CHAPTER VI.

BATTERIES.

THE primary cells most generally used in signal installations are the following: (1) Gravity; (2) Gordon; (3) Edison. All are of the closed-circuit type; that is, they are capable of withstanding continuous full normal-current discharge.

Open-circuit cells are but little used; for, while certain work is intermittent in character, it has been found that cells of this type are not to be depended upon. For ringing electric bells at places where inoperation will not result in serious consequences, the Leclanche or sal-ammoniac cell has been applied with restrictions.

In the gravity cell, which is of the two-fluid type, the different specific gravities of the liquids used is the only principle involved in keeping them apart; porous cups and diaphragms being thereby eliminated. These liquids are a saturated solution of copper sulphate and a dilute solution of zinc sulphate and sulphuric acid, the latter being formed only during the action of the cell, which is shown in Fig. 88. The copper element, *C*, rests upon the bottom of the containing jar, and is connected to the external circuit by an insulated wire. The copper is partly covered with crystals of blue stone or copper sulphate (CuSO), these crystals being surrounded by a strong solution of copper sulphate. Above this latter solution, and distinctly separate from it, is the solution of zinc sulphate, in which the zinc, *Z* (a common type of which is shown also at *D*), is immersed. This zinc is supported by the bent bare copper wires, *G*, which are cast in the former. The action of the cell is as follows:

When the external circuit is closed, the small amount of sulphuric acid (or water if the former is not present) attacks the zinc, forming zinc sulphate and hydrogen. The zinc sulphate remains in the upper part of the liquid, while the hydrogen passes to the copper sulphate, and thus forms sulphuric acid and metallic copper. The copper is deposited upon the copper element, while the sulphuric acid rises and attacks the zinc, this cycle being repeated as long as the external circuit is closed.

These reactions are expressed as follows: —

$$Zn + H_2SO_4 = ZnSO_4 + 2H.$$
$$2H + CuSO_4 = H_2SO_4 + Cu.$$

When the water of the solution is decomposed, oxygen is liberated. The copper which is deposited upon the copper element must be loosened each time the cell is renewed, or the accumulations

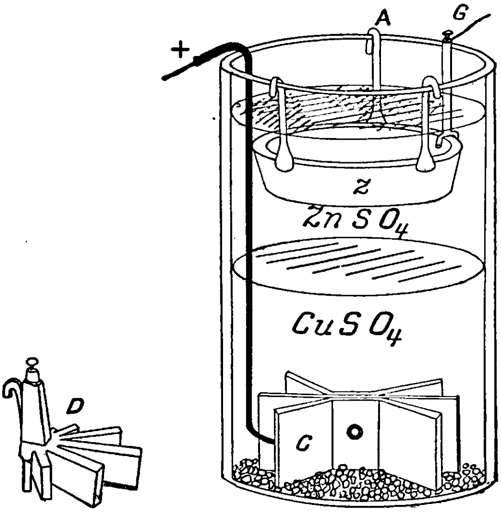


FIG. 88

will become too solid for removal. When a gravity cell is in proper condition, the blue line of separation should be midway between the two electrodes.

The e.m.f. of this cell on open circuit is 1.07 volts; and the internal resistance from about .5 to 3 ohms. This will give a current on short circuit of from .3 to 2.5 amperes. The cell is most commonly used for track circuits on account of its perfect electrochemical depolarization. To a certain limit of saturation of the upper or zinc sulphate solution, the greater the continued demand the more satisfactory the operation. A disadvantage of the cell, however, is the high internal resistance.

The loss this entails depends upon the resistance of the circuit to which it is connected; since this loss (C^2R) depends upon the relation of the internal resistance to the total resistance.

The internal resistance of a gravity cell being 0.5 ohm, the maximum $\frac{c^2}{v}$ factor that can safely be allowed is 2, which at .30 gives an economic power valuation of 2.2.

In the Gordon cell, the elements are iron and zinc, while the exciting liquid is a strong solution of sodium hydrate or caustic soda, $NaOH$. The containing jar is either glass, porcelain, or enameled steel, depending upon the conditions to be met. Steel and porcelain have a longer life, and are much less liable to failure during recharging and operation than glass, but the operation of the cell is not visible, as is desirable to determine the point when renewal must be accomplished.

