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EDUCATIONAL COURSE

PAMPHLET E-1

ELEMENTARY ELECTRICITY

PRIMARY CELLS

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The first lesson in this paper consists of......questions 1 to 9, inclusive.
The second lesson..questions 10 to 16 “
The third lesson..questions 17 to 21 “
The fourth lesson..questions 22 to 24 “
The fifth lesson..questions 25 to 30 “

These should be answered one lesson at a time.

PRIMARY CELLS.

The principal sources of current electricity with which we shall have occasion to deal are the primary battery and the dynamo. In the present paper are the descriptions of three general types of primary cells used extensively for various purposes and with which it is advisable to become familiar.

The action between different metals as used at present in our primary batteries was first detected by Galvani, an Italian, in 1786, when he was making some experiments with frogs' legs which he had supported by the spinal cord upon copper hooks fastened to a strip of iron. He noticed that the legs contracted to a considerable degree when the muscles happened to touch the iron, which indicated to him that some action must be taking place. This chance experiment led to the production of our present electrolytic cells. The name "galvanic battery" was thus originated.

A simple cell may be made by merely inserting a strip of zinc and one of copper in a jar partly filled with water and a small amount of acid, or even with salt and water for a solution. This solution in which the elements are immersed is called the *Electrolyte.* By joining the copper and zinc strips by means of a metallic conductor outside the jar, keeping the strips separated in the electrolyte, a current of electricity will be produced, and it is said to flow from the copper strip through the conductor back to the zinc. It then passes from the zinc through the electrolyte to the copper. The exact manner in which the current passes through the electrolyte is not well understood, but it is accompanied by the oxidation of the zinc which is in reality a slow burning process. At the same time hydrogen gas is formed at the copper plate, known as the negative element in this combination.

The element from which the current leaves the cell is connected to the positive binding post or terminal (+), but is the negative element or cathode, while the element through which the current enters the cell is connected to the negative binding post or terminal (—), but is the positive element or anode. In the above cell the copper forms the positive terminal and the zinc the negative terminal.

The primary cause of the flow of current in an electrolytic cell is chemical action between the electrolyte and elements known as the oxidation or combustion of the positive element. If the cell is properly designed, the amount of current which can be supplied is proportional to the amount of material consumed in the positive element.

The cell is said to Polarize when the hydrogen gas, which is formed by the chemical action, collects in bubbles upon the negative element. This gas on the negative element greatly increases the internal resistance of the cell which correspondingly reduces the current flowing and the efficiency of the cell. Means can be provided to prevent this gas formation on the negative element. This is accomplished by supplying certain chemicals known as Depolarizers which unite with the hydrogen before it collects on the negative element. The kind of Depolarizer is determined by the type of cell.

The positive and negative elements of a cell are determined by the relative intensity of the chemical action of the electrolyte upon the plates forming the elements. The more intense action takes place at the positive plate. The following table is arranged with the most positive first, although authorities differ somewhat upon the order in which the elements should appear. Their order is different in the different electrolytes.

1. Aluminum.
2. Zinc.
3. Tin.
4. Cadmium.
5. Lead.
6. Antimony.
7. Bismuth.
8. German Silver.
9. Brass.
10. Mercury.
11. Iron.
12. Steel.
13. Copper.
14. Silver.
15. Gold.
16. Carbon.
17. Platinum.
18. Iron Sulphite.
19. Manganese Dioxide.
20. Lead Peroxide.

From the above table it is then seen that any element mentioned may be taken as positive and any of those following it in the list would then be negative to that particular element, the greater voltage being secured from those farthest apart in the list. In the practical battery, however, the cost of the elements and the convenience of handling determine which are best adapted.

Different solutions are used for electrolytes, each one being especially adapted for some particular type of cell. The following is a list of compounds so used: caustic potash, caustic soda, ammonia, sulphuric acid, nitric acid, hydrochloric acid, stannous chloride, stannic chloride, iron chloride, silver nitrate, copper sulphate (blue stone), zinc sulphate, ferrous sulphate, potassium iodide, ammonium chloride (sal ammoniac), sodium chloride (common salt).

Current Direction.

In a circuit the current is said to always flow from a positive toward a negative source, thus in the external circuit of a cell that pole or terminal which would be considered as positive would be negative when considered with reference to the direction of the current flow of the internal circuit or inside the cell.

The principal reason for primary batteries not being used at the present time for large power producers is that the same power may be produced much more cheaply by means of the dynamo electric machine, which also occupies much less space and requires less attention than the primary battery.

Voltaic Action and Local Action.

There are two kinds of chemical action which take place in the electrolytic cells: (a) Voltaic Action, which occurs only when current is flowing; (b) Local Action, which exists whether or not current is flowing. The *Voltaic Action* is essential to the operation of the cell and its energy is available for maintaining the current.

Local Action takes place to a greater or less extent in all primary cells and its presence represents an absolute waste. This local action is usually caused by the presence of impurities in the elements, which are responsible for chemical action between the elements and these impurities in the presence of the electrolyte. This action continues, setting up local currents, eating away the element until the foreign substance is set free and falls to the bottom of the jar.

A means sometimes employed to remedy this trouble is to amalgamate the surface of the zinc plate with a film of liquid mercury. To do this the plate must be carefully cleaned, any grease present should be removed by the use of potash or soda and then immersed for a few moments in an acid. The acid to be used for the electrolyte will be satisfactory. This makes a very clean surface on the zinc over which the mercury spreads quickly and evenly when immersed in it. This prevents the electrolyte from attacking the zinc when current is not being drawn from the cell.

Primary cells may be divided into two general classes depending upon the service for which they are used, namely: open and closed circuit cells. The Open Circuit cells are those, which, on account of their construction and nature of the plates, are not suitable to furnish current continuously. They are designed to furnish current for short time intervals only, but these may be some time apart, like the operation of a door bell, telephone, etc. These cells must necessarily be quite free from local action, else they would literally exhaust themselves. The common dry cell is a good example. The Closed Circuit cells are designed to give continuously a constant current of uniform voltage for a considerable length of time. They must be free from polarization. Gravity, Edison and Gordon cells are all closed circuit cells. Most Telegraph circuits operate on closed circuits and necessarily employ closed circuit batteries.

Rating of Cells.

The capacity of many cells are rated in Ampere Hours, as the Gordon 300 ampere hour cell. This term has reference to the total current output which can be obtained from the action of the cell, and is based upon the current supplied and the period of time for which it can supply this current. In other words, it is the product of the current and time.

Take, for an example, a single cell on a circuit supplying 0.5 amperes continuously for 26 days. The total time this cell was operating was 624 hours. Then the product of time and current would be $624 \times 0.5 = 312$, the number of ampere hours supplied by the cell in the given time. If this had been an intermittent current, that is, not a constant current, but one used at certain intervals of say 10 minutes per hour for this same length of time, then the total time the cell would be furnishing the current would be 24×10 or 240 minutes or 4 hours per day. The total time this current 0.5 ampere was furnished would be 26×4 or 104 hours and the total current output would be 104×0.5 or 52 ampere hours.

Assuming that the cell used was of 400 ampere hour capacity, then it would last approximately 400 ÷ (4 × .5) or 200 days, a little over three months, on the circuit discharging ½ ampere for 10 minutes each hour.

