G.B.Todd,RM1c.

# Fourth Week.

## VOLTAIC ELECTRICITY, PRIMARY CELLS, STORAGE BATTERIES - CARE AND MAINTENANCE.

QUESTION #1. What is electromotive force?

ANSWER #1. We have two bodies raised to different potentials in a voltaic cell, and to the difference of potential between them is due the current flowing through the external circuit. The greater this difference of potential the greater the current, or effect of the current produced.

Potential is the force which moves electricity through the circuit. Thus, the total force required to cause the current to flow through the circuit is called the electromotive force.

A difference in potential existing between but two points in a circuit would cause the current to flow just between these two points, therefore:

Electromotive force is the total difference of potential that is maintained in any circuit.

QUESTION #2. On what does the EMF of a cell depend?

ANSWER #2. A cell consists, essentially of two dissimilar metals immersed in a solution which will attack one of the plates. These two plates must be dissimilar so the the degree of intensity of the chemical action on one plate will be greater than on the other.

The EMF of a cell depends, therefore, on the difference in intensity of the chemical action, and on the solution used for electrolyte. The size or area and the distance between the plates does not affect the EMF.

QUESTION #3. What substances are known as the electro-chemical series? Give their polarities when immersed in a dilute solution of $H_2SO_4$.

ANSWER #3. The following substances are known as the electro-chemical series. Their polarity in a dilute solution of sulphuric acid depends on the substance chosen for the opposite plate. Their position in the series depends on the intensity that a dilute solution of sulphuric acid will act upon them:

POSITIVE

Direction of current through external circuit. ←

ZINC IRON TIN LEAD COPPER SILVER PLATINUM CARBON

→ Direction of current through solution.

NEGATIVE

In this table, any substance is positive to any substance which follows it and negative to any preceding it. For instance, Iron is positive to Copper, while Copper is positive to Platinum; Silver is negative to lead, while lead is negative to Tin.

QUESTION #4. What is meant by electrolysis? Give some examples.

ANSWER #4. The rate at which the negative plate of a cell, wastes away, or is consumed, is entirely dependent on the amount of current the cell is supplying. Were no current being supllied, supposing that the metals were pure, all chemical action would cease, and no material would be consumed.

The reverse of the above process is called electrolysis, where the liquid is broken up and the metal deposited. The rate of consumption of a substance when one ampere is drawn from a cell, and the amount of metal deposited per hour by electrolysis, is termed the Electrochemical Equivalent of the substance. A table follows:

ELECTROCHEMICAL EQUIVALENTS OF ELEMENTS.

| ELEMENT | SYMBOL | GRAMS PER AMPERE-HOUR | AMPERE-HOURS PER GRAM |
|---|---|---|---|
| Aluminum... | Al | 0.3369 | 2.969 |
| Copper..... | Cu | 1.186 | 0.843 |
| Gold....... | Au | 3.677 | 0.2720 |
| Hydrogen... | H | 0.03759 | 26.60 |
| Iron....... | Fe | 0.695 | 1.439 |
| | | 1.042 | 0.959 |
| Lead....... | Pb | 3.858 | 0.2592 |
| Nickel..... | Ni | 1.094 | 0.914 |
| Nitrogen... | N | 0.261 | 3.828 |
| Oxygen..... | O | 0.2983 | 3.352 |
| Silver..... | Ag | 4.025 | 0.2485 |
| Zinc....... | Zn | 1.219 | 0.820 |

By means of this table, it is possible to determine the amount of metal necessary to produce a given current for a given time.

One example of electrolysis is electroplating. Advantage is taken of the fact that if a current is passed through a solution containing the salt of a metal the metal will be deposited on the negative plate.

Another example is the destruction of metal watermains etc., due to electrolysis, or the electrolytic actio For instance, an electric railway uses the track for the return circuit. The rails are not insulated and therefore allow the current to leak into the ground. This stray current will follow the path of least resistance, such as a watermain or a gasmain back to the generator, which is also grounded. There is no harm done where the current enters the pipe, but at the place where the current leaves the pipe, the soil around the pipe is usually moist and salty, the salt acts as an electrolyte and chemical action is set up between the pipe and the salt water, and the metal of the pipe is consumed by the salt and carried to some other substance that is acting as the negative plate at the moment. The only method of preventing the latter is to provide a path of lower resistance than watermains or gasmains, such as welding all lengths of the rails together, or using a second trolley for a return.

QUESTION #5. Explain the chemical action of a zinc-copper cell using dilute sulphuric acid for the electrolyte.

ANSWER #5. A zinc-copper cell consists of: A jar containing a dilute solution of sulphuric acid into which are immersed the two dissimilar plates, one of zinc and the other of copper. The chemical symbols are: $H_2SO_4$, dilute sulphuric acid; Zn, zinc; Cu, copper. Upon completing the circuit by connecting a wire to both plates, externally, the electrolyte commences to attack the zinc. The $SO_4$ part of the electrolyte has a strong affinity for the zinc, and combines with the Zn to form $ZnSO_4$ (zinc sulphate). For every $SO_4$ part of the solution that combines with the zinc, there are two parts of hydrogen ($H_2$) liberated. The moment that the $H_2$ is liberated from the compound of $H_2SO_4$, it possesses unusual readiness unite with other molecules. As there are many more compounds of $H_2SO_4$ in the solution, the first $H_2$ unites with the $SO_4$ of the next molecule, and the resulting $H_2$ which is liberated unites with the $SO_4$ of the next, and so on across the cell, until the copper electrode is reached, where the last $H_2$ rises to the surface.

