American Railway Signaling Principles and Practices

CHAPTER V

BATTERIES

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BATTERIES

Batteries are to the signal system what engines are to trains. They supply the power or energy to operate the direct current apparatus.

While there are many different types and makes of batteries, they are divided into two general classes, primary and secondary, which will be treated separately. Each class is divided into various types. The principal types of primary batteries used are gravity, dry and caustic soda. The types of secondary batteries used are lead acid and nickel, iron, alkaline. The service which the battery is called on to perform usually determines which class and type is to be used. Ordinarily the primary battery is used where normally low discharges are required and no practical means of charging are available. The secondary (or storage) battery is generally used where higher discharges are required, in which case a means of charging must also be available.

Method of connecting.

There are four general arrangements for connecting and operating batteries; namely, series, multiple, multiple-series and series-multiple.

Series. The series connection is generally used with storage cells and where a single set of primary cells is used for other than track circuit work. This method of connection is used where the voltage of one cell is not sufficient for the circuit.

Fig. 1.

Series connection is illustrated in Fig. 1 and consists of the positive terminal of one cell being connected to the negative terminal of the next.

Multiple. The multiple connection is used largely on track circuits where energy is furnished by primary cells and where the voltage of one cell is sufficient but where more capacity is desired. A broken jar or connection will not prevent the battery from function-

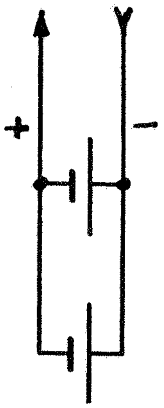


Fig. 2.

ing as the remaining cells are still connected to the circuit. Multiple connection is illustrated in Fig. 2 and consists of connecting the positive terminals to one side of the circuit and the negative terminals to the other side.

Multiple-series. The multiple-series connection is used where more than one group of cells is necessary, either to provide additional capacity or where uninterrupted service is desired as a broken connection or defective cell in a series-connected battery puts the entire set out of service. Multiple-series connection is illustrated in Fig. 3, and consists of connecting in multiple two or more sets of cells connected in series.

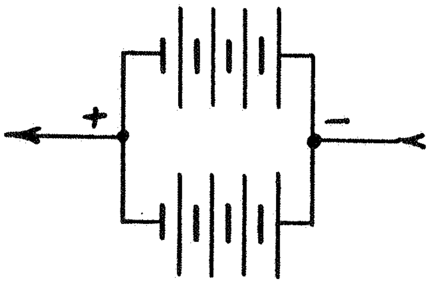


Fig. 3.

Series-multiple. The series-multiple connection is occasionally used where it is desired to remove one cell without putting the entire series connection out of service. Series-multiple connection is illustrated in Fig. 4 and consists of connecting in series two or more groups of cells connected in multiple.

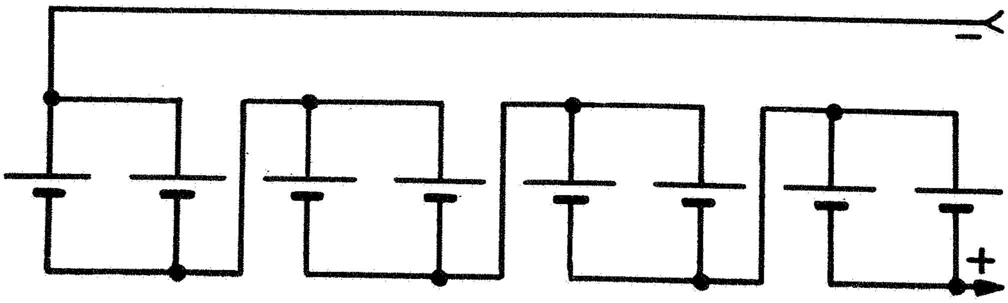


Fig. 4.

In Figs. 1, 2, 3 and 4 the short heavy line is used to designate the cathode or negative electrode of the cell to which is connected the positive terminal, while the long light line is used to designate the anode or positive electrode of the cell to which is connected the negative terminal. The use of the short heavy and the longer light lines outside the signal field is usually the opposite to signal practice.

Elements.

The elements of a cell are the cathode and anode. The cathode is the negative element and is the electrode by which current leaves the cell when it is on discharge and has connected to it, as stated above, the positive terminal. The depolarizing element (usually carbon or copper) of a primary cell is the cathode.

The anode is the positive element and is the electrode by which current returns to the cell when it is on discharge and has connected to it, as stated above, the negative terminal. The zinc element in a primary cell is the anode.

It will be noticed that what is commonly called the positive side of a cell is, chemically, the negative element to which is connected the positive terminal. This frequently leads to confusion in the mind of the student. In practice the polarity of the elements (anode and cathode) are generally disregarded and the positive terminal (the one connected to copper or carbon element in a primary cell) is considered the positive side of the cell and the negative terminal (the one connected to zinc element in a primary cell) is considered the negative side of the cell.

Primary Batteries

Definition.

A primary cell is a device for the direct transformation of chemical energy into electrical energy.

Historical.

At the close of the eighteenth century there was no recognized connection between chemical and electrical energy, the knowledge of electricity being confined at that time entirely to statical phenomena, such, for example, as the attraction of a glass rod, which had been rubbed violently, for small pieces of paper or pith balls.

In about the year 1785, Galvani, who was an Italian physician, observed that recently skinned frogs, in the neighborhood of an electrical machine, moved whenever an electrical discharge took place, and later, that frogs' legs hung by a copper wire to an iron balcony were convulsed whenever they touched the iron. After studying the matter he finally concluded that the legs were convulsed by electricity which he attempted to explain as the static with which he was familiar. His conception was that whenever the specimen touched the iron support there was a separation of positive and negative electricities on the nerves and muscles which caused the parts to move.

The error of Galvani's reasoning was finally demonstrated by Allessandro Volta who had continued to experiment along the same lines as had Galvani. He, in turn, discovered that if any two of the common metals were joined at one end, the other of which was caused to touch the same muscle, the convulsion was not due to separation of electricities in the specimen, but, as he supposed, to a junction of the two metals. This theory, known as "Volta's Contact Theory" is now known to be insufficient to explain his results, but, nevertheless, the fundamental principle of two dissimilar metals in contact with each other was recognized as a source of electricity under certain conditions.

Believing that a current of electricity was set up at the junction of two unlike metals, Volta proceeded to construct a device which should have as large an area of contact between metals as seemed practicable. Discs of copper and zinc were arranged alternately in a pile with pieces of moist cloth between each pair and in this manner were extended to a considerable height. All of Volta's expectations must have been realized, for his apparatus gave a current at a very high pressure and his theory, therefore, was considered of great importance. This was in 1799 and it is generally agreed that his device, the first "Voltaic Pile" should properly be regarded as the first primary battery.

The theory that the junction of two unlike metals was the source of an electric current suffered a serious blow when it was found that a pile of copper and zinc plates alternated as before, but with dry paper separating each pair instead of moist cloth, would give no appreciable current at all. It, therefore, became necessary to recognize another essential for a primary cell; namely, moisture; although the notion prevailed for a long time that the real seat of the current was the junction of the two metals, but that the passage of current was conditioned upon the metals being in contact with water.

Only a very short step remained for Volta to find that his plates gave out much more current when immersed in a solution of common salt than in water, following upon which discovery he made what he himself called his "Crown of Cups." This consisted simply of a series of cups containing common salt solution in each of which was immersed a copper and zinc plate, the copper in each being connected to the zinc of the next. This arrangement, which will certainly be recognized by any modern user of primary cells as a battery connected in series, not only yielded a current of high pressure but also of much greater quantity than had the "Voltaic Pile" and for this reason marked a very decided advancement in the art.

As is common in such cases these first primary cells took their name from their originators and are, to this day, known as Voltaic cells and possibly just as frequently as Galvanic cells, after Galvani, who first gave Volta his clue and who afterward contributed much toward the success of primary cells.

The difference between voltage and quantity was recognized at an early date and various modifications were introduced by Wollaston, Hare and others toward the reduction of internal resistance.

Kemp, followed by Sturgeon in 1830, drew attention to the important decrease in local action brought about by the amalgamation of zinc plates when used in acid solution.

The particular type of gravity cell with which we are familiar today was patented by Varley in the year 1854, though it may be said that it was not very generally used until the year 1884. It was modeled after the Daniel cell, of the closed circuit class and probably played the most important role in the earliest installations of automatic signaling, being used by the Philadelphia & Erie Railroad in its installation of the Robinson automatic signals at Kinzua, Pa., in the year 1870.

Though several cells were brought out in the interim, the Leclanche cell which appeared in the year 1868 marked the beginning of that class of cells known as "open circuit cells" and in their present form as "dry cells" which will be taken up later in the chapter.

It was in the year 1867 when the late Dr. William Robinson entered actively upon the development of an automatic signal system for preventing accidents of various kinds on railroads. He had at his disposal two main types of cells (power distribution having not yet been developed); namely, those patterned after the Leclanche cell or open circuit class and those patterned after the Daniel cell or closed circuit class.

As would naturally be the case, the early designs of signals were very largely influenced by characteristics of those early primary cells and as the cells functioned best at low current rates all those designs which preceded the electric semaphore were of types requiring exceedingly small rates of current either continuously or intermittently.

The Lalande cell, which was destined to play a very important part in railway signaling, was brought out in the year 1883 and marked the beginning of that class of cells known today as the "caustic soda type." Its most noteworthy assets as compared to its predecessors were an ability to deliver relatively high rates of current continuously and maintain a uniform voltage, even under relatively low temperature conditions, as well as an ability to exhaust its entire capacity without any labor being involved in the interim.

Polarization.

Polarization is the accumulation of gas bubbles (hydrogen or other gas) on the surface of the element. These bubbles retard the flow of current between the electrodes.

Local action.

The ordinary commercial zinc contains other metals which are negative to the zinc and which set up circuits within the zinc by means of these metals and the electrolyte. With an arrangement of this kind, it is readily seen that the zinc would soon become exhausted without the regular external circuit being closed. This condition is known as local action. The purer the zinc, the less will be the local action on it, but chemically pure zinc is difficult and costly to obtain and prepare. About the only practical way to lessen local action is to amalgamate the zinc. This is accomplished by combining mercury with the zinc which accounts for the surface of the zinc plate presenting a silvery appearance. As zinc is consumed from this alloy by voltaic action, the mercury penetrates into fresh pores of the zinc, thus keeping the alloy rich in mercury. When zinc is amalgamated it is in large measure protected from local action, as amalgamation seals up the foreign metal, preventing the electrolyte from coming in contact with it and thus reducing or eliminating the difference of potential.

Gravity Cells

A gravity cell consists of a glass jar, used as a container, a copper plate, a zinc, crystals of copper sulphate, copper sulphate solution and zinc sulphate solution.

The copper plate is placed in the bottom of the jar surrounded by crystals of copper sulphate and covered with copper sulphate solution. A rubber-covered insulated wire is connected to the copper plate and through the solution to the outside of the jar forming a terminal connection for the circuit. The zinc is suspended at the top of the jar in a diluted solution of sulphuric acid or zinc sulphate and is equipped with a binding post for terminal connection. The copper sulphate solution being heavier remains at the bottom, although does not remain entirely separate from the zinc sulphate but slowly diffuses upward. The heavier solution around the copper plate prevents polarization.

This type of cell was used almost exclusively in the early days of electric signals and track circuits but in recent years has been largely replaced by the caustic soda cell.

Instructions.

Gravity cells should be maintained in accordance with the following instructions:

Inspection of material prior to installation.

1. Jars must be handled carefully to prevent breakage and must be tapped to ascertain if any are cracked.

2. Jars with large bubbles in glass or glass fins on inside of jar must not be used.

3. Jars must not be placed on stone, iron, or other cold substances while setting up or renewing, but must be placed on wood or other similar substance.

4. Upon receipt of material, examination must be made to see that brass binding post is tight in zinc post and that posts surrounding hanger wires are not exposed in body of zinc.

5. Zincs with broken binding posts must not be used in battery chutes.

6. Riveted connections must be tight and no wire used which is broken or on which the insulation is cracked.

7. Copper sulphate (blue vitriol) must be free from chips, straw or other foreign substances; it must not be powdered nor larger than will pass through a sieve having 1¾ inch mesh.

8. Defective material must be reported to .... and held for disposition.

Setting up new cells.

9. Place battery copper in bottom of jar with leaves spread equally.

10. Place sufficient copper sulphate (blue vitriol) 3½ pounds in jar to the top of copper leaves.

11. Place zinc in top of jar with hanger wires bent outward, and as nearly as practicable at right angles to the top of the zinc, which will bring bottom of zinc about 2¾ inches above top of copper.

12. Hanger wires must be bent down closely around outside of jar.

13. Where obtainable, use clean, soft or distilled water in jar to within 1 inch of top of zinc.

14. If zinc sulphate (top solution of old cell) is available, pour carefully (about 1 pint) on top of zinc sufficient to cover same about ½ inch, when cleaning one cell; when cleaning all cells, add about 1 quart, bringing liquid to same height.

15. If old solution is not available, zinc must be covered ½ inch with water and cell put on short circuit for 48 hours before using.

16. Gravity must not be below 15 degrees on the hydrometer (Baume graduated 10 degrees to 40 degrees) before using new or cleaned cell.

17. Battery receptacles must be neat and clean and contacts must be cleaned before making connections. Connections must be tight so that there will be no movement of the wire under the thumb screw.

18. Zinc hanger wires and connectors must be kept clear of sides of well or chute and connectors secured so that they cannot drop and short circuit or ground battery.

Taking cells out of circuits. (Connected in series.)

19. To remove cells from battery, place ends of a jumper on adjoining cells, then remove cell to be cleaned; if end cell is to be removed, fasten one end of jumper to lead wire and other end in adjoining cell. Not more than one cell must be removed at one time and then only by use of a jumper; after replacing cell, remove jumper. Not more than 25 per cent of number of cells in a series battery should be renewed at one time.

Taking cells out of circuits. (Connected in multiple.)

20. Cell to be renewed can be taken out without the use of a jumper. Cells connected in series with themselves and in multiple with storage battery can be renewed without using jumper.

21. Not more than one cell of track battery must be renewed at any one time.

Cleaning cells.

22. Remove zinc, being careful not to let any dirt accumulation drop back into cell. Thoroughly clean zinc with scraper, brush and water.

23. Retain part of clear zinc solution for setting up new cells and destroy remainder. Solution must not be poured where it will run outside the right-of-way, into running water or on metal, such as pipe lines, steel battery tanks or into trunking or on grass line.

24. Wash and clean unused copper sulphate, separating from it all metallic copper.

25. Remove all loose copper from copper element and clean element in water. If copper element weighs over 2 pounds, or is liable to bind in jar at next renewal, it must not be used again.

26. Clean jar thoroughly with brush or waste and a small amount of fine wood ashes to cut the deposit on inside of jar.

27. Water in which zincs, sulphate, coppers, or jars have been cleaned, must not be used in batteries.

28. Zincs smaller than 1¼ pounds must not be used on a track cell renewal. One full sized zinc must be installed in each track battery at time track cells are renewed.

Necessary attention during life of cells.

29. Zincs must be cleaned at least once a month in all batteries.

30. Specific gravity must never be allowed to get above 35 degrees on gravity battery hydrometer and should be kept between 15 and 25 degrees. Specific gravity may be reduced to 15 degrees by removing some of the zinc sulphate solution and replacing with water.

31. Water must be poured slowly and carefully on the zinc.

32. In track sections where it is necessary to use three or more cells to keep up the service on account of wet or poor ballast, or track occupied for long periods by trains, battery must be cleaned at least every two weeks, or more frequently if necessary, to keep it in good working condition.

General.

33. Copper sulphate must not be added to a cell in service as this will cause caking or crystallizing.

34. Oil must not be allowed to get on battery material.

35. Water from a stagnant pool, particularly near a battery well, must not be used in the batteries.

36. All scrap sulphate, old coppers and copper deposit and old zinc must be shipped to .... for credit.

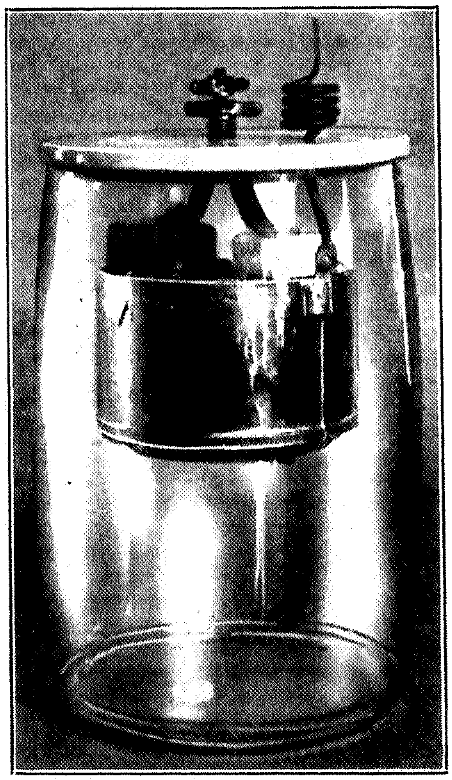
37. Copper and zinc scrap must be kept separate.

38. Battery material must not be stored in chutes, battery wells or other damp places.

Caustic Soda Cells

The caustic soda cell, because of its reliability and ease of maintenance, was well established during the latter part of the nineteenth century but it did not come into common use for railway signaling until the advent of the electric semaphore signal. As is the case today, the early types of semaphore signals required a very low rate of current normally to hold them in the proceed position, but a rate far beyond the range of a single series set of gravity cells to clear them. Because of the comparatively low internal resistance of the caustic soda cell it was possible for it to operate the semaphore signal with one series-connected set of battery, even under low temperature conditions; whereas, with gravity battery, because of its high internal resistance, it was necessary to use several series sets in multiple for each signal. Thus the use of caustic soda cells for semaphore signals meant not only a saving in the number of cells required but also a material reduction in maintenance effort due to the fact that the single set of caustic soda cells involved needed no attention whatsoever between their renewal periods as compared to the necessity for frequent cleaning of the larger number of gravity cells.

Between the advent of the electric semaphore signal and the year 1915 caustic soda cells had generally displaced gravity and all other types of primary cells on practically all signal units with the exception of track circuits. However, about 1910, their adaptability for this service was demonstrated after which their use became general. The first caustic soda cells tried were of the same low internal resistance type as those in common use on signal motors, but the low internal resistance characteristic which made the caustic soda cell



Waterbury Unit Cell Type.

ideal for semaphore operation militated against it on the earliest track circuit tests, making its life uneconomical because of the severe waste of current during the train shunt condition. A study of the cause of this condition led to the universal adoption of the present track circuit limiting resistance unit which will be dealt with further in a subsequent chapter.

Design.

A cell consists of electrodes of copper oxide and amalgamated zinc suspended from a porcelain cover in a jar of electrolyte which is a solution of caustic soda (sodium hydroxide) in water. The copper oxide electrode is connected to the pcsitive terminal and the amalgamated zinc electrode is connected to the negative terminal.

The early designs of caustic soda cells for signal service were of such nature that they necessitated the complete reassembly of each individual element each time the battery was renewed. Obviously, this procedure meant no end of trouble and inconvenience to those men in the field whose duty it was to renew the cells. In order to reduce this phase of maintenance effort to a minimum, the elements were later redesigned as they are today, in complete units, which eliminates the necessity of assembly in the field.

