RADIO OPERATOR.

STUDENTS MANUAL

FOR ALL ARMS.

PART I.—RADIO SETS.

UNIT OPERATIONS.

PRIMARY BATTERIES USED IN RADIO COMMUNICATION.

Information.

Effects of electricity.—The word electricity has been applied to a form of energy, but just exactly what electricity is we can not say. Electricity is known to exist for the simple reason that it can be observed and measured. For example, electricity lights lamps, drives motors, raises to a high temperature all sorts of electrical heating devices, and energizes the telephone, the telegraph, and the electric bell. It also makes radio communication possible.

Electricity produces these various effects only when it is in motion, just as air must be in motion in order that wind may be produced. Moving air causes the windmill to revolve, and propels the sailing vessel. However, if air is not in motion no such effects are produced. In a similar way, electricity at rest has few effects of practical value. Electricity in motion is spoken of as a *current* of electricity.

Conductors; nonconductors.—In order to transfer electricity from its source to the point at which it is to be used, a path or *conductor* must be provided. For convenience and efficiency this conductor usually consists of a copper wire. Gold, silver, iron, lead, brass, zinc, carbon, and the earth are also conductors of electricity. Certain substances, such as glass, porcelain, hard rubber, bakelite, mica, and sealing wax, are poor conductors of electricity and are therefore called *nonconductors* or *insulators.*

Questions.

(1) *What is energy?*

(2) *What are some forms of energy other than electrical energy?*

(3) *What is meant by "energizing the telephone"?*

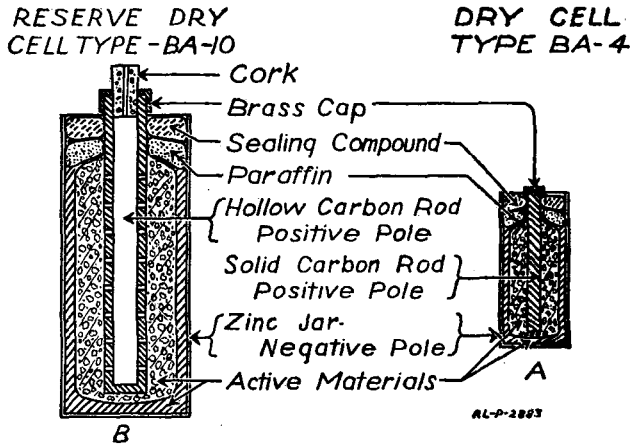
(4) *What are the usual sources of electricity?*

(5) *Why is it evident that such a thing as electricity exists?*

(6) *Will electricity produce any practical effects if no current is flowing?*

(7) *What is a conductor?*

Batteries.—The electricity necessary to operate the radio sets used in the Army is obtained from two sources, namely, an electric battery or a generator. For portable and small type sets the necessary electrical energy is supplied by a battery. Two types of batteries are used in general, one a primary battery and the other a secondary or storage battery.



Figures 1, A–B.—Sectional view of primary cells, types BA–10 and BA–4.

Primary batteries.—A primary battery consists of two or more units called *cells*. Each cell produces electricity by certain chemical actions which take place inside the cell. There are many types of primary cells. Those which contain a liquid which is easily spilled, or those in which the liquids are placed in glass containers are unsuitable for use where they are to be transported with radio sets accompanying troops in the field. The type of primary cell most practical for such use is known as the dry cell. The BA–4 cell is an example of this type of dry cell. (See Fig. 1, A, and Fig. 3, B.)

It consists of a small cylindrical zinc container, in the center of which a carbon rod is placed. The space between the carbon rod and the inner wall of the zinc container is filled with certain chemicals and absorbent materials. The top of the cell is sealed with sealing

wax. The carbon rod is equipped with a small brass cap which acts as one terminal of the cell. The other terminal of the cell is formed by the zinc container itself.

EXPERIMENT NO. 1.

Equipment.

1 cell, type BA–4, serviceable, with leads soldered to terminals.
1 voltammeter, Weston model 280.

NOTE.—The voltammeter, Weston model 280, is a combination voltmeter and ammeter. When the voltammeter is used to measure voltage it will be spoken of as a voltmeter, and when it is used to measure amperes it will be spoken of as an ammeter.