The Internal Resistance of a cell is the resistance to the flow of current through the cell offered by the electrolyte. This varies in the same cell for different current outputs. Low internal resistance is desirable when large current output is required, but it is not so important if the circuit outside the cell is of comparatively high resistance. If E is the voltage of the cell on open circuit, V the voltage of the cell when the external circuit is closed, and I the current, then the internal resistance of the cell is

$$R = \frac{E - V}{I}. \qquad \text{Eq. (1).}$$

The lower the internal resistance of the cell, the greater is the total amount of energy available for the external circuit and the electrical efficiency is correspondingly increased.

The positive and negative terminals or binding posts are so named from the fact that the current in the circuit outside of the cell always flows from one terminal through the circuit and back to the cell through the second terminal. That one *from which* the current flows is always designated as *positive,* and is marked (+), while the one by which the current returns to the cell is known as the *negative,* and is marked (—).

In referring to positive or negative *elements* or *electrodes* of a cell, it is meant those parts of a cell from which and to which the current passes inside the cell. For instance: the current inside a gravity cell, shown in Fig. 1, flows *from* the zinc *to* the copper plates. This means that the zinc is the *positive element* or electrode and copper the *negative element* or electrode. The external circuit just reverses this condition, as the current comes out of the cell through the copper electrode or terminal, which is known as positive terminal, and returns through the zinc or negative terminal. These conditions may be confusing and should be thoroughly and clearly understood, as it is always important that the cells be connected correctly. This may be understood better by referring to the diagram showing the course or direction of current through a gravity cell in Fig. 30.

Authorities differ in the use of the term electrode so that care should be taken when using it. A safe course to follow is to mention an electrode with reference to the kind of the plate, thus, in a gravity cell—the copper electrode or the zinc electrode, etc., instead of designating them as positive or negative electrodes.

GRAVITY CELL.

Where Used.

The Gravity Cell, shown in Fig. 1, is used principally on closed circuits where there is a constant drain on the battery; for the operation of relays and sounders in telegraph work; for transmitter batteries on switchboards and telephones to a limited extent; in some cases for railroad signal work at interlocking points; operation of automatic signals and for track circuits.

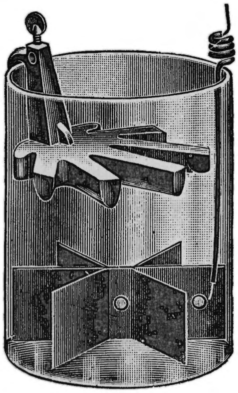


Fig. 1.
GRAVITY CELL, SHOWING.

Glass Jar,
Crowfoot Zinc,
Copper Plate.

Rubber covered wire to copper plate—positive terminal. Binding post on zinc plate or negative terminal.

Installing or Setting Up.

The containing jar of glass which holds about a gallon, being 6 inches in diameter by 8 inches high, should be thoroughly cleaned. The elements consist of copper; zinc, either crow-foot or star-shaped; and electrolyte or solution consisting of about three pounds of crystals of copper sulphate, commonly called blue vitriol or blue stone; and pure water.

The copper (positive terminal, but negative element) for the bottom of the cell should be provided with a rubber insulated wire long enough to reach above the top of the liquid. Before placing it in the bottom of the jar, the copper plate should be opened up in star shape so that it will stand on edge.

The connection to the zinc (negative terminal, but positive element) is usually made by means of a binding post which is part of this element, and which engages with that part used to suspend the zinc on the side of the jar.

The star-shaped copper with wire attached is first placed in the bottom of the jar, the wire extending above the top of the jar. About three pounds of *blue vitriol* or *blue stone* crystals which are free from dirt and other impurities and of a size not smaller than a pea nor larger than a hen's egg, are then evenly distributed in the spaces between the different arms of the copper plate.

The zinc plate should then be suspended securely to the top of the jar so that it will be about four inches above the copper plate. Pure water containing no iron or other impurities (rain water is usually satisfactory) should be used. This is poured in and should be sufficient to cover the zinc.

Better action will be secured and the cell will be ready for service sooner if about a tablespoonful of sulphuric acid or oil of vitriol is added to the solution.

To prevent evaporation and creeping of the salts, it is advisable to cover the solution with a small amount of pure mineral oil. This should be free from naphtha or acid, and have a flashing point over 400 degrees Fahrenheit.

The trouble which may arise from the use of oil in this manner is that it may rot the insulation of the wire, which runs to the copper plate. For this reason only a good quality of petroleum lubricating oil or heavy paraffine oil should be used.

If it is intended to coat the top of the jar with melted paraffine, dip the inverted jar about ½″ to 1″ into melted paraffine, tipping the jar sidewise to admit air so the paraffine will go up inside the jar.

In case the proper shaped dish cannot be secured in which to melt the paraffine, a deeper dish can be used, and nearly filled with hot water. The paraffine can then be placed on the water as they do not mix. Then heat the water until the wax melts. When the tops of the jars have been coated, allow the water to cool. The wax will harden and turn white when cold, and it can then be readily removed.

If there is no sulphuric acid, or oil of vitriol, added when the cell is first set up, it should be short circuited (that is, it should be connected between the copper and zinc terminals with a piece of wire) for one or two days to form sulphate of zinc and at the same time lower the internal resistance. This will also protect the zinc from chemical action as the zinc sulphate surrounds the zinc element. They should be kept in a room whose temperature is 70 degrees Fahrenheit or above, as the internal resistance, which is normally 2 or 3 ohms, increases very rapidly with a drop in temperature below this point, 70 degrees. For this reason they should be kept in a warm place as heat promotes chemical action upon which the cell depends for its operation. The blue line marking the boundary between the blue copper sulphate solution in the bottom of the cell and the colorless zinc sulphate solution in the top of the cell should be about half way between the copper and zinc elements.

These solutions remain separate on account of their different specific gravities or densities, the colorless zinc sulphate being lighter in weight for the same volume. It is from this fact that the cell derives its name, "Gravity Cell," sometimes called *Blue Stone Cell.* If the blue line marking the boundary between the two solutions is above this point, some of the blue solution or copper sulphate can be siphoned off or the cell may be short circuited to form more of the zinc sulphate or colorless solution. When the blue line is too low, more of the blue stone or copper sulphate crystals and water should be added.

Blue color at the bottom of the cell indicates that it is in good condition, but brown color in any part indicates that the cell is deteriorating. This cell does not polarize, meaning that hydrogen gas does not form on the negative element, which is a common fault with many types of electrolytic cells. Blue stone crystals should always be kept in the bottom of the cell.

If this cell is used on open circuit and it does not have sufficient work to do, the two solutions are very likely to mix, and when the copper sulphate comes in contact with the zinc electrode, the copper sulphate is decomposed. The oxygen of the sulphate unites with the zinc, forming zinc oxide, and the copper deposits itself on the zinc like black or dark brown mud.

This sometimes takes the form of streamers hanging from the zinc and may reach to the bottom of the cell. When in this condition it has practically no value for producing current and should be completely cleaned. If the elements (zinc and copper) are badly decomposed or eaten, they should be replaced by new ones. Save the old elements as they can be sold for junk.

