of 15 V. and a minimum current of 5 A., the length of wire required for the complete rheostat would be about 750 ft. Using platinoid wire, only about 120 ft. would be required.

LOOPING IN AT LAMP HOLDERS

It is not within the scope of the present book to describe the actual building of discharge boards, mounting of switches, etc. This is left to the ability of the reader, but a few hints may be of use.

The lamp holders used in the various rheostats described in this chapter can be obtained with flat bases drilled for direct screwing to the boards, and known as back-plate type.

The connecting wires are brought to the terminal blocks of the holders, through one large hole drilled through the board directly below the holder.

The wire is looped wherever possible into the contacts. This means that, instead of using separate pieces of wire for connection between lamp holders, one long wire is taken, fastened in the usual way to the first lamp's terminals, laid along the board to the next, the length of wire required judged, and the insulation stripped without cutting the wire. The insulation is bared for about 1 in. and the covering trimmed back for about 2 in. The bared portion

is then bent at the middle and twisted so as to fit under the binding screw. The wire is then carried to the next holder and the operation repeated as often as required.

Only the rubber insulation should enter the hole in the porcelain base. Cotton covering should not touch the base plates.

Precautions for Operators.

Keep a bottle of strong ammonia at hand with which to neutralize any acid spilled on clothes and to soak rag for wiping terminals and outside of battery cases.

The skin irritation due to acid spray is much alleviated by washing the hands and arms in water to which ordinary or bicarbonate of soda has been added.

If acid splashes into the eyes, wash immediately with warm water, or cold if warm is not at hand, drop olive oil into the eye, or vaseline or lubricating oil, whichever is most convenient.

Be clean about the person, hands, nails, and nose when working on plates.

Do not eat food with dirty hands, and drink plenty of milk.

CHAPTER VIII

GENERATOR METHODS OF CHARGING

THE rheostat methods of charging previously explained in detail are applicable to all D.C. circuits. Such methods are comparatively inexpensive to install and extremely simple to operate. The maintenance costs are practically nil and the attendance required, as far as actual current regulation is required, is zero.

In every case, however, by far the greater part of the energy taken from the mains is absolutely wasted in the lamps or resistance frame. Since the maximum voltage required for one battery rarely exceeds 15 V., it would appear to be far more economical, especially for charging on a large scale, if this voltage could be produced and supplied direct to the battery terminals without the wasteful insertion of resistances. This can be done, but on D.C. circuits such transformation of voltages requires rotating machinery, which is somewhat expensive in first cost.

Motor Generator or Rotary Transformer.

The simplest means of reducing a high voltage D.C. supply to low voltage D.C. is by means of a motor generator. This sometimes consists of two separate machines, a D.C. motor and D.C. dynamo, mounted on the same shaft and bedplate. The motor is connected through a starter to the main supply, and running the dynamo causes this to generate at a voltage suitable for direct connection to the battery to be charged. The voltage and output of the dynamo is variable through a definite range by means of its field rheostat.

Fig. 29 illustrates such a set suitable for a large garage,

and shows all the necessary connections and instruments required for starting the motor and charging the battery.

Small motor generators or rotary transformers, as they are sometimes called, are made in one complete unit, instead of two separate machines. In this case both motor and generator armature windings, side by side, are mounted on one armature core. The motor windings are connected

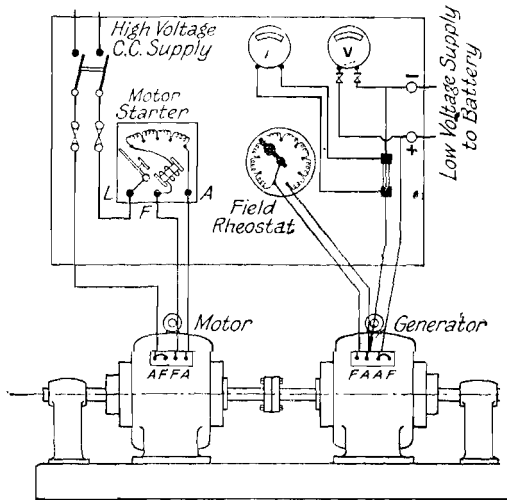


FIG. 29. CONNECTIONS FOR MOTOR-GENERATOR SET

to a commutator at one end of the shaft, and the dynamo' windings to a commutator at the other end of the shaft. Only one field system of magnets is thus needed.

Such sets can be obtained small enough for running off the home mains, and of a capacity equal to that needed to charge one or two batteries. Naturally they are somewhat expensive, but after years of usage their efficiency may repay the great initial outlay. A set complete with instruments and charging board suitable for charging a 5 A. battery at 10 V. costs about £18.

A larger type suitable for connecting to mains of 100 to 250 V., and capable of charging twelve 12-V. 120 A.h., or forty 6-V. 60 A.h. batteries, is listed at about £50.

The economy of such machines, as compared with rheostat methods of charging, may be estimated roughly from the following example—

To charge a battery of 12-V. 60 A.h. from 230 V. mains singly would take about 18 units, whereas, with a small set, the total consumption would probably be not more than 2-3 units, which, at 2d. per unit, means a saving of 2s. 6d.

CHARGING FROM A.C. CIRCUITS

Motor Generator's and Rotary Converters.

It is absolutely impossible to charge accumulators from alternate current supply mains without using some kind of converter or rectifier, which will convert the A.C. to D.C. suitable for battery charging.

