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WAR DEPARTMENT

U.S. Dept. of Army

TECHNICAL MANUAL

STORAGE BATTERIES FOR SIGNAL COMMUNICATION EXCEPT THOSE PERTAINING TO AIRCRAFT

January 16, 1942

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WAR DEPARTMENT
WASHINGTON, January 16, 1942.

STORAGE BATTERIES FOR SIGNAL COMMUNICATION EXCEPT THOSE PERTAINING TO AIRCRAFT

Prepared under direction of the
Chief Signal Officer

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*This manual supersedes TR 1190-5, May 16, 1931, including Changes No. 1, January 2, 1932.

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SECTION I

FUNCTION AND DESCRIPTION

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1. **Use.**—Storage batteries are used by the Signal Corps both in fixed locations, such as common battery telephone exchanges, and as portable sources of moderate amounts of power for the operation of electrical signal communication equipment. Since the voltage delivered by the usual type of storage battery is low, storage-battery-driven dynamotors are extensively used to obtain the high voltages

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required for the operation of radio transmitters and receivers. In many motor vehicle radio installations the storage battery used is the same one used in operation of the vehicle. In these cases the battery is supplied and maintained by the arm or service responsible for procurement and maintenance of the vehicle. (See par. 3, AR 850-15.) In addition to the Signal Corps portable batteries described in section V, commercial type motor vehicle batteries are used in some field signal communication equipment. These batteries are described in TM 10-580.

2. Description and definitions.—A storage battery consists of one or more storage cells which are a special form of voltaic cell. A voltaic cell is a device in which chemical energy is converted into electrical energy when the terminals are connected to a closed electrical circuit. Such cells are classified as primary cells or secondary cells. The primary cell, of which the most common type is the "dry cell," is characterized by the fact that the materials of which it is composed are consumed in the production of electrical energy and must be replaced in part or entirely as the process continues. The secondary cell is the type to which the storage cell belongs, and is characterized by the fact that the conversion of chemical to electrical energy is a reversible process. Before describing the storage cell further, it is desirable to define a number of terms which will be used with reference to it.

a. Electrodes.—Metals or metallic compounds which are placed in the cell and connected to its two terminals. The materials of which the electrodes are composed must be different. They are usually constructed in the form of plates or groups of plates.

b. Electrolyte.—Solution which conducts electric current. It is placed in a cell so that it covers both electrodes. Depending upon the nature of the cell, the electrolyte may or may not take part in the chemical action which occurs at the electrodes.

c. Under load.—Term used to describe the condition when a storage cell or battery is delivering current to an external circuit. This condition is also expressed by the term "closed-circuit."

d. Open-circuit.—Term which means that the battery is disconnected from an external electrical circuit and is delivering no current.

e. Terminal voltage.—Voltage or difference of potential as measured by voltmeters connected between the terminals of a storage cell or battery. This is called closed-circuit or load voltage when the battery is delivering current and open-circuit voltage when the battery is not delivering current to an external circuit. The minute current drawn by the voltmeter itself is neglected. The voltage

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which is obtained from a cell depends upon the materials of which its electrodes and electrolyte are made and upon the concentration of the electrolyte.

3. Chemical action.—There are two varieties of storage cells which may be encountered in connection with signal communication: the lead-lead-acid cell, sometimes called the lead accumulator; and the nickle-iron-alkali cell or Edison cell. The two-cell portable battery BB–29 (fig. 1) is an example of the lead type.

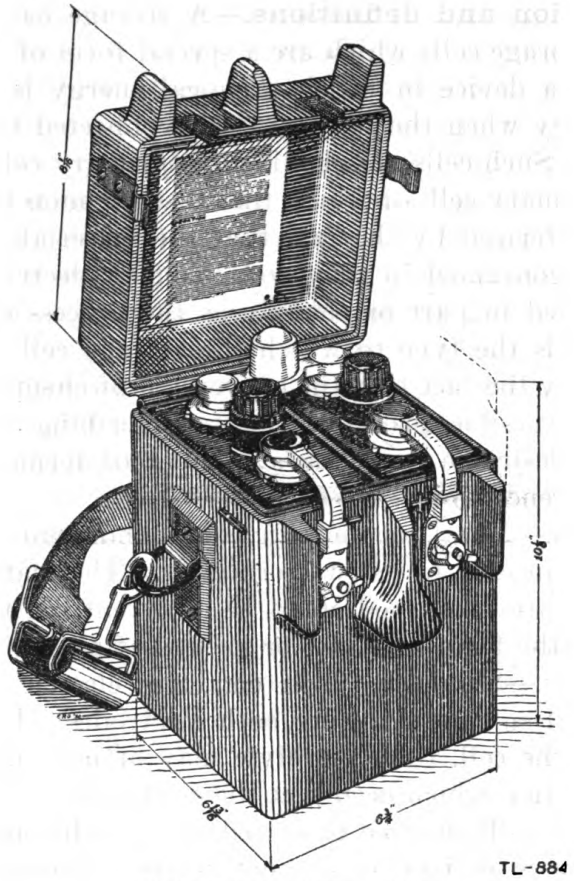


FIGURE 1.—Battery BB–29.

a. Lead-lead-acid cell.—In the lead-lead-acid cell the materials are as follows: The positive electrode is made of a chocolate-brown-colored lead peroxide. The negative electrode is made of gray metallic lead in finely divided form commonly called spongy lead. The electrolyte is a solution of sulphuric acid in water. The open-circuit terminal voltage of this cell when fully charged is approximately 2.2 volts and when discharged is about 1.75 volts. When the cell is

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delivering current to an external circuit, that is, when it is discharging electrical energy, the chemical actions may be summarized as follows:

$$\left.\begin{matrix}PbO_2\\ \text{Lead peroxide}\end{matrix}\ \text{(positive plate)}\right\}\text{plus}\left\{\begin{matrix}Pb\\ \text{spongy lead}\end{matrix}\ \text{(negative plate)}\right\}\text{plus}$$
$$\left\{\begin{matrix}2H_2SO_4\\ \text{sulphuric acid}\end{matrix}\ \text{(electrolyte)}\right.$$

is converted to:

$$\left.\begin{matrix}PbSO_4\\ \text{Lead sulphate}\end{matrix}\ \text{(positive plate)}\right\}\text{plus}\left\{\begin{matrix}PbSO_4\\ \text{lead sulphate}\end{matrix}\ \text{(negative plate)}\right\}\text{plus}$$
$$\left\{\begin{matrix}2H_2O\\ \text{water}\end{matrix}\ \text{(electrolyte)}\right.$$

Note this action removes acid from the electrolyte, lowering its specific gravity (see par. 6) and that both plates become converted in part to the same substance, lead sulphate, thus reducing the voltage delivered by the cell. The process may be reversed by connecting to the cell through suitable resistance an external source of d-c electrical power of higher voltage than that of the cell, connecting the positive terminal of the external source to the positive terminal of the battery or cell and the negative terminal of the external source to the negative terminal of the battery or cell. This causes an electric current to flow through the cell in the opposite direction to that in which current flows when the cell is discharging (see par. 16). This process is called charging and results in converting electrical energy into chemical energy. The chemical processes on charging may be summarized as follows:

$$\left.\begin{matrix}PbSO_4\\ \text{Lead sulphate}\end{matrix}\ \text{(positive plate)}\right\}\text{plus}\left\{\begin{matrix}PbSO_4\\ \text{lead sulphate}\end{matrix}\ \text{(negative plate)}\right\}\text{plus}$$
$$\left\{\begin{matrix}2H_2O\\ \text{water}\end{matrix}\ \text{(from electrolyte)}\right.$$

is converted to:

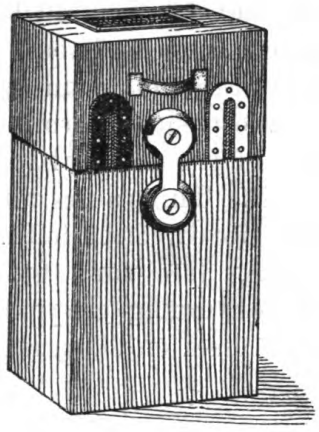
$$\left.\begin{matrix}PbO_2\\ \text{Lead peroxide}\end{matrix}\ \text{(positive plate)}\right\}\text{plus}\left\{\begin{matrix}Pb\\ \text{spongy lead}\end{matrix}\ \text{(negative plate)}\right\}\text{plus}$$
$$\left\{\begin{matrix}2H_2SO_4\\ \text{sulphuric acid}\end{matrix}\ \text{(electrolyte)}\right.$$

Note that this action restores acid to the electroylte, thus increasing its specific gravity, and that the plates are reconverted to the original materials. Upon completion of charging, the battery or cell is again ready to deliver current to an external circuit by conversion of chemical energy into electrical energy. During both the discharging and the charging processes some of the water in the electroylte is decomposed into its elements, hydrogen and oxygen, both of which are gases. These gases bubble from the solution. This bubbling is much greater

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in quantity during charging than during discharging. *A mixture of hydrogen and oxygen gases is highly explosive.* For this reason a *battery charging room must always be well ventilated and all flames must be kept out of it.* Distilled water must be added occasionally to replace that lost by decomposition.

b. Edison cell.—The Edison cell has its electrodes made of nickel oxide and finely divided metallic iron with an electrolyte of potassium hydroxide (an alkali commonly called caustic potash) dissolved in water. This cell was developed to provide a very rugged type of storage battery which could stand physical shocks and much abuse. Its voltage is about 1.2 when fully charged and about 0.9 volt when discharged. Its state of charge can be tested by measurement of its terminal voltage. The methods of charging Edison cells are the same



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FIGURE 2.—Battery BB-41.

as those of charging lead acid cells, but the chemical actions upon charge and discharge are different. The potassium hydroxide does not enter into the chemical action as does sulphuric acid in the lead cell, hence concentration of the electrolyte does not change. Subsequent to the development of this cell, methods of construction of the lead cell have so improved the ruggedness of that type of cell that its advantages as compared to those of the Edison cell have greatly increased. Only the lead type is now being procured for signal communication purposes. Some Edison cells are, however, still found in service.

4. Plate structure.—The active materials of the electrodes of storage batteries are soft, porous, and flaky. They have inadequate mechanical strength to support themselves, especially in the portable

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types of batteries. It is therefore necessary to provide support for these materials by means of a rigid framework of some inactive substance which is also an electric conductor. There are various different ways of preparing the plates of a lead cell, but in the final form each consists of a framework containing the active material in a porous form which exposes a considerable amount of surface of its particles to the electrolyte. The material of which the supporting framework is usually made is a hard lead-antimony alloy. Especially in the portable types of batteries, this framework usually takes the form of a grid structure of horizontal and vertical wires (see fig. 3). The single plates are assembled into positive and negative groups (see fig. 6).

