CHAPTER XVIII.

DYNAMIC ELECTRICITY.

GENERATION OF THE ELECTRIC CURRENT.

When two dissimilar metals, such as pure copper and pure zinc, are placed in contact in acidulated water, evidences of activity immediately appear in the form of a cloud of microscopic bubbles constantly rising to the surface of the water. If the metals are individually capable of resisting the action of the acid solution, it will be noticed that on separating them the action ceases, but it will commence again as soon as the metals are brought into contact. The same action is noticed if the two metals are brought into contact or connected by a wire above the surface of the acidulated water.

The bubbles are hydrogen resulting from the decomposition of the water. They escape from the copper, while the oxygen resulting from the analysis unites with the zinc, forming zinc oxide.

The copper is scarcely attacked, while the zinc slowly wastes away. If the wire connecting the zinc and copper be cut and the two ends placed on the tongue, a slight but peculiar biting sensation is experienced, which will not be felt when the wires are disconnected from the metals.

A piece of paper moistened with a solution of iodide of potassium and starch placed between the ends of the wires turns brown at this spot, showing that there is here a species of energy capable of effecting chemical decomposition. If a wire joining the copper and zinc is placed parallel with and near a delicately suspended magnetic needle, it will be found that it is endowed with properties capable of affecting the needle in such a manner as to cause it to swing and tend to take a position at right angles to the wire. This form of energy is dynamic or current electricity, generated in this case by chemical action and confined to and following a continuous conductor, of which the two metallic elements and the acid solution form a part, the whole comprising a complete electric circuit.

For the purpose of studying the generation and behavior of dynamic electricity, the elements referred to may be formed into an electric generator or battery, and the magnetic needle and conducting wire may be combined to form an electrical indicator or galvanometer, as illustrated in Plate VI., which shows convenient apparatus for making the primary experiments in dynamic electricity. The glass tank or cell is built with special reference to projecting the visible manifestations of the phenomena exhibited in the cell upon a screen, by means of the lantern, to enable a number of persons to observe simultaneously.

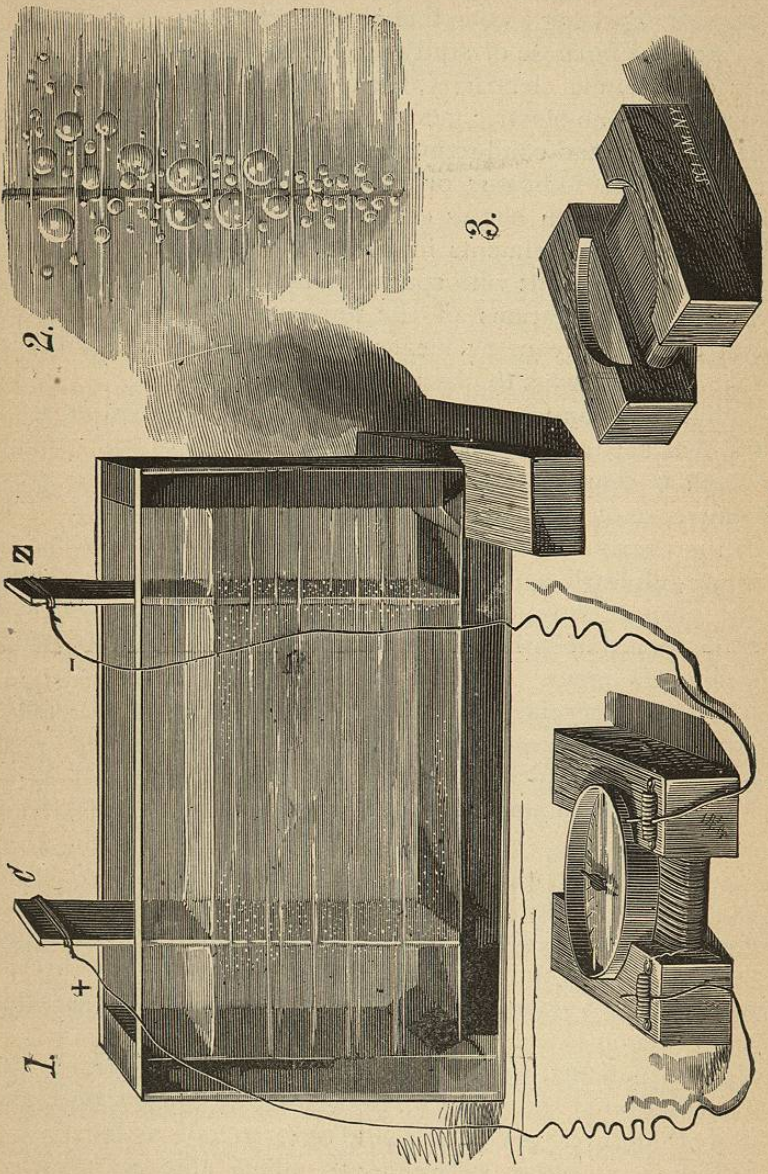
The cell consists of two plates of transparent glass 4 by 6 inches, separated by a half inch square strip of soft rubber, which is cemented to both glasses by means of a cement composed of equal parts of pitch and gutta percha. The cell is nearly filled with the exciting liquid, consisting of dilute sulphuric acid (acid 1 part, water 15 parts), in which are placed two plates, one consisting of a strip of zinc about one-sixteenth of an inch thick, the other plate being a strip of copper.