Sulphate of zinc is constantly forming in the top of the cell as long as the cell is in action. When this becomes too dense (above 1.15 specific gravity) it is necessary to draw out a portion of the top liquid and replace with clear water.

The best operation is secured if the cell is operated on closed circuit about 60 per cent. of the time. When the cell is on open circuit too long, the solutions mix and the cell is not ready for immediate use.

When in good condition, the cell generates an electromotive force (E.M.F.) of 1 volt and on continuous work will operate very satisfactorily with an output of about ¼ ampere.

Cleaning Cells.

When used constantly they should be cleaned about every three months. If the cells are to be used again immediately, it is advisable to save some of the zinc sulphate or colorless solution from the top of the cells. The zincs should be carefully removed from the top of the cells, scraped with a knife or good scraper and washed clean with water. If the solution of zinc sulphate is to be saved, the clear liquid should be carefully siphoned off into a separate jar after the copper has been removed. The sediment should be dumped where it will do no damage. After carefully cleaning the jar and the copper, replace the copper in the bottom of the jar. Place the blue stone crystals around the copper and pour back the clean liquid, if this was saved for immediate use. Replace the zinc and add water to cover the zinc. If the cell is now short circuited, it will be ready for operation in short order.

If entirely new solutions are used, it is necessary to short circuit the cell at least 24 hours. Fresh solution gives the best results where time and expense are negligible.

Creeping of Salts.

Unless proper precautions are taken when setting up the cells, the jars are soon coated at the top and down the sides with white crystalline salts. These are sulphate of zinc crystals and are from the colorless solution in the top of the cell. Their appearance not only indicates a considerable loss of active material from the cell, but also presents a dirty appearance and when moist may cause a leakage of current between the cells. This is caused by the evaporation of the solution in the top of the cell which leaves a portion of the salt adhering to the side of the jar. This, in turn, on account of capillary attraction, acts the same as a lamp wick and draws more of the solution up, which in turn dries and continues the operation until the deposit reaches the base of the outside of the jar. In case that adjoining jars touch each other in this condition, or if they are resting on a damp support, this deposit acts as a conductor, producing a leakage of current which is wasted and runs down or exhausts the battery, besides preventing the cell from giving its full voltage to the circuit.

This creeping is prevented by using oil on top of the solution or immersing the top of the jar in melted paraffine as previously mentioned.

DRY CELLS.

Dry cells are used principally for open circuit work; that is, on circuits which do not require the use of the battery but a small part of the time, allowing the battery to rest or recuperate for the remainder. For example: telephone transmitters or talking battery; bell or buzzer systems; gas or gasoline engine sparking, both stationary and portable; testing circuits.

This name is applied to cells in which the solution or electrolyte is held by some absorbent material and sealed so that it may be placed in any position without spilling the electrolyte or interfering with the operation of the cell. A large variety of compounds and absorbent substances are found in the various makes of dry cells on the market, as each manufacturer has something special which he claims to be superior to others, and whose composition is carefully guarded as a trade secret.

Common types of these cells are shown in Figs. 2 and 4. A sectional view is shown in Fig. 3, showing some of the details of construction of a common dry cell.

The elements, zinc and carbon are quite generally used and form the containing case or zinc cup and the carbon pole or center terminal, respectively. A cardboard jacket or carton, which fits over the zinc cup, is used to insulate the cells from each other when placed together.

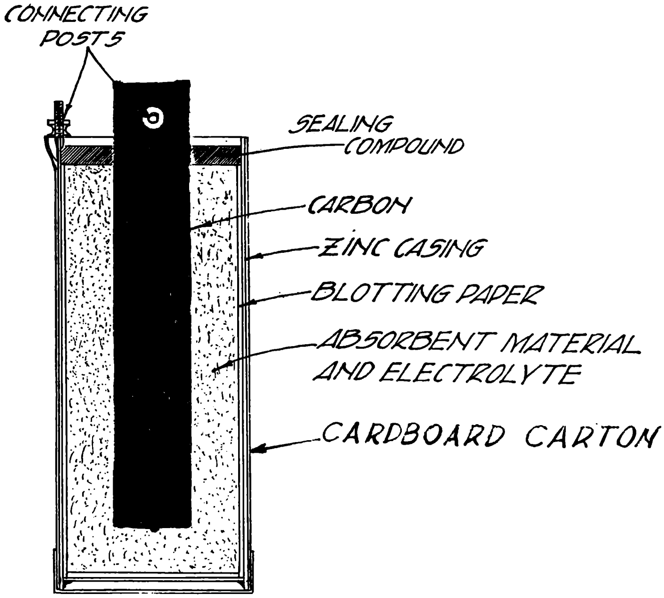
The absorbent material used to fill the space between the carbon and the cylindrical zinc may be mineral wool, saw dust, blotting paper, asbestos, plaster, etc. This absorbent material is soaked with the electrolyte or exciting liquid, such as sal ammoniac, zinc chloride or common salt, depending upon the type of cell.

Fig. 2.
DRY CELL WITH CARTON, OR
PASTEBOARD JACKET.

On account of the fact that hydrogen gas is given off when chemical action takes place between the materials used, it is necessary to use some depolarizer to absorb this hydrogen. The compound manganese dioxide is quite generally employed for this purpose. It also tends to lower the internal resistance of the cell, thereby giving a higher short circuit test which will be explained later. It is essential that any gases formed should be absorbed, as the cell is sealed up air tight by means of some resinous compound, which also prevents the evaporation of the electrolyte.

The amount of electrolyte is very limited, as the absorbent material occupies a considerable amount of space. For this reason it is extremely important that the sealing should be perfect, as otherwise the water of the electrolyte solution would evaporate and there would be practically no action between the electrolyte and the dry mixture.

The sealing compound many times becomes cracked by handling or contracts by age, so that cells after being kept on the shelf for a length of time like a year are apt to give almost no current reading when tested. They may sometimes be reclaimed when apparently exhausted by merely drilling a small hole in the sealing compound and adding a small amount of water or sal ammoniac solution. If this is done the hole should be resealed.



SECTION OF DRY CELL

Fig. 3.

In all dry batteries the zinc is known as the negative terminal or anode and the carbon or center connection as the positive terminal or cathode. The voltage obtained from fresh dry cells varies from 1.3 to 1.6.

A common method of testing dry cells is to connect an ammeter across the terminals which gives the short circuit reading. This instrument should not be kept on the cell longer than is necessary to obtain the desired reading, as it is a very severe drain upon the cell.

The short circuit test may show from 12 to 30 amperes. This test is apt to be misleading if the quality of a cell is to be determined entirely by this ammeter reading, as the real value of a dry cell is determined by the length of service which it will give under operating conditions. This depends very largely upon the ability of the cell to recuperate from a given drain. This drain may be in the nature of a telephone conversation or the operation of a bell and the recuperation takes place after the circuit is again opened by hanging up the receiver or releasing the push-button of the circuit. A high initial reading on the ammeter is obtained by adding material to the compound surrounding the carbon, which would lower the internal resistance, but which would tend to shorten the life of the cell. The dry cell manufacturers are aware of the fact that the layman is most apt to buy the battery which gives the high test on short circuit, regardless of the length of service, and so construct their cells as to give this high initial reading. This quality may be useful for some classes of work, but the relative value of different types should be based upon their length of life under actual service conditions. This test could be made only by connecting the different types to be tested, to some mechanism which would automatically close their circuits through the same resistances for the same periods of time, and then determine their value after a given time has elapsed. The circuits through which they are to be connected for test should be as nearly as possible like those of the circuit on which they are to be used.

