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Lesson Text No. 18

RADIO BATTERIES THEIR CONSTRUCTION AND OPERATION

Originators of Radio Home Study Courses
···Established 1914···
Washington, D. C.

Regularity Important

A Personal Message from J. E. Smith

Most persons, nevertheless, do find it worthwhile to have a definite time and a definite place to study. What the place and time are does not matter so much as their definiteness and regularity. One should plan how much time he can give to study, not setting up too much time at first, at what hour and on what days he will do the work, and where he will do it.

Then he should stick to his plan. For success in writing, study, or any other occupation that requires concentration, a keeping to one's plans counts enormously.

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RADIO BATTERIES AND THEIR CONSTRUCTION

The entrance of many forms of tubes, both for receiving and transmitting, has created a demand for a direct-current source of supply which is free from even the slightest fluctuation in voltage. For a long while primary cells usually of the so-called dry cell type, and secondary (or storage) batteries far outrivalled any other source of power for use with a vacuum tube receiving set, but the popularity of various battery "Eliminators," the general name applied to any battery substitute, is steadily increasing.

Before investigating at length the available sources of power, it would be well to call to mind the type of demand or load that will be imposed upon them. First, there is the filament of the tube which is usually of the five volt type and consumes .25 ampere, although there are others which operate at a pressure of 1.5 volts and consume .25 ampere and still others which function at a 3 volt pressure and draw .06 ampere. Generally, therefore, it may be stated that a suitable source of power for the filament or "A" circuit (as it is more commonly known) is one of a comparatively *low voltage*, capable of delivering a *fair load* for a considerable time at a constant pressure, or in other words of low voltage and of substantial current capacity.

Second, there is the plate of the tube which is to be maintained at a voltage depending upon the type of tube and the use to which it is put, a soft detector tube requiring only from about 16 to 22½ volts while a hard tube may be used with from 45 to 150 or more volts on its plate. The current consumed in either case is very small, being expressed usually in milli-amperes so that a suitable plate or "B" source of energy is one of high *voltage*, preferably supplied with taps, whose *current* capacity need not be very high.

Third, since there is extremely little current flowing in the grid circuit of a tube, the current capacity of the "C" or grid battery is practically of no importance. The battery is usually tapped to provide voltages ranging from 1.5 to 9 volts, although the new power tube UX120—requires a 22½ volt bias.

DRY CELL BATTERIES

The dry cell, of the size and type well known, in external appearance at least to even the most inexperienced layman, is suitable as an "A" or filament battery in any set where the current demand is not too high or too prolonged. A dry battery composed of several dry cells, much smaller in size than the one just mentioned, connected together and sealed in a compact block, serves as a good all around "B" or "C" battery depending upon the number of cells used.

The modern dry cell is the result of extensive experimenting that began when Volta discovered that an electrical pressure or voltage was developed between two unlike metals placed in contact with certain liquids. He learned by research that all metals have a relationship to each other, and if one metal such as zinc is brought into contact with another metal such as iron, an electric current will flow. This phenomenon can be readily demonstrated by any one. One of the simplest experiments is to take a copper penny and a silver dime and lay between the two a moistened piece of paper. If the two terminals of a pair of phones are placed one on the dime and the other on the penny, a click will be produced in the phones. *This* indicates that, in the circuit consisting of the penny, the moisture, the phones and the dime, a current is flowing which is caused by the voltage or electromotive force being produced by the contact of the two dissimilar metals.

A scale for the different metals has been worked out, showing which metals are most positive and which are least positive. The following list is so arranged that the metal first on the list becomes positively electrified when touched by any taking rank after it:

+ Zinc
Lead
Tin
Iron
Copper
Silver
Gold
— Graphite.

For example, zinc is more positive than iron, but iron when used with graphite becomes the positive element. In the experiment given above the copper penny is more positive than the silver dime.

Going still further, Volta found that certain liquids acted in a similar manner when brought into contact with metals.

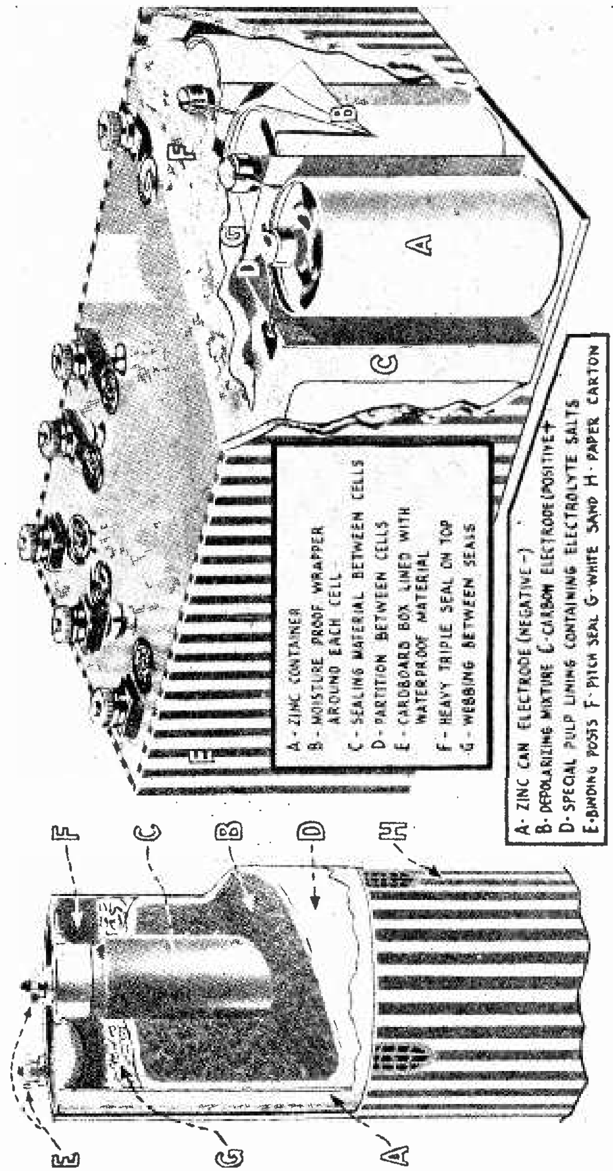


Fig. 1.

He found that by virtue of the chemical action between the liquid and the metals, a source of voltage can be produced that will cause a current to flow when the unit is connected to an outside source. *He therefore had a device that converted the chemical action between the liquid and metals into electrical energy.*

The dry cell in common use at the present time is an outgrowth of the Leclanche cell, which is a voltaic cell with poles or electrodes of carbon and zinc immersed in a solution of sal-ammoniac. The zinc unites with the sal-ammoniac (NH_4CL) forming zinc chloride ($ZnCL_4$) ammonia (NH_3) and hydrogen (H). This chemical action causes the zinc to become negative with respect to the carbon so that a current of electricity will flow in a wire connecting them. However, this action is hindered and eventually stopped by the bubbles of hydrogen (—) which collect on the carbon (+), practically substituting a sheet of hydrogen for the carbon. This action is called polarization. To prevent this, an oxidizing agent, manganese dioxide (MnO_2), is packed around the carbon pole to combine with the hydrogen preventing the latter from collecting on the carbon. This action is called depolarization. The E. M. F. resulting from this combination of elements is 1.5 volts regardless of the size of the elements. The current capacity is, however, affected by the physical dimensions of the zinc and carbon electrodes.