Therefore, as long as the circuit is completed, this chemical action takes place, and current is supplied to the external circuit, but at the cost of the zinc electrode, and the solution. The zinc gradually wastes away and the solution becomes weaker.

QUESTION #6. Explain local action in a primary cell.

ANSWER #6. Were the metals of the two electrodes in a primary cell pure there would be no chemical action upon breaking the external circuit, but it is nearly impossible to obtain such pure metal, therefore they contain many impurities, such as small particles of iron, tin, lead, carbon, etc., which substances, according to the table of electrochemical series, would act as the negative plate or plates, when the rod of zinc was immersed in the solution. These numerous small particles of dissimilar metal set up numerous small independent cells, the chemical action of which is similar to the action in the large cell, therefore, even though the external circuit be broken, the zinc in a zinc-copper cell, will gradually waste away due to the action of the smaller local cells. This is called local action. It is usually prevented by amalgamation. The zinc is thoroughly cleaned with sand-paper, immersed in dilute sulphuric acid, and while still wet, covered with mercury. This forms a bright amalgam which protects the foreign material from the action of the acid, although not preventing the action of the acid upon the zinc. As the zinc wastes away, the mercury amalgam reforms, thus preventing local action for the life of the zinc electrode. Some manufacturers cast the zinc electrode with a small percentage of mercury.

QUESTION #7. What is meant by polarization? How is it prevented?

ANSWER #7. As explained in Question #5, hydrogen is liberated from the electrolyte, due to the combining of the SO4 with the zinc. This hydrogen accumulates on the copper plate. Of course, if the circuit were broken and the cell allowed to stand idle for a period of time, the hydrogen would escape to the surface, but when the cell is being used, the hydrogen accumulates, faster than it can be dissipated. The copper plate coated with hydrogen becomes nearly a hydrogen plate. As hydrogen is more positive than zinc, a counter-action similar to that between the zinc and the copper, would be set up between the hydrogen and the zinc, which would oppose the main current. This action would weaken the cell, cause it to deliver less current to the external circuit. The coating of the negative plate in a cell is termed polarization. This action is prevented by means of a depolarizer, which is another chemical which has a strong affinity for hydrogen, and which will combine with the hydrogen, preventing it from accumulating on the negative plate. This chemical may be either a liquid or a solid. The difference in the various primary cells now manufactured, is mainly in the method by which they accomplish the depolarization. Some use two fluids: the electrolyte and the depolarizer. Some use mechanical means, such as rough surfacing the negative plate so that the hydrogen will not cling to it but will rise to the surface, or such as rotating the negative plate, but no mechanical method will entirely prevent polarization, so the most of the cells utilize a chemical.

QUESTION #8. Explain the chemical action of a Daniell cell.

ANSWER #8. The Daniell cell is made in many forms, but they all consists essentially of a zinc positive plate and a copper negative plate separated by a porous partition. On the zinc side is pute dilute sulphuric acid. On the copper side is put sulphate of copper dissolved in water together with some sulphate of copper crystals to keep the solution of copper sulphate saturated. Upon closing the circuit, the SO4 of the H2SO4 combines with the zinc, forming ZnSO4 (zinc sulphate, and liberating two atoms of hydrogen (H2) which pass through the porous partition. If the solution of copper sulphate were not there, the hydrogen would accumulate on the copper plate, but as it is there, the H2 meets with the CuSO4 (copper sulphate) and as it has a greater affinity for the SO4 than the Cu, it combines to make H2SO4. This combination liberates CU, which forms on the copper plate. When the Cu is liberated from the CuSO4 the solution is deprived of some of the Copper and would in time lose its strength to the extent of being unable to prevent polarization. But the copper crystals keep the Copper sulphate solution constantly saturated. The Daniell is a closed-circuit cell and will deliver a small but steady current at about one volt.

QUESTION #9. What three other types of primary cells are commonly used?

ANSWER #9. Three other types of primary cells commonly used are the Leclanche, the Weston Standard, and the Dry cell

The Leclanche is a single solution-open circuit cell utilizing a solid depolarizer surrounding the negative plate of carbon, the positive element being zinc. The electrolyte is a strong solution of ammonium chloride, commonly known as sal-ammoniac. The solid depolarizer is composed of small pieces of carbon and manganese dioxide, which will take care of the limited amount of hydrogen produced when the cell is on closed circuit but if the cell is allowed to remain on closed circuit for any length of time, polarization occurs. The zinc is consumed only on closed circuit and as the cell is used for open circuit work such as bell ringing, etc., it is economical and requires very little attention. The EMF is about 1.4 volts and the internal resistance is about 4 ohms.

The Weston Standard cell is used as the base for computing the value of a standard volt, one standard volt being 1/1.0183 of the voltage of a Weston Standard cell under standard conditions. This figure is used because the cell will produce 1.0183 volts at 20° Centigrade. The Weston is chosen as Standard because it will maintain a constant EMF for a long time on open circuit. It uses mercury as the positive plate and an amalgam of 12% cadmium as the negative, with an electrolyte of cadmium sulphate. The current delivered is very small, but appropriate for the use the cell is put to, as for drop measurements a high resistance is used with it so that the current taken from it will be minute.