Since the ampere-hour capacity has a fundamental bearing upon the number of days service cells will render between renewal periods, it was possible to reduce the effort necessary for the maintenance of the cells still further by increasing the ampere-hour capacity of the cells themselves, thus decreasing the number of renewals of the cells over any extended period of time. This general procedure has been carried to the point where caustic soda cells today are manufactured in sizes which, though convenient to handle, have capacities ranging upward to 1000 ampere hours.

The two standard capacities of cells now in general use for signal purposes are the 500 and 1000 ampere-hour. The service for which intended usually determines the particular capacity to be used; generally, circuits of a low discharge use the 500 ampere-hour cell, while those requiring higher discharges use the 1000 ampere-hour cells.

Typical voltage curves of both 500 and 1000 ampere-hour cells are shown in Figs. 5 and 6.

This general increase in ampere-hour capacity has not been accomplished entirely by a more proportionate increase in the size of the original jars and active materials, but also to a large extent by refinements such as those listed as follows:

1. The use of higher quality materials to eliminate local action and waste of energy.
2. The better proportioning of the relative amounts of active materials to take full advantage of the capacity of the jar.
3. The limiting of the size of the inactive members such as insulators, structural parts, etc., which, though necessary, take up otherwise valuable space in the electrolyte.
4. The increase in porosity of the copper oxide to allow maximum contact with the electrolyte.
5. The making of the copper oxide electrode in the form of a compact mass to assure perfect physical and electrical contact between the minute particles as well as between the entire electrode and the supporting frame.
6. The moulding of the zinc electrode in such manner that at the normal exhaustion point of the battery it will contain a minimum amount of excess zinc, but still have as nearly as practicable its original surface area to prevent a waste of otherwise useful space and still allow a full surface of zinc exposed to the solution when most needed.
7. The better amalgamation of the zinc electrode to eliminate local action.
8. The better spacing and design of the electrodes in relation one to another and the cell as a whole, so that chemical action may proceed freely between them.
9. The greater refinement in processing and proportioning the soda for battery solution to insure maximum safe capacity.

Other important improvements which have had a tendency to increase the ease with which caustic soda cells may be maintained and to a certain extent increase their effective ampere-hour capacity are as follows:

1. The substitution of heat-resisting glass jars for porcelain jars.
2. The fact that it is possible to mix caustic soda solutions quickly in heat-resisting glass jars without fear of breakage even in cold weather, whereas considerable time formerly was lost through the necessity of mixing the solution slowly in porcelain jars.
3. The fact that glass jars have materially decreased the time required to make inspections, it now being possible to see the condition of the elements without the old procedure of lifting them out of the porcelain jars.

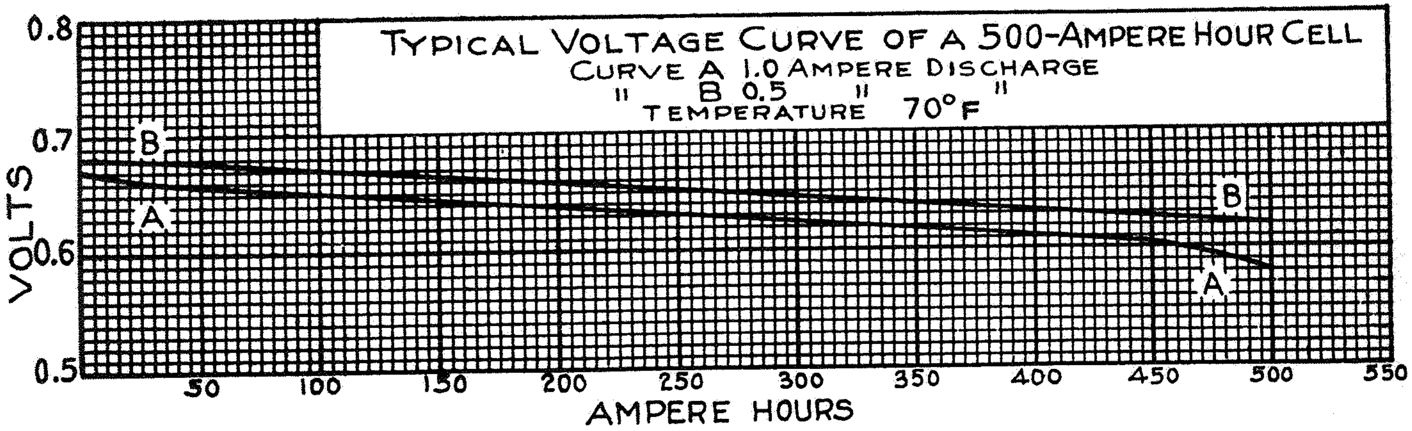

TYPICAL VOLTAGE CURVE OF A 500-AMPERE HOUR CELL
CURVE A 1.0 AMPERE DISCHARGE
" B 0.5 " "
TEMPERATURE 70° F
B
A
B
A
VOLTS
0.8
0.7
0.6
0.5
50
100
150
200
250
300
350
400
450
500
550
AMPERE HOURS

Fig. 5.

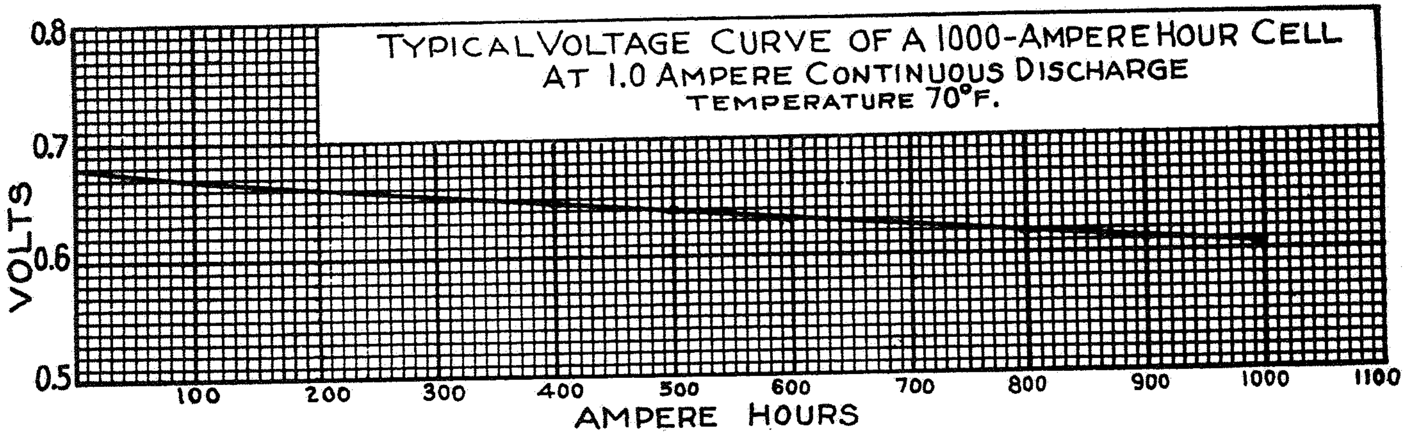

TYPICAL VOLTAGE CURVE OF A 1000-AMPERE HOUR CELL
AT 1.0 AMPERE CONTINUOUS DISCHARGE
TEMPERATURE 70°F.
VOLTS
0.8
0.7
0.6
0.5
100
200
300
400
500
600
700
800
900
1000
1100
AMPERE HOURS

Fig. 6.

The fact that it is possible to see the elements through the glass has, in itself, led to refinements such as the construction of certain elements whose entire areas may be seen at a glance, having the advantage of making it possible to ascertain quickly their exact condition. In certain cells this is accomplished by the inclusion of small indicator panels moulded in the lower portion of the zinc electrode. The thickness of these panels with relation to the remaining portion of the electrode is such that they start to perforate when approximately 90 per cent of the rated capacity of the cell has been expended and are completely cut out shortly after the cell reaches the end of its rated capacity, but prior to the actual exhaustion of the cell. In other cells the zinc electrodes are tapered from the bottom upward in such manner that the lower portion of the electrode exhausts first. In another type cell the approaching exhaustion is indicated when the re-enforcing band on the zinc electrode has been eaten through at any place on its circumference. With these methods of visual indication of the condition of the cell a large surface area of the zinc electrode is maintained to the end of the life of the cell when large surface area is most needed.

Columbia Standard Voltage Cell.

Electro-chemistry.

The copper-oxide zinc couple immersed in a caustic soda solution of the proper density constitutes the cell.

The ampere-hour capacity of the cell is fixed by the proper amount or proportion of the three elements above mentioned.

One of the ways of expressing the action within the cell is as follows: When the circuit is closed the caustic soda solution (sodium hydroxide) $NaOH$ is decomposed into the sodium ion carrying the positive charge and the hydroxyl ion carrying the negative charge. The sodium ion upon delivering its charge to the copper electrode unites with the water of the electrolyte thus releasing hydrogen which in turn combines with the oxygen of the copper oxide producing water and reducing the copper oxide to metallic copper. The hydroxyl ion delivers the negative charge to the zinc plate combining with the zinc and forming zinc hydroxide $Zn\ (OH_2)$ which being soluble in the electrolyte produces sodium zincate (Na_2ZnO_2). The above reactions are expressed as follows:

$$2\ NaOH = Na_2 + (OH)_2$$
$$2\ Na + H_2O = 2NaOH + H_2$$
$$CuO + H_2 = Cu + H_2O$$
$$(OH)_2 + Zn = Zn(OH)_2$$
$$Zn(OH)_2 + 2NaOH = Na_2ZnO_2 + 2H_2O$$

The chemical action in a caustic soda cell is proportioned to the ampere-hour output. Definite quantities of material are required to yield a given ampere-hour capacity. It is evident, therefore, that the ampere-hour capacity that has been delivered by any cell may be determined from the condition of the cell in various ways; namely, the quantity of zinc in solution, the extent of the reduction of the copper oxide to metallic copper or by inspection of the quantity of zinc remaining or by other careful analysis or measurement of the extent to which any of the various substances have been consumed or by-products formed.

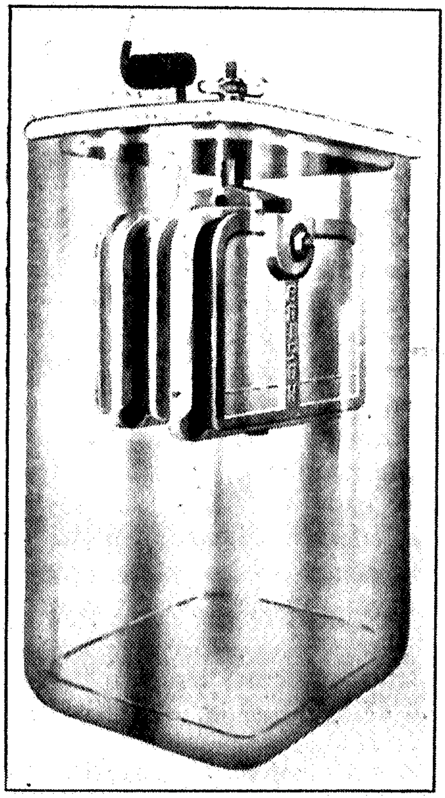
The proper proportion or amount of caustic soda for the electrolyte is furnished by the manufacturers and if used as directed there should be no difficulty caused by the electrolyte. If, however, the amount of soda is varied thus changing the density of the solution, the solution will then clearly indicate the irregularity thus caused, by various forms of crystallization, which in turn indicate the exact nature of the difficulty.

There are three forms of crystallization that occur under certain conditions in the use of these cells, as follows:

1. Granular, glassy crystals.
2. Fine, white powder precipitate.
3. Long, needle-like crystals.

The granular, glassy crystals form upon the inner surface of the jars and upon the surface of the zinc and copper oxide electrodes, usually starting near the bottom of the jar. The formation of these crystals indicates approaching exhaustion or saturation of the solution. These crystals form when a solution of normal density is discharged beyond its capacity, or they may appear before the capacity of the cell has been discharged if a solution of less than normal density is used. They may also form after cells that have been discharged to a point near exhaustion are disconnected and allowed to remain on open circuit. Higher temperatures accelerate this phenomena.

The fine, white powder precipitate forms in combination with the granular, glassy crystals or between and around the zinc and copper oxide electrodes, and in the bottom of the jar. The precipitation of this powder indicates the saturation or exhaustion of the solution beyond its normal capacity. When this precipitation occurs before the exhaustion of the zinc and copper oxide electrodes, it indicates a solution of less (weaker) than standard density, due to the use of insufficient caustic soda for the volume of water. This condition is also intensified by higher temperatures.



Edison Multiple Plate Cell.

The long, needle-like crystals usually form first on the zinc and between the zinc and copper oxide, starting at the bottom of the electrodes, and then rapidly filling the space between and around the electrodes and in the bottom of the jar. The formation of these crystals usually indicates a solution of greater (stronger) than standard density, and it is most likely to occur when cells in an advanced state of exhaustion are subjected to low temperatures, especially if an excess of soda or too little water had been used in mixing the solution. These crystals will dissolve or go back into solution when the temperature is sufficiently higher than that at which the crystallization occurred.

Instructions.

Caustic soda cells should be installed and handled in accordance with the following instructions:

Housing.

1. Housing must be such as to provide protection against rain, snow, extreme heat or cold, and must be kept clean and locked.

2. Where concrete boxes are used they should be installed with the bottom of the box at least 10 inches in the ground.

3. Drainage must be provided as necessary to prevent flooding of housings.

4. Cells must set level on floors, shelves or racks and be arranged to permit of ready inspection of any cell or element.

Materials.

5. One complete cell (except water) consists of the following:

1 Jar.
1 Cover.
1 Hexagonal nut.
2 Wing nuts.
2 Washers.
1 Unit (positive and negative elements assembled).
1 Can caustic soda.
1 Bottle battery oil (when not self-contained).

6. Units must not be unpacked except as required.

7. Packages containing cells or renewals must be kept dry.

8. Caustic soda which has been damaged by exposure to air or dampness must not be used.

Setting up new caustic soda cells and renewals.

9. Material must be checked to see that jars, covers, terminals, nuts, washers, elements, caustic soda and oil (when not self-contained) are of proper size and quantity.

10. Separators and other packing material must be removed from assembled elements.

11. Assembled elements must be examined. See that electrodes hang approximately in a vertical position, parallel to each other, and that connections are firmly made. Broken or cracked electrodes must not be used.

12. Jars and covers must be thoroughly cleaned. Cracked jars or covers must not be used.

13. Material unfit for use must be called to attention of proper official for disposition.

14. Clean water for mixing solution must be used. Water known to contain an excess of metallic salt, acid, alkali, sewage or other impurities must not be used.

15. Jars must be filled approximately three-fourths full with water.

16. Caustic soda must be added gradually and stirred with non-metallic strip or rod until thoroughly dissolved.

17. Soda used must be of exact amount furnished with each cell by manufacturer of other parts of renewal.

18. Care must be exercised in mixing and handling the solution as it is caustic and will burn the skin or clothing. If accidentally splashed on the skin or clothing, wash off immediately. The skin may be protected by applying lard or similar animal oil, or vegetable oils.

19. Connecting wire and suspension bolt must be passed through holes in cover and assembled elements securely tightened to cover.

20. Assembled elements must be inserted in solution and jar, where practicable, placed in permanent position. Water must be added to bring top of solution, when cool, ¾ inch to 1 inch from top of jar with elements in position, and stirred thoroughly by agitating solution with the element.

21. Exact amount and kind of oil furnished (except when oil is self-contained) must be added to top of solution.

22. When oil is self-contained in elements or soda, elements must be inserted before solution has cooled.

23. When elements are placed in solution while hot, cells must be connected up at once. When not practicable to operate apparatus to cause immediate discharge, battery must be discharged at approximately 3 amperes for 10 minutes.

24. Connections must be clean to insure good electrical contact.

25. Cells in circuit must be connected in accordance with plans or instructions.

26. Changes in arrangement of connections must not be made without proper authority.

27. The performance of primary batteries must be recorded on A.R.A. Sig. Sec. 7007.

ARA
SIG. SEC.
7007
SEPT 1926
M-1927

3

PRIMARY BATTERY RECORD

HOUSING, TYPE AND CAPACITY................................ LOCATION...................... BATTERY NUMBER.................

APPARATUS (OPERATED FROM THIS BATTERY)

NUMBER OF CELLS	HOW CONNECTED	MAKE	TYPE	CAPACITY	DATE SET UP	DAYS LIFE	NORMAL LOAD AMPS.	NUMBER OF CELLS	HOW CONNECTED	MAKE	TYPE	CAPACITY	DATE SET UP	DAYS LIFE	NORMAL LOAD AMPS.

Renewal of exhausted cells.

28. Except when necessary to make replacements, due to defect, all cells of a series-connected battery should be renewed at the same time.

29. When renewing or installing cells, care must be exercised to avoid interruptions to traffic.

30. Discarded solution, cans and bottles must be disposed of where they can do no damage to property, persons or animals.

Inspection.

31. Battery must be examined as often as necessary to prevent failures. The voltage readings should be taken of the battery when on maximum load to check its condition.

32. Jars and covers must be kept clean. Broken or cracked jars and covers must be replaced promptly.

33. Connections must be kept tight and free from corrosion.

34. Any unusual appearance or defect of the elements or solution must be reported promptly and if defect cannot be remedied, cells must be replaced, and the removed elements and solution be held intact for instructions.

Disposition of exhausted elements.

35. Exhausted elements must be drained off and then spaced on racks, floors or shelves away from inflammable material and allowed to dry for three days or longer, after which they must be packed in renewal cases and forwarded to the storehouse or other designated place, each case being marked to show name of shipper, number and type of exhausted elements contained.

36. Exhausted elements must be kept dry as chemical activity of wet elements may cause fire. Packing cases must be labeled "Keep dry."

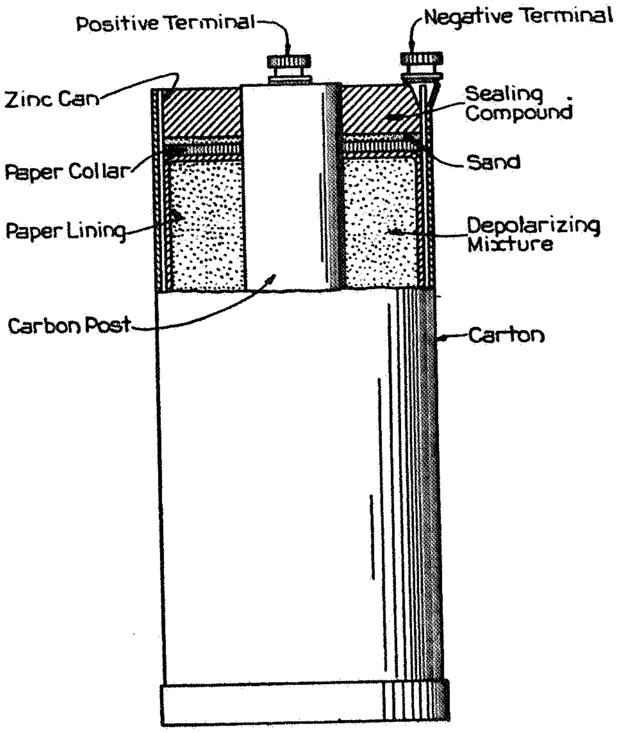
Dry Cells

History.

The modern dry cell, one of the most common forms of primary battery, is the outgrowth of the Leclanche cell, which is still used for some purposes.