In the accompanying Figure 1, we have the modern dry cell, which strictly speaking is not "dry" at all as will appear, with the zinc can forming one of the electrodes. On the inner side of the can is a paper liner saturated with a solution of sal-ammoniac. Between the liner and the carbon pole, there is a layer of "mix" which consists of carbon and a high grade ore of manganese dioxide thoroughly mixed. The carbon serves as an electrical channel for the passage of the current to the carbon pole, reducing the internal resistance of the cell, while the manganese dioxide changes the hydrogen to water. Near the top of the cell is a layer of sawdust and sand. This space affords an expansion chamber for excess gas and electrolyte. The cell is sealed with pitch to retain the liquids and to prevent evaporation.

Battery manufacturers have designed a dry cell, which although exteriorly similar to those used for door-bell and ignition systems, has a life that is double that of its prototype. This result is attained by using special mix material to maintain high *closed* circuit voltage during heavy current drain, and by employing a special electrolyte which saturates a special pulp paper line of low electrical resistance but of great mechanical strength.

"B" batteries are an assembly of small dry cells soldered together in series, i. e., the carbon of one to the zinc of the next, usually in blocks of 15 or 30 cells giving 22½ and 45 volts, respectively. See Figure 1. The construction of the individual cell is the same as in the larger size just described. In the assembled block "A" is a one-piece seamless zinc can which requires heavier, more pure and more uniform metal than a solder can, all of which add to the life of the cell. Also, it prevents any leakage through a weak joint and eliminates voltage differences on the inside of the can, a condition which might cause stray currents and potential differences and results in noisy voltage fluctuations and short-lived battery.

Fig. 2
22.5 Volt "B" Battery
Vertical Type.

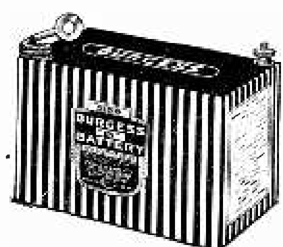


Fig. 3
"C" Battery, Large Size.

"B" is the moisture-proof wrapper around each cell, one of the ways in which individual insulation is secured.

"C" is a sealing material between cells to provide additional insulation and prevent movement between cells.

"D" is the water-proof partition between cells, another feature in the individual cell insulation and a means of confining internal moisture due to cell discharge within the compartment.

"E" is the heavy water-proof non-metallic insulating material, the first line of defense against moisture getting into the battery. As it is non-conducting, it will not collect stray currents and produce capacity effects between adjacent batteries.

"F" is the heavy triple seal over the top, another factor of safety which adds to the strength of the battery and increases the moisture-proof qualities.

"G" is the webbing between seals, adding to the strength of the top.

The cells are sometimes arranged in two vertical layers to reduce table space.

TABLE 1

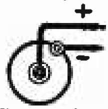
Dry Cell Batteries for Various Vacuum Tubes

	CLASSIFICATION OF TUBES WITH RESPECT TO NECESSARY BATTERY AND TUBE FILAMENT CURRENT		DRY CELL BATTERY TUBES				Storage Battery Tubes	
			Low Current	High Current				
VACUUM TUBES CHARACTERISTICS	Vacuum Tube Style Number		UV or UX 199 C 299 DV 1	WD 11 WX 12	UV or UX201A C301A	UX-120	UX-112 UX-112A	UX-210
	Filament Volts		3.0	1.1	5.0	3.0	5.0	6.0
	Filament Amperes		0.06	0.25	0.25	0.125	0.5 UX112A 0.25	1.1
	Rheostat Ohms		30	6	6	20	6	None
BATTERY VOLTS	"A" Battery Volts (Filament Battery)		4.5	1.5	6.0	4.5	6.0	6.0
B	"B" Battery Volts (Plate)	Tube as Detector	22.5 to 45	22.5 to 45	22.5 to 45	Not a Detector	90.	Not Used
		Tube as Amplifier	45 to 90	45 to 90	45 to 112.5	135 Audio Amplifier	157.	90
	"B" Battery Current (Plate) Milliamperes	"B" Volts 22.5 / 45 / 90; No. "C" Volts	0.3 1.5 4.0	0.4 1.5 4.0	0.6 1.5 4.0	6.5 When used with high Voltage	Det. 2.4 Amp. 5.8	3.0
			These currents can be reduced by a "C" voltage					
	"C" Battery C Volts (Grid Bias) Tube as ampl.	"B" Volts 45-67.5 67.5-90 90-112.5	1.5 to 3.0 3.0 to 4.5	1.5 to 30 3.0 to 4.5	1.5 to 3.0 3.0 to 4.5 4.5 to 6.0	22.5 Not used as a Detector	Det. 6.0 Amp. 10.5	4.5

Fig. (A)

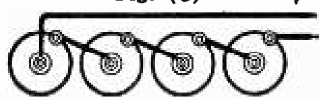
Series, 4.5 Volts

Fig. (B)



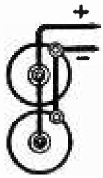
Single Cell
1.5 Volt

Fig. (C)



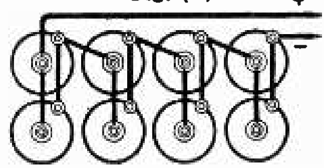
Series 6.0 Volts

Fig. (D)



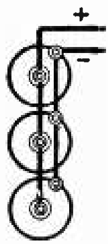
Parallel
1.5 Volt

Fig. (E)



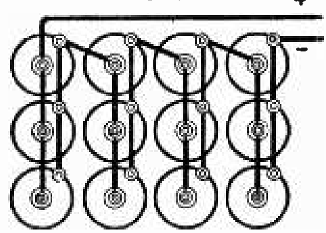
Parallel Series, 6.0 Volts

Fig. (F)



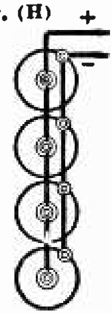
Parallel
1.5 Volt

Fig. (G)



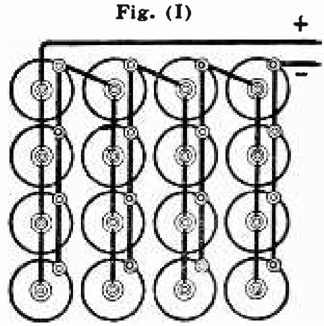
Parallel Series, 6.0 Volts

Fig. (H)



Parallel
1.5 Volt

Fig. (I)



Parallel Series, 6.0 Volts

Fig. 4.

A "C" battery is identical in construction with one of the "B" type, the difference being only that it is usually composed of three or four cells instead of 15 or 30 resulting in, of course, a correspondingly low potential. Fig. 3.

Table I will be extremely helpful in the selection of proper "A," "B" and "C" batteries for a given installation.

CONNECTING BATTERIES

Explaining the terms "Series" and "Parallel" which are applied to modes of connecting batteries; cells are connected in **series** when the positive pole of one is connected to the negative of another, the resulting voltage being the sum of the voltages of the individual cells. For example, two dry cell "A" batteries in series will produce double 1.5 volts or a total of

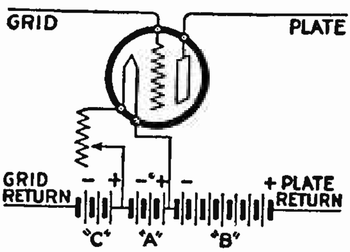


Fig. 5.—Connections for A, B, C Batteries in a Radio Set.