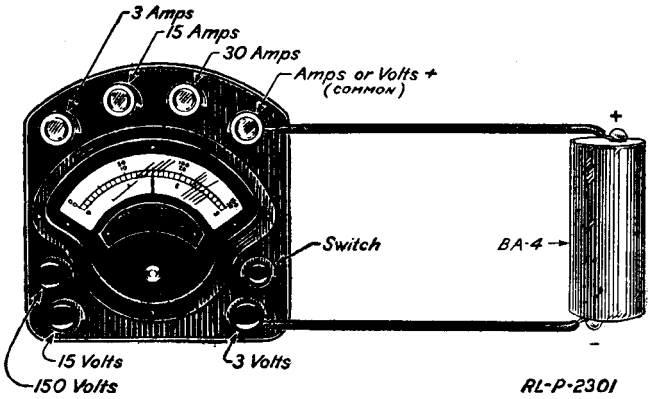


Fig. 2.—Method of connecting type BA–4 cell to a voltmeter.

Directions.

1. Connect the wire leading from the carbon rod or positive pole of the BA–4 cell to the terminal marked " Amps or Volts + " on the voltammeter. Connect the wire leading from the bottom of the zinc case or negative terminal of the cell to the terminal marked " 3 Volts " on the voltmeter. (See Fig. 2.) Press the small button switch on the voltmeter and watch the indicating needle.

Questions.

(8) *In which direction does the indicating needle turn?*

(9) *Where does the needle come to rest?*

(10) *What is the voltage of the cell as indicated by the voltmeter?*

Directions.

2. Reverse the leads by connecting the lead from the positive terminal of the cell to the terminal on the meter marked "3 Volts,"

and the negative lead from the cell to the terminal on the meter marked "Volts." Again press the small button switch and observe the needle.

Questions.

(11) *When the connections are reversed, in which direction does the indicating needle move?*

(12) *Which is the proper way to connect the meter, as described in direction 1 or as in direction 2?*

Information.

Direction of current.—The electricity generated by a dry cell is known as *direct current* electricity and flows in one direction through the wires and apparatus connected to the cell terminals.

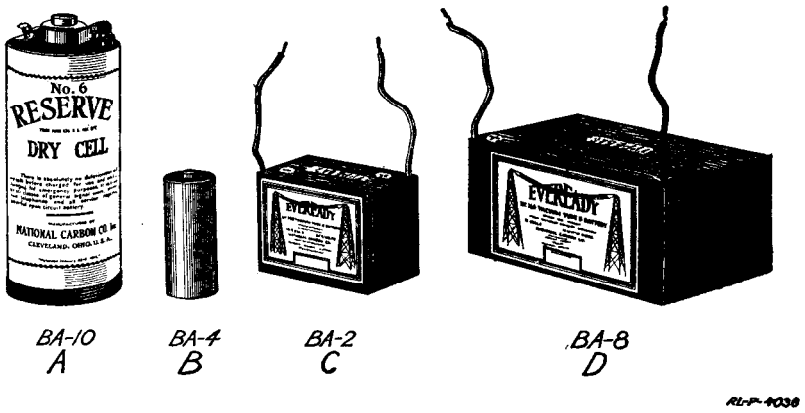


Fig. 3, A–B–C–D.—Types of dry cells and batteries used in signal communications.

The direction in which the current flows in a wire or piece of apparatus is determined by the connection to the cell terminals. The current generated by the cell is always considered as flowing outside the cell from the positive pole to the negative pole. It should be observed that if current flows from positive to negative *outside the cell*, in order to complete the electrical circuit it must flow from negative to positive *within the cell.* In referring to the direction of the current the *external* circuit is always referred to unless it is otherwise specifically stated.

Certain forms of electrical apparatus will not work unless the current flows through them in the proper direction. For this reason they must be correctly connected to the source of current supply,

with respect to the positive and negative poles. The voltmeter in Experiment No. 1 is an example of this.

Question.

(13) *If the current generated by the cell flows from the positive to the negative terminal, why did the needle move to the left of the zero of the scale in Direction 2?*

Information.

BA–10 Dry Cell.—The BA–10 reserve dry cell is similar to the BA–4 cell. (See Fig. 1, B and Fig. 3, A.) It consists of a cylindrical zinc container in the center of which a hollow carbon rod is placed. The space between the carbon rod and the inner wall of the zinc case is filled with certain chemicals and absorbent materials. The top of the cell is sealed with an asphalt insulating compound. Two spring clip terminals are provided on the top of the cell, one being attached to the zinc case itself and the other to the carbon rod. A paraffin coated cork closes the opening in the top of the carbon rod.

The BA–10 cell differs from the BA–4 cell in that it must be charged by being filled with water before it is placed in service. (See U. O. No. 3, Basic Manual.)