In 1868, Leclanche devised a cell having a solid depolarizer in the shape of manganese dioxide packed with fragments of carbon into a porous pot around a carbon plate. A zinc rod formed the positive element and a solution of sal ammoniac (ammonium chloride) the electrolyte. A demand for a portable, unspillable type soon resulted in a construction consisting of a zinc can as anode and container, and a carbon rod surrounded by depolarizing mixture moistened with electrolyte to approximately the consistency of a mud pie.

Cells of essentially this "dry" construction first appeared in America about 1890, and the industry has since made rapid progress. The general construction of the dry cell of today is shown in the accompanying illustration.



Theory.

The relation of the principal parts of the cell to one another may be given as follows: Zinc metal as anode, solution of sal ammoniac (ammonium chloride) and mixture of carbon and manganese dioxide as cathode.

While the chemical reactions during service are not exactly understood, a brief explanation of the principal changes taking place at the electrodes can be given as representing the generally accepted conclusions.

The zinc in contact with the solution of sal ammoniac becomes negatively charged because of the departure of positive zinc ions from its surface. As zinc dissolves in the solution, zinc ions, ammonia and hydrogen are produced.

The carbon-manganese dioxide electrode in contact with the solution of sal ammoniac becomes positively charged, since hydrogen ions are discharged at the surface of the composite electrode and render it positive. The manganese dioxide rapidly oxidizes the hydrogen which would otherwise accumulate on the surface of the electrode, and polarize the cell. The manganese dioxide is thereby reduced to a lower state of oxidation.

Aside from any theory, the fact remains that the manganese dioxide diminishes the polarization of the cell and is at the same time reduced to a lower state of oxidation. If the positively charged electrode (carbon-manganese dioxide) is connected with the negatively charged electrode (zinc) by a wire, a current will flow through the wire from the carbon to the zinc. Within the cell the current will flow from the zinc through the electrolyte to the carbon-manganese dioxide. When the cell is new the surface of the composite carbon-manganese dioxide electrode may be considered to be the outside surface of this mixture next to the zinc, but as the cell is discharged the manganese dioxide is reduced and the effective surface of the electrode travels around the carbon rod which is in the center axially with the cell. This carbon rod only serves to conduct the current out of the mixture to the terminal.

Uses.

Dry cells differ in electrical characteristics as well as in size and construction, but they are often used indiscriminately without reference to the purposes for which they are best adapted. The most efficient service, however, can only be obtained when proper attention is given to the selection of the cell for the kind of service for which it is designed.

The amount of electricity which can be obtained from a dry cell depends very largely on the rate at which the cell is discharged. If the current is too small, the time required to discharge it will be so great that the factor of natural depreciation consumes a measurable proportion of the cell's capacity, leaving less than the full amount for useful service. If the current is too great, the cell will be overloaded and this, too, reduces its capacity. It is, therefore, quite essential to use the proper type and size of cell for the particular work to be done.

The great variety of uses requires numerous types of unit cells or batteries. The cell to be used for radio "A," ignition, etc., is so constructed as to stand a heavy drain or flow of current for intermittent periods.

This type of cell usually tests high in initial short circuit current and must recuperate rapidly when standing on open circuit after being in service for periods of time. Proper qualities and proportions of the constituents are very essential in order to produce these properties.

Certain definite properties of a comparatively low-amperage cell fit it for long service and good shelf life on light drains, while a third cell of average properties and classified as a general-purpose cell meets a small demand.

Other cells of special size and shape form a small part of the demand and are used in special equipment and apparatus.

As the user found the need of higher voltage or amperage than the single cell, he connected several cells in series, multiple, or series-multiple, to produce the required capacity. This led the manufacturer to assemble various numbers of cells in proper order and connection arrangement and enclose such units in a suitable container with negative and positive terminals for the convenience of the customer.

Instructions.

Dry cells should be maintained and handled in accordance with the following instructions:

Service.

1. Cells must be of a design best adapted for the service in which they are to be used.

(a) Ignition and heavy-service cells.

1. These cells are designed for use in the ignition of internal combustion engines, lighting, and other service requiring considerable current. The open circuit voltage is approximately 1.5 volts. The current on short circuit, when the cells are new, should be 30 amperes on the average and not less than 25 amperes as a minimum. They are intended for service that will exhaust them within a comparatively short time and are constructed to give the maximum current.

(b) General purpose cells.

1. These cells have some of the characteristics of the ignition cells on the one hand and of the telephone cells on the other. They may be used for ignition, telephone, or for general purposes. They are convenient, having almost as low a resistance as the ignition cells and some of the lasting qualities of the telephone cell. The open circuit voltage is the same as for the ignition cells, but the short circuit current of these cells may be slightly lower.

(c) Telephone cells.

1. These cells are commonly called telephone or open circuit cells. They are intended for light intermittent service, such as telephone, bell ringing, and similar work. When used for such service they will outlast the two classes of cells mentioned above. The open circuit voltage is the same as for the ignition cells, but the current on short circuits may be relatively low as the cells are designed for long life on light drain rather than for a heavy discharge rate.

Testing.

2. Open circuit voltage test.

(a) The voltage of an unused dry cell is usually from 1.50 to 1.60 volts. Higher voltages are sometimes found but do not indicate superiority of cell. Lower voltages than 1.45 volts may indicate manufacturing defects, deterioration due to age, or damage. Abnormally low values indicate probably low service capacity. Hence the open circuit voltage test made with the voltmeter is the best test available for picking defective cells in a shipment.

(b) An accurate voltmeter of at least 100 ohms resistance per volt of the scale and having at least 50 divisions per volt should be used for this purpose.

3. Short circuit current test.

(a) A short circuit current test is of value in judging the uniformity of a group of cells, purchased at the same time or in comparing the condition of one or more cells with the normal value for the short circuit current of the same brand. Cells of low short circuit current may give a satisfactory performance on the light intermittent service test and, therefore, the short circuit current readings ought not to be relied upon in choosing cells for telephone or similar light duty. This test gives no indication of the service capacity of different brands of cell.

(b) A deadbeat ammeter accurately calibrated must be used. The resistance of the lead wires and shunt of the ammeter should have a value of 0.01 ohm to within 0.002 ohm. The maximum swing of the needle is taken as the short circuit current of the cell. Results of tests vary with the temperature. They should be made only when the cell is at normal room temperature, that is, about 70 degrees Fahrenheit.

4. Defective cells must be reported to .... and held for disposition.

Placing in service.

5. Cells must be placed in service as soon as practicable. They must not be kept in storage more than 6 months unless absolutely necessary.

6. Insulated wire must be used for connections between cells; the ends connected to binding post must be scraped clean.

Maintenance.

7. Binding posts must be kept free from dirt or other deposits. The nuts on binding posts of cells in service must be kept tight.

Storage or service.

8. Cells should be placed in a cool place, free from dampness and protected against mechanical injury.

9. Wood separators, or other suitable insulating material, must be placed between cells so that zinc sides and/or binding posts will not touch adjoining cell.

Short circuit.

10. Tools or metal must not be placed where they might cause a short circuit of cells.

11. Contact between the positive and negative terminals of a cell must be avoided.

Temperature.

12. Effect of temperature on dry cells.
    (a) The effect of temperature on the open circuit voltage of dry cells is small and for most purposes can be neglected entirely.
13. Effect of temperature on cells in storage.
    (a) Heat produces deterioration of dry cells in two ways. First, it tends to produce leakage; this may be observed when the sticky electrolyte has oozed out around the seal of the cell. Second, it increases the rate of the chemical reactions taking place within the cells.
14. Effect of temperature on service capacity.
    (a) For heavy service a moderately high temperature is desirable, but for light service a low temperature is better.

Storage Batteries

Definition.

A storage cell is a secondary cell used primarily for storing electrical energy at one time for use at another. A secondary cell is any combination of two metals or metalloids immersed in an electrolyte which in itself will not produce electricity without first having the metallic portion of the element decomposed by the passage of an electric current.

Historical.

The storage battery of today is the outgrowth of many early experiments in electro-chemistry as mentioned under primary batteries. Shortly after Volta's discovery of the galvanic battery, Gautherot discovered in certain experiments that after the passage of an electric current through a cell which he used for studying the decomposition of water, a feeble current was returned when he connected the external wires of a cell after having disconnected the source of current.

In 1803, Ritter went a step further by constructing small piles from plates of several metals between which he placed moistened layers of cloth. These piles were charged with an electric current from which a discharge current was obtained after disconnecting the charging source. He thought the piles stored electricity in much the same way as a condenser. Volta indicated that this explanation was incorrect, attributing the effect to the decomposition of water.

A number of other experiments were made by various men, but it remained for Plante to develop a valuable form of cell as the result of his study of electrolytic polarization which he began in 1859.

As a result a battery was devised for the storage of electrical energy which consisted of two sheets of lead separated by strips of rubber rolled into the form of a spiral, all of which was immersed in a dilute solution of about 10 per cent sulphuric acid. Following periods of charge he would discharge the cell or allow it to remain on open circuit for a while, during which time local action transformed the covering of peroxide on the positive plate into lead sulphate. He also found he could materially increase the capacity of the cell by a process which is now called formation.

One of the noticeable advantages which this cell possessed at this time was its ability to deliver much larger currents than could be obtained from the voltaic piles.

There were serious disadvantages with this cell, however, chief of which was the time required for formation, also primary batteries were the only means available for charging these storage cells which made the process costly.

Since 1881 the development of storage batteries has been very rapid on account of decreased time required for formation of the plates and the development of machines for generating electric current for charging purposes.

While there are numerous types of storage batteries in use today this article will deal only with those in general use in the signal field.

General.

The types of batteries usually used in railway signaling are known as lead acid and nickel, iron, alkaline, each of which will be treated separately.

Lead Acid Type

Under this class the Signal Section of the American Railway Association has prepared specifications, etc., for composite type stationary, lead type portable and pure lead type stationary. However, in a general description they can all be grouped under the heading of "Lead Acid Type."

The essential parts to make up a complete cell are: One group each of positive and negative plates, separators, glass or hard rubber jar, cell cover and electrolyte.

Plates.

The plates are connected into positive and negative groups and arranged so that the positive plates always have a negative plate exposed to them.

The positive plates are of different types, depending on the particular cell in question. Certain ones are of the pasted type, others consist of a hard alloy grid securely supporting cylindrical forms of pure lead, while others are of the Plante type, made from one integral piece of pure rolled or cast lead of uniform density and thickness and free from foreign metal.

The negative plates also vary, depending on the cell in question; some are of the pasted type, others for larger sized cells are either pure lead or made with the active material inclosed in a hard alloy frame with finely perforated sides, while others are of the Plante type similar to the positive plates.

In the pasted type of plates, the grids serve as supports for the active material as well as conductors for the electric current on account of their low resistance.

Pastes are made from the various oxides of lead, and also from finely divided lead and lead sulphate, but the oxides are more generally used.

The pastes most commonly used are made from litharge, PbO, or red lead, Pb_3O_4, or a combination of these two oxides made into a stiff paste with sulphuric acid, which may range from 1.100 to 1.250 in specific gravity.

The paste has about the consistency of mortar and is applied to the grids where it is subsequently converted electro-chemically into the active materials of the finished plates.

The pasting of the plates is considered the most secret part of all the manufacturing process. The formula for mixing the paste must be adapted to the physical and chemical properties of the lead oxides which are used.

Plante plates differ essentially from pasted plates, in the fact that the active materials of the former are derived from the body of the plate itself instead of being formed from oxides or other pastes, which are applied to the plate mechanically. The active materials of the Plante plate are obtained by oxidizing the surface of the lead plate or reducing this material to sponge lead.

Separators.

Adjacent plates are separated in various ways to prevent their being short circuited, some by a sheet of hard rubber and a sheet of grooved and treated wood, others by a specially treated wood separator. Where the wood and rubber sheets are used, the flat side of the wood sheet is placed against the negative plate while the rubber sheet is placed against the positive plate.

Jars.

The jars are of hard rubber composition or glass, depending on the particular type of cell. Where the rubber jars are used, they are not less than 7/64 inch thick with sufficient strength to withstand considerable weight. The bottom of jar is also reinforced with at least one intermediate reinforcement. The size of the jar is, of course, dependent upon the particular size or capacity of the elements.

Glass jars are rectangular in shape of clear transparent glass, approximately 1/4 inch thick, the other dimensions being dependent upon the size or capacity of the elements to be contained therein, the capacity of the jar being molded or etched in the glass or stamped on the cover.

Cell covers.

The covers are generally of the same composition and arranged to accommodate the particular jar for which intended.

Electrolyte.

The electrolyte used is of the best quality of dilute sulphuric acid the specific gravity of which is approximately 1.210 to 1.220. When necessary to use water to dilute the acid it should be distilled and free from ammonia and other impurities.

Capacity.

The capacity of the various cells used is expressed in ampere hours the same as for primary batteries. The sizes generally used for signal purposes are 40, 50, 75, 80, 100, 120, 200, 320 and 400 ampere-hours. The particular size depends upon the service for which it is required as well as type of jar; the rubber jars coming in the 50, 75 and 100 ampere-hour size, while the glass jars are for the other capacities.

*Theory of chemical action.**

Space will not permit of an elaborate explanation of the action taking place during charge and discharge. This can be gone into further by the student, if desired, from standard text books on storage batteries.

In a fully charged cell the active material of the negative plates is metallic sponge lead and is represented by the chemical symbol Pb. The active material of the positive plate is lead peroxide and is represented by the chemical symbol PbO_2. The active material of both plates is in a porous condition.

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*For additional information see "Storage Batteries" by George Wood Vinal.

The electrolyte is a mixture of sulphuric acid (H_2SO_4) and water (H_2O), mixed in proper proportion to obtain the specific gravity desired. For batteries used in signaling the sulphuric acid and water are usually mixed in a proportion to give a specific gravity of from 1.210 to 1.220. As an example, concentrated sulphuric acid has a specific gravity of 1.835 and water has a specific gravity of 1.000. If it is desired to mix this acid and water to obtain a specific gravity of 1.210 the proportion would be four parts of water by volume to one part of sulphuric acid.

When a lead acid storage cell is being charged or is discharging chemical action takes place within the cell in accordance with the following equation:

$$\frac{\text{Charge}}{Pb + PbO_2 + 2H_2SO_4} = \frac{\text{Discharge}}{2PbSO_4 + 2H_2O}$$

in which:

Pb = metallic sponge lead (active part of negative plate charged).

PbO_2 = lead peroxide (active part of positive plate charged).

$2H_2SO_4$ = sulphuric acid (active part of the electrolyte at full charge).

$2PbSO_4$ = lead sulphate (negative and positive plate at end of complete discharge).

$2H_2O$ = water (electrolyte at complete discharge).

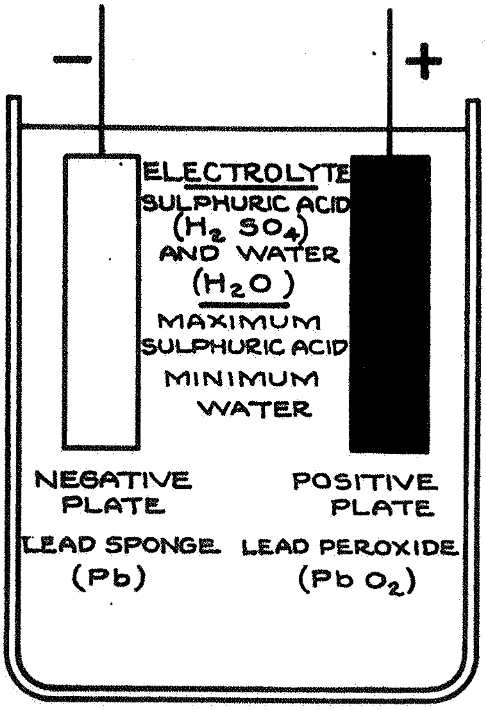


Fig. 7.
Charged.

In order to explain the above equation a simple cell having one negative and one positive plate will be followed through a cycle of discharge and charge and the results noted. The left side of the equation $Pb + PbO_2 + 2H_2SO_4$, as it is written, represents the chemical state of a fully charged cell, as shown in Fig. 7, that is, the active material of the negative plate, as stated before, is now sponge lead (Pb) and the positive plate lead peroxide (PbO_2). In this fully charged condition there is no acid combined with the active material, all the acid (H_2SO_4) is in the electrolyte or liquid surrounding the plates.

As the cell discharges, the acid in the electrolyte will break up and separate from the electrolyte. The SO_4 (sulphate) part will penetrate into the pores of both the negative and positive plates. This action will continue as long as current is being drawn from the cell. As the discharge continues and as the acid continues to separate from the electrolyte and enters into the pores of the lead plates, it is seen that the proportion of acid in the surrounding electrolyte becomes less and less, and the specific gravity of the electrolyte will gradually decrease. This action will continue until all the acid has separated from the electrolyte and combined with the negative and positive plates to form lead sulphate. The cell is now said to be completely discharged, and can be represented by the right-hand side of the chemical equation; namely, $2PbSO_4 + 2H_2O$. These two symbols show us the state or condition of the completely discharged cell.

There are now two plates that are chemically alike. The acid penetrating the pores of the positive and negative plates has combined with the active material of these plates to form lead sulphate ($2PbSO_4$) and only water ($2H_2O$) is left as electrolyte. This state of condition, however, is only theoretical because in actual practice not all of the acid in the electrolyte enters into combination with the plates to form lead sulphate, and there is always some acid left in the electrolyte and the plates are not completely converted into lead sulphate as the acid does not penetrate to the center of the plates. The central portion or core of the active material of the negative plates remains metallic lead, and the positive plates lead peroxide. The completely discharged cell is shown in Fig. 8.

The completely discharged cell will be placed on charge to see what action takes place.

As the current from the charging source flows into the positive plate, through the electrolyte and out through the negative plate the SO_4 part of the acid that is combined with the plates in the form of lead sulphate ($2PbSO_4$) will be gradually driven out of the plates into the electrolyte as the charge progresses. Thus, it is seen that as the charge continues and acid is being returned from the plates back into the electrolyte the proportion of acid in the electrolyte

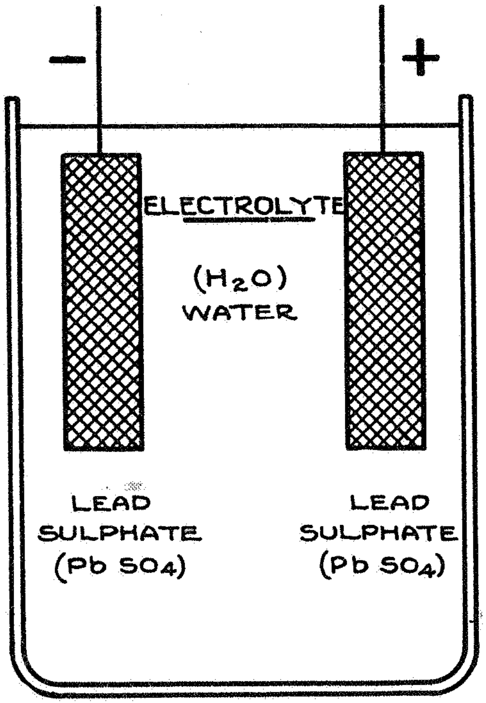


Fig. 8.
Discharged.
(Complete)

increases, the specific gravity of the electrolyte will continue to increase until all of the acid is driven out of the plates, back into the electrolyte, and when this stage is reached, the cell is at its maximum gravity, and is said to be fully charged.