The various forms of Dry cell are the most common of the primary cells, being used for general ignition. The electrolyte in this case is combined with some absorbent, making the battery easily portable, another reason for its common use. In the usual type of dry cell, the positive element (zinc) is used as a container in cylinder form which holds the negative element (carbon) and the depolarizer (manganese dioxide) and the electrolyte. The electrolyte is composed of: oxide of zinc, 1 part; sal-ammoniac, 1 part; chloride of zinc, 1 part; water, 2 parts; by weight. The chemical action in this cell is identical with the Leclanche cell, the only difference be-ing the absorbent material, which permits the ease of portability. They are very inefficient, though, as their capacity is small, and their electrodes and electrolyte can not be replaced without excessive trouble, although a fully discharged dry cell may be partially and temporarily renewed by punching holes in the case and immersing the cell in a saline solution. Their renewed life is very short, however.

QUESTION #10. What is a storage cell? What does it store?

ANSWER #10. A storage cell is simply a voltaic cell, consisting of two dissimilar metals immersed in an electrolyte but which have been chosen so that after delivering a current to an external circuit for a period of time, may be restored to their original condition by passing a current through them in an opposite direction. In the most common of storage cells, the lead cell, the materials and the electrolyte have been chosen so that passing a current through the cell will change the plates to dissimilar metals and the solution to a liquid which will attack the plates, thus converting the electrical energy into chemical energy. Upon closing the external circuit the electrolyte attacks the plates and changes the material, in fact, makes them identical, thus reducing the difference in potential to zero, so that no current can flow. When this has occured it is necessary to again force a current through the cell in an opposite direction to restore the dissimilarity of the materials and the strength of the electrolyte. Two or more storage cells connected electrically is called a storage battery.

A storage cell does not store electricity. It stores chemical energy (dissimilarity of electrodes and strength of electrolyte) that may be converted into electrical energy by closing the external circuit.

QUESTION #11. What are the active materials of a lead acid cell? Of an Edison cell?

ANSWER #11. The active material of a lead cell consists of a negative plate of spongy lead (Pb) and a positive plate of lead peroxide ($PbO_2$).

The active material of an Edison cell consists of a negative plate of pure iron (Fe) and a positive plate of nickle oxide ($Ni_2O_3$). The nickle oxide was at first nickle hydrate but on the initial charge was changed to nickle oxide and never return to nickle hydrate. On discharge it changes only to a lower oxide of nickle oxide, while the negative plate of pure iron is changed to iron oxide.

QUESTION #12. Explain the chemical action that takes place in a lead cell.

ANSWER #12. Composition of a lead cell and chemical symbols:

Electrolyte.....Dilute sulphuric acid...$H_2SO_4$
Negative plate..Spongy lead.............Pb
Positive plate..Lead peroxide...........$PbO_2$

On discharge, the sulphuric acid breaks up into positively charged $H_2$ ions and negatively charged $SO_4$ ions. The $SO_4$ ions unite with the lead plate forming lead sulphate ($PbSO_4$) giving up their negative charge to the lead plate. The hydrogen ions ($H_2$) carry their positive charges to the lead peroxide plate giving them up to the plate and uniting with the oxygen of the lead peroxide of the plate and forming water($H_2O$). The hydrogen ions actually

ANSWER #12. Continued.

get electrons from the lead peroxide. This is equivalent to giving the lead peroxide a positive charge. The sulphuric acid in contact with the peroxide plate is also broken up into ions of H2 and SO4. These H2 ions unite with the oxygen of the lead per oxide and form more water. The SO4 ions instead of going over to the negative plate unite with the lead, (Pb) of the lead peroxide (PbO2) plate and form lead sulphate (PbSO4) on the positive plate. Thus both plates are being reduced to lead sulphate. The cell continues to deliver current until the plates are entirely reduced to lead sulphate, when of course, all action will cease, since there would be but one kind of material present, and a battery requires two kinds. The practical limit of discharge, however, is reached long before both plates are completely reduced to the same material. On discharge, the electrolyte is constantly growing weaker, resulting in a lower EMF, and the active materials, lead and lead peroxide, are being replaced by lead sulphate, which has a much higher resistance.

On charge, both plates are lead sulphate. An outside current flowing through the battery in an opposite direction breaks up the water which has been formed during discharge into positively charged hydrogen ions (H2) and negatively charged oxygen ions (O). Part of the positively charged hydrogen ions are now attracted to the negative plate and unite with the SO4 of the lead sulphate, forming sulphuric acid (H2SO4) and leaving pure spongy lead at the negative plate. The negatively charged oxygen ions (O) flowing against the current are attracted to the positive plate. Here they unite with the lead (Pb) of the lead sulphate (PbSO4) plate and form lead peroxide (PbO2). The SO4 part of the positive plate is finally united to the rest of the hydrogen ions liberated when the electric current broke up the water H2O into H2 and O. This action forms still more sulphuric acid, and a positive plate of lead peroxide. When all the lead sulphate has been changed over to lead peroxide and pure lead, the battery is restored to the state it was in before it was discharged, and is now ready to furnish current again. The acid grows denser during charge so, as the EMF depends in part on the strength of the electrolyte, the EMF increased on charge.

The chemical equations for charge and discharge:

$$\xrightarrow{\text{DISCHARGE.}}$$

PbO2 plus Pb plus 2 H2SO4 equals 2PbSO4 plus 2 H2O

$$\xleftarrow[\text{Charge.}]{}$$

QUESTION #13. Explain the chemical action that takes place in an Edison cell.

ANSWER #13. The Edison cell consists of a jar of nickle-plated sheet steel containing an electrolyte (21% potash in pure distilled water) into which are immersed the positive and negative plates. The positive plate consists at first of nickel hydrate (Ni(OH)2) and the negative plate consists of iron oxide (FeO)

The chemical actions which take place are not clearly understood but the following are supposed to be the approximate actions:

When the cell is first charged, the nickel hydrate Ni(OH)2 is changed to nickel oxide NiO2 and the iron oxide FeO is reduced to metallic iron, Fe. The nickel oxide NiO2 soon decomposes to a lower oxide Ni2O3.