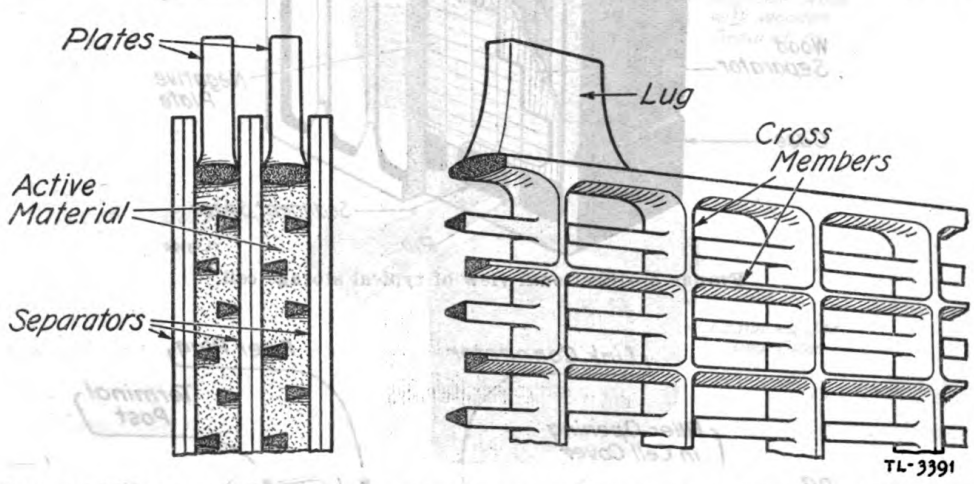


FIGURE 3.—Section of battery plate grid with cross section showing active material in place.

Each negative group always has one more plate than the positive group with which it is to be used. The plates of each group are permanently joined to a connecting post strap by melting a portion of each plate and the strap at the point where they come together (see figs. 4 and 5). This process is known as "lead burning" and is done with a gas flame or an electric arc. An assembly consisting of a positive group and a negative group with separators is called an element. The separate plates of the positive and negative groups alternate within the element assembly.

5. Separators.—To reduce the internal resistance of the cell the plates are separated by as small a space as practicable. To prevent the plates from actually touching and causing a short circuit, sheets of insulating material called separators are inserted between them. Separators are made of various materials such as treated acid-resisting wood, perforated rubber, or a combination of the two, porous rubber, or spun glass. When wood separators alone are used they are grooved

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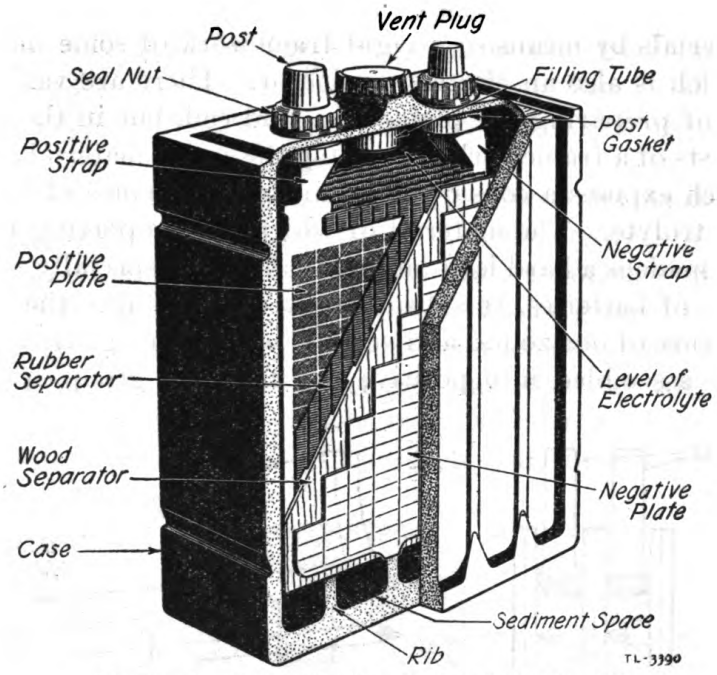


FIGURE 4.—Sectional view of typical storage cell.

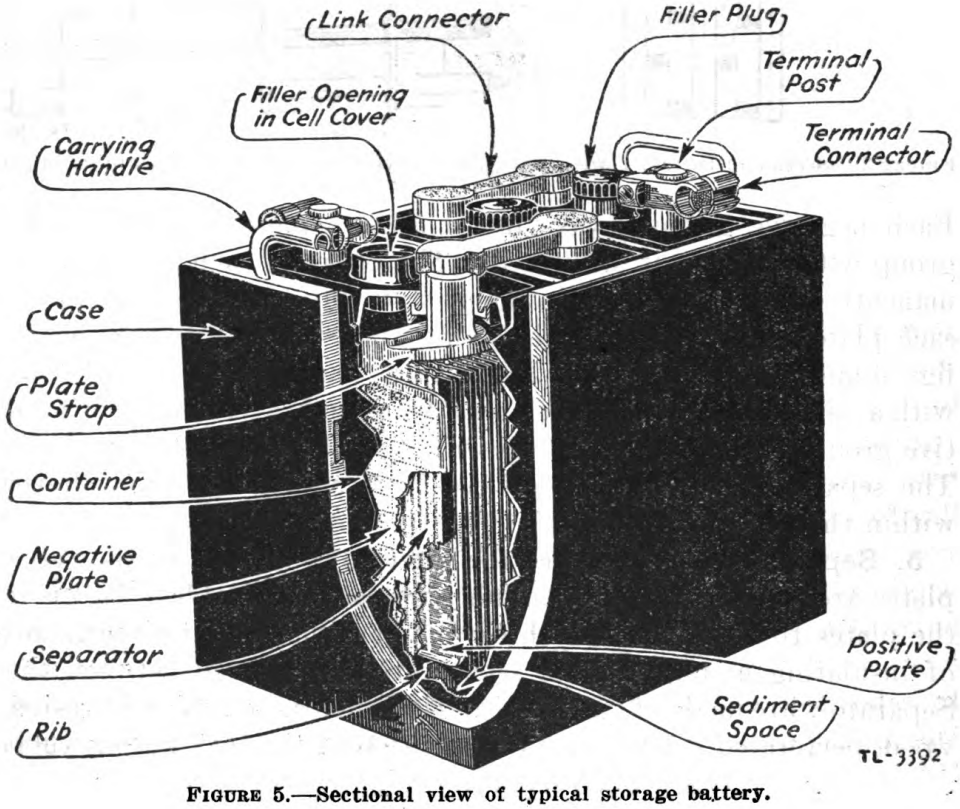


FIGURE 5.—Sectional view of typical storage battery.

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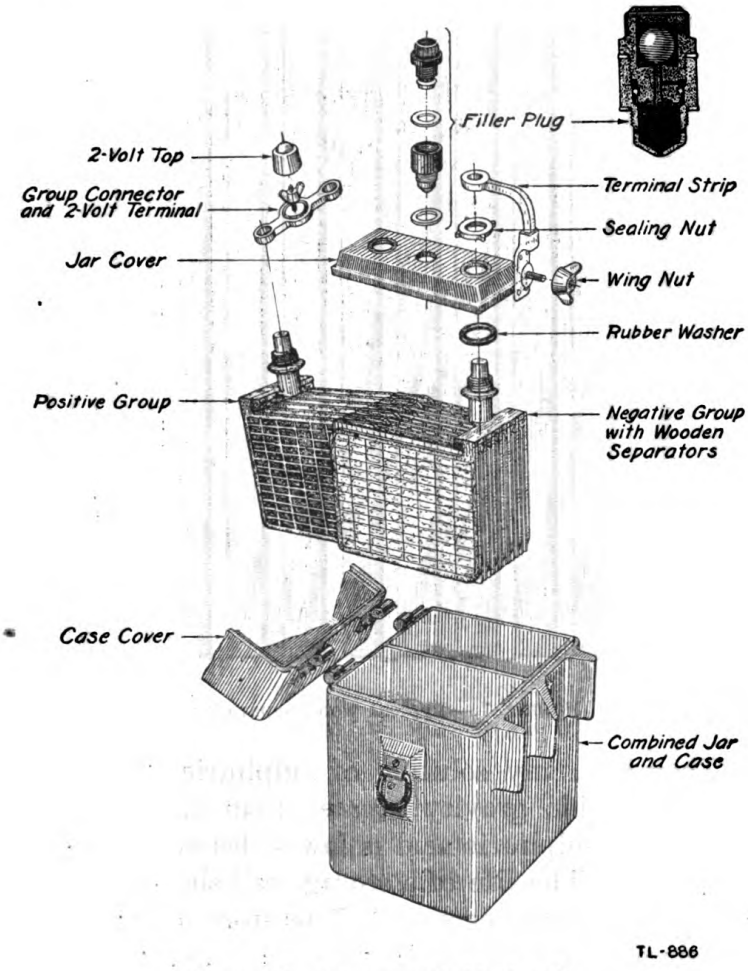


FIGURE 6.—Battery BB–29, details.

vertically to allow the escape of oxygen gas formed during charging (see par. 3*a*) and to provide room for active material which flakes from the positive plates to drop to the sediment space below. (See fig. 7.) If the oxygen is not permitted to escape rapidly it will deteriorate the wooden separators. Also the active material of the positive plates is more susceptible to flaking than that of the negative plates. When a combination of wood and perforated rubber separators is employed, the rubber separator is placed next to the positive plate.

6. Electrolyte.—Dilute sulphuric acid is used as the electrolyte in lead-acid storage cells. The strength or concentration of the acid solution is an important indication of the condition of the cell and is usually measured in terms of its specific gravity. Specific gravity is the ratio of the weight of a given volume of acid to the weight of the same volume of water. Pure sulphuric acid has a specific gravity

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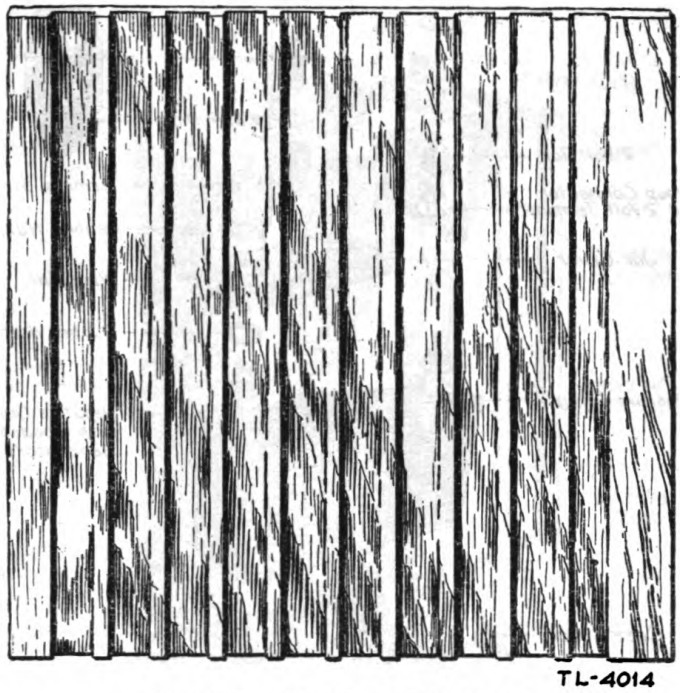