A dry cell of the BA–4 type, when stored for a length of time, becomes useless due to certain reactions which take place inside the cell when it is not in use. The cell could be stored for a much longer period of time if during construction the water had been omitted from the chemical in the cell. This is done in the type BA–10 reserve cell, but the small size of the BA–4 cell, together with the manner in which it is used, prohibits the use of a device for adding water.

BA–2 Battery.—The type BA–2 battery shown in Fig. 3, C, consists of 15 dry cells, each cell being similar to the BA–4 type cell, but smaller. The cells are connected together in series and sealed in a cardboard container with sealing wax. Two wire terminals are brought out through the sealing compound at the top of the batteries. One of the wire terminals is covered with black insulation to indicate the negative pole, while the other wire is covered with red insulation to indicate the positive pole. It is important to remember these colors.

BA–8 Battery.—The type BA–8 battery (Fig. 3, B), is similar to the type BA–2 battery. The two batteries differ only in the size of the cells, those of the BA–8 battery being about twice the diameter of the cells of the BA–2.

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SERIES AND PARALLEL CONNECTIONS OF DRY CELLS AND BATTERIES.

Equipment.

1 type BA–4 cell (serviceable).
4 type BA–10 cells (serviceable).
2 type BA–2 batteries (serviceable).
1 type BA–8 battery (serviceable).
1 voltammeter, Weston, model 280.
1 ammeter, 0–50 scale.

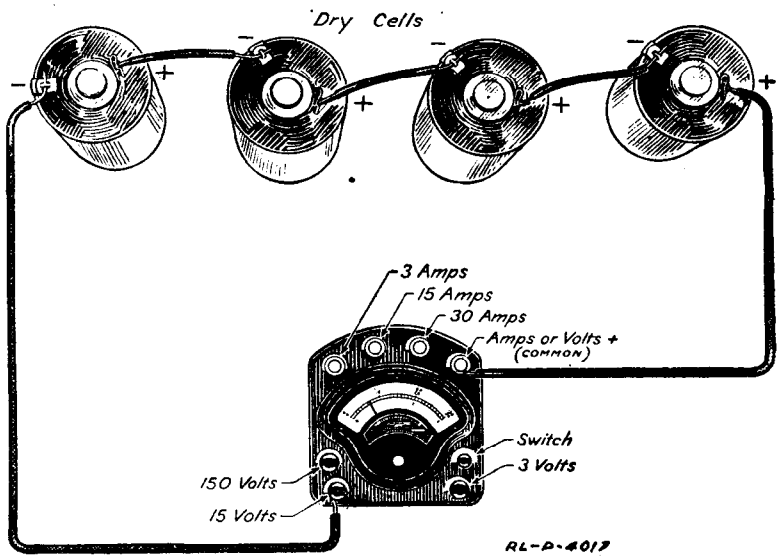


Fig. 4.—Method of connecting four dry cells in series.

Information.

Series connections.—At times it is necessary to use a voltage greater than the initial voltage of a single cell. As stated in the description of the BA–2 and BA–8 batteries, 15 cells are connected together in order to obtain 22 volts. When the cells are connected in this manner they are said to be connected in *series*. Fig. 4 shows how four type BA–10 reserve dry cells are connected in series for delivering current at a pressure of 6 volts.

Directions.

1. Measure the voltage of one of the BA–10 cells. Prepare a table similar to the one shown at the end of this Unit Operation. Record the reading obtained.

2. Connect four type BA–10 cells in series as shown in Fig. 4. The positive terminal of one cell is connected to the negative terminal of the second cell. The negative terminal of the second cell is connected to the positive terminal of the third cell and so on. Measure the voltage of the four cells in series using the terminals marked " 15 Volts " and " +Volts " on the voltammeter.

3. Record the reading in the table prepared.

Questions.

(1) *What voltage does the meter indicate?*

(2) *Multiply the voltage of one cell by the number of cells (4). What is the answer?*

(3) *Compare the answers to Questions 1 and 2. Would the same relation hold true if six cells were used in Direction 2?*

Information.

When measuring the voltage of a battery such as the type BA–2 or the type BA–8 battery, the terminals marked " Volts + " and " 150 Volts " are used. The " Volts + " terminal is connected to the positive terminal of the battery while the " 150 Volts " terminal is connected to the negative pole of the battery. With these connections the figures at the top above the scale are used. When measuring the voltage of a battery consisting of less than 10 dry cells, connections are made from the battery to the " Volts + " and the " 15 Volts " terminals on the meter. The " 3 Volts " terminal and the " Volts + " terminal are used when measuring the voltage of one or two dry cells. In this last case, the figures below the scales are used. When measuring the voltage of a battery, the voltmeter is always connected across the terminals of the battery.