As commercial zinc is so impure as to be violently attacked by the exciting liquid, it is well to dip the zinc strip into the solution, and then apply to it a drop or so of mercury, which amalgamates the surface and prevents local action.

When these two plates are brought into contact with each other in the exciting liquid, hydrogen gas is given off copiously at the copper plate, while the action at the zinc plate is almost unnoticeable. If the plates are connected together by a conductor outside of the solution, the same phenomenon is observed.

The plane flat surfaces of the cell offer facilities for the examination of the plates by means of the microscope, and if so examined it will be found that so long as there is no metallic connection between the plates, they will remain unaltered, and no action is discoverable; but when the cir-

PLATE VI.



Experimental Battery and Galvanometer.

cuit is completed, the first visible indication of action is the sudden whitening of the copper plate as if it were frost-covered; the next indication of action is the formation over the entire surface of the plate of myriads of minute silvery bubbles, which grow until they become detached, when they rise to the surface and escape into the air. These bubbles may be discharged into the mouth of a small test tube, and when a sufficient quantity of gas has accumulated it may be ignited, showing that it is hydrogen.

The appearance of the copper plate when the cell is in action is shown at 2 greatly magnified. The gas bubbles formed on the surface of the copper are at first very minute, but they rapidly increase in size and begin to merge one into another, taking an upward course. When a large bubble has absorbed a large number of the smaller bubbles and becomes sufficiently buoyant to overcome its adhesion to the plate, it rises to the surface and is lost in the air.

The bubbles of hydrogen are very bright, appearing and acting much like globules of mercury. Often an equatorial belt of very small bubbles will be seen surrounding a larger one.

The accumulation of hydrogen on the copper plate seriously affects the strength of the current. To ascertain to what extent and at what time this happens, a simple galvanometer, like that shown at 1, will be required. This instrument consists of a common pocket compass, a wooden frame or spool, and about 20 feet of No. 32 silk-covered copper wire. The wood spool (3) has a recess cut in the top at either end to receive the compass, which is placed a short distance from the flat body of the spool, and the wire is wound evenly around the body back and forth until the spool is full. Then the terminals of the wire are connected with two spiral springs fastened to the ends of the spool and forming "binding posts" for receiving the wires from the battery.

In regard to the adjustment of the compass, it should be arranged with the line marked N S parallel with the wires of the coil, and the instrument should be turned until the N S line is exactly under the needle, then a weak current from a constant battery should be sent through the coil and the deflection noted. The current should then be sent in the opposite direction, when the needle will be deflected in the opposite direction. If the amount of deflection is the same in both cases, the galvanometer is in condition for use; but if the deflections differ in degree, the compass must be turned in its socket until the proper adjustment is secured. The only precaution necessary in the construction of this instrument is to select a compass whose needle is delicately poised and vibrates freely.