On discharge, the nickel oxide NiO2 starts changing to a lower oxide of nickel Ni2O3, and oxygen is liberated which is negatively charged and goes over to the iron plate, gives up its negative charge, and unites with the plate to form iron hydroxide, Fe(OH)2. The electrolyte grows lighter during charge which effect is opposite to that of the lead cell. The electrolyte, potassium hydroxide KOH, is not broken up, and seems to act merely as a catalyzer or carrier.

On charge, the iron hydroxide Fe(OH)2 is broken up and the negatively charged oxygen leaves the iron plate, travels back against the current through the cell and unites with the positive nickel oxide, Ni2O3 and forms a higher oxide, NiO2.

The chemical equations for charge and discharge:

$$\text{Fe plus Ni2O3}\cdot\text{1.2H2O plus 1.8 H2O} \underset{\text{CHARGE}}{\overset{\text{DISCHARGE}}{\rightleftarrows}} \text{equals Fe(OH)2 plus 2 Ni(OH)2.}$$

QUESTION #14. What voltage should a fully charged lead acid cell have when on the charging circuit with normal charging current, flowing thru?

ANSWER #14. The average voltage of a fully charged lead acid cell, gassing freely, when the charging current is normal is 2.5 volts.

QUESTION #15. What voltage should a fully charged Edison cell have under the same conditions as in Question #14?

ANSWER #15. The average voltage of a fully charged Edison cell, gassing freely, when the charging current is normal is 1.85 volts.

QUESTION #16. Describe the element of a lead acid cell telling of the connections within the cell and the colors of the plates.

ANSWER #16. The most common form of lead cell uses the Faure or pasted type of plate, in which the active material in paste form is spread on the surface of the plate or placed in the apertures of the grid. The paste masses used in practice utilize the cementing action which results from the formation of lead sulphate to harden the paste. Many form of grid for locking the materials have been developed; they consists of antimony-lead castings of various patterns, such as the shelf and diamond type.

In the Exide cell the positive and negative plates consists of lead-anitmony grids which support the active material in the form of a series of vertical strips held between the grid bars and locked in place by horizontal surface ribs that are staggered in opposite sides. After the grids are cast, they are pasted with oxides of lead made into a paste of special composition which sets in drying. The plates then go through an electro-chemical process which converts the material of the positive into brown peroxide of lead and that of the negative into gray spongy lead. The positives are all connected together in one group to a common terminal by means of a lead strap, and the negative plates are connected in a similar group, the two sets of plates being interleaved with each other, so that each positive plate has a negative plate adjacent to and facing it on either side. This requires one more negative plate in each cell than positives. When the positive and negative groups are assembled together, the adjacent plates, being of opposite polarity, must be kept separated and insulated from each other, as electrical contact between the two groups at any point will short-circuit the entire cell. For this reason separators are placed between the plates to prevent contact between them and these separators are now almost universally made of wood. The positive and negative groups, together with the separators, are collectively called the element. The element is usually set vertically in a containing jar of hard rubber or glass, or in a lead-lined wood tank. The positive plate is brown peroxide of lead and the negative plate is gray spongy lead.

QUESTION #17. Describe the element of an Edison cell telling of the connections within the cell.

ANSWER #17. The Edison, or nickel-iron type of cell, consists of positive plates which are made up of perforated sheet metal tubes into which is tamped the active material consisting of alternate layers of nickel hydroxide and flake nickel, the tubes being mounted in steel frames. The negative plates are steel frames with thin rectangular pockets of perforated sheet steel which hold the active material, iron oxide and metallic iron. The frames, tubes, and pockets are nickel plated. The positive and negative plates are assembled together, with one more negative plate than positive, so that the maximum surface of the positive plates may be utilized, with hard rubber separators.

QUESTION #18. State how acid electrolyte is prepared for use. What is meant by specific gravity?

ANSWER #18. The electrolyte in a lead cell is a definite mixture of chemically pure sulphuric acid and distilled water. The proper amount of distilled water, according to the table shown below, should be placed in a glass or earthenware (porcelain) jar, large enough to hold the whole of the mixture. The proper amount of acid, according to table, should be placed in a similar jar or pitcher. The ACID IS POURED INTO THE WATER (Never water into acid) very slowly and the mixture is constantly stirred to dissipate the heat which is generated. The table of solution follows:

| SPECIFIC GRAVITY | PARTS DISTILLED WATER TO 1 PART ACID |
|---|---|
| 1.300 | 2.47 |
| 1.250 | 3.22 |
| 1.220 | 3.84 |
| 1.200 | 4.33 |

As sulphuric acid is heavier than water, the electrolyte will also be heavier than water. By "specific gravity" we mean the ratio between the density of a body and the density of an equal volume of water. Water is considered to have a specific gravity of 1.000. When we speak of the specific gravity of a battery, we mean the ratio of the density of a cubic inch of electrolyte to the density of a cubic inch of water. The specific gravity of the electrolyte varies with the different manufacturers, and in certain cases is as high as 1.300. Commercial batteries are generally rated at 1.280 fully charged.

Navy standard storage batteries are so designed that when they are fully charged they will give hydrometer readings (specific gravity) of between 1.210 and 1.220 at a temperature of 80° F. and of 1.130 at 80° F. when fully discharged. The Navy uses batteries containing electrolyte of low specific gravity, because by so doing the life of the battery is prolonged, yet sufficient power is furnished for all purposes for which the battery is designed.