Directions.

4. Measure the voltage of one of the BA–2 batteries using the terminals " 150 Volts " and " Volts + " on the meter.

5. Record the reading in the table prepared.

6. Connect two of the BA–2 batteries in series. The positive or red wire lead of one battery should be connected to the " Volts + " terminal of the meter. The black or negative lead should be connected to the red or positive terminal of the second battery. The remaining black lead should be connected to the " 150 Volts " terminal on the meter. Take the voltage reading and record it in the table prepared.

7. Measure the voltage of the BA–8 battery.

8. Record the reading in the table prepared.

Question.

(4) *What difference is there between the voltage of a BA–2 battery and a BA–8 battery?*

Information.

Ammeters.—When using the meter shown in Fig. 2, as an ammeter, the connections are made with the terminals at the top of the meter. (See Fig. 5 and Fig. 6.) The three terminals marked "3 Amps," "15 Amps," and "30 Amps" are the negative terminals. The positive or "Amps +" terminal is the same terminal used for the "Volts +" connection. When measuring the amperage of a dry cell or battery one terminal of the meter (usually the positive terminal) is connected directly to the positive terminal of the cell or

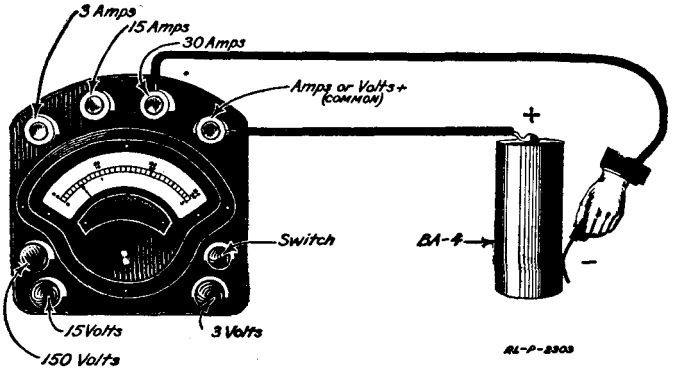


Fig. 5.—Method of making short-circuit test of type BA–4 cell.

battery. One end of the remaining wire is connected to the negative terminal of the meter. The other end of the wire is held against the negative terminal of the meter for an instant, just long enough to allow the needle to swing and come to a stop at the proper reading. This is important, for if the wire is held against the terminal too long the life of the battery will be shortened considerably.

Directions.

9. Measure the amperage of the BA–4 cell, making the connections as shown in Fig. 5. Take the readings quickly so as not to run down the cell. Record the reading in the table prepared.

10. Measure the amperage of the BA–10 cell using the terminal marked "30 Amps" and "Amps +" as shown in Fig. 6. Record the reading in the table prepared.

Questions.

(5) *Which cell gave the greater amperage reading, the BA–4 cell or the BA–10 cell? Note the difference in size between the two cells.*

(6) *Which of the two cells will deliver the same current for a longer period of time?*

Directions.

11. Using the "15 Amps" and "Amps +" terminals on the meter, measure the amperage of the BA–2 battery. Record reading in table prepared.

12. Using the same terminals as in Direction 11, measure the amperage of the BA–8 battery. Record the reading in the table prepared.

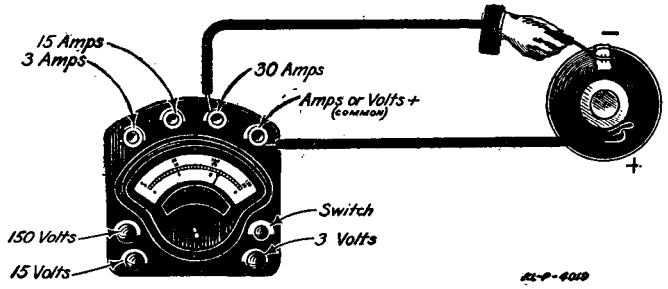


Fig. 6.—Method of making short-circuit test of type BA–10 cell.

Questions.

(7) *Which battery showed the higher reading?*

(8) *Why does one type of battery give a greater reading than the other?*

Information.

Parallel connections.—It is also possible to connect batteries in such a way that increased capacity in amperes may be obtained. Batteries connected in this way are said to be connected in *parallel.* Four reserve dry cells, connected in parallel are shown in Fig. 7. The positive terminals of the four cells are connected together and the negative terminals are connected together. One wire from the meter is connected to one of the positive poles while the other wire is connected to a negative pole, as shown. It is possible with this connection to draw four times the current which can be obtained from one cell.

Directions.