By connecting the galvanometer with the cell as indicated in the engraving, it will be noticed that after a little time the galvanometer needle begins to fall back toward 0°, a point which it ultimately reaches if the circuit is kept closed; and the shorter the circuit, the sooner the cessation of the current. This enfeeblement of the current is principally due to three causes, one of which has already been noticed, that is, the accumulation of hydrogen on the copper plate. The film of hydrogen not only prevents contact between the exciting solution and the plate, but it actually renders the surface to a certain degree like the zinc. Another cause of enfeeblement of the current is the reduction on the copper, by the hydrogen, of a portion of the zinc sulphate accumulating in the liquid. This increases the similarity of the two plates, and consequently assists in diminishing the current. The reduction of the strength of the exciting liquid of the cell by mixture with zinc sulphate contributes still further toward the diminution of the current. All this results in making the two plates similar in their action, and in a consequent weakening of the current; but this chemical action cannot be avoided, as to secure any action in a galvanic cell the exciting fluid must be capable of decomposition. The production of local currents, the accumulation of hydrogen on the copper plate, and the weakening of the exciting solution are the three great causes of inconstancy in batteries. The first may be remedied in a great measure by amalgamation; the remedy for the last is obviously the strengthening of the solution, and the second, the accumulation of hydrogen on the copper

plate, or the polarization of the plate can only be remedied by mixing with the exciting liquid some substance, such as nitric or chromic acid, which will oxidize the hydrogen as fast as it is liberated by oxidation of the zinc, or by brushing it while in the solution, or by violently agitating the exciting solution. The galvanometer needle faithfully indicates the result of either treatment. The polarization of the electrode may be strikingly exhibited by allowing the copper plate to become polarized and then replacing the zinc with a clean copper strip like the one already polarized. The galvanometer needle will be deflected in the opposite direction, showing that the polarized copper plate acts in the same manner as the zinc. Now, by removing the polarized copper plate and wiping and replacing it, the deflection of the needle will be much less, and it will not fall back to 0° until the very slight coating of zinc which has been deposited on the copper is removed from the polarized plate by means of emery paper or otherwise. Precisely the same effect is noticed when a newly amalgamated zinc plate is opposed to an oxidized zinc plate. The oxidized plate in this case will act as if it were copper.

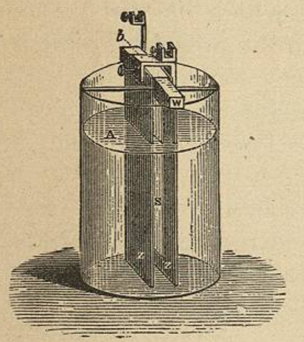
This method of showing the effect of the polarization of the copper plate is conclusive. The phenomenon attributed to the polarized plate manifests itself in an unmistakable manner in polarizable batteries under the conditions of actual use.

While the entire office performed by the mercury in amalgamation is not known with certainty, one of its purposes is to present to the liquid a surface made up of zinc and mercury, and these two only. The acid acts on the zinc, which is at the same moment not in contact with any of the impurities, such as particles of carbon, iron, etc., that are diffused throughout the commercial zinc. Local currents are thus almost entirely avoided. The object of amalgamation is to prevent local currents as much as possible, and to present clean zinc to the liquid for oxidation. Yet, in spite of the mercury, local currents exist to some extent, and they are often quite as important as other causes in decreasing the effective value of the battery.

All batteries are more or less defective in operation, and require a great deal of care and attention. Many of the large uses to which batteries were applied a few years since now depend entirely upon dynamos for current. Nevertheless, batteries have many uses to which the dynamo cannot be conveniently or economically applied; such for example as working the smaller lines of telegraph, ringing call bells, operating indicators, annunciators, etc., and all closed circuit work where a comparatively small current is used. In telephone transmitters, and in open circuit work where a current is required only at long intervals, the dynamo cannot be substituted for batteries.

Terms such as "electric current," "electric fluid," "flow of the current," are based on the assumption that the action of dynamic electricity is analogous to that of fluids; but as nothing is positively known of the nature of electricity, these expressions are to be considered as purely conventional.

FIG. 391.



Smee's Battery.

SINGLE-FLUID BATTERIES.

Several of the batteries employing only a single exciting fluid are very useful in experimental work, and a number of them are of great value commercially. One of the oldest of these batteries is Smee's, which is illustrated in Fig. 391. A wooden strip, W, which rests upon the jar, A, supports the platinized silver plate, S. The zincs, Z, are clamped to the sides of the strip, W, by a clamp, *b*, which is provided with a binding post for receiving a wire. A binding post is also connected with the silver plate, S.