Referring again to the chemical equation, it will now be written in the reverse order to show what took place when the cell was charged, that is, when electrical energy was supplied or added to the discharged plates ($2PbSO_4$) and the electrolyte ($2H_2O$); $2PbSO_4 + 2H_2O = Pb + PbO_2 - 2H_2SO_4$. This equation shows that by charging a discharged cell $2PbSO_4 + 2H_2O$, it is restored to a fully charged condition, as is represented on the right side of the equation $Pb + PbO_2 + H_2SO_4$.

The fact that the chemical equation is reversible, that is, can be written forward or backward, indicates that the lead acid cell is "restorable" or in other words, after discharge it can be recharged and used over again.

The chemical equation and explanation as given above represents the reaction which takes place in an ideal or perfect cell when the discharge is carried to completion, that is, when the discharge is carried to where all the active material of the plates is in combination with all the acid of the electrolyte as lead sulphate, and as a result chemical action ceases, and the cell will not give any further energy or current even though it be short circuited on itself.

In the fully charged cell the electrolyte is shown in the equation of reaction as sulphuric acid ($2H_2SO_4$). However, the electrolyte in this case is really a mixture of sulphuric acid (H_2SO_4) and water (H_2O) and the reason that only $2H_2SO_4$ is shown in the equation is because only the acid of the electrolyte and not the water is active in producing chemical energy. During discharge the acid of the electrolyte ($2H_2SO_4$) is ionized or broken up into $2H_2$ and $2SO_4$, the $2H_2$ part going to form water in the electrolyte and the $2SO_4$ part going to form lead sulphate in combination with the lead (Pb) of the plates. The full and complete reaction can be explained by reference to the following equation wherein the electrolyte is a mixture of $4H_2SO_4$ and $2H_2O$:

$$\frac{\text{Negative Plate}}{Pb} + \frac{\text{Positive Plate}}{PbO_2} + \frac{\text{Electrolyte}}{4H_2SO_4+2H_2O} = \frac{\text{Neg. and Pos. Plates}}{2PbSO_4} + \frac{\text{Electrolyte}}{2H_2SO_4+4H_2O}$$

On discharge some of the sulphuric acid ($2H_2SO_4$) of the electrolyte is broken up into SO_4, SO_4 and $2H_2$. The two SO_4 parts from the acid combine with the negative and positive plates to form $2PbSO_4$, the positives losing O_2 in this reaction. This leaves O_2 from the positive plates to combine with the $2H_2$ left from the acid so as to form additional water $2H_2O$.

At the beginning of discharge, the electrolyte was $4H_2SO_4 + 2H_2O$ and at the end of discharge it is $2H_2SO_4 + 4H_2O$. Thus, it is seen that acid has been taken from and water has been added to the electrolyte during discharge.

On charge the reverse is true and acid is added while water is taken or subtracted from the electrolyte as shown in the equation.

In the reaction just given the purpose was to show the changes that take place in the electrolyte and therefore, showing the active material of the discharged plates as $2PbSO_4$ is not strictly correct as the plates are not fully converted to lead sulphate.

In a practical cell and in the practical operation of storage batteries the discharge cannot and is not carried so far that the reaction is complete. A cell could not be discharged to where all the active material is converted into lead sulphate if desired, and discharge is usually stopped while there is still some energy left in the battery. Consequently there is always some acid left in the electrolyte at the end of a normal discharge and the central portion or core of the plates is not converted into lead sulphate as the acid does not penetrate sufficiently deep into the pores of the plates to do so. The discharged cell in actual operation is shown in Fig. 9.

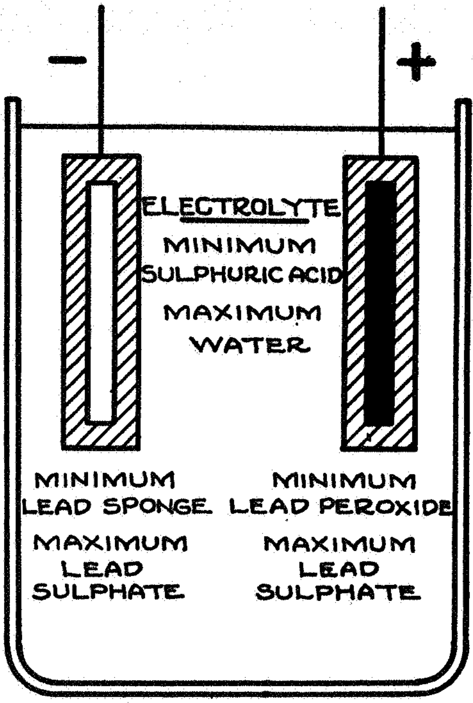


Fig. 9.
Discharged.
(Actual)

The following equation should make clear the reaction which takes place during a cycle of charge and discharge in the normal or actual operation of a cell:

Charged

$$\frac{\text{Negative Plate}}{\text{Maximum Pb}} + \frac{\text{Positive Plate}}{\text{Maximum PbO}_2} + \frac{\text{Electrolyte}}{\text{Maximum H}_2\text{SO}_4 + \text{Minimum H}_2\text{O}} =$$

Discharged

$$\frac{\text{Negative Plate}}{\text{Minimum Pb} + \text{PbSO}_4} + \frac{\text{Positive Plate}}{\text{Minimum PbO}_2 + \text{PbSO}_4} +$$

$$\frac{\text{Electrolyte}}{\text{Minimum H}_2\text{SO}_4 + \text{Maximum H}_2\text{O}}$$

Instructions.

Lead acid type storage batteries should be installed, maintained and operated in accordance with the following instructions:

Information.

1. Storage batteries used in railway signaling are of two general types: Stationary and portable.

2. Storage battery is primarily a device for storing electrical energy at one time for use at another.

3. The fundamentals of storage batteries are two kinds of plates, positive and negative, and a solution termed electrolyte.

4. The process of putting energy into battery is termed charging; of taking energy out, discharging.

5. During discharge some of the acid is absorbed by the plates; during the charge acid is driven out. When all of the acid is driven out of the plates the battery is fully charged.

6. The strength of electrolyte is measured in terms of specific gravity.

7. The specific gravity of electrolyte changes during charge and discharge of cells and indicates condition of charge.

8. The specific gravity and voltage of cells increase during charge.

9. Lead acid storage cells are distinguished by their lead plates and lead covered terminals.

10. The positive pole is designated by the dark color of its plates, and/or by a plus (+) mark or red paint, on or adjacent to terminal.

11. The negative pole is designated by the light color of its plates, and/or by a minus (—) mark or black paint, on or adjacent to terminal.

12. Direct current must be supplied at battery terminals for charging purposes.

Installation.

13. Isolate open type battery in a room or box, as the acid fumes given off during charge are of a corrosive nature. This housing should be well ventilated and lighted, and as dry as practicable.

14. Inside of housing should contain no exposed metal other than lead. If this is not practicable, such metal parts should be protected by vaseline or at least two coats of acid-proof paint.

15. Floor of battery room should be sloped to provide proper drainage.

16. Battery must be supported on wooden racks, pegs or shelves of sufficient strength to prevent sagging; or be placed on a layer of sand on floor of battery box. They must be arranged to permit access for inspection, cleaning or for the removal of any cell or element.

17. Fill the sand trays level with top with clean dry sand; space trays uniformly on support so as not to touch adjacent trays.

18. Clean the jars and press them into sand until they have solid bearing and are in proper alignment.

19. Scrape the contact surfaces of connecting straps and elements to insure good electrical connection.

20. Place the negative groups crosswise on a strip of webbing; then slip the plates of the positive group between those of the negative group, so that the vertical edges of all plates will be flush. Insert spacing sticks between plates to keep them apart while lifting. Lift the element by webbing and place it in the middle of the jar, making sure that the hanging lugs rest evenly on the sides of the jar. Withdraw webbing and spacing sticks.

21. Bolt the connecting straps together with the bolt connectors, making each connection tight. Connect rows of cells with lead strap or rubber-covered copper wire. Cover all bolt connectors and exposed copper with vaseline.

22. Connect the charging circuit wires to the battery terminals with positive wire of the charging circuit connected to the positive terminal. Polarity of charging circuit must be determined by meter test.

23. One cell in each battery, so situated as to be well lighted and easily accessible for inspection and tests, should be designated and marked as the pilot cell. (Preferably a center cell.)

24. A permanent number should be assigned to each cell or container, preferably painted or stenciled thereon.

25. Before proceeding further, inspect all connections carefully to insure that they are tight and properly made, connections between cells being positive and negative; be sure that charging current at proper voltage and under control is available, and that the initial charge can be started immediately and can be continued to its completion.

26. Unpack the wooden separators, which include veneers and dowels. Insert veneers in the dowels with the grain of the veneer crosswise to the dowel. Place the separators between adjacent positive and negative plates with the dowels vertical. Place the glass hold-down in position in each cell.

27. The wood separators, which have been given special treatment, are shipped wet. They must be kept so, until installed in the battery. If there is any delay in setting up battery the veneers and dowels should be left in packing cases and kept wet with water (approved for storage battery use) at least once a week.

28. Wood separators and dowels carried on hand must be kept immersed in water (approved for storage battery use), to which electrolyte of 1.210 specific gravity has been added in the proportion, by volume, of one part electrolyte to 10 parts water. The container must be covered to keep out impurities.

29. Immediately after separators are placed in position the cells should be filled with electrolyte to a height of ¾ inch above the

tops of the plates or to the electrolyte line. The electrolyte (R.S.A. Specification 4314) should be of 1.210 specific gravity, at 70 degrees Fahrenheit.

30. The initial charge should be started immediately after the electrolyte has been added to the cells.

31. Unfilled assembled cells, before being placed in service, must be filled with electrolyte of the proper specific gravity and given an initial charge.

Instruments.

32. Where practicable, hydrometers and thermometers in accordance with R.S.A. 1175 and 1375 should be used.

Initial charge.

33. The initial charge should continue for 10 hours after maximum voltage and gravity have been reached. This should require from 40 to 60 hours at the normal rate. If the temperature of the electrolyte exceeds 110 degrees Fahrenheit the charge should be stopped until the battery cools.

34. Adjust the charging current to the normal eight-hour charging rate and maintain this value throughout the charge. Readings should be taken on every cell with a low reading voltmeter immediately after starting the charge, to insure that all the connections are properly made, positive to negative, and that no short circuits exist.

35. At one-hour intervals during the course of the charge, read the battery voltage and also the specific gravity of one or two selected cells. The voltage and specific gravity should rise as the charge progresses, and near the end of charge, each should have reached maximum value. Continue to charge for 10 hours after the maximum values have been reached. At the end of the charge, all the cells should be gassing freely and the specific gravity of the electrolyte in every cell should be stationary.

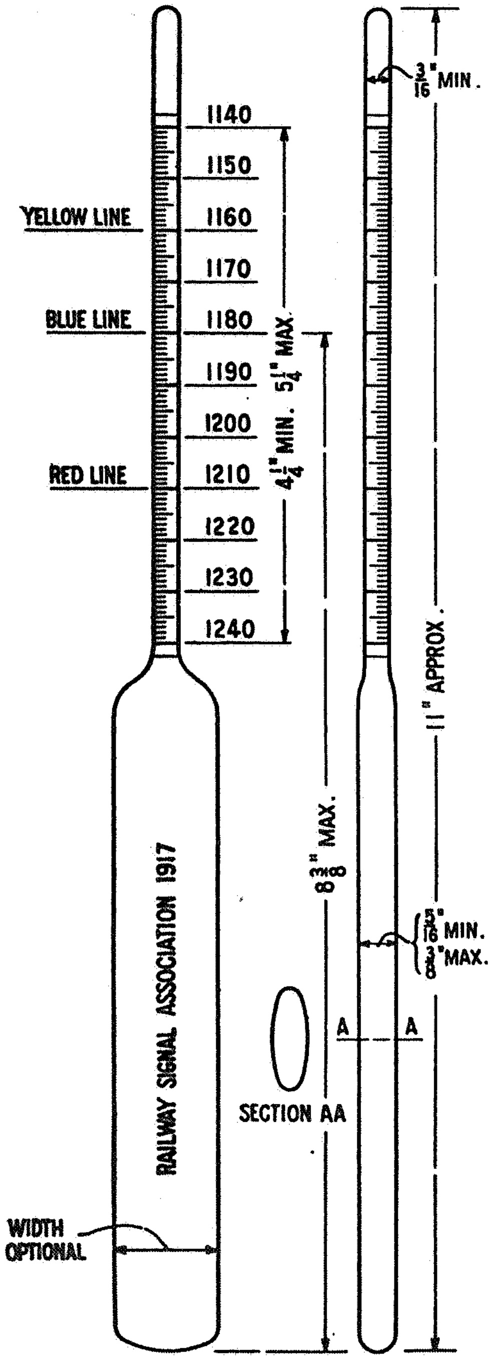
36. If, at the end of charge, the electrolyte is not at 1.210 specific gravity, at 70 degrees Fahrenheit, it should be adjusted to this value, at the proper height above the plates.

37. To raise the specific gravity, electrolyte of a higher density, or, if this is not available, electrolyte of 1.210 specific gravity should be added before next charge. To lower specific gravity, water should be added. If necessary, remove a part of the solution from battery before adding electrolyte or water.

38. Water used in batteries should be either distilled or from a source which has been tested and approved for storage battery use.

39. An open flame should not be permitted near battery, as the cells give off hydrogen during charge.

40. A.R.A. Signal Section Form 18 should be used for reporting readings.



NOTE: INSTRUMENTS SHALL BE ACCURATE WITHIN TWO (2) DEGREES.

SPECIFIC GRAVITY SCALE OF HYDROMETER SHALL BE GRADUATED FOR ELECTROLYTE AT 70° FAHRENHEIT

HYDROMETER SHALL BE FURNISHED IN TUBULAR CONTAINER WITH TELESCOPE COVER.

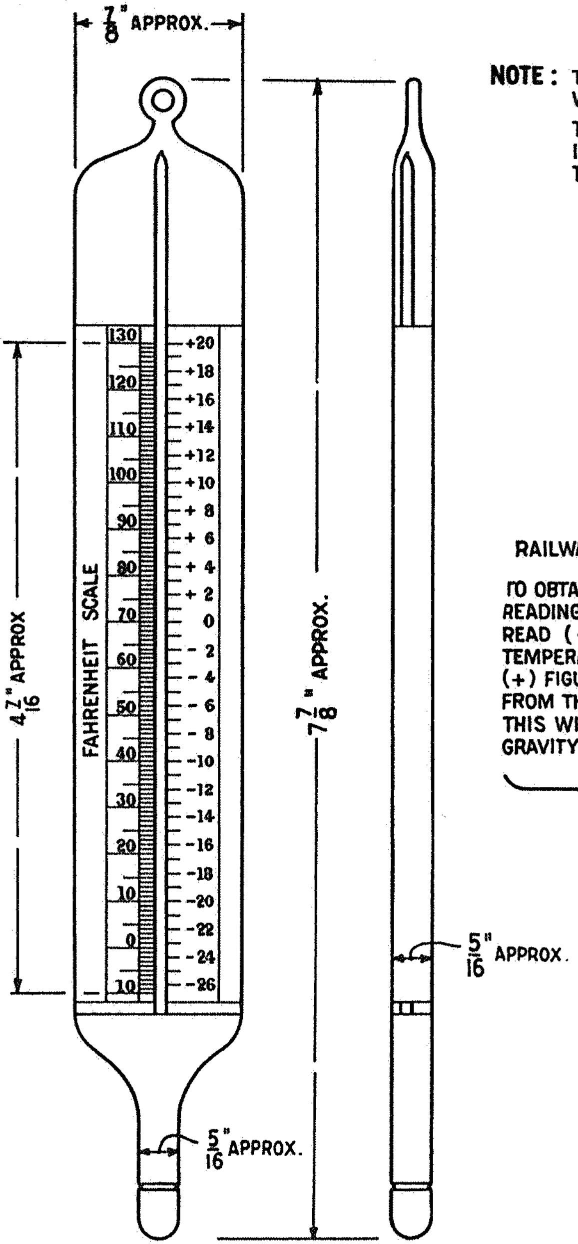
NOTE: WHEN ORDERING APPARATUS OR PARTS SHOWN ON THIS PLAN GIVE NUMBER AND NAME APPEARING IN **LARGE** TYPE.

11751 - HYDROMETER.

HYDROMETER

(STATIONARY LEAD TYPE STORAGE BATTERY.)

									SEPT. 1916	MAR. 1916	MAY 1915	**RSA 1175**



13751 - THERMOMETER.

NOTE: THERMOMETER SHALL BE ACCURATE WITHIN THREE (3) DEGREES.

THERMOMETER SHALL BE FURNISHED IN TUBULAR CONTAINER WITH TELESCOPE COVER.

RAILWAY SIGNAL ASSOCIATION 1917.

TO OBTAIN CORRECTED SPECIFIC GRAVITY READING FOR ELECTROLYTE AT 70° F. READ (+) OR (−) FIGURE NEAREST THE TEMPERATURE OF THE ELECTROLYTE, ADD (+) FIGURE OR SUBTRACT (−) FIGURE FROM THE HYDROMETER READING. THIS WILL GIVE THE CORRESPONDING GRAVITY FOR THE SOLUTION AT 70° F.

NOTE TO BE INSERTED IN THERMOMETER TUBE SO AS TO BE VISIBLE FROM THE BACK.

NOTE: WHEN ORDERING APPARATUS OR PARTS SHOWN ON THIS PLAN GIVE NUMBER AND NAME APPEARING IN **LARGE** TYPE.

THERMOMETER

(STATIONARY LEAD TYPE STORAGE BATTERY)

NOV 1917 OCT. 1917

RSA 1375

Maintenance.

41. All connections must be kept clean and tight. A loose or dirty contact will cause excessive heating, also drop in voltage.

42. Jars or containers must be kept clean, level and as dry as practicable.

43. Trays and supports must be kept clean, dry and in such condition as to prevent surface leakage of current.

44. All exposed brass or copper battery connections must be kept covered with vaseline.

45. Battery supports must be kept coated with acid-resisting paint.

46. Defective jars or containers must not be left in service.

47. Cells showing defects must be taken out of service and held for instructions.

48. Care must be exercised to avoid short circuiting or dropping foreign matter in cells.

49. Should any foreign matter be found in cells, steps must be taken to remove it at once.

50. Water of electrolyte is depleted through gassing that occurs during charge. Water in accordance with Instruction 38 must be used to replace loss.

51. The electrolyte must be maintained at a level ¾ inch above top of plates, or at electrolyte level mark. Exposure of top of plates to air causes rapid sulphation and will seriously injure plates and wood separators.

52. Electrolyte or water for battery use must be furnished in glass carboys and must be kept tightly corked.

53. Hard rubber, glass, lead-lined or porcelain vessels only must be used in handling electrolyte or water for storage battery use.

54. The accurate specific gravity of electrolyte is indicated only when it is at the proper level.

55. The temperature affects specific gravity of electrolyte. This must be considered and correction made as follows:

(a) To correct to normal temperature 70 degrees Fahrenheit, subtract one point (0.001 specific gravity) for each 3 degrees Fahrenheit below 70 degrees Fahrenheit and add one point for each 3 degrees Fahrenheit above 70 degrees Fahrenheit; for example, electrolyte which is 1.213 at 61 degrees Fahrenheit will be 1.210 at 70 degrees Fahrenheit.