Fig. 89 illustrates a 300-ampere-hour cell, such as is most frequently used for signal and grade-crossing circuits, the jar being 6 in. by 8 in. in size. *Z* is the positive zinc element, which is a sheet bent to a cylindrical form; it being of about one-eighth of an inch in thickness. This is thoroughly amalgamated, to prevent local action, and is supported on three porcelain lugs, *P*, fastened to the perforated cylinder, *D*, which it surrounds. This latter is partly filled with a flaky oxide of copper (CuO), the iron and this compound forming the negative element. Contact is made to *D* by a binding post or connector, the threaded connection to which is screwed into a nut in the top of the cylinder. The sheet iron cover, *C*, supports *D* and *Z* by the binding action of two porcelain washers, *A*, one above and the other below *C*. The zinc is connected to the external circuit by the insulated wire, *W*, which is riveted to the former and further insulated from *C* by a small porcelain bushing. The riveted connection is covered with asphaltum to prevent local action at the junction of the copper and zinc.

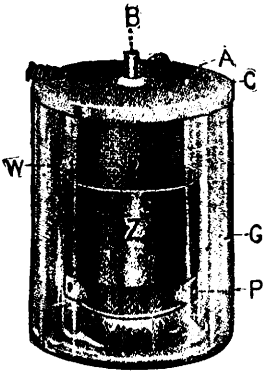


FIG. 89

When the cell is renewed, the entire cylinder and contents, also the remaining zinc, is thrown in a scrap pile. Formerly, the exhausted copper oxide was removed and replaced, the entire arrangement being dismantled to do this; resulting in much labor and, without care, painful sores on the hands of the batteryman. Thus one of the objectionable features of the sodium hydrate cell has been removed.

An exciting solution of from 20 to 25 per cent is employed; in other words, three or four pounds of water to one pound of pure caustic soda. The copper oxide and zinc are so proportioned that all the elements are exhausted at once. A heavy mineral oil is used to cover the surface of the exciting solution, as this latter has a strong affinity for the CO_2 of the atmosphere, which if not otherwise prevented would result in rapid deterioration of the cell. The reaction is shown in the formula:

$$2NaOH + CO_2 = Na_2CO_3 + H_2O.$$

The sodium carbonate (Na_2CO_3) thus formed is not only of little value in setting up an e.m.f., but it also is of a creeping character, crystalization taking place over the edges of the jar and cover, resulting in rapid destruction of the latter.

During the action of the cell, sodium zincate is formed as follows:

$$2NaOH + Zn = Na_2ZnO_2 + 2H_2.$$

The hydrogen passes to the copper oxide and forms water and metallic copper, thus:

$$2H + CuO = Cu + H_2O.$$

The Edison cell is also of the single-fluid type, and now employs an exciting solution of caustic soda or sodium hydrate, NaOH. In its action it is somewhat similar to the Gordon, but of a different mechanical construction. Formerly, caustic potash solution was used, but as this is even more difficult to handle than the sodium compound, it has been abandoned. Fig. 90 shows the cell in part section. A cover, *B*, of porcelain, has a recess which fits into the top of the containing jar. In the center of this cover there is a boss, on each side of which stems or lugs, *L*, incorporated with the zinc plates, *Z*, are securely clamped by the thumbscrew connector, *C*. Within a slotted frame of copper, *F*, are placed two porous, compressed, and beveled plates of cupric oxide, *O*, with surfaces reduced to the metallic state for increased conductivity. These plates have a binder of magnesic chloride, and are secured in place by the copper thumb bolts, *N*. Two insulating tubes of hard rubber, *T*, are placed on part of the frame which emerges from the liquid, and prevent the current from leaking across the surface of the liquid to parts of opposite polarity, also protecting the frame from corrosion at the junction of the oil and solution. The liquid is covered as before with a heavy mineral oil, and the external circuit wires are fastened to the connectors, *A* and *C*.