FIGURE 7.—Typical wood separator.

of 1.835. Therefore, any solution of sulphuric acid in water will always have a specific gravity greater than 1.000. The electrical resistance of dilute sulphuric acid is lowest between specific gravities of 1.150 and 1.300. The life of a storage cell shortens as the specific gravity of the electrolyte increases. Therefore, maximum life is obtained by using electrolyte of as low specific gravity as is practicable. In stationary batteries where size and weight are not so important as in portable batteries, the acid used is generally of lower specific gravity than that used in portable batteries, varying from about 1.225 to 1.250 on charge to about 1.150 on discharge. In portable batteries the question of bulk and weight and of the requirement of large currents for short periods of time outweighs the consideration of long life and, as a consequence, the acid used in portable batteries is ordinarily between about 1.270 and 1.310 when fully charged and between 1.150 and 1.210 when discharged. The intensity of any chemical action increases with rising temperature. In storage batteries using electrolyte with maximum specific gravity between 1.270 and 1.310, the action increases to such a degree above 110° F. that permanent damage may be done to the plates if the battery is used at these temperatures. In some climates the atmospheric temperature will exceed 110° F. In these localities it is better to use electro-

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lyte of lower specific gravity than would be used in a temperate climate. For example, a stationary battery designed to use electrolyte of specific gravities varying from 1.225 to 1.250 in temperate climates will operate more efficiently and with longer life in temperatures above 110° F. if the electrolyte of the battery when fully charged is from 1.200 to 1.210 specific gravity. In portable batteries using electrolyte specific gravity of 1.270 to 1.310 at normal temperatures, it is desirable to reduce the electrolyte specific gravity to between 1.250 and 1.270 when the batteries are used at temperatures above 110° F.

7. Containers.—The containers used for storage cells may be made of any material which will not be acted upon by the electrolyte over the range of temperature encountered. Materials often used are glass, hard rubber, celluloid, treated wood, or lead-lined wood. Glass is most commonly used for the stationary batteries used in connection with signal communication and hard rubber for the portable batteries. In the case of portable batteries the container is usually made up in the form of a box with partitions separating it into compartments for two or more cells. Each cell compartment has a row of ribs across the bottom which serve to hold the plates off the bottom of the container. This provides space into which sediment from the flakes may settle without coming in contact with the plates where it would cause a short circuit of the cell. Care is taken in the design and manufacture of portable batteries to make the containers leakproof and, in some cases, spillproof by the use of specially designed vent caps which allow gases to escape but prevent the escape of electrolyte. Ordinarily each cell of the portable battery has its own cover of the same material as the container. (See fig. 6.) This cover has three holes, one for each of the two terminal posts which are part of the terminal straps holding the plates together in groups, and one for the filler plug into which the vent cap is fitted. The covers are sealed to the containers by an acid-proof thermoplastic compound. The terminal post holes are made leakproof by the use of washers or sealing compound. Stationary batteries of the glass type may be provided with hard rubber or glass covers or may be without covers.

8. Electrical connections.—In batteries of two or more cells, the cells are usually connected in series (sometimes in parallel) by connecting straps. These are usually of lead or lead-coated copper and are permanently connected to the terminal posts by burning.

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9. Ratings.—Storage batteries are usually rated in closed-circuit terminal voltage at a normal discharge current and in ampere-hour capacity. The voltage rating is a function of the number of cells in series and is based on voltage of 2 volts per cell. The open-circuit voltage of a fully charged lead-acid cell is approximately 2.2 volts, but due to the internal resistance of the cell this may drop to 2 volts or less under load. The ampere-hour rating of portable batteries is normally based on an 8-hour (or sometimes 5-hour) discharge rate at 77° F. To obtain the number of amperes which may be delivered by a storage battery in order to discharge it to its normal discharged condition in 8 hours (which is 1.75 terminal volts per cell under load), divide its ampere-hour rating by 8. Thus, a battery having a rating of 4 volts and 80 ampere-hours will be delivering a current of 10 amperes at 3.5 volts at the end of an 8-hour period of discharge at 10 amperes. The ampere-hour rating is a function of the total plate area in each cell, multiplied by the number of cells in parallel. In automobile batteries, since the plates are nearly always of a standard size, the ampere-hour rating is a function of the number of plates per cell. If a battery is discharged at a current higher than its normal 8-hour rate, its ampere-hour capacity will be much less than its rated ampere-hours; if discharged at a lower rate, it may deliver considerably more than its rated ampere-hours. Batteries which are designed for special purposes may be rated in terms of other than 8-hour discharge rates.

10. Life expectancy.—*a.* The life of a storage battery depends upon several conditions, among which are the—

(1) Type of plates used.
(2) Care given to the battery.
(3) Actual cycles of charge and discharge undergone by the battery.
(4) Temperatures at which it has been charged and discharged.

b. If the battery were used intermittently and kept on trickle charge for long periods, its life might extend to 5 or more years. If, however, it is used continuously under normal conditions, its life may be anywhere from 2 to 4 years. The life is limited to a great extent by the shedding of active material (see par. 37) and by sulphation of the plates (see par. 30). If charging and discharging are conducted at normal rates and under proper conditions, the plates will remain in good condition over a long period of time. However, if subjected to abnormal load or misuse, their life will be shortened.

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SECTION II

OPERATION

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11. Capabilities and connections.—To obtain the best service from storage batteries, they should be discharged at as low a rate as possible. The normal rate of discharge for most storage batteries is the 8-hour rate, but if a lower rate can be used it is advantageous to do so. The voltage delivered by a storage cell is 2 volts, and sufficient cells must be connected in series to give the required voltage. Sufficient cells to provide the necessary current drain over a reasonable period of time must be connected in parallel. Suppose, for example, a particular piece of equipment requires 30 amperes at 24 volts for its operation, and that only batteries BB–29 are available. The rating of the battery BB–29 is 4 volts and 80 ampere-hours. The 8-hour discharge rate of this battery is 80 divided by 8, or 10 amperes. Since 30 amperes are required, 3 cells in parallel must be used if the 8-hour rate is not to be exceeded. To give 24 volts, 6 batteries must be connected in series. Therefore, three parallel sets of 6 batteries BB–29 in series (18 batteries, or 36 cells in all) are required to operate this equipment for 8 hours (see fig. 8). This is an unusual requirement (720 watts), and usually from 1 to 6 batteries BB–29 will operate the equipment likely to be encountered in the field. In an emergency, 24 volts at 30 amperes might be provided by 12 batteries BB–29, connected as two parallel sets of 6 batteries in series, but the drain on the batteries would be excessive and their discharge time would be *less* than ⅔ of 8 hours. For intermittent use in an emergency, this connection would probably give very satisfactory service. If plenty of batteries were available, it would be advantageous to connect 24, 30, or even more batteries (in groups of 6) in

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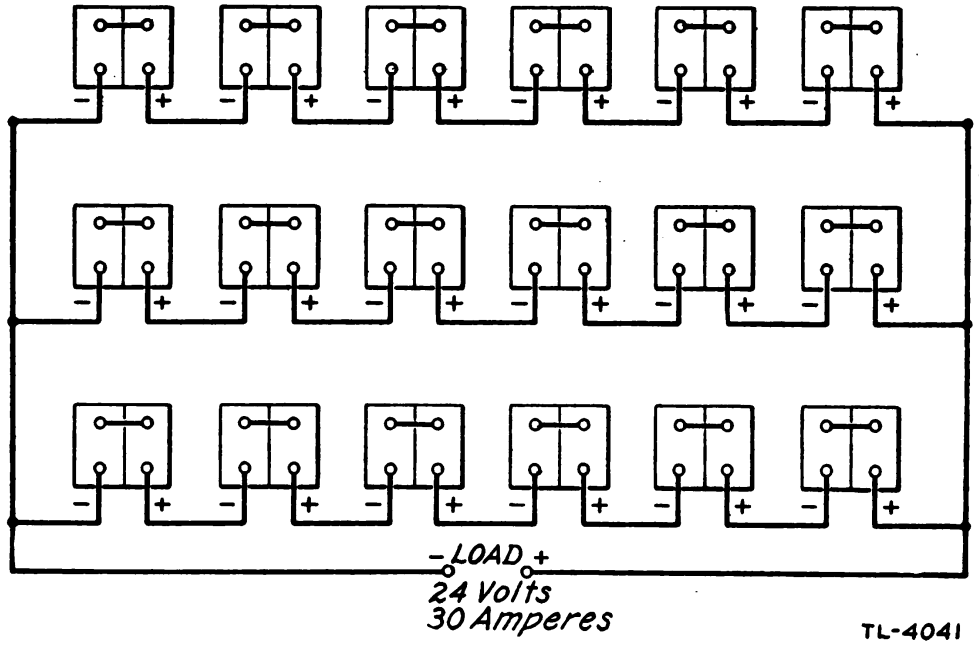


FIGURE 8.—Method of connecting batteries for heavy loads. (Those shown are batteries BB-29, connected to deliver 24 volts at 30 amperes for 8 hours.)

the circuit, thereby reducing the drain on each battery below the 8-hour rate, and extending the discharge time.

12. When to charge.—The most advantageous time to charge a storage battery is immediately after it has been used to any extent. In any event, a battery should be charged immediately if its specific gravity has fallen to 1.150. Batteries should never be left in a discharged condition longer than is absolutely necessary. Allowing a battery to remain in a partially or completely discharged condition for excessive periods of time causes the lead sulphate on the plates (see par. 3*a*) to become crystallized, thereby making it next to impossible to charge the battery without removing large amounts of active material from the plates. This is ruinous to the battery (see par. 37). In addition to this, the sulphate coating over the active material is a nonconductor and it is difficult or impossible to pass charging current through the battery.