Fig. 4.
DRY CELL WITH CARTON, OR PASTEBOARD JACKET.

Care should be exercised in locating them in a dry place, as the cardboard jacket is liable to absorb moisture, causing the zinc case to corrode, and also producing appreciable current leaks that would exhaust the cell. When a large number of them, like 100 cells or more, are used to form a high voltage battery, it is well to keep them separated so that they do not touch each other. This may be done by using a battery cabinet provided with thin wood partitions between the individual cells.

On account of their small cost, it is impracticable to renew the ordinary dry cells, so that they are thrown away when exhausted.

Defective cells may often be detected by breaks in the sealing material or by spots in the zinc can which have been corroded, either from the action of the chemicals in the cell or by substances which have come in contact with the cell from other sources. The presence of these corroded spots may be detected many times by damp spots on the cardboard carton encasing the cell.

Fig. 5.
BSCO CELL WITH SODA AND BATTERY OIL FOR CHARGE.
Glass Jar used to show plates.

When installing them on a circuit it is well to mark the date on the cardboard, as this information may be useful later.

Their being very compact, requiring no attention after once connected, having no gases to corrode nearby material, nor liquids to spill out and the simplicity with which they are connected, especially fits them for many purposes for which the wet cells could not be applied.

Caustic Soda Cells.

The different types of these cells such as the Edison "R. R.", "BSCO", and Gordon depend upon the same principle for their operation, although they vary in capacities and in some of the details of construction.

Elements.

They consist of an oxide of copper plate, known as the positive terminal (+), and oxide of zinc plates, forming the negative terminal (—). These are immersed in a solution of caustic soda and water, which forms the electrolyte.

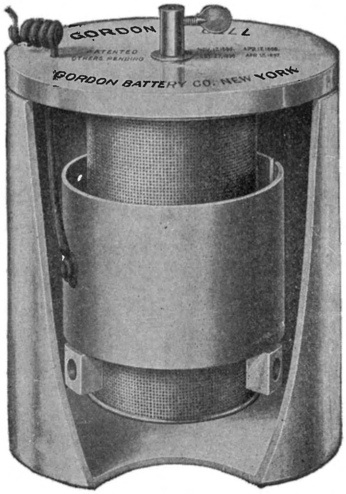


Fig. 6.
GORDON CELL.
Cut away to show assembly of parts.

In the Edison cells, shown in Figs. 5 and 7, the zinc plates are rigidly fastened together on opposite sides of the copper plate, although the zinc plates are insulated from the copper plate. In the Gordon cell, shown in Fig. 6, the copper oxide plate shown in Fig. 8, is in flake form in a perforated cylinder, which is provided with three porcelain insulating supports or lugs. The zinc plate in circular form, shown in Fig. 9, forms the other element of the Gordon cell.

The positive connection is brought out at the binding post in the center of the cover, which also serves to suspend the plates.

The negative connection is made by means of the insulated wire at the side of the cover and which runs to the zinc plates.

The action of the cell gradually dissolves the zinc plates, and converts the oxide of copper into pure copper by taking away its oxygen. The copper oxide at the surface is the first to be converted into metallic copper, the reduction gradually penetrating towards the centre. When the cell is exhausted, nearly all of the black oxide of copper is reduced to metallic copper. The amount of unused oxide in the Edison cells can be ascertained at any time by picking into the plate with a penknife. The portion that has been exhausted, and converted into metallic copper will be red or

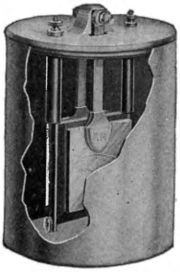


Fig. 7.
ASSEMBLY OF R. R. CELL.
Side cut away to show assembly of plates.

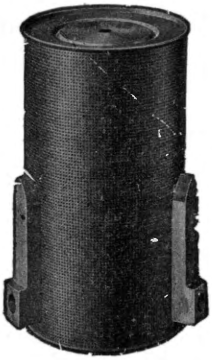


Fig. 8.
COPPER OXIDE IN FLAKE FORM IN PERFORATED CYLINDER FOR GORDON CELL.

Fig. 9.
ZINC PLATE WITH WIRE ATTACHED.
Gordon Cell.

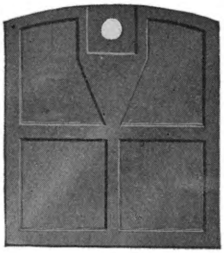


Fig. 10.
VIEW OF NEW ZINC PLATE, BSCO, SIDE TOWARD COPPER OXIDE, SHOWING RIBS.

copper color, while the unchanged oxide of copper will be black. This affords another way, though less convenient, of determining when the cell is exhausted, or about what proportion of its capacity is consumed.

However, for convenience and to avoid the possibility of injury to the cell, it is recommended that this be determined by an examination of the zinc plates.

To Determine when Cells are Exhausted.

Edison-BSCO Cells are equipped with zinc plates made from pure zinc, having ribs on their inner surfaces, as shown in Fig. 10, for the purpose of maintaining the entire surface of zinc until the rated capacity of the elements has been discharged. This makes it difficult to tell, by examination of the edges of the plates, how much has been consumed, but the zinc in the plates is so distributed that the lower panels will eat through, as shown in Figs. 11 and 12, when the rated capacity has been discharged.

Fig. 11.
APPEARANCE OF ZINC PLATE WHEN COMPLETELY EXHAUSTED. BSCO.

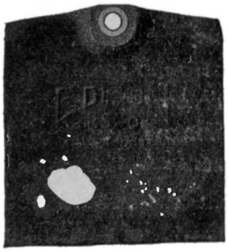


Fig. 12.
APPEARANCE OF ZINC PLATE WHEN NEARLY EXHAUSTED. BSCO Cell.

When the zincs are consumed, the copper oxide plates will be reduced to metallic copper and will be brick red or copper color practically throughout their entire mass, as the amount of material in the plates is such that there will remain only a very thin layer of black oxide in the centre when the cell is exhausted. The solution will also be exhausted, as it will then have become saturated with sodium zincate.

The active materials in each type of these cells are so proportioned that each element becomes exhausted at nearly the same time; therefore, when holes appear in the zinc plates, the cells will be practically exhausted and the entire charge, consisting of zinc-oxides, caustic soda and oil, should be renewed.

In many of the signal installations, the renewals are made late in the fall so that the cells will be in good shape for cold weather regardless of whether or not they are entirely exhausted. The proper size of cell is used to avoid making renewals oftener than once a year, unless at some very busy point, and also to prevent wasting the elements by using too large cells. An occasional voltage test would readily detect any defective or exhausted cells.

To Set Up or Renew Cells.

Renewals for each type of cell consist of copper oxide and zinc plates assembled, one can caustic soda and one bottle of battery oil. This is just sufficient for one cell. The capacity of the cell should always be mentioned when securing renewals.