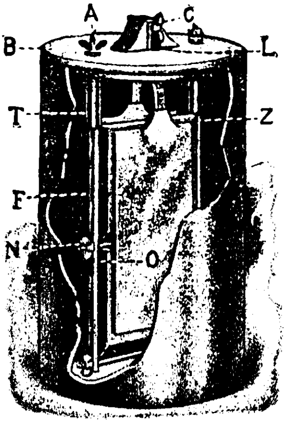


Fig. 90

The cell is renewed by removing the zincs, oxide plates, and solution, and replacing by new elements, care being taken to have all nuts and connections tight. The entire old solution is thrown away and the new liquid substituted, a fresh bottle of oil being poured over the surface. Before replacing the new elements, they should be dipped in clean water, to prevent the oil, which is of high viscosity, from adhering when they are immersed in the solution.

The water used in renewing all cells should be taken from a running stream or hydrant, as stagnant water contains vegetable and animal impurities which render it unfit for battery purposes. For this reason it is not practicable to locate barrels filled with water near the battery chutes, as animalculæ soon manifest themselves. Spring water is not always valuable, as it may contain mineral substances whose reaction is deleterious to the proper action of the cell. When mixing caustic soda solution, the soda should be slowly poured into the water, and the latter rapidly stirred at the same time, as failure to do this will result in its falling to the bottom and solidifying. Should any of the solution get on the hands or face it may be readily eliminated by applying a vegetable or animal oil or grease, which is thus converted into soap. If glass jars are used, they should be placed on dry wood or ties, to prevent cracking at the bottom, owing to unequal expansion.

The surface of the liquid should be about one inch above the top of the zinc and oxide plates, for if the latter project above the liquid, the bare parts will be rapidly destroyed. Also fine particles of metallic copper may fall from the oxide plates and by floating upon the plane of separation of the oil and solution, ultimately short-circuit the cell. The condition of the oxide plates may be ascertained by picking into them with a sharp knife. Should they be copper colored throughout, they are exhausted; but if the central portion is black, they are still of use, the continuity of life depending upon the relative thickness of this inner black layer. Using an exhausted set of plates results in rapid depolarization, while it is not advisable to use plates that have been left in the air and consequently partially reoxidized, as this natural oxidization occurs only superficially.

A 300-ampere-hour capacity has an internal resistance of .025 ohm, a working voltage of .667, a continuous-current delivery of 6 amperes, a short-circuit current of 26.7 amperes; consequently a $\frac{c^2}{v}$ factor of 17.78, and a $\frac{c^2}{pr}$ factor of 5.34, when $p = .30$. The low internal resistance is advantageous when the cell is called upon to deliver heavy currents; that is, when connected to a low external resistance. The ratio of the energy lost in the cell to the total energy expended is then very low.

The disadvantages of the sodium hydrate cells are the caustic nature of the exciting liquid, the low terminal voltage, the rapidity with which they give out, and the excessive heat caused by the dissolving of caustic soda in water. The indication that a cell needs renewing is the segregation of crystals of sodium zincate upon the zinc element, a condition occurring without much warning. The use of oil on the surface of a liquid is also rather troublesome, as the inside surface of the jars must be frequently cleaned. Also a large percentage of the cost of operation is in scrap which is not really utilized.

The advantages are the uniformity of operation, freedom from local action, low internal resistance, constancy of current output, ability to withstand low temperatures, the absence of noxious or combustible vapors, and the adaptability for heavy current output.

Storage cells have many advantages over primary cells which make them particularly adaptable to certain phases of signaling.

Where large amounts of energy are required, and it is not advisable to install a separate generating plant, storage cells may be economically applied, being charged by a portable generating set. Such an arrangement has the advantage of a large and steady output, with a smaller number of cells than the closed-circuit primary cells we have considered can have. The average e.m.f. of a storage cell is 2 volts, so that three Edison cells can be replaced by one storage cell, as far as voltage is concerned. When a stationary generating set is used, the signal batteries are charged through the aid of line wires which run from the plant and include the cells in series.

Most of the accumulators used in signal practice have positive and negative plates of lead and an electrolyte of dilute sulphuric acid (four parts of water by volume to one part of acid, giving a specific gravity of 1.2). The lead plates are "formed" mechanically or electrically, and are fastened together in substantial shape.

Storage cells are rated according to the number of ampere-hours they are capable of discharging until the terminal e.m.f. of a cell falls to 1.8 volts, the e.m.f. when fully charged being 2 volts. However, since sulphating sets in below 1.9 volts, they should never be discharged until the e.m.f. becomes less than this figure.

