PRIMARY BATTERIES

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PRIMARY BATTERIES.

General Theory and Characteristics of Various Kinds of Primary Cells and Descriptions of Signal Corps Types.

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IT WAS AN early discovery in electrical phenomena that all metals had certain characteristics peculiar to each, such that if two different metals were brought into contact, a difference of potential was established between them. If a circuit made up of various substances and including no source of energy is closed on itself, the various contact emfs. will just compensate and the resultant emf. of the circuit will be zero. However, if the circuit includes a source of energy such as heat or chemical reaction, an unbalance of emf. will be produced and a current established. The current thus established tends to reduce the emf. of the source and restore the static balance of the system. This action of the current is called "polarization" and may be overcome to greater or less degree by the use of certain substances called "depolarizers."

A battery consists essentially of two metallic conductors or poles dipping into an electrolyte. Copper or carbon is commonly used for the positive pole and zinc for the negative pole. The positive pole or terminal of a battery is the one which is at the higher potential, and the other pole is called the negative pole or terminal. The negative pole is the anode or positive electrode or plate and the positive pole is the cathode or negative electrode or plate. For example, in a copper-acid-zinc battery, the copper is the positive pole but the negative electrode or plate. The electrolyte of a primary cell may be sulphuric or nitric acid, or sal ammoniac, caustic soda or other salt or hydroxide. The open circuit emf. of batteries made of given materials is always the same, providing the temperature, degree of concentration of the electrolyte and the purity of the materials are the same. The terminal emf. or potential difference on closed circuit is always less than the open circuit emf. due to three characteristics of the battery; namely, the internal resistance, the polarization and the degree of exhaustion.

The internal resistance of a battery may be determined from the following formula:

$$r=\frac{E-e}{I},$$

where I is the current drawn on closed circuit, e the potential difference when this current is flowing and E the open circuit

emf. measured immediately upon interrupting this cu
that is, before the load condition of the cell has had t
change.

Polarization of a primary cell may be explained
change produced in the relative concentration of the ele
around the poles of a cell; or, as the formation at the p
new chemical substances such as hydrogen, which ad
the poles. A depolarizer, then, is any substance which
in the electrolyte or on the poles of a cell will part
wholly prevent these changes. Polarization always ten
duce the effective emf. of a cell. The chief cause of pol
is the formation of hydrogen gas at the positive pole.
brought about by the transfer of the metal from the
pole to the positive pole in accord with the following

Chemical Generation of Electrical Energy.

A primary cell is essentially a device for converting
energy directly into electrical energy. If a plate of c
pure zinc and a plate of copper are immersed in c
phuric acid, no chemical action takes place. As soon
as the zinc plate and copper plate are connected by
conductors outside the liquid, a vigorous chemical
set up, the zinc dissolving in the acid to form zinc su
liberating hydrogen at the positive pole. The hy
erated accumulates on the copper plate and causes th
action to weaken and the intensity of the electric
diminish for two reasons: the hydrogen coating
electrode of the cell and sets up a local emf. opposed
of the cell; and it also acts to decrease the effective
plate. This polarizing effect may be largely overcom
ing an oxidizing agent to change the hydrogen or met
at the positive pole to a form readily soluble in the
and thereby prevent its accumulation at the positive
oxidizing agent most frequently used in dry batte
ganese dioxide, MnO_2. Other good depolarizers are
phate, $CuSO_4$, strong nitric acid, HNO_3, chromic
copper oxide, CuO, and silver chloride, AgCl.

Another deteriorating effect present in the us
which must be overcome is what is termed "local a

impurities which are always present in the zinc, form with the zinc small short circuited voltaic cells acting to waste away the zinc without producing any current in the external circuit. This wasteful action can be largely prevented by amalgamating the zinc, that is, coating it with mercury. This is easily done by dipping the zinc electrode into diluted sulphuric acid to clean the surface and then rubbing mercury over it.

The emf. of a given type cell is the contact emf. and is therefore, independent of the dimensions of the battery. The total energy capacity of a battery, however, is directly affected by the dimensions. For a given battery, the capacity stands in direct ratio to the weight of active material. The ampere-hour capacity of a given number of cells in series is determined by the area of the plates. The emf. of a given type of battery is of course dependent only on the number of cells in series.

There are a great many different types of primary cells in use, all of which operate according to the same general principles, but differ in the kind of electrodes, electrolyte and depolarizing agent, and the voltage, internal resistance, etc. The voltage, however, of almost all makes of cells, will be between the limits of 1 and 2 volts when new, the average battery delivering about 1.5 volts. A new cell on short circuit through an ammeter should give a current of from about ½ amp. to 20 amp. depending on the size of electrodes. The internal resistance of primary cells when newly made will vary from .07 ohms up to 3 or 4 ohms. This resistance gradually increases due to polarization and the formation of insulating substances on the plate, until it becomes perhaps several times this amount. This high ultimate internal resistance and rapid rise of internal resistance when heavy currents are demanded, are inherent characteristics of the primary battery which limit its practical use to service where relatively large currents are required for only a few moments, or where for continuous service over long periods only a few milliamperes are required.

Various Types of Primary Batteries.

Primary batteries may be divided in two general classes, known as open circuit and closed circuit batteries, and while there is a great variety of each class, the basic principle is the same.

Open circuit cells are used for intermittent service where current is required for only short intervals of time, such as in operating electric bells. Open circuit cells kept in continuous service for some time become polarized or completely exhausted, but will recuperate to a considerable degree on open circuit. The so-called dry battery is a good example of the open circuit type.

Closed circuit cells are adapted for supplying current continuously until the chemical reaction producing the current flow is complete. This form of primary cell is used most extensively in telegraphy, where a small but continuous flow of current is required. The so-called wet battery is generally used for closed circuit work.

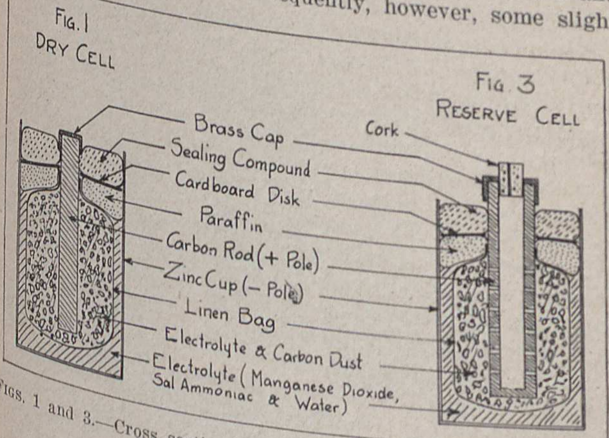
Dry Batteries.

The general construction of a dry battery is illustrated in Fig. 1. A central carbon rod forms the positive pole of the cell. The upper extremity of this carbon rod is provided with a tight fitting brass cap, to which a connection wire may be soldered. The rod is set in the center of a linen bag which is then packed with a mixture of carbon dust, manganese dioxide, and ammonium chloride (sal ammoniac). The bag is then pressed into a cylindrical zinc container which serves also as the negative pole of the cell. The mixture is then impregnated with water and a special electrolyte paste, and is carefully sealed with paraffin and an asphalt compound.

The chemical reaction taking place within the cell between the carbon rod and the zinc container to produce the electric current is thus seen to occur in a pasty solution of ammonium chloride in water. The reaction taking place when the cell is closed through some external circuit, is quite complex. One of the products of the reaction is free hydrogen gas, which if allowed to collect around the carbon rod, would soon prevent contact of the latter with the electrolyte and would thus make the cell inoperative. This is called polarization of the cell. This effect is counteracted by the manganese dioxide of the mixture which thus forms the depolarizing agent. The hydrogen unites with some of the oxygen of the manganese dioxide to produce water. By this means, the operation of the cell is continued satisfactorily over a much longer period of time than would be possible without the depolarizer.

After a cell has been used for some time, the chemicals in the electrolyte mixture are used up completely, and the cell becomes inoperative, and must be discarded. The length of life of a cell depends to some extent on the rate of discharge, but also on the dimensions of the carbon rod and of the zinc container, and on the quantity of electrolyte mixture present.

The type of cell described above, if manufactured properly, using materials of high purity, will remain in good condition when not in use, since the electrolyte is completely sealed in and hence will not deteriorate. Frequently, however, some slight



Figs. 1 and 3.—Cross sectional sketches showing internal make-up of dry and reserve type cells.

impurities are present in the zinc making up the container of the cell, which produce local action and decomposition of the electrolyte, even though the cell terminals may not be connected to any outside circuit. This gradually weakens the electrolyte and may completely exhaust the cell. For this reason, it is generally best not to store dry cells for periods longer than a few months.

The type of cylindrical cell described above is manufactured for the Signal Corps in various sizes, and a number of identical cells are grouped in series to form a dry battery. The standard types are briefly described below.

Battery, Type BA-1.—This battery, formerly known as type A, is a 2-cell battery with the two cells connected in series by placing them end to end in a cardboard tube which holds th together and protects them mechanically. The approximate mensions of the battery are 6¼ in. in length by 1¼ in. in diame The terminal voltage is about 3.5 volts.

Battery, Type BA-2.—This battery is made up of 15 cylin cal cells connected in series. Each cell is about 1⅞ in. high an in. in diameter. The 15 cells are assembled in a cardboard b 3½ in. x 2½ in. x 2 in. weighing a little less than 1 lb. The ent assemblage of cells is covered and sealed with an asphalt co pound, through which two terminal wires are brought o The polarity is marked in the compound. The terminal volta of the battery is 22.5 volts when new. The battery may used safely until the voltage runs down to 17.5 volts. Ca should be taken when handling these batteries, not to bri the two terminal wires in electrical contact, since this wou short circuit the battery, and exhaust it in a very short time.

This battery is intended primarily for use with the thre electrode vacuum tubes, where it supplies the potential in t plate circuit. The discharge rate is 0.3 milliamp. when co nected to a type VT-1 tube used as a detector, and 3 milliam when the tube is used as an amplifier. The approximate life the battery is 75 to 100 hours.

Battery, Type BA-3.—This is a 3-cell, 4.5-volt cylindrical ba tery, 9½ in. long and 1-5/16 in. in diameter. The three cells ar placed end to end in a cardboard tube and connected in serie The normal discharge rate is 0.3 amp. when used on the typ SCR-57 or SCR-57-A airplane interphone sets for which th battery was originally designed.

Battery, Type BA-4.—This is a single cell battery, cylindrica in shape, 3-1/16 in. long and 1¼ in. in diameter. The open cir cuit voltage is about 1.5 volts. This battery is used to energi small buzzers, such as the detector adjusting buzzer of the typ SCR-54 or SCR-54-A radio receiving set.

Battery, Type BA-8.—This is a 15-cell battery, of the same electrical characteristics (voltage and discharge rate) and intended use as the type BA-2. The individual cells are, how- ever, of larger size, which results in a greater life (500 hours) under similar conditions of use. The 15 cells are sealed in a card- board box 4 in. x 3 in. x 6-11/16 in., and the entire battery weighs about 3.9 lb. It should be noted that, due to its larger size, the type BA-8 battery is not interchangeable with the type

BA-2. It may be used on the same sets however, by placing it near the radio set box, and connecting the battery terminal wires to the proper terminals of the radio set box.

Battery, Type BA-9.—This is a 3-cell battery, having the approximate dimensions of $2\frac{5}{8}$ in. x $2\frac{7}{16}$ in. x $\frac{7}{8}$ in. It is the well known dry battery for use in pocket flash lights.

Batteries, Type 4, 6 and 8.—These batteries were used to quite some extent by the Signal Corps, and are fully described in the Signal Corps Manual No. 3. They are obsolete, however, and are therefore simply mentioned in this pamphlet.

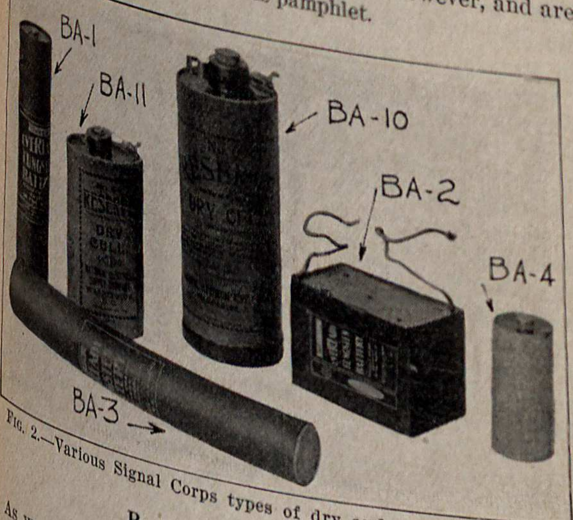


Fig. 2.—Various Signal Corps types of dry and reserve batteries.

Reserve Type Batteries.

As was explained above, the dry cell contains a mixture of electrolyte salts, absorbent material (carbon dust), and water, the cell being then sealed air tight, and ready for operation. It was also pointed out that, due to local chemical reactions, the cell may deteriorate while in storage, though not used at all. This is a serious objection to the use of dry batteries which has been overcome in a measure by the so-called reserve type dry batteries. These batteries differ from the ordinary dry battery described above in that they do not contain any water or moisture whatsoever, so that no chemical reaction can take place inside

the cell. This also makes the cell inoperative
to an external circuit, so that it is necessary to
cell before using it. This may be done shortly
the cell into use, after which it will operate exa
manner as the ordinary type of dry cell. Before
it may be stored without deterioration for a long

In order to permit the addition of water to th
sealed by an asphalt compound, the carbon rod el
hollow and porous. (See Fig. 3.) While the ce
this carbon tube is sealed by means of a cork di
To place the cell in service, proceed as follows:

1. Remove the cork from the carbon electrode
2. Fill with distilled or rain water and c
sufficient water to keep the cell full during
Then fill every 30 minutes until no more water i
3. During the entire operation, take care n
water on the top of the cell, as this establishe
tween the two terminal clips and discharges the
4. When the watering is finished, that is, when
is absorbed, empty out the water and replace the

Battery, Type BA–10.—This is a one-cell, cylin
$6\frac{3}{4}$ in. high and $2\frac{1}{2}$ in. in diameter; formerly kno
6 reserve battery. It will absorb $3\frac{1}{2}$ oz. of wate
ready for service. The terminal voltage is about

Battery, Type BA–11.—This is a one-cell batte
shape of an oval base cylinder, $4\frac{3}{4}$ in. x $2\frac{1}{4}$ in. x
was formerly called the No. 4–O reserve battery.
$1\frac{1}{4}$ oz. of water, and has a voltage of about 1.4 v

Battery, Type BA–5.—This battery is essentiall
the type BA–2 dry battery, the only difference b
of the "reserve" type.

Wet Batteries.

While dry and reserve type batteries find very
in the field for open circuit work, due to the a
breakable jar or corrosive liquid, they are not
closed circuit work where a continuous flow of
quired for extended periods of time. They also
paratively high internal resistance so that their
as great as may be derived from other types of ce

poses where these characteristics of current supply are required, "wet" batteries are used, especially in stationary installations. These wet cells consist essentially of a jar containing a liquid electrolyte solution, into which the two electrodes are inserted. The advantages of this type of cell are the ease with which the electrode plates may be cleaned and the possibility of renewing them and the electrolyte solution. The disadvantages are the breakable jar, the possibility of spilling the solution which is generally corrosive, and the gradual evaporation of the electrolyte. The three types of wet cells used by the Signal Corps are described below.

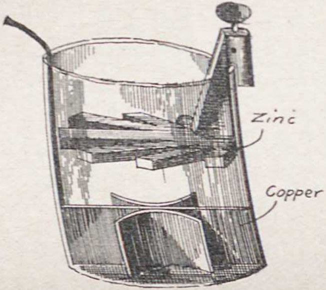
Battery, Type BA-12.—This battery is commonly known as the "gravity cell." (See Fig. 4.) It comprises a glass jar 5 in. x 7 in., at the bottom of which is placed the positive pole consisting of three copper strips riveted together and having a rubber-insulated wire attached to one of them to form the terminal. The zinc electrode forming the other pole is cast with a hook which rests over the edge of the jar, and supports the electrode in the electrolyte about 3 in. above the copper electrode. The zinc is given a special shape from which the cell derives the often used name of "crowfoot battery."

To set up the cell, 3 lb. of copper sulphate (blue vitrol) are placed in the jar around the copper electrode. The zinc is then hung in place and the jar filled with water, without stirring. The cell is then short circuited by connecting the terminals together, and left this way until, after several days, part of the copper sulphate has dissolved, giving a blue solution in the lower portion of the jar. The clear solution above is zinc sulphate. The battery is then ready for service.

If it is necessary to make the cell ready in a hurry, a tablespoon of salt may be dissolved in the water before pouring it into the cell. However, this should be avoided if possible, as it shortens the life of the cell.