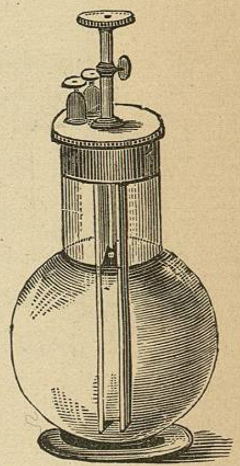
The wooden strip, W, is paraffined, and the zinc plates are amalgamated. The liquid generally used to charge the cell is 1 part of sulphuric acid to 10 of water.

The electro-motive force of the Smee battery is 1·09 volts when not in action, when in action it is 0·482 volt. Its internal resistance is about 1 ohm. The depolarization of this

battery is due to the facility with which the hydrogen is detached from the rough surface of the platinized silver plate. The Smee battery has been used largely in telegraphy and electro-metallurgy.

The Grenet battery (Fig. 392) is a very good form of experimental battery where constancy of current is not required, as, for example, in the laboratory and mechanical work rooms. The cell is in the form of a bottle, and contains a solution formed by adding one part of sulphuric acid to five parts of a saturated solution of bichromate of potash in water. The top is provided with a brass frame, to which is fastened a vulcanite cover; to this are attached two carbon plates, that dip permanently into the fluid; and between them a zinc plate is suspended by a rod, by means of which it may be plunged into the fluid or withdrawn at pleasure. When the zinc is withdrawn, the action ceases. This battery gives a powerful current for a short time, but it rapidly polarizes. The length of time during which the fluid will retain its power depends on the use that is made of the battery.

FIG. 392.

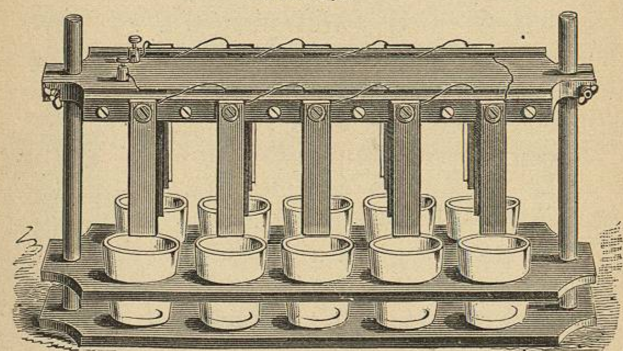


Grenet Battery, Bottle Form.

Fig. 393 represents an inexpensive and easily made plunge battery, which is very convenient for temporary use.

Ten tumblers, arranged in two rows of five, are held in place by an apertured board supported a short distance above the base board by the round standards. To these is fitted a board which is split from the standards outward, and provided with two bolts with wing nuts, by which the board may be clamped at any desired height. To opposite edges of this movable board are clamped six plates of carbon, 1¼ inches wide, ¼ inch thick, and 6 or 8 inches long. The upper ends of these plates are heated and saturated with wax or paraffine, and a copper wire is interposed between the carbon plate and the edge of the board. The strips of wood by which the carbons are clamped are $\frac{3}{8}$ inch thick. To these wooden strips are secured zinc plates of the same dimensions as the carbon plates, by means of ordinary wood-screws passing through holes in the zinc into the wood. The wires connected with the carbons are bent over and inserted between the zinc plates and the wood, as shown in the engraving. That is, the carbon of one pair is connected with the zinc of the next pair in order, and so on throughout the series, and the terminal plates are connected with the binding posts.

Fig. 393.



Simple Plunge Battery.

The zincs are amalgamated, and the tumblers are nearly filled with the bichromate solution.