56. When replacing losses due to evaporation, water must be added at the beginning of charge.

57. Acid must not be added to raise specific gravity of electrolyte, without definite instructions.

58. Electrolyte of the same specific gravity as that of balance of cells must be used in replacing loss due to cracked or broken jars.

59. Electrolyte should be handled carefully as it is injurious to person, clothing and other foreign matter.

60. To avoid injury caused by electrolyte coming in contact with clothing, a bottle of strong ammonia should be kept in battery room at all times, and in the event of accidental splash of acid on clothing an immediate application of a small quantity of ammonia may neutralize the acid and prevent burning hole in material. A strong alkaline solution of baking soda and water will be found useful for washing the hands after working in electrolyte. In the event of splash of electrolyte in eye, it should be washed out at once with clean water, preferably warm water, and then put one or two drops of olive oil in the eye, and a physician should be consulted as soon as possible. If olive oil is not immediately available, any kind of engine oil is better than none.

61. Open flame must not be allowed in battery housing.

62. Proper ventilation must be maintained and housing kept neat, clean and dry.

63. Temperature of battery housing should be maintained as near as practicable to 70 degrees Fahrenheit and should not be allowed to exceed 115 degrees Fahrenheit. Battery must be shielded from direct sun-rays.

64. Care must be exercised in handling portable cells to prevent spilling of electrolyte or short circuiting while in transit.

65. Carrying cases and handles for portable cells must be kept in good condition so as to prevent injury while handling cells.

66. Metal tape or wire must not be used to attach shipping tags to portable cells.

67. Connectors on portable cells must not be used for any other purpose than that intended.

Method of charging.

68. The following methods are used for charging storage batteries: Floating and non-floating.

69. Floating method provides for charging rate at a constant potential. Non-floating method provides for charging at the normal rate, or a tapering rate.

70. The rate of charge by the floating method is that necessary to maintain battery in fully charged condition; a voltage of between 2.1 and 2.2 per cell, but not gassing continually.

71. The rate of charge by the non-floating normal rate method, is that rate by which the battery would be discharged, in an eight-hour period.

72. The initial rate of charge by the non-floating tapering method should be such that (due to the rise in cell voltage as the charge progresses) the current will be automatically reduced to a point no higher than normal rate when cells begin to gas.

Operation—All types.

73. Batteries must not be repeatedly over or undercharged.

74. The voltage of the charging source must be sufficiently greater than the battery voltage to cause the proper charging current to flow in the circuit.

75. Two or more sets of batteries may be charged together, either in series or multiple, provided the charging rate of each is properly regulated and is within the limits of the charging unit.

76. Cells must not be charged at higher rate than normal, without specific instructions, or under any condition at higher rate than normal after cells are gassing. If temperature of cells rises to 115 degrees Fahrenheit, charge must be reduced or stopped.

77. Excessive gassing causes abnormal deterioration of plates.

78. The prescribed method of charging must not be changed, except by proper authority.

79. If battery has been completely discharged, it should be charged immediately and not allowed to stand completely discharged. Part of a charge is better than none.

80. Upon receipt of charged cells, they must be carefully examined and any electrolyte lost, due to spillage, must be replaced with the proper amount of electrolyte (R.S.A. Specification 4314) of same specific gravity as that of other cells. Spillage will be shown by the changed color or rotting of packing material.

81. In lowering specific gravity or raising level of electrolyte in cell, the added water must be thoroughly mixed with electrolyte before taking hydrometer reading. Neglect of this precaution will result in a decided fall in specific gravity after a few days.

82. When water is added to electrolyte of cell at temperatures below freezing, agitate the electrolyte with a syringe, the end of which reaches bottom of plates.

83. Care must be taken when mixing sulphuric acid and water, to pour acid slowly into water, thoroughly stirring with glass or hard rubber paddle. Never pour water into acid as an explosion may result.

84. Before putting in service, battery that has been received in a charged condition should be charged until specific gravity and voltage ceases to rise, and then charged continually for 5 hours. Temperature of electrolyte must not exceed 115 degrees Fahrenheit; to avoid this, it may be necessary to stop charge or reduce charging rate.

85. On batteries charged by the non-floating method the regular charge should be prolonged to constitute an equalization charge every 30 days or after each sixth regular charge.

86. An equalization charge is a charge continued until specific gravity of electrolyte shows no further rise after five successive fifteen minute readings, *i.e.,* having reached one hour maximum.

87. Cells must not be discharged below .... specific gravity at .... degrees Fahrenheit, or 1.75 volts with current at normal rate.

88. Cells must be charged when specific gravity reaches .... at .... degrees Fahrenheit.

89. When one or more cells, relative to balance of cells in battery, shows falling off in specific gravity or voltage, deficiency in gassing on equalization charge, or color of plates markedly darker or lighter, the conditions may be caused by short circuit between plates, reversal of charging current, impurities in electrolyte (such as iron, rust, mineral waste, etc., which may cause plates to be darker or lighter in color). Conditions should be immediately corrected.

90. Short circuit must be removed by means of a thin clean strip of hardwood, glass or rubber. Never use metal.

91. If there is any doubt as to the condition of electrolyte a half-pint sample taken at end of discharge (replacing with an equal amount of electrolyte of same specific gravity) should be taken out, in a perfectly clean bottle and held for disposition. If all the electrolyte is to be removed, cell should be thoroughly flushed with water approved for storage battery use, before electrolyte is replaced with new electrolyte.

92. When a cell fails to gas freely or specific gravity fails to rise to proper point on regular charge, after short circuit or other trouble has been remedied, the cell may be brought up to proper condition, where practicable, by disconnecting it from battery during discharge and again connecting into the circuit just before beginning the next regular charge. If this does not put cell in proper condition the process should be repeated.

93. Thermometers, hydrometers or other utensils that have been used for other purposes must not be used for testing and handling sulphuric acid electrolyte, as electrolyte may become contaminated. Hydrometers should be free from attached gas bubbles.

94. Specific gravity and voltage readings must be taken each specified period.

95. The indications of sufficient regular charge are as follows:

(a) The gravity of the pilot cell having risen to a point which is five points (0.005 specific gravity) below the maximum reached on the preceding equalization charge; for example, if the maximum reached on the preceding equalization charge was 1.209 at 70 degrees Fahrenheit, the gravity to be reached on the regular charge is 1.204 at 70 degrees Fahrenheit. If jars are but partially filled with plates, and the excess electrolyte is not displaced, the limit should be three points (0.003 specific gravity) instead of five points (0.005 specific gravity).

(b) The voltage across the battery having risen to a point which is 0.05 to 0.10 volt per cell below what it was on the preceding equalization charge, the charge rate being the same in both cases; for example, if the maximum voltage per cell attained on the equalization charge was 2.62, the regular charge is from 2.52 to 2.57 volts per cell.

(c) The cells all gassing moderately.

96. Electrolyte must not be placed in cells until it has cooled.

97. A.R.A. Signal Section Form 19 should be used as required for recording readings or inspections.

Operation—Stationary type.

98. In renewing batteries, following will govern:

(a) Siphon off electrolyte, which may be used again, into thoroughly clean glass receptacles. Remove cells from rack; remove elements from cells and throw away wood separators. Remove and clean sand trays. Thoroughly clean battery supports with an alkaline solution, rinse with water, dry and paint. Clean jars thoroughly and rinse with water (approved for storage battery use), being careful that solution and sediment removed is buried. Fill trays level with top with clean dry sand. Place elements on stand or table; carefully inspect and remove any loose or foreign matter. Scrape both sides of lugs at the bolt hole to insure good contact when the cells are connected together.

(b) Arrange positive and negative groups in accordance with Instruction 20.

(c) Place jar in the center of sand tray and put sand tray on the rack, spacing them uniformly on support so as not to touch adjacent trays.

(d) Thoroughly clean and brighten connecting bolts, applying vaseline to brass studs and connect cells, installing wood separators and dowels, removing from package case or water-bath only sufficient separators and dowels for equipping a few cells at a time. The dowels must always be placed on the separators at right angles, *i.e.*, across the grain of the wood. The separators, when equipped with dowels, should be inserted from the top, one between each two plates of the element.

(e) The wood separators and dowels are shipped wet and must be kept so, until installed in the battery.

(f) Immediately fill cell with electrolyte in accordance with Instruction 29. Place the glass hold-downs in position on the separators and dowels, removing from packing case or water-bath cover plate. Connect charging current and give battery initial charge in accordance with Instructions 33 to 40 inclusive.

99. When sediment in cells accumulates until it is liable to touch or short circuit the plates it should be leveled off with an "L" shaped glass or all-wood stick. When sediment has reached a point where it has to be removed and when the plates can be easily removed, such as in the smaller type of batteries, they should be carefully lifted out, after the electrolyte has been siphoned or drawn off, disturbing the sediment as little as possible and sediment then removed and jar thoroughly rinsed, with water approved for storage battery use. In the larger type, the solution should be siphoned off, disturbing sediment as little as possible. The sediment may then be removed with a glass or all-wood scoop, leaving the plates undisturbed. Plates must be exposed to the air only the shortest possible time.

100. Just before equalization charge inspect all cells for any peculiarities in color or accumulation of moss (spongy lead) on the top of negative plates. Remove moss as it tends to short circuit the plates by bridging over the separators. Make sure that the separators and dowels are in place, and that hanging lugs are not touching adjoining lugs. Any cells noted as low on the periodical readings or that do not gas freely on the equalization charge should be examined.

Batteries out of service.

101. In the event of jar being cracked or broken and there is no jar or electrolyte of proper specific gravity available, plates and separators must immediately be placed in water (approved for storage battery use) in a container approved for handling water or electrolyte, while out of service. If plates are to remain out of service more than 24 hours, positive plates should be taken out and allowed to dry, the negative plates and separators being kept in water.

102. When restoring to service plates which have been temporarily out of service and stored in water, the correct specific gravity of electrolyte to use is 10 points (0.010 specific gravity) higher than that of balance of cells in battery.

103. If use of the battery is to be entirely discontinued for a period of not longer than six months, proceed as follows: Give an equalization charge just before idle period and add water to the cells during the equalization charge so that gassing will insure thorough mixture, raising level of electrolyte ¼ inch below top of jars. After equalization charge is completed, remove the fuses to prevent the use of battery during the idle period. Though not likely, the level of the electrolyte may, due to excessive evaporation during the idle period, fall below the top of the plates. If this should occur, add water to keep them covered. If in a place where freezing is apt to occur, stir electrolyte after adding water, as thoroughly mixed electrolyte under these conditions will not freeze at temperatures above zero degrees Fahrenheit.

104. If battery is to be entirely out of service for more than six months, proceed as follows: Give equalization charge, siphon off electrolyte (which may be used again) into thoroughly cleaned glass receptacles and as each jar becomes empty immediately fill it with water (approved for storage battery use). When water is in all the jars, allow to stand 12 or 15 hours. Then remove and throw away wood separators. Next siphon water out of each jar and elements can then be allowed to stand indefinitely. If negative plates show a tendency to heat, they should be sprinkled with water approved for storage battery use. If there is any considerable amount of sediment in the jars it should be removed before it dries.

105. When restoring cells to service where electrolyte has not been withdrawn, add water, if needed, and give equalization charge until gravity of electrolyte has ceased to rise over a period of 5 hours.

106. If battery has been standing without electrolyte, proceed as follows: Equip cells with new separators and fill with either new electrolyte of 1.210 specific gravity at 70 degrees Fahrenheit, or if old electrolyte has been saved, add enough new of 1.210 specific gravity at 70 degrees Fahrenheit to replace loss and charge at least 35 hours at normal rate and continue, if necessary, until both the specific gravity and voltage have reached a maximum, showing no rise over a period of 10 hours and all plates are gassing freely.

Nickel, Iron, Alkaline Type

This type of battery is more familiarly known as the Edison storage battery. It is radically different from the lead acid type in that lead does not enter into the make-up, neither is sulphuric acid used as the electrolyte. It is also of rather recent development, having been invented and developed by Thomas A. Edison, being placed on the market in its present form about 1906.

The make-up of a complete cell consists essentially of the positive and negative plates, separators, container and electrolyte.

Elements.

The positive plates consist of perforated steel tubes in which is placed nickel hydrate and flake nickel, the latter being required to give the active material sufficient electrical conductivity. These steel tubes are made from cold rolled carbon steel ribbon which is nickel plated. They are ¼ inch in diameter and 4½ inches in length. After the tubes have been filled with the nickel hydrate and flakes, they are closed, trimmed and inspected, after which the desired number are mounted on a nickel plated steel grid and pressed into permanent position by hydraulic pressure to form the positive plate.

A.R.A. Signal Section - Form 18

LEAD ACID TYPE STORAGE BATTERY - INITIAL CHARGE REPORT.

______________ Company.

Location ________ Cells ______ Type ________ No. of plates per cell. ________

Charge started ______ A.M. P.M. ________ Date Completed ______ A.M. P.M. ____________ Date.

Date	Time	Amperes	Ampere Hours.	No. of cells in circuit	Total volts of cells in circuit.	Ave. volts per cell in circuit.	Pilot cell (Cell No. ______)		
							Sp. Gr.	Volts	Temp.

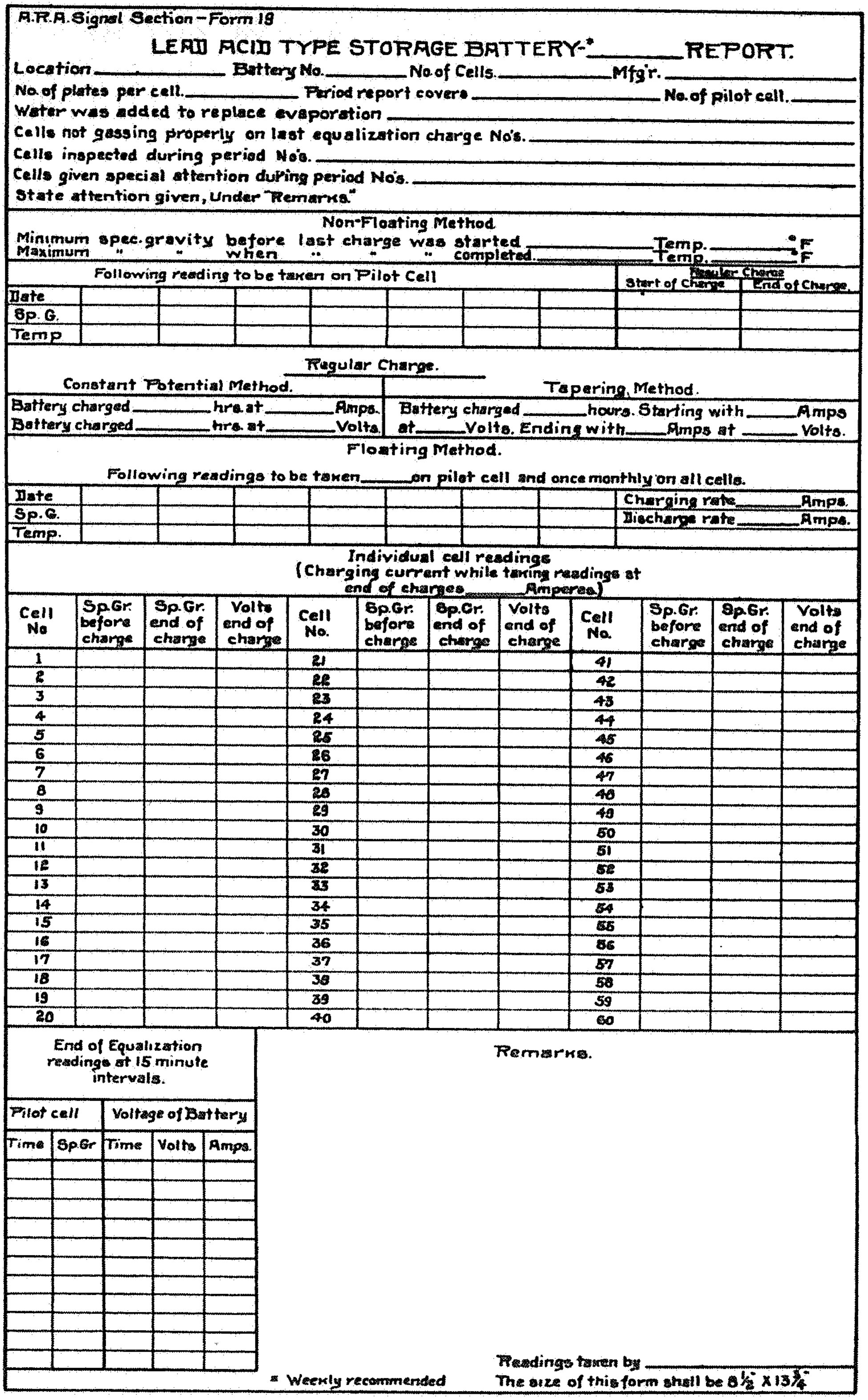
Cell Readings

Cell	Sp.Gr	Volts	Sp.Gr	Volts	Sp.Gr	Volts	Cell	Sp.Gr	Volts	Sp.Gr	Volts	Sp.Gr	Volts	Cell	Sp.Gr	Volts	Sp.Gr	Volts	Sp.Gr	Volts
1							21							41						
2							22							42						
3							23							43						
4							24							44						
5							25							45						
6							26							46						
7							27							47						
8							28							48						
9							29							49						
10							30							50						
11							31							51						
12							32							52						
13							33							53						
14							34							54						
15							35							55						
16							36							56						
17							37							57						
18							38							58						
19							39							59						
20							40							60						

Directions :- The readings called for on the top section of the sheet are to be taken hourly for the first and second hours, each three hours between second and thirty-fifth hours, and hourly thereafter until the end of the charge, carefully noting any interruption or change in the charging rate.

The individual cell readings are to be taken after charging for thirty-five and forty-five hours, also just before the end of the charge.

The size of this Form shall be 8½" x 13½".



A.R.A. Signal Section—Form 18

LEAD ACID TYPE STORAGE BATTERY-*________REPORT.

Location________ Battery No.________ No. of Cells.________ Mfg'r.________

No. of plates per cell.________ Period report covers________ No. of pilot cell.________

Water was added to replace evaporation________

Cells not gassing properly on last equalization charge No's.________

Cells inspected during period No's.________

Cells given special attention during period No's.________

State attention given, Under "Remarks."

Non-Floating Method

Minimum spec. gravity before last charge was started________ Temp.________°F

Maximum " " when " " " completed.________ Temp.________°F

Following reading to be taken on Pilot Cell								Regular Charge	
								Start of Charge	End of Charge.
Date									
Sp. G.									
Temp									

Regular Charge.

Constant Potential Method.	Tapering Method.
Battery charged________hrs. at________Amps. Battery charged________hrs. at________Volts.	Battery charged________hours. Starting with______Amps at______Volts. Ending with______Amps at______Volts.

Floating Method.

Following readings to be taken______on pilot cell and once monthly on all cells.

Date								Charging rate______Amps.
Sp. G.								Discharge rate______Amps.
Temp.								

Individual cell readings
(Charging current while taking readings at end of charges______Amperes.)

Cell No	Sp. Gr. before charge	Sp. Gr. end of charge	Volts end of charge	Cell No.	Sp. Gr. before charge	Sp. Gr. end of charge	Volts end of charge	Cell No.	Sp. Gr. before charge	Sp. Gr. end of charge	Volts end of charge
1				21				41			
2				22				42			
3				23				43			
4				24				44			
5				25				45			
6				26				46			
7				27				47			
8				28				48			
9				29				49			
10				30				50			
11				31				51			
12				32				52			
13				33				53			
14				34				54			
15				35				55			
16				36				56			
17				37				57			
18				38				58			
19				39				59			
20				40				60			

End of Equalization readings at 15 minute intervals.