Remove covers with exhausted plates attached and clean jars thoroughly. Before filling, tap jars to see if they are cracked. Cracked jars should not be used.

Fill the jars with pure water (rain or distilled water preferred) to 1¾ inches from the top. Disregard colored lines, if any, on inside of jars. Avoid hard water containing lime, iron, etc.

Caution.—Be careful, in emptying old solution and mixing the new, to avoid spilling it on either the clothing or skin. Should it get on the hands or face, wash off at once, or if water is not available, wipe off with a rag or soft paper.

Add gradually one can of soda to the water in the jar, stirring with a piece of wood until the soda is thoroughly dissolved. It is best to mix a little soda at a time; if the entire contents of a can are poured in at once some of the soda may solidify in the bottom of the jar. Be sure that all particles of the soda are dissolved before proceeding further.

Detach exhausted plates from cover by removing nuts and washers from suspension bolt.

Attach new plates to cover after removing any packing material from between the plates which may adhere to them. The zinc plates should always be placed so that the hole or slot in cover is on the side of the zinc to which the wire is connected.

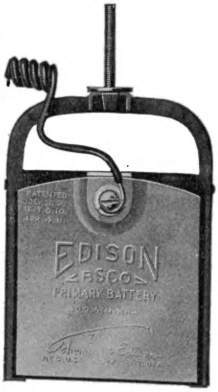


Fig. 13.
ASSEMBLY OF COPPER OXIDE AND ZINC PLATES, BSCO,
showing supporting frame, rod and middle or positive terminal, connection of wire to zinc plate or negative terminal.

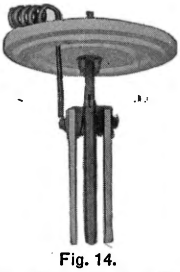


Fig. 14.
VIEW OF EDGE OF PLATES BSCO ATTACHED TO COVER.

Fig. 15.
ASSEMBLY OF PLATES AND COVER.
Gordon Cell.

With covers having a hole near the edge, for the connecting wire, the wire should be straightened and threaded through the hole before passing the suspension bolt through the central hole in the cover. With covers having a slot in the edge, for the connecting wire, the elements should be attached by passing the suspension bolt through the central hole in the cover, and the wire placed in the slot after the zinc plate is fastened.

The solution, which becomes very hot while mixing the caustic soda, should be allowed to cool to about 90 degrees Fahrenheit before the plates are inserted in it. The elements should never be immersed in the solution while it is still hot.

Fasten the assembled plates securely to the cover by screwing down the lower nut on top of the cover, and place the cover, with the elements attached, in position in the jar. Move the cover a little to one side and pour in one bottle of oil, being careful not to raise the plates above the top of the electrolyte.

It is important that the oil should not be omitted, and also that it should not be poured on the solution before the plates are inserted.

Assembly of Parts.

The only permanent parts to be retained when the cell is exhausted are the jar, cover, nuts and washers.

It requires the tightening of only one nut to fasten the plates in place, and only one connection per cell to connect a number of cells in series, as the connecting wire is permanently connected to zincs.

No parts that have been in the solution are used or handled in renewing; therefore, no handling, scraping or cleaning of such parts is required.

The BSCO Cell.

The copper oxide and zinc plates are suspended in the solution by a channelled horse-shoe or inverted U-shaped frame, as shown in Figs. 13 and 14, hung by a threaded bolt which is permanently attached to the frame. The channels of the hanger embrace the flat and beveled side edges of the copper oxide plate, and the tongues at the bottom of each leg of the hanger are bent inward under the bottom corners of the plate. The channels of the hanger are drawn tightly against the edges of the oxide plate by a crossbar fastened in the frame just above the top of the oxide plate, thus making forcible contact with the plate.

The zinc plates are hung from porcelain insulators which pass through the crossbar, the zincs being held firmly in position by an amalgamated steel bolt. The copper oxide and zinc plates are properly spaced by the insulators, and the plates are fastened permanently in their best relation. Therefore, it is not possible for the zincs to be attached loosely to the cover or to touch the copper oxide plates, nor can they be spread too far apart, causing increased internal resistance.

Fig. 16.
RENEWAL FOR BSCO CELL.

Fig. 17.
RENEWAL FOR R. R. CELL.

The Gordon Cell.

The parts should be assembled as shown in Fig. 15. To do this, place the zinc on the lugs of the perforated cylinder, run the zinc wire through the hole in the cover and fasten the cylinder to the cover by screwing the brass connector, Fig. 20, into the nut at the top of the perforated cylinder.

See that no copper dust is on the porcelain lugs. The opening of the zinc plate, shown at the right of Fig. 9, should not rest upon the lugs, but should be placed between two of them.

Fig. 18.
PORCELAIN JAR AND COVER.
Gordon Cell.

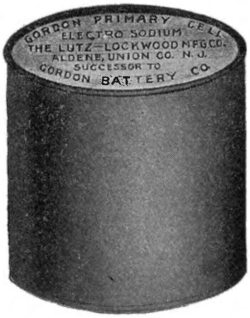


Fig. 19.
CAUSTIC SODA FOR GORDON CELL.

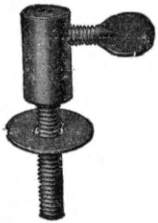


Fig 20.
BRASS CONNECTOR OR BINDING POST
FOR GORDON CELL.

When the elements are put into the solution, the zinc plate should rest evenly on the lugs, and care should be exercised to prevent splashing the solution on the hands or clothing.

Copper-Oxide Plates.

The Copper-Oxide Plates, shown in Figs. 8, 21 and 22, serve the double purpose of negative elements and depolarizers, the oxygen in the plates combining with hydrogen as the latter is set free in the action of the battery.

These plates are made of black oxide of copper. As this is, in itself, a very poor conductor, a film of metallic copper is produced on the surface of the plates and cylinder by a special process, to insure proper conductivity.

All copper-oxide plates have a bright copper or brick red color when they leave the factory, and will remain in this condition practically indefinitely if kept in their original wrappers and in a dry place. This surface film, like all copper, tends to oxidize or tarnish if it becomes wet or if exposed to damp air. It will also be affected if the plates are immersed in the caustic soda solution while it is hot or if the battery remains idle, or on open circuit for a considerable period immediately after the plates are inserted.

Fig. 21.
BLACK OXIDE OF COPPER PLATE
FOR R. R. CELL.

Fig. 22.
COPPER OXIDE PLATE IN FRAME WITHOUT
ZINCS. BSCO CELL.

If the battery is discharged through resistance for an hour or more immediately after it is set up, the plates will acquire a permanent copper surface, and periods of open circuit, thereafter, will do no harm. If, however, the plates have been wet or exposed to a moist atmosphere, they will have a dark color, and, in such case, it may be necessary to keep them on closed circuit (not short circuit), for a long period, to restore them to their normal condition.

This may be accomplished quickly by short circuiting for one or more periods of three minutes each, with intervals of rest of five minutes between each short circuit; but as far as possible, short circuiting should be avoided, as it is likely to produce scale on the zinc if continued too long.

Zinc Plates.

The zinc plates are made from pure zinc and are amalgamated with mercury to prevent local action.

Caustic Soda.

