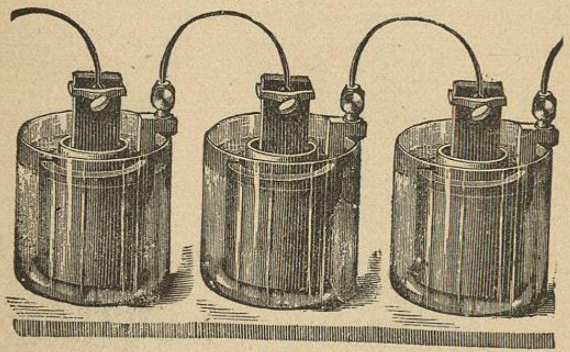
The glass vessel, A, is partly filled with dilute sulphuric acid (1 part of acid to about 10 or 12 parts of water). In this vessel is placed an amalgamated zinc cylinder, Z, which is open at both ends and slit down one side. In this cylinder is placed the porous cell, V, containing ordinary nitric acid. 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 on the platinum decomposes the nitric acid, forming hyponitrous acid, which is dissolved or is disengaged as nitrous fumes.

Fig. 408.



Chromic Acid or Carbon Battery.

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.

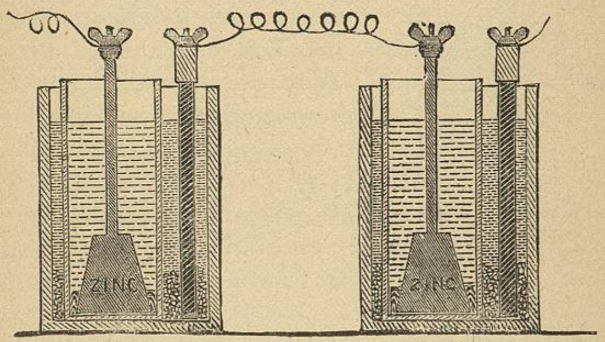
The chromic acid battery, shown in Fig. 408, is a modification of the Bunsen and is similar to the Grove in form. In this battery an amalgamated zinc cylinder surrounds the porous cup, and a rod of carbon replaces the platinum foil in the Grove. The jar is filled with saturated solution of common salt, 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 diminished, but its constancy is to a great extent insured. The action, after the battery is charged and the elements are connected with each other, commences almost immediately, and reaches a maximum in the course of a few hours.

The rod connected with the zinc element requires a protecting covering of gutta percha.

This is an excellent battery for open circuit work. It has an electro-motive force of nearly two volts, and an internal resistance of about two ohms.

MECHANICAL DEPOLARIZATION OF ELECTRODES.

In all single-fluid batteries polarization necessarily takes place to some extent, whatever precautions may be adopted for its prevention. The means of depolarizing single-fluid batteries are mechanical, and consist in the agitation of the exciting fluid by gravity, as in the fountain battery, by air jets, as practiced by Grenet and others, by stirring the fluid by mechanical means, by rotating or swinging the electrodes, and by roughening the electrode, as in the case of Smee's battery, in which the platinum plate is covered with a deposit of finely divided platinum.

In single-fluid batteries polarization may be greatly retarded by enlarging the plate on which the hydrogen tends to collect, so as to afford a great surface for its dissipation. In two-fluid batteries the depolarization is effected by chemical means, and perhaps more perfectly in the sulphate of copper batteries than any other.

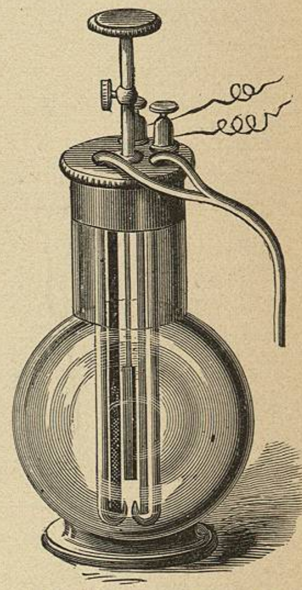
In all single-fluid batteries the oxidation of the zinc liberates hydrogen, and this rapidly reduces the power of the battery in the manner explained in the former paper. In Smee's battery the microscopic points formed by the roughened platinum surface facilitate the escape of hydrogen, and in this way may tend to maintain the power of the element.