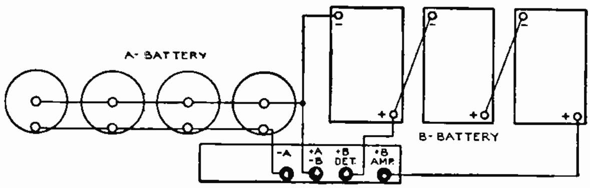
3.0 volts at the terminals. In "B" batteries, usually fifteen cells are soldered together in series and the voltage is, therefore, 22.5 volts. Series connection has no effect on the amount of current which can be taken out at the leads as the current must flow through each cell in turn, and it is limited by the smallest amount produced by the zinc of any one cell.

Series connection multiplies the voltage and does not affect the current capacity.

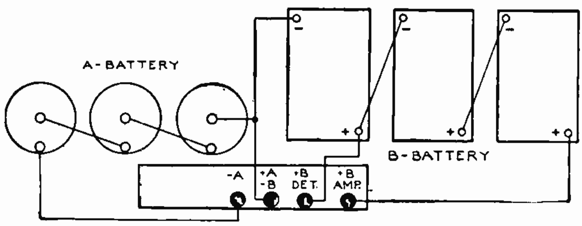
Plate I on page 9 shows four illustrations of A and B batteries assembled in various ways for operating Radio receiving sets.

Parallel connection of dry cells is made by connecting the positive of one to the positive of the other and the negative to the negative, see Fig. 4, B, D, F, H. In parallel connection there is no change of the voltage, but the arrangement is equivalent to increasing the amount of zinc surface and this results in an increase of the available energy as current. As a matter of fact, doubling the number of cells in parallel more than doubles the available energy. Parallel connection, therefore, is recommended to reduce the unit cost of battery energy.

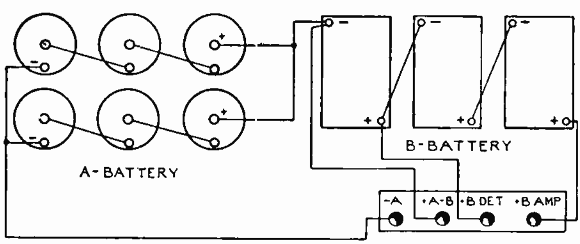
SHOWING BATTERY CONNECTIONS WHEN USING
1½ VOLT TUBES, SUCH AS WD-12



SHOWING BATTERY CONNECTIONS WHEN USING
3 VOLT TUBES, SUCH AS UV-199



SHOWING BATTERY CONNECTIONS WHEN USING
3 VOLT TUBES SUCH AS UV-199



SHOWING BATTERY CONNECTIONS WHEN USING
6 VOLT TUBES SUCH AS UV-201A

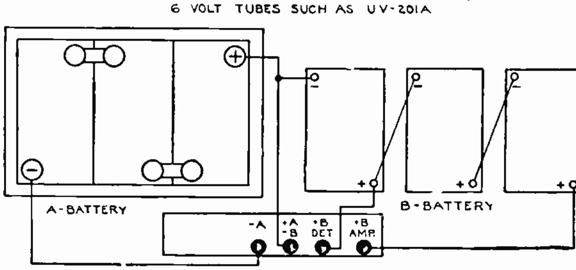


Plate I.

With vacuum tubes which must have a definite current, it is seen that by connecting the dry cells in parallel the necessary current is divided between the cells. For example, a 0.25 ampere tube when connected with cells in parallel has the current divided depending on the number of cells thus connected. With two cells, each would furnish 0.125 ampere; with three cells, each would furnish 0.0833 ampere. As the current in a cell is reduced the cell becomes more efficient and lasts longer. This explains why parallel connections between cells will reduce the cost of battery energy.

Parallel connection multiplies the available current capacity and does not affect the voltage.

Dry cells are sometimes connected in **parallel series** when it is desired to increase both the current capacity and the voltage. For example, if the current capacity is to be doubled, or the current drain per cell cut in half, two cells are connected in parallel thus increasing the zinc area. If the voltage is then to be trebled, three of such parallel connected units are wired in series. Referring to Fig. 4, figures (e), (g), (i), one can imagine that each set connected in parallel vertically is equivalent to one large cell of 1.5 volts and the current increased proportionally and that any number of these units are then connected in series increasing the voltage proportionally. Fig. (f) shows three cells in parallel, Fig. (c) four cells in series and Fig. (g) three cells in parallel and four in series.

TESTING BATTERIES

The dry cell type of "A" battery of the standard size can be tested by touching the terminals of an ammeter across the binding posts of the cell. A new and fresh cell should give a reading of 30 to 35 amperes.

The proper way to test either a "B" or "C" battery is to use a good high resistance voltmeter. The open circuit voltage, that is with no load other than the voltmeter, should be 1.5 per cell.

The "A" battery needs replacing if the signal strength is below normal, when the filament rheostat is moved to the furthest "on" position. It is also indicated to the eye by a dimming of the filament in the tube.

While the nominal voltage rating of a 15 cell "B" battery is given as 22.5 volts, the actual voltage of a satisfactory "B" cell is slightly under 1.5 volts. Consequently, the complete battery, when tested on a voltmeter, may not test quite 22.5 volts, but it should not be considered defective for this reason.

The minimum working "B" voltage of a detector tube is about 17 volts. Therefore a "B" battery should give results until its voltage drops to this figure. Some "B" batteries, when their voltage drops, cause noise in the phones and, if this is the case, the battery should not be used. A low voltage "B" battery may produce weak or wavering signals.

The "C" battery should be replaced when its voltage has dropped to 1.0 volt per cell. An exhausted "C" battery usually produces distorted signals.

STORAGE BATTERIES

The batteries just described are "primary" batteries, that is, they are capable of spontaneously generating electric energy without being supplied by some outside force. As no doubt the student will recall, this generation of electricity is at the

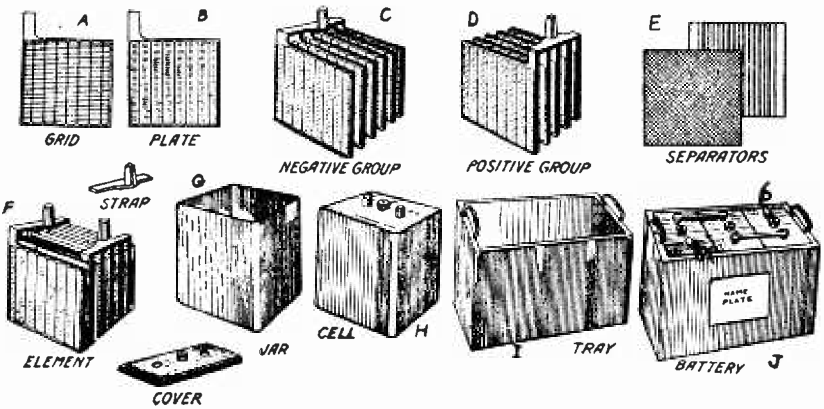


Fig. 6.—Parts of a Standard Storage Battery.

expense of the zinc electrode which is consumed or, more correctly, changed to zinc chloride. It is evident that as the zinc is eaten away the capacity of the cell decreases until eventually it becomes "dead." There is no way of reviving a dry cell when the zinc has been so destroyed and the cell must be discarded.

In contradiction to this "primary" type of battery which although it generates its own power must be thrown away after a comparatively short time, there is a "secondary" type known as the storage battery which must first be supplied with electrical energy or "charged" before it is capable of delivering current but has the advantage that it can be "recharged" almost an indefinite number of times.

To prevent a possible misunderstanding, it must be stated that the term "storage" is not the proper term. There is no storage of electricity. A current of electricity flowing through a secondary battery merely changes the composition of some of the components of the battery in such a manner that it will deliver current for a time. Although there is actually no storing of electricity, the practical effect is the same as if there were.