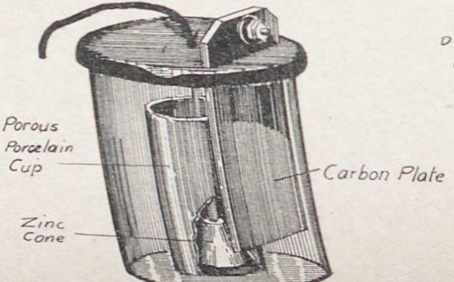
As the cell is being used, the zinc sulphate solution becomes stronger and stronger, white crystals forming at the surface. These climb up the side of the jar and along the zinc electrode, corroding the connections and damaging the insulation. The best practice to avoid this trouble is to withdraw part of the zinc sulphate solution with a battery syringe as soon as the crystals appear, replacing it with pure water. A good practice for preventing evaporation of the solution is to pour a layer

FIG. 4



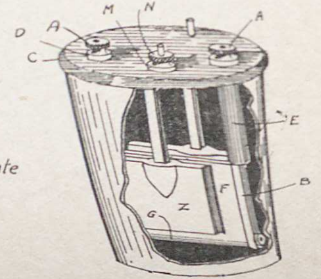
GRAVITY CELL

FIG. 5



FULLER CELL

FIG. 6



EDISON CELL. TYPE V.

of good paraffin oil over the electrolyte as soon as the cell is set up. Bluestone or blue vitriol is added from time to time as required, to keep the blue solution up to the proper level.

Frequent inspection of the cells is a good practice. In cleaning them out, wet cotton waste dipped in sand will clean the electrodes of any oil adhering to them.

The approximate emf. of this cell is 1 volt and the internal resistance about 3 ohms.

Battery, Type BA-13.—This battery is commonly known as the "Fuller cell battery." It belongs to the class commonly called "acid batteries." The cell has high electromotive force, a comparatively low internal resistance (0.5 ohm), and is much used as a transmitter battery on long distance heavily worked telephones or local battery telephone switchboards. Its only disadvantage is that it uses a corrosive solution containing sulphuric acid, necessitating much care in handling.

The Fuller cell consists of a glass jar about 8 in. high and 6 in. in diameter fitted with a wooden cover treated with asphaltum or P.&B. paint. (See Fig. 5.) This supports a carbon plate about 4 in. wide, 9 in. long and ¼ in. thick which extends down into the jar and forms the positive pole. The top of this plate is coated with paraffin to prevent corrosion of the connection. In the center of the jar is placed a porous earthenware cylinder measuring 7¼ in. high x 3 in. in diameter, in the bottom of which is about 2 ounces of mercury. The cylinder is filled up with distilled water in which a tablespoon of salt has been dissolved. A conical zinc casting to which is fastened a copper wire extending out of the top of the cell, forms the other pole of the battery. The electrolyte or "electropion" solution, is made by slowly adding 1 lb. of strong sulphuric acid to 9 lb. of distilled water, and then stirring in 3 lb. of pulverized bichromate of potash or 2½ lb. of bichromate of sodium. The latter is preferable as the crystals formed in the action of the cell are not so hard and insoluble as those produced by the potash solution.

This cell will usually require little attention for three or four months. When the solution assumes a muddy bluish tinge, it is about exhausted. If the copper wire at its junction with the zinc is covered with paraffin or ozite, or if the copper wire is well amalgmated by rubbing with mercury after dipping it into acid, it is not as likely to be eaten off at the junction as it otherwise is under heavy service. The Signal Corps i material for the solution in dry form, which when forms the electrolyte. This is purchased under vari mercial names such as chromac, voltac, chromite, etc., being the usual designation. It is packed in tin cans cut-out top, containing one pound, which is the amoun charge. Full directions for using are marked on each

The carbon of this cell lasts indefinitely but it s soaked in warm water when renewals are made. The last through several renewals of the electropoion fluid. cury should be saved and used repeatedly.

Battery, Type BA-14.—This battery is commonly k the "Edison primary cell." The cell shown in Fig. standard Edison cell. This cell has a very low intern ance (not exceeding 1/8 ohm) and will remain set up circuit for a long time without appreciable deteriora has a capacity of about 150 ampere-hours, which mean will furnish about 210 days' continuous service on a li the current is 30 milliamp. and 40 days' service when rent is about 0.16 amp. It gives an emf. of but 0.67 steady work.

The following complete directions for setting up, renewal of these cells are furnished by the company turing them:

To make the solution, fill the cells with water up to the top. Add the caustic soda gradually to the water, stirr the soda is entirely dissolved. When the solution coo water should be added to bring it up to 1½ in. of the to pour the contents of the bottle of heavy paraffin oil f for each jar of the solution, into the electrolyte. Care be taken in handling the cell, as the caustic soda will skin and clothes. In stirring the liquid, avoid splashin

To set up the cells, unscrew the nut *N* and the jamb (Fig. 6) from the screw on the brass neck of the dou plate and remove the leather washer. Pass the scre below through the two round holes in the cover *C*. Rep leather washer and the jamb nut *M* on the screw and down the jamb nut until the zinc plate is rigid to the The thumb nut *N* can then be screwed on.

Unscrew the nuts *AA* and jamb nut *D* from the screw two side pieces *BB* of the copper frame, leaving the flat washers in position on the screws and pass the screws from below through the two round holes in the cover *C*. Replace the jamb nut on one of the screws and one of the thumb nuts on the other screw and tighten both down until the frame sides are rigidly clamped to the cover. Replace the other thumb nut on the screw holding the jamb nut. Then slip the hard rubber insulating tubes *EE* over the sides of the frame, one on each side.

To fill the copper frames, slide the oxide plate *F* sufficiently far into the frame to enable the copper bolt *G* to be passed underneath it through the slots in the bottom of the frame sides and the copper nut *H* tightened up on same.

Be careful that the zinc plates do not touch the copper oxide plates or the cells will be short circuited.

The copper connection is made between the thumb nut *A* and the jamb nut *D* on one end of the copper frame and the zinc connection between the thumb nut *N* and the jamb nut *M* on the brass bolts suspending the zincs.

After the oxide and zinc plates are properly connected to the cover, as above, soak them in water and while still wet, insert them in the jar filled with caustic solution. (Wetting the plates prevents the oil in the jar from adhering to them.)

In order to make the cover on the jar go in place easily, it is advisable to wet the rubber gasket ring. This will cause the cover to slip on easily and will make the cell liquid tight.

It is absolutely necessary that the upper edge of the oxide plates be submerged at least 1 in. below the surface of the caustic soda solution in the jar; also, on no account can the layer of oil on top of the solution be omitted.

When the cell becomes exhausted, the solution and the remains of the zinc and oxide plates must be thrown away. The other parts can be used again.

To take the cells apart, lift the lids, unscrew the bolts, and remove the zincs and oxide plates. Wash off (with water) the copper frames, bolts and rubber insulators, brightening up the metal, where corroded, with emery paper, especially the inside grooves of the copper frame sides. Pour away the solution carefully and set up cells with new caustic soda, oxide plates, and zincs according to directions.

In taking the cells apart, the parts that have been immersed in the caustic soda must be washed before they can be handled.

To ascertain if the oxide plates are exhausted, pick int body of them with a sharp pointed knife. If they are throughout the entire mass they are completely exhausted need renewing. If on the contrary there is a layer of bla the interior of the plate there is some life still left, the am being dependent entirely upon the thickness of the layer of oxide still remaining.

When renewing the battery it is desirable to clean the grooves of the copper frames, where the copper oxide p make contact, so as to insure a good electrical connection. is especially important where the batteries are required to g heavy current for cautery or motor purposes. These frame be easily cleaned by wrapping a small piece of emery around a stick which will just fit into the groove, or by im ing them in a dilute solution of 1 part of sulphuric acid parts water, and then carefully rinsing them in clean wa remove all traces of the acid.

Caution.—The oxide plates should never be removed fro caustic soda solution and allowed to dry in the air, si this is done, the surface of the plates becomes oxidiz absorbing the oxygen from the air and the oxide thus f is much more difficult of reduction than the original ox which the plates are formed. The internal resistance is sequently very greatly increased and the current mat diminished.

Where batteries are placed in warm places they sho examined every two or three months to see that the solutio not evaporated as this will gradually take place in spite oil, if the batteries are in a hot room. If the solution is to be evaporated, add more water to bring it again to the height. It is of the first importance that all binding po connecting wires should be kept clean and bright at the of connection.

The type BA-14 cell is excellent for use as an ignitio tery, or in lieu of small capacity storage batteries whe charging current source exists. The Signal Corps use type of battery quite extensively in connection with the Military Cable and Telegraph System.

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STORAGE BATTERIES

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STORAGE BATTERIES.

General Theory of Operation and the Use and Maintenance of Edison and Lead-Acid Batteries—Detail Data Covering Signal Corps Standard Types.

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TABLE OF CONTENTS.

I. GENERAL THEORY OF STORAGE BATTERIES.

1. THE ORDINARY primary battery is almost ideal for purposes such as supplying a relatively large current momentarily, or a very small current for a long period of time. However, when a battery is desired for use in lighting small lamps and running motor driven apparatus, or for any use requiring an appreciable current flow for any length of time, the high internal resistance and rapid polarization of the dry battery prevent its satisfactory use for these purposes. The storage battery, or secondary cell, is much better suited for these classes of service as it has a low internal resistance, slow polarization, low cost of upkeep and a capacity to deliver a large amperage for a period of several hours with only a slight decrease in voltage. It consists of a chemical couple which can be renewed after exhaustion by passing an electric current through it in the opposite direction to that of the discharge flow.

Alkaline Type Storage Battery.

2. Storage batteries may be divided into two general classes, those using an alkaline electrolyte and those using an acid electrolyte. The first type is generally called the Edison battery since this is the only one manufactured in the United States at the present time using an alkaline electrolyte. It was designed by Thomas A. Edison about 1904 and is at present in extensive use for the propulsion of electric trucks, for lighting trains, etc. The elements used in the Edison cell comprise a positive plate of nickel and nickel hydrate, an electrolyte of potassium or sodium hydroxide and a negative plate of iron and iron oxide.

3. In the operation of this cell, it is generally agreed that the electrical energy is stored and dissipated by the transfer of oxygen back and forth between the plates. This oxidation and reduction of metals takes place in an electrolyte which neither combines with nor dissolves the metals or their oxides. And although the electrolyte is decomposed by the action of the battery, it is immediately re-formed in equal quantities and is therefore a practically constant element without change of density or conductivity over a long period of time.

For this reason, only a small quantity of the electrolyte is necessary, permitting a very close proximity of the plates to each other. As the active materials of the electrodes are insoluble in the electrolyte, no chemical deterioration takes place in them. The chemical equations for these reactions have been written as follows:

On first forming charge—

$$\overset{-}{Fe_2O_3} + 6KOH + 3H_2O + 3\,\overset{+}{Ni(OH)} = 2\overset{-}{Fe} + 6KOH + 6H_2O + 3\overset{+}{NiO}$$

On discharge—

$$3\,\overset{-}{Fe} + 8KOH + 4H_2O + 6\,\overset{+}{NiO_2} = \overset{-}{Fe_3O_4} + 8KOH + 4H_2O + 2\,\overset{+}{Ni_3O_4}$$

On recharge—The equation on discharge is just reversed.

The reaction indicated is in reality made up of a combination of a large number of reactions which take place simultaneously, making the exact analysis very difficult to ascertain. The equation given is sufficient for ordinary purposes.

Acid Type Storage Battery.

4. The principle of the lead acid storage cell was discovered in 1801, but was not developed to any useful purpose until about 1860. This development was made by Gaston Planté. At the present time, there are two general types of lead plate storage batteries, one known as the Planté type and the other as the pasted type. The former consists in the main of pure lead plates so constructed by corrugating as to give the maximum exposed surface. These plates are oxidized electrolytically until they are covered with lead peroxide, PbO_2, to form the positive plates. The negative plates are formed by changing the peroxide after electrolytic formation of the plates, to a spongy lead by a reversal of the current through the electrolyte. By this process a thin layer of active material or lead sponge is produced which clings to the supporting lead plate. The active material of the positive plate is lead peroxide, and of the negative plate, spongy lead. This type battery is used chiefly where weight and space occupied make little difference, as in stationary lighting or standby batteries.

In the pasted type lead cell, the active material of both positive and negative plates is lead peroxide which is applied in the form of a stiff paste to a grid composed of lead-antimony, instead of being formed electrolytically as in the Planté type battery. The negative plate coating is then changed electrolytically to spongy lead as before. This type of battery is used chiefly where it is desired to obtain the greatest possible capacity with a minimum of weight and space occupied.

5. There are a number of theories as to the electro-chemical reactions of the lead plate storage battery, but as they are very complicated and as all authorities do not agree on them, only the simple chemical reaction will be included here. The active elements in any lead-acid type secondary cell are a positive plate of lead and lead peroxide, a negative plate of lead and spongy lead, and an electrolyte of dilute sulphuric acid. The reaction taking place on charge and discharge may be written as follows for simple explanation:

On discharge:

$$\overset{+}{2PbO_2}+2H_2SO_4+\overset{-}{2Pb}=(PbSO_4\overset{+}{+}PbO_2)+2H_2O+(Pb\overset{-}{S}O_4+Pb)$$

On charging, this equation is just reversed. From this it is seen that the electric current is generated in the cell by the chemical change of both positive and negative plates to lead sulphate which forms a coating thereon. Normally, this sulphate is soft and porous and can be readily returned to the original condition of lead and lead oxide and sulphuric acid by the charging current. It is readily seen, however, that if the discharge is carried too far, or if the electrolyte is too strong, the lead peroxide and spongy lead normally remaining on the plates will be changed into lead sulphate. This sulphate is a very good non-conductor of electricity and if the coating becomes too thick over the plates, the sulphate becomes hard and white and not enough current will flow on the recharge to break down the sulphate and return the active materials to their former condition. Restoration after sulphating can be accomplished only with great difficulty, the process including a series of cycles of overcharge and discharge with distilled water substituted for the electrolyte.

Rating and Capacity of Storage Batteries.

6. Storage batteries are rated in ampere-hours. This term applies to the normal capacity when uniformly discharged over a period fixed for each type and size of battery at a temperature of 80 deg. F., from full charge at the rated voltage down to a certain voltage given for each battery. In lead cells, this lower voltage may be taken at 1.75 volts per cell unless otherwise specified, and for Edison cells at

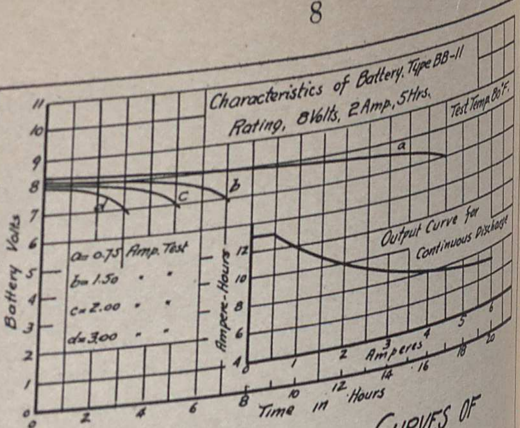
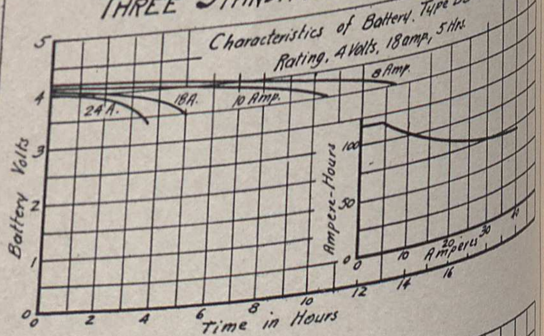
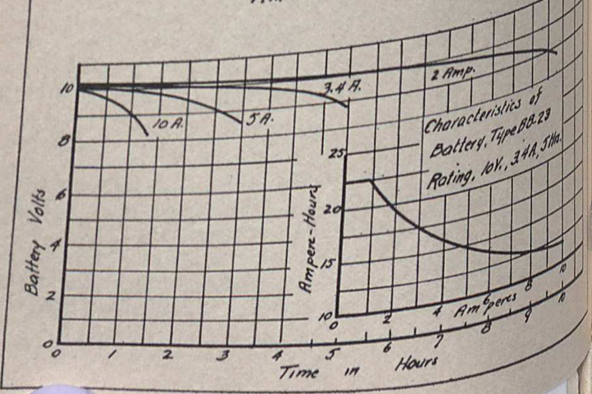


FIG. I CHARACTERISTIC CURVES OF THREE STANDARD LEAD BATTERIES





.9 volts. The watt-hour capacity of a battery is the product of its ampere-hour capacity and its average voltage during discharge. Thus a battery designated as one having a 100-amp-hr. capacity, would supply a 10-amp. continuous current flow for a period of 10 hours, the potential falling approximately from 2 volts to 1.75 volts per cell for lead batteries, and from approximately 1.5 volts to .9 volts per cell for Edison batteries.

7. The available capacity of a storage battery varies with the rate of discharge, the ampere-hour continuous flow decreasing with the increase of the rate of discharge. (See Fig. 1.) The ampere-hour capacity of storage batteries depends upon the area of the plates exposed to the electrolyte and hence upon the depth of the active material on their surfaces. In order to reduce the size of containers, batteries are made up of cells having a number of plates connected in parallel to form one positive and one negative element. In this combination there is always one more negative plate than positive. The capacity of American batteries may be taken at approximately 50 amp-hr. per sq. ft. of plate area.

8. Where a large number of batteries of different sizes are to be charged, the general rule for connecting them in order to charge the maximum number at one time, can be briefly summed up as follows: The limiting factors are the voltage and amperage of the charging source. The voltage determines the number of cells that can be connected in series, and the amperage determines the number that can be connected in parallel to the charging source. Batteries of different voltages are therefore connected for charge in series provided their ampere-hour capacity is approximately the same. They are connected in multiple if their voltage is approximately the same. The voltage required to charge a number of lead batteries in series may be determined approximately by multiplying the number of cells by 2.5 volts, and Edison batteries by multiplying the number of cells by 1.75. The amperage drawn from the charging source can be approximated by dividing the ampere-hour capacity per cell by 7 or 8, or the normal charging time in hours.