13. Hydrometers.—*a.* A convenient tool for making rapid measurements of specific gravity of electrolyte is the hydrometer. The syringe type hydrometer consists of a glass syringe containing a glass hydrometer float (see fig. 9). The float is a long-necked bottle, weighted in the lower end and having a long, thin neck graduated from 1.100 to 1.300. Electrolyte is sucked into the syringe until the float is floated by the electrolyte. The division of the scale in line with

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the surface of the electrolyte in the syringe indicates the specific gravity of the electrolyte (see fig. 10). In common practice, the decimal point is omitted from hydrometer readings; thus, the specific gravities in figure 10 are read as 1275, 1200, and 1150. In stationary batteries without covers, a hydrometer consisting of the float only is used and is left floating in one cell which is called a pilot cell.

b. Care should be exercised in using the syringe hydrometer. The electrolyte should be drawn in slowly to prevent breakage of the float against the top of the syringe; similarly the electrolyte should be

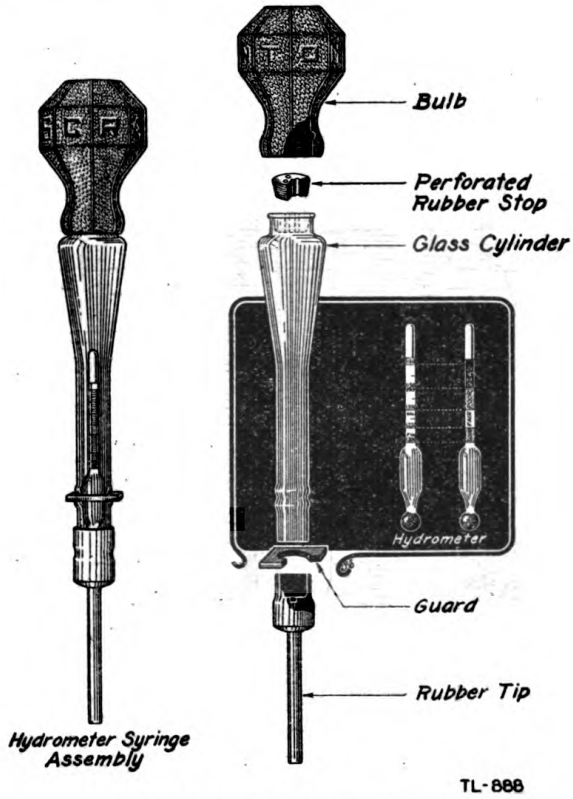


FIGURE 9.—Hydrometer HY–2.

expelled gradually to avoid breaking the float against the bottom of the syringe. The instrument must be held upright while taking a reading, otherwise the float may stick against the side of the syringe. Hydrometers should always be tested against a standard instrument before being put into service.

c. Hydrometer readings should always be corrected for temperature. This is done by adding 0.001 (or simply 1 in common practice) for every 2½° above 80° F., or by subtracting a like amount for every 2½° below 80° F. A correction table is given in figure 11.

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To use this chart, add (or subtract) the figure opposite the temperature reading to the temperature reading. For example, a hydrometer reading of 1280 at 40° F. should be 1280−16=1264; a reading of 1210 at 110° F. should be 1210+12=1222.

d. Another type of specific gravity indicator, which is used in cells having glass containers, consists of two balls of different specific gravities and different colors, each about ¼ inch in diameter. They

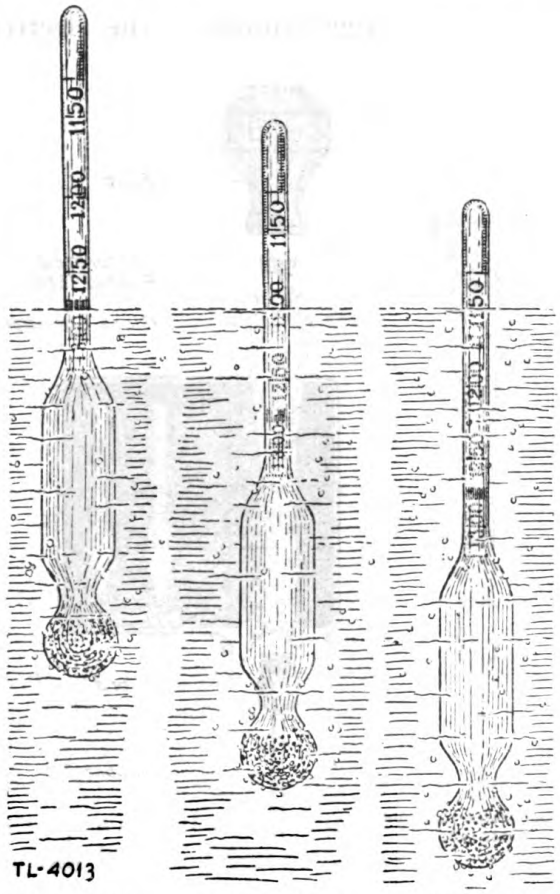


FIGURE 10.—Hydrometer readings. (Those shown are 1.275, 1.200, and 1.150 from left to right.)

are confined in a vertical cage against the container wall. When both float, the battery is approximately fully charged. When one sinks, the battery is partly discharged; when both sink, it is discharged and should be recharged. This method is unreliable above 110° F. and thereafter if the balls have ever been heated to such a temperature.

14. Charging rates.—The charging rate of a storage battery depends upon several factors, among which are the ampere-hour rating

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of the battery, its age, its previous history, and the charging method used (see par. 16). Under no circumstances should a battery be charged at a rate which causes the temperature of its electrolyte to rise above 110° F. A battery placed on charge should be carefully watched for several minutes for excessive gassing, which indicates too high a charging rate. Gassing is the giving off of many small bubbles at such a rate as to make a hissing sound. The occasional gurgling or bubbling sound from a battery on charge is normal and should not be confused with the hissing sound of excessive gassing.

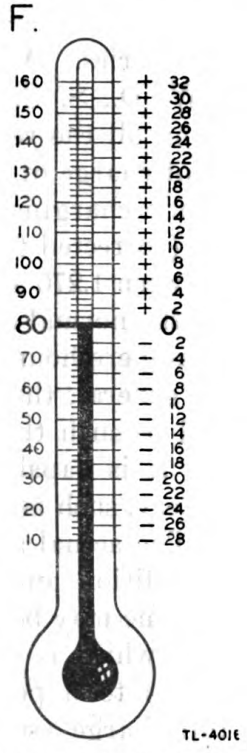


FIGURE 11.—Temperature correction chart for hydrometer readings.

Caution: *The gas given off by storage batteries is a mixture of hydrogen and oxygen and is highly explosive. No flame or spark should be allowed near batteries which are on charge or discharge.* Any rate which does not cause excessive gassing or excessive temperature rise may be used, although when high starting rates (50 percent of rated ampere-hour capacity or more) are used the batteries should be carefully watched.

15. Charging time.—Charging should always be continued until the battery is fully charged. Readings of specific gravity (corrected for electrolyte temperature) and cell voltage should be made every half hour, and charging continued until no rise in either oc-

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curs on any one of four successive readings (1½ hours' time). Accurate records of the progress of batteries on charge should be kept by the charging-station attendants. For this purpose, charts should be made for 24-hour intervals, divided into columns for half-hourly intervals, and providing space for the largest number of batteries which the charging equipment is capable of handling at one time. Provision should be made for entering batteries on the chart at any time. Each half-hourly reading for a battery should consist of a reading of specific gravity and a reading of terminal voltage (with normal charging current flowing) for each cell. If more than one type of battery is handled, separate charts may be made for two-cell, three-cell, and six-cell batteries. A convenient form for use with stationary batteries is W. D., S. C. Form No. 1173 (Storage Battery Report). By recording all the readings indicated, all question of the state and progress of charge of each battery will be eliminated, and the liability of undercharging or overcharging will be reduced. The specific gravity (corrected for electrolyte temperature) of the electrolyte should be between 1.270 and 1.300, and the cell voltage 2.3 to 2.5 volts (with half the normal charging current, or a current equal to 5 percent of the ampere-hour rating, flowing) when the battery is fully charged. In general, the time necessary to charge fully a discharged battery will be such that more ampere-hours will be put into the battery than it is capable of delivering. This is due to various losses in the battery, such as heat, local chemical action in the cells, electrolysis, etc. The actual ampere-hours necessary for full charge depend on the condition and starting state of charge of the battery. The charging time may be reduced materially by the use of a tapered charging rate, which is one which starts at a high current and gradually decreases to 5 percent of the ampere-hour capacity of the battery at full charge (see par. 16*b*). Batteries on taper charge should be carefully watched during the first hour for excessive temperature rise or gassing.

16. Charging methods.—All charging methods are fundamentally alike, in that they are all methods of applying unidirectional (direct) current of the proper voltage and current for charging. The most common methods are by the use of resistances in series with d-c mains, d-c generators, and rectifiers. Supplementary parts of battery chargers are regulating controls (rheostats or lamp banks) and measuring instruments (voltmeters and ammeters). Rectifiers are commonly used in charging stationary type storage batteries used in such installations as fixed station common battery telephone installations. The method of charging generally used in fixed installations

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is trickle charging and this should always be conducted in accordance with instructions supplied with the battery by the manufacturer. Portable batteries, such as the BB–29, used for field radio equipment may be charged by the use of rectifiers (see TM 10–580) or by the use of the battery charging set SCR–169 which supplies a voltage of 32 volts and may be used for either constant-current or constant-voltage charging, depending upon the number and arrangement of the batteries being charged see TM 11–302).

a. Constant-current charging.—When a voltage source considerably higher than that necessary for charging is used, through appropriate dropping resistors, lamp banks, etc. (see fig. 12), the variations in battery voltage are small compared to the voltage across the dropping resistors, and the current remains practically constant

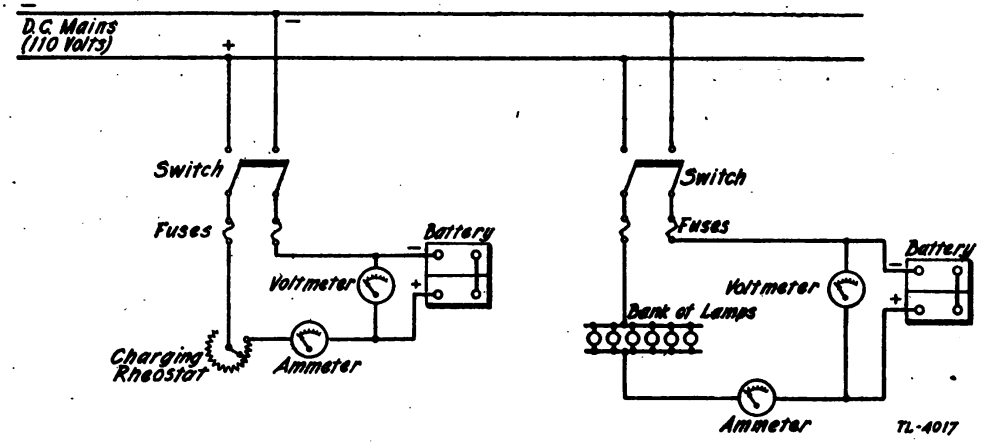


FIGURE 12.—Constant-current charging, showing connections for rheostat and bank of lamps.

throughout the charging period. This method of charging requires almost constant attention, since excessive overcharging (see par. 38) may easily take place. If a number of batteries are to be charged together, this difficulty may be largely overcome by connecting them in series, thereby decreasing the difference between the line voltage and the battery voltage, and making the method approach more nearly the constant-voltage method (see *b* below). Series connection is also more economical than separate charging from the d-c mains, because as much power is required to charge one battery as several. A safe charging current for constant-current charging is one-eighth of the 8-hour rating in ampere-hours of the battery, reduced to half of that value as the battery approaches full charge. Care should be taken that the charging rate is not too high, as evidenced by excessive gassing or temperature rise (see pars. 14 and 37).