We may divide storage cells into two principal types, as follows:

1. The Lead cell.
2. The Edison cell.

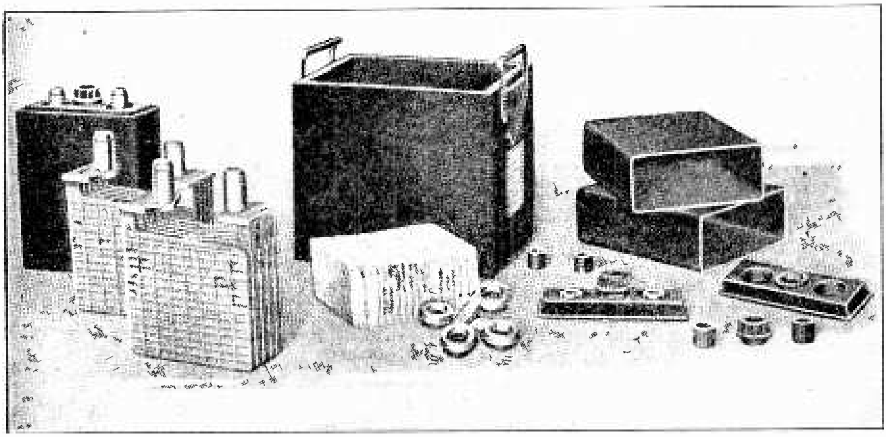
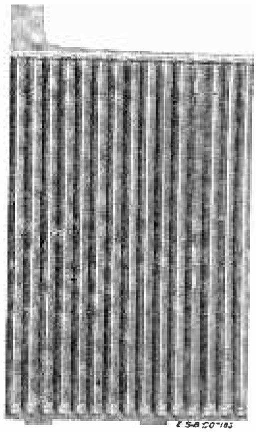


Fig. 7.—Partly Assembled Lead Storage Battery.

THE LEAD CELL

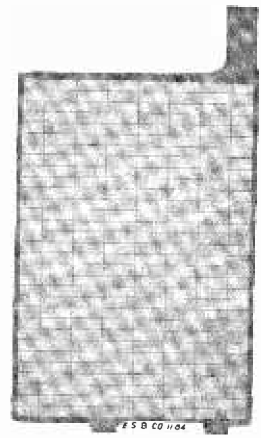
The lead cell has plates of lead and lead oxide and an electrolyte of dilute sulphuric acid. Although the physical appearance of lead "A" and lead "B" batteries differ, the general construction of the elements is the same and the action identical.

A popular type of storage "A" battery is made of a number of lead plates (see Fig. 6) containing holes or grooves which are coated with a paste made of red lead or litharge (see Fig. 8-B). Alternate plates are connected to different terminals, those connected to the negative terminal being one more in number than those connected to the positive terminal. The plates are placed in a vessel containing a dilute solution of sulphuric acid added. (See Fig. 7). A current of electricity is then caused to flow through the cell for a number of hours, the result being that hydrogen gas collects on the plate from which the current leaves the cell. This hydrogen gas combines with the oxygen of the plate, leaving the paste in the form of spongy lead. At the same time, the place at which the current enters the cell is absorbing oxygen, converting the paste into lead peroxide. Finally, one



A
The Positive Plate

Fig. 8.



B
The Negative Plate

plate will be filled with spongy lead, forming the negative plate while the other plate is filled with lead peroxide and is termed the positive plate. (Fig. 10—discloses an "Exide" battery, or

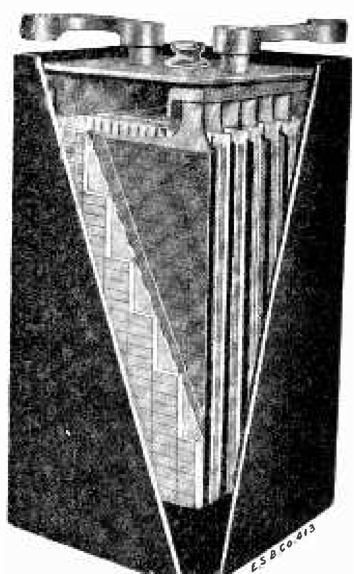


Fig. 9.—Cutaway View of an Assembled "Exide" Lead Cell.
Courtesy of The Electric Storage Battery Co.

number of cells in a common casing, using this construction). On discharge a reverse action takes place.

When a cell is placed on discharge the current is produced by the combination of the sulphuric acid of the solution with the active material of the plates. The product of this combination is lead sulphate and water. The lead sulphate fills the pores of the active material, and the water is left in the solution, causing it to become thinner. The volume of sulphate formed by this combination is greater than the volume of lead which entered into the combination. The result of this is that as the discharge goes on, the sulphate which fills the pores in the plates prevents the action of the solution on the active material. Therefore, the voltage will gradually drop as more and more sulphate

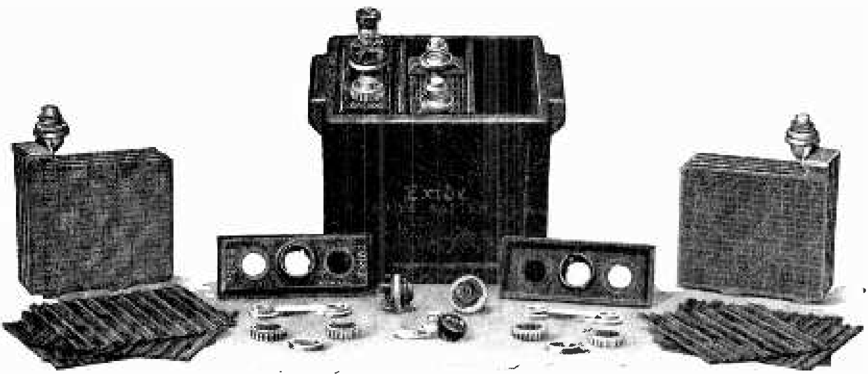


Fig. 10.—Exide Storage Battery, Showing Parts of One Unassembled Cell.

is formed. The voltage of a lead cell at the beginning of discharge is ordinarily about 2.1 while the lower limit is 1.75. The voltage at normal discharge rate should not be allowed to drop below 1.75, because after this point is reached the voltage falls off very rapidly.

In charging, direct current of greater voltage than the open circuit potential of the storage battery is caused to flow through the cells in an opposite direction to that which the current takes when the cell is discharging.

The sole object of charging, then, is to drive the sulphate from the plates back into the solution, thus leaving spongy lead on the negative plate and lead peroxide on the positive.

Chemical Action on Discharge. Consider Fig. 11. The sulphuric acid, H_2SO_4 acts chemically upon the lead plate, Pb, and is broken up into positively charged H_2 and negatively charged SO_4. The SO_4 unites with the lead plate, forming lead sulphate, $PbSO_4$, and gives up its negative charge to it. The hydrogen carries its positive charge to the lead peroxide plate, where it gives it up, and unites with the oxygen of the lead peroxide, forming water H_2O. The sulphuric acid in contact with the peroxide plate is also broken up in to H_2 and SO_4. The H_2 of this portion of the acid also unites with the oxygen of the lead peroxide and forms more water. The SO_4 part of the acid instead of going over to the negative plate unites with the lead, Pb, of the lead peroxide plate and forms lead sulphate, $PbSO_4$, on the positive plate. Thus both plates are being reduced to lead sulphate $PbSO_4$. The cell continues to deliver

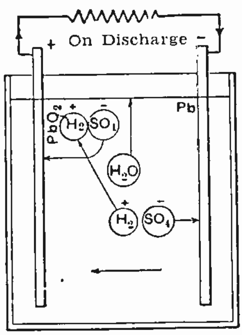


Fig. 11.—The Chemical Action of Lead Storage Cell on Discharge.