The normal charge and discharge rates for practically all Signal Corps batteries is marked inside the cover of the case. These are also given in the table at the end of this pamphlet.

II. EDISON-ALKALINE STORAGE BATTERY INSTRUCT

General Description.

9. The active materials used in the Edison type Signal storage batteries are nickel hydrate in the positive plates, an oxide in the negative plates, and the alkaline electrolyte is a so containing mainly potassium h ide. The chemical actions taking in the batteries on charge and dis are given in paragraph 3.

FIG. 2.—Magnified Section Through a Positive Tube. The Dark Lines Are the Nickel Flake.

10. The nickel hydrate in the po plate is packed under heavy pr into thin layers in perforated steel as shown in Fig. 2, this being a m fied cross-sectional view of a port one of the tubes. Between the of nickel hydrate are still thinner of pure nickel, which appear as lines in the cut. These metallic are made up of small flakes of n each flake being about 1/16-in. and much thinner than tissue p During charge and discharge of th teries, the passage of the electric cu alternately oxidizes and reduce nickel hydrate. The metallic n acts as a conductor forming a path of low resistance to all pa the active layers of hydrate. After the steel tubes are loaded, are strengthened by a number of encircling seamless steel rin shown in Fig. 3. They are then mounted in a steel grid or f which holds them in a vertical position and equally spaced.

11. The negative plate consists of a steel grid which suppo number of flat, perforated steel containers or pockets as show Fig. 4. The iron oxide is held within these pockets which subjected to a hydraulic pressure of 120 tons, forcing them permanent contact with the grids. The passage of current d operation of the battery causes the active material of the neg plate alternately to be reduced and oxidized.

12. The positive and negative plates are mounted on two rods which form an integral part of the tapered steel poles. These project through the top of the cell for external connection. The positive and negative groups thus formed are intermeshed as shown in Fig. 5 and are kept separate electrically by suitable rubber insulation. In this form, they are ready to be put into the steel containers.

13. The cell container is made of high grade sheet steel and, like all other metal parts of the cell, is heavily nickel plated inside and out. All seams are welded together by means of an oxy-acetylene flame so that the cells are sealed tight except for an opening in the cover which is provided for the escape of gases given off during charging, and for pouring in electrolyte and water.

14. Two different types of filler caps are provided with Signal Corps cells. One type has a plug which is threaded and will permit of a battery being laid on any of its four sides without the electrolyte spilling out. With this cap, if a cell is completely inverted, the solution will spill out. The second type of cap, which is held in place by a bayonet lock, is so designed that the cell can be completely inverted without spilling any electrolyte. The holes in the cell top through which the poles pass are sealed by suitable rubber gaskets. The cell poles, washers, connecting rods, nuts and so forth, are all made of high grade steel. The insulating material, both internal and external, is of hard rubber.

FIG. 3.—Steel Tube Container for Positive Active Material, Reinforced With Steel Rings.

15. The cell-to-cell connectors are made of heavily nickel plated copper, swedged or soldered into suitable lugs or terminals of steel. The positive pole of an Edison type Signal Corps cell is designated by a red bushing around the pole and a plus sign stamped on top of the can. The negative pole is designated by a black bushing around the pole and no designating mark. Fig. 6 shows a cut away section of an Edison type Signal Corps cell from which the manner of assembly can be seen.

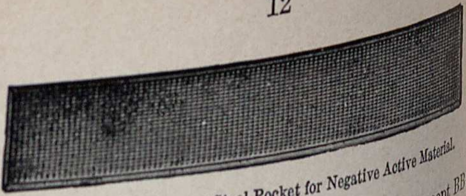


FIG. 4.—Flat, Perforated Steel Pocket for Negative Active Material.

16. The tray which supports the cells of a battery (except BB-5) is made of nickel plated steel. Openings are cut in the sides and ends of the tray to reduce the weight as much as possible. The cells are supported and held rigidly in the tray by means of hard rubber buttons which fit over steel bosses. These bosses are spot welded to the sides of the cell container. The supporting button is held firmly in place by reason of its fitting into a corresponding round hole in the side of the steel tray, Fig. 1.

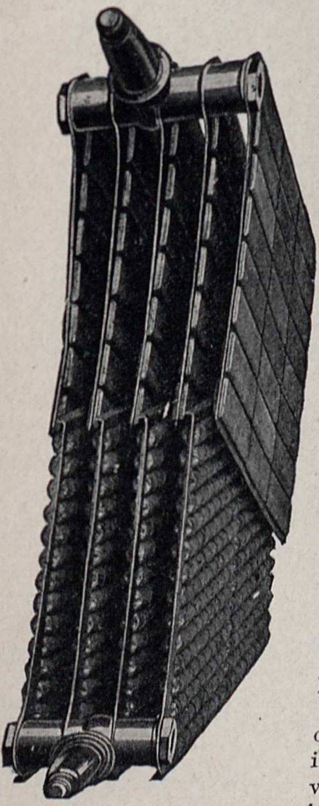


FIG. 5.—Method of Intermeshing Positive and Negative Plates.

17. **Signal Corps Battery Types and Sizes.**—At the time of this writing, the Signal Corps has adopted eight different types of Edison storage batteries for use in radio communication work. These are designated by the type numbers BB-1, BB-2, BB-3, BB-4, BB-5, BB-7, BB-8, and BB-9. Rather complete data as to rating, make-up of batteries, charge and discharge rates, etc., are contained in the table of data at the end of this pamphlet.

18. The BB-5 battery is made up of six Edison type G-4 cells, forming a 7.5-volt battery capable of developing 120 amp-hr. This battery is intended primarily for use with the SCR-67 radio telephone trans

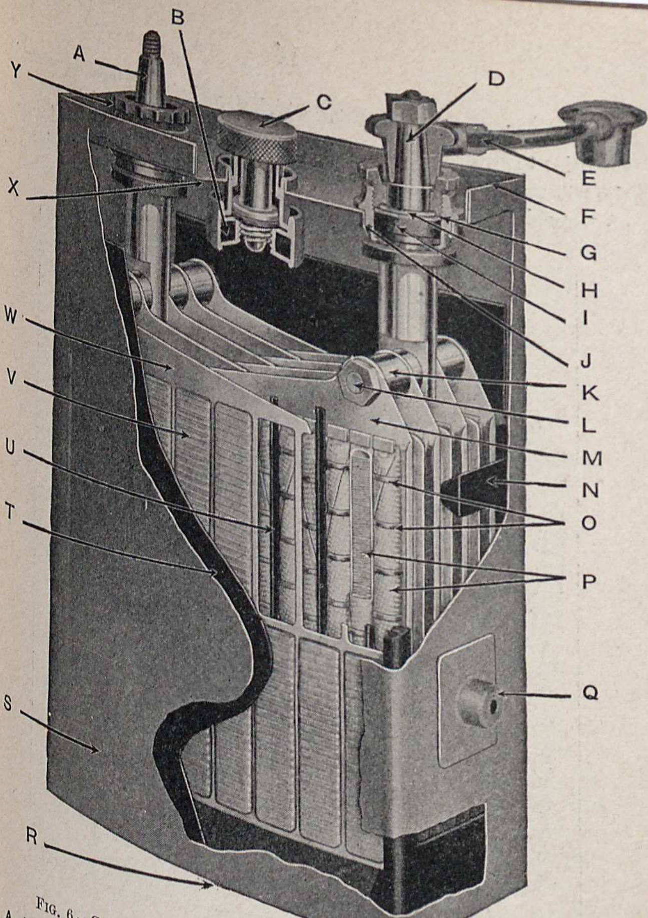


FIG. 6.—Cell Construction in Type BB-2 Edison Signal Corps Battery.

A—Negative pole.
B—Valve.
C—Filler cap.
D—Positive pole.
E—Copper wire swedged into steel lug.
F—Cell cover welded to container.
G—Stuffing box.
H—Gland ring.
I—Stuffing box gasket.
J—Weld to cover.
K—Spacing washer.
L—Connecting rod.
M—Positive grid.
N—Grid separator.
O—Seamless steel ring.
P—Positive tubes (nickel hydrate and nickel in layers).
Q—Suspension boss.
R—Cell bottom (welded to sides).
S—Solid steel container.
T—Side insulator.
U—Pin insulator.
V—Negative pocket (iron oxide).
W—Negative grid.
X—Cell cover.
Y—Hard rubber gland cap.

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mitting and receiving set for which two batteries are connect in series to supply 15 volts for driving a dynamotor which suppli the 300-volt plate current. The terminals of the BB-5 batteries a of a special type to facilitate making connection at any point t

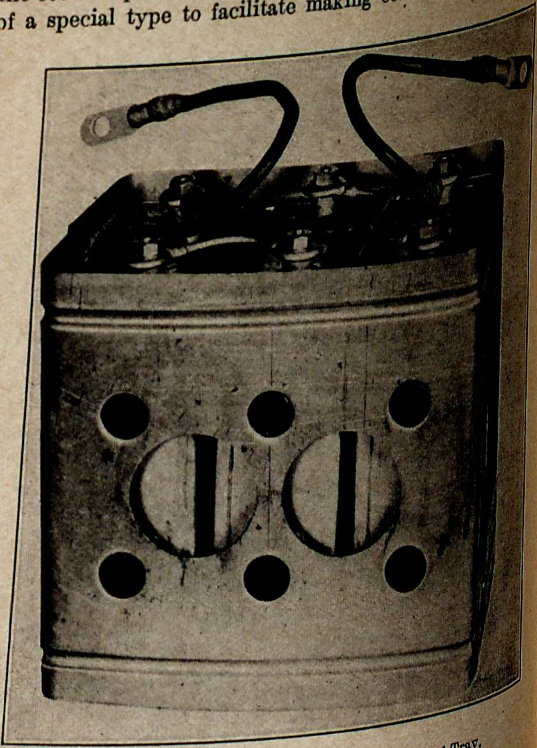


FIG. 7.—Manner of Assembling Edison Cells in Steel Tray.

obtain voltages from 5 to 15 volts. A 15-in. flexible jumper is supplied with each battery for connecting the pairs in series.

19. Battery Carrying Cases.—All carrying cases for Edison type Signal Corps storage batteries are made of steel. They are welded at the bottom and are water tight up to the cover. When the cover is fastened down, the case is rainproof. Each carrying case complete with carrying straps, terminals, hinges, cover hooks, etc. (minus battery), is given a Signal Corps type number; for example, the case for battery BB-1 is known as BC-1, and for BB-2, as BC-2, etc. The BC-1, BC-2 and BC-3 cases are provided with adjustable carrying straps made of O. D. cotton webbing. These straps are attached to the case at such an angle that they draw evenly on the holding cleat when carried with the strap over the far shoulder. Fig. 11 shows the case properly carried. The BC-4 case is provided with special brackets whereby it can be readily secured in the fuselage of an airplane. The BB-5 batteries are assembled in a wood tray provided with two metal carrying handles. All carrying cases are given two coats of olive drab enamel paint on the outside and thoroughly coated with asphaltum paint on the inside. On the top of the cover of each carrying case, the voltage of the battery is marked in raised letters. This is done so that any mistake in selecting a battery of wrong voltage from the charging station may be avoided.

20. The cell poles of the batteries are connected to the terminals which extend out through the metal carrying case either at the top or at the back corners as shown in Figs. 8, 9 and 10, to facilitate making connections to apparatus. A wing nut is provided on each of these terminals which is prevented from screwing off by a washer riveted to the top of the terminal stud. The wing nut on the positive terminal of cases BC-1, BC-2, BC-3 and BC-5 backs off to allow only a maximum opening of 9/32-in. The wing nut on the negative terminal allows a maximum gap of only 5/32-in. Since the hook terminal on the positive lead to the apparatus is ¼ in. in thickness, it can be readily placed in the opening allowed by the wing nut on the positive terminal, but cannot be placed on the negative terminal. This arrangement is provided to assist in preventing the reversing of polarity of leads when connecting apparatus to the batteries. A further precaution against wrong polarity is provided in that the insulating washer around the positive terminal is red while the one around the negative terminal is black. Also, a plus sign is stamped in the steel cover beside the positive terminal and a minus sign beside the negative terminal.

The terminals on the BC-4 case are smaller than those described above. The wing nut on the positive terminal backs off to leave a maximum gap of 5/32 in., and the negative nut to allow only a 3/32-in. gap.

Manner of Shipping Edison Batteries.

21. Prior to shipment, all cells are completely assembled in the steel trays (Fig. 7), at the manufacturer's factory. All connectors and pole nuts are fastened securely in place. The tray containing

FIG. 8.—Battery Type BB-2 Placed in Its Steel Carrying Case.

the cells is placed in the steel carrying case and the leads from the battery poles connected to the case terminals. The batteries are then fully formed by long overcharges. Directly following this treatment, all of the cells are given a complete discharge, after which they are short circuited for at least one hour. The electrolyte is

then emptied out entirely so that the cells may be shipped dry and completely discharged.

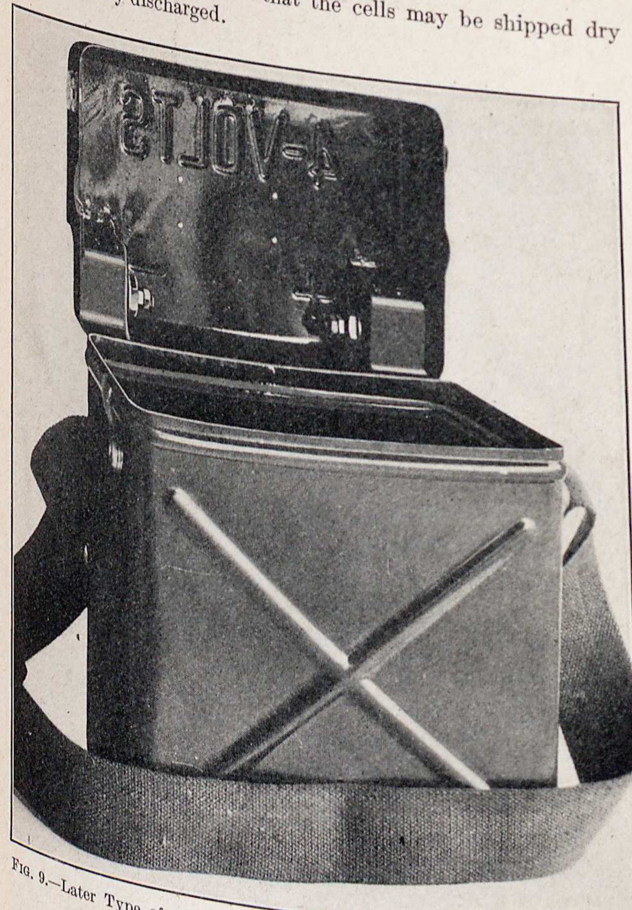


FIG. 9.—Later Type of Steel Carrying Case for Edison Batteries, with Binding Posts Inset at the Back Corners.

22. The electrolyte may be shipped in either liquid form ready for use or in dry powder form. In the latter case, complete instructions for mixing it with water to form the proper concentration of

solution are pasted on each container. For convenience, the electrolyte is put up in steel containers, each one holding sufficient electrolyte to completely fill one battery of cells, and each container being marked with the battery type number for which the contents are intended. The standard method of shipping is to crate up

FIG. 10.—Back View of Later Design Edison Battery Carrying Case Showing Welded Seam and Marking on the Cover.

together, three complete batteries, three steel containers holding the necessary electrolyte, one disconnecting jack and one wrench. The type number and number of batteries contained in the crate is stencilled on one end so that the batteries may be stored in stock as they are received without further marking. To date the Signal Corps practice has been to purchase the electrolyte in liquid form almost entirely.

Preparing New Edison Batteries for Service.

23. Open the shipping crate and remove the batteries, electrolyte and tools. If the electrolyte is in liquid form, puncture the cover of the steel container, preferably at diagonally opposite corners, by means of a chisel or other sharp tool. This will permit the electrolyte to flow freely from the container. If the electrolyte is in powder form, complete instructions for mixing it with water will be found pasted on one side of the steel container. If by any chance this label should be missing, mix the powder with sufficient water to make the specific gravity of the solution approximately 1.250 when all the powder is dissolved. If distilled water is available, it should be used; if not, proceed as instructed in ¶ 45. The mixing of this powder with water will cause the solution to heat. If conditions will permit, it is best to allow it to cool before pouring into the cells.

FIG. 11.—Provision Made for Carrying an Edison Battery. Later Cases Are Equipped with Rings into Which the Carrying Straps Snap.

24. To fill the cells of the battery with electrolyte, proceed as follows:

a. First open the cover of the steel carrying case.
b. Unscrew and remove the filler plug caps.
c. Insert a suitable glass or black iron funnel (not tinned).
d. Pour electrolyte in until the level is ½ in. above the tops of the plates.

e. Screw the filler plug caps back into place.

f. Test the height of the solution by means of a tube as described in ¶ *49*. The battery should now be ready to receive its initial charge.

Charging Edison Batteries.