The most obvious method of doing this would be to connect an A.C. motor to the supply and utilize this motor to drive a D.C. generator of the required voltage and output.

This method is actually used in motor generator sets which are similar to those just described, except that the motor is of the A.C. type.

Just as both motor and dynamo windings may be put on one armature in the rotary transformer, so they may be put on one armature in the converter, to produce a single unit machine for converting A.C. to D.C. Such a combination is called a rotary converter, but in this case the same armature windings used for both motor and dynamo are connected to slip rings and the A.C. supply at one end, and to a commutator and the D.C. supply at the other. A small rotary complete for charging a battery of 15 V. and 4 A. would cost about £12.

RECTIFIERS

It is possible, however, to rectify A.C. so as to be suitable for charging batteries, without the use of rotating machinery, by means of what are called rectifiers.

There are many kinds of rectifiers, among which are included the following types—

- | | |
|-----------------|-------------------|
| Mechanical. | Electrolytic. |
| Mercury vapour. | Gas-filled bulbs. |

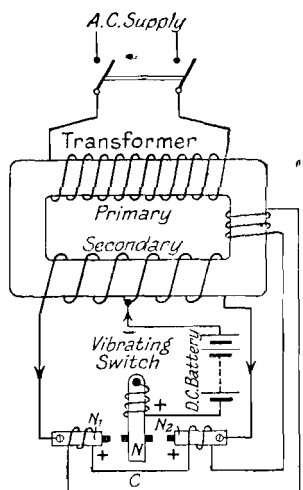


FIG. 30. MECHANICAL RECTIFIER

Mechanical Rectifier.

This device has a mechanical arrangement which, acting in synchronism with the supply, changes the connection to the battery in such a way that the current is always flowing in the same direction.

Fig. 30 illustrates the general arrangement.

N is a permanent magnet suspended at its upper point so that it can vibrate and make contact with N_1 and N_2 alternately."

The electro-magnets N_1 and N_2 are magnetized by an A.C. supply from an auxiliary winding on the main transformer, and their polarity changing at every alternation causes the permanent magnet N to be attracted first to one side and then the other. This connects the battery, through contacts N_1 and N_2 , first to one end of the main transformer secondary windings and then to the other, and the magnet coils of N_1 and N_2 are so wound that this takes place when the supply at the contacts N_1 and N_2 is of positive potential. The current through the battery therefore is always in the same direction.

Voltage regulation to suit the battery requirements is obtained by varying the position of the tapping points at the two ends of the transformer winding.

Mercury Vapour Rectifier.

The action of this depends on the fact that if a mercury vapour arc be started between a mercury electrode and another of some conducting material, a current will flow from the conductor, called the anode, to the mercury, called the kathode, but not in the opposite direction. An alternating current, therefore, when used to form the arc, is only allowed to flow when passing in one direction. When it reverses it is not allowed to pass through the rectifier. By this means the A.C. is only supplied to the battery circuit when flowing in the same direction, or, as it is called, after rectification.

For connection to single-phase supply, two anodes are used, with an auxiliary anode for first starting the arc, and also for maintaining it when the battery circuit is accidentally opened.

The upper portion of the bulb is used to condense the mercury vapour. The minute globules fall from it after condensation into the lower portion, which forms the mercury kathode and positive terminal of the rectifier.

Voltage and current variation are obtained by varying

the position of the tapping points on the secondary winding of the transformer, or by inserting resistance in the battery circuit.

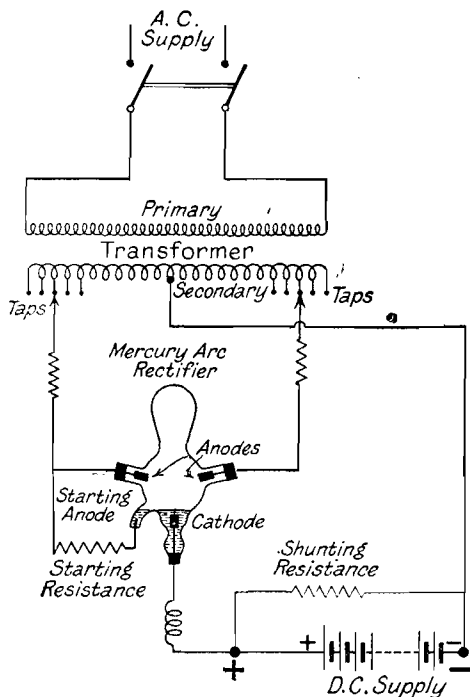


FIG. 31. MERCURY ARC RECTIFIER

Fig. 31 illustrates the connections and general appearance of the rectifier.

Electrolytic Rectifier.

The action of this type of rectifier depends on the fact that an electrolytic cell, having electrodes of certain metals, and having a particular electrolyte, will only allow the current to flow through the cell in one direction. If an

A.C. supply be connected to the terminals of such a cell, it will therefore act as a rectifier and allow the current to flow only in one direction.

Fig. 32 illustrates such a rectifier, with electrodes of aluminium and lead in an electrolyte of sodium ammonium phosphate. The current in this case will only flow from the lead to the aluminium within the cell.