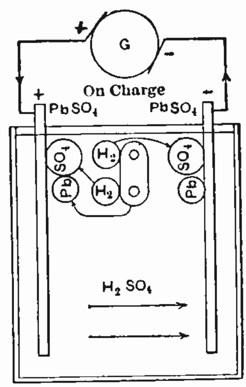


Fig. 12.—Chemical Action of Lead Storage Cell on Charge.

current until the plates are entirely reduced to lead sulphate, when of course, all action will cease, since there would be but one kind of material present, and a battery requires two kinds. The practical limit of discharge, however, is reached long before both plates are completely reduced to the same material.

Note **two things** which are taking place when a cell is discharging:

1st. The acid is continually growing weaker. This results in a lower E. M. F.

2nd. The active materials, lead and lead peroxide, are being replaced by lead sulphate, which has a much higher resistance and is more bulky than the active materials. It therefore takes up more space in the holes of the grids and tends to buckle them; especially if the cell is discharged very rapidly and the lead sulphate forms quickly.

The chemical equations for the different actions on discharge and charge may be written as follows:

Discharge →

$$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$$

← **Charge**

or

DISCHARGING		CHARGING	
Positive Plate	Negative Plate	Positive Plate	Negative Plate
PbO_2	Pb	$PbSO_4$	$PbSO_4$
+	+	+	+
H_2	SO_4	O	H_2
+		+	
H_2SO_4		H_2O	
Produces		Produces	
$PbSO_4$	$PbSO_4$	PbO_2	Pb
+ $2H_2O$		+ $2H_2SO_4$	

Chemical Action in Charging.—Refer to Fig. 12. Assume both plates to consist of lead sulphate, $PbSO_4$. When a current from an outside source G is sent through the cell, it breaks up the water which has been formed during **discharge** into positively charged hydrogen H_2 and negatively charged oxygen O. Part of the positively charged hydrogen is now attracted to the negative plate and unites with the SO_4 of the lead sulphate, forming sulphuric acid, H_2SO_4 and leaving pure spongy lead at the negative plate. The negatively charged oxygen O flowing against the current is attracted to the positive plate. Here it unites with the lead Pb of the lead sulphate $PbSO_4$ plate and forms lead peroxide, PbO_2. The SO_4 part of the positive plate is finally united to the rest of the hydrogen liberated when the electric current broke up the water H_2O in H_2 and O. This action forms still more sulphuric acid, and a positive plate of lead peroxide. When all the lead sulphate has been changed over to lead peroxide and pure lead, the battery is restored to the state it was in before it was discharged, and is now ready to furnish current again.

Note that the acid has been growing denser during charge, therefore the E. M. F. must have been increasing as the charging continued.

CARE OF LEAD STORAGE CELLS

From a study of the chemical action of a storage cell and the physical results of this action, we can determine what treatment such a cell should receive in order to give the most efficient service.

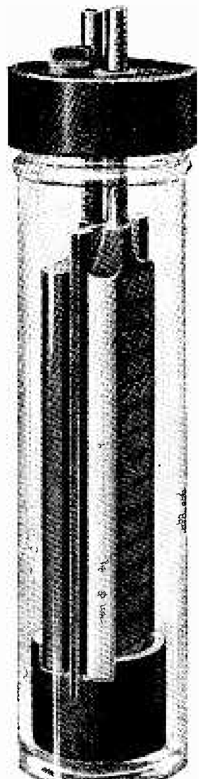


Fig. 12-A.—Showing Construction of a Lead Type "B" Battery Cell.

In the first place, it should be said that storage batteries should have the care of a conscientious skilled attendant. They are costly in the first place and easily ruined. Without proper care they deteriorate at an alarming rate. The main points to be avoided are the following:

(1) *Too rapid charging or discharging.* 8

(2) *Use of impure electrolyte.*

(3) *Use of too dense or too light electrolyte.*

(4) *Over-charging and over-discharging.*

The harm that may result from disregarding these points is evident on inspection of the chemical actions.

Although all lead cells are identical in operation, they vary somewhat in the specific form of some of their elements. One form of plate construction used in the Exide has been outlined.

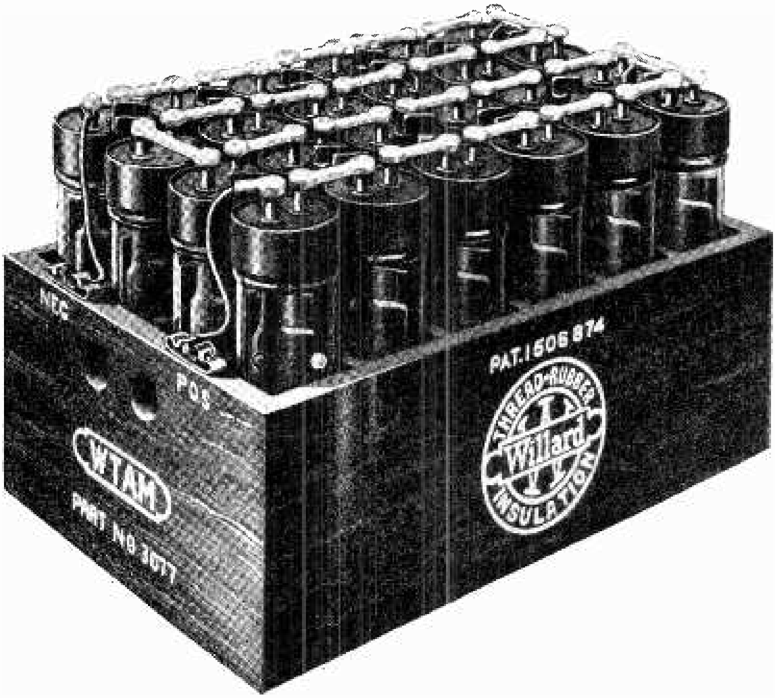


Fig. 12-B.—A 24-Cell Lead Type "B" Battery Unit, Equivalent to a 45 Volt Unit.

Another type very similar to the "Exide" has the trade name "Ironclad Exide." Instead of a perforated plate filled with peroxide of lead, the Ironclad-Exide positive plate is made up of a series of vertical tubes of hard rubber, filled with active material (see Fig. 8-A), each tube having a central metallic core joined to the top and bottom bars of the plate. The tubes are slotted horizontally to admit the electrolyte. The negative plate of spongy lead is identical with that of the "Exide" cell. With both types of cell, sheets of hard rubber or wood are used to separate the plates.

The "chloride" cell has a positive plate made by filling the openings of a perforated cast-lead plate with coils of soft corrugated lead ribbon. The cast grid serves not only as a rugged support, but also as a good conductor. The box type negative plate consists of a grid of vertical and horizontal ribs forming square pockets, which are closed on each side by perforated sheet lead to retain the active material.

Other things being equal, the greater the number of plates in a cell, the greater is its *current* capacity.