25. When charging any of the Edison type Signal Corps batteries, the cover of the carrying case should be lifted and left open during the entire charging period. The filler caps on the tops of the cells should not be removed during charging. There is no occasion to remove them except when watering or renewing the electrolyte. When a battery is received at the charging station, an inspection should be made to see if any water has gotten into the carrying case. If so, this should be emptied out before the charge is started. Before placing the battery on charge, inspect the height of electrolyte in each cell. If the level is found to be below the plate tops, water should be added. (See ¶s 45 to 48 and 51.)

26. To charge a battery, the positive side of the line should be connected to the positive carrying case terminal and the negative side to the negative terminal. If a number of batteries are to be charged in series at one time, the negative terminal of one battery should be connected to the positive terminal of the next battery. If the carrying case terminals are covered with mud, they should be wiped off before the charging leads are connected, to insure good electrical contact. The normal charging rate for different types of Edison cells, vary according to the type of plates used and according to the number and size of plates in the cells. The normal charging rates for the Signal Corps types are given in the table in the back of this pamphlet.

27. The initial charge to be given a new battery should be longer than a normal charge. For type BB-2, the initial charge should be 12 hr. long at normal rates. For types BB-1, BB-3, BB-4 and BB-5, the initial charge should be 8 hr. long at normal rate. The evaporation of electrolyte during the initial charge is excessive and the cells should be watered at the end of the charge.

28. The normal charging time for type BB-2 is 7 hr. at normal rate, and for types BB-1, BB-3, BB-4 and BB-5, it is 5 hr. at normal rate. A normal length charge should be given a battery if it is received in a completely discharged condition. If it is received only half discharged, it should be charged for one-half the normal

length of time at normal rate. If only one-quarter discharged, it should be charged for one-quarter of normal time at normal rate. If the extent of previous discharge is unknown, charge at the normal rate until the voltmeter has remained constant for 30 min. at about 1.8 volts per cell with normal charging current flowing, and the cells gassing freely.

29. **Charging Methods.**—Batteries may be charged by either the "constant current" or the "tapering current" method. The latter is also known as the "constant potential" method. The constant current method may be employed when an adjustable rheostat is included in the circuit. The tapering current method may be employed with an adjustable rheostat or with a fixed resistance of proper design in the circuit.

30. As the name implies, the constant current method of charging is a scheme for keeping the charging current at the normal cell rate throughout the charge. To accomplish this, it is necessary to adjust the rheostat every half hour or so in order to keep the current at the right value. Set the current each time a few amperes high, so that even though it may drop below normal before the next adjustment, the average will be approximately equal to the normal cell rate.

31. The tapering current method is one in which the current automatically tapers off, due to the increase in the counter emf. of the battery as it becomes more nearly charged. If an adjustable rheostat is used in the circuit when this method is employed, set the current rate high enough above normal (about 50 to 75 per cent above will be found right in most cases) so that as it decreases it will average normal. Then do not touch the rheostat again until the charge is completed. Charge the same number of hours as though the rate were constant at normal value. By this method the current will taper off until at the end of the charge it will be considerably below the normal rate. If the charging equipment includes a fixed resistance especially designed for this method of charging, it is simply necessary to close the main supply switch. The curve of Fig. 12 shows the variation of current values throughout a normal tapering current charge. The ordinates of this curve will vary somewhat according to the amount of resistance in the circuit. The more resistance in a charging circuit, the more nearly flat is the charging current curve.

32. *Boosting.*—It is possible to charge Edison batteries at high rates during brief periods of idleness. The following table gives figures that may be used under average conditions.

An Edison type battery can be given—

5 min.	charge at	5 times	normal rate.
10 "	" "	4 "	" "
20 "	" "	3 "	" "
40 "	" "	2 "	" "

In case of emergency, these values may be exceeded somewhat. Frothing at the filler opening is an indication that the boosting rate is too high (provided the solution is at the proper level). If this is

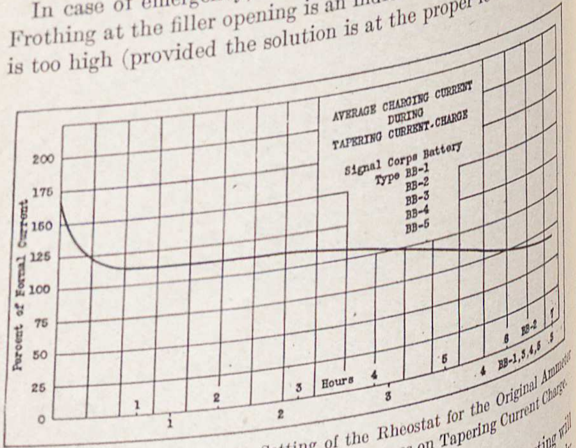


FIG. 12.—Curve Indicating the Setting of the Rheostat for the Original Ammeter Reading and Showing How the Current Decreases on Tapering Current Charge.

seen to occur, the rate should be cut down. High rate boosting will cause the cells to heat up. If conditions will permit, excessively high cell temperatures should be guarded against. A battery will not take its charge as satisfactorily when temperatures in excess of 115 deg. F. are encountered. The batteries will not show any immediate ill effect from an electrolyte temperature as high as 140 deg. F., but continued high temperatures, particularly on charge, will shorten the life of the battery somewhat.

33. *Low Rate Charging.*—Charging an Edison type Signal Corps battery at low rate can in no way injure the cells. If service conditions are such that relatively high discharge rates are encountered, then low rate charging is not advisable as the voltage on the subsequent discharge will be lower than normal. For example, the type

BB-2 battery has a normal charge rate of 15 amp. If conditions are such that this battery is to be discharged at a 15-amp. rate, then the charging rate should be normal. If, on the other hand, the discharge rate is relatively low, say 5 amp., then charging may be at a correspondingly low rate, but of course for a much greater length of time so that the total ampere-hour input will be normal. Generally speaking, it is well where conditions will permit to charge at the normal rate, regardless of the discharge rate.

34. **Determination of the State of Charge.**—The open or standing voltage of any storage battery cannot be used to determine the state of charge or extent of discharge. Neither can the specific gravity of the electrolyte of an Edison battery be used as a guide. In fact, the ordinary methods of testing the condition of a battery in the field are not dependable and it is therefore essential that a fresh battery be secured from the charging station after every period of use in order to be certain of ample capacity for the work in hand. As explained in ¶28, the proper method of determining the state of charge is to read the cell voltage while the battery is on charge or discharge. On charge, if the voltage remains constant at 1.8 volts per cell or above this for 30 min. with normal charge current flowing through the battery, then the battery can be considered fully charged. A very good check on this is to observe the extent of gassing. If a cell or battery of cells is gassing freely with normal current flowing, it is a pretty good indication that a condition of full charge has been reached. In this connection, distinction between gassing and frothing must be made. (See ¶38.)

35. **Overcharging Batteries.**—If the level of the solution is kept above the top of the plates, overcharging of Edison type batteries will in no way injure the cells. Overcharging wastes current and causes abnormal evaporation of the solution. For these reasons it should be avoided. However, in field service, if there is any doubt as to whether or not a state of full charge has been reached, it is advisable to overcharge somewhat to be on the safe side.

36. **Charging With Reversed Connections.**—If a battery should be connected up wrongly and charged in the reverse direction through a mistake on the part of the attendant, it is not probable that the cells will in any way be injured. Should this occur, the battery should be given a long charge in the right direction to restore the cells to their normal condition. This long charge should be made in the same manner as the initial charge described in ¶27.

37. **Charging Different Types of Batteries in Series.**—Conditions may frequently arise where batteries of different types with different charging rates must be charged in series. In such cases, charge at a rate equal to the average of the rates of the various batteries involved. For example, if a BB-2 battery with a normal rate of 15 amp. and a BB-3 battery with a normal rate of 7.5 amp. are to be charged together, a rate of 10 or 11 amp. would be about correct.

38. **Frothing.**—Frothing at the filler openings of a battery indicates either too rapid charging, too high a level of electrolyte, or impurities in the cells. If frothing takes place while charging at normal rate with the level of the electrolyte at the proper height, it is a sure indication that some form of animal fat or oil has gotten inside the cell. If the frothing continues for any length of time, the cell should be emptied and rinsed out and new electrolyte put in.

Clear distinction should be made between frothing and gassing of the battery. Frothing is evidence of something wrong. Gassing is a normal action which always takes place during charge. The click of the valves in BB-4 batteries, caused by the escaping hydrogen, may be distinctly heard and is somewhat of a barometer as to the state of charge.

39. **Warning.**—*Do not hold a match or open flame near a storage battery while it is being charged.* Hydrogen gas is given off during the process and this ignites very readily.

40. **Segregating Batteries.**—Inasmuch as the open circuit voltage of any storage battery is no guide as to the state of charge, a system of storage at the charging station must be instituted whereby charged and discharged batteries will be kept entirely separate.

Discharge.

41. The normal discharge rates for Edison type Signal Corps batteries will be found in the table at the end of this pamphlet. It is well to remember that the normal discharge rate (as designated by the manufacturer) for any type of Edison cell is always the same as the normal charge rate.

42. The average voltage of any Edison type cell, discharging at normal rate, is 1.2 volts. At rates lower than normal, the voltage will average slightly higher. The curves of Fig. 13 show the variation of discharge voltage at different discharge rates. High rate discharges may be employed without fear of injury to the cells.

As the rate of discharge is increased, however, the average voltage is lowered. High rate discharges, that is, up to 4 or 5 times normal, do not materially affect the ability of the cell to deliver full ampere-hour output.

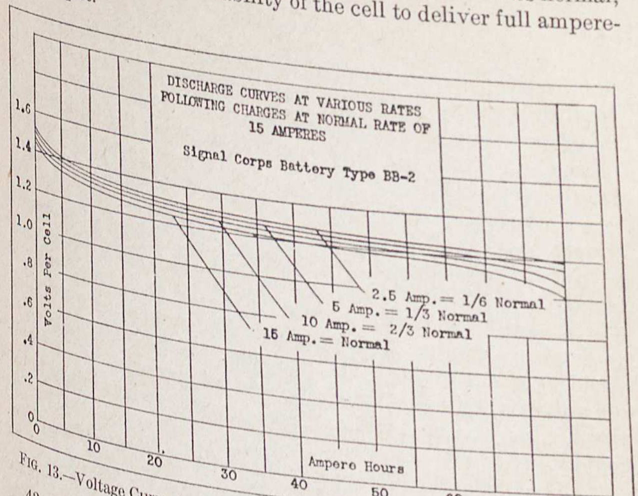


FIG. 13.—Voltage Curve for Battery Type BB-2 for Different Rates of Discharge.

43. Edison type cells are not injured by a short circuit discharge. When given a dead short circuit for any length of time, the cells will heat up excessively. An occasional discharge to complete exhaustion will keep the negative plates in good active condition and is therefore desirable.

44. **Capacity of Batteries.**—Under proper treatment storage batteries in general improve with use. A new cell will continue to increase in capacity for a period of at least 30 cycles of charge and discharge. If a new battery or one which has been standing idle for a long time, operates somewhat sluggishly, use it as much as possible, giving it occasional complete discharge and it will soon pick up to normal capacity. If the capacity of a battery falls off, it is usually an indication that the electrolyte needs to be changed. (See ¶ 54.) Experience in commercial service indicates that several years of continuous service under normal conditions may reasonably be expected from batteries of the Edison type. Hence, a battery should not be condemned as useless because it is perhaps a year or two old, as a thorough inspection will more than likely determine

that the plates are all right and that all that is needed is a renewal of the electrolyte and a forming charge.

Watering.

45. During charge, water of the solution is driven off as gas and must be replaced. Under normal conditions, it will probably be found necessary to add water after each three complete cycles of charge and discharge. The evaporation during the initial or any long overcharge is considerable. Hence the cells should be watered upon completion of the charge, to bring the electrolyte up to the proper level.

Distilled water should be used for flushing (filling) a battery if it is available. If distilled water is not to be had, use any pure water which may be at hand. Rainwater is very good. Any water fit to drink may be used. The principal precaution necessary is to avoid water containing acids or sulphur. Water containing moderate amounts of iron or lime, although not approved by the manufacturer, may be used without fear of causing serious injury to the battery.

46. *The level of the solution must be kept above the top of the plates.* When the level gets down to the plate tops, the cells should be watered. The proper level of the solution is ½ in. above the plate tops.

47. Care should be exercised when filling a battery to avoid spilling water over and around the cells and not to exceed the specified level of ½ in. above the plates. Water spilled around the outside of the cells and into the bottom of the case may set up an electrolytic action which will eat away the steel. If the cells are filled too full, the electrolyte will be forced out during the charge and the solution will thereby be weakened.

48. The cells should always be filled before placing them on charge, not after they are connected to the charging source. When a battery is placed on charge, the gas formed lifts the electrolyte to a false level so that watering must be done before connecting to the charging source in order to insure measuring the true level.

49. To test the height of solution in a cell, a glass tube may be used, Fig. 14. Insert the tube into the cell through the filler opening until the tops of the plates are touched. Close the upper end of the tube with the finger and withdraw. The height of liquid in the tube indicates the height of the solution above the plate tops. The

glass tube must not be less than $\frac{3}{16}$ in. inside diameter and its ends must be cut straight.

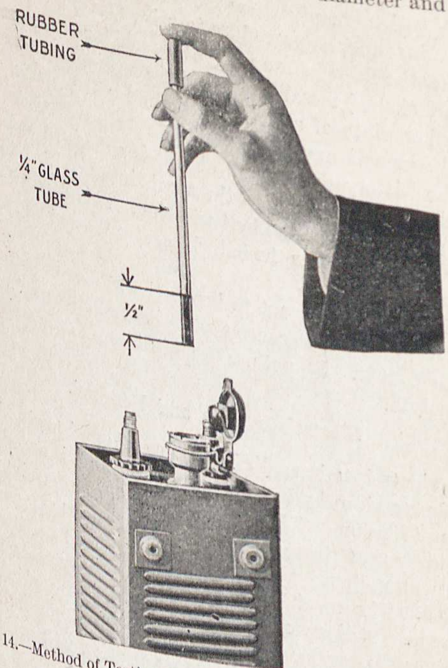


Fig. 14.—Method of Testing Height of Electrolyte in an Edison Battery.

50. **Electric Filling Outfit.**—A convenient means of keeping the level of the solution at the proper height when a battery is brought in for charging is supplied in the electric filling outfit manufactured by the Edison Storage Battery Co. The set is very simple, and a home-made substitute may be easily rigged up in the absence of an outfit purchased for the purpose.

A tank filled with distilled or other pure water for watering a battery is mounted on a wall or other convenient place so that the tap is 4 or 5 ft. above the top of the cells. A rubber hose attached to the tank is fitted with a special nozzle which is so arranged that upon insertion into a cell, if the solution is at the proper height, it will make an electrical connection and cause an electric bell to ring. Hence, in testing a battery, it is only necessary to insert this nozzle, and if the bell does not ring (indicating that the solution is not at the proper level), to simply allow the water to flow until the bell does ring. The manner of procedure in using this outfit is as follows:

51. Test the filler before using it by making connection between the funnel shaped metal collar and tip of the nozzle with a knife, key or other piece of metal. If the bell will not ring, either the electrical connections of the filler are broken, the bell needs adjusting, or the battery on the bell circuit is exhausted and should be recharged or replaced. Insert the nozzle into a cell. If the solution is at the proper height, the bell will ring. If it does not ring, start the flow of water. When the bell rings, stop the flow and remove the nozzle from the cell.

Care should be taken not to break the rubber insulation on the nozzle as this is likely to cause a short in the bell circuit. Use only water in this outfit. Do not use the outfit for refilling a battery with new electrolyte.

Electrolyte Data and Renewal.

52. The electrolyte in an Edison type cell consists of a 21 per cent solution of potassium hydrate in water, to which is added a certain percentage of lithium. The normal strength of electrolyte in a cell should be such that the specific gravity is about 1.200 as measured by a hydrometer, but at times when newly mixed up, it may be as high as 1.230. The specific gravity varies slightly according to the state of charge. It is lowest when a cell is in a fully charged condition and highest when the cell is completely discharged, just the reverse of the lead-acid battery. This variation will average about 20 points.

53. After a period of use, the electrolyte will weaken and must then be completely renewed. The interval between necessary electrolyte renewals will vary greatly according to the nature of the service and the care of the battery. It may be anywhere from 9 months to 4 or 5 years, based on experience in commercial use. In the Signal Corps service, this question must be determined by specific gravity readings taken now and then. If the electrolyte in a cell is found to have a specific gravity of 1.160 or less, when tested after a full charge, it should be renewed. But before measuring the specific gravity always make sure that the cell is filled to the proper height and that the electrolyte is thoroughly mixed. If a gravity reading is taken directly after the addition of water, unless the cell is thoroughly shaken, a false reading will result.

54. **Method of Renewal.**—The renewal of the electrolyte in a cell is simply done according to the following procedure:

a. Discharge the battery completely.

b. Empty out the old solution. (Do not pour out the old solution until the new has been received and is ready to be poured into the battery, since the negative plate may not be completely discharged and will then oxidize on exposure to the air and heat up.)

c. Refill immediately with new electrolyte to the proper height of ½ in. over the plate tops.

d. Give the battery a long charge, similar to the initial charge explained in ¶ 27.