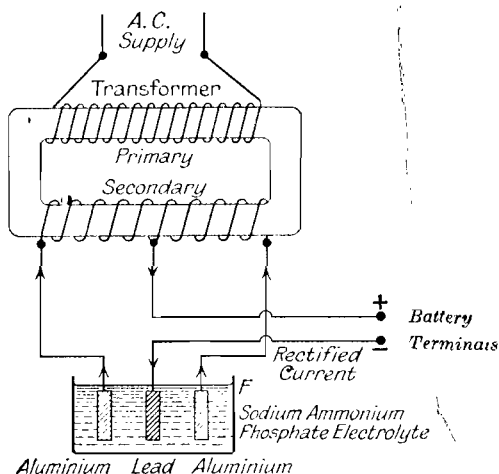


FIG. 32. ELECTROLYTIC RECTIFIER

The connections of the rectifier to the secondary of the transformer and to the battery are clearly indicated in the diagram.

Voltage regulation may be obtained by tapping points at the transformer or by inserting resistance in the battery circuit.¹

Bulb Rectifiers.

Two electrodes at different temperatures in a vacuum may act as a rectifier. One such rectifier, having a cold

¹ For a complete description of this apparatus, see *The Electrolytic Rectifier*, de Bruyne. (Pitman.)

anode of graphite and a hot spiral cathode of tungsten, is made to operate on circuits of 40–75 V. and at currents varying from $\frac{1}{2}$ to 30 A.

All the above types of rectifiers may be obtained, in compact arrangement—eminently suitable for small battery charging—and often designed to give various charging currents and voltages suitable for different kinds of batteries. They are easy to operate and are simply connected to the A.C. mains by an ordinary adapter arrangement, fitted to the end of a flexible connecting wire. The cost varies from about £5 to £7 per set.

If the reader decides to install any type of the above machines, he should clearly state his requirements as to nature and number of cells to be charged, voltage of supply, C.C. or A.C., No. of phases, frequency of supply, etc., to a reliable firm of electrical engineers. Such a firm would give particulars as to cost of machine and operation and advise generally on the best method of fulfilling the requirements.

CHAPTER IX

DISEASES AND THEIR TREATMENT

THE chief troubles connected with battery operation can be avoided if the battery is properly charged, specific gravity readings taken and corrected, individual cells tested for voltage, and the directions issued by all manufacturers generally attended to.

The principal diseases to which batteries are subject are as follows—

Sulphation.

Buckling and cracking.

Short circuits.

Internal discharge.

Shedding of active material.

SULPHATION

Indication.

When only slightly in evidence, white patches are noticeable on the plates.

When badly sulphated, the growth of white matter on and between the plates is evidence indeed to the most inexperienced, that there is something radically wrong with the battery.

Where the condition of the cell cannot be examined owing to the non-transparency of the case, loss of capacity, overheating, and eventual uselessness of the battery at once suggest sulphation.

Cause.

The natural chemical result of battery discharge is the production of normal lead sulphate at both + and - plates. This sulphate forms on the surface of the plates in the first

place and prevents the acid freely reaching the active material beneath. A rapid discharge quickly covers the plate with this sulphate, and the cell apparently gives out a very low discharge in consequence.

The sulphate normally formed is easily converted into peroxide and spongy lead respectively on charge, but if the cell is discharged below 1.75 V. the sulphate assumes a crystalline structure instead of the finely divided nature of the ordinary sulphate. These crystals grow with continued discharge and are very difficult to reconvert into active material by ordinary methods of charging.

Impurities in acid or plates will cause hard sulphate to be formed, due to the constant internal discharge of the cell, which results even on open circuit.

Only the best and the cleanest of distilled water should therefore be used in the battery for any purpose whatever. Using acid of too high specific gravity, or running the battery at temperatures above 100° F. will, on account of the increased chemical action produced, result in the formation of this hard, inconvertible sulphate.

If the tops of the plates emerge from a too low electrolyte these portions will sulphate.

The most prevalent cause of sulphation is an attempt to discharge and continually discharge a battery, without charging sufficiently to make up for the energy taken out of it, or leaving it discharged for a long period before commencing to recharge.

A battery should never be allowed to stand discharged. If fully charged, it may be safely left for weeks or even months with very little attention.

Treatment.

Slight Sulphation. If it is taken in time, charging at a low rate will reduce sulphation. The value of the current should be about one-twentieth of the normal rate, and the charge should be continued until the cells gas freely, even

though it takes days or weeks to bring this about. After this, discharge the cells partially at a low rate and again charge as before. Repeat these operations until the full charge voltage shows a value of 2.65 per cell, the plates are clean and of a good colour, and the specific gravity has a constant value of 1.245 for celluloid or 1.295 for car batteries when charged.

Bad Sulphation. Empty the container and fill with pure water. Charge at normal rate. Test the specific gravity at intervals, and if at any time it rises above 1.15, stop the charge, empty out the electrolyte, and refill with pure water, after which continue the charge.

If at any time during the operations the temperature rises above 100° F., reduce the charging current or switch off temporarily until the temperature falls. When all the sulphate is reduced, as indicated by the colour of the plates, empty out the jars and refill with acid of about 1.225 specific gravity and charge again. After full charge, test and correct the specific gravity of the electrolyte.

Very Badly Sulphated. Under these circumstances it is a waste of time and energy to attempt a cure.

BUCKLED AND CRACKED PLATES

Indication.

Instead of being evenly spaced and perfectly flat, the plates are saucer shaped, with the bulging edges touching, or tending to touch, the sides of the jar and the adjacent plates.