In the Grenet battery the carbon plate quickly polarizes, rendering the battery unfit for uses of more than a few minutes' duration. However, the agitation of the exciting fluid by the withdrawal and replacement of the zinc restores the battery to its normal strength. Grenet agitated the exciting fluid by means of air blown in through glass tubes, as shown in Fig. 410. This prevents polarization to a great extent, and renders the battery very active. Dr. Byrne, of Brooklyn, adopted this plan of depolarization in his battery with remarkable results.

Figs. 411, 412, and 413 show a purely mechanical agitator, consisting of spring-actuated stirrers, controlled by an electro-magnet of high resistance in a shunt around the battery. The magnet absorbs but a very small proportion of the current, and has only sufficient power to move the lever controlling the spring motor.

This motor, which may be of the cheaper class, is mounted on a base, A, secured to two parallel bars, B, carrying the zinc and carbon plates, *z c*, of the battery. These plates are placed flat against the bars, B, and secured by screws and washers. The zinc of one element is connected with the carbon of the next by a wire passing diagonally through the bar, and the first zinc and last carbon are connected with the binding posts at the ends of the bars, B.

FIG. 410.



Grenet Battery, with Air Tubes

The second shaft in the train of gearing is provided with a crank connected by a rod, C, with the lever, D, which is fastened to a rock shaft and connected with the bar, E, extending the whole length of the battery between the zinc and carbon of each element, and carries a series of vertical rods, F, of vulcanite, one such rod being located between the zinc and carbon plates of each element. The zinc in one of the elements is broken away in the engraving to show this rod, and the small horizontal sections at the top of Fig. 411 show the

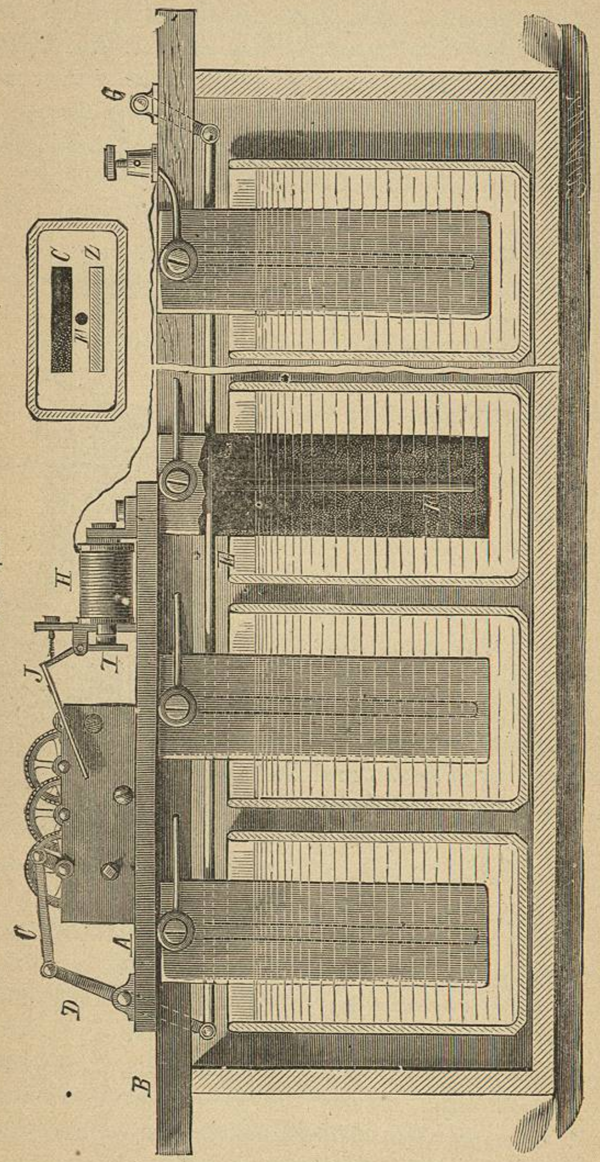


Fig. 411.

Depolarization of Electrodes by Mechanical Agitation.

position of the rod relative to the plates. A swinging arm, G, supports the extremity of the rod, E. A high resistance magnet, H, mounted on the base, A, is connected with the two binding posts of the battery, so as to receive a small portion of the current. The armature attached to the lever, I, when drawn against the poles of the magnet, brings the lever, I, into engagement with the fan, J, which is the last element in the train of gearing composing the spring motor. A light retractile spring draws the lever, I, away from the fan, J, and removes the armature from the magnet when the power of the battery is reduced to a certain limit. The spring motor, being free to act, oscillates the rods, F, and by stirring the exciting liquid disengages the hydrogen from