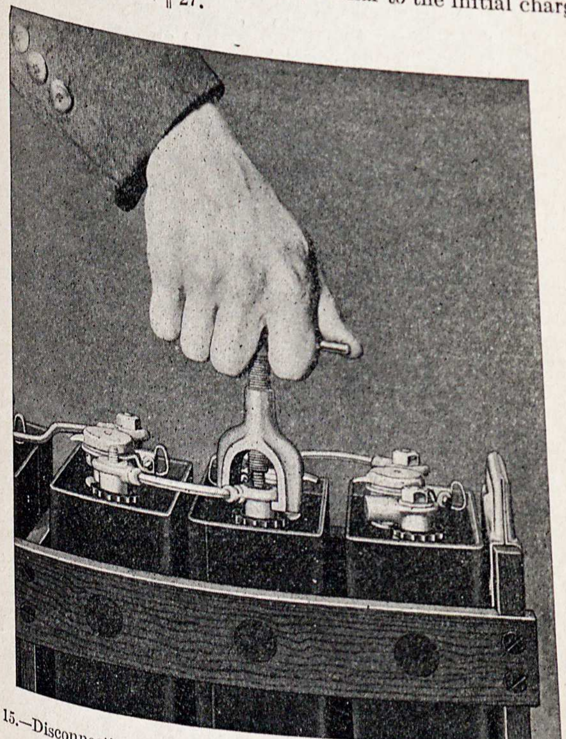


Fig. 15.—Disconnecting Jack for Removing Cell-to-Cell Connectors, Edison Batteries

55. In putting the electrolyte into a cell, an earthenware pitcher and glass or black iron funnel should be used. Do not use a tinned funnel.

In handling the solution, care should be used to avoid getting it on the hands and clothes as it has a destructive effect.

General Information.

56. **Standing Idle.**—The Edison type battery may be allowed to stand idle in either a charged, partially charged or completely discharged condition without fear of injury. If a battery is to be stored, the cells should be filled with water to the usual level and the steel container thoroughly coated with vaseline to prevent possible corrosion. The battery should always be stored in a dry place if possible and right side up. The evaporation of electrolyte from the batteries standing idle is very slight. If the cells are properly filled before being stored, it should not be necessary to add water more frequently than about once in six months to maintain them in perfect condition.

57. If a battery stands idle for a considerable length of time, it becomes very sluggish and is very similar in its action to a new battery. When it is placed in service again, it should first be completely discharged and then given a long charge similar to the initial charge. This will bring it back to an active condition.

58. **Reshipment of Batteries.**—If batteries that have been in service in training camps are to be shipped overseas, or if a move of considerable length is to be made under any conditions, proceed as follows:

a. Discharge the battery completely.

b. Connect a piece of wire across the carrying case terminals and short circuit the batteries for one hour.

c. Drain all the electrolyte from the cells so that they may be shipped dry.

d. If possible, secure renewal solution from the supply depot for refilling at destination, and pack it in the same crate with the battery.

e. When the batteries are received at the destination, proceed as though they were new batteries in putting them back in service.

59. When batteries are to be transferred from one point to another near at hand, the electrolyte may be left in the cells, provided the crates are marked, "This Side Up," and care is taken to see that this instruction is followed.

60. **Removing a Connector or Cell.**—To remove a cell-to-cell connector, first remove the nut on the top of the cell pole. Then, by means of a disconnecting jack, the connector can be readily pulled off as illustrated in Fig. 15.

61. To remove a cell from its steel tray, first remove the cell-to-cell connectors. Then take the tray apart by pulling out the cotter pins from the ends and the cells can readily be lifted out. If the cells are assembled in a wooden tray as is the case with type BB-5 batteries, remove the screws from both ends of the upper and lower side slats on one side of the tray, and the cells can then be readily lifted out.

62. When placing a new cell in a tray, see that the steel bosses on the sides of the cell fit securely in the supporting rubber buttons. Also, be sure that the cell is properly placed in the tray, so that the positive pole of one cell will be connected to the negative pole of the adjacent cell. When replacing the connectors, make sure that the contact surface on the tapered section of the cell pole is clean, likewise the inside of the lug which fits over the pole. This will insure good electrical contact. Seat the connector tightly on the pole by screwing down the pole nut.

63. When batteries are charging, it is advisable to occasionally feel of the cell-to-cell connectors and lugs to see if they are getting hot. A hot connector as a rule indicates that dirt has gotten on the pole contact surface underneath the lug. This may be remedied by removing the connector and cleaning the contact surfaces.

64. **Low Temperature Effects.**—If the specific gravity is normal, an Edison type cell will not freeze until the electrolyte temperature gets lower than 20 deg. below zero F. If electrolyte temperatures lower than this are encountered, the solution will not freeze solid but will congeal into a snowy consistency. This, of course, temporarily discontinues the action of the battery but does not injure it permanently in the least. The rate of cooling of the electrolyte is very slow, particularly when being discharged even at a very low rate, and due also to the dead air insulation around the cells in the carrying case. It is therefore doubtful if conditions causing a battery to freeze will ever be encountered.

65. A battery will absorb its charge quite readily, even though the electrolyte temperature may be very low. If batteries are discharged at relatively high continuous rates, with a low electrolyte temperature, a temporary loss of capacity will be noted. If the rates of discharge are low, such as are used in the filament circuit of vacuum tubes, or if the discharge is of an intermittent nature, the effect of low temperatures is very much less than under normal rated discharge current.

66. If conditions will permit, it is advantageous to keep the temperature of the charging room above 32 deg. F.

67. **Cleaning and Coating Cells.**—Edison type cells do not require any internal cleaning as there is practically no sediment precipitated to the bottom of the container. However, they should be kept clean externally, since in field service, the space around the cells inside the carrying case is likely to become packed with mud and dirt and this should be carefully cleaned out. The outside of the container, trays, etc., should be kept as dry as practicable.

A slight deposit of potash salts will collect under normal conditions on the tops of the cells. This is not at all injurious but if it becomes too heavy it should be brushed off.

The outside of the cell containers is coated with a vaseline compound containing a small amount of resin, the purpose of which is to protect the steel containers from possible corrosion. If this coating is wiped off, it should be replaced. Any ordinary commercial vaseline may be used for the purpose.

68. *Do not under any conditions put acid in an Edison cell.* It will ruin the battery completely. Edison batteries have an entirely different appearance from lead batteries and there is absolutely no excuse for the mistake of putting acid in them.

69. On all Edison type Signal Corps batteries, a pair of rubber covered wires are used as connectors between the battery poles and the carrying case terminals. If the rubber insulation on these wires becomes chafed, it is possible that some of the cells of the battery may be short circuited. This should be guarded against.

70. Each charging station should maintain a supply of spare parts. These will be available and should be secured.

III. LEAD-ACID STORAGE BATTERY INSTRUCTIONS.

General Description.

71. In the plates of practically all lead-acid batteries used for Signal Corps purposes, a grid made of stiff lead-antimony alloy supports the active material in the form of a series of vertical strips held between the grid bars, and locked in place by horizontal surface ribs which are staggered on the opposite sides. After the grids are cast, they are "pasted" with oxides of lead made into a paste of special composition which sets, in drying, like cement. The plates then go through an electro-chemical process which converts the material of the positive plates into brown lead peroxide and that of the negative plates into gray, spongy lead.

72. Both the positive and negative plates are provided with an extension or "lug," and they are so assembled that all the positive lugs come together at one side of the jar and all the negative lugs, at the other, thus enabling each set to be burned together with a connecting strap to produce one positive and one negative pole. The burning is usually done by a hydrogen flame which melts the metal of both lugs and strap into an integral union. A set of plates burned to a strap is known as a "group," either positive or negative. The straps are made of hard lead alloy and are provided with posts to which the cell connections are made. When the positive and negative groups are assembled together, the adjoining plates are kept out of contact by means of separators which are ribbed on the side against the positive plate. These separators are made of rubber or tough wood particularly adapted to the purpose. They are given a special treatment to remove harmful substances. A positive and negative group, assembled with separators properly placed, is called an "element."

73. **Lead Battery Jars.**—The container for the cell is made of either hard rubber or transparent celluloid. Both are so built as to have the proper insulating and acid-resisting qualities and at the same time to be mechanically strong enough to withstand the knocks and misuse to which a storage battery is subjected. On the bottom of the jar are several stiff ribs built integrally with the jar, upon which the plates rest, thereby giving room for sediment to accumulate without affecting the operation of the battery.

74. The covers for the rubber cells are of simple flanged construction, fitting over the two binding posts. They are held in place by sealing nuts. An effective seal is formed by using washers

between the cover and collars on the binding posts. In some storage batteries the binding posts of each cell are threaded to the end to accommodate a bolted connection between cells. In others, the burned connections are used. In each cover, there is a filling plug which may be unscrewed and taken out when it becomes necessary to test or change the electrolyte.

75. *Rubber vs. Celluloid Jars.*—Both hard rubber and celluloid jars are used on the standard Signal Corps batteries. Their relative merits may be summed up as follows:

For rubber jars, the very best grade of rubber is required and it is very difficult to secure since the market product is very variable. Celluloid, on the contrary, is a very definite composition, variation in its composition being due mainly to the extent to which the curing process is carried. Rubber, according to the specifications, must indicate a tensile strength of 5000 lb. per square inch with a 6 per cent elongation. Celluloid must withstand a tensile strength of 6000 lb. with a 10 per cent elongation. The celluloid jar is one-half as thick as the rubber jar and weighs one-half as much, some jars being only $\frac{1}{16}$-inch thick, while the rubber jars are never less than $\frac{1}{8}$ in. thick. Rubber is subject to progressive hardening with use through contact with acid, and it softens through contact with gasoline and water. Celluloid is not affected in this manner. The rubber jar is always more brittle than the celluloid jar and consequently the latter will stand more rough handling without breakage. The celluloid jars are transparent for the first several months of their use. While the transparency remains, it gives the advantage that the height of the electrolyte and the condition of the plates may readily be observed from the outside of the battery. The rubber cell is much more easily dismantled than the celluloid, it being almost impracticable to attempt to dismantle and re-assemble the latter. The celluloid is more inflammable than the rubber, and for this reason, the celluloid jar is never used on airplanes or in tanks.

76. **Battery Carrying Cases.**—Contrary to the practice with Edison batteries, no type numbers are assigned to the carrying cases of lead plate storage batteries since the cells of the battery are assembled in the case and are never supplied without the case. The Edison batteries are assembled in a tray which in turn is put in a carrying case. The cases for lead batteries are always made of wood, preferably white oak or birch. They are equipped with hinged lids to make them rain proof and are always provided with straps made of O. D.

rubber belt, two-ply, 2 in. wide, with snaps on either end for hooking into rings attached to the battery case ends.

The cases are painted outside with O. D. acid-proof paint. The battery leads are connected inside the cover to the binding posts mounted at the back corners of the lids and equipped with wing nuts

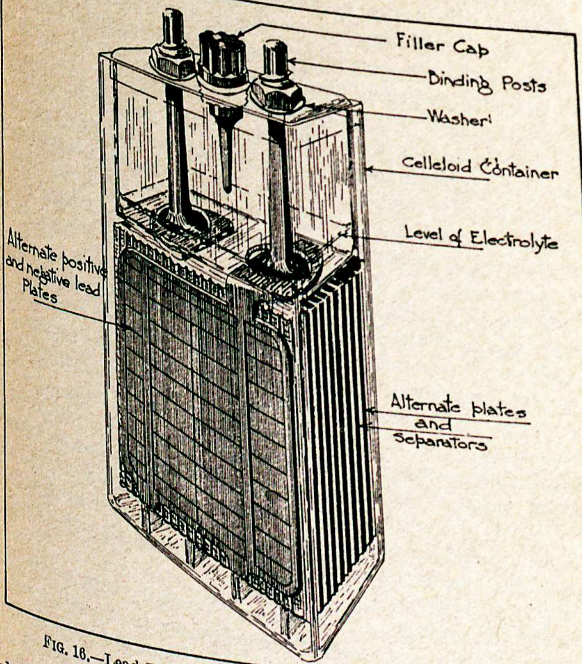


Fig. 16.—Lead Plate Battery of Non-spill Design in Celluloid Jar.

which cannot be unscrewed except for a sufficient amount to permit inserting the terminal of a connecting lead. These two binding posts are marked with red and black paint respectively to indicate the plus and minus connections. The newer batteries have in addition to the colors the "+" and "—" signs stamped on the case. In addition to the binding posts, all lead battery cases ordered to date are equipped with a standard French receptacle which is polarized by the position of the connecting studs and jacks. To protect the batteries in a measure from shock, a ¼-in. layer of spongy rubber is placed in the bottom of each case and the cell jars rest on this.

Acid Electrolyte.

77. **Specific Gravity.**—The electrolyte used in lead plate batteries consists of dilute sulphuric acid. Concentrated sulphuric acid is a heavy oily liquid having a specific gravity of approximately 1.835. A battery will not operate if the acid is too strong and it is therefore diluted with sufficient pure water to bring it down to a specific gravity of about 1.275 for a fully charged battery.

78. During discharge of a battery the acid reacts with the lead to form lead sulphate and water, thereby further diluting the electrolyte and lowering its specific gravity. The drop during a complete discharge is from 100 to 150 points. Upon being charged, the sulphate combines with the water to form acid, thus bringing the gravity up to its normal value. No exact specific gravity for an electrolyte can be set, but it should be maintained between the limits of 1.250 to 1.300 in a fully charged battery. Conversely, a battery should never be discharged beyond the point at which the specific gravity of the electrolyte reaches about 1.180. Further discharge beyond this lower limit will be accompanied by a permanent sulphating of the plates which seriously impairs the output of the battery.

79. During operation, water evaporates from the electrolyte and must be replaced. The acid does not evaporate and unless some of the electrolyte is spilled out, or seeps out through a cracked jar, there is no need for replacement. The acid in an electrolyte will last the life of the battery and unless it is positively known that some has been lost, none should be added.

The specific gravity will lower somewhat as the battery ages, but the battery should continue to give good service as long as the gravity reading on full charge remains between the limits of 1.250 and 1.300. If the specific gravity should ever read above 1.300, it should be promptly lowered by replacing some of the electrolyte with water. Low gravity in a battery or cell is usually the result of acid being combined in the plates through insufficient charge, although if acid is spilled out, no amount of charging will restore the specific gravity. Decreasing gravity throughout the cells of a battery (when not due to insufficient charging) may indicate that sediment is accumulating in the bottom of the jars. This is accompanied by a falling off in the capacity.

80. **Adjusting the Specific Gravity.**—Adding high specific gravity electrolyte to bring up the specific gravity should be done only after the battery has been fully charged. In other words, it is necessary to first make sure that the maximum gravity has been reached, or that no acid remains combined in the plates. This is essential, since if the electrolyte in a cell should be adjusted to 1.275 when 50 points of acid remain in the plates, the gravity would come up to 1.325 if the cell were afterward fully charged. The only way that it may be certain that the specific gravity has been brought to its true maximum is by charging the battery at about half the normal finishing rate until there is no further rise during a period of at least 24 hours. If after this manner of charge, the gravity still remains low, the electrolyte should then be removed down to the top of the plates and replaced with 1.300 electrolyte to bring up the specific gravity.

For best operation, it is essential that both acid and water used in the electrolyte be pure. Pure acid is called "battery acid" by commercial manufacturers. The water used must be distilled. In the event that no distilled water is available, rain water may be substituted in emergency.

81. *Watering.*—In adjusting the specific gravity downward the best time to add water to the electrolyte is just before a charge. Then the gassing and chemical action during the charge will stir up the freshly added water with the electrolyte. If added after a charge, the water has a tendency to remain at the top and the electrolyte will be non-homogeneous.

82. Evaporation should be replaced every five to 15 days, depending upon the conditions of service. For this purpose, it is safest to use only distilled water, for even small quantities of impurities permanently injure a battery. Water for this purpose should be transported and stored in vessels made of glass, lead, or tin. Distilling apparatus should be made only of copper or tin. Iron and chlorine are the two most injurious impurities present in water. If it becomes necessary to empty out the electrolyte to form a correct mixture or to make a new mixture, *the acid should always be poured into the water*, not the water into acid. A great amount of heat is given off when the two are mixed, and if the water is poured into the acid, the liquid will boil violently, spattering acid around badly.

83. *It is necessary that the plates and separators be covered with electrolyte at all times. A level about ½ in. over the tops of the plates is the correct level.*

84. **Measuring Specific Gravity.**—In reading specific gravities, that of water (unity) is written 1.000 and is called "one thousand." This has come into common usage due to the fact that the gravity is carried out to three decimal places. Similarly, the gravity of concentrated sulphuric acid is spoken of as "eighteen thirty five." In determining the specific gravity of an electrolyte, a hydrometer is generally used. This consists essentially of a closed narrow tube with a partly evacuated bulb at one end, which will float vertically in a liquid. The side of the tube is graduated so that the level to which the tube sinks in the liquid, as read on the scale, corresponds to the specific gravity of the liquid compared to water. A commonly used hydrometer has the floating bulb in a glass barrel on one end of which is a rubber bulb. On the other end is a rubber tube. When this tube is put in a liquid and the rubber bulb pressed and released, the liquid is sucked up into the barrel, floating the hydrometer so that the gravity may be measured. Then the liquid can be put back into the container, or in the case of a battery, back into the jar, by squeezing the rubber bulb.