13. Take four cells and connect all the positive terminals together and all the negative terminals together. (See Fig. 7.) Cells connected in this manner are said to be connected in parallel. Test the voltage of this combination. Record the reading in the table prepared.

Question.

(9) *How does this voltage compare with the voltage of one of the cells?*

Directions.

14. Connect two cells in parallel. Using the 0–50 scale ammeter (or two model 280 voltammeters with their 30 Amp. terminals con-

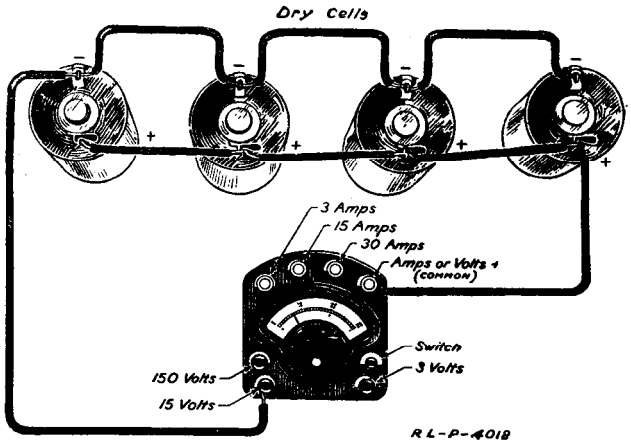


Fig. 7.—Parallel connections of four dry cells.

nected in parallel), make a short circuit test of the two cells thus connected. If the two model 280 voltammeters are used, the total current will be the sum of the readings of the two meters. Record the readings in the table prepared.

Questions.

(10) *How does this reading compare with the reading obtained when measuring the amperage of one cell?*

(11) *Multiply the reading obtained with one cell by the number of cells connected in parallel (two in this case). How does the answer compare with the meter reading of two cells in parallel?*

Directions.

15. Measure the voltage of the two cells connected in parallel. Record it in the table prepared.

Question.

(12) *How does this reading compare with the voltage of one cell?*

Information.

From the above experiments it may be seen that when cells are connected in series the voltage of the combined cells is equal to the voltage of one cell multiplied by the number of cells connected in series. The amperage of the cells in series, however, is the same as that of one cell.

When the cells are connected in parallel the voltage of the combined cells is the same as that of one cell, while the amperage is equal to the amperage of one cell multiplied by the number of cells.

Directions.

16. Using the "15 Amps" and "Amps +" terminals on the voltammeter measure the short circuit current of the BA–2 battery.

17. Using the same terminals measure the short circuit current of the BA–8 battery.

18. Record the readings in the table prepared.

Questions.

(13) *Which battery gave the higher reading?*

(14) *Upon what does the capacity in amperes of a battery such as the BA–2 or the BA–8 depend?*

Directions.

19. Using the information obtained in the above experiment, insert the correct values in the blank spaces in the table prepared as below.

Arrangement of cells.		Type of cell or battery.			
		BA–4.	BA–10.	BA–2.	BA–8.
1 cell	Volts				
	Amps				
2 cells in series	Volts				
	Amps				
4 cells in series	Volts				
	Amps				
15 cells in series	Volts				
	Amps				
30 cells in series	Volts				
2 cells in parallel	Volts				
	Amps				
4 cells in parallel	Volts				

STORAGE BATTERIES.

Equipment.

1 storage battery, type BB–14 (fully charged).
1 storage battery, type BB–28 (fully charged).
1 storage battery, type BB–41 (fully charged).
1 storage battery, type BB–5 (fully charged).
1 voltammeter, Weston model 280 (with leads).
1 pair battery leads, with clip terminals.
1 ruler.

Information.

Storage batteries.—The secondary battery or storage battery is somewhat similar to a primary battery. The storage battery, like the