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b. Constant-voltage charging.—The time required for charging can be reduced by the use of a tapering current (see par. 15). If a source of constant voltage equal to 2.5 volts per cell is used, this is accomplished automatically (see fig. 13). The initial charging current under these conditions is much higher than the normal rate, sometimes several times the normal rate, but the current drops rapidly as the battery charges, until at full charge the current is approximately half the normal rate. Care should be taken to ascertain that the initial rate is not too high, as evidenced by excessive gassing. After the charging current drops to the normal value, little attention to batteries on taper charge is required, since the charging rate decreases automatically as the batteries become charged.

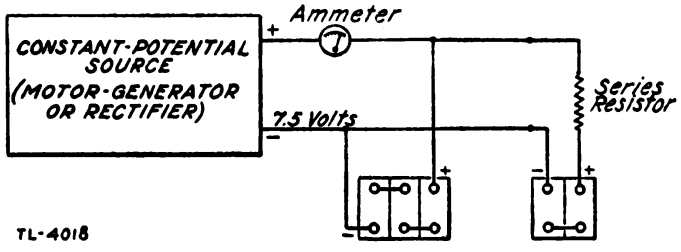


FIGURE 13.—Constant-voltage (automatic taper) charging, showing connections for 2- and 3-cell batteries.

c. High-rate charging.—Various types of high-current chargers for rapid charging of storage batteries are being developed commercially. These chargers deliver an extremely high current (100 amperes or more) initially, dropping rapidly to a normal value. They charge batteries in a very short time but are capable of completely destroying a battery if not controlled intelligently. They are not used at present by the Signal Corps.

d. Trickle charging.—Trickle charging is the continuous application of low charging current and is usually a constant-voltage method. This maintains the maximum electrolyte specific gravity and insures that the batteries will remain at full charge over long periods of time. It is particularly well suited to batteries which are used intermittently over long periods of time, such as stationary batteries. Trickle charging may be accomplished by any device capable of delivering 1 percent or 2 percent of the ampere-hour rating of the battery, or sometimes as high as 5 percent if the intermittent loads are heavy.

e. Overcharging.—Occasional overcharging, as indicated by cells gassing freely, is beneficial to batteries, but if carried to excess may destroy the plates (see par. 38).

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17. Preparing new batteries for service.—New batteries may be received in either a wet or a dry condition.

a. Batteries shipped wet are always fully charged before shipping and may be put into service immediately, although a finishing charge at half the normal rate is advisable.

b. Batteries shipped dry must be filled with electrolyte and given the initial charge before being put into service. Instructions stating the amount and specific gravity of the electrolyte necessary, as well as the rate and time of the initial charge, are usually provided with new batteries. The vent plugs of a battery shipped dry are ordinarily sealed and should not be removed until the battery is to be filled and charged. If the plugs are not disturbed and the battery is properly stored (see par. 41), it may be stored dry over periods of many months without harmful effects.

18. Preparing electrolyte.—Sulphuric acid for electrolyte may be furnished as pure acid, as dilute acid of 1.400 specific gravity, or as dilute acid of 1.300 specific gravity. Unless furnished at the proper specific gravity for use, it must always be diluted to the proper specific gravity (1.300 unless otherwise specified by the manufacturer) by adding to distilled water.

a. When pure sulphuric acid (specific gravity 1.835) is furnished, great care must be exercised in its dilution, because heat is always developed when water and sulphuric acid are mixed. A container of suitable size, which will not be acted upon by sulphuric acid, should be used. ***Caution:*** *Never pour water into acid—pour the acid into water, and go slowly, stirring the mixture gently but thoroughly meanwhile. Large quantities of acid may require hours for safe dilution. Always correct hydrometer readings for temperature when measuring specific gravity of the mixture; otherwise the specific gravity will be too high when the mixture cools.*

b. If acid at 1.400 specific gravity is furnished, distilled water may safely be added slowly to it, if stirred vigorously meanwhile, since 1.400 specific gravity acid has already been made by mixing sulphuric acid and water. Not as much heat will be developed when diluting 1.400 specific gravity acid as when pure acid is added to distilled water.

c. In diluting sulphuric acid of specific gravities 1.835 or 1.400 to suitable specific gravities for use in storage batteries, it is desirable to use a table to determine the quantities by volume which should be mixed. This is because the total volume shrinks somewhat after mixing, with the result that calculations as to volume-weight relation-

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ships after mixing cannot be determined from those before mixing by simple arithmetic. Below is a table which gives proportions by volume of water and sulphuric acid which should be mixed in order to obtain a limited number of specific gravities commonly used in storage batteries.

When mixing by volume using 1.835 acid		Specific gravity desired, 80° F.	When mixing by volume using 1.400 acid	
Parts water required	to Part acid required		Parts water required	to Part acid required
1. 97	1	1. 350	0. 16	1
2. 50	1	1. 300	. 37	1
2. 90	1	1. 270	. 55	1
3. 24	1	1. 250	. 69	1
3. 77	1	1. 225	. 90	1
4. 13	1	1. 210	1. 04	1
4. 40	1	1. 200	1. 15	1

19. Filling cells of new batteries.—A hard rubber or glass funnel is suitable for filling cells. If these are not available, the electrolyte may be poured from a glass pitcher into the cells, or a temporary funnel may be made of paper to answer the purpose. After filling, the cells should be allowed to stand for 15 minutes, when they should have electrolyte added as necessary to make up for that absorbed by the plates and separators. The battery should then be allowed to stand 8 or 10 hours, when the cells should once more be filled to the proper level. Any electrolyte spilled on the outside of the battery should be washed off with water.

20. Heat due to new electrolyte.—When electrolyte is first placed in new batteries, heat will immediately be developed, sometimes raising the temperature of the electrolyte above 110° F. This cannot be avoided, but the batteries should not be placed on charge until cooled to atmospheric temperature.

21. Conduct of initial charge.—Instructions for giving a specific battery its initial charge are generally supplied with the battery. The general principles followed by these instructions are similar to those in *a* to *d*, inclusive, below.

a. Before charging, remove vent plugs and fill each cell with 1.300 specific gravity electrolyte to a height of ⅜ inch* above the top of the

*This height varies with types and manufacturers of batteries.

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separators. After 15 minutes, go over the cells and fill again to this height to make up for electrolyte absorbed by the plates.

b. Allow the battery to stand 8 to 10 hours and add more electrolyte if the level has fallen.

c. Charge the battery at a current numerically equal to 5 percent of the ampere-hour capacity (i. e., 5% of 80=4 amperes for an 80 ampere-hour battery) for a period of from 70 to 80 hours. Reduce the charging current if necessary to keep the electrolyte temperature below 110° F., but the full number of ampere-hours must be put in. Never discontinue the charge until maximum specific gravity and cell voltage have been obtained.

d. After the battery is completely charged, adjust the specific gravity of the electrolyte to 1.300 unless otherwise prescribed by the manufacturer. Wipe off any electrolyte that has gassed over on the rubber cover.

e. More time than the instructions indicate may be required to charge a new battery completely. The specific gravity may rise much higher than 1.310, but in any case *the initial charge must be continued until the specific gravity has attained its highest reading for a period of at least 2 hours.*

22. Adjustment of electrolyte after initial charge.—After the initial charge, the specific gravity of the electrolyte should be adjusted to 1.300. To accomplish this, some of the electrolyte should be withdrawn from the cells with the hydrometer syringe and replaced by—

a. Distilled water if the specific gravity is above 1.300, or

b. 1.400 specific gravity acid if the specific gravity is below 1.300.

Batteries thus treated should again be placed on charge at the same rate as the initial charge for 2 or 3 hours to mix the electrolyte. If still too high or too low after the mixing charge, repeat the adjusting and mixing operations.

23. Capacity after initial charge.—The capacity of any storage battery under normal conditions is only from 75 to 80 percent as great directly after its initial charge as it will be after the battery has had a few cycles of charge and discharge. Therefore, batteries should not be sent into the field to function at their full capacity immediately after their initial charge.

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SECTION III

MAINTENANCE

	Paragraph
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Short circuits	40

24. Charge and discharge schedule.—The most important point in the care of storage batteries is that they should never be allowed to remain in a discharged condition any longer than is absolutely necessary. Stationary batteries should be charged and the condition of charge should be verified in accordance with the manufacturer's instructions. For portable batteries, tactical units using storage-battery powered equipment should be furnished charging equipment capable of reducing this time to a minimum. For example, a divisional signal company is furnished battery-charging equipment for charging Signal Corps storage batteries of all units of the division. All spare batteries on hand should be kept at the charging station so that they may periodically be given a freshening charge. A schedule may be worked out by the charging-station attendants whereby all spare batteries on hand will be placed on charge at regular intervals, for example, 2 hours every 2 weeks at 5 percent of rated capacity. If facilities for continuous trickle charge (1 percent or 2 percent of rated capacity) are available, all batteries not in use may be kept freshly charged over long periods of time. To obtain maximum life of the batteries they should be used in rotation, rather than having some batteries stand idle continuously while others go through rapid successive charges and discharges.

25. Electrolyte level.—The electrolyte should be maintained at its proper level (3/8 inch or more above the top of the separators, as specified by the manufacturer) by regular addition of distilled

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water. A certain method of ruining a storage battery is to allow the level of the electrolyte to remain below the top of the separators over a period of time. (See par. 33.)

26. Exposed metal parts.—Any electrolyte spilled on the outside of a storage battery should be wiped off with a cloth moistened with ammonia or soda solution (see par. 31), since it may come in contact with exposed metal parts and cause corrosion. Terminals may be protected from corrosion to some extent by coating with petrolatum; cell connectors and other metal parts by coating with petrolatum or painting with melted paraffin.

27. Indications of condition of storage batteries.—When batteries are returned to a charging station for attention, the first thing to be done is to determine their condition. There are several ways of accomplishing this, among which the following are probably the easiest and most reliable:

a. Take specific gravity readings of the electrolyte. If the specific gravity is approximately 1.200, a normal discharged condition is indicated. If no report of trouble with the battery is received, it is safe to charge it at its normal rate. If the specific gravity is approximately 1.250, this indicates that the battery is nearly half discharged, assuming the battery is in good condition. If no report of trouble with the battery is received, it should be placed on charge at its normal rate.

b. If a report is received that the battery would not hold its charge, was not very active, or any other report indicating unsatisfactory service, specific gravity readings of each cell and voltage of each cell under normal discharge should be taken.

(1) If all cells show about the same low specific gravity of 1.150 and terminal voltage of 1.75 volts or less at the normal discharge rate, it is probable that the battery has been subjected to accidental overdischarge, such as leaving a radio set turned on all night. In this case, the battery should be placed on charge at the normal rate.