Cause.

Grids are composed of lead, which is an inelastic substance. It easily bends and, if once bent, does not resume its original shape. Unequally distributed chemical action at the plate results in unequal heat distribution, for chemical action is always accompanied by heat production, and

will cause irregular expansion at different parts of the plate. This irregular expansion results in bending, buckling, and breaking. On discharge the active material changing to sulphate always increases in volume, especially at the positive plate, and this expansion throughout the mass of the paste exerts pressure on the grid, causing it to bend most at the centre, where it possesses the least mechanical resistance and to grow outwards at the sides.

Excessive and prolonged discharge causes maximum expansion on this account, and especially if the sulphate formed is of the crystalline variety.

Hard sulphate, if formed in patches, as it always is at first, reduces the conductivity of the plates, since it is an insulator, and covers the active material, which is not covered up and which forms the conducting paths, to be worked at excessive rates even on normal charge and discharge. This results in the production of high temperatures, in quite local patches, and unequal expansion.

At even low rates of discharge or charge a badly sulphated plate may on this account become buckled and cracked if this has not already resulted from the formation of the sulphate itself. It is largely on account of this that the charging rates used in the attempt to retrieve sulphated cells are suggested of an extremely low value.

When acid is mixed with water, heat is developed. When the plates are being charged, the acid produced at their surfaces mixes with the water in the vicinity, and as a result heat is generated. At excessive rates of charge, and during prolonged charging, this heat may be so great and so irregularly distributed that the plates are warped and bent by the irregular expansion which results.

Treatment and Result.

Buckling in itself will not harm the action of the cell, but if the bent plate forces itself in contact with an adjacent plate, a short circuit of more or less resistance, results.

Any bending of the plate, however, causes loosening of the active material, and this, falling away from the grid, reduces the capacity of the cell. It may also cause a short circuit by bridging between plates, whilst in any case it goes to the bottom of the jar and helps to swell the quantity of sludge which gathers there. This sludge in itself is a danger to short circuiting and absorbs energy from the supply on charge.

If not too badly buckled, the plates can be strengthened in vice or press, as described in Chapter X.

Cracked plates are difficult to repair. Occasionally lead burning may be resorted to if the crack is near a connecting bar or post, but if the plates have shedded considerably, and their condition is dubiously useful, the only and best cure is replacement of the plate or section.

SHORT CIRCUIT

Indication.

Rapid loss of capacity after apparently full charge, even on open circuit.

Low gravity and voltage immediately after charging.

Little or no gassing when adjacent cells are gassing fully.

Cause.

The formation of hard sulphate from any cause almost invariably results in short circuit. This is produced either by direct bridging, due to fallen pieces of hard sulphate and the active material adhering to it, by "treeing," or by actual growth of sulphate from plate to plate through the separators themselves.

Excessive gassing invariably results in the loosening and falling out of active material and may result in short circuit.

Impurities in the plates and electrolyte may cause internal discharge, which, though not exactly the result of short

circuit, yet brings about the discharge of the cell even on open circuit.

Sludge gathering at the bottom of the jar may become so deep that the bottom of the plates may be short circuited by it.

Treatment.

In cells with transparent and open jars, short circuits may often be located directly and be removed by passing a strip of wood or ebonite between the plates.

Removal of sludge is best carried out by a thorough cleansing of the cell and refilling with fresh electrolyte.

In sealed and closed batteries the jar must be opened up and the plates taken out, examined and treated, according to circumstances.

When a battery consists of two or more cells in series, and it is apparent from loss of capacity or otherwise that a short circuit is present, it is no use simply testing the terminal voltage to determine the condition of the battery. Each cell should have its voltage and specific gravity tested at the conclusion of charge or discharge. Low readings will at once indicate the faulty cell. Unless this be done the repeated charging to which the battery as a whole will no doubt be subjected in an endeavour to restore its voltage and capacity to normal, will not only not do it any good, but will be positively harmful to those cells in the battery which are not short circuited and consequently being overcharged.

Individual cell attention to voltage, specific gravity, gassing, and addition of water to restore the electrolyte level is essential at all times if the battery is to be kept in good and useful condition.

LOSS OF CAPACITY

Indication.

The battery "runs down" very quickly after charging, perhaps even when no discharge is being taken out of it.

Cause.

All the diseases previously discussed affect the capacity of the battery. Investigation of these must therefore be made, and the indications are often so clear that further tests need not be applied to determine the cause of the battery's failure.

LOW DENSITY OF ELECTROLYTE

Whenever the condition of the electrolyte is in question, the operator should consider the condition of the cells as regards charge and discharge. When fully charged, the active material contains no sulphate and the acid is most dense. When discharged, the active material is largely sulphate and the acid weakest. The corresponding or correct specific gravity, under certain conditions, therefore can be judged.

Cause.

Low density is a natural result of short circuit, but it may result from leakage, excessive gassing and spraying or frothing. It may be due to spilled acid, when testing gravity by syringe hydrometer followed by topping up with water.

Topping is only required to make up for water lost by gassing and evaporation, and should restore the specific gravity to its original value under normal conditions.

Treatment.

If after being fully charged the specific gravity is below 1.245 for celluloid batteries and 1.295 for car batteries, withdraw a quantity of electrolyte and make up with acid of 1.400 specific gravity. Recharge to mix the newly added acid and test half an hour after switching off the supply. Repeat until the specific gravity reading is correct. If, after several trials, the specific gravity refuses to rise on charging, the cell must be examined for short circuit.