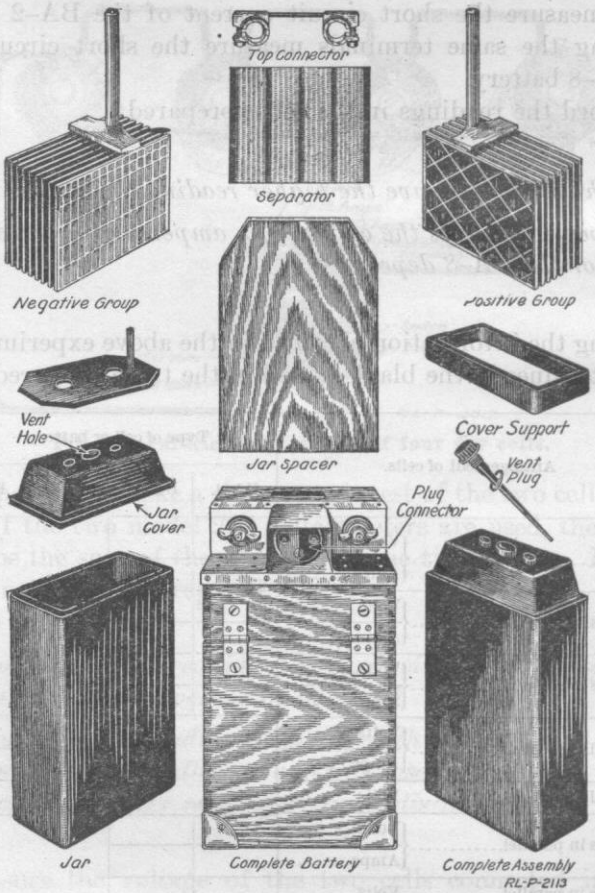
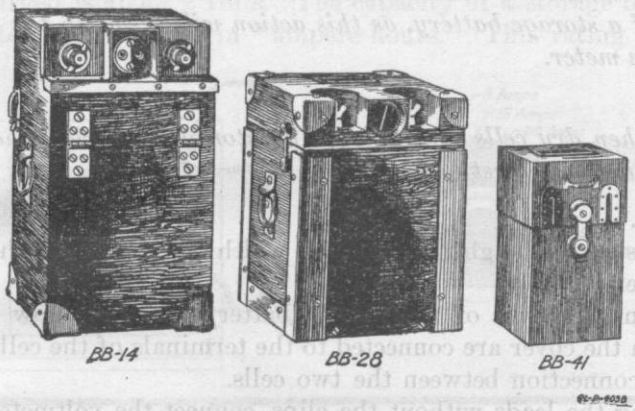


Fig. 8.—Various parts used in construction of type BB–14 storage battery.

primary battery, generates electricity by chemical reaction. The principal difference, however, is that before the storage battery can generate electricity it must first be *charged*. In other words, a direct current from an outside source of electricity, commonly a generator, must be sent through the battery. Usually this current is applied for a number of hours until the necessary chemical changes have taken place inside the battery. The battery is then ready for use. When current is taken from a storage battery, the battery is said to be *discharging*. After a battery has been used for a certain number of hours, it becomes discharged and can not be used again until the charging process is repeated.

Lead cell battery.—There are two types of storage batteries, one the lead cell type, and the other the Edison battery in which the



Figs. 9, A–B–C.—Three types of lead cell storage batteries used in signal communication.

plates are made of nickel and iron. A storage cell of the lead type consists of a hard rubber or composition jar in which are placed two sets of lead plates. (See Fig. 8.) The plates of one set fastened together to a common terminal form the negative pole of the battery, while the plates of the other set also fastened together to a common terminal, form the positive pole of the battery. The negative plates are made with small rectangular indentations or pockets on both sides. These pockets are filled with active chemical material. The positive plates are made in the same manner, but are filled with a different active chemical material. The group of negative plates are immeshed with the group of positive plates in such a manner that beginning from one side of the cell the first plate is negative in polarity, the next plate positive, the next negative, and so on. In order to keep the plates from touching one another, a wooden or a hard rubber

separator is placed between the plates. The cell jar is filled with a dilute solution of sulphuric acid and water.

The majority of storage batteries used in the Signal Corps for radio purposes consist of two cells. In order to protect the cells against damage, they are inclosed in a strong wooden box at the top of which terminals for connections are provided. The battery shown in Fig. 8 and Fig. 9, A, is the type BB–14 storage battery.

The type BB–28 storage battery shown in Fig. 9, B, is similar in construction to the type BB–14 battery. The type BB–41 is a portable, two-cell, storage battery which is much smaller in size than the other type of batteries. This battery is shown in Fig. 9, C.

As the short circuit amperage of a storage battery is very high it is impractical to determine its serviceability by the short-circuit test. *Under no conditions should an ammeter be connected across the terminals of a storage battery, as this action will result in the burning out of the meter.*

Question.

(1) *When dry cells are replaced by storage batteries what additional equipment must be provided?*

Directions.

1. Measure the height, length, and width of each of the three lead type batteries.

2. Open the cover of the BB–14 battery and note how the terminals on the cover are connected to the terminals of the cells. Also note the connection between the two cells.

3. Using the leads without the clips, connect the voltmeter to the outside cover terminals of the battery. A strip of red fiber marks the positive terminal of the battery, and a strip of black fiber marks the negative terminal. Measure the voltage of the battery.