(2) If one cell shows lower specific gravity than the others, or if its voltage under normal discharge is lower than the other cells, this cell may have internal trouble. The first thing to be done in this case is to place the battery on charge at its normal rate until the better cell or cells have reached their maximum specific gravity, when they should be cut out of the circuit and the charging of the low cell continued. The charge of the poor cell should be carried on until it has been definitely shown that the electrolyte has risen to its highest specific gravity and the cell's voltage will rise no higher. This may require many hours, and excessive heating may

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require reduction of the charging rate. If the cell will not come up to normal specific gravity and voltage, look for internal trouble.

28. Troubles and remedies.—Paragraphs 29 to 40, inclusive, deal with a number of maintenance troubles encountered in caring for storage batteries and appropriate remedies for these troubles. It will be noted in many cases that the remedies include instructions for removing the groups of plates and direct treatment or replacement of plates and separators. This is practical in most types of stationary batteries and it can be done with some types of portable batteries such as the BB–29, for which it is possible to obtain replacement parts. It is not a very practical procedure with automobile type storage batteries because the amount of labor involved is frequently more costly than the price of a new battery. Removal and replacement of plates, both in automobile type batteries and in Signal Corps portable batteries such as the BB–29, should be done only by highly skilled technicians.

29. Loss of capacity.—*a. Indications and effects.*—(1) Battery will not deliver its rated current for the proper length of time.

(2) Specific gravity rapidly decreases after charging.

b. Causes.—(1) Clogging of pores of plates or separators with sulphate or other impurities, due to abuse.

(2) Contraction of the pores of the plates due to overcharging.

(3) Loss of active material from the grid. This is the most usual cause of loss of capacity (see par. 37).

(4) Formation of a layer of sulphate on the grids of the plates. This condition generally results in break-down of the plates and will necessitate replacing the unserviceable parts, or discarding the battery, depending upon its type.

(5) Loss of electrolyte.

(6) Low temperature.

(7) Charging and discharging at an excessively high rate, particularly discharging.

(8) Overcharging for long periods.

(9) Short circuits, internal or external. External short circuits may be caused by spilling electrolyte on the outside of the cell.

(10) Oversulphation.

(11) Normal wear. After a battery has been in service for an extended period, it is natural that its capacity be less than when new. The normal life expectancy of a storage battery is discussed in paragraph 10.

c. Remedies.—It is always a safe procedure to put batteries which show indications of trouble on charge at a normal rate and try to

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bring their specific gravity to normal. This action will provide a simple means for accurately judging the condition of a battery. If the battery has been given a normal charge and the specific gravity rises to its maximum, around 1.240 for example, the battery should then be placed on test discharge at the normal rate and readings of both specific gravity and voltage should be taken every 30 minutes. This test will indicate the number of hours of service which the battery will give. When the voltage per cell falls to 1.75, the battery has reached its normal discharge voltage. This is the indicator of capacity performance and the battery has done all it can do in its condition. If this test indicates that one or more cells are in bad condition and the battery has been in service a long time, the battery should be declared unserviceable.

30. Abnormal sulphation.—*a. Indications and effects.*—(1) Light color of both the positive and negative plates.

(2) Loss of capacity.

(3) Continued low specific gravity.

(4) Hardening of the plates.

(5) High internal resistance, which may be indicated by an abnormally high charging voltage or an abnormally low discharge voltage.

(6) Loosening of active materials.

(7) Buckling of positive plates (see fig. 14).

(8) Abnormal length of time required for charging.

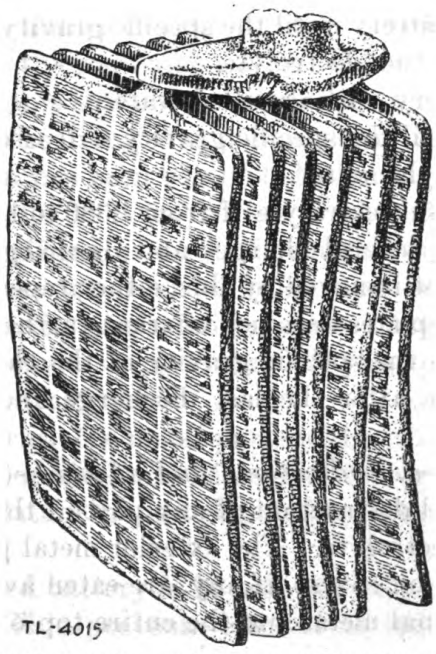


FIGURE 14.—Group of buckled plates, such as caused by abnormal sulphation or excessive heating.

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(9) Low open-circuit voltage.

(10) Low charging current under normal charging voltage.

b. Causes.—(1) Neglect or misuse.

(2) Standing idle in a discharged condition too long.

(3) Habitual undercharging. That is, instead of carrying the charge to its completion where the specific gravity reading should have risen to its highest value and stayed at that value for at least 1½ hours, the charge is cut off before this condition has been obtained. Therefore, all of the sulphate has not been converted into active material.

(4) Electrolyte level too low.

(5) Neglecting trouble in individual cells of a battery.

(6) Adding raw acid or electrolyte to bring up the specific gravity of the cell when it is in a discharged or partially discharged condition. One of the most common mistakes made in storage-battery work is to give what is called a *quick* charge. This is ordinarily done by adding acid to the battery to bring up its specific gravity. For a very short time the battery will function under a nearly normal condition. The ultimate result, however, is complete break-down of the entire battery.

c. Remedy.—When a cell is not too badly sulphated, it is possible in the majority of instances to remove the sulphate from the plate and convert it into active material by long successive charges at low rates. During each charge the specific gravity should rise. It may rise to its normal value. If successive charges do not accomplish this, proceed as follows:

(1) Charge the battery until the specific gravity will rise no higher.

(2) Throw away the electrolyte.

(3) Fill the battery with distilled water.

(4) Charge it until the specific gravity will rise no higher.

(5) Throw away the water.

(6) Fill with fresh electrolyte of from 1.330 to 1.340 specific gravity.

(7) Put through several charges and discharges at normal rates.

If the sulphate is not removed by this, either repeat the process, or, if the condition of the plates does not warrant further use of the battery, discard it. Be sure the specific gravity of the electrolyte is adjusted to the proper value after the last discharge and charge have been made.

31. Corrosion.—*a. Indications and effects.*—(1) Gradual deterioration and eventual destruction of any part of the battery which can be acted upon by electrolyte. The exterior metal parts of the battery, such as spring clips on covers, if any, are eaten away. The corrosion may cover the external metal and the entire top of the battery with a greenish white substance. Terminals are weakened and easily broken.

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(2) Increased resistance indicated by a decreased capacity and terminal voltage while in use although a hydrometer reading of specific gravity of 1.250 to 1.300 may be indicated. There may be no indication of loose connections. The positive terminal of a battery is more susceptible to corrosion than the negative terminal, due to electrolytic action.

b. Causes.—(1) Carelessness, dust, dirt, moisture; the last particularly in the Tropics.

(2) Neglect; loose or dirty connections. The electrolytic action is greater with a loose connection than with a tight one.

(3) Adding so much water to a cell as to cause it to overflow when the battery is being charged and is gassing freely. (The electrolyte expands when charging, due to heat and the formation of bubbles.)

(4) When gassing, electrolyte is thrown out of the cell in a fine spray by the escaping bubbles, and it will attack the exterior metal parts and cause their rapid sulphation. This may result in the total loss of the battery.

(5) Poor sealing.

c. Remedies.—Use the following procedure:

(1) If the cells of the battery are interconnected by wires, remove the wires and clean them.

(2) Brush the corroded parts thoroughly with a wire brush. Make a mixture of baking soda and water to the consistency of a thin cream. Apply this mixture to the metal parts, making fresh applications until any gassing action ceases, or, in other words, until the acid has been neutralized by the soda and water. Other suitable naturalizing substances are ammonia solution or a concentrated solution of washing soda prepared by dissolving common washing soda in warm water. After neutralization has been completed, thoroughly wash the top of the battery with water and dry with a cloth. Care should be taken to see that the neutralizing material thoroughly enters each little crevice or opening between terminals or other exterior parts of the battery in order to complete the neutralizing action. ***Caution:*** *Do not allow the neutralizing mixture to enter the cells through the vent openings as this will ruin the battery.*

(3) When dry, brush the metal parts with a wire brush.

(4) Examine all of the connections and repair any poor ones.

(5) Apply petrolatum to the assembled and cleaned parts of the battery when dry.

(6) When a sealed battery is in use, the vent plugs should be kept tightly in place. This prevents electrolyte spilling and splashing. If a battery becomes wet it should be gone over before it dries with a

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cloth moistened with ammonia or soda solution, and dried with a dry cloth. This neutralizes the acid and prevents corrosion.

32. Cracked or broken containers.—*a. Indications and effects.*—(1) The electrolyte gradually becomes diluted due to leakage, as indicated by the specific gravity not rising to its proper value upon charge; the capacity of the cell may diminish, and it may not develop proper voltage upon discharge.

(2) If there are any metal binders, screws, handles, etc., on the case they eventually will be eaten away by the leaking electrolyte.

(3) It becomes necessary to add much more water to the electrolyte of a cell whose container is broken than to the other cell or cells of the battery.

b. Causes.—(1) Vibration.

(2) Slight falls, such as a drop from a height of 1 or 2 inches upon a concrete floor or rough handling of the battery when loading it into a truck, might crack the container.

c. Remedies.—(1) Tear the battery down.

(2) Replace the broken container with a serviceable one. If the old container is so badly broken it will not hold electrolyte, provision must be made for keeping the plates and separators in water until a new container is available.

(3) Adjust the electrolyte to the specific gravity consistent with the condition of the battery. The proper specific gravity is sometimes difficult to determine. In cases where the battery's condition is not definitely known, that is, whether the battery is charged or discharged, it is best to add electrolyte of 1.250 specific gravity to the reassembled battery, charge it at a normal rate, and adjust the specific gravity to its proper value after it is known that the charge has been completed.

33. Consistently low electrolyte.—*a. Indication and effects.*—(1) Decreased voltage; capacity decreases in proportion to surface of plates uncovered.

(2) A band of gray sulphate across the plates indicating where they have been exposed..

(3) Rotted separators.

b. Causes.—(1) Lack of proper maintenance—not replacing the evaporated water promptly.

(2) Excessive evaporation due to some internal abnormality.

(3) Loss of electrolyte due to spilling or flooding battery. This may easily take place in field work where batteries are tipped over and some of the electrolyte is spilled.

(4) Loss of electrolyte due to leakage or broken container.

