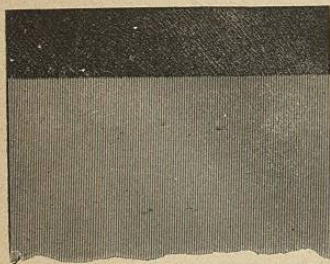


plate being located between two carbon plates and separated from them by strips of paraffined wood  $\frac{1}{4}$  inch thick,  $1\frac{1}{2}$  inches wide, and 8 inches long. The plates and separating

FIG. 395.

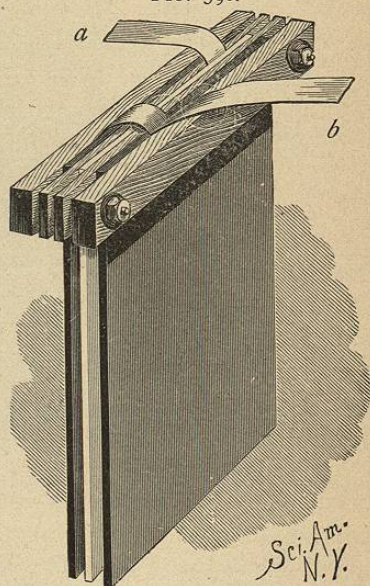


strips are clamped together by thick strips of paraffined wood arranged upon the outer side of the carbon plates, and bolts, preferably of brass, passing through the ends of all of the strips. The electrical connection with the zinc plate is made by inserting a copper strip, *a*, between the plate and the wood strip. The connection with the carbon plates is made in a similar way, the strip, *b*, being looped so as to form a contact with both plates without touching the zinc.

Before the elements are put together, the zinc plates should be carefully amalgamated. This is done by dipping each plate into a jar of dilute sulphuric acid (acid 1 part, water 10 parts), containing mercury at the bottom. As soon as the lower end of the plate is coated with mercury it may be lifted from the solution, inverted, and allowed to stand until the entire surface of the plate is perfectly covered with mercury. If there are portions which do not receive the mercury, they are scraped or sandpapered and returned to the acid solution, when mercury is applied locally.

If the amalgamation is perfect, the plates will not require

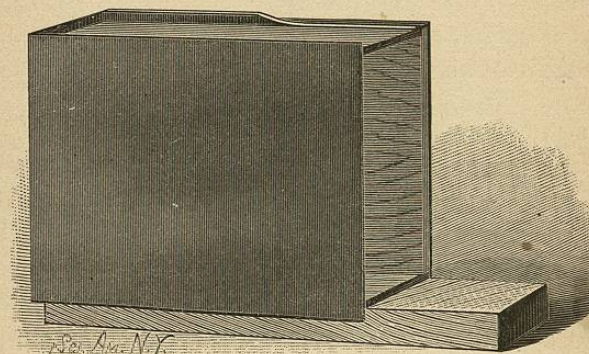
FIG. 396.



Sci. Am.  
N. Y.

re-amalgamation. An amalgamating solution is made by dissolving mercury in nitric acid, then adding water so as to make a 10 per cent. solution of the mercury nitrate. A zinc plate immersed in the solution becomes amalgamated, but the operation requires frequent repetition. The cells consist of pine boxes of the size mentioned lined with gutta percha. The operation of lining is quite simple, and the cell, if well made, is durable. A wooden form is made which is the thickness of the gutta percha smaller than the boxes. Around the sides and end of this form is wrapped a sheet of gutta percha, which is  $\frac{3}{4}$  inch wider than the form, the edges of the sheet being allowed to project beyond the form, as shown in Fig. 397.

FIG. 397.



Forming the Gutta Percha Lining.