4. Prepare a table similar to the one shown below and record the readings taken in this experiment and those following.

Type of storage battery.	No. of cells.	Voltage of one cell.	Voltage of battery.	Ampere-hour capacity.
BB–14				
BB–28				
BB–41				
BB–5				

5. Using the leads provided with the clip terminals, connect the voltmeter to the inside battery terminals, being careful to get the polarity right. Measure the voltage of the battery and record it in the table.

6. Measure the voltage of one cell by clipping the meter leads to the cell terminals as shown in Fig. 10. Record the reading in the table.

7. Connect the voltammeter to the outside terminals of the BB–28 battery. The positive and negative poles are clearly marked on the cover. Read and record the voltage.

8. Open the cover of the BB–28 battery and connect the voltmeter to either one of the cells using the leads with the clip terminals. (See direction 5.) Measure and record the voltage.

9. Repeat directions 6, 7, and 8, using the BB–41 battery in place of the BB–28 battery.

Information.

Voltage and amperage.—The voltage of a lead storage cell when fully charged is about 2 volts. The capacity of a storage battery is represented by its rating in " ampere-hours." This rating theoreti-

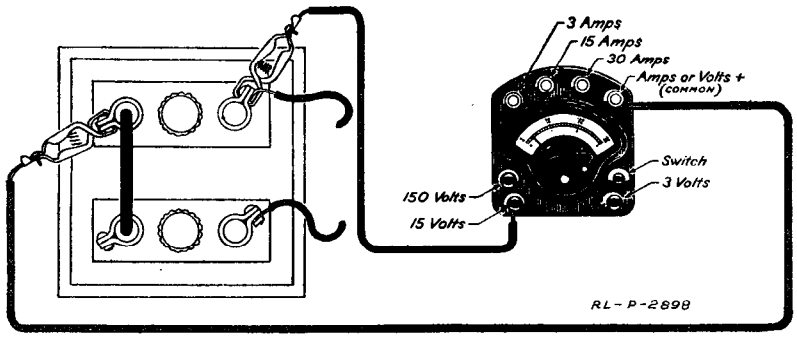


Fig. 10.—Method of measuring the voltage of one cell of a storage battery.

cally represents any discharge rate in amperes multiplied by the number of hours the battery may be discharged at that rate. For instance, a 100 ampere-hour battery will deliver 100 amperes for 1 hour, 50 amperes for 2 hours, 25 amperes for 4 hours, 10 amperes for 10 hours, or 2 amperes for 50 hours. It is not practical, however, to draw as many as 100 amperes for 1 hour from a storage battery of the small portable type, such as is used with radio sets. This rate of discharge is too great, and in a very short time would cause the battery to become completely ruined. It is necessary therefore to discharge the battery at a lower rate. A normal rate of discharge is usually specified by the manufacturer of the storage battery. The normal discharge rate is the rate at which experience has shown can not be exceeded without more or less injury to the battery. For instance, if the normal discharge rate of a 100 ampere-hour battery is

20 amperes, in no case should the battery be discharged at a higher rate than at 20 ampers.

The ampere-hour capacity of a battery depends mainly upon the size and number of plates in the cells. The greater the size and number of plates there are in a cell the greater will be the ampere-hour capacity of the battery.

The type BB–14 storage battery is a 100 ampere-hour battery consisting of two cells. Since the voltage of one cell is 2 volts and the cells are in series, the battery is rated at 4 volts.

The type BB–28 storage battery is a 90 ampere-hour battery. Since it contains two cells, the battery is rated at 4 volts.

The type BB–41 storage battery is a 2-cell, 4-volt, 16 ampere-hour battery. The plates are smaller in size and therefore the capacity of the battery is much less than the type BB–14 or BB–28 batteries.

Directions.

10. Fill in the ampere-hour capacity for all three batteries in the table prepared under Direction 4.

Questions.