85. *Comparison of Specific Gravity and Baumé Scales.*—It is the European practice to express densities of electrolyte in degrees Baumé, and some of the hydrometers now in use are so graduated. In American practice, on the other hand, it is customary to use specific gravity, and instructions for American batteries and the calibration of American hydrometers will probably be in these units. In order to convert from one method to the other the following table for liquids heavier than water is given:

Degrees, Baumé.	Specific gravity.	Degrees, Baumé.	Specific gravity.	Degrees, Baumé.	Specific gravity.
0.0	1.000	19.0	1.151	38.0	1.355
1.0	1.007	20.0	1.160	39.0	1.368
2.0	1.014	21.0	1.169	40.0	1.381
3.0	1.021	22.0	1.179	41.0	1.394
4.0	1.028	23.0	1.189	42.0	1.408
5.0	1.036	24.0	1.198	44.0	1.436
6.0	1.043	25.0	1.208	46.0	1.465
7.0	1.051	26.0	1.219	48.0	1.495
8.0	1.058	27.0	1.229	50.0	1.526
9.0	1.066	28.0	1.239	52.0	1.559
10.0	1.074	29.0	1.250	54.0	1.593
11.0	1.082	30.0	1.261	56.0	1.629
12.0	1.090	31.0	1.272	58.0	1.667
13.0	1.099	32.0	1.283	60.0	1.706
14.0	1.107	33.0	1.295	65.0	1.813
15.0	1.115	34.0	1.306	70.0	1.933
16.0	1.124	35.0	1.318	75.0	2.071
17.0	1.133	36.0	1.330		
18.0	1.142	37.0	1.343		

Formula: Specific gravity = 145×(145—Deg. Baumé.)

86. **Temperature Effects.**—Acid electrolyte expands when heated due to the chemical action, and the expansion effects a change in the specific gravity of the electrolyte. For every 3 deg. rise in temperature, its gravity drops one point (0.001). For instance, if an electrolyte has a gravity of 1.268 and the temperature is increased from 73 deg. F. to 76 deg. F., the gravity will be reduced to 1.267. For convenience, 80 deg. F. is considered normal temperature from which such corrections as are necessary are made.

87. An electrolyte may freeze in cold weather, the freezing point being lower the higher the specific gravity. This is easily understood for the percentage of acid in the solution is greater for the higher gravities. Thus, batteries which are kept properly charged are less likely to freeze. The curve of Fig. 17 gives an idea of the

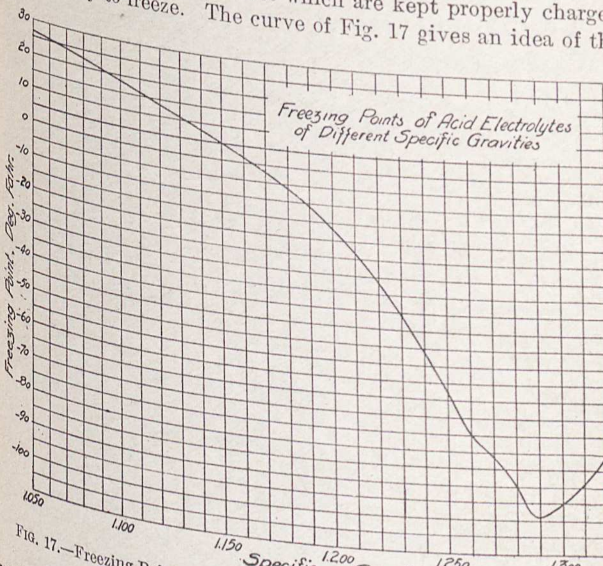


Fig. 17.—Freezing Points of Acid Electrolytes of Different Specific Gravities.

variation of freezing point with specific gravity. This curve will vary for different batteries as the freezing temperature depends somewhat on the proportion of electrolyte to lead making up the volume of the battery. From test records, it has been found that with the specific gravity down to 1.150 at full discharge, the electrolyte of a lead battery will freeze at a temperature as high as 5 deg. F

88. **Action on Discharge.**—When a cell is put on discharge, the current is produced by the acid of the electrolyte combining with the lead of the porous part of the plates called the "active material." As the discharge progresses, the electrolyte becomes weaker by the amount of acid that is used in the reaction. The product of the reaction is the electric current and the compound, lead sulphate. As this sulphate accumulates, it fills the pores of the plates. This reduces the surface area of active material and the free circulation and action of the acid is retarded. Since the acid can not then get into the plates fast enough to maintain the normal action, the battery becomes less active and this is indicated by a rapid drop in voltage.

Whenever possible, batteries should be discharged at their normal rate. In exceptional cases, higher discharge rates may be used. This should never be done, however, if the rate of discharge is great enough to heat the battery above 125 deg. F. in any part. Ordinarily, 110 deg. F. is considered a maximum normal working temperature.

89. **Action on Charge.**—To charge a battery, a direct current (alternating current cannot be used unless rectifying apparatus is available for changing it to direct current) is passed through the cells in a direction opposite to that of the flow of the discharge current delivered by the battery. This charging current reverses the action which took place in the cells during discharge. It will be remembered that the acid of the electrolyte combined with the active material of the plates filling the pores with sulphate and causing the electrolyte to become weaker. Reversing the current through this sulphate in the plates restores the active material to its original condition and returns the acid to the electrolyte. Thus during charge, the electrolyte gradually becomes stronger as the sulphate in the plates decreases until no more sulphate remains and all the acid has been returned to the electrolyte, when it will be of the same strength as before the discharge and the same acid will be ready to be used over again during the next discharge. Summing up, the acid absorbed by the plates during discharge is, during charge, driven from the plates by the charging current and restored to the electrolyte. This is the whole object of charging.

The charging rate in amperes is limited by the state of discharge. When a battery is fully discharged, at which time the plates contain the greatest amount of sulphate, it can utilize current at the highest

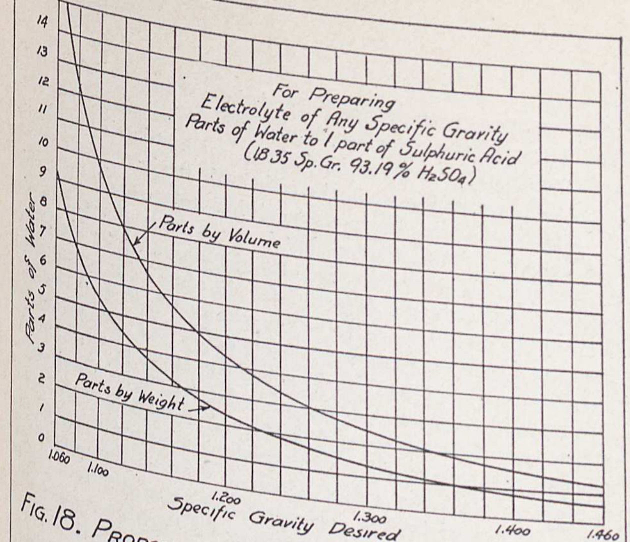
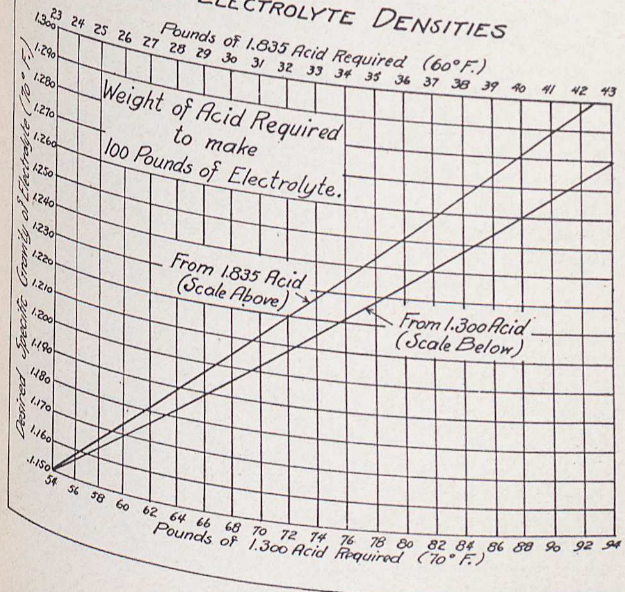


FIG. 18. PROPORTION OF WATER TO ACID FOR VARIOUS ELECTROLYTE DENSITIES



rate. As the charge progresses and the amount of sulphate in the plates decreases, the battery can no longer utilize current at the same rate and the current should be reduced. The time at which to reduce the current is when the cells begin to give off gas.

90. *Gassing.*—The gassing of a cell is a feature of charging which has been very little regarded, but is of great importance. Gassing shows at any time whether or not the charging rate is too high. Current passing through an electrolyte will always do something. It will do the easiest thing first. When current is passed through a discharged cell, the easiest thing is to decompose the sulphate. As there is a comparatively large amount of sulphate in a fully discharged cell, a high rate of current can be used, but as the amount of sulphate decreases a point will be reached at which there will not be sufficient sulphate remaining in the plates to utilize all the current passing through. The excess current will then begin to do the next easiest thing, which is to decompose the water of the electrolyte, producing gas. Therefore, when the cells begin to gas freely, it indicates that current is being passed through the cells at too high a rate and the current should be lowered sufficiently to stop the gassing. As the charge is continued at the lower rate, the remaining sulphate will continue to decrease in amount until there is not sufficient left to utilize this lower rate of current and the cells will again begin to gas. The current should be lowered each time the gassing begins. When the cells begin to gas freely at a very low rate, it indicates that there is no sulphate remaining and the charge is completed.

91. *Frothing.*—Frothing of lead batteries may occur and it should not be confused with gassing. A certain amount of gassing is natural. Frothing is due to imperfectly treated wood separators or it may occur when the battery is first put into service after storage. It will usually cure itself. If it continues, the battery will likely become permanently defective.

Charging Lead Batteries.

92. It is best to charge batteries at the normal rate usually specified in the cover. Under some circumstances it may be advisable and necessary to use a higher rate of charge. It should not, however, be high enough to cause excessive gassing or to raise the temperature of any part of the battery higher than 125 deg. F.

Before starting the charge, the voltage of the battery and the specific gravity of one cell should be measured, all readings during the charge being taken on the same cell to indicate the general state

of charge of the entire battery. In connecting batteries to the charging source, care must be taken to make sure that the positive and negative terminals of the charging source are connected respectively to the positive and negative terminals of the battery. A rheostat or lamp bank is generally used to adjust the current to the proper value.

93. **Determination of the State of Charge.**—The best guide as to the state of charge or extent of discharge of a lead-acid battery is the specific gravity of the electrolyte. But this is not absolute, for a battery which has not been properly watered, may show a high specific gravity indicating a full charge when the battery is really partly or even completely discharged. Dependence on specific gravity then must be on the assumption that the electrolyte has been properly maintained, and if this is true, the gravity reading relative to the safe limits of operation, namely, 1.180 to 1.280, will indicate closely the state of charge or discharge. In charging, when the specific gravity has reached about 1.280 and the battery has been gassing for one-half hour without further increase in gravity, the charge may be considered complete. Never allow the specific gravity to exceed 1.300; if it does, there is something wrong with the electrolyte which should be corrected at once. Never allow a battery to be discharged beyond the point at which its specific gravity reaches 1.180.

94. The open or standing voltage cannot be depended on to determine the state of charge or extent of discharge. With all other considerations normal, and particularly with a normal discharge rate, the voltage will drop very rapidly after reaching 1.8 per cell, so that in general, it is advisable not to use a battery further after the voltage has reached 1.7 volts per cell.

95. **Voltage of the Charging Unit.**—The voltage of a charging unit required to charge a battery must always be greater than that of the battery itself, since some voltage is required to get the charging current through the resistance of the circuit. Suppose, for example, that a battery of 40 cells in series (each with a voltage of 1.85, making the battery voltage 74) is to be charged from a generator, that the combined resistance of the battery and leads to the generator is, say, 2 ohms and that the charging current is 15 amp. The charging generator must then have a voltage of 74 to overcome the battery voltage, and of 30 (2×15) to drive the current through the resistance, making a total of 104.

As the voltage of the battery rises during charge, the charging current will be decreased unless the generator voltage is raised in proportion. Thus, suppose the generator voltage is kept at 104; when the battery is fully charged and gassing freely, its voltage will have risen to 2.5 per cell, that is, 100 volts, so that there is now only 4 volts left to send current through the 2-ohm resistance of battery and leads, and the charging current will therefore be reduced to 2 (4÷2) amp. To keep the charging current up to 15 amp., the generator voltage must be raised to $100+(15\times2)=130$.

96. In praçtice, the charging set is always supplied with an ammeter and voltmeter. A rheostat is also provided, by means of which the charging current can be varied. The voltage of the charging generator can be varied, either by reducing or increasing the speed of the engine, or by a field rheostat (supplied with the generator) or by both.

Roughly, calculate the voltage required to charge a battery or batteries in series on the lines, then adjust the charging generator to this voltage and switch over to the batteries. Keep some resistance of the charging rheostat in before switching over to charge; do not leave all the resistance "all in" or "all out." Then adjust the resistance (or if necessary the voltage of the charging generator) to obtain the necessary charging current through the battery.

97. *Charging Different Types of Batteries in Series.*—When a number of batteries of different sizes and ratings are to be charged in series, the charging rate should be approximately the normal rate of the smallest battery. When this battery has become fully charged, it should be removed, when the rate may be increased to the normal rate of the next larger battery, etc.

98. **Preparing New Lead Batteries for Service.**—Lead Batteries which are received charged and ready for service or charged and dumped will not require any special charging process to put them in service. Batteries which are received "bone dry," will require a long forming charge which will be at least 72 hours long. The rate of charge should be taken at about one-half normal rate for the first 48 hours and at about one-quarter normal rate for the remainder of the charge. The battery may be considered ready for service when this rate of charge has been continued until the battery is gassing freely and the voltage and specific gravity remain about constant.

99. **Charging Methods.**—After the first forming charge, batteries should thereafter be charged at the normal charging rate as noted on the directions which always appear on the inside of the cover or which may be taken from the table at the end of this pamphlet. The method of charging may be either the constant potential or constant current method, applied in the same manner as described for the Edison batteries in ¶s 30 and 31.

100. *Boosting.*—Lead batteries will not withstand charging at excess current rates. A boosting charge at excess rates can be made use of in case of emergency but it should be avoided as far as possible. A boosting charge at normal rate is entirely permissible and can be made use of during intervals of idleness to good advantage where the amount of work required of the battery during a day is great. The chief objection to the abnormal rate charging of lead batteries is that it causes heavy gassing which is very undesirable due to its destructive effect upon the active material.

101. In the question of low rate charging, the same comment made in connection with Edison batteries in ¶ 33 applies also to lead batteries. To this comment should be added, that the so-called "trickle" charge may prove of great value in properly maintaining lead batteries at a charging station where there may be a number of batteries standing around idle for periods of from a few hours to a few days. In this case, if such batteries are connected up to a charging source and charged at a rate of approximately .2 amp. per 100 amp-hr. capacity, the result will be a very beneficial one and the deterioration of the battery through idleness will be avoided.

102. *Overcharging.*—An overcharge of from one-half hour to several hours once a month or so, will help to keep down sulphation. In doing this, excess current rates should be avoided, the proper rate being that equal to about the end of the tapering off rate. A pronounced overcharge will not be particularly injurious so long as there is not excess gassing, but of course it wastes current and causes abnormal evaporation.

103. *Charging with Reversed Connections.*—If a battery is wrongly connected for charging, it will usually ruin the plates. The cause of this amounts practically to over-exhaustion. If the charge in the wrong direction is not carried to such a state that the degree of discharge of the battery is falling below its normal discharge voltage and specific gravity, then no great injury may be done. But when a battery is connected wrongly it will usually be connected with other

batteries in series and the wrong connection not noted until the battery has discharged so far that the active material is converted to a state from which it cannot be recovered, thereby ruining the plates.

Lead Battery Troubles.

104. Battery troubles are indicated by (1) decrease of ampere-hour capacity, (2) loss of voltage and (3) inability to bring the electrolyte up to the correct gravity by proper charging. These troubles may be caused by (1) sulphating, (2) loss of active material, (3) buckling of plates or (4) local action in the active material.

105. **Sulphating.**—During discharge of a battery, lead sulphate is formed without which there would be no production of current. However, if charging is neglected, the sulphating proceeds to such an extent that it tends to fill the pores of the plates and make the active material dense and hard. It is this condition which is ordinarily described when a battery is referred to as "sulphated."

106. The cause of this condition is some form of abuse, such as standing discharged for some length of time, habitual undercharging, neglecting evidence of trouble in individual cells, restoring proper specific gravity by adding electrolyte or acid to the cell instead of bringing it up by proper charging, etc.

107. Also, if the level of the electrolyte is too low in the battery, the acid has a tendency to creep up the plates, producing a sulphating of them above the electrolyte. The plates are then not restored to their original condition when the battery is recharged. Further, if the electrolyte is not kept up to the proper level, the wood separators tend to dry out and crack, thereby creating the possibility of short circuits between plates.

108. If sulphating has not progressed too far, the sulphate on the plates may be removed and put back into solution by long, successive charges and discharges at a low rate. It will be noted that after each charge the specific gravity rises. It may eventually come back to its normal value. If it does not, a more effective method is to fully charge the battery and then throw out the electrolyte. The battery is then filled with distilled water and discharged. It is then filled with fresh electrolyte of a specific gravity of from 1.180 to 1.210 and put through several charges and discharges as before. If the sulphating is not removed by this, there remains practically no further remedy except to renew the elements.