The specific gravity of a battery is determined by an instrument called a "hydrometer" which is immersed in the electrolyte. The hydrometer consists of a long glass rod having a bulb at one end loaded with shot or mercury, while the other end carries printed on it a scale graduated so that a direct specific gravity reading may be taken. When the hydrometer is dropped in the electrolyte, it will sink to a certain depth, depending on the weight of the liquid. The reading of the hydrometer scale at the surface of the liquid is the measure of the specific gravity of the liquid. Specific gravity is affected by temperature; an increase in the temperature of the electrolyte causes it to expand and thus show a lower specific gravity, although the strength

ANSWER #18. Continued.

of the electrolyte will be unchanged. As the standard temperature rating in the naval service is 80° F., hydrometer readings must be corrected for temperature by adding 0.001 for every 3° of temperature above 80° F., and by subtracting 0.001 for every 3° of temperature below 80° F. When applied to the hydrometer reading the result will be the true specific gravity of the liquid. Some special battery thermometers have opposite the scale the corresponding number, according to the reading of the scale, which must be added to or subtracted from the actual specific gravity reading.

QUESTION #19. State how Edison alkali electrolyte is prepared for use.

ANSWER #19. The electrolyte of an Edison cell consists of a 21% solution of potash in water with a small percent of lithia. The density of the solution is 1.210 and does not change.

The Edison electrolyte need never be prepared by Naval Radiomen, as the solution comes from the manufacturer ready mixed in a nickel steel container. When a cell needs a new solution, open the container and pour the solution into the cell, taking care to use a black iron funnel and an earthenware pitcher. Never use a tin or an enamel funnel.

QUESTION #20. Tell when and how you would dump a lead acid cell to renew the electrolyte.

ANSWER #20. The electrolyte in a cell should be dumped whenever it becomes poluted with foreign materials, or when a cell is leaking, so that the elements can be taken out and repaired, or when the sediment in the bottom of the cell piles high enough to short circuit the plates, so the cell may be cleaned. In each case the electrolyte must be renewed.

Before dumping the electrolyte, the battery must be fully discharged in order to drive all of the acid out of the plates. Then half of the electrolyte is poured out and the other half is swished around in the battery, so that most of the dirt and sediment is washed out when the remaining electrolyte is poured out. Then the cell is filled with distilled water and given a "dry charge" to drive out what little remaining acid there is in the plates. This water is then dumped and the cell is ready for the new solution, providing it needs no repairs.

QUESTION #21. Tell when and how you would dump an Edison cell to renew the solution.

ANSWER #21. The specific gravity of the solution in an Edison cell when made is from 1.200 to 1.230 and will remain the same on charge and discharge for an indefinite period of time, but eventually the electrolyte will drop in

ANSWER #21. Continued.

specific gravity due to age or when part of the mixture is spilled and the volume is brought back to normal by the addition of distilled water.

When the specific gravity falls to 1.150 the solution needs renewing. To dump the electrolyte, first charge the battery, then pour out half the solution swish the remainder around in the cell a few times to break loose any sediment in the cell, then pour it out and fill the cell with distilled water and again thoroughly charge the cell. Empty the water and the cell is ready for the new solution. Always be careful to use a black iron funnel and an earthenware pitcher to pour the solution. Never a tin or an enamel funnel.

QUESTION #22. What precautions whould be taken around the battery compartment in regard to ventilation and open lights or flames?

ANSWER #22. Adequate ventilation must be provided in a battery compartment to carry off all of the hydrogen gas which is manufactured in charging storage batteries This hydrogen gas is very explosive so extreme care must be taken never to expose a naked flame in a battery compartment.

QUESTION #23. What gases are liberated from storage batteries when charging.? What does this indicate?

ANSWER #23. Hydrogen gas is liberated from storage batteries when they are on charge. The hydrogen gas is caused by the decomposition of water $H_2O$ in the solution by the electric current flowing through the battery after the cell is fully charged. The water is broken up into $H_2$ and O. These come to the surface in form of bubbles. The hydrogen gas is explosive.

A uniform bubbling, or gassing, or liberation of hydrogen in all cells is an indication that the battery is either being charged at too high a rate or that the battery is fully charged.

QUESTION #24. What four instruments are necessary for the proper care of batteries? Explain the use of each.

ANSWER #24. The four instruments necessary for the proper care of batteries, are: An ammeter, a voltmeter, a hydrometer, and a thermometer.

The ammeter is used to measure the amount of current being used to charge a battery. The voltmeter is used to determine the state of charge or discharge of a battery. The hydrometer is used to measure the specific gravity of a battery and the thermometer is used to check the temperature of the battery so as not to exceed the limit of 110°F., and to apply the correction to the specific gravity described in the answer to question #18.

QUESTION #25. What is the minimum allowable voltage of a lead acid cell? Of an Edison cell? What is the minimum allowable specific gravity?

ANSWER #25. The minimum allowable terminal voltage of a lead acid cell is 1.75 volts. The minimum allowable terminal voltage of an Edison cell is from .9 to 1.0 volts. The minimum allowable specific gravity of a Navy lead cell is 1.130. The specific gravity of an Edison cell, normally does not change on charge or discharge, though the solution will drop after being in use a long time, and should be renewed when it drops to 1.160.

QUESTION #26. Upon what does the capacity of a cell depend?

**ANSWER** #26. The capacity of a cell depends on the area of the active material immersed and on the distance between the plates, and upon the conductivity of the electrolyte, and upon the thickness of of the plates, and the rate of discharge.