REVERSAL OF CELLS

This is generally due to short circuit, so that as a result, a particular cell is already discharged, more or less, when the others are just beginning to be discharged. As the discharge continues, the run-down cell adds nothing to the output and is finally charged in the wrong direction by the discharge current passing through it. The + plate thereby is partially converted into spongy lead, just as if it had been charged the reverse way from the mains, and the - plate is covered with peroxide. Such a cell, therefore, will show a reversed voltage and actually detract from the voltage available at the battery's terminals. On charging up the battery from the mains, the voltage of the defective cell will be reversed and corrected, and if the short circuit has been removed, the cell, if treated lightly for some time, will regain its lost capacity.

LOSS OF ACTIVE MATERIAL

Indication.

Reduced capacity, necessitating more frequent charging.

Cause.

The faults producing this have been frequently mentioned in previous pages. Shedding of active material takes place more at the positive than at the negative plates, hence these require more frequent renewal. Generally, three sets of positive plate renewals are required to two of negatives.

Excessive gassing and sulphation is perhaps the chief cause of shedding, and should be avoided in normal operation.

Treatment and Prevention.

If the plates are sulphated, the charging current should be very much below normal rate to prevent excessive heating and expansion. At normal rates, sulphation

produces local gassing in the reduced conducting portions of the plates.

SLUDGE

Cause.

This is the name given to the sediment which collects at the bottom of the jars. It is the result of bad treatment or excessive vibration. It represents lost active material, and its excessive production indicates wrong treatment and results in direct loss of capacity. It is produced by shedding, and may be short circuiting the plates dipping into it, with consequent internal discharge, loss of capacity, and sulphation of the plates.

Treatment.

It is advisable to thoroughly clean out all batteries once per year after a full charge period, and replace the electrolyte. The gravity of this should be 1.245 to 1.250 for celluloid cells and 1.290 to 1.300 for starting batteries.

The acid which is drained off from the settled sludge may, if desired, be used again—but the impurities it contains are retained, and it is not advisable to so economize in small batteries.

GENERAL INDICATIONS OF DISEASE OR FAULTS

Bad conditions due directly to wrong treatment may result in the following indications—

High specific gravity when discharged.

Low specific gravity although gassing.

Impossible to charge the battery.

Temperature trouble.

High Gravity.

This may be the direct result of topping with acid instead of water. Charge at a current equal to about $\frac{1}{10}$ A.h.

capacity to gassing point, remove some of the electrolyte, and replace by water. Test specific gravity half an hour after a subsequent charge and adjust till correct.

Low Gravity.

Treated previously on p. 99.

Open Circuit.

Loose terminals, or connections insulated by corrosion and dirt, will probably account for an open circuit on the battery. Clean all connections, examine for broken wires, tighten connections, and smear with vaseline after rectifying. If the battery shows closed circuit by giving voltmeter reading, the dynamo connections and leads must be examined.

Temperature Trouble.

Occasionally the temperature of the battery rises rapidly when on charge. This may be due to charging at an excessive rate or overcharging consequent on small discharges from the battery. The position of the battery on the car should be examined with regard to its position near hot portions of the engine, or exhaust, and rectified accordingly. Shedded active material, burned separators, and buckled grids will result from excessive temperatures.

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CHAPTER X

REPAIRS AND WORKSHOP

CAR BATTERIES

If the battery has been charged, specific gravity corrected, terminals examined, and still the fault persists, or the indications at once suggest internal trouble, such as short circuit or excessive sulphation, the battery must be opened out for examination. The procedure for sealed-in batteries may be briefly summarized as follows—

Cleaning of case, terminals, and cover.

Removal of connecting straps.

Removing covers and compound.

Examination of plates.

Recharging.

Pressing and straightening.

Reassembling and insertion of separators.

Replacement in jars and filling with electrolyte.

Resealing, recharging, and putting into service.

Cleaning Case.

Wipe or scrape off all dirt and give a thorough clean with a cloth dipped in soda or ammonia. Make a sketch of the connections and location of the cells for future reference.

Removing Connecting Straps.

Various types of cells require different treatment, but the following notes will be found to have a general application.

Exactly centre punch the top of a post, and with a bit the same diameter as the post drill about half-way through the connecting strap. Use a screw-driver as a lever and a

strip of steel laid along the top edge of the case as a fulcrum and gently force off the strap. If the connector is difficult to release, heat may be applied to soften the lead, when it will come off more easily.

Removing Covers and Compound.

Clear all gas from within the cells by means of a hand-bellows to prevent an explosion when a flame is applied.

If there are any sealing nuts for locking posts and covers together, remove these with the tools provided. Warm the cover by means of a spreading blow-pipe flame. Run the flame along the edge of cover and case, and remove the compound from the edge. When the compound is soft, insert the heated point of a screw-driver into the joint between cover and case. Move the screw-driver along to free the edge, then press it under the cover near a post until it emerges on the opposite side. Clear away the compound and gently lift off the cover. Apply the blow-pipe to the compound above the bottom cover and dig it out with a screw-driver.

After this, pass the tip of a small flame along the joining of bottom cover and jar, and by means of a screw-driver free the lower covers from the inside of the case and the tops of the jars. Lift out the groups of plates by means of two pairs of pliers. Rest the plates for a few minutes only, in an inclined position, across the top of the case to drain.