109. **Loss of Active Material.**—The active material of the lead plate is a soft porous metal which can be dislodged easily by rough handling or warping of the plates. The batteries are designed to compensate for a certain amount of loss of this nature, and the space at the bottom of the jar collects the sediment without noticeable detriment for a long time. Beyond this, there is nothing to be done to correct this trouble except to eliminate the cause of it, that is, to dismantle the battery, remove the sediment and perhaps renew the elements. In some batteries with small space below the plates, the sediment may collect in sufficient quantity to short circuit a pair of plates in a comparatively short time if badly treated, in which case washing out the jars with fresh water and replacing the electrolyte may be of some assistance. This should not be attempted by anyone not thoroughly familiar with the care of batteries.

110. **Buckling of Plates.**—High temperature is practically always the cause of buckled plates. This results in the loss of active material as explained in the preceding paragraph and, in some instances, may even cause a direct short circuit between plates by forcing aside or puncturing the insulating separators. It is occasionally possible to locate the short circuit and insert additional spacers to restore normal operation, but usually it is not discovered until the cell has discharged within itself to such a point as to make further action far below normal and to make further use impracticable.

111. It may happen that one or more cells of a battery will become shorted internally during use in the field with no means at hand to repair the plates. If it is necessary to operate the battery, the defective cells may be shunted out of the battery by making electrical connection around the defective cell. This will reduce the capacity of the battery and if connected to the same load will increase the discharge rate per cell, but this is permissible in such an emergency.

112. **Local Action.**—Local action in a battery is due to impurities in the water which attack the plates and destroy the materials of which they are composed. Local action in a battery does not usually make itself evident in the external characteristics of the battery until the injury to the plates has reached an advanced stage. Hence, there is usually very little that can be done after the trouble is ascertained.

The water supply must be watched carefully, as it is doubtful if a cell may be reclaimed after having been operated with an appreciable amount of iron or chlorine in the electrolyte. If local action trouble is suspected before it has had time to do much damage, it may be mitigated by replacing the electrolyte with fresh electrolyte of the proper specific gravity.

113. In service, some of the electrolyte may be spilled or may leak out of one of the cells and if there are several cells in the battery, this one will be overloaded and likely to overheat. In such a case, the usual emergency practice is to transfer a little electrolyte from each of the other cells and equalize the level in all cells. In this way, the reduction of capacity due to loss of electrolyte will be distributed among all the cells. Then as soon as the battery can be sent back to a charging and repair station, the electrolyte in all cells should be brought up to the proper level.

Manner of Shipping Lead Batteries.

114. All lead battery purchases to date, made on the assumption that the batteries would be sent overseas, have been specified for "bone dry" delivery. The electrolyte has been purchased separately and has been specified, for A. E. F., to have a specific gravity of 1.834. It is supplied in glass carboys and the specific gravity is always stenciled or tagged on the carboy.

Purchases which will now be made for use in this country, will vary as to the manner of shipping specified, according to how soon it is expected the batteries will be put into use. Purchases may be made in three classes.

115. Class 1 purchases are those made when the batteries are required for immediate service. In this case, they are shipped formed and charged ready for use. For this class of service, grooved wood separators are specified.

116. Class 2 purchases are made when it is expected that the batteries will be put in storage for a short time, not to exceed nine months. In this case, they are shipped charged and dumped so that the plates are formed but the batteries are received without electrolyte. When the electrolyte is dumped out, the batteries are sometimes washed out before shipping and in this case, they may be stored safely for nine months. If not washed, they can be safely stored for not more than seven months. For Class 2 purchases, combination wood and rubber separators are specified.

117. Class 3 purchases are made when the batteries are intended for future use, and where it is known that they are presumably to be in storage for considerable periods. The batteries are shipped

"bone dry." For this class purchases, combination wood veneer and perforated ribbed rubber separators or so-called "threaded rubber" separators are specified. When it is desired to put a battery of this class into service, it requires at least a 72-hour forming charge.

IV. METHODS OF STORING BATTERIES.

118. When it becomes necessary to retain storage batteries in stock and unused for periods varying in length from a few months to several years, many considerations must be taken into account if the batteries are to be prevented from undergoing permanent deterioration. These considerations are dealt with in the paragraphs which follow. In general, the Edison battery may be stored for an indefinitely long time absolutely without deterioration. The lead battery, however, cannot be safely stored under any condition for much longer than two years, and the consideration of storage is one of the controlling factors in its purchase, as explained in ¶s 114–117.

Lead-Acid Batteries.

119. There are several methods of putting batteries into storage which depend upon the length of time the batteries are to be out of service, upon the condition of the batteries, upon whether they have been in active service for some time or are practically new, and if new, whether they have been received with electrolyte in the cells or bone dry or charged and dumped. The internal construction of the battery also must be taken into consideration. The method may also depend to a great extent upon the number of batteries to be stored at any one depot or warehouse and the facilities available for handling work of this nature.

120. Ordinary small portable, high efficiency, high specific gravity (1.280 to 1.310) batteries, such as batteries type BB–11, BB–14, BB–17, BB–18, BB–21, and BB–23, which have been in service for a period of a year or more, or have received 30 to 40 or more cycles of charge and discharge, are hardly worth any special effort or expense to keep them available for distant future service. It would be better, if possible, to redistribute such batteries to active training camps for use in the immediate future. If this cannot be done, they might as well be scrapped and sold for junk.

121. Small specially constructed batteries, such as the airplane ignition battery (Bureau of Aircraft Production Specs. 28103 and

28103–A), which in a general way belong to the class described in paragraph 2, but which have high grade rubber containers, etc., may be worth the work of dismantling and storing the parts; or still better, they may be sent to the manufacturer to be prepared for indefinite dry storage and then returned to the Government depots and warehouses.

122. Small portable or semi-portable types, such as those built under Navy specifications but supplied to various War Departments (Ordnance Dept.), having thick pasted plates and low gravity electrolyte (1.200 to 1.225), which have not been in service more than two years and which have not received more than 200 cycles of charge and discharge, if in good mechanical condition, are worth being saved for future service.

123. Small, portable or semi-portable types, such as those built under Navy specifications (for Ordnance Dept.), having so-called ironclad plates and low gravity electrolyte, which have not been in service more than three years and which have not received more than 400 cycles of charge and discharge, are worth being saved for distant future service.

124. Stationary batteries of the Planté type, which have been placed in service, such as those required for telephones, if not more than five years old should be saved.

125. New batteries of any type whatsoever are, of course, worth saving, and it is with this class that the Signal Corps is principally concerned.

126. Stationary Planté types of batteries, which have not been placed in service, require no special attention, since the only parts liable to depreciation in this case are the wooden separators, and if these have been shipped packed in metal containers, which have not been opened, there is little chance for the separators to dry out and crack. If it is desired to discontinue the service of such a battery for a period not exceeding twelve months, it should not be dismantled, but should be first given an overcharge and then given a freshening charge once each month during the idle period. In the case of glass jar batteries, set up in a room in which no provision is made for heating during the idle period and especially if the battery is located in a cool climate, it may be necessary to remove the acid to prevent freezing unless care is taken to see that the battery is kept in a fully charged condition.

127. In any case, if it is desired to take the battery out of service so that it will require no attention during the idle period, it should first be given an overcharge, at the end of which the electrolyte may be siphoned off into suitable carboys. The wood separators may then be removed. When the negative plates become hot as they do from contact with the air, a little water should be sprinkled on them. If the plates are left in the cells, the sprinkled water will not particularly harm the positives, but if the plate groups are removed, the positives should be set apart from the negatives and simply allowed to dry out. The negative groups should not be stacked close together until they are dry. The positive plates should not be rinsed in water. The negative plates should be allowed to dry out slowly and not to become very hot. It will not be possible to use the wooden separators again unless they are kept moist during the out-of-service period. The manufacturers will furnish instructions for placing the batteries in service again.

128. Portable lead storage batteries may be placed in storage either "assembled wet" or "dismantled dry":

Wet Storage.—Any lead battery which is to be out of commission for less than a year, providing it will not soon require repairs making it necessary to dismantle the battery, and provided there exists means for charging, should be stored assembled wet.

Dry Storage.—Any battery which is to be out of commission for several years no matter what its condition, or any battery on which repairs necessitating dismantling are or soon will be required, or provided there are no means available for charging at any time, should be stored dismantled dry.

129. It is well to note that, as a matter of fact, Navy type batteries, which are to be stored in a moderate climate, if given a long overcharge at one-half normal charging rate until all the cells have reached a maximum specific gravity, may be allowed to stand idle with the electrolyte in the cells for a period of six to nine months without any charging. At the end of this time they should be given another overcharge. It is better practice, however, to adjust the level of the electrolyte and give the battery an overcharge every four months or to place the battery on "trickle" charge as discussed below.

130. If long period storage is contemplated for lead batteries which have been in service, it is generally better to dismantle them. The procedure in this case is first to remove the connectors, lift the indi-

vidual cells out of the boxes, remove the elements, remove the separators, separate the positive groups from the negative and store in this condition. Charged negative plates, when exposed to the air will become hot. They should be allowed to stand in the air until cooled. If the positive plates show much wear they should be scrapped. If not, remove any loose particles adhering to them by passing a smooth paddle over the surface, but do not wash the positive plates under any circumstances. Place the positive groups together in pairs, put them into the jars and store away. Place the negative groups together in pairs and put them into the remaining half of the jars and cover them with acid saved for the purpose and allow them to stand for at least five hours. Pour off and throw away the acid and store away the jars containing the negatives. The manufacturer will supply instructions for reassembling the batteries upon application. Wooden separators should be thrown away. Rubber separators, unless broken, should be saved.

131. Portable batteries of small size, such as all BB types of lead batteries, are usually shipped charged ready for service in the case of domestic shipments, and dry (without electrolyte) in the case of export shipments. Ordinarily batteries of this type for domestic use are equipped with wooden separators only, as in general this results in better performance and lower cost. Batteries for export are prepared in a great many different ways, and it is necessary to consider some assemblies in detail to determine what course to pursue.

132. Batteries which have been received charged ready for service, which are new or which have been in service but a short time should preferably be sent to depots where they can be used or where they can be placed on "trickle" charge or given an occasional overcharge and where they may be inspected from time to time and the level of the electrolyte adjusted by adding distilled or other suitable water to replace the evaporation. Such batteries should be placed in active service as soon as possible. This is the only safe method of storing this type of battery without dismantling, if the storage period is to exceed several months.

133. New batteries, which are assembled "bone dry" if intended for export and which are equipped with suitable plate separators may be stored in this condition for several years, if necessary, without any danger of deterioration. Batteries in this class are Willard, type SY-13 or Exide, type 4-AC-7 (Bureau of Aircraft Production

Spec. 28103), the Willard battery being equipped with threaded rubber separators and the Exide with combined wood and perforated ribbed rubber separators. These batteries were obtained in large quantities for Liberty motor ignition purposes. The type BB-23 Signal Corps batteries (Luthy) may also be included in this class since they have no complete separators but are equipped with celluloid spacing strips. The type BB-23 Signal Corps batteries made by Multiple Storage Battery Company have dry wood separators only, and might be included in this class also except for the danger of some of the separators cracking, with consequent development of short circuits after a few cycles of charge and discharge when placed in service.

134. Signal Corps batteries, such as the type BB-14, BB-17, BB-18 and BB-23, assembled with wet wood separators only, or any batteries so equipped, which have been shipped charged and dumped, may be safely stored "dry" for a period of from nine to twelve months (preferably not over nine months) when they should be put into service either active or idle.

135. To sum up then it appears that small, portable storage batteries delivered charged more than a year ago are not worth considering for indefinite storage. Batteries placed in service within a year should be shipped to points where they may be placed in useful service or where they may be stored wet and given a little attention. Batteries newly received dry must be divided into two classes; namely, those suitable for indefinite storage as received and those suited only to a definite storage period.

136. **Trickle Charge for Stored Storage Batteries.**—About the surest way to maintain lead batteries in perfect condition during long periods of storage is to place them on what is termed a "trickle" charge. This is done by connecting them to a source of energy in groups, in series, so that the rate of charge will be approximately 0.2 amp. per 100 amp-hr. capacity of the individual batteries. This of course means that the batteries grouped together and connected in series must be of the same voltage and amp-hr. rating. This very low rate of charging current is allowed to flow continuously, and it acts to keep the battery fully charged and the plates in perfect condition. The vent plugs should be in place and the batteries should be inspected once every six weeks and a little water added to each cell to replace evaporation. Batteries stored in this manner are ready for service at any moment and the cost of the energy

consumed per annum amounts to about 1 per cent to 1½ per cent of the cost of the battery. For example, the cost per battery per year of maintaining 10-volt, 20-amp-hr. storage batteries on trickle charge is about 24 cents, taken on the basis of a current flow of 0.04 amp., a voltage supply of 110 volts, and an energy charge of five cents per kilowatt-hour.

Edison-Alkaline Batteries.

137. The Edison storage battery, such as Signal Corps types BB-1, BB-2, BB-3, BB-4, BB-5, BB-7, BB-8 and BB-9, may be allowed to stand idle in any condition of charge without fear of injury. If the battery is to be stored, the cells should be filled with water to the usual level. The steel container should be thoroughly coated with vaseline to prevent possible corrosion. The battery should always be stored in a dry place, if possible, and right side up. The evaporation of electrolyte from the batteries standing idle is very slight. If the cells are properly filled before being stored it should not be necessary to add water more frequently than about once in six months.

138. If a battery stands idle for a considerable time it will become sluggish, and when placed in service again it should first be completely discharged and then given a long over-charge.

139. If an Edison battery is to be placed in dry storage, proceed as follows:

(*a*) Discharge the battery completely.

(*b*) Connect a piece of wire across the terminals and short circuit the battery for one hour.

(*c*) Drain all the electrolyte from the cells so that they may be stored dry.

140. Edison electrolyte will freeze at approximately 20 deg. below zero F. and this should be taken into account in cold climates when considering the best method of storage.

V. COMPARISON OF THE TWO TYPES OF BATTERIES.

141. The following are a number of points of comparison between the Edison and lead plate storage batteries, taken from the point of view of utility in the Signal Corps service:

1. The ampere-hour capacity per pound of battery weight is practically the same for both types of battery when they are in good condition and have had good treatment and history.

2. The ampere-hour capacity per pound is much higher for the Edison battery after it has passed through even a short period of neglect or mal-treatment than is that of the lead battery under similar mistreatment.

3. The voltage regulation of the lead plate battery is more constant than that of the Edison battery. The initial or gas voltage of the latter may be almost entirely eliminated, and the voltage regulation thus improved, if the battery is short-circuited for from 40 to 60 sec. after being charged. When this is done with a three-cell battery, the voltage may be pulled down to 4.2 volts, above which it will not rise again on that discharge. The short circuiting process is apparently beneficial to the battery and reduces its capacity on that charge by less than 5 per cent.

4. A fully charged lead battery becomes discharged on standing idle about one month and its capacity thereafter is considerably decreased. An Edison battery will retain over half its charge at the end of six months or more of idleness.

5. The partly or fully discharged lead battery is greatly deteriorated by standing idle for more than a few days. Any delay in recharging lowers the capacity of the battery. The Edison battery may stand indefinitely in any state of discharge without damage.

6. The voltage of the Edison cell is brought down under lowering temperature, but its ampere-hour capacity is not seriously altered, particularly at low current rates. A 4-volt Edison battery, tested at the Office of the Chief Signal Officer, which normally gave about 100 hours at 1-amp. discharge rate and about 65 deg. F., gave 25 hours at 1-amp. discharge rate when held at a temperature of 20 deg. to 25 deg. F., before its potential fell to 3.6 volts.

7. Lead batteries will freeze at comparatively high temperatures when partly or fully discharged and may thereby be injured. The Edison battery suffers no damage from temperatures as low as 40 deg. below zero F. It regains its ability to deliver full ampere-hour capacity if, when charged, it is cooled to any temperature and then warmed up again.

8. Short circuiting of the Edison battery, either by accident or design, has a beneficial effect while it is ruinous to a lead battery.

9. The Edison battery may be forced to full charge at any rate of charge without injury to the battery. The lead battery will not stand being forced to any degree.

10. The shipment of the electrolytes for storage batteries for overseas work is extremely important. For the lead battery, the acid electrolyte must be shipped in liquid form in glass carboys, or the chance of obtaining it on the other side must be taken. With the Edison battery the electrolyte may be shipped in powdered form in steel cans or in liquid form in steel cans.

11. Upon assembling the batteries, a considerable forming process must be gone through with the acid battery. The Edison battery, on the other hand, requires only one long charge and it is ready for service, but it improves in capacity with use.

12. It is absolutely essential that the electrolyte of lead batteries be filled or flushed with distilled water. Edison batteries may be filled with any water available without injury to the cell, although the manufacturer recommends the use of distilled or rain water.

13. The acid electrolyte of the lead batteries and the alkaline electrolyte of the Edison battery are both destructive to clothing, equipment, and human tissue.

14. The mechanical ruggedness of the Edison battery is very greatly superior to that of the lead battery.

15. The Edison battery has such characteristics that it will be useful in the field until it is either lost or mechanically broken, under all conditions of use and misuse and inactivity which will be met there. The lead battery, however, will require more particular care and nearly continuous use and will therefore have a more doubtful period of usefulness under field conditions.