A piece of gutta percha of suitable width and length is placed upon the form within the projecting edges of the sheet already in position. The edges are then warmed sufficiently to render them adhesive, by means of a lamp flame or by holding a hot iron near enough to soften the gutta percha. The edge is then turned over in the manner illustrated. The fingers should be moistened to prevent the gutta percha from adhering to them. When the lining is complete, it is placed in the wooden box and expanded to fit by filling it with warm water. The upper edges of the lining should be turned over upon the edge of the box and made to adhere by heating. The box should be thoroughly

coated with shellac varnish inside and outside, and allowed to dry before introducing the lining. Eight of these cells are placed in a box having removable sides and a frame extending over the top. To the vertical standard of the frame is loosely fitted a horizontal frame which supports the plates of the battery. In the upper part of the frame is journaled a shaft provided at opposite ends with drums, to which are attached chains for lifting the horizontal frame and plates supported thereby. The shaft is provided with a crank by which it may be turned, and with a ratchet which is engaged by a spring pawl attached to one of the standards.

The copper strips connected with the zinc plates are clamped to the strips extending from the carbon plates, and the terminal strips are provided with binding posts for receiving conductors. Each set of plates is provided with a hook, attached to the clamping strips by means of a cross-bar of vulcanite or vulcanized fiber. These hooks are designed to be placed on the shaft when it is desired to use only a part of the cells, the unused plates being detached from the others and suspended out of contact with the solution. On account of the difficulty of removing the hard and almost insoluble crystals of chrome-alum formed in batteries employing a solution of bichromate of potash, a bichromate of soda solution is substituted. The crystals forming in the bichromate of soda solution are readily removed from the cell.

This solution is made by dissolving bichromate of soda in warm water to saturation, allowing it to cool, then slowly adding commercial sulphuric acid to the amount of one-fifth of the volume of the bichromate solution. As the gutta percha lining of the cells melts at a low temperature, the solution should be allowed to cool before pouring it into the cells.

The plates should not be plunged into the solution to a greater depth than is necessary for the production of the desired current, and they should always be withdrawn after use. The electro-motive force of this battery is 16.0 volts, and the maximum current is 4 amperes.

De la Rue's chloride of silver battery is well adapted for electrical testing. Its electro-motive force remains practically constant under various conditions. It is shown about half size in the sectional view (Fig. 398).

The top of the tube, A, is closed by a cork, D. The negative pole, C, consists of a cylindrical rod of chemically pure zinc supported by the cork stopper, which is perforated to receive it. The zinc rod has a hole in the top to allow the silver, connecting wire or electrode which goes to the next element to be soldered in.

The positive pole consists of a cylinder of silver chloride, B, having a silver wire or electrode, *b*, cast into it. This chloride rod is usually inclosed in a hollow cylindrical diaphragm of fine parchment paper. The zinc rod is amalgamated.

The solution for charging the cell is made by dissolving 1 ounce of pure sal-ammoniac (ammonium chloride) in one quart of water.

The electro-motive force of each element is about 1.10 volts, and the internal resistance is about 8 ohms.

In the action of the cell, pure silver is reduced and deposited on the bottom of the cell. To prevent short-circuiting, the zinc rod is raised about three-eighths of an inch above the bottom of the cell. This pure silver deposit can be readily converted into chloride of silver, which is melted and recast into rods for use, or if preferred the pure silver may be sold.

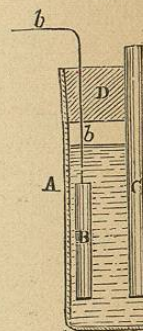
This battery is largely used in electro-medical apparatus.

The Leclanche battery is one of the best for open circuit work. It is, in fact, a distinctively open circuit\* battery. So long as the circuit is open there is no action in the cell, and as a consequence there is no loss.

This battery is shown in its improved form in Figs. 399 and 400. The carbon plate, which is suspended from the cover of the jar, supports two prisms clamped to the plate

\* An open circuit is one which is normally without a current, and in which the current flows only while the circuit is in use.

FIG. 398.