A 300-ampere-hour cell may be charged at a normal current of 30 amperes, the charging continuing for 10 hours; which also represents the normal rate of discharge. Smaller capacities require less current; a 50-ampere-hour cell taking 5 amperes under normal conditions. It is better practice to prolong the charging time by decreasing the current. Better results are also obtained when discharging at a low rate, a 150-ampere-hour cell being capable of delivering 190 ampere-hours with 38 hours allowed for both charge and discharge, and only 120 ampere-hours at 5 hour discharge rate.

When charging, the e.m.f. of the generator should be 10 per cent greater than the total e.m.f. of the cells when charged. The resistance of a cell is very low (.003 ohm for an average 300 ampere-hour cell), hence it is necessary to include a resistance of some kind in series when charging. To illustrate, suppose 40 such cells were connected in series on a 110-volt circuit. The cell e.m.f. which will oppose that of the supply circuit would be

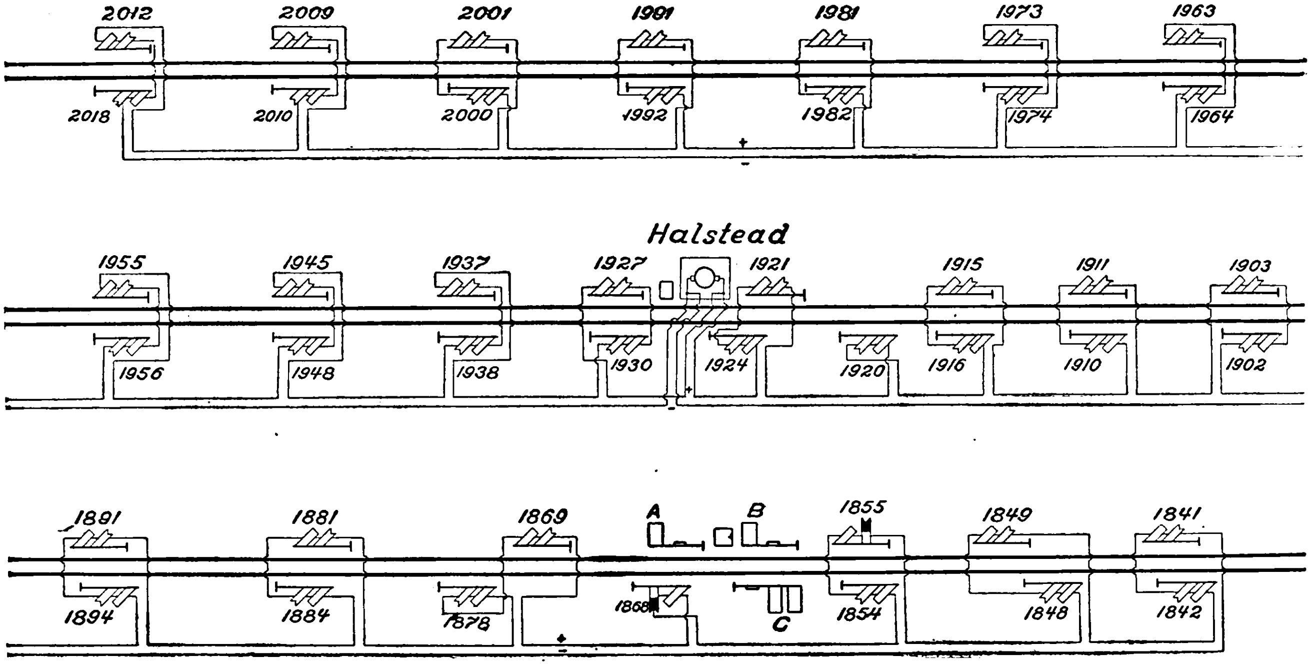
40 × 1.9, or 76 volts. Then 110 − 76 = 34 volts; resulting in a flow of 34 ÷ (40 × .003) = 283.3 amperes, which of course is an excessive current. With a resistance of one ohm in series, on the other hand, the current would be 34 ÷ 1.12, or 30.3 amperes, which is a normal value.

Usually the line has sufficient resistance to prevent an excessive current flow; but in any event it requires careful calculation. It is advantageous to have a small variable resistance (rheostat) in circuit so that the charging current may be adjusted to the required value.