Remove all covers, scrape, and clean with a cloth dipped in petrol. If bent, they can be softened again if necessary by being placed in boiling water, and straightened by cooling on a flat board. Label and store until required.

Examination of Plates.

Place a group of plates on their edges, with the posts away from the operator. Gently prise open the plates and examine. If in condition for further service, insulate any

visible short circuits by inserting small pieces of ebonite or separator. Replace in jars and charge fully. This charge should be given before any attempt is made to straighten the plates. It softens the plates and makes them in the best possible condition for handling.

After fully charging, drain, remove a few separators with the help of a putty knife pushed between separators and negative plates; place on a board in an upright position and, grasping a post in each hand, gently toggle the two groups backwards and forwards until they are separated.

Examine the plates in detail for hard, shiny, sulphated surfaces; buckled, and cracked frames, and emptied grids.

Straightening Plates.

The negatives should always be kept in water except during the few minutes they are being attended to.

Wash thoroughly and insert boards of the correct thickness between the plates. Clamp tightly between end boards in a vice or press for 5 min. Meanwhile prepare a second group for pressing. Replace in water to prevent heating immediately the operation is completed.

If it is considered safe to attempt the pressing of the positives, do this in the same way as the negatives. Usually it is only advisable to straighten them with a pair of pliers.

Separators.

If these are of wood, especially if badly burnt or no longer porous, replace them. Rubber separators, unless broken in handling, last indefinitely and may be used again.

Nest the positive and negative plates of one unit together on the bench on edge, with the bottoms of the plates towards the operator. Insert a new separator, if needed, about midway in the group, with the grooved edge next to the positive plate. If rubber sheets are used, they should be inserted with the wood separators, between the grooved side and the positive plate. Work alternately to

right and left of the centre, inserting separators until the job is finished.

Stand the group upright, gently line up the edges of plates and separators with a block of wood. By means of the terminal posts and pliers, lower the reassembled group into the jar as carefully as possible, so as not to break it.

Fill up at once with acid of 1.300 specific gravity for car batteries with wood separators, and 1.275 for rubber separators.

Resealing the Jars.

Warm the tops of the jars, clean with a knife, and press until straight if necessary. Clean the lower covers with rag dipped in ammonia to remove all acid, or the compound will not stick. Warm until they are limp enough to handle safely and press gently into position above the jars. Caulk any cracks at edges or posts with asbestos string, or fit rubber gaskets if provided. For convenience in pouring, warm the compound in a coffee-pot over a gas burner and fill above the lower covers with fairly soft compound. Make a good joint between compound and case by running a hot iron around the inside edge.

Complete the filling with softer compound to the top of the case. While the compound is hot, make the top covers limp by gently heating, and, fitting them over the posts, press well down into position. Clean off any exuded compound with a knife, and fill in any cracks around posts or edges with compound. Fasten lock-nuts sealing covers to posts if provided.

Burning on Connecting Straps.

All connecting straps must be boiled in soda and water to clear them of acid. They must be brushed with a wire brush to clean them, and the holes scraped out with a knife.

Insert a large drill in a brace and take a shaving off the top of each post. Scrape the outside with a knife to a slight taper. Place connecting straps over posts, tap into position, and test the voltage of the complete battery to see if it equals the sum of all the cell's voltages. This ensures correct series connection before the cells are finally burnt together.

Blow out all gas from the insides of the accumulators with a pair of hand-bellows. Cover vents and exposed portions with pieces of asbestos.

Get a hot, pointed, blow-pipe flame and play it around the top of the post, starting from the centre. As soon as the lead is melted, take a stick of lead and fill up the hole above the post with molten metal. Heat the stick and the inside edge of the hole at the same time, to fuse the metals together. Keep the flame moving from the centre of the post, upwards and around the connector metal. Do this as quickly as possible, filling up with metal to a level a little above the connecting strap. Finish off with a less hot flame from the centre of the post; gradually working round and outwards, until the inner edge of the connector melts and unites with the molten post. As soon as this is done, lift the flame quickly from off the work, before the outer edge has time to melt and run away. The job, if done quickly, is complete.

• SOLDERING THE CONNECTING STRAPS, USING SOLDERING IRONS

The soldering irons to be used in place of the blow-pipe must be heavy and filed to a fine taper. The heads of the posts must be cleaned with brace and bit as before described and the edges scraped clean.

Heat the iron very hot, file it clean, rub with lump of sal ammoniac, and tin with solder. Dip the tinned iron into spirits of salt to clean. Hold the iron vertically, with its tip resting on the centre of a post. As the lead melts,

hold a stick of solder to the iron, and gently moving the iron about the top of the post, fuse the melted lead and the molten solder together.

Treat each post in this manner. Place cleaned and scraped connecting straps over the posts and tap smartly into position. Rub a plumber's tallow candle as a flux inside the hole above the post.

Tin a freshly heated iron and hold vertically, resting on post as before. Turn the iron round so that its edges touch and melt the inside of the strap. Run in solder to mix with the molten lead, and fill up as quickly as possible. Finish off with flat of iron as neatly as possible.

After completion, adjust level of acid if necessary, and place on charge at about one-third normal rate.

Test gravity half an hour after completion of charge, and adjust to about 1.300 by replacing electrolyte with water or acid as the case may be.