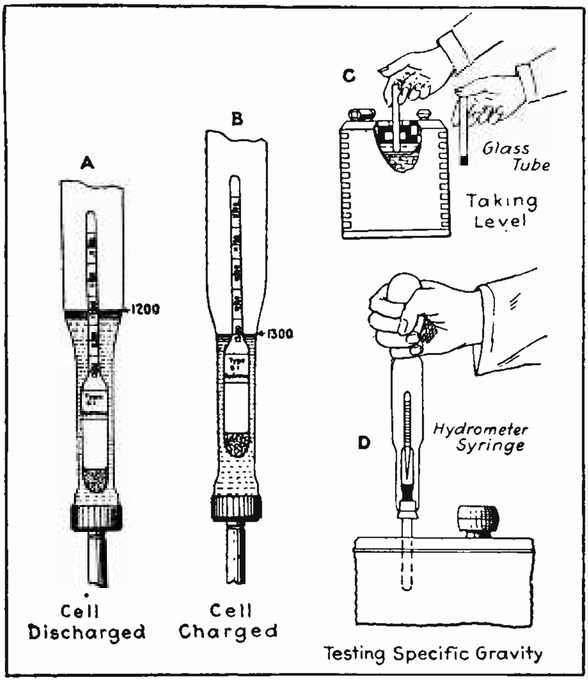


Fig. 13.—Illustrates the method of reading the hydrometer and determining the condition of a storage battery.

The storage "B" cell is a miniature of the type used for filament lighting as is evidenced by Fig. 12-A. A 45 volt unit is shown in Fig. 12-B.

There are two general methods of determining the state of charge, or condition of a storage cell. The first is by taking a voltmeter reading *while the cell is discharging at its normal rate.* It should be about 2.05 volts, somewhat higher immediately after charge. The voltage under the condition stated should *not be allowed to drop below 1.75.*

A more satisfactory test is by taking a specific gravity reading of the electrolyte. When studying the chemical action of the cell we saw that the battery solution grew lighter as the cell was discharged and heavier as the cell was recharged, therefore, it is apparent that its density is a reliable index of its state of charge.

The device employed in determining the specific gravity of the electrolyte is called a "hydrometer." The hydrometer proper (see Fig. 13) is a glass tube closed at both ends, and somewhat enlarged at the lower end. It is suitably loaded at its lower end so that it will float in a vertical position in a sample of the battery solution, which is drawn up into the syringe barrel. Inside the hydrometer a paper scale, graduated from 1.300 at the bottom to 1.100 at the top, is placed. The reading is taken by noting where the level of the solution in the syringe crosses the hydrometer scale. Care should be taken that the hydrometer should float freely in the electrolyte. When the battery is in a fully charged condition, the specific gravity reading should be approximately 1.275-1.300 depending on the age of the cell. When the reading drops to 1.170 the battery should be put on charge.

The instructions of the manufacturer of the particular battery used as to the correct, fully-charged hydrometer reading and the permissible drop before recharging is necessary, *should be carefully followed.*

NOTE: Over-discharging, undercharging and excessive over-charging are all injurious to the plates of the cell causing buckling of plates, loosening of active material, and other disastrous effects, chemical in nature.

The rate of charge and discharge should not be excessive if the battery life is to be conserved since both cause loosening of the active material. About 2 to 5 amperes is a conservative charging current for the filament batteries and ¼ ampere for the plate battery. Lead storage batteries should not be allowed to stand long in a discharged or nearly discharged condition since the lead plates become sulphated, i. e., turn to lead sulphate and are no longer active.

The level of the electrolyte should be maintained about ⅜ to ½ inch over the tops of the plates by adding pure water to compensate for evaporation and decomposition. In this connection, it should be recalled that hydrogen is evolved during the charging process and since this gas is inflammable and forms an explosive mixture with air, it is advisable to keep naked flames away from the vicinity of the battery vents during the charging period especially after the battery begins to "gas."

The cells should be kept clean and dry, allowing no dust or debris to collect on the tops. Acid spray or moisture in combination with dust or other particles will cause a leakage from the positive to the negative terminal.

To put a battery in wet storage that is to be out of commission for less than a year, the most satisfactory result can be obtained by charging continuously at a very low rate, which is so low that gassing is avoided and yet giving enough charge to maintain the batteries in good condition. This type of charge is termed "Trickle Charge." It has the advantage of keeping the batteries in condition for immediate service.

If this method is impossible or impractical under the particular circumstances, put on charge at the proper current rate and continue the charge until the specific gravity of the electrolyte in all cells, as shown by the hydrometer syringe, has held at a maximum (ceased to rise) for a period of five hours and all the cells are gassing freely. When fully charged, place the battery where it will be dry, cool and free from dust. To avoid freezing in cold weather special care must be taken that water is added just before and not after charging.

Once every four months during the out of service period, remove filling plugs and add water, replace plugs and give battery what is known as a "freshening charge," that is, charge until all cells have been gassing freely and evenly for one hour. Then the battery may be allowed to stand for another four months. Disconnect terminals to prevent loss of charge.

The unit of capacity of any storage battery is the ampere-hour. This is generally based on an eight-hour rate of discharge.

Thus a 100 ampere-hour battery will give a continuous discharge of 12½ amperes for eight hours. Theoretically it should give a discharge of 25 amperes continuously for four hours, or 50 amperes for two hours. As a matter of fact, however, the ampere-hour capacity decreases with an increase of discharge rate.

The capacity of a cell is proportional to the exposed area of the plates to which the electrolyte has access, and depends on the quantity of active material on these plates.

The capacity of batteries depends, therefore, on the size and number of plates in parallel, their character, the rate of discharge and also the temperature. Taking the eight-hour rate of discharge and temperature of 60 degrees F. as standard, the capacities which are obtained in American practice are from 40 to 60 ampere-hours a square foot of positive plate service (equals number of plates in parallel multiplied by the length of the breadth reduced to square feet and by 2).

The terms "cell" and "battery" should not be confused by the student. A "cell" is one unit consisting of a set of positive and negative plates immersed in a solution contained in a single jar or container; while a "battery" is made up of two or more cells connected either in series or parallel.

The same term "battery" is used in many other fields of engineering, such as for example, two or more guns are called a battery, two or more steam boilers acting together are called a battery of boilers.

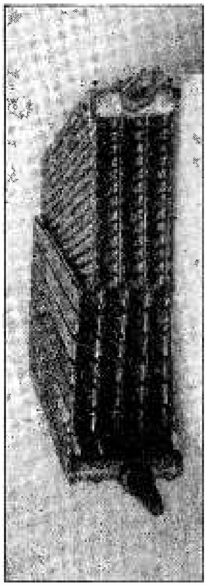
The three things which determine the voltage of a battery are first the type of cell (dry cell, 1.5 volts; lead cell, 2 volts); second, the number of cells in the battery, and third, the method of connecting these cells together.

EDISON CELL

This cell differs from the lead cell in both construction and material. The plates of the "Edison" are made of iron oxide and nickel and immersed in a solution of caustic potash.

Construction of the Edison.—The positive plate of the Edison cell consists of a nickel steel grid or frame which supports thirty perforated steel tubes filled with alternate layers of pure flake nickel and nickel hydrate, while the negative plate consists of a nickel steel grid which supports twenty-four steel pockets filled with iron oxide and a small quantity of metallic mercury. The addition of pure flake nickel in the positive plate increases the conductivity of the active material, and likewise the metallic mercury increases the conductivity of the negative plate. A view of these plates is given in Fig. 14. Each cell has a number of positive and negative plates arranged in alternate order, the positive being connected to one terminal and the negative to the other. The electrolyte is a 21% solution of potassium hydrate (caustic potash) and a small amount of lithium hydrate. It is claimed that caustic potash is a preservative of nickel, steel, and therefore there is no deterioration of the cell due to standing in a discharged or partially discharged condition. The water added to this type cell should be free of impurities as in the case of the lead type cell.

Figure 15 shows a cut-away view of the assembled Edison cell.