16. The initial cost of the Edison battery is approximately double that of the lead battery.

U. S. SIGNAL CORPS STORAGE BATTERY DATA.

Type number.	Kind of battery.	Number of cells per battery.	Rated volts.	Name plate amp.-hrs.	5-hour rate amp.-hrs.	Amperes discharge for (at 80° Fahr.)—					Average volts (at 80° Fahr.).			Terminal volts.	
						3 hours.	5 hours.	7 hours.	12 hours.	24 hours.	3-hour rate.	5-hour rate.	24-hour rate.	Start.	Finish.
BB-1	Edison	7	10	37.5	37.5	12.3	7.5	5.4	3.1	1.66	8.4	8.6	8.9	9.90	7.0
BB-2	Edison	3	4	75	75	24.5	15.0	10.8	6.4	3.3	3.5	3.6	3.8	4.25	3.0
BB-3	Edison	8	10	25	25	8.1	5.0	3.6	2.13	1.13	9.5	9.8	10.2	11.30	8.0
BB-4	Edison	3	3.6	18.75	18.75	6.2	3.75	2.7	1.60	.85	3.6	3.7	3.8	4.25	3.0
BB-5	Edison	6	7.5	100	100	32.5	20.0	14.5	8.6	4.50	7.2	7.4	7.6	8.50	6.0
BB-6	Edison	9	10.8	18.75	18.75	6.20	3.75	2.7	1.60	.85					
BB-7	Edison	5	6	18.75	18.75	6.20	3.75	2.7	1.60	.85	6.0	6.15	6.35	7.10	5.0
BB-8	Edison	7	8.4	12.5	12.5	4.10	2.5	1.8	1.06	.65	8.4	8.60	8.90	9.90	7.0
BB-9	Edison	4	4.8	75	a 75	24.5	15.0	10.8	6.40	3.3	4.65	4.80	4.95	5.70	4.0
BB-10	Edison														
BB-11	Lead b c	4	8	9	10	3.0	2.0	1.55	0.98	0.54	7.70	7.85	7.90	8.15	7.0
BB-11-A	Lead b c	4	8	9	10										
BB-13	Lead	160	300	0.1	0.15	0.045	0.03				300			320	280
BB-14	Lead b e	2	4	100	90	26.7	18.0	13.7	8.75	4.85	3.86	3.92	3.95	4.1	3.5
BB-14	Lead b c	2	4	100	90	26.7	18.0	13.7	8.75	4.85	3.86	3.92	3.95	4.1	3.5
BB-15	Lead	5	10	30	30										
BB-16	Lead b c	2	4	17	17	5.0	3.37	2.56	1.64	0.90	3.86	3.92	3.95	4.15	3.5
BB-16-A	Lead b c	2	4	17	17										
BB-17	Lead c d	2	4	160	135	40.0	27.0	20.5	13.1	7.25	3.86	3.92	3.95	4.15	3.5
BB-18	Lead b c	3	6	100	90	26.7	18.0	13.7	8.75	4.85	5.78	5.87	5.92	6.22	5.25
BB-18	Lead b e	3	6	100	90	26.7	18.0	13.7	8.75	4.85	5.78	5.87	5.92	6.22	5.25
BB-19	Lead	2	4	35											
BB-20	lead b e	2	4	65	65	20.2	13.6	10.3	6.7	3.6	3.86	3.92	3.95	4.15	3.5
BB-21	Lead	2	4	140	140										
BB-22	Lead	3	6	75	75										
BB-23	Lead b c e	5	10	20	17	5.05	3.40	2.59	1.66	0.91	9.65	9.80	9.87	10.4	8.75
BB-23	Lead b	5	10	20	17	5.0	3.4	2.59	1.66	0.91	9.65	9.80	9.87	10.4	8.75
BB-24	Lead	3	6	17	17	5.0	3.4	2.59	1.66	0.91	5.78	5.87	5.92	6.22	5.25
BB-24-A	Lead b	3	6	17	17	5.0	3.4	2.59	1.66	0.91	5.78	5.87	5.92	6.22	5.25
BB-25	Lead b c	2	4	90	90	26.7	18.0	13.7	8.75	4.85	3.86	3.92	3.95	4.15	3.5

Type number.	Charging rates.		Total hours for charge.	Maximum voltage of charge.	Dimensions of battery box.			Overall dimensions of battery.			Plate dimensions.		Electrolyte, specific gravity.		Pounds, electrolyte per battery.	Pounds, elements only.	Pounds, battery complete.
	Start.	Finish.			Length.	Width.	Height.	Length.	Width.	Height.	Positive.	Negative.	Charged.	Discharged.			
BB-1	11.25	11.25	4 3/4	12.95	15 1/4	6 3/4	10 7/8	15 3/4	7	10 7/8	5 1/4 × 5 1/8	5 1/4 × 5 1/8	{ 1.230 / 1.160	1.230 / 1.160 }	7.7	25	46
BB-2	15.0	15.0	7	5.55	9 11/16	6 3/8	11	10 1/8	6 5/8	11	5 1/4 × 5 1/8	5 1/4 × 5 1/8	Electrolyte density practically constant during discharge.	Electrolyte density decreases slightly with each cycle; 1.160 low limit.	5.0	16	31.5
BB-3	7.5	7.5	4 3/4	14.80	10 1/16	6 5/8	9 13/16	10 5/8	7	11 5/16	2 5/8 × 5 1/8	2 5/8 × 5 1/8			6.4	17.5	31.0
BB-4	5.6	5.6	4 3/4	5.55	6 1/4	4	9 1/2	8 1/4	4	10 3/8	2 5/8 × 5 1/8	2 5/8 × 5 1/8			2.0	4.9	11.0
BB-5	30.0	30.0	4 3/4	11.10	18 1/2	6 3/4	16 3/8	19	7	16 3/8	5 1/4 × 10 1/4	5 1/4 × 10 1/4			14.5	44.0	76.0
BB-6																	
BB-7	5.6	5.6	4 3/4	9.25	10 1/16	3 13/16	9 5/8	10 1/16	4 1/4	11 11/16	2 5/8 × 5 1/8	2 5/8 × 5 1/8			3.2	8.1	16.0
BB-8	3.75	3.75	4 3/4	12.95	10 5/8	3 3/4	8 3/4	10 5/8	4 3/16	10 11/16	2 5/8 × 5 1/8	2 5/8 × 5 1/8			3.5	6.8	16.0
BB-9	15.0	15.0	7	7.40	13 1/8	6 1/2	11 1/4	13 1/8	7	13 11/16	5 1/4 × 5 1/8	5 1/4 × 5 1/8			6.8	21	38
BB-10																	
BB-11	1.5	.7	10	10.5	6 7/16	4 27/32	10 3/16	6 11/16	5 11/32	10 5/16	3 × 3 1/16	3 × 3 1/16	1.300	1.200	1.5	7	14
BB-11-A								6 7/16	4 27/32	10 5/16			1.300	1.200			
BB-13	f .2	.2	5	94.0	13 1/4	3 3/4	9	14 1/4	3 3/4	9 3/4	1 1/2" disc.						10
BB-14	{ 10.0 / 20.0	{ 10.0 / 7.0	10 / 7	5.2 / 5.0 }	7 13/16	7 3/16	14 5/16	8 7/8	7 3/8	14 9/16	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	7.0	23	37
BB-14	10	7.0	{ 10 / 7	5.2 / 5.0 }	7 13/16	7 1/8	13 3/8	8 1/16	7 1/2	13 5/8	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	7.0	23	37
BB-15																	30
BB-16	{ 2.0 / 4.0	2.0 / 2.0	12 / 8	5.0 / 5.0 }	5 3/16	4 11/16	10 5/16	5 7/16	5 3/16	10 7/16	3 × 3 1/16	3 × 3 1/16	1.300	1.200	1.0	5.6	13
BB-16-A								5 1/4	4 11/16	10 7/16			1.300	1.200			13
BB-17	{ 20.0 / 33.0	20.0 / 15.0	10 / 7	5.2 / 5.0 }	12 3/8	7 3/4	10 5/8	12 3/8	8 1/4	10 5/8	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.280	1.200	9.0	34.0	55
BB-18	20.0	9.0	{ 10 / 7	7.8 / 7.5 }	10 3/4	7 5/8	13 1/2	11 3/8	8	13 5/8	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.210	8.5	34.0	58
BB-18	20.0	9.0	7	7.5									1.300	1.210	8.5	34.0	50
BB-19																	20
BB-20	{ 10.0 / 17.0	10.0 / 7.5	10 / 7	5.2 / 5.0 }							5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	4.5	17	30
BB-21																	55
BB-22																	50
BB-23	{ 2.0 / 4.0	2.0 / 2.0	12 / 8	12.5 / 12.5 }	6 3/4	4 5/8	12 1/4	7 5/16	4 7/8	12 7/16	5 11/16 × 4	5 11/16 × 4	1.300	1.200	3.0	13.0	25
BB-23	{ 2.0 / 4.0	2.0 / 2.0	12 / 8	12.5 / 12.5 }	10 1/16	4 7/16	10 7/8	10 15/16	4 13/16	11 1/8	3 × 3 1/16	3 × 3 1/16	1.300	1.200	2.5	14.0	25
BB-24	{ 2.0 / 4.0	2.0 / 2.0	12 / 8	7.5 / 7.5 }	7 3/8	4 11/16	10 5/16	7 5/8	5 3/16	10 7/16	3 × 3 1/16	3 × 3 1/16	1.300	1.200	1.5	8.4	17
BB-24-A								7 3/8	5 3/16	10 7/16			1.300	1.200	1.5	8.4	17
BB-25	20.0	9.0	{ 10 / 7	5.2 / 5.0 }	7 5/16	7 1/8	13 1/4				5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	6.5	23	37

a Capacity, 60 amp.-hrs., at 32° Fahr.
b Nonspill design.
c Rubber jars.
d Nonsplash type.
e Celluloid jars.
f Four 40-cell units in parallel for charge.

U. S. SIGNAL CORPS STORAGE BATTERY DATA.

Average volts (at 80° Fahr.). 3-hour rate.	5-hour rate.	24-hour rate.	Terminal volts. Start.	Finish.	Charging rates. Start.	Finish.	Total hours for charge.	Maximum voltage of charge.	Dimensions of battery box. Length.	Width.	Height.	Overall dimensions of battery. Length.	Width.	Height.	Plate dimensions. Positive.	Negative.	Electrolyte, specific gravity. Charged.	Discharged.	Pounds, electrolyte per battery.	Pounds, elements only.	Pounds, battery complete.	Apparatus with which battery may be used.	Specification No.
8.4	8.6	8.9	9.90	7.0	11.25	11.25	4 3/4	12.95	15 1/4	6 3/4	10 7/8	15 3/4	7	10 7/8	5 1/4 × 5 1/8	5 1/4 × 5 1/8	1.230 1.160	1.230 1.160	7.7	25	46	SCR—71, 112	....
3.5	3.6	3.8	4.25	3.0	15.0	15.0	7	5.55	9 11/16	6 3/8	11	10 1/8	6 5/8	11	5 1/4 × 5 1/8	5 1/4 × 5 1/8	Electrolyte density practically constant during discharge.	Electrolyte density decreases slightly with each cycle; 1.160 low limit.	5.0	16	31.5	SCR—69, 70, 72–B, 79, 83, 84, 99, 119	....
9.5	9.8	10.2	11.30	8.0	7.5	7.5	4 3/4	14.80	10 1/16	6 5/8	9 13/16	10 5/8	7	11 5/16	2 5/8 × 5 1/8	2 5/8 × 5 1/8			6.4	17.5	31.0	SCR—71, 74, 76–A	....
3.6	3.7	3.8	4.25	3.0	5.6	5.6	4 3/4	5.55	6 1/4	4	9 1/2	8 1/4	4	10 3/8	2 5/8 × 5 1/8	2 5/8 × 5 1/8			2.0	4.9	11.0	SCR—59, 59–A, 75, 91, 93, 115	2060
7.2	7.4	7.6	8.50	6.0	30.0	30.0	4 3/4	11.10	18 1/2	6 3/4	16 3/8	19	7	16 3/8	5 1/4 × 10 1/4	5 1/4 × 10 1/4			14.5	44.0	76.0	SCR—62, 67, 67–A, 109	2047
6.0	6.15	6.35	7.10	5.0	5.6	5.6	4 3/4	9.25	10 1/16	3 13/16	9 5/8	10 1/16	4 1/4	11 11/16	2 5/8 × 5 1/8	2 5/8 × 5 1/8			3.2	8.1	16.0	SCR—89, 116	2061
8.4	8.60	8.90	9.90	7.0	3.75	3.75	4 3/4	12.95	10 5/8	3 3/4	8 3/4	10 5/8	4 3/16	10 11/16	2 5/8 × 5 1/8	2 5/8 × 5 1/8			3.5	6.8	16.0	SCR—65–A	....
4.65	4.80	4.95	5.70	4.0	15.0	15.0	7	7.40	13 1/8	6 1/2	11 1/4	13 1/8	7	13 11/16	5 1/4 × 5 1/8	5 1/4 × 5 1/8			6.8	21	38	SCR—84	2057
7.70	7.85	7.90	8.15	7.0	1.5	.7	10	10.5	6 7/16	4 27/32	10 3/16	6 11/16 6 7/16	5 11/32 4 27/32	10 5/16 10 5/16	3 × 3 1/16	3 × 3 1/16	1.300 1.300	1.200 1.200	1.5	7	14	SCR—65–A	2114 2118
300			320	280	f .2	.2	5	94.0	13 1/4	3 3/4	9	14 1/4	3 3/4	9 3/4	1 1/2″ disc.						10	SCR—58, 68, 80, 90, 91, 93, 116	....
3.86	3.92	3.95	4.1	3.5	10.0 20.0	10.0 7.0	10 7	5.2 5.0	7 13/16	7 3/16	14 5/16	8 7/8	7 3/8	14 9/16	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	7.0	23	37	SCR—67–A, 69, 70, 72–B–77, 79, 83, 84, 99, 112, 119	2009–A
3.86	3.92	3.95	4.1	3.5	10	7.0	10 7	5.2 5.0	7 13/16	7 1/8	13 3/8	8 1/16	7 1/2	13 5/8	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	7.0	23	37	SCR—67–A, 69, 70, 72–B–77, 79, 83, 84, 99, 119, 112	2009–B
3.86	3.92	3.95	4.15	3.5	2.0 4.0	2.0 2.0	12 8	5.0 5.0	5 3/16	4 11/16	10 5/16	5 7/16	5 3/16	10 7/16							30	....	2014–A
3.86	3.92	3.95	4.15	3.5	20.0	20.0	10	5.2				5 1/4	4 11/16	10 7/16	3 × 3 1/16	3 × 3 1/16	1.300	1.200	1.0	5.6	13	SCR—59, 59–A, 75, 115	2019
5.78	5.87	5.92	6.22	5.25	33.0	15.0	7	5.0	12 3/8	7 3/4	10 5/8	12 3/8	8 1/4	10 5/8			1.300	1.200			13	....	2019–A
5.78	5.87	5.92	6.22	5.25	29.0	9.0	10 7	7.8 7.5	10 3/4	7 5/8	13 1/2	11 3/8	8	13 5/8	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.280	1.200	9.0	34.0	55	SCR—78, 78–A	2035
					20.0	9.0	7	7.5							5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.210	8.5	34.0	58	SCR—81	2018–A
3.86	3.92	3.95	4.15	3.5	10.0 17.0	10.0 7.5	10 7	5.2 5.0									1.300	1.210	8.5	34.0	50 20	....	2018–B 2010
															5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	4.5	17	30	SCR—67–A, 69, 70, 72–B, 79, 83, 84, 99, 119	2011–B
																					55 50	....	2012–A 2013–A
9.65	9.80	9.87	10.4	8.75	2.0 4.0	2.0 2.0	12 8	12.5 12.5	6 3/4	4 5/8	12 1/4	7 5/16	4 7/8	12 7/16	5 11/16 × 4	5 11/16 × 4	1.300	1.200	3.0	13.0	25	SCR—71, 74, 76–A, 105, 112	2020–A
9.65	9.80	9.87	10.4	8.75	2.0 4.0	2.0 2.0	12 8	12.5 12.5	10 1/16	4 7/16	10 7/8	10 15/16	4 13/16	11 1/8	3 × 3 1/16	3 × 3 1/16	1.300	1.200	2.5	14.0	25	SCR—71, 74, 76–A, 105, 112	2020–B
5.78	5.87	5.92	6.22	5.25	2.0 4.0	2.0 2.0	12 8	7.5 7.5	7 3/8	4 11/16	10 5/16	7 5/8	5 3/16	10 7/16	3 × 3 1/16	3 × 3 1/16	1.300	1.200	1.5	8.4	17	SCR—89, 116	2106
5.78	5.87	5.92	6.22	5.25								7 3/8	5 3/16	10 7/16			1.300	1.200	1.5	8.4	17	....	2106–C
3.86	3.92	3.95	4.15	3.5	20.0	9.0	10 7	5.2 5.0	7 5/16	7 1/8	13 1/4	....	....	....	5 11/16 × 4 7/8	5 11/16 × 4 7/8	1.300	1.200	6.5	23	37	SCR—84	....

l design.

c Rubber jars.

d Nonsplash type.

e Celluloid jars.

f Four 40-cell units in parallel for charge (in series for discharge).