QUESTION #27. What is the most common source of injury to a cell?

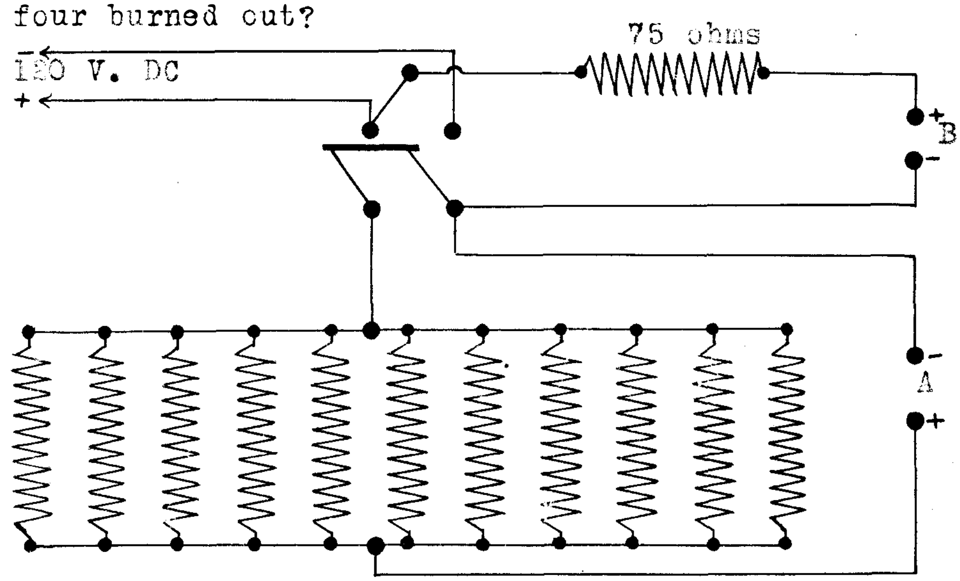
ANSWER #27. The most common source of injury to a lead acid cell is overdischarge which produces an excess of lead sulphate in the deeper crevices of the plates, which is very hard to remove, and may occasion buckling of the plates or fracture. Buckled plates should be straightened out as soon as observed. Do not let the battery stand in a discharged condition.

QUESTION #28. How long would you charge a battery at normal charging rate?

ANSWER #28. The standard time of charge of storage batteries to be used in stationary work is 8 hours. If charge or discharge is carried on more rapidly than this, the ampere-hour capacity of the cell is lowered somewhat. It is to be understood that the eight-hour rate is merely that rate for the longest life and the greatest efficiency. No great harm is done, however, if higher charging rates are used, provided the current in amperes at no time is greater than the number of ampere hours which can still be put into the battery. For instance, if a 100 ampere-hour battery is completely discharged, the charging rate might start at 100 amperes. But when 25 ampere hours had been put into the cell, the charging current should not exceed 75 amperes, the current continually decreasing as the battery becomes charged. When higher rates are used, the chemical action is violent, excessive gassing occurs, the temperature rises rapidly, and the active elements are not properly deposited on the plates and are likely to form a deposit in the bottom of the jar, which may eventually rise high enough to reach the plates and short-circuit them, if it is not removed.

QUESTION #29. Draw a diagram of the SE 3602 charging unit. How are the resistances connected in this circuit? What would be the effect if two of them burned out? If four burned out?

ANSWER #29.




NAVY STANDARD TYPE S.E.3602c, Battery Charging Res.

There are eleven 75-ohm resistors in a parallel bank in series with the Filament batteries. There is one 75-ohm resistor in series with the Plate batteries.

The total resistance of the bank of eleven 75-ohm resistors in parallel is equal to the resistance of one divided by the number of resistors:

$$\frac{75}{11} = 6\frac{9}{11} \text{ ohms.}$$

Therefore, the bank has a total resistance of 6 and 9/11 ohms in series with the batteries. This resistance would pass a current of 17.6 amperes at 120V.

If two of the resistors burned out the total resistance of the bank would increase and the current in the circuit would, of course, decrease, since the current is inversely proportional to the resistance:

$\frac{75}{9} = 8\frac{1}{3}$ ohms, total resistance, which would pass a current of 14.4 amperes at 120V.

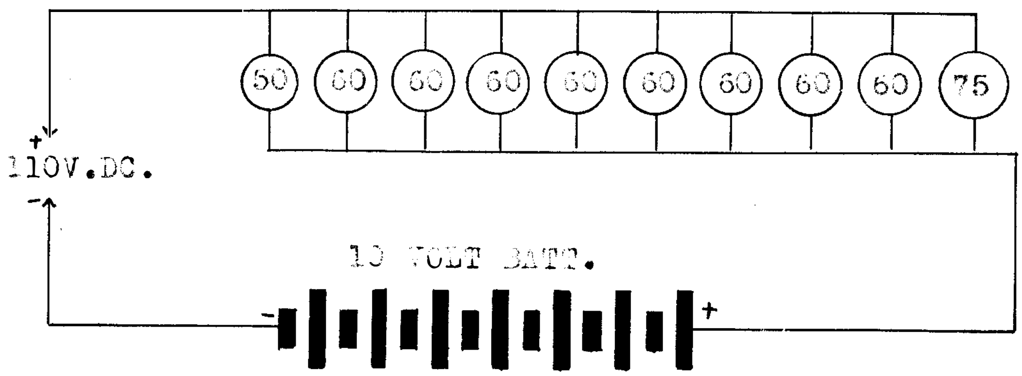
If four burned out the resistance of the bank would be further increased and the current would be further decreased:

$\frac{75}{7} = 10\frac{5}{7}$ ohms, total resistance, which would pass a current of 11.2 amperes at 120V.