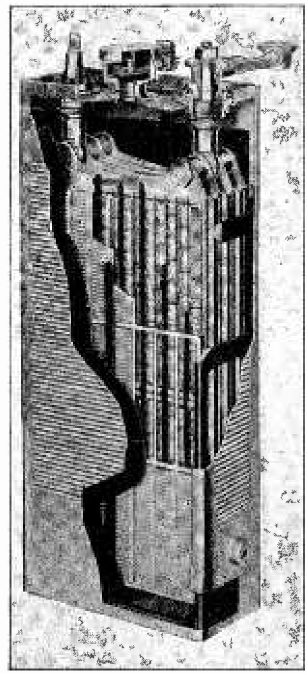


Fig. 14.—Plates of Edison Cell. Fig. 15.—Assembled Edison Cell.
Courtesy of the Edison Storage Battery Co.

Notice:—The student's attention is called to the fact that he is not required to study the following paragraph on the

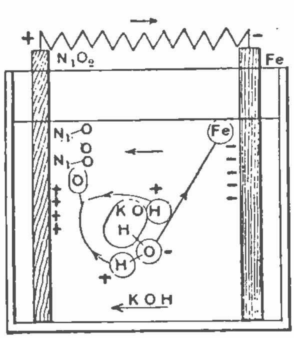


Fig. 16.—Action within Edison cell on discharge.

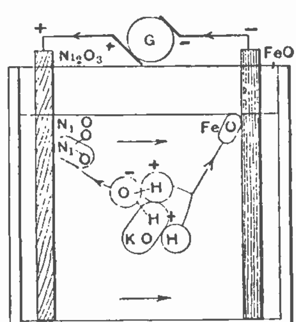


Fig. 17.—Action within Edison cell on charge.

chemical action of the Edison cell. One may, however, be interested in the subject matter and a brief explanation of the symbols will be of great help to him. Ni is Nickel, O is Oxygen, H is Hydrogen and Fe is Iron. For example, $NiOH_2$ means one part of Nickel, one part of Oxygen and two parts of Hydrogen.

Chemical Reaction of the Edison Cell.—When the cells are *first charged*, the nickel hydrate, $NiHO_2$, is changed to nickel oxide NiO_2, and the iron oxide, FeO, is reduced to metallic Fe. The cell may thus be considered to consist of a positive plate of nickel oxide, NiO_2, and a negative plate of pure iron, Fe.

The following equations show the chemical reaction:

Discharge →

$$Fe + 2NiO_2 + H_2O + KOH = FeO + Ni_2O_3 + H_2O + KOH$$

← **Charge**

DISCHARGE

Positive Plate	Negative Plate
NiO_2 } NiO_2	Fe
+	+
H_2	O

+ KOH

Produces

Ni_2O_3	FeO

+ H_2O + KOH

CHARGE

Positive Plate	Negative Plate
Ni_2O_3	FeO
+	+
O	H_2

+ KOH

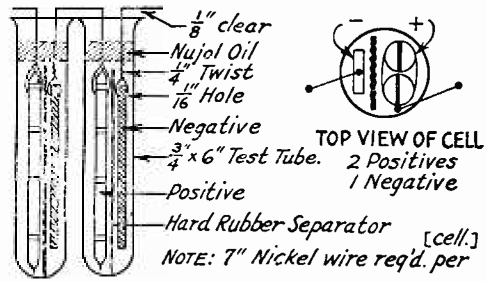
Produces

{ NiO_2 NiO_2	Fe

+ H_2O + KOH

On Discharge.—The nickel oxide, NiO_2, probably goes to a lower oxide of nickel, Ni_2O_3; that is, there are only three parts oxygen to two of nickel, instead of two oxygen to one of nickel. The oxygen thus liberated is negatively charged and goes over to the iron plate, gives up its negative charge, and unites with the plate to form iron oxide, either FeO or Fe_2O_3. The electrolyte neither loses nor gains strength in the process and therefore remains at the same density throughout discharge and charge, thereby making gravity readings of no value for indicating the state of charge or discharge. The potassium hydroxide seems to act merely as a catalyzer or carrier. Figure 16 shows the action on discharge.

On Charge.—The iron oxide, FeO, is broken up and the negatively charged oxygen leaves the iron plate, travels back



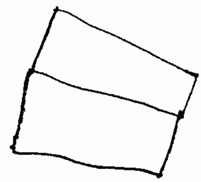


Fig. 18.—Edison Type of "B" Battery Cell.

against the current through the cell and unites with the positive nickel oxide, Ni_2O_3, and forms a higher oxide, NiO_2. Figure 17 shows this action during charge.

The "Edison" "B" battery is made up of a series of test-

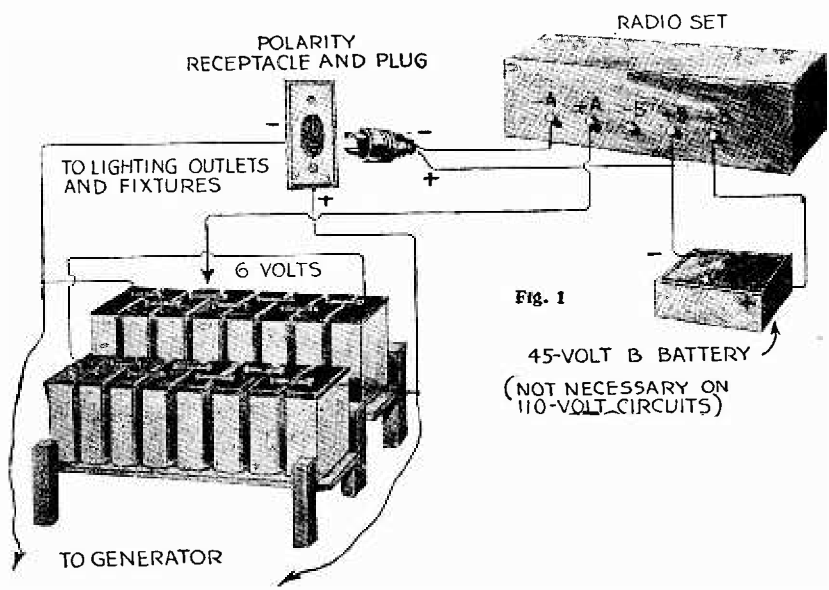


Fig. 19.—Wiring Diagram for Supplying Filament Working Current From a Farm Lighting Battery System, by Tapping Three Cells.

tubes each containing one or two of the perforated steel tubes that comprise the plate of the larger filament battery and a section of the negative plate of the same (as shown in Fig. 18).

A layer of oil is above the top of the electrolyte to prevent creeping. The assembly is usually placed in a rack if the battery is of home construction or in a sealed container if made commercially.

Since the specific gravity of the electrolyte does not change as in the lead cell, such a reading does not indicate the condition of charge of an Edison battery. The voltmeter test is the only available one. This type cell has a maximum voltage of 1.2 and a minimum of .9.

How to operate a receiver from a 32 volt farm lighting plant.

Thousands of American homes are equipped with independent lighting plants that supply a D. C. source of power which can be utilized to directly operate a radio set eliminating the use of a special "A" or "B" battery.