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(5) Excessive gassing, indicating excessive local action which is due to some detrimental local condition.

c. Remedies.—If the condition has not lasted too long, add water to bring the electrolyte level ½ inch above the top of the plates, give the battery a long, low rate (one-half normal) charge, and continue to operate the battery. *Electrolyte should never be added to a cell under any circumstances unless it is definitely known that electrolyte has been lost from the cell.* When it becomes necessary to add electrolyte, never add it in the form of raw, concentrated acid but in a dilute form of not over 1.400 specific gravity. After the electrolyte has been adjusted, place the cell or cells on charge at the normal rate and readjust the specific gravity at the end of a complete charge. Repeat the readjustment of the specific gravity until continued charging fails to increase it above a proper maximum. Very often, the excessive use of water by a cell indicates that the cell is not in good internal condition. Where there is internal action, due often to a short circuit or partial short circuit, there will be more or less constant chemical action which uses up water in the electrolyte. Regardless of whether or not the cell is used, there is a certain amount of evaporation of water from the electrolyte. This water must be replaced, and sufficient replacement must be made to prevent the tops of the separators or plates becoming exposed to the air. When exposed to air, the plates will rapidly sulphate or oxidize and render the exposed portions inoperative. Batteries not in use should be filled with water once every 2 weeks in temperate climates, and once every week in warm climates. While in use they should be filled as often as the electrolyte drops to a dangerous level.

34. Freezing.—*a. Indications and effects.*—(1) Broken containers.

(2) Disintegration of active materials.

(3) Broken separators.

b. Causes.—Exposure to low temperatures when partially or fully discharged, or after adding water without placing the battery on charge to mix the electrolyte.

c. Remedies.—(1) Gradually let the battery thaw out by placing it in a room of normal temperature (about 73° F.). The battery may be saved if the freezing has not progressed too far.

(2) If necessary to prevent freezing, place batteries on trickle charge. This will keep up the specific gravity and, as indicated in the table in *d* below, abnormally low temperatures will be required to cause freezing. Never permit a battery to remain discharged at low temperatures.

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(3) Take readings of specific gravity at proper intervals to insure that there is no abnormal drop in the specific gravity of the electrolyte. If water is added to the battery in freezing weather and not immediately mixed into the electrolyte by charging, the water will float on top of the electrolyte, since it is lighter, and may freeze.

d. A table indicating the freezing point of electrolytes of various specific gravities is given below:

Specific gravity	Freezing point	Specific gravity	Freezing point
1.000 (water)	32° F. above 0.	1.200	16° F. below 0.
1.100	18° F. above 0.	1.250	62° F. below 0.
1.150	5° F. above 0.	1.300	95° F. below 0.

Low temperatures greatly reduce the available capacity of a battery, but the normal capacity should be regained with the operation of the battery under normal temperature.

35. Frothing.—*a. Indications and effects.*—An evolution of persistent bubbles or foam in the vent-plug opening.

b. Cause.—Impurities in the cells, such as animal fat or oil.

c. Remedies.—(1) Condition of frothing usually cures itself by carrying the impurities out of the cell in the foam.

(2) If frothing continues for any length of time, empty the cell and renew the electrolyte.

(3) If the procedure prescribed in (2) above does not completely remedy the condition, the cell should be torn down and the plates examined to determine whether or not the cell should be declared unserviceable.

36. Impurities in electrolyte.—*a. Indications and effects.*—(1) Abnormal sulphation.

(2) Clogged separators, particularly rubber separators.

(3) Rapid deterioration of plates and separators.

(4) Frothing.

(5) Specific gravity drops quickly when discharging.

(6) A continued condition of low voltage per cell, which condition will prevail even when the battery is charging. This voltage may be 2.1 to 2.2 per cell and remain at this value even when the charge should be complete.

(7) Discoloration of plates and separators.

(8) Excessive local action.

b. Causes.—(1) Impurities may be present in the acid or plates. Proper precautions should be taken by purchasing agents in obtaining pure acid and high-grade plates to prevent this.

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(2) Impurities may be introduced into the cell by using water containing mineral salts, such as those occurring in water used for drinking purposes. A common error is to believe that boiling water will clarify it of impurities and thus make it suitable for use in storage batteries. The only method of purifying water for battery work is distillation. Distillation will remove metallic salts or metals themselves if the distilling apparatus is constructed of materials which will not rust or oxidize.

(3) The use of freak electrolytes which may be very injurious.

(4) Using a hydrometer that has been used in Edison or other alkaline batteries.

(5) Presence of oils or greases. These may get into the cell through carelessness and will cause a rapid drop of capacity.

c. Remedies.—(1) Pour out the old electrolyte and fill the cell with water. Charge it for 3 or 4 hours. Replace this water with fresh water and charge again for about an hour. Again remove the water and immediately replace with fresh electrolyte at about 1.300 specific gravity.

(2) Adjust the specific gravity of the electrolyte after charging the cell completely.

37. Loss of active material.—*a. Indications and effects.*—(1) It may be necessary partially to remove the plates from the container to see the deterioration, but this should be done when there is any suspicion of loss of active material. The condition may often become apparent before charging. If the electrolyte seen in a hydrometer syringe is brown, this indicates active material in suspension which must have come from the plates.

(2) Excessive sediment in the bottom of the cells is the best indicator of loss of active material from the plates. The active material is heavier than the electrolyte and will sink to the bottom of the cell. Even under ideal conditions, sediment will accumulate in time. It is a conductor of electricity, and, if not removed in time, will short-circuit the cell and ruin it.

(3) Other indications of loss of active material are losses in capacity as discussed in preceding paragraphs.

b. Causes.—(1) Age.

(2) Overdischarging causes excessive sulphation. The active materials, if loosened from the grid, fall to the bottom of the cell. This shedding is hastened by any condition causing abnormal sulphation.

(3) Overcharging, if carried to excess, causes the conversion of the grid wires into active material. Upon discharge in this condition, the grid wires will become sulphated, and since this sulphate is on

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the inside of the plate, it is unlikely that it will ever be converted back into active material. This conversion of the grid into active material and thence into sulphate defeats the purpose of the grid—that of supplying mechanical strength and electrical conductivity to the plate; the entire structure is weakened and shedding of active material is hastened. Any loss of active material means a corresponding loss of capacity to the cell.

(4) When a discharged or sulphated battery is charged at too high a rate, excessive heat is developed due to the high internal resistance of the cell. This heat may cause the plates to buckle, thereby placing a strain upon the active material and allowing it to shed easily (see fig. 14).

(5) Short circuits cause an intense sulphation; this sulphate may eventually become crystallized and can never be completely reconverted into active material.

(6) Chemical processes are always accelerated by heat; thus when storage batteries are operated at abnormally high temperatures (above 110° F.), the plates sulphate excessively or the grid wires may form into active material and allow the active material of the plate to loosen (see par. 6).

c. Remedies.—(1) Where the sediment in a cell has accumulated to the extent that it may short-circuit the cell, the electrolyte and element should be removed, the container flushed out, and the element washed with distilled water. If the element is still in good condition, it may be replaced in the container with fresh electrolyte of the proper specific gravity. The cell should then be given a long charge at a low rate and put through a test discharge at the normal rate. If sufficient active material has been lost to reduce appreciably the capacity of the cell, the deteriorated plate groups should be discarded. It is not unusual to find one group of plates in better condition than the other, in which case the poorer group should be replaced and the cell reassembled.

(2) If the battery must be operated in atmospheric temperatures greater than 110° F., reduce the specific gravity of the electrolyte (see par. 6).

38. Overcharging.—*a. Indications and effects.*—(1) Buckling of plates.

(2) Shedding of active materials.

(3) Overheating of the elements.

(4) Excessive loss of water.

(5) Excessive gassing.

(6) Excessive sediment.

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(7) Conversion of the grid wires to active material. This always happens when overcharging is carried to excess.

b. Causes.—(1) Misunderstanding or carelessness on the part of the handler.

(2) Defective regulating equipment.

c. Remedy.—Prevent repeated overcharge by examination of the regulating equipment and clear up any misunderstanding on the part of the attendant as to the proper rate and time of charge. Consult the directions given with each battery regarding the proper rate and time of charge.

NOTE.—Occasional overcharging is beneficial but habitual overcharging decreases the life of a battery.

39. Reversal of polarity.—*a. Indications and effects.*—(1) Loss of capacity.

(2) If long continued, the plates will be destroyed.

(3) The active material becomes rough or sanded.

In the negative plate, the spongy lead shrinks and becomes solidified. This condition can best be described by stating that if a portion of the negative active material is dug out on the point of a knife, it will feel like fine sand when rubbed between the fingers.

b. Causes.—(1) Overdischarging a cell of low capacity in series with cells of higher capacity. The high-capacity cells will act as a charger to the low-capacity cell, with the terminals connected in the wrong direction.

(2) Charging the battery in the wrong direction, thus reversing all the cells. This is the most common cause of reversal of polarity, and is usually caused by carelessness on the part of the battery attendants, one battery in a group on charge being incorrectly connected. This severely oversulphates the plates.

c. Remedy.—If the reversal has not extended over too long a period, the plates may be restored to their normal condition by recharging at normal rates and continuing the charge until the cell is brought to its normal condition. Care should be taken to prevent overheating and overgassing. Although the specific gravity may not rise to its previous maximum, it will attain nearly as high a value, and can be adjusted after the maximum specific gravity has been definitely reached.

40. Short circuits.—*a. Indications and effects.*—(1) Continued low specific gravity readings as compared to other cells in the battery.

(2) Lower voltage on charge than other cells in the battery.

(3) Low open-circuit voltage. This should not be depended upon too much.

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(4) Low voltage on discharge.
(5) Lack of capacity.
(6) Heating.
(7) Poor color of plates.

b. Causes.—(1) Worn-out or defective separators.
(2) Excessive sediment accumulation.
(3) Defective cell insulation.
(4) Buckled plates.
(5) Any other condition which causes electrical connection between positive and negative plates.

c. Remedies.—(1) Eliminate the cause of the short circuit.
(2) Replace defective parts, or, if too far gone, condemn the battery for further service.

SECTION IV

STORAGE AND SHIPMENT

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Removal from storage	42
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Shipping cases	44
Oversea shipment	45
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41. Storage.—*a. Wet.*—The only definitely safe way of storing new or slightly used storage batteries without dismantling is wet storage. Batteries stored in this manner must be kept fully charged, either by a trickle charge applied continuously or by periodic charges. Distilled water should be added every 2 weeks to replace that lost by evaporation and electrolysis. Batteries may be stored several months in this manner and are available for immediate use at any moment.

b. Moist.—New batteries may be stored moist for a period of from 9 to 12 months (preferably not over 9 months). The batteries are fully charged, the electrolyte poured out (it may be stored separately and used again), the cells rinsed two or three times with water and drained for 15 minutes, and the vents closed and sealed with paraffin or sealing compound. Once stored in this manner, the batteries should not have their vent plugs disturbed until they are to be filled and charged.

c. Dry.—Batteries or their parts may be stored dry indefinitely. The plates are fully charged and dried, and may be stored in their containers or disassembled and stored separately. Wood separators are always removed and stored in water or weak electrolyte solution

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(1 part of 1.200 specific gravity electrolyte to 10 parts of distilled water) in a hermetically sealed container. Rubber or spun glass separators may be stored dry. Wood separators cannot be stored dry since they will be attacked by air and will crack unless kept moist.