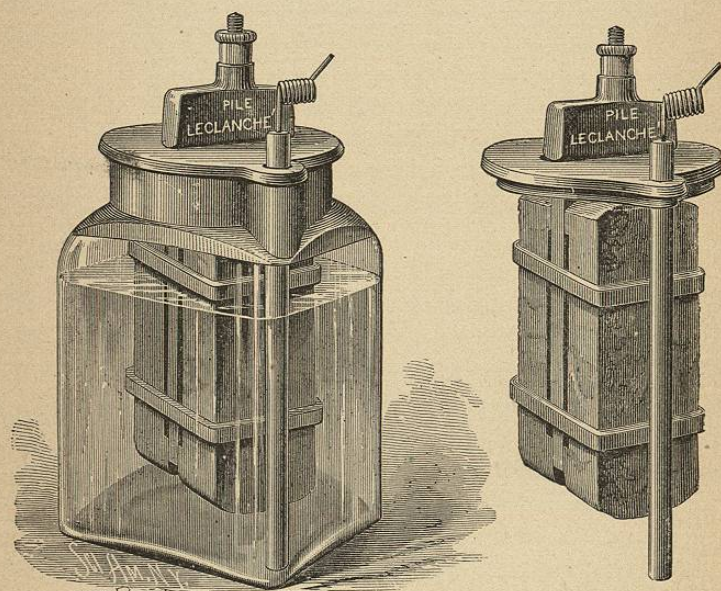


*1/2 full size*  
Chloride of  
Silver Cell.

by elastic rubber bands, as represented in Fig. 400, which shows the elements removed from the jar. The cover of the jar is perforated to receive the amalgamated zinc rod which extends down into the solution.

The prisms consist of 40 parts of granulated black oxide of manganese, 52 parts of granulated carbon, 5 parts of gum shellac, and 3 parts of potassium bisulphate. These ingredients are mixed, heated to  $212^{\circ}$  Fahr., and compressed in

FIGS. 399 AND 400.



Leclanche Battery.

moulds under a pressure of two tons. A saturated solution of sal-ammoniac forms the exciting solution. In the Leclanche battery the hydrogen of the decomposed water unites with the oxygen of the manganese.

If the solution becomes too much reduced, zinc oxide is formed, and the solution becomes milky. When this occurs, more sal-ammoniac should be added. This cell has a resistance of 5 to 6 ohms, and an electro-motive force of 1.47 volts.

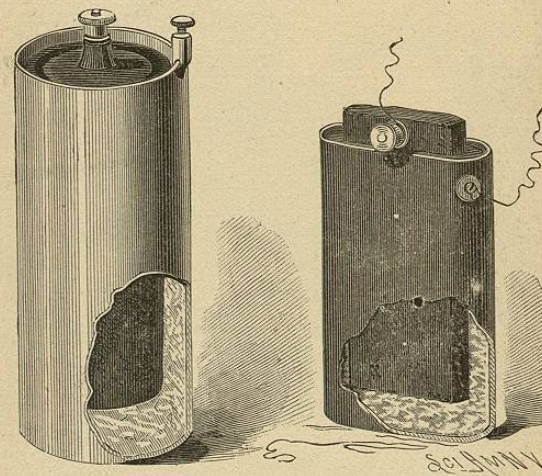
Dr. Carl Gassner's patent dry battery is much the same in principle as the Leclanche, but the exciting fluid is contained in a paste, and the zinc element forms the containing vessel. Two forms of the battery are made, one being cylindrical, as shown in Fig. 401, the other elliptical, as shown in Fig. 402.

The carbon rod or plate occupies about one-half of the space in the cell, and the space between the carbon and the cell is filled with the following mixture:

"Oxide of zinc, 1 part, by weight; sal-ammoniac, 1 part,

FIG. 401.

FIG. 402.



Dr. Gassner's Dry Battery.

by weight; plaster, 3 parts, by weight; chloride of zinc, 1 part, by weight; water, 2 parts, by weight. The oxide of zinc in this composition loosens and makes it porous, and the greater porosity thus obtained facilitates the interchange of the gases and diminishes the tendency to the polarization of the electrodes."