The electrolyte or solution is made by dissolving one can per cell of the caustic soda (sodium hydroxide) in water as directed.

The Soda furnished with the cells and renewals is a special grade, ground and put up in sealed cans, each can containing the proper quantity for one cell. The label indicates the particular type of cell for which each can is intended, and care should be exercised to see that the proper can of soda is used in setting up or renewing cells.

A practice followed by some in renewing a large number of cells at one time, is to mix the caustic soda and water in a large tank, kettle or other receptacle and then fill the individual cells from this. With this method the solution is not all of the same density, that at the bottom being the stronger, which would not give uniform results in the different cells.

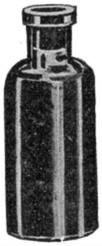


Fig. 23.
BATTERY OIL FOR GORDON CELL.

It is most important that the entire contents of one can, shown in Figs. 16 and 19, be used for each cell, and the solution stirred until all of the particles of soda are thoroughly dissolved.

The cans must not be opened until ready for use, as the soda rapidly absorbs moisture, causing it to cake. It also combines with the carbonic gas in the air, forming sodium carbonate, which, if excessive, will decrease both the efficiency and the capacity of the electrolyte.

When the soda is added to the water, the temperature of the solution rises rapidly. Breakage of jars, porcelain or glass, will be avoided if they are *not* placed on cold surfaces while mixing the solution.

Water.

The purest water gives the best results, though such water as is available at most locations will answer for all practical purposes. Rain water that has been collected and kept in wooden receptacles or distilled water will give excellent results. Avoid "hard" water, containing lime, iron, etc.

Fig. 24.
AMALGAMATED ZINC PLATE FOR
R. R. CELL.

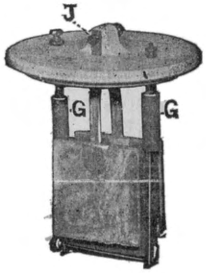


Fig. 25.
PLATE ASSEMBLY OF R. R. TYPE.
J—Brass bolt connecting zincs and forming terminal.
G. G.—Hard rubber insulators.

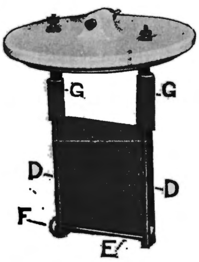


Fig. 26.
COPPER OXIDE PLATE AND FRAME ASSEMBLY, R. R. TYPE.
G. G.—Hard Rubber Insulators,
D. D.—Side of Copper Frame.
E.—Copper Bolt Connecting Frame.
F.—Copper Nut on Bolt.

It is most important that a sufficient amount of water be used to cover the plates properly and if an insufficient amount of water is used, it will increase the possibility of the solution freezing in cold weather. The plates must always be completely covered by the electrolyte. In cells properly set up, the top of the zinc plates will be at least an inch below the surface of the solution after the liquid has cooled.

Special Battery Oil.

The oil supplied with the cells and renewals, shown in Figs. 16, 17 and 23, is a heavy mineral variety, selected because it has no chemical action on the soda solution. The objects of the oil are three fold: it prevents evaporation, crystalization and creeping, and the carbonating of the solution by preventing contact with the air.

It is most important that the proper oil be used, as many oils form a soapy compound when combined with soda.

It is also important that the oil be poured in the jar after the plates are inserted; if dry plates are passed through the layer of oil it will adhere to and soak into the copper oxide plates. If, however, the oil has been put on the solution before inserting the plates, the plates must be dipped in water, so that their entire surface is moistened. They will then pass into the solution without the oil adhering.

Selection of Cells.

These caustic soda cells are equally suitable for open circuit (intermittent discharge) or closed circuit (continuous discharge).

It is important, in order to obtain the best results, that the proper number of cells be used to furnish the necessary working voltage and that the type selected be large enough to deliver the current required.

The open circuit or initial voltage of all these cells is .95 volt per cell; but in all batteries, either primary or secondary, the initial or open circuit voltage is higher than the effective or working voltage on continuous closed circuit. The high initial voltage is effective for work only when cells are discharged at an extremely low current rate, and in some cases, such as with ordinary "dry cells," even at low rates of discharge, it is available only for intermittent contacts of short duration.

The closed circuit or effective voltage depends, in all cases, upon the frequency and duration of contacts, internal resistance of the cell and the rate of current discharge, the voltage dropping proportionately as the rate of current flow is increased. With the 400 Ampere Hour BSCO types, for example, the mean effective voltage on continuous closed circuit, with current flowing at the rate of one-half ampere, is approximately .65 volt per cell; at one ampere .6 volt per cell; at two amperes .55 volt per cell; at three amperes .5 volt per cell, and so on. The Gordon Cell is nearly the same as above.

When the external circuit of the cell is completed, that is, when current is being drawn from the cell, the zinc dissolves in the caustic soda forming sodium zincate. The hydrogen gas which is set free by this process immediately attacks the copper oxide plate, reducing it to metallic copper and at the same time forming water from the oxygen and hydrogen. Sodium oxide, which is also formed, is unstable in water and unites with it to form caustic soda, which is the same compound as the original electrolyte. The caustic soda is used up only as it combines to form zincate of sodium.

They are especially suited for continuous closed circuit work, because of their low internal resistance and effective depolarization, the voltage at normal discharge rates being practically constant throughout the life of the cells.

Some of the purposes for which the Caustic Soda Cells are used:

Railway signals, crossing alarms, telephone train dispatching systems, telephone talking circuits, program and self-winding clocks and time recorders, fire alarm systems, mine signals, wireless telegraph, bell systems, annunciators, electric lights for motor boats and other small lighting systems, gas and gasoline engine ignition.

Battery Connections.

The information given on preceding pages regarding the current capacity and voltage of the different types of cells had reference to a single cell. It is possible to connect a number of them in different ways so that higher voltage or increased current capacity may be secured as desired from the battery consisting of several cells.

The ampere hour capacity and the voltage of the battery are dependent upon the nature and capacity of the individual cells and upon their method of connection. The current output of a given cell depends upon the area of the plates exposed to the electrolyte and upon the amount of the electrolyte, while the voltage is dependent upon the elements used. The same elements in a given electrolyte always produce the same voltage or difference of potential regardless of the size of the cell.

Series Connection.

Series connection increases the voltage or electrical pressure by adding the voltage of the individual cells, but does not increase the number of ampere hours available over that of the individual cell.

The same chemical action takes place in each cell, as the same current must pass through each cell, they being connected in series. As the total current available from each cell is dependent upon the chemical action in the cell, then by increasing the number of cells in series on a circuit that has a given resistance, there will be an increase in the amount of current passing through the circuit, but will result in the cells becoming exhausted sooner. For this reason, it is important to determine before making an installation, just what voltage and current are necessary to operate the apparatus in the circuit. Increasing the cells in series increases the voltage and current in the circuit, but decreases the life of the battery.

Series Connections are made as shown in Fig. 27, by connecting the positive terminal of one cell to the negative of the adjacent cell. It should be noted that in connecting any number of cells in series, their total internal resistance would be the sum of the internal resistances of all these cells.