Pilot cell		Voltage of Battery		
Time	Sp. Gr	Time	Volts	Amps.

Remarks.

Readings taken by________

* Weekly recommended

The size of this form shall be 8½" X 13¾".

The negative plates consist of perforated steel pockets in which is placed black iron oxide. These steel pockets are likewise made from cold rolled carbon steel which has been nickel plated, and formed in halves similar to a paper scarf-pin box, in which the box proper and cover are approximately equal, one fitting over the other. After the negative pockets have been filled with the black iron oxide, they are likewise closed, trimmed and inspected, after which the proper number of sets are placed in the openings of the negative grid and hydraulic pressure used to clamp them firmly in place.

Separators.

Hard rubber rods or pin insulators are placed between the plates to keep them from touching. Hard rubber ladder pieces or grid separators are placed to the edges of the plates to prevent their touching the containers.

Containers.

The containers are made of nickel plated sheet steel with sides corrugated to provide increased strength. The single side seam, tops and bottoms being welded on by an oxy-acetylene blowpipe. The top in addition to being provided with two holes through which the vertical poles from the plates pass, is also equipped with a valve box. This opening permits the placing of the solution in the cell or the addition of distilled water. In the top of the lid is a small valve which allows the gas generated during charging to escape, but no impurities or air to get in.

Electrolyte.

The electrolyte is a solution of potash and water to which a small amount of lithium hydroxide is added. The normal specific gravity is approximately 1.200. The low limit beyond which it is inadvisable to run an electrolyte is 1.160. It is not necessary to take specific gravity readings during charge and discharge as the electrolyte does not change appreciably. The state of the charge is determined by voltage readings.

Assembly.

The necessary number of positive and negative plates for the particular size of cell are mounted on steel rods which pass through the eyes of the grids at the tops of the plates. The plates are separated from one another by means of washers fitting on this rod, and are locked in place by a lock washer and nut which is screwed on the end of the rod. The groups of positive and negative plates are intermeshed to form the element, there being one more negative than positive plate, so that each positive plate will have the surface of a negative plate exposed to it, similar to the arrangement of lead acid type cells. After the necessary separators, etc., are applied the assembled element is placed in the container, after which the top is welded on.

The recommended capacities of the cells used in signal work are 75, 150, 300 and 450 ampere hours. The various capacity cells are designated by a letter and figure such as B4, A4, A8, etc., in which the letter represents the size of plate and the figure the number of positive plates. In the B type of plate, there are 15 of the positive tubes in each positive plate and 16 sets of pockets in the negative plate, while in the A type there are 30 tubes in the positive plate and 24 pockets in the negative plate, hence the B4 is rated at 75 ampere hours, A4 at 150, A8 at 300, etc., the capacity being dependent upon the size as well as the number of positive plates.

Chemical action.

The chemical reactions in charging this type of battery are the oxidation (NiO) from a lower to a higher (NiO_2) oxide of nickel in the positive plate, and the reduction from ferrous oxide to metallic iron in the negative plate. The oxidation and reduction are performed by the oxygen and hydrogen set free at the respective poles by the electrolytic decomposition of water during the charge. The charging of the positive plate is, therefore, simply a process of increasing the proportion of oxygen to nickel. The proportions of nickel to oxygen in definite oxides of nickel are as follows:

	Atomic	Proportions	By	Weight
	NI	0	NI	0
NiO	1	1.	1	0.273
Ni_3O_4	1	1.33	1	0.364
Ni_2O_3	1	1.5	1	0.409
NiO_2	1	2.	1	0.545

The discharge of the cell is simply the reversal of the above reactions, the hydrogen reducing the higher oxides of nickel to lower oxides and the oxygen oxidizing the iron to ferrous oxide.

Instructions.

Nickel, iron, alkaline storage batteries are to be installed, maintained and operated in accordance with the following instructions:

Information.

1. Storage battery is primarily a device for storing electrical energy at one time for use at another.

2. The fundamentals of storage batteries are two kinds of plates, positive and negative, and a solution termed electrolyte.

3. The process of putting energy into battery is termed charging; of taking out, discharging.

4. The strength of electrolyte is measured in terms of specific gravity.

5. The specific gravity of electrolyte remains practically constant, except that in time it will decrease due to gassing. It, therefore, furnishes no indication of the state of charge.

6. The voltage of cells increases during charge and indicates condition of charge.

7. Nickel, iron, alkaline storage cells may be distinguished by their steel containers.

8. The positive pole is designated by a red bushing around the pole and a plus (+) mark stamped on top of container.

9. The negative pole is designated by a black bushing around the pole.

10. Direct current must be supplied at battery terminals for charging.

11. Cells are shipped filled and charged unless otherwise specified.

12. The rated ampere-hour capacity and the normal rate in amperes of any type or size of nickel, iron, alkaline cell is equal to the number of positive plates (as given by the type numbers) times the following factors:

(a) Regular high or high-wide type "A" cells.

Ampere hours per positive plate	37.5
Amperes per positive plate	7.5

(b) Regular or high type "B" cells.

Ampere hours per positive plate	18.75
Amperes per positive plate	3.75

(c) Regular "G" type cells.

Ampere hours per positive plate	25.0
Amperes per positive plate	7.5

13. The numeral following the letter designates the number of positive plates, *i.e.*,

A-6, 6 positive plates.
B-4, 4 positive plates.

Installation.

14. The battery housing must be well ventilated, lighted and as dry as practicable.

15. Inside of housing should contain no exposed wood, or metal other than iron or steel. If this is not practicable, such exposed parts must be protected by a film of rosin-vaseline compound or at least two coats of alkali-proof paint.

16. Floor of battery room must be sloped to provide proper drainage.

17. Battery must be supported on wooden racks, pegs or shelves of sufficient strength to prevent sagging; or be placed on floor of battery box. They must be so arranged to permit access for inspection, cleaning or for the removal of any cell.

18. Contact surfaces of connectors, jumper lugs and cell poles must be clean to insure good electrical connection.

19. The connector and jumper lugs over the cell poles must be tightened by screwing down the pole nuts. All cell tops and exposed copper must be covered with film of rosin-vaseline compound.

20. Charging circuit wires to the battery terminals must be connected with the positive wire of the charging circuit connected to the positive terminal. Polarity of charging circuit must be determined by meter test.

21. A permanent number must be assigned to each cell, preferably painted or stenciled thereon.

22. Connections must be inspected carefully to insure that they are tight and properly made.

Instruments.

23. Thermometers and hydrometers of approved design and graduation must be used for temperature and specific gravity readings. They must be thoroughly cleaned before using.

Placing in service.

24. New cells must be examined and any spillage replaced with refill electrolyte. Spillage will be indicated by a discoloration of the packing material.

25. New battery, before putting in service, must be charged as follows:

(a) If less than 30 days have elapsed since battery was shipped from the factory, or since it was fully charged, it should be charged at normal rate until it shows a voltage of approximately 1.8 volts per cell for 30 minutes.

(b) If more than 30 days have elapsed since battery was shipped from the factory, or since it was fully charged, it should be discharged at normal rate to 0.5 volt per cell, short circuited from 2 to 4 hours and charged for 12 hours at normal rate.

Maintenance.

26. All connections must be kept clean and tight. A loose or dirty contact will cause excessive heating, also drop in voltage.

27. Trays and battery compartments must be kept dry. Care must be taken that dirt and other foreign substances do not collect at the

bottom or between the cells. A steam or air blast will be found most satisfactory for cleaning. Cell tops must be protected from rusting by a film of rosin-vaseline compound. Exposed terminal poles must be kept clean and free from rust. When required, they must be polished with fine sandpaper, then wiped with a very slightly greasy cloth. Jumper lugs must be handled in the same way.

28. Vents and valves in filling aperture must be kept clean and free from obstruction, to allow gas to escape; otherwise when gas is generated, due to charging, container may be damaged.

29. Cells must occasionally be removed from trays to permit thorough inspection, cleaning and painting.

30. Cells must be thoroughly inspected for defects that may cause leakage. Grease, dirt and incrustations must be removed from cells and trays. Incrustations may be removed by warm water or wet steam. After being thoroughly cleaned and free from moisture, they must be recoated with an alkaline-proof insulating paint, either with a brush or by dipping.

31. Before reassembling, all terminals, connectors and jumper lugs must be clean, and cells, trays and compartments dry before replacing.

32. At least ¼ inch space must be maintained between adjacent cells or trays.

33. Exposed brass, lead or copper battery connections must be kept covered with rosin-vaseline compound.

34. Battery supports must be kept coated with alkali-proof paint.

35. Defective containers must not be left in service.

36. Cells showing defects must be taken out of service and held for instructions from ....

37. Care must be exercised to avoid dropping foreign matter in cells and should any foreign matter be found in cells, steps must be taken to remove same at once.

38. Water of electrolyte is depleted through gassing that occurs during the charge. Add distilled water to cells often enough to maintain solution levels at recommended height. Distilled water from approved containers only must be used.

39. Approved containers for distilled water and electrolyte are:
   (a) Glass.
   (b) Porcelain or glazed earthenware.
   (c) Enameled or agate ware (free from chipping).
   (d) Rubber.

40. The height of electrolyte must be in accordance with printed instructions accompanying battery. If filled too high, electrolyte will be forced out during charge. If not filled high enough, capacity of cells will be reduced.

41. The height of electrolyte can be determined by the use of a glass tube not less than 3/16 inch inside diameter. The end of the tube must be straight cut. Insert one end in cell until the top plates are touched. Close the upper end with the finger and withdraw the tube. The height of the liquid in the tube will indicate the height of electrolyte above the plates.

42. Electrolyte must be handled carefully as it is injurious to person, clothing and other foreign matter.

43. To avoid injury caused by electrolyte coming in contact with person or clothing, it should be immediately neutralized with a weak acid such as a 5 per cent acetic acid solution or commercial vinegar, or in the absence of these acids plenty of water must be used and then a vegetable oil, such as olive, linseed or cotton seed oil, or an animal oil such as lard or fish oil. Mineral oil is not of much use as it will not saponify and, therefore, will not combine with the potash electrolyte as will the vegetable or animal oils, but may be used in the absence of these to ease any burns, after plenty of water and the weak acids mentioned above have been used. Should any potash or soda electrolyte get in the eyes or mouth, use pure olive or cotton seed oil.

44. The accurate specific gravity of electrolyte is indicated only when it is at the proper level.

45. The maximum specific gravity of electrolyte in cells varies from 1.225 to 1.230. To correct to normal temperature (60 degrees Fahrenheit), subtract one point (0.001 specific gravity) for each 4 degrees Fahrenheit below 60 degrees Fahrenheit and add one point for each 4 degrees Fahrenheit above 60 degrees Fahrenheit; for example, electrolyte which is 1.226 at 56 degrees Fahrenheit and 1.224 at 64 degrees Fahrenheit will be 1.225 at 60 degrees Fahrenheit.

46. When replacing losses due to evaporation, water must be added at beginning of charge.

47. The use of an electric filling outfit equipped with bell insures the proper watering and saves labor and trouble.

48. Electric filler must be tested before using by making metallic connection between metal collar and tip of nozzle. If bell does not ring, trouble should be remedied before filler is used.

49. When electric filler is used, tank must be perfectly clean, then filled with distilled water. When gravity feed is used, tank should be a sufficient height above top of cells to allow proper flow of water. Insert the nozzle into the cell. With electrolyte at proper height, bell will ring. When bell rings, stop the flow and remove nozzle from cell. Care should be taken not to break rubber insulation on the nozzle as it is liable to cause short circuit. Never use filler for renewing electrolyte.

50. Proper ventilation must be maintained and housing kept neat, clean and dry.

51. Temperature of battery housing should be maintained as near as practicable to 70 degrees Fahrenheit and should not be allowed to exceed 115 degrees Fahrenheit. Battery must be shielded from direct sun-rays.

52. Care must be exercised in handling cells to prevent spilling of electrolyte or short circuiting while in transit.

53. Carrying cases and handles of cells must be kept in good condition so as to prevent injury while handling cells.

54. Metal tape or wire must not be used to attach shipping tags to cells.

55. Connectors on cells must not be used for any other purpose than that intended.

Method of charging.

56. The following methods are used for charging storage batteries: Floating and non-floating.

57. Floating method provides for charging rate at a constant potential. Non-floating method provides for charging at normal rate, or a tapering rate.

58. The rate of charge by the floating method is that necessary to maintain battery in fully charged condition; a voltage of between 1.4 and 1.5 per cell, but not gassing continually.

59. The rate of charge by the non-floating normal rate method, is that rate by which the battery would be discharged, in a five-hour period.

60. The initial rate of charge by the non-floating tapering method should be such that (due to the rise in cell voltage as the charge progresses) the current will be automatically reduced to a point no higher than normal rate when temperature of electrolyte reaches 115 degrees Fahrenheit.

Operation.

61. Batteries must not be repeatedly over or undercharged.

62. The voltage of the charging source must be sufficiently greater than the battery voltage to cause the proper charging current to flow in the circuit.

63. Two or more sets of batteries may be charged together, either in series or multiple, provided the charging rate of each is properly regulated and is within the limits of the charging unit.

64. The prescribed method of charging must not be changed, except on authority of ....

65. The total charge given a battery should be approximately 25 per cent greater than the previous discharge. This should always apply except:

(a) When capacity treament and test are being made.

(b) When solution is being renewed.

66. Specific gravity tests must be taken at least once a year.

The following directions must be observed:

(a) Electrolyte must be at its proper height.

(b) The cell must then be fully charged.

(c) At least ½ hour must be allowed to elapse after the end of the charge before taking reading.

(d) The temperature of electrolyte must be brought to 60 degrees Fahrenheit or corrections made. (See Instruction 45.)

67. Electrolyte must be renewed:

(a) When specific gravity is 1.160 or less at 60 degrees Fahrenheit, test being made as per Instruction 66-a.

(b) When cells fail to develop capacity after being given the following test cycles:

1. Discharge at normal rate to zero voltage (when the current can no longer be kept up, either reverse the battery on the line with sufficient resistance in series, or connect in another more nearly charged battery in series—then continue the discharge). It is of prime importance that the rate be kept at normal throughout.

2. Then short circuit the battery in groups of not more than five cells for at least 2 hours.

3. Charge at normal rate for 15 hours for "A" and "B" types and 10 hours for "G" type.

4. Discharge at normal rate to approximately 1.0 to 0.9 volt per cell.

5. Charge at normal rate for 7 hours for "A" and "B" types and 4¾ hours for "G" type.

6. Discharge at normal rate to approximately 1.0 to 0.9 volt per cell, the capacity of the cells to be determined by this test. If the cells do not respond noticeably to this treatment, and the electrolyte is still above the low limit of 1.160, there is probably marked contamination due to the use of impure water, etc., and the electrolyte should be renewed.

(c) When the specific gravity has reached approximately the low limit of 1.160 the new solution should be standard renewal electrolyte.

(d) When the specific gravity is appreciably above the low limit of 1.160, the solution should be standard refill electrolyte.

68. Hydrometers or other utensils that have been previously used for other purposes must not be used in testing and handling alkaline electrolyte as it is injurious to the battery.

69. Surplus stock of electrolyte must be kept in clean air-tight approved containers.

70. Cells must be totally discharged and the battery short circuited in groups of not more than five cells for not less than 2 hours before old electrolyte is removed. At no time must more than five cells be short circuited in series and the voltage at the time of short circuiting must not exceed 0.5 volt per cell.

71. Old electrolyte must not be removed until new electrolyte is on hand. Where more than two trays are in service, it is best to complete the whole operation of changing electrolyte of not more than two trays at a time, as soon as the whole battery has completed the short circuit period, so that the cells will be empty only just long enough for a thorough outside cleaning.

72. Electrolyte other than that recommended by manufacturer must not be used in this type of cell.

73. When electrolyte is to be renewed, cells must first be discharged at the normal rate to approximately 0.5 volt per cell, and then battery short circuited in groups of not more than five cells for 2 hours. Pour out about one-half of solution into a receptacle. Shake cell vigorously and empty, and continue until cell is entirely clean of any sediment. Use rubber stopper in filler opening to avoid sloppage of electrolyte when rinsing cell.

74. Only exhausted electrolyte must be used to rinse out cells. In a discharged condition the plates have a tendency to absorb water and when placed on charge, water would be driven into the solution, thereby decreasing the specific gravity.

75. After cell has been cleaned, new electrolyte must immediately be placed in cell by means of a glass or enamelware funnel, or directly from the drum by means of a rubber tube.

76. After cells are filled with new electrolyte, they must be charged at normal rate for 12 hours.

77. Filler caps must be kept closed except when it is necessary to open them to fill cells, etc.

78. Cells may be discharged to zero voltage without harmful effect, but in regular operation must not be discharged below 1 volt.

79. A cell may be considered fully charged when normal current, temperature, etc., prevail when the voltage remains practically constant at about 1.8 volts.

80. Cells may be charged at a higher rate than normal, during brief periods of idleness, provided the temperature of electrolyte does not exceed 115 degrees Fahrenheit. Frothing at the filler open-

ing is an indication that the higher rate has been carried too far (if the electrolyte is of the proper height) and the high rate must be discontinued at once.

81. If cells, operating on low rate of discharge, become sluggish they should be discharged at normal rate to approximately 0.5 volt per cell and then short circuited for 2 to 4 hours, followed by a charge of 12 hours at normal rate, this treatment to be given only when operation of battery indicates sluggishness.

82. Where there is ample ventilation and no possibility of collection of explosive gases in the housing, short circuiting may be accomplished by closing the circuit close to the battery; otherwise, point of closing short circuit must be outside the housing.

83. A.R.A. Sig. Sec. Forms 7000 and 7001 should be used as required for recording readings or inspections.

Batteries out of service.

84. Cells taken out of service for a period to exceed two months must be stored. Cells that are to be stored must be discharged at normal rate to 0.5 volt per cell, then short circuited. When the cells are out of service, they must be kept in a dry place. Care must be exercised to see that electrolyte does not fall below top of plates.