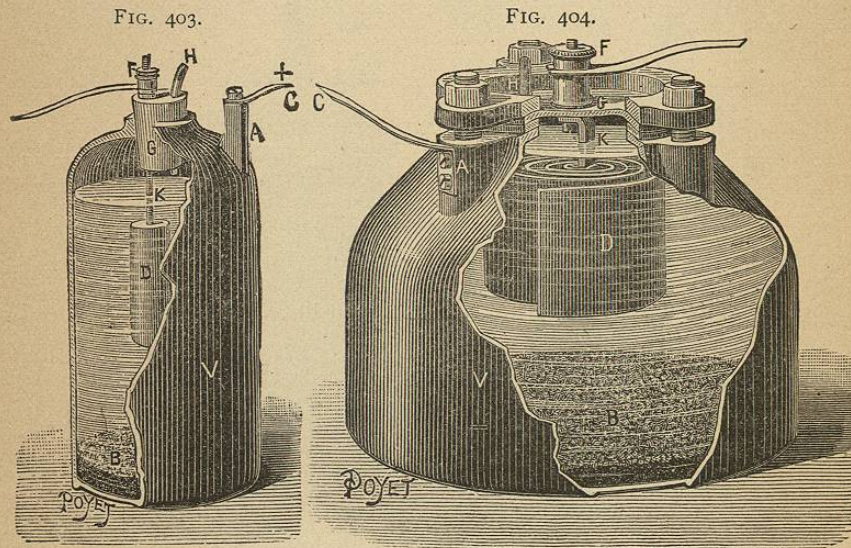
The battery works well on an open circuit, and is cleanly and portable.

The caustic potash battery represented in two forms in Figs. 403 and 404 is of comparatively recent invention. It

is adapted to either open or closed circuit work, and will operate for several months without replenishing. It has been used successfully in electro-plating and in electric lighting on a small scale.

The cell is made of cast iron and serves as one of the plates of the battery. It is much heavier than a glass cell, but this is compensated for by its non-liability to breakage.

In the small pattern the iron cell, V, is closed by a rubber stopper, G, through which passes a brass rod, K, provided at its upper end with a binding post, F, and carrying



Caustic Potash Battery.

at its lower end the zinc cylinder, D. A lug, A, on the cell is provided with a binding screw for clamping the conductor, C. The cell is filled with a saturated solution of caustic potash, and upon the bottom of the cell is distributed a quantity of black oxide of copper.

A valve, H, formed of a piece of rubber tubing, is inserted in the stopper to admit of the escape of gas.

The large pattern shown in Fig. 404 is 9 inches in diameter. It is similar in its construction to the smaller cell. The zinc element in this case is formed of a plate bent spi-

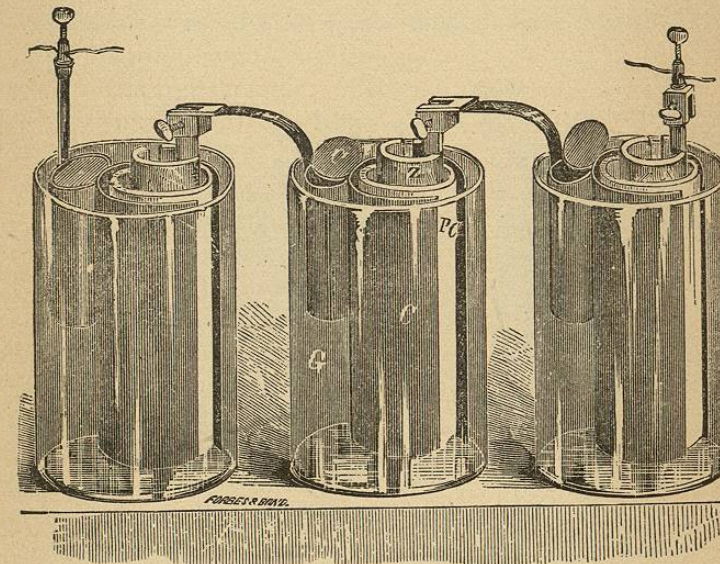
rally. It is not necessary to amalgamate the zincs in this battery. It is stated that the small cell yields a current of 2 amperes, while the larger one is capable of yielding 8 amperes. The E. M. F. is one volt.