CELLULOID BATTERIES

These have a great advantage, in that an examination can be made without opening out.

The soldering and burning operations, treatment of plates, etc., are exactly the same as for sealed-in batteries of the car type.

The electrolyte, when in fully charged condition, should be about 1.250, however, and not 1.300 as for the heavier type.

To take off the top covers of celluloid, insert a penknife in the joint at the top of the cell and gradually prise open. Follow the crack thus produced and the whole top will soon be free.

To seal after cleaning, etc., procure some amyl acetate and dissolve in it a little scrap celluloid, so as to form a thick solution. Scrape clean the parts to be joined and apply the solution just in the same way as rubber solution is used to join two rubber surfaces.

Fix clips to hold the joined surfaces together until they unite firmly when the clips can be removed.

Pasting Grids.

Paste for positive plates made directly from lead peroxide is not satisfactory and falls out.

The composition of the pastes used for + and - grids varies, but that used for positives generally consists of a mixture of litharge and red lead. This mixture is made into a paste with dilute sulphuric acid (2 parts water, 1 part acid), just thick enough to work into grids with the hands or piece of wood.

It should be pasted partly on one side of the plate and then on the other alternately, as quickly and firmly as possible, until the whole grid is a solid mass. The paste commences to set immediately it is made, and the plates are left to complete the hardening process for several days in the air or in ovens.

Negative plates are pasted in a similar way with a paste of litharge and dilute sulphuric acid, and allowed to harden in the same way as the positives.

The hard concrete mass which results in both cases is largely lead sulphate, and the next operation is to form this into lead peroxide on the positives and pure lead on the negatives.

To do this the negatives are grouped together and the positives are grouped together and given a charge for 70 or 80 hours in acid of specific gravity 1.300 and 1.250 for car or celluloid batteries respectively.

The plates, after forming, are best placed in the jars directly for immediate use, but, if desired, the positives may be rinsed in water, dried, and stored; and the negatives simply drained and dried and stored, though they tend to heat up and are far better if put into service immediately.

LAYING UP, OR PUTTING BATTERY OUT OF SERVICE

There are two methods available for laying aside a battery when it is not going to be required for some considerable time. These might be termed the wet and the dry methods respectively.

Wet Method.

This is the simplest and best method to adopt when the battery is only going to be out of requisition for a few weeks or months and it is possible to give it a little attention occasionally.

Fill up to correct level with water and charge fully at normal rate. Clean the case, connecting bars, and terminals with a cloth dipped in ammonia. Smear all metal parts liberally with vaseline. Place in a dark position where there is no danger of frost or excessive temperature.

Every two months attend to level of the electrolyte and give a freshening charge at normal rate until the battery is fully charged. Attended to in this way the battery may be safely stored for any length of time.

Dry Method.

This is the only available method where the battery has to be put aside for a long period and no attention is possible.

(a) Charge the battery fully. Empty out the acid and fill the jars with distilled water. Take out the positive plates at the end of 15 min. Leave the negative plates in the water for at least 24 hr.

Drain the positive plates and straighten them with pliers if their condition allows of it.

At the end of the longer period take out the negative plates, fit boards, and straighten in vice or press.

Examine the negative plates periodically for some time, and if they heat, dip in clean water. This dipping must be repeated until all signs of heating of the negatives

disappears. Store the plates separately in a dark room, free from excessive temperature ranges.

Clean covers, terminals, cases, and jars, label and store.

Wooden separators are almost invariably thrown away.

(b) Another method is to empty the electrolyte from the jars and immediately refill these with water. Discharge the battery down to 0.5 V. per cell. Empty the jars and allow the plates to dry. If the negatives heat up, sprinkle them with water to cool. When the heating does not recur, dry the plates and store as directed above.

PUTTING INTO SERVICE AFTER LAYING UP

Batteries stored in the wet method only require a full charge and light treatment for a time to bring them back into full working order.

Batteries stored in the dry way want treating in something like the "First Charge" method given to a new battery.

Make sure that the supply, instruments, etc., are ready for a long charge. Replace the separators. Fill the jars with acid of 1.300 or 1.250 for car and celluloid batteries respectively, and charge immediately at normal rate, until every plate in every cell is fully charged. Discharge slowly to 1.85 V. per cell by the discharge board. Charge again, and again discharge. Again charge, and at the end of the period correct the specific gravity of the electrolyte of each cell.

The battery is now ready for service, but subsequent discharges for some time should be as light as possible, and followed as soon as convenient by full charges.

CHAPTER XI

EDISON IRON-NICKEL-ALKALINE CELL

ALTHOUGH the lead acid cell has come to be looked upon as the combination for an accumulator, any substances which will give reversible changes in composition on charge and discharge may be used to form a storage cell.

The only other combination used for commercial purposes is the Edison iron-nickel-alkaline cell.

Positive Element.

The positive plate is made up of perforated steel tubes filled with alternate layers of tightly compressed nickel hydroxide and metallic nickel flakes. These tubes are strengthened by a framework of steel rings, and numbers of them clamped rigidly in a steel frame form a positive plate.

The tubes are seen in the positive grid shown in the illustration.

Negative Element.

The negative plate is built up of a large number of rectangular pockets filled with powdered iron oxide. The pockets are enclosed in a corrugated steel grid forming the negative plate.