As each cell of gravity type gives about 1 volt, the effective voltage across the terminals shown in Fig. 27, will be about 4, but the current, or rate of flow, which could be drawn from this battery is limited by the capacity of each cell and the internal resistance to about ¼ ampere. This current flow is also determined by the external resistance of the circuit through which the current passes. These terms referring to the electrical pressure, rate of flow of current and resistance, will be explained in paper E-2.

Multiple, Parallel or Bridging Connection.

These are different names for the same arrangement of the cells. This scheme, shown in Fig. 28, increases the ampere hour capacity of the battery, but does not increase the voltage over that of the single cell.

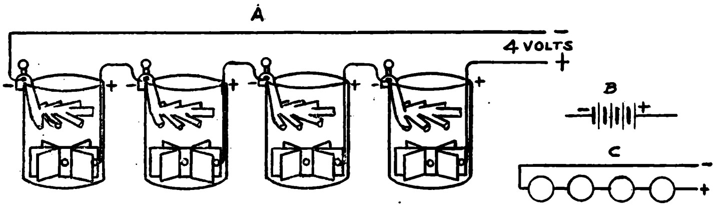


FIG. 27

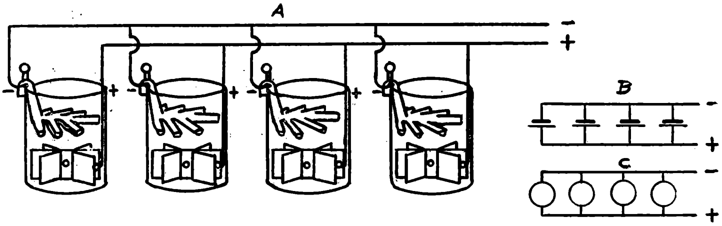


FIG. 28

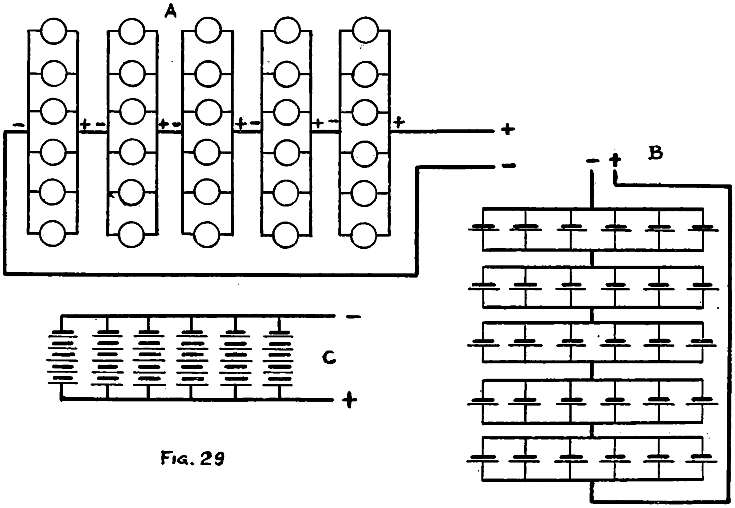


Fig. 29

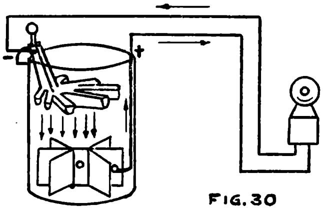


FIG. 30

This method of connecting amounts to the same thing as increasing the size of the plates of a cell to obtain a higher current capacity, as will be noted from the schematic arrangement shown in Fig. 28, b. The internal resistance of the battery consisting of cells in parallel is diminished instead of being increased as in the case of the series connections for the reason that the volume of the liquid through which the current would pass would be increased in proportion to the number of cells so connected. The resistance of a conductor is inversely proportional to the area of its cross section.

The total ampere hours available from cells connected in parallel is equal to the sum of the capacities of the cells so connected; the voltage is equal to that of the single cell; and the internal resistance is equal to that of a single cell divided by the number of cells.

Take for an example, 10 cells each having a voltage of 1 volt, internal resistance .025 ohms and ampere hour capacity equal to 200. If they are connected in series, the total voltage would be 10 × 1 or 10 volts, an internal resistance of 10 × .025 or .25 ohms, but the capacity is only 200 ampere hours, so that (from E-2 for definition of watt-hours) the total watt-hours capacity of the battery would be 10 × 200 or 2000 watt-hours. When connecting them in parallel, the total voltage would be 1, the internal resistance of .025 ÷ 10 or .0025 ohms and a capacity of 200 × 10 or 2000 ampere hours, so that the total watt-hours capacity of the battery would be the same as above 1 × 2000 or 2000 watt-hours. Therefore, the total energy is the same in each case.

Series Multiple Connection.

Combinations of the above methods, namely, series and multiple or parallel connections, can be made as shown in Fig. 29, which builds up both the voltage and ampere hour capacity of the battery. The total voltage is determined by the number of series connections and the ampere hour capacity by the number of cells in multiple. In Fig. 29, there are shown 5 in series and 6 in multiple. If we use the same type of cells as described above, 1 volt, 200 ampere hour and .025 ohms internal resistance, then the voltage available would be 5, the ampere hours 6 × 200 or 1200 and the total watt-hours available 5 × 1200 or 6000. This is the same as the total energy of the 30 cells at 200 ampere hours and 1 volt each, 30 × 200 × 1 or 6000. The internal resistance of the battery is the resistance of an individual cell divided by the number of cells in multiple or .025 ÷ 6 and multiplied by the number of cells in series which is 5 or $\frac{.025}{6} \times 5 = .0208$ ohms.

These conditions above mentioned are determined by the laws of divided circuits, which will be explained in another paper E-2.

REVIEW QUESTIONS.

1.—Of what do the elements of a gravity cell consist?

2.—What is the difference between the elements and the electrolyte in the gravity cell?

3.—What are the indications that the solution or electrolyte is in good condition?

4.—What precautions are taken to prevent the deposit of crystals on the outside of the gravity cell?

5.—What two methods can be employed to secure prompt action of the gravity cell shortly after setting it up?

6.—Give two or three reasons for the gravity cell not being adapted for telephone work.

7.—What happens in the cell in case that the blue solution comes in contact with the zinc in top of the cell?

8.—Why is it not just as practical to have a small generator in place of so many primary batteries?

9.—Why is it necessary to protect the wire leading to the copper plate in the bottom of the gravity cell with a rubber insulation reaching above the solution?

10.—In what respect do the Edison and Gordon cells differ from the gravity cells when making renewals?

11.—What care should be taken to prevent breaking the jars when renewing Edison or Gordon cells?

12.—What provision is made with the Edison and Gordon cells to prevent creeping of the salts?

13.—What is meant by polarization? Is this a characteristic fault of the gravity cell? How is it overcome in the Gordon and Edison cells, and in the dry cells?

14.—For common magneto telephone talking battery which of the foregoing types of cells is especially suited and why?

15.—What tests should be made to determine the relative values of the different types of dry cells?

16.—What tests are usually employed by dealers when selling dry cells and why would they be unreliable, disregarding the probable errors in the small portable pocket instrument usually used for these measurements?

17.—If you were to replace a gravity cell with a Gordon or an Edison BSCO cell, which terminal would connect in the place of the zinc of the gravity cell?