#### TWO-FLUID BATTERIES.

The Daniell battery, shown in Fig. 305, is scentless and does not evolve any poisonous or disagreeable vapors.

In this battery, and in several cells derived from it, the

FIG. 405.



Daniell Battery.

two liquids are separated by a porous cell of unglazed clay. The glass vessel, G, is filled with a solution of copper sulphate. The porous cell, P C, contains the zinc, Z, which is not amalgamated. The curved sheet of copper, C, has attached to it a perforated pocket, c, for containing crystals of copper sulphate. The porous cell may be filled with a solution of common salt or water slightly acidulated.

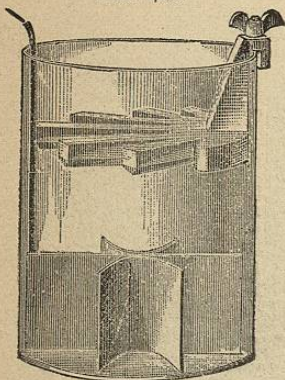
This battery is especially adapted for closed circuits; it is less suitable for open circuits. It has an electro-motive

force of about 1.079 volts. This amount varies somewhat with the density of the copper sulphate solution. The internal resistance of this battery varies considerably with the construction.

In a battery like that shown in the engraving, the resistance is about  $\frac{1}{2}$  ohm, but this may run up as high as 8 or 10 ohms in some forms.

In this battery, as well as in the gravity battery, described below, an example of the most perfect depolarizing action is found. Here the hydrogen resulting from the action of the dilute acid on the zinc is liberated on the surface of the copper plate, where it reduces the sulphate of

FIG. 406.



Gravity Battery.

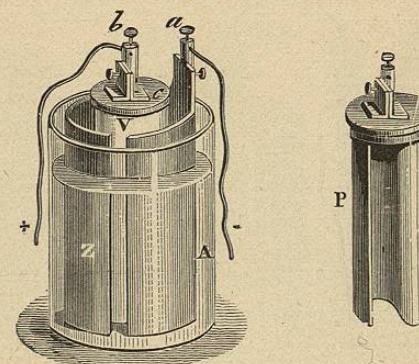
copper, forming sulphuric acid and metallic copper, the latter being deposited on the surface of the copper plate. So long as sulphate of copper is present in the battery this action continues, and the current from the battery remains practically constant.

The gravity battery, which is shown in its simplest form in Fig. 406, consists of a glass jar about 8 in. high and 6 in. diameter, having a zinc casting suspended near the top, and at the bottom three copper plates which are riveted together, the side plates being bent away from the central one as shown. One of the plates is provided with a gutta percha covered wire leading out of the jar. About two pounds of sulphate of copper are placed on the bottom of the jar, and enough water is poured in to cover the zinc about 1 inch. After standing 24 to 36 hours, the battery is in working condition. As the name of this battery indicates, its action is dependent on the separation of the zinc sulphate, which is formed at the top of the jar, and the copper sulphate solution, which gravitates toward the bottom of the jar. When the two solutions have properly separated, the fluid in the lower part of the jar will be blue, and that in the upper part will

be colorless and transparent. The zinc should always be surrounded by the colorless fluid, and as the blue fluid decreases in volume, some of the zinc sulphate solution is removed and replaced by water.

When the water in the upper portion of the jar becomes saturated with zinc sulphate, the sulphate crystallizes upon the zinc plate, stopping the action of the battery. The conducting power of a solution of zinc sulphate is greater when diluted. Part of the solution, therefore, should be from time to time removed, and replaced by water. Undissolved crystals of sulphate of copper should always remain in the bottom of the jar. Any disturbance of the jars when

FIG. 407.



Grove Battery.