Accumulators should be installed in a dry place, having an average temperature of about 70° F. Charging may be continued until gasing sets in, a phenomenon caused by the liberation of hydrogen, which gives the electrolyte a boiling appearance. High insulation must be maintained; otherwise the leakage factor will be high, and trouble encountered with foreign currents in the track circuits.

Storage batteries may be charged from commercial power circuits, or through the medium of a portable generating plant. In the latter case, gasoline engines are preferable, the generator being direct driven, except in the case of small units. If alternating current is available, it is converted to direct at the proper voltage by a motor generator or mercury rectifier. In all-electric interlocking 110 volts is the standard pressure; 55 storage cells being connected in series to obtain this e.m.f. The capacity of the individual cells depends upon the work they perform in a given time, usually 24 hours, the cells being charged so often. With such installations, a switchboard is necessary. Such a board should contain an ammeter, voltmeter, pilot lamps for indicating grounds, circuit switches, charging rheostat, fuses, and circuit breakers (both overload and reverse current).

A mercury converter or rectifier is now used for charging storage signal-batteries from alternating-current mains. This device suppresses the negative wave of the alternating side and converts it into a pulsating direct current, with intervals of partial current cessation. Such a current can readily be employed for charging purposes, although it could not be used directly on the signal motors or relays, due to the resistance offered by such inductive devices; with consequent heating and loss of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1915
1911
1903
1956
1948
1938
1930
1924
1920
1916
1910
1902
1891
1881
1869
A
B
1855
1849
1841
1894
1884
1878
1868
C
1854
1848
1842

FIG. 91

energy from eddy currents and inconstancy of the available e.m.f.

Mercury rectifiers should be mounted upon a switchboard, containing the main switches and connections, with a transformer, having a variable secondary voltage. The charging wires run either to separate portable battery sets, or to the charging line. This arrangement is not only economical, but practicable; and transmission may be effected over great distances, and from isolated points, at any primary potential.

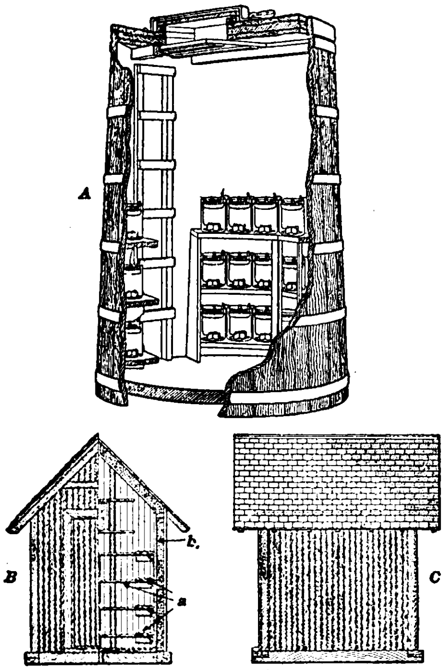

Fig. 92

Fig. 91 is the plan of a charging arrangement used on the D. L. & W. is shown. The charging plant is located at Halstead, N. Y. (192.5 miles from New York City), the total territory covered being 17.7 miles. Forty-four two-arm signal mains are charged in this fashion; *A*, *B*, and *C* being slotted mechanical signals.

While nearly all forms of primary batteries used in signal practice are of the non-freezing types, it is advisable to make battery shelters or houses as impervious to cold as possible. The internal resistance of cells increases with decrease of temperature, and when the surrounding air has a temperature below that of freezing, the action is sluggish, the current discharge being low and the requisite circulation of the exciting liquid poor. In Fig. 92, *A* is a wooden battery tank or well which may conveniently be installed below ground, with the top projecting above the surface. The latter is weatherproof and provided with a hinged cover, while the cells are arranged in tiers, upon ventilated shelves, for ease of inspection and renewing. The inner base is provided with drainage holes, the scrap material being contained in suitable boxes.

At *B* and *C* a sectional and side elevation of a common type of battery house is given. The shelves *a* are arranged on the inside walls, giving a maximum of room for the batteryman's operations. The walls are lined with felt, asbestos, or similar material, *b*, for protection from the varying temperature of the outer air. With this arrangement inspection is rapid, and safety from high water assured.