18.—Which terminal of the dry cell corresponds to the zinc terminal of the gravity cell?

19.—What characteristic of the gravity cell makes it very unfit for outdoor use in connection with signals, telephones or other devices in the winter time?

20.—When is it advisable to connect the cells in parallel and why?

21.—Assume that 10 cells, each having a rated capacity of 400 ampere hours, are connected in series on a circuit having a resistance of 50 ohms. If the voltage per cell available is .75, the internal resistance of each cell is .005 ohms, and the circuit is closed 8 hours each day, what will be the length of life of the battery? Show sketch of connection.

22.—What would have been the life of the above battery if the cells were each of 250 ampere hours?

23.—What would the life of the battery in problem 21 be if the circuit was closed for 3 hours each day through 100 ohms?

24.—Assume that it will be convenient to renew the battery in a certain installation once every six months, that the circuit is closed for a period of 2 hours each day, requiring 2.1 amperes and 5 volts for operation. If the cells used are capable of furnishing current at .65 volt, what number of cells should be connected in series? What capacity in ampere hours per cell would it be advisable to install? How should they be connected? Show sketch of connections which should be made.

25.—If 2 Edison 400 ampere hour cells are connected in series and discharging at the rate of .2 amperes continuously, what will be the life of the cells?

26.—If these same cells had been in multiple and the total discharge the same, how would the life of the cells be affected?

27.—Show sketch of battery with 3 cells in multiple and 3 in series.

28.—If these each had a capacity of 250 ampere hours and were capable of discharging at the rate of ½ ampere continuously at a voltage of .6, what would be the total current in the battery in problem 27, the external resistance being adjusted to admit of this current on the voltage available?

29.—What would a voltmeter register if connected across the terminals of the battery in problem 28?

30.—How long will the battery continue to operate?

EDUCATIONAL COURSE, P. R. R.

PRIMARY CELLS

PAMPHLET E-1

MARCH, 1913.

The following corrections and additions apply to pamphlet E-1; issue, November, 1912. Notations should be made in the pamphlet to indicate that the original information has been superseded and to use that contained in the following:

Page 7, first paragraph should read:

"Assuming that the cell used was of 400 ampere hour capacity, then it would last approximately $400 \div (4 \times .5)$ or 200 days, a little over six months, on the circuit discharging $\frac{1}{2}$ ampere for 10 minutes each hour."

Eq. 9 should be Eq. 1.

Add after Eq. 1:

"Example: A primary cell on open circuit has a voltage of 0.95 volts. When it is furnishing current at the rate of .8 amperes, the voltage falls to 0.7 volts. What is the internal resistance of the cell or battery?

Solution: From equation 1, this resistance is found by dividing the difference between the open and closed circuit voltage by the current in amperes.

In the problem $E—.95$ $V=.7$ and $I=.8$. Then, by substituting these values in the equation, it would be written as follows:

$$R=\frac{.95—.7}{.8}=\frac{.25}{.8}=.31=\text{the number of ohms internal resistance."}$$

Page 8, "Installing or Setting Up," should read:

"The containing jar of glass which holds about a gallon, being 6 inches in diameter by 8 inches high, should be thoroughly cleaned.

The *elements* consist of copper and zinc plates.

The *electrolyte* or solution consists of copper sulphate in water forming the clear blue solution in the bottom and the colorless zinc sulphate solution which is formed by chemical action at the top of the cell."

Page 9, first paragraph should read:

"The copper (positive terminal, but negative element) for the bottom of the cell should be provided with a rubber insulated wire long enough to reach above the top of the liquid. This wire is rubber-covered to prevent action of the chemicals on the copper conductor and to keep the wire from coming in contact with the zinc plate and causing a short circuit. Before placing the copper electrode in the bottom of the jar, the copper plate should be opened up in star shape so that it will stand on edge."

Page 9, paragraph five should read:

"Better and quicker action of the cell will be secured and it will be ready for service sooner if some of the colorless solution of zinc sulphate is saved from the old cells and added to the new solution. Quick action is also secured by adding a small amount of sulphuric acid, common salt or short circuiting the cell for one or two days."

Page 10, paragraph three should read:

"A clear blue color at the bottom of the cell, the dividing line between the solutions about midway between the elements and a colorless solution in the top of the cell indicates that it is in good condition, but brown color in any part indicates that the cell is deteriorating. This cell does not polarize, meaning that hydrogen gas does not form on the negative elelement, which is a common fault with many types of electrolytic cells, if blue stone crystals are kept in the bottom of the cell, as they prevent the cell from polarizing."

Page 11, first paragraph should read:

"This deposit sometimes takes the form of streamers hanging from the zinc and may reach to the bottom of the cell. When in this condition the cell has practically no value for producing current and should be completely cleaned. If the elements (zinc and copper) are badly decomposed or eaten, they should be replaced by new ones. Save the old elements as they can be sold for junk."

Page 11, add after first paragraph:

"A deposit forms on the zinc which can be cleaned off, while pure copper is deposited on the copper element, especially when the cell is in action. If the copper plate is to be used when renewing the cell the crystals of copper should be knocked off."

Page 13, second paragraph should read:

"The absorbent material used to fill the space between the carbon and the cylindrical zinc may be mineral wool, sawdust, blotting paper, asbestos, plaster, etc. This absorbent material is soaked with the electrolyte or exciting liquid, such as sal ammoniac, zinc chloride or common salt, depending upon the type of cell, and mixed with the depolarizing substance."

Page 14, second paragraph should read:

"In all dry batteries the zinc is known as the negative terminal or anode and the carbon or center connection as the positive terminal or cathode. The voltage obtained from fresh dry cells varies from 1.3 to 1.6, but about 1.5 volts is a fair average."

Page 14, add to last paragraph:

"The short circuit test should be used merely to determine the condition of a given type of cell when the short circuit current of this particular type is known and not for a comparison between different types or makes."

Page 20, second paragraph should read:

"The active materials in each type of these cells are so proportioned that each element becomes exhausted at nearly the same time; therefore, when holes appear in the zinc plates, the cells will be practically exhausted and the entire charge, consisting of zinc, copper oxides, caustic soda and oil, should be renewed."

Page 29, add before first paragraph:

"The rating of the standard caustic soda cells is as follows: 100, 150, 200, 250, 300, 400 and 600 ampere hours, but their voltage is all the same."

Page 32, part of last paragraph should read:

"The total voltage is determined by the number of cells connected in series and the ampere hour capacity by the number of cells in multiple."

Page 33, add:

"When showing a battery in any wiring diagram it is advisable to represent it as in Figs. 27–B, 28–B or 29–C."

Page 34, add at top of page:

"Note: One or more complete lessons should be answered at one time."

Page 35, problem 26 should read:

"If these cells in problem 25 had been in multiple and the total discharge of the battery the same, what would be the life of the cells in days?"

Page 35, problem 28 should read:

"If the nine cells in the battery connected as in problem 27, each had a capacity of 250 ampere hours and were capable of discharging at the rate of ½ ampere continuously at a voltage of .6, what would be the total current in the battery, the external resistance being adjusted to admit of this current on the voltage available?"

Page 35, problem 30 should read:

"How many days will the battery in problem 28 continue to operate?"

Supt. Telegraph.