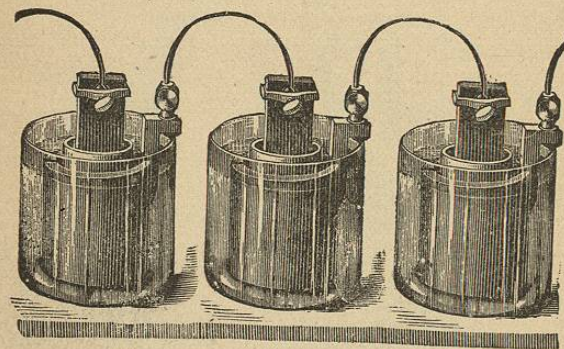
in use causes the solutions to mix, thus seriously affecting the working of the battery. The water requires replenishing occasionally, to compensate for evaporation. The action of this battery is the same as that of the Daniell. The resistance varies from two to four ohms. Its electro-motive force is the same as that of the Daniell cell. It is used largely in telegraphy, and its electro-motive force is so nearly one volt, that it is used in making ordinary electrical measurements.

In Grove's battery the sulphate of copper solution used in the Daniell is replaced by nitric acid, and the copper by platinum. By this change greater electro-motive force is obtained. Fig. 407 represents one form of this battery.

The glass vessel, A, is partly filled with dilute sulphuric acid (1 part of acid to about 10 or 12 parts of water). In this vessel is placed an amalgamated zinc cylinder, Z, which is open at both ends and slit down one side. In this cylinder is placed the porous cell, V, containing ordinary nitric acid. A plate, P, of platinum, which is bent in the form of an S, is fixed to the porous cell cover, and is immersed in the nitric acid. The platinum is connected with the binding screw, *b*, and there is a similar binding screw, *a*, on the zinc.

In this battery the hydrogen which would be disengaged

FIG. 408.



Chromic Acid or Carbon Battery.

on the platinum decomposes the nitric acid, forming hyponitrous acid, which is dissolved or is disengaged as nitrous fumes.

The resistance of the Grove cell is about half ohm. Its electro-motive force is 1.956 volts. The action of this battery is constant.

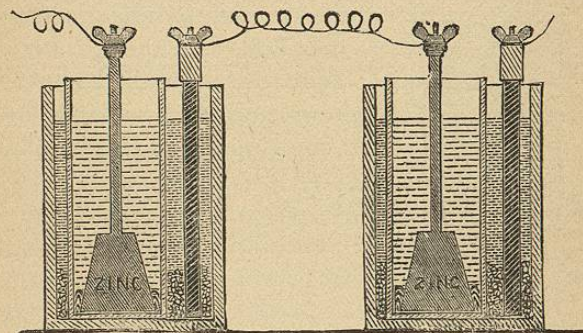
The chromic acid battery, shown in Fig. 408, is a modification of the Bunsen and is similar to the Grove in form. In this battery an amalgamated zinc cylinder surrounds the porous cup, and a rod of carbon replaces the platinum foil in the Grove. The jar is filled with saturated solution of common salt, or with sulphuric acid diluted with 12 parts of water.

The porous cell is filled with the bichromate of potash or the bichromate of soda solution previously described.

When the bichromate of potash solution is used in the porous cell, and a saturated aqueous solution of common salt is placed in the jar, the action is as follows: The chlorine of the salt unites with the zinc, forming zinc chloride, and at the carbon plate the sodium replaces the hydrogen of the sulphuric acid, forming sodium sulphate. The nascent hydrogen reduces the chromic acid of the solution, producing chromium sesquioxide.

The Bunsen battery differs from the chromic acid in employing nitric acid in the porous cell and dilute sulphuric acid in the jar.

FIG. 409.



The Fuller Cell.

The electro-motive force and resistance of these batteries are about the same as in the Grove.

In the Fuller battery (Fig. 409), the zincs, so long as they last, are permanently amalgamated. In the accompanying figure two cells are shown. The carbon plate is placed in the outer vessel in the bichromate of soda solution. The zinc element, which is of the shape shown in the figure, is placed in a porous cell, into which an ounce of mercury is poured, and which is then filled up with water only. The addition of this mercury is the essential feature of the battery. The zinc plate is in this way kept permanently amalgamated so long as it lasts; the consequence is that not only is the internal resistance of the battery largely dimin-