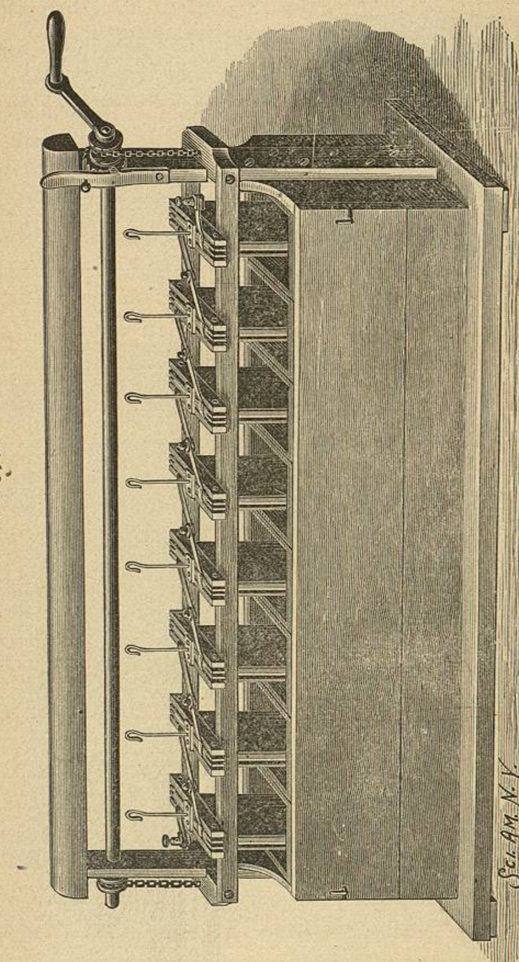
To maintain the amalgamation of the zincs, a small quantity of bisulphate of mercury is added to the bichromate solution, say $\frac{1}{8}$ ounce to every quart of solution.

The tumblers should be as large as can be conveniently obtained. Those holding one pint are not too large.

The plunging battery shown in Fig. 394 is a very powerful one, designed for running an electric motor or for supplying a current to three or four small incandescent lamps. The battery consists of eight elements, each formed of two 6×10 inch carbon plates $\frac{1}{4}$ inch thick, and one zinc plate of the same size, suspended in a cell $3\frac{1}{2} \times 7\frac{1}{2}$ inches and 9 inches deep.

The upper ends of the carbon plates are paraffined, as shown in Fig. 395, by heating the ends only and rubbing on paraffine, allowing it to melt and soak into the pores of the plate until a strip about $1\frac{1}{2}$ inches wide across the end of the

Fig. 394.

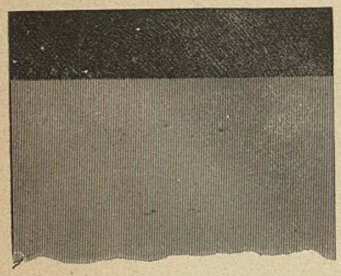


Large Plunge Battery.

plate is well filled with paraffine. This treatment prevents the solution from ascending by capillarity and destroying the connections.

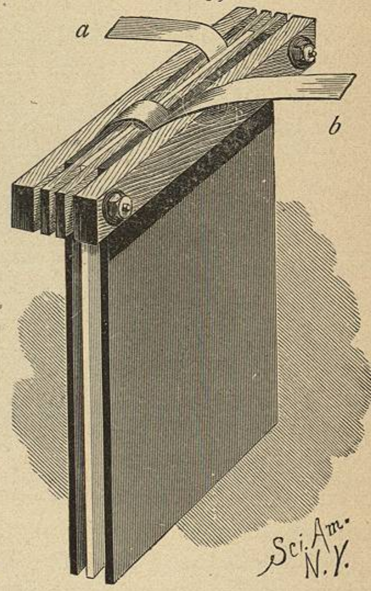
The plates are arranged as shown in Fig. 396, the zinc plate being located between two carbon plates and separated from them by strips of paraffined wood $\frac{1}{4}$ inch thick, $1\frac{1}{4}$ inches wide, and 8 inches long. The plates and separating strips are clamped together by thick strips of paraffined 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.

Fig. 395.



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.

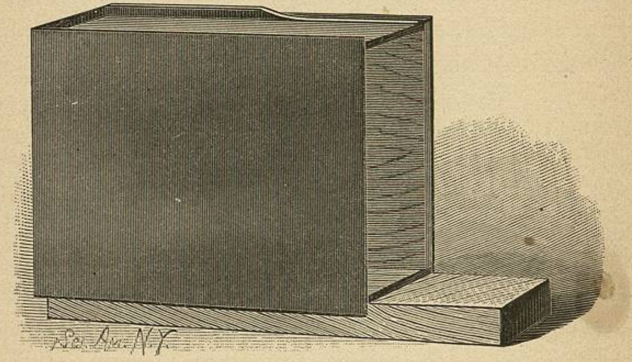
Fig. 396.



If the amalgamation is perfect, the plates will not require

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