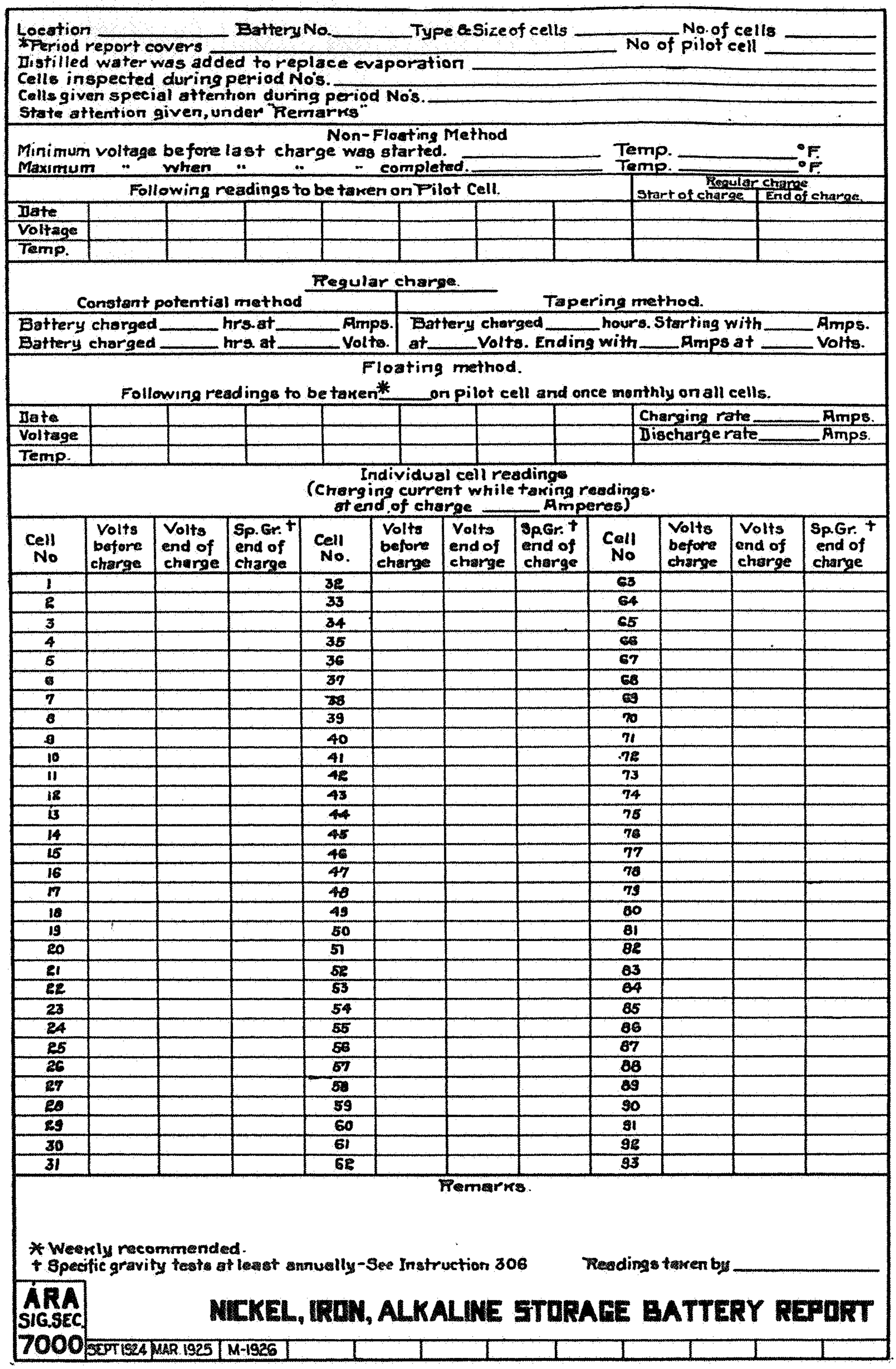
85. Before restoring a cell to service after having been stored in a completely discharged condition, it must be given a charge of 12 hours at normal rate, with solution at the proper level.

Charging.

In all storage battery installations it is very essential that means are provided for the proper charging of them.

Ordinarily an alternating current supply is available, but as the battery must be charged by direct current it is necessary to provide a means of changing or converting the alternating current to direct current.

Various schemes are available, but those generally used in signal work are grouped under the following: Mercury arc, vibrating, electrolytic, copper-oxide rectifiers, and motor driven generator sets. An explanation will be made of the five schemes in a subsequent chapter.



Location ________ Battery No. ________ Type & Size of cells ________ No. of cells ________

*Period report covers ________ No of pilot cell ________

Distilled water was added to replace evaporation ________

Cells inspected during period No's. ________

Cells given special attention during period No's. ________

State attention given, under "Remarks"

Non-Floating Method

Minimum voltage before last charge was started. ________ Temp. ________ °F.

Maximum " when " " " completed. ________ Temp. ________ °F.

Following readings to be taken on Pilot Cell.								Regular charge	
								Start of charge	End of charge
Date									
Voltage									
Temp.									

Regular charge.

Constant potential method	Tapering method.
Battery charged ______ hrs. at ______ Amps. Battery charged ______ hrs. at ______ Volts.	Battery charged ______ hours. Starting with ______ Amps. at ______ Volts. Ending with ______ Amps at ______ Volts.

Floating method.

Following readings to be taken* ______ on pilot cell and once monthly on all cells.

Date								Charging rate ______ Amps.
Voltage								Discharge rate ______ Amps.
Temp.								

Individual cell readings
(Charging current while taking readings at end of charge ______ Amperes)

Cell No	Volts before charge	Volts end of charge	Sp. Gr. † end of charge	Cell No.	Volts before charge	Volts end of charge	Sp. Gr. † end of charge	Cell No	Volts before charge	Volts end of charge	Sp. Gr. † end of charge
1				32				63			
2				33				64			
3				34				65			
4				35				66			
5				36				67			
6				37				68			
7				38				69			
8				39				70			
9				40				71			
10				41				72			
11				42				73			
12				43				74			
13				44				75			
14				45				76			
15				46				77			
16				47				78			
17				48				79			
18				49				80			
19				50				81			
20				51				82			
21				52				83			
22				53				84			
23				54				85			
24				55				86			
25				56				87			
26				57				88			
27				58				89			
28				59				90			
29				60				91			
30				61				92			
31				62				93			

Remarks.

* Weekly recommended.

† Specific gravity tests at least annually—See Instruction 306

Readings taken by ________

ARA
SIG. SEC.
7000

NICKEL, IRON, ALKALINE STORAGE BATTERY REPORT

SEPT 1924 | MAR. 1925 | M-1926

Location_______________ Battery No.____________ Type & Size of Cells______
No. of Cells__________ No. of Pilot Cell_____________

Battery charged______hrs. at_____Amperes constant current.
Specific Gravity of Pilot Cell______Temp.____°F. (One half hour after end of charge)

Discharge at Constant Current

Time	Hrs.	Amps.	A.H.	Voltage Individual Cells 1	2	3	4	5	6	7	8	9	10	11	12	13

Voltage Individual Cells

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

* See Instruction 307(b). Readings taken by____________________

ARA
SIG. SEC.
7001

NICKEL, IRON, ALKALINE STORAGE BATTERY CAPACITY TEST *

SEPT. 1924 M-1926

American Railway Signaling Principles and Practices

QUESTIONS ON

Chapter V—BATTERIES

QUESTIONS ON CHAPTER V—BATTERIES

1. How do batteries in a signal system compare with engines used on trains?

2. Into what general classes are batteries divided?

3. What are the principal types of primary batteries used?

4. What are the types of secondary battery?

5. What usually determines which class and type is to be used?

6. In what service is primary battery ordinarily used?

7. For what service would the secondary or storage battery generally be used?

Method of connecting.

8. Name the general arrangements for connecting and operating batteries.

Series.

9. Where is the series connection generally used?

10. Describe the method of connecting series cells.

11. Draw a diagram of the series connection.

Multiple.

12. Where is the multiple connection largely used?

13. Why is the multiple connection used?

14. What effect will a broken jar or connection have when cells are connected in multiple?

15. Describe the multiple connection.

16. Draw a diagram of the multiple connection.

Multiple-series.

17. Where is the multiple-series connection used?

18. Why is the multiple-series connection used?

19. Describe the multiple-series connection.

20. Draw a diagram of the multiple-series connection.

Series-multiple.

21. Where is the series-multiple connection occasionally used?

22. Describe the series-multiple connection.

23. Draw a diagram of the series-multiple connection.

24. What does the short heavy line used in Figs. 1, 2, 3 and 4 designate?

25. What does the long light line used in Figs. 1, 2, 3 and 4 designate?

26. Outside of the signal field, do the lines always have this same designation?

Elements.

27. What are the elements of a cell?

28. What is the negative element called?

29. When a cell is on discharge, does the current leave or return at the cathode?

30. What is the depolarizing element and of what is it composed?

31. What is the positive element of a cell?

32. When a cell is on discharge, does the current leave or return at the anode?

33. Of what is the anode of a primary cell composed?

34. The side of the cell that is commonly called positive and to which is connected the positive terminal, is chemically what element?

35. In practice, is the polarity of the elements (anode and cathode) generally regarded?

36. Disregarding the anode and cathode, which is considered the positive and which the negative side of the primary cell?

Primary Batteries

Definition.

37. Define a primary cell.

Polarization.

38. What is polarization?

39. What effect do bubbles have on the flow of current between the electrodes?

Local action.

40. What causes local action?

41. What lessens local action?

42. How is amalgamation accomplished?

43. When zinc is amalgamated, how in a large measure is it protected from local action?

Gravity Cells

44. Of what does a gravity cell consist?

45. Where is the copper plate placed and with what is it surrounded?

46. How is the terminal connection to the opper plate for the circuit formed?

47. How and in what solution is the zinc placed?

48. How is the zinc equipped for terminal connection?

49. What causes the copper sulphate solution to remain at the bottom?

50. Does the copper sulphate remain entirely separate from the zinc sulphate?

51. What is the effect of the heavier solution around the copper plate?

Inspection of material prior to installation.

52. How must jars be handled and how must it be ascertained if any are cracked?

53. What defects in the glass or inside of jars prohibit their use?

54. When setting up or renewing cells, what substances must jars not be placed on and on what substance may they be placed?

55. Upon receipt of material, what examination must be made of binding post and posts surrounding hanger wires?

56. Where must zincs with broken binding posts not be used?

57. In what condition must riveted connections be and what defects in insulated wire prohibit its use?

58. Copper sulphate (blue vitriol) must be free from what substances? What is the maximum size that may be used? May it be used if powdered?

59. What must be done with defective material?

Setting up new cells.

60. How must battery copper be placed in jar?

61. How much blue vitriol must be used and where must it be placed?

62. Where must zinc be placed and what must be done with hanger wires?

63. How far does this bring the zinc from the top of the copper?

64. How must hanger wires be bent in relation to top of jar?

65. Where obtainable, what kind of water must be used and how far from the top of the zinc must jar be filled?

66. If zinc sulphate (top solution of old cell) is available, how much must be added and to what height above the zinc must it be brought when cleaning one cell?

67. When cleaning all cells, how much zinc sulphate must be used and how high above zinc must solution be brought?

68. If zinc sulphate is not available, how high must water be brought and what action taken before placing cells in service?

69. Gravity must not be below how many degrees on the hydrometer (Baume graduated 10 degrees to 40 degrees) before using new or cleaned cell?

70. What must be the condition of battery receptacle and contacts before making connections?

71. What under the thumb screw determines that the connection is tight?

72. What must be done with zinc hanger wires and connectors to prevent short circuiting or grounding battery in a well or chute?

Taking cells out of circuits. (Connected in series.)

73. To remove a cell, other than an end cell, from a battery, how must jumper be arranged?

74. To remove an end cell from battery, how must jumper be arranged?

75. How many cells is it permissible to remove at one time and only by the use of what?

76. After replacing cell, what must be done with the jumper?

77. What is the maximum per cent of number of cells that should be renewed at one time?

Taking cells out of circuits. (Connected in multiple.)

78. May a cell, to be renewed, be taken out of a multiple-connected set without the use of a jumper?

79. May cells connected in series with themselves and in multiple with storage battery be renewed without using jumper?

80. How many cells of a track battery may be renewed at any one time?

Cleaning cells.

81. How must zinc be handled and cleaned?

82. What must be done with zinc solution?

83. What precaution must be used in disposing of zinc solution?

84. How must copper sulphate be handled when cleaning?

85. How must copper element be handled?

86. What weight or size of copper element must not be used again?

87. How must jars be cleaned?

88. May water in which zincs, sulphate, coppers or jars have been cleaned be used in batteries?

89. What minimum weight zinc must not be used on a track cell renewal?

90. How many full size zincs must be installed in each track battery at time track cells are renewed?

Necessary attention during life of cells.

91. How often must zincs in all batteries be cleaned?

92. What degree, on gravity battery hydrometer, must specific gravity never be allowed to get above?

93. Between what degrees should specific gravity be kept?

94. How may specific gravity be reduced to 15 degrees?

95. How must the water be poured on the zinc?

96. How frequently must battery in track sections, where it is necessary to use three or more cells, be cleaned?

General.

97. Why must copper sulphate not be added to a cell in service?

98. Is it permissable to allow oil to get on battery material?

99. May water taken from a stagnant pool be used in batteries?

100. What must be done with scrap sulphate, old coppers, copper deposit and old zincs?

101. Must copper and zinc scrap be kept separate?

102. Is it permissible to store battery material in chutes, battery wells or other damp places?

Caustic Soda Cells

Design.

103. Of what does the caustic soda cell consist?

104. To which terminal is the copper oxide electrode connected?

105. To which terminal is the amalgamated zinc electrode connected?

Electro-chemistry.

106. By what is the ampere-hour capacity of the cell fixed?

107. What is one of the ways of expressing the action within the cells?

108. How are these reactions expressed?

109. To what is the chemical action in a caustic soda cell proportioned?

110. What is required to yield a given ampere-hour capacity?

111. How may the ampere-hour capacity that has been delivered by any cell be determined?

112. In what way should there be no difficulty caused by electrolyte?

113. If the amount of soda is varied, thus changing the density of the solution, by what will the irregularity thus caused be indicated?

114. What three forms of crystallization occur under certain conditions in the use of caustic soda cells?

115. Where do the granular crystals form and where do they usually start?

116. What does the formation of these crystals indicate?

117. When do the crystals form?

118. What will accelerate this phenomena?

119. With what and where does the fine white powder precipitate form?

120. What does the precipitation of this powder indicate?

121. When this precipitation occurs before the exhaustion of the zinc and copper oxide electrodes, what does it indicate?

122. What intensifies this condition?

123. Where do the long, needle-like crystals usually form?

124. What does the formation of these crystals usually indicate?

125. When is the formation most likely to occur?

126. When will these crystals dissolve or go back into the solution?

Housing.

127. What must housing provide protection against and how must it be kept?

128. Where concrete boxes are used, how deep in the ground should the bottom of the box be when installed?

129. What must be done to prevent flooding of housings?

130. How must cells be set and arranged?

Materials.

131. Of what (except water) does a complete cell consist?
132. When should units be unpacked?
133. How must packages containing cells or renewals be kept?
134. Caustic soda damaged by what exposure must not be used?

Setting up new caustic cells and renewals.

135. What must be determined by checking material?
136. What must be removed from assembled elements?
137. For what must assembled elements be examined?
138. What electrodes must not be used?
139. Must jars and covers be thoroughly cleaned?
140. What must be done with material unfit for use?
141. What kind of water must be used for mixing solution?
142. What water must not be used for mixing solution?
143. Approximately how full must jars be filled with water?
144. How must caustic soda be added and stirred?
145. What amount of caustic soda must be used?
146. Why must care be exercised in mixing and handling the solution?
147. If accidentally splashed on the skin or clothing, what must be done?
148. How may the skin be protected?
149. How must assembled elements be fastened to cover?
150. What must then be done with the assembled elements?
151. To what height in jar must water be added?
152. By what process must the solution then be thoroughly stirred?
153. What amount and kind of oil (except when oil is self-contained) must be added to top of solution?
154. When must elements be inserted in solution if oil is self-contained in elements or soda?
155. When must cells be connected up if elements are placed in solution while hot?
156. When not practicable to operate apparatus to cause immediate discharge, what must be done with the battery?
157. How must connections be to assure good electrical contact?
158. How must cells in circuit be connected?
159. What must be secured before changes in arrangement of connections can be made?

Renewal of exhausted cells.

160. What form must be used in recording the performance of primary batteries?
161. Except when necessary to make replacement, due to defect, how many cells of a series-connected battery should be renewed at the same time?
162. When renewing or installing cells, what must be done to avoid interruptions to traffic?

163. In discarding solution, cans and bottles, where may they be disposed?

Inspection.

164. How often must batteries be examined?
165. When should voltage readings of battery be taken to check its condition?
166. In what condition must jars and covers be kept?
167. What must be done with broken or cracked jars and covers?
168. How must connections be kept?
169. What must be done when any unusual appearance or defect of the elements or solution is found?

Disposition of exhausted elements.

170. How must exhausted elements be handled?
171. Why must exhausted elements be kept dry?
172. How must packing cases be labeled?

Dry Cells

Theory.

173. How may the relation of the principal parts of the cell to one another be given?
174. What are the generally accepted conclusions of the chemical reactions during service?

Uses.

175. Do dry cells differ in electrical characteristics?
176. How can the most efficient service of dry cells be obtained?
177. Upon what does the amount of electricity which can be obtained from a dry cell depend?
178. What is the result if the current taken from a dry cell is too small?
179. What is the result if the current is too great?
180. Why are the numerous types of unit cells or battery required?

Service.

181. Of what design must cells be for service?

Ignition and heavy-service cells.

182. For what service are the ignition and heavy-service cells designed?
183. What is the approximate open circuit voltage of these cells?
184. What should the current on short circuit of new cells be on the average?
185. What should the minimum current on short circuit of new cells be?
186. For what service are these cells intended?

General purpose cells.

187. How do the general purpose cells compare with other cells?

188. For what service are they intended?

189. How does the resistance compare with ignition cells and the lasting qualities with the telephone cell?

190. How does the open circuit voltage compare with the ignition cell?

191. How does the short circuit current compare with the ignition cell?

Telephone cells.

192. What are the telephone cells commonly called?

193. For what service are they intended?

194. When used for such service, how will they last compared to the ignition and general purpose cells?

195. What is the approximate open circuit voltage of the telephone cell?

196. How would the current on short circuit compare with the other types of cells?

197. Why is the current relatively low?

Testing.

Open circuit voltage test.

198. What usually is the voltage of an unused dry cell?

199. If higher voltages are found, do they indicate superiority of cell?

200. What may lower voltages than 1.45 volts indicate?

201. What do abnormally low values indicate?

202. What is the best test available for picking defective cell in a shipment?

203. What is the requirement of the voltmeter that should be used for making this test?

Short circuit current test.

204. For what purpose is the short circuit current test of value?

205. Why should the short circuit current reading not be relied upon in choosing cells for light duty?

206. Does the short circuit current test give an indication of the service capacity of different brands of cells?

207. What kind of an ammeter must be used for testing?

208. What value should the resistance of the lead wires and shunt of the ammeter have?

209. What movement of the swing of the needle is taken as the short circuit current of the cell?

210. How do the results of tests vary?

211. At what temperature should cells be when tests are made?

212. What must be done with defective cells?

Placing in service.

213. When must cells be placed in service and for what period of time may they be kept in storage?

214. What must be used for connections between cells and in what condition must the ends connected to the binding posts be?

Maintenance.

215. In what condition must binding posts be kept?

Storage or service.

216. Where should cells be placed for storage or service?

217. What must be done so that zinc sides and/or binding posts will not touch adjoining cell?

Short circuit.

218. Where must tools or metal not be placed when around cells?

219. What between the positive and negative terminals must be avoided?

Temperature.

220. Is the effect of temperature on the open circuit voltage of dry cells great or small? For most purposes, can this be neglected?

221. In what two ways does heat produce deterioration of dry cells?

222. How may leakage be observed?

223. For heavy service, is a moderately high temperature desirable?

224. For light service, is a low temperature desirable?

Storage Batteries

Definition.

225. Define a storage cell.

226. Describe a secondary cell.

General.

227. What types of batteries are usually used in railway signaling?

Lead Acid Type

228. What are the essential parts to make up a complete lead acid type cell?

Plates.