If the single 75-ohm resistor in series with the Plate batteries, burned out the line would be open and no current would flow. The single 75-ohm resistor will pass a current of 1 and 3/5 amps at 120V.

QUESTION #30. How would you connect a ten volt storage battery to a 110 volt line (DC) to send a current of five amperes through it, using incandescent lamps? Draw a diagram of the circuit giving the number of lamps used and their size or rating.

ANSWER #30.




Disregarding the internal resistance of the battery and the resistance of the lines, the 10 volt battery bucking the 110 volt supply would be the same as a 10 volt drop in potential across the battery.
Since we must have a current of 5 amperes flowing through the battery, we must have a resistance, in series with the battery, which will cause a drop in potential equal to the difference between the charging voltage of the battery, 10 volts, and the E.M.F. 110 volts, which is 100 volts. To find this resistance:

Formula: $R = \frac{E}{I} = \frac{100}{5} = 20$ ohms.

To obtain this resistance using incandescent lamps we must obtain such lamps that will consume a total of 500 watts on a 100 volt circuit (5 amps x 100V). Since incandescent lamps are rated at 110 volts, it is necessary to compute the total power consumed by the same resistance, 20 ohms, (disregarding the temperature coefficient of resistance):

20 ohms on a 110 volt line would draw 5.5 amperes. To find the power consumed:

Formula: $P = IE = 5.5 \times 110 = 605$ watts.
One combination of incandescent lamps which would consume 605 watts on a 110 volt line, are: 8-60W, 1-75W, and 1-50W, total 605 watts.

QUESTION #31. Draw TW Transmitter.

ANSWER #31. See separate diagram.

Care and upkeep of Lead cells.

The attention that should be given to storage batteries is summed up under the following general heads:

1. Add distilled water often enough to replace evaporation, keeping plates covered at all times.
2. Keep all connections tight and covered with a light film of vaseline.
3. Keep the filling plugs tight and the battery dry and clean
4. Take hydrometer readings at regular stated periods accord- to the duty being performed by the battery.
5. When the battery is to be idle for any great length of time place it in storage.

The batteries should be charged at regular intervals. They should be charged at the normal rate and the charge completed. Habitual undercharging is one of the causes of a battery becoming sulphated. A battery should never be allowed to stand in a completely discharged condition, as this may render it unfit for further service. In the course of time sediment will collect in the bottom of the cell; this should be removed before it reaches the bottom of the plates to prevent short circuiting.

To remove this sediment first provide another jar with similar electrolyte and then charge the battery fully. Lift the plates out of the container, placing them temporarily in the jar of electrolyte, then draw off the electrolyte from the container from which the plates were removed, placing this electrolyte in an earthenware vessel. Remove sediment from the bottom of the container and wash out container with distilled water. Next replace plates and original electrolyte and complete filling of all cells with new electrolyte. If, after cleaning the battery the specific gravity is found to be low, the battery should be brought up to standard by adding the electrolyte instead of water when replacing loss from evaporation.

If any of the following symptoms are noted in a cell compared with surrounding cells, the cell in question should be examined for a short circuit:

1. Falling off in specific gravity.
2. Lack or deficiency of gassing on regular charge.
3. Color of plates markedly lighter or darker.
4. Excessive temperature.
5. Lower voltage.

Individual cell voltages should be taken when the battery is discharging at the normal rate as the open circuit voltage of a cell is of no value in determining the state of charge, due to the fact that a normal cell although fully discharged will regain almost its full voltage on open circuit. Manufacturers instructions are usually available. These should be studied and carefully following in the care and operation of the battery.

Management and Location and Repair of Minor Defects.

There are a few important rules that one should bear in mind in the management of a lead storage battery.

Always use pure electrolyte.

Never allow the surface of the electrolyte to fall below the upper edge of the plates.

Always keep the electrolyte as furnished by the manufacturer

Keep all the separators in place so that there is no danger of the plates coming in contact with each other.
Keep cells well insulated by placing them in trays that are supported on insulators.
Inspect the cells occasionally for leaks in the container.
Always charge the battery as soon as possible after discharge.
Never overcharge the battery except to remedy sulphation.
Do not charge regularly at high rates.
Watch the battery for sulphation, and if any sulphate appears treat the plates immediately.
Never allow the battery to discharge below 1.75 volts per cell, or 1.130 at 80° F. specific gravity.
Always keep the temperature of the battery below 110°F.
Do not expose the battery to extreme temperature.
Batteries should have plenty of ventilation as they give off hydrogen gas.
Naked lights should not be carried into a room where storage batteries are charged.
The following troubles are the most important ones encountered in the operation of a storage battery:

1. Loss of voltage.
2. Loss of capacity.
3. Corrosion of electrodes and sulphation.
4. Buckling of plates.
5. Shedding of active material.

Loss of Capacity and Voltage.

When a battery is overcharged, too much lead sulphate is formed, and this sulphate collects on the plates in crystals, thus reducing the capacity and voltage. The remedy is to charge the battery at a high rate until the plates gas freely, then reduce the rate to the normal eight-hour rate until the plates again gas. Then reduce to half the eight-hour rate and continue until the plates gas. At this point partly discharge the battery and recharge as before.

Buckling of Plates.