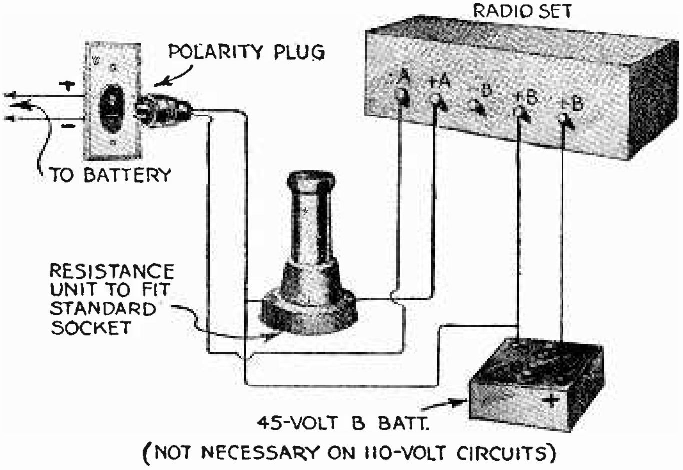


Fig. 20.—Diagram of Connections for Filament Current Supplied from 110 D. C. Source with Resistance in the Circuit.

Most of the lighting units comprise either a 32 volt or 110 volt storage battery which is automatically maintained in a charged condition by a generator.

If your home is equipped with a 32 volt system, you can dispense with all extra batteries for your radio set if your receiver uses only one tube. A multi-tube set, however, requires more than 32 volts, so that with such a set it still will be necessary to use one block of "B" battery to obtain the correct plate voltage for the amplifier tubes.

With the 110 volt system, the voltage will be found ample for all requirements.

Figure 19 shows one way to hook up the receiving set to either the 32 volt system or the 110 volt system, provided different sets of cells are used successively so that the drain will be equally distributed over all of the cells. *No connection is necessary to the minus "B" binding post, because this post is connected inside the set with either the minus or plus "A" binding post and this connection is already made for you in the battery itself.*

Figure 20 illustrates another way of connecting up which obviates the long lead from "A" of the set to the terminal of the battery.

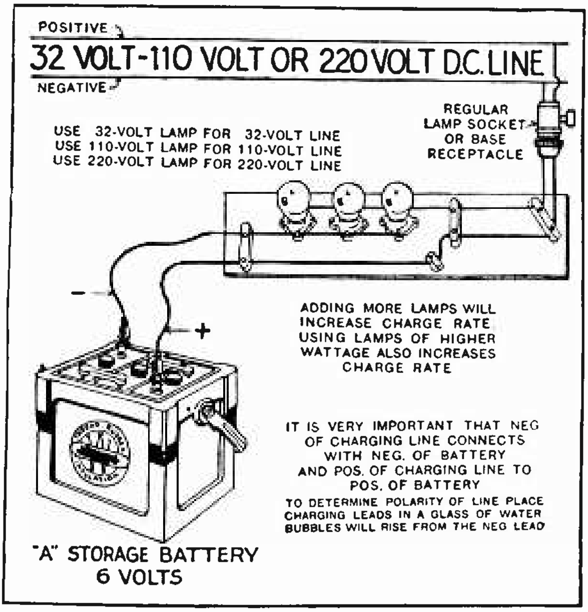


Fig. 21.—Charging a Storage Battery From a D. C. Line Using Lamps as Charging Resistance.

Table No. 2 gives the value of the fixed resistance that should be used with the hook-up shown in Fig 20 to cut down the voltage for the filament circuit when from one to five .06 ampere or quarter-ampere storage battery tubes are used on either 32 or 110 volts. If the battery is situated a considerable distance from the receiving set, the resistances specified for 32 volt circuits may have to be cut down somewhat, owing to the drop in voltage over the line.

There is one point that should be mentioned in connection with the circuit of Fig. 20. Do not turn off or remove one

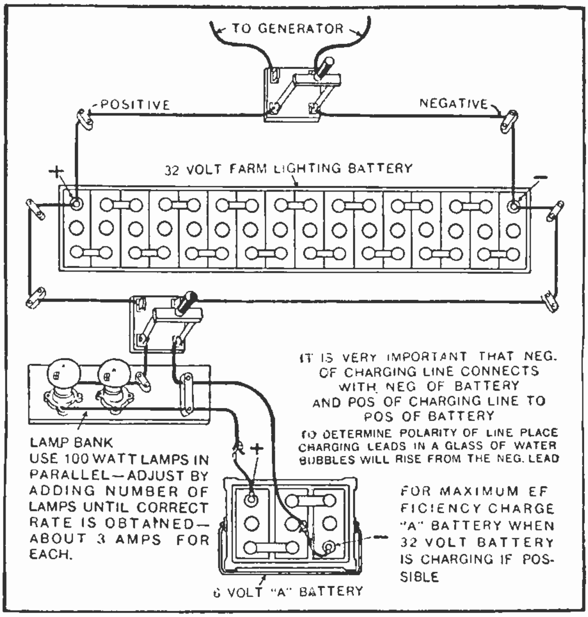


Fig. 22.—Charging a 6-Volt Storage Battery From a 32-Volt Farm Lighting System.

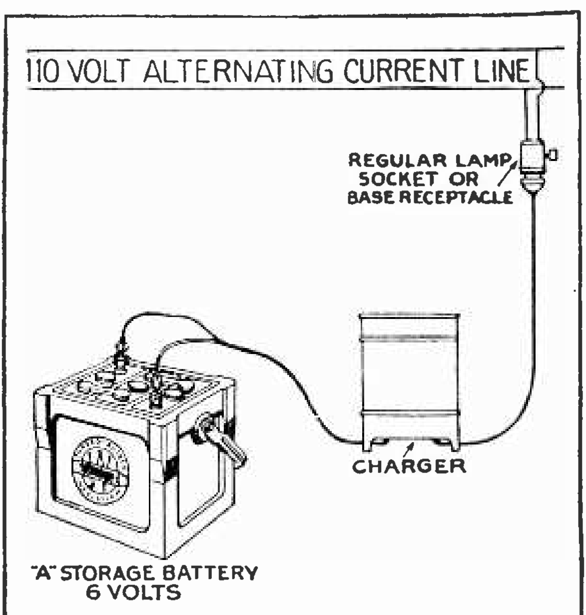


Fig. 23.—Charging a 6-Volt Storage Battery From 110-Volt A. C. Line Using a Rectifier to Change the A. C. to D. C.

tube from the socket while the current is turned on, as this will throw an extra load on the other tubes and they might burn out.

TABLE NO. 2

No. of tubes	.06-Ampere Tubes 32 volts	.06-Ampere Tubes 110 volts	Quarter-Ampere Tubes 32 volts	Quarter-Ampere Tubes 110 volts
1	450 ohms	1750 ohms	100 ohms	420 ohms
2	230 "	870 "	55 "	210 "
3	150 "	590 "	36 "	140 "
4	115 "	440 "	27 "	105 "
5	90 "	350 "	21 "	84 "

If a multi-tube set is to be employed, there will be an objectionable hum if the generator is operating while the set is being used. It will be worth while having a service man install a switch near the set to cut the generator off when it is desired to receive.

TEST QUESTIONS

1. Explain the difference between "A," "B" and "C" types of dry cell radio batteries.
2. How many single unit cells are used in a 45 volt "B" battery and how are they connected?
3. Show by a drawing the arrangement of dry cell batteries for supplying filament current to a five-tube set using UV-199 tubes.
4. What type and voltage "C" battery would you use on the amplifying tubes (UV or UX-199) with a 67.5 or 90 volt plate battery (see table I) ?
5. Name the tests in checking the condition of a dry cell filament battery.
6. What is the difference between the primary cell and the storage cell?
7. Explain how to test the specific gravity of an electrolyte.
8. Mention a few important requirements for the proper care of a storage battery.
9. What things determine the voltage of all batteries?
10. Show by drawing the wiring diagram for connecting a 32 volt lighting system to the filament circuit of a one-tube receiver.

RADIO BY MAIL

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