229. How are the plates connected and arranged?

230. Are positive plates all of the same type?

231. Describe the various types.

232. Do negative plates vary in type?

233. Describe the various types.

234. In the pasted type of plates, what purpose do the grids serve?
235. From what are pastes made?
236. What are the pastes most commonly used made from?
237. The paste has the consistency of what?
238. To what is the paste applied?
239. Subsequently, how and into what is the paste then converted?
240. What is considered the most secret part of all the manufacturing process?
241. To what must the formula for mixing the paste be adapted?
242. How do Plante plates differ essentially from pasted plates?
243. How are the active materials of the Plante plates obtained?

Separators.

244. How are the adjacent plates separated to prevent their being short circuited?
245. Where the wood and rubber sheets are used, how are they placed?

Jars.

246. Of what material are jars made?
247. Where the rubber jars are used, what is the minimum thickness of the material?
248. How is the bottom of the jar reinforced?
249. Upon what is the size of the rubber jar dependent?
250. Of what shape are glass jars?
251. What kind of glass is used?
252. What is the approximate thickness of the glass?
253. Upon what is the size of the glass jar dependent?
254. On what is the capacity of the glass jar shown and how?

Cell covers.

255. Of what composition are covers generally, and how are they arranged?

Electrolyte.

256. What electrolyte is used and what is its approximate specific gravity?
257. If necessary to use water to dilute the acid, what kind should be used and from what should it be free?

Capacity.

258. How is the capacity of the various cells used expressed?
259. What are the sizes generally used for signal purposes?
260. What does the particular size depend upon?
261. What sizes, in ampere hours, do the rubber jars come in? What jar is used for the other sizes?

Theory of chemical action.

262. In a fully charged cell, what is the active material of the negative plates and by what chemical symbol is it represented?

263. In a fully charged cell, what is the active material of the positive plate and by what chemical symbol is it represented?

264. In what condition is the active material of both plates in a fully charged cell?

265. Of what mixture is electrolyte and in what proportion is it mixed?

266. What is the chemical symbol for sulphuric acid?

267. What is the chemical symbol for water?

268. For batteries used in signaling, in what proportion is sulphuric acid and water usually mixed?

269. What specific gravity has concentrated sulphuric acid?

270. What specific gravity has water?

271. If it is desired to mix acid and water to obtain a specific gravity of 1.210, what would be the proportion?

272. Indicate by equation the chemical action which takes place within the cell during charge and discharge.

273. Define the symbols used in the equation of chemical action.

Information.

274. What are the general types of lead acid type storage batteries used in railway signaling?

275. What, primarily, is a storage battery?

276. What are the fundamentals of storage batteries?

277. What is the process of putting energy into a battery termed?

278. What is the process of taking energy out of a battery termed?

279. What action takes place between the acid and the plates during discharge and charge?

280. When all the acid is driven out of the plates, what is the condition of the charge.

281. The strength of electrolyte is measured in terms of what?

282. Does the specific gravity of electrolyte change during charge and discharge? What does it indicate?

283. How does specific gravity and voltage of cells vary during charge?

284. How are lead acid storage cells distinguished?

285. How is the positive pole designated?

286. How is the negative pole designated?

287. What kind of current must be supplied at battery terminals for charging purposes?

Installation.

288. How should open type battery be housed?

289. What should be the condition of the housing?

290. Should inside of housing contain exposed metal other than lead?

291. If this is not practicable and inside of housing contains exposed metal other than lead, how should it be protected?

292. Why should floor of battery room be sloped?

293. How must battery be supported?

294. How must the cells be arranged?

295. With what must sand trays be filled?

296. How must they be spaced on support?

297. How must jars be placed on trays?

298. What should be done to contact surfaces of connecting straps and elements to insure good electrical connection?

299. How must elements be assembled and placed in jar?

300. With what must connecting straps be bolted together?

301. With what must rows of cells be connected?

302. With what should all bolt connections and exposed copper be covered?

303. To what must the positive wire of the charging circuit be connected?

304. How must the polarity of the charging circuit be determined?

305. How should one cell in each battery be designated and where should this cell preferably be located?

306. What should be assigned to each cell or container?

307. At this stage of installation, what must be inspected and of what must you be assured?

308. How should wood separators be assembled and installed?

309. In what condition are wood separators, which have been given special treatment, shipped?

310. If there is any delay in setting up battery, where should veneers and dowels be left and how kept?

311. How must wood separators and dowels carried on hand be kept?

312. When should cells be filled with electrolyte?

313. What is the proper height for electrolyte in cells?

314. What should be the specific gravity of electrolyte?

315. When should the initial charge be started?

316. What should be done with unfilled assembled cells before placing in service?

Instruments.

317. What instruments should be used where practicable?

Initial charge.

318. How long should the initial charge continue after maximum voltage and gravity has been reached?

319. How many hours, and at what rate, should be required for battery to reach maximum voltage and gravity?

320. If temperature of electrolyte exceeds 110 degrees Fahrenheit, what should be done?

321. What charging current value should be maintained throughout the charge?

322. What test should be made immediately after starting the charge to insure that all the connections are properly made and that no short circuits exist?

323. What readings should be taken at one-hour intervals during the course of the charge?

324. How should voltage and specific gravity vary as the charge progresses?

325. How long should charge continue?

326. What should be the condition of all the cells at the end of the charge?

327. What should be done if, at the end of the charge, the electrolyte is not at 1.210 specific gravity at 70 degrees Fahrenheit?

328. How should the specific gravity of electrolyte be raised?

329. How should the specific gravity of electrolyte be lowered?

330. What water should be used in batteries?

331. Should an open flame be permitted near battery?

332. What form should be used for reporting readings?

Maintenance.

333. In what condition must all connections be kept?

334. What will a loose or dirty contact cause?

335. In what condition must jars or containers be kept?

336. In what condition must trays and supports be kept?

337. With what must all exposed brass or copper battery connections be kept covered?

338. With what must battery supports be kept coated?

339. What must be done with defective jars or containers?

340. What must be done with cells showing defects?

341. What must be exercised to avoid short circuiting or dropping foreign matter in cells?

342. Should any foreign matter be found in cells, what steps must be taken?

343. How is water in electrolyte depleted and with what must it be replaced?

344. At what level must electrolyte be maintained?

345. What does exposure of top of plates to air cause and what will be seriously injured thereby?

346. In what kind of containers must electrolyte or water for battery use be furnished and how must it be kept?

347. What kind of vessels only must be used in handling electrolyte or water for storage battery use?

348. When only is the accurate specific gravity of electrolyte indicated?

349. Does temperature of electrolyte affect its specific gravity?

350. How is specific gravity corrected to normal temperature?

351. When replacing losses due to evaporation, when must water be added?

352. What must be obtained before acid is added to raise specific gravity of electrolyte?

353. What must be the specific gravity of electrolyte used in replacing losses due to cracked or broken jars?

354. How should electrolyte be handled and why?

355. What should be done to avoid injury caused by electrolyte coming in contact with clothing?

356. What solution will be found useful for washing the hands after working with electrolyte?

357. In the event of splash of electrolyte in eye, what should be done?

358. Is an open flame allowed in battery housing?

359. In what condition must battery housing be kept?

360. What temperature should be maintained in battery housing?

361. Must battery be shielded from direct sun-rays?

362. What must be exercised in handling portable cells to prevent spilling of electrolyte or short circuiting while in transit?

363. In what condition must carrying cases and handles for portable cells be kept?

364. What must not be used to attach shipping tags to portable cells?

365. May connectors on portable cells be used for any other purpose than that intended?

Method of charging.

366. What methods are used for charging storage batteries?

367. For what does floating method provide?

368. For what does non-floating method provide?

369. What is the rate of charge by the floating method?

370. What is the voltage of a cell in fully charged condition?

371. What is the rate of charge by the non-floating normal rate method?

372. What should be the initial rate of charge by the non-floating tapering method?

Operation—All types.

373. May batteries be repeatedly over or undercharged?

374. How must the voltage of the charging source be to cause the proper charging current to flow in the circuit?

375. Under what condition may two or more sets of batteries be charged together?

376. What must be obtained if cells are to be charged at higher rate than normal? Is this permissible after cells are gassing?

377. If temperature of cells rises to 115 degrees Fahrenheit while being charged, what must be done?

378. What does excessive gassing cause?

379. May the prescribed method of charging be changed?

380. What should be done if battery has been completely discharged?

381. With what must electrolyte lost, due to spillage, be replaced?

382. How will spillage be shown?

383. What must be done when adding water to electrolyte before taking hydrometer reading?

384. What will result from neglect of this precaution?

385. What must be done when adding water to electrolyte of cell at temperature below freezing?

386. How must sulphuric acid and water be mixed, and why?

387. Why should water never be poured in acid?

388. Before putting in service batteries received in a charged condition, what should be done?

389. On batteries charged by the non-floating method, how often should the regular charge be prolonged to constitute an equalization charge?

390. What is an equalization charge?

391. Below what specific gravity or volts with current at normal rate must cells not be discharged?

392. When must cells be charged?

393. What may cause one or more cells, relative to balance of battery to show falling off in specific gravity, or voltage, deficiency in gassing or equalization charge, or color of plates markedly darker or lighter?

394. What should be done when such conditions exist?

395. By means of what must short circuit be removed? What must never be used to remove short circuit?

396. What should be done if there is doubt as to the condition of electrolyte?

397. With what should cell be flushed if all electrolyte is removed?

398. What should be done if cell fails to gas freely or specific gravity fails to rise to proper point on regular charge, after short circuit or other trouble has been remedied?

399. May thermometers, hydrometers or other utensils that have been used for other purposes be used for testing and handling sulphuric acid electrolyte?

400. Should hydrometers be free from attached gas bubbles?

401. When must specific gravity and voltage readings be taken?

402. What are the indications of sufficient regular charge?

403. May electrolyte be placed in cells before it has cooled?

404. What form should be used for recording readings or inspections?

Operation—Stationary type.

405. What method must be followed in renewing batteries:
    - (a) Dismantling and cleaning batteries, trays and supports?
    - (b) Arrangement of positive and negative groups?
    - (c) Replacement of sand trays and jars?
    - (d) Re-assembly of cells?
    - (e) Care of separators?
    - (f) Addition of electrolyte and initial charge?

406. What should be done to keep sediment from touching or short circuiting the plates?

407. When sediment has reached a point where it has to be removed, what method must be followed?

408. For what should cells be inspected just before equalization charge and what action taken to correct defects?

Batteries out of service.

409. What must be done with plates and separators in the event of jar being cracked or broken and there is no jar or electrolyte of proper specific gravity available?

410. What must be done if plates are to remain out of service more than 24 hours?

411. What is the correct specific gravity of electrolyte to use when restoring to service plates which have been temporarily out of service and stored in water?

412. How must battery be handled if use of the battery is to be entirely discontinued for a period of not longer than six months?

413. What must be the procedure if battery is to be entirely out of service for more than six months?

414. What must be the procedure when restoring cells to service where electrolyte has not been withdrawn?

415. What must be the procedure when restoring cells to service if battery has been standing without electrolyte?

Nickel, Iron, Alkaline Type

416. The make-up of a complete nickel, iron, alkaline storage cell consists of what?

Elements.

417. Of what do the positive plates consist?

418. Why is the flake nickel required?

419. How are the steel tubes made?

420. How large are the steel tubes?

421. After the tubes are filled with nickel hydrate and flakes, what is done with them?

422. Of what do the negative plates consist?

423. How are the steel pockets made and formed?

424. After the negative pockets have been filled with the black iron oxide, what is done with them?

Separators.

425. What is placed between the plates to keep them from touching?

426. What is placed to the edges of the plates to prevent their touching the containers?

Containers.

427. How are the containers made?

428. How are the single side seam tops and bottoms put on?

429. The top, in addition to the two holes through which the vertical poles from the plates pass, is provided with what?

430. Why is a valve placed in the lid?

Electrolyte.

431. What is the electrolyte?

432. What is the normal specific gravity of the electrolyte?

433. What is the low limit beyond which it is inadvisable to run the electrolyte?

434. Is it necessary to take specific gravity readings during charge and discharge?

435. How is the state of charge determined?

Assembly.

436. How are the plates assembled?

437. How is the element formed?

438. After the necessary separators, etc., are applied and the assembled element is placed in the container, how is the top put on?

439. What are the recommended capacities of cells used in signal work?

440. How are the various capacity cells designated?

441. What does the letter represent?

442. What does the figure represent?

443. How many positive tubes are there in each positive plate in the B type of plate?

444. How many sets of pockets in the negative plate?

445. How many positive tubes are there in each positive plate in the A type of plate?

446. How many sets of pockets in the negative plate?

447. At what ampere hour is the B 4 rated?

448. At what ampere hour is the A 4 rated?

449. What is the capacity of the cells dependent upon?

Chemical action.

450. What are the chemical reactions in charging this type of battery?

451. How are the oxidation and reduction performed?

452. What is the process of charging the positive plate?

453. What are the proportions of nickel to oxygen in definite oxides of nickel?

Information.

454. What is a storage battery?

455. What are the fundamentals of storage batteries?

456. What is the process of putting energy into a battery termed?

457. What is the process of taking energy out of a battery termed?

458. In what terms is the strength of electrolyte measured?

459. Does the specific gravity of electrolyte remain practically constant?

460. What causes the specific gravity in time to decrease?

461. Does the specific gravity furnish an indication of the state of charge?

462. What indicates condition of charge?

463. How may nickel, iron, alkaline storage cells be distinguished?

464. How is the positive pole designated?

465. How is the negative pole designated?

466. What kind of current must be supplied at battery terminals for charging purposes?

467. In what condition are cells shipped unless otherwise specified?

468. What is the rated ampere-hour capacity and the normal rate in amperes of any type or size of nickel, iron, alkaline battery equal to?

469. How is the number of positive plates designated?

Installation.

470. What should be the condition of the housing?

471. Should exposed wood or metal other than iron or steel be used inside of battery housing?

472. If this is not practicable and inside of housing contains exposed wood or metal other than iron or steel, how should it be protected?

473. Why should floor of battery room be sloped?

474. How must battery be supported?

475. How must the cells be arranged?

476. What must be done to connectors, jumper lugs and cell poles to insure good electrical connection?

477. How must connector and jumper lugs over cell pole be tightened?

478. How must cell tops and exposed copper be protected?

479. To what must the positive wire of the charging circuit be connected?

480. How must the polarity of the charging circuit be determined?

481. What must be assigned to each cell?

482. At this stage of installation, what must be inspected and of what must you be assured?

Instruments.

483. What instruments must be used for temperature and specific gravity readings?

484. How must they be treated before using?

Placing in service.

485. With what must spillage be replaced?

486. How will spillage be indicated?

487. How must new battery, before putting in service, be charged if less than thirty days have elapsed since battery was shipped from factory, or since it was fully charged?

488. How must new battery, before putting in service, be charged if more than thirty days have elapsed since battery was shipped from factory, or since it was fully charged?

Maintenance.

489. In what condition must all connections be kept?

490. What will a loose or dirty contact cause?

491. In what condition must trays and battery compartment be kept?

492. What will be found most satisfactory for cleaning?

493. How must cell tops be protected from rusting?

494. How and from what must exposed terminal poles and jumper lugs be kept and, when required, what else must be done?

495. In what condition must vents and valves in filling aperture be kept, and why?

496. Why must cells occasionally be removed from trays?

497. For what defects must cells be thoroughly inspected?

498. Describe the process of cleaning before recoating with an alkaline-proof insulating paint.

499. In what condition must all terminals, connectors, jumper lugs, trays and compartments be before battery is re-assembled?

500. What minimum space must be maintained between adjacent cells or trays?

501. With what must exposed brass, lead or copper battery connections be kept covered?

502. With what must battery supports be kept coated?

503. What must be done with defective containers?

504. What must be done with cells showing defects?

505. What must be exercised to avoid dropping foreign matter in cells?

506. What must be done should foreign matter be found in cells?

507. How is water of electrolyte depleted and with what must it be replaced?

508. How often must water of electrolyte depleted through gassing be replaced?

509. What kind of water must be used?

510. What are the approved containers for distilled water and electrolyte?

511. What must the height of electrolyte be in accordance with, and why?

512. How can the height of electrolyte be determined?

513. How must electrolyte be handled, and why?

514. What should be done to avoid injury caused by electrolyte coming in contact with person or clothing?

515. What should be done if any potash or soda electrolyte gets in the eye or mouth?

516. When is the accurate specific gravity of electrolyte indicated?

517. What is the maximum specific gravity of electrolyte in cells?

518. How is specific gravity corrected to normal temperature?

519. When replacing losses due to evaporation, when must water be added?

520. What outfit insures the proper watering and saves labor and trouble?

521. How must electric filler be tested before using?

522. Describe process of adding distilled water with electric filler.

523. May electric filler be used for renewing electrolyte?

524. What must be maintained and how must battery housing be kept?

525. What temperature should be maintained in battery housing?

526. Must battery be shielded from direct sun-rays?

527. What must be exercised in handling cells to prevent spilling of electrolyte or short circuiting while in transit?

528. In what condition must carrying cases and handles of cells be kept?

529. What must not be used for attaching shipping tags to cells?

530. May connectors on cells be used for any other purpose than that intended?

Method of charging.

531. What methods are used for charging storage battery?

532. For what does floating method provide?

533. For what does non-floating method provide?

534. What is the rate of charge by the floating method?

535. What is the voltage of a cell in fully charged condition?

536. What is the rate of charge by the non-floating normal rate method?

537. What should be the initial rate of charge by the non-floating tapering method?

Operation.

538. May batteries be repeatedly over or undercharged?

539. How must the voltage of the charging source be to cause the proper charging current to flow in the circuit?

540. Under what conditions may two or more sets of batteries be charged together?

541. May the prescribed method of charging be changed?

542. How much greater should the total charge be than the previous discharge?

543. Under what conditions does this not apply?

544. How often must specific gravity tests be taken?

545. What directions must be observed when taking this test?

546. At what specific gravity of electrolyte must it be renewed?

547. What other condition necessitates the renewal of electrolyte?

548. Give test cycle for restoring capacity to determine if it is necessary to renew electrolyte.

549. What new solution should be used when the specific gravity has reached the low limit of 1.160?

550. What new solution should be used when the specific gravity is appreciably above the low limit of 1.160?

551. May hydrometers or other utensils previously used for other purposes be used in testing and handling alkaline electrolyte?

552. How must surplus stock of electrolyte be kept?

553. How must cells be prepared for removing old electrolyte?

554. How many cells may be short circuited in series and what is the maximum allowable voltage per cell at time of short circuiting?

555. How must renewing of electrolyte be done to have cells empty only long enough for a thorough outside cleaning?

556. What electrolyte must be used?

557. How must battery be discharged when electrolyte is to be renewed?

558. Describe the operation of removing old electrolyte.

559. What must be used to rinse out cells and why?

560. When and how must new electrolyte be placed in a cell after the cell has been cleaned?

561. At what rate and how long must charge be after cells are filled with new electrolyte?

562. Must filler caps be kept closed?

563. May cells be discharged to zero voltage without harmful effect?

564. Below what voltage should they not be discharged in regular operation?

565. When may a cell be considered fully charged?

566. May cells be charged at a higher rate than normal?

567. What is the indication that the higher rate has been carried too far?

568. What treatment should be given cells which while operating on a low rate of discharge have become sluggish?

569. Under what condition may short circuit be applied in the battery housing and under what condition must it be applied outside?

570. What forms should be used for recording readings or inspections?

Batteries out of service.

571. What must be done with cells taken out of service for a period to exceed two months?

572. What treatment must be given cells that are to be stored?

573. What must be given a cell before restoring to service after having been stored in a completely discharged condition?