Continual excessive overcharging, or violent discharging, heats the battery beyond all bounds , and if indulged in repeatedly is very apt to injure the plates. Overcharging a battery is usually the result of faulty apparatus; that is, the regulating apparatus does not regulate, so that instead of sending, say, the rightful 12 amperes into the battery, the generator is cramming 30 amperes into it, and keeping it up long after the battery has had enough. This causes buckling of plates. Be sure regulator is regulating charge correctly.

Sulphation.

One of the troubles to which plates are liable in the service of a careless operator is a hardening called sulphation, and is caused by lack of charging or by a dry area at the tops of the plates caused by lack of water. Sulphation in plates produces a white chalky substance which is a nonconductor of electricity. Sulphation of 50 percent of the plate area will cut down the battery's power capacity even more than 50 percent because of the energy wasted in overcoming the increased internal resistance caused by this chalky deposit. Always keep plates fully covered with electrolyte.

## Equalizing charge.

(a) Charge the battery at the finishing rate for the normal charge, or at about one-third or one-fourth the normal charge. Continue charging until five hydrometer readings taken on each cell at 15-minute intervals show no increase in specific gravity; that is, obtain five identical hydrometer readings, taken at 15-minute intervals, on each cell. Readings should be logged. Temperature readings should be taken at the same time that the specific gravity readings are taken.
(b) The density of the electrolyte must be corrected to 80° F., as the hydrometer readings may remain constant while the temperature is rising. This condition indicates that the specific gravity is increasing.
An equalizing charge is given to insure that all the sulphate is driven from the plates and to restore the cells of a battery to normal capacity when the battery can not be brought to normal specific gravity with a normal charge.

## Dry Storage.

The battery should be fully charged as per instructions. The plates should be removed and the wood separators discarded. Also discard the old electrolyte. Soak the positive and negative plates in cold distilled water for at least 15 minutes. Positive plates can then be laid aside to dry. The negative plates will probably heat when removed from the water, and they should be redipped until they cool off. The parts can now be stored in a dry place, care being taken not to let the positive and negative plates come in contact.

The following data table is very useful in ascertaining the condition of a battery in its various stages from a fully charged to a fully discharged condition. Data are given for both the lead-acid battery and the Edison or nickel-iron battery:

| STATE OF CHARGE | VOLTAGE | | SPECIFIC GRAVITY | |
|---|---|---|---|---|
| | LEAD BATT. | EDISON | LEAD BATT. | EDISON |
| Cell fully charged gassing freely | 2.5 | 1.85 | 1.210 | 1.210 |
| Fully charged after standing | 2.1 | 1.6 | 1.210 | 1.210 |
| Fully charged by discharging normal rate | 2.0 | 1.5 | 1.210 | 1.210 |
| Fully discharged, discharging normal rate | 1.75 | 1.0 | 1.175 | 1.210 |
| Fully discharged on open circuit, standing | (1) | ---- | 1.175 | 1.210 |

(1) Lead cells may recover up to fully charged voltage; drops immediately to 1.75 if circuit is closed.

## CARE AND UPKEEP OF EDISON STORAGE BATTERIES.

Under proper treatment Edison cells will improve with use. A new cell will continue to increase in capacity for a period of at least 30 cycles of charge and discharge. If a new battery or one which has been standing idle for a long time operates somewhat sluggishly use it as much as possible, giving it occasional discharges, and it will soon pick up to normal capacity. If the capacity of the battery falls off, it is usually an indication that the electrolyte needs to be changed. Empty old electrolyte and refill with new solution, taking care to use a black iron funnel and earthenware pitcher. Never use tin or enamel funnel. Keep the salt deposits that collect on tops of cells cleaned off at all times, and keep cell tops and containers coated with vaseline compound. Never put acid in an Edison battery, An Edison cell can remain idle for long periods without charging and not sustain serious damage. Always keep in a dry place. Never bring a naked flame near any battery that is being charged, as hydrogen and oxygen gases are given off and will ignite very readily. Edison batteries will freeze in temperatures of 25° F. below zero. If possible an even temperature, not too warm, should be maintained.

## BATTERY CONNECTIONS.

Connections, such as series, parallel, and series parallel are the methods generally used in grouping cells.

### Series.

Cells are said to be connected in series when the positive terminal of one cell is connected to the negative terminal of the next cell and so on. The effect of this grouping is to sum up the characteristics of the cells; that is, the total voltage is the sum of the individual voltages of each cell, the total resistance is the sum of the internal resistances of each cell. Cells are grouped in series when the resistance of the circuit is large so that the increas of internal resistance is not of much moment, the increased voltage producing increased current. The largest amount of current from this grouping on short circuit or closed circuit is the same as the current of one cell. The arrangement is used when the voltage desired is greater than the voltage of one cell.

### Parallel.

Cells are in parallel when all the positive terminals are connected to one common conductor and all the negative termainals are connected to one common conductor. The effect of this grouping is as follows: The total voltage will be the same as the voltage of one cell but the total internal resistance of the battery will be the resistance of one cell divided by the number of cells in parallel. This arrangement is used when the current desired is greater than the current of one cell.

### Series Parallel.

Cells are connected in series parallel when one or more cells are connected in series to form one bank, then the positive terminals of a number of identical banks are connected to one common conductor and the negative terminals are connected to another common conductor. The banks must have equal voltage, or the difference in pot ential will cause one bank to charge another bank. The effect of this grouping is: The total terminal voltage is equal to the sum of the voltages of the number of cells connected in series in one bank. The total internal resistence in equal to the number of cell in one bank, divided by the number of banks, times the internal resistance of one cell. This system is used for most battery work, especially where a higher voltage and a greater current than one cell could give is required.