42. Removal from storage.—*a. Wet.*—Batteries on removal from wet storage are ready for immediate service and need no special treatment. The electrolyte level and specific gravity should be checked to be sure of the condition of the battery.

b. Moist.—Batteries which have been stored moist for more than 12 months should be opened and examined for cracked separators. When separators are in good condition, the battery may be reassembled and filled. The procedure for preparing the batteries for service is the same as new batteries (see pars. 17 to 23, incl.).

c. Dry.—Batteries stored dry must be treated as new batteries on their initial charge (see pars. 17 to 23, incl.). Before filling with electrolyte, examine the plates and separators and replace any not in good condition.

43. Preparation for shipment.—*a. Charged and filled.*—Batteries may be shipped with electrolyte, provided they are fully charged and the vent plugs sealed. Tags should be attached to the batteries stating the specific gravity of the electrolyte. When shipped in this manner, batteries should be used as soon as possible.

b. Charged and moist.—Batteries may be shipped charged and moist by preparing as for moist storage (see par. 42). Tags should be attached stating the specific gravity of the electrolyte to be used.

c. Dry.—Batteries may be shipped dry, either assembled with spacing boards in place of wood separators, or as disassembled parts. Batteries using only rubber or spun-glass separators may be completely assembled except for electrolyte, but wood separators must be shipped moist. When wood separators are to be shipped overseas or stored over long periods of time, it is advisable that they be hermetically sealed in a wooden or hard-rubber container and soaked in water or weak electrolyte solution. For domestic use, wood separators are often inclosed in paraffined paper while wet and are not hermetically sealed. A shipment of separators should not be opened until needed.

44. Shipping cases.—*a.* When shipping batteries, a shipping case should be made of 1½-inch lumber, so shaped as to prevent anyone from tipping the battery over. A space of 3 inches between the battery and the bottom and sides of the case should be allowed. This space should be packed with excelsior. Nail strongly. Before putting on the cover, place a piece of paraffined paper over the top of the battery and force a layer of excelsior tightly under the cover as the

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boards are put on. Mark the shipping case plainly, HANDLE WITH CARE.

b. In addition to the address and destination be sure to mark with the name of the shipper for identification on arrival.

c. When unfilled or filled batteries are shipped by freight, the proper classification in the United States is "Electric storage batteries assembled."

d. When filled batteries are shipped by express in the United States, caution labels marked ACID must be attached to each case.

45. Oversea shipment.—When shipping batteries overseas or where salt water is apt to come in contact with them, coat all exposed terminals, link connectors, etc., with melted paraffin to prevent corrosion.

46. Unpacking.—Keep the case and battery right side up when unpacking to avoid spilling electrolyte. Thoroughly brush off all dirt and excelsior and examine the case for cracks. Note height of electrolyte if battery has been shipped wet. If low, fill to proper height with distilled water and allow to stand for 10 hours; then inspect again for leakage of electrolyte.

SECTION V

CHARACTERISTICS

	Paragraph
Special batteries for radio sonde	47
Table	48

47. Special batteries for radio sonde.—Special meteorological batteries, classified as batteries BB–51 and BB–52, are being developed for use with the radio sonde ML–128. These are designed for operation at extremely low temperatures (−70° C.), with extreme light weight combined with high capacity for 2-hour periods (see fig. 15.) Due to the extremely small size of the batteries and the necessity of using very small vent holes for cells to avoid spilling electrolyte, it is necessary to use a hypodermic needle for filling the cells. The life expectancy of these types of batteries is approximately 20 cycles of charge and discharge, the short life being caused by the high specific gravity of the electrolyte necessary to withstand the low temperatures encountered when the cells are discharged. This condition exists because of the fact that as the altitude of the radio sonde increases, the batteries discharge, and at the same time the temperature decreases (see par. 34).

a. Battery BB–51.—The battery BB–51 (see fig. 15) is a 3-cell, 6-volt, plug-in storage battery designed to deliver 165 milliamperes

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(for tube filament and meteorograph motor) for a period of 2 hours. The specific gravity of its electrolyte at full charge is 1.350. The battery weighs approximately 5½ ounces when filled. Its charging rate is tentatively set at 165 milliamperes, tapering to 120 milliamperes in 4 or 5 hours. Because of the very small amount of electrolyte used, specific-gravity readings are not practicable, and the terminal

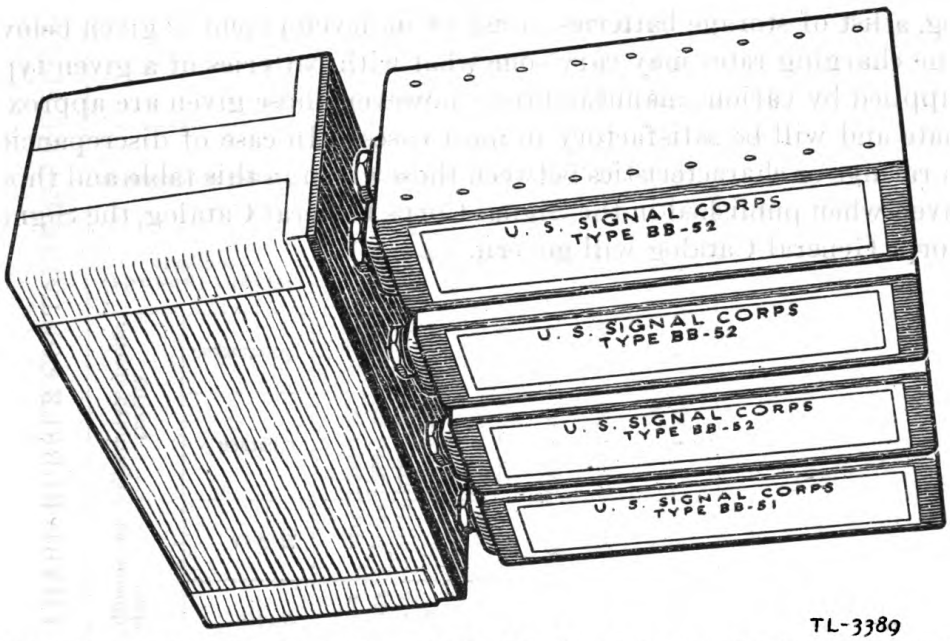


FIGURE 15.—Power supply for radio sonde ML–128, showing battery BB–51 and 3 batteries BB–52. (A cover fits over the batteries and the jack box into which they are plugged.)

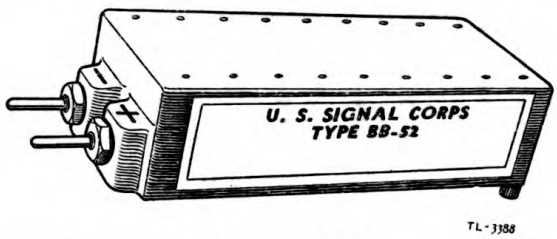


FIGURE 16.—Battery BB–52. (Battery BB–51 is similar in appearance, except that there are only 6 filler holes, 2 for each cell; and the projections at the right are on the top instead of on the bottom.)

voltage with normal charging current flowing is taken as an indication of the battery's condition. At full charge its voltage should be 7.5 volts with normal charging current (120 milliamperes) flowing.

b. Battery BB–52.—The battery BB–52 (see fig. 16) is an 18-cell, 36-volt, plug-in storage battery designed to deliver 15 milliamperes (for tube plate, at approximately 110 volts, since batteries BB–52 are always used in groups of 3) for a period of 2 hours. The specific

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gravity of its electrolyte at full charge is 1.350. The battery weighs approximately 5 ounces when filled. Its charging rate is tentatively set at 15 milliamperes, tapering to 10 milliamperes in 4 or 5 hours. At full charge its terminal voltage should be 45 volts, or 135 volts for 3 batteries in series, with normal charging current (10 milliamperes) flowing.

48. Table.—Pending inclusion in the Signal Corps General Catalog, a list of storage batteries in use or in development is given below. The charging rates may vary somewhat with batteries of a given type supplied by various manufacturers; however, those given are approximate and will be satisfactory in most cases. In case of discrepancies in ratings or characteristics between those given in this table and those given when published in the Signal Corps General Catalog, the Signal Corps General Catalog will govern.

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LEAD-ACID STORAGE BATTERIES (WITH HARD RUBBER CONTAINERS AND SPILL-PROOF VENTS)

Battery	Number of cells	Terminal volts	Ampere-hours (5-hour rate)	Amperes (5-hour rate)	Terminal volts (discharged)	Charging rate (amperes)		Maximum charging volts	Over-all dimensions (inches)			Electrolyte specific gravity		Weight (pounds) complete	Specification number	Use and remarks
						Start	Finish		Length	Width	Height	Charged	Discharged			
BB-29	2	4	90	18	3.5	11	5.5	5.0	8	9⅞	8 9/16	1.270–1.290	1.210	37¼	70-20	SCR-197-( ).
BB-41	2	4	16	3.2	3.5	2	1.0	5.0	5 5/32	4⅝	8 1/16	1.270–1.280	1.200	11	70-7	
BB-42	2	2	32	6.4	1.75	4	2	2.5	5 5/32	4⅝	8 1/16	1.270–1.280	1.200	11	70-13	Same as BB-41 except cells are in parellel.
BB-45	2	4	80	16	3.5	10	5	5.0	10 (max.)	8 (max.)	11 (max.)	1.270–1.290	1.210	38 (max.)	70S-20	Commercial substitute for BB-29.
BB-46	6	12	75	15	10.5	9	4.5	15.0	15⅞	6½	14 9/16	1.270–1.290	1.210	97	70-33	SCR-177-B. (1) TC-1, TC-2.
BB-47	6	12	*185	*9.75	10.5	23	11.5	15.0	19¾	11¼	10	1.270–1.290	1.210	182	SCL-49	*20-hour rate. 1-hour rate—85 ampere-hours (1), (2), SCR-193, 209, 210, 245, etc.
BB-48	6	12	*200	*10	10.5	25	12.5	15.0	19¾	13 9/16	10	1.270–1.290	1.210	182	SCL-49-A	*20-hour rate. 1-hour rate—100 ampere-hours. (2), (3), SCR-193, 209, 210, 245, etc.
BB-50	6	12	*55	*2.75	10.5	6.5	3.2	15.0	12⅞	7⅛	9⅞	1.270–1.290	1.210	62	70-37	*20-hour rate. SCR-177, 188, 177-A, SCR-177-A, SCR-188, SCR-299.
BB-51	3	6	See paragraph 47a.			0.165	0.120	7.5	4 3/16	1⅜	1 1/16	1.350	(4)	5½ oz.	(5)	Special battery for radio sonde ML-128.
BB-52	18	36	See paragraph 47b.			0.015	0.010	45.0	4 3/16	1 3/16	1	1.350	(4)	5 oz.	(5)	Do.

[1] Additional taps for 2 and 8 volts.
[2] Supplied by Ordnance Department. (Vehicular battery).
[3] To supersede battery BB-47.
[4] See paragraph 47.
[5] No formal specification to date.

[A. G. 062.11 (6-27-41).]

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(For explanation of symbols see FM 21–6.)

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