(2) *Upon what does the voltage of a storage battery depend?*

(3) *Upon what does the ampere-hour capacity of a storage battery depend?*

(4) *A certain lead-cell type of storage battery has three cells connected in series and is rated at 60 ampere-hours. What is the voltage of the battery? For how many hours will it deliver 2 amperes of current?*

(5) *Which would be the easiest to carry in the field, the BB–14, BB–28, or BB–41?*

(6) (*a*) *A radio set which uses the type BB–41 battery is to be placed in service for continuous use with a combat unit in the field. This set requires 4 amperes for operation. Batteries can be delivered only once each night. How many batteries should be supplied in order to operate the set?*

(*b*) *If a BB–28 is used, how many batteries should be supplied for the same set?*

(*c*) *If a BB–14 is used, how many batteries should be supplied for the same set?*

(7) (*a*) *How many men would be required to carry the batteries in question* (6) (*a*)*?*

(*b*) *How many men would be required to carry the batteries in question* (6) (*b*)*?*

(*c*) *How many men would be required to carry the batteries in question* (6) (*c*)*?*

(8) *Which type of battery would a radio section chief decide to carry for the set in Question* (6) *if he were given his choice? Why?*

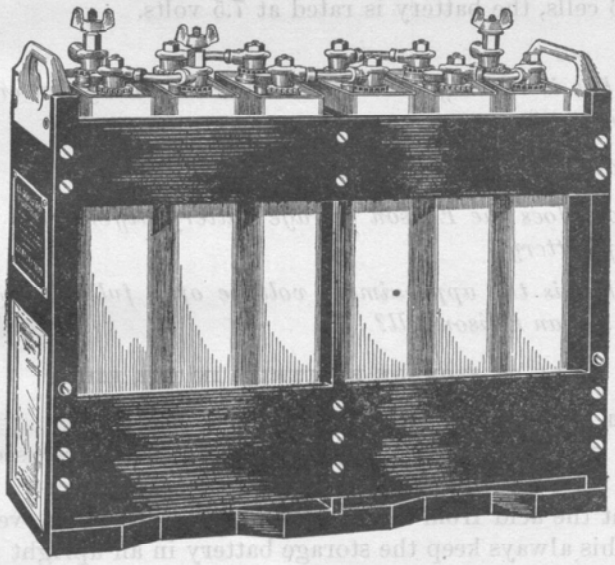


Fig. 11.—Edison storage battery, type BB–5.

Information.

Edison battery.—The Edison battery generates electricity in the same manner as the lead cell type of battery; that is, by chemical reaction. The Edison battery differs from the lead battery in construction, however, the positive plates of the Edison cells being composed of nickel while the negative plates are of pure iron. The cell jars are made of nickel-plated sheet steel. The solution used in the cells consists of caustic soda and water. The type BB–5 storage battery is an Edison battery having 6 cells. (See Fig. 11.) For situations requiring a portable battery, the Edison cells are contained in sheet-steel boxes, while for permanent installations a wooden rack is provided as a container for the cells.

Questions.

(9) *What is the chief advantage of the storage cell?*

(10) *What is the chief disadvantage?*

Directions.

11. Measure the voltage of the type BB–5 Edison battery. Measure the voltage of any one cell. Record the measurements in the table prepared under Direction 4.

The type BB–5 storage battery is a 6-cell, 8-volt, 100 ampere-hour Edison battery. The voltage of each cell is about 1.25 volts. Since there are 6 cells, the battery is rated at 7.5 volts.

Questions.

(11) *What is the difference between a secondary battery and a primary battery?*

(12) *How is a storage battery charged?*

(13) *How does the Edison storage battery differ from the lead cell type of battery?*

(14) *What is the approximate voltage of a fully charged lead type cell? Of an Edison cell?*

CARE OF STORAGE BATTERIES IN THE FIELD.

Information.

Spilling of acid.—Some of the lead storage batteries used by the Army for field service are of the nonspill type. However, this will not prevent the acid from leaking should the battery be overturned. To avoid this always keep the storage battery in an upright position. If any acid should spill or leak from the cell it must be carefully wiped off at once as it causes corrosion of the cell terminals. Take care never to get the acid on the hands or clothes as it may cause a burn or eat holes in the clothing.

Keeping terminals clean.—The action of the acid on the terminals of the cell is such as to cause a green insulating material to collect upon them. Should this material collect to too great a degree it will thoroughly insulate the terminal thus making it impossible to secure a good contact. Care must be taken that both terminals of the storage battery are kept clean as all times.

Testing.—Never short-circuit a storage battery to determine its state of charge as this may buckle the plates and permanently ruin the battery. The testing of a storage battery in the field should be by means of a voltmeter. When the battery is fully charged the

voltage should be from about 2.0 to 2.2 volts per cell. The voltage drops as the battery is used until at discharge it is about 1.8 volts per cell.

Using one cell.—Sometimes it may be necessary to use only two volts instead of four volts. If only one cell of the battery is used the cells should be used alternately so as to discharge the cells to the same degree. This is to facilitate charging.

Dropping of batteries.—The case of each cell is made of hard rubber which if subjected to severe usage will crack and allow the acid to leak. Never throw the battery down on the ground or drop it.