Groups of plates are formed by bolting the units to steel connecting rods fitted with steel terminal pillars. Rubber separators are fitted between the plates, and also between the edges of the plates and the sides of the steel-containing jar.

Electrolyte.

This is an aqueous solution of potassium hydroxide or caustic potash, having a specific gravity of 1.400. This

hydroxide combines with the carbon dioxide present in air, forming potassium carbonate, which is useless in the cell. For this reason the cells must be airtight. It has no effect, however, on the steel containing jars, which is a great advantage over the lead acid cell.

After a period of six or twelve months, according to the duties the cell is called upon to supply, the electrolyte must be replaced.

Topping up is done with pure water when necessary.

Formation of Plates.

After being assembled, the cells are put through a series of four cycles of alternate charge and discharge, after which they are ready for service.

Working Characteristics.

The capacity per pound weight of cell is about 50 per cent greater than that of the lead acid cell. The voltage required for charge is about 1.75 per cell, and on discharge the cells maintain a voltage of about 1.2 at normal rates.

The advantages this cell possesses are due to its great mechanical strength and consequent suitability for heavy vehicular work. Coupled to this it possesses valuable electrical properties. It may be short circuited with impunity. Over discharge does not appear to permanently injure it, and if left standing for months, even in a discharged condition, it suffers no detriment.

Boosting charges of five times the normal rate, with relatively high efficiency, may be given when desirable; and the only maintenance charges appear to be the replacement of the electrolyte after several months' service.

Indications of State of Charge.

Since the cell gases throughout the whole of the charging period, it cannot be utilized as an indication of the completion of the charge as in the lead acid cell.

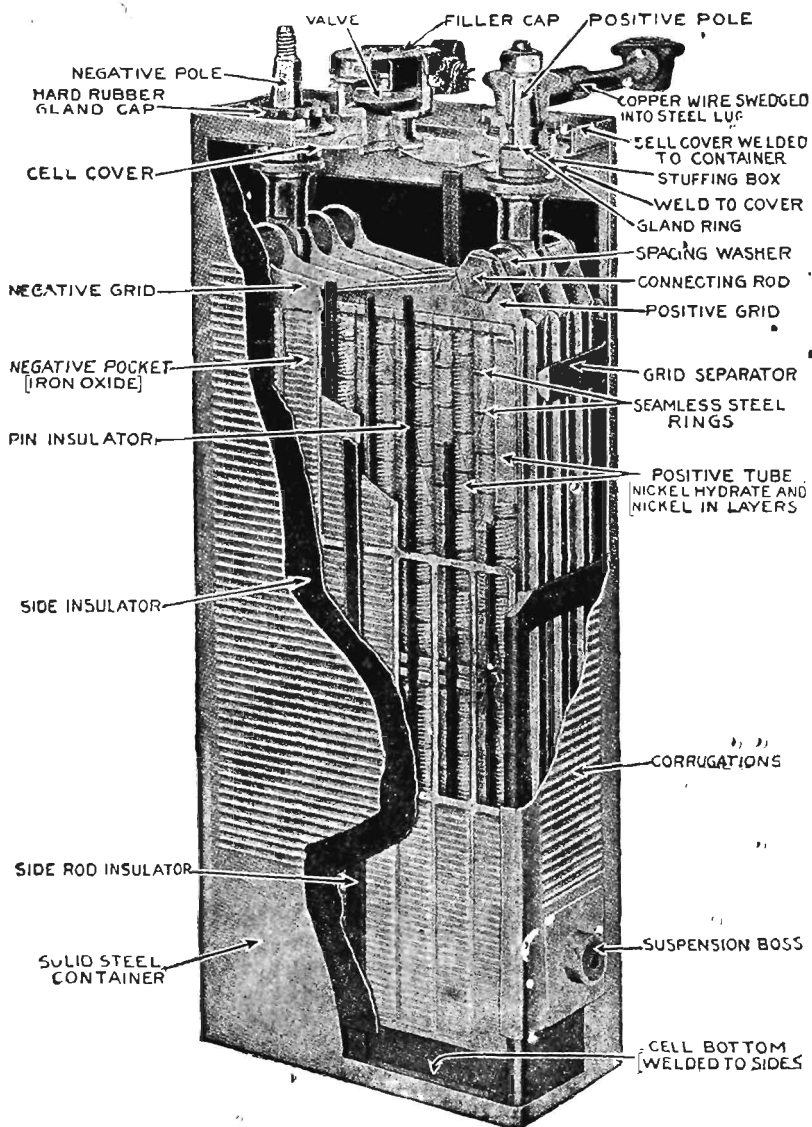


FIG. 33. SECTIONAL VIEW OF EDISON IRON-NICKEL-ALKALINE CELL

Similarly, the specific gravity of the electrolyte is of no value for this purpose, since this remains constant under all conditions of charge and discharge.

The state of the cell, therefore, is judged solely from a study of its voltage.

When fully charged it is about 1.75, and the cell may be taken as discharged when it falls below 1.2.

The rate of charge should never be below the normal rate prescribed for any particular cell by the makers, but the maximum limit is only reached when the temperature of the electrolyte exceeds 115° F.

Storing.

This requires no elaborate preparation. Clean the case and connections, fill to correct level with electrolyte and store in a dry room. This is all that is needed, and the cell may be thus left safely for any length of time.

The illustration (Fig. 33) clearly shows the component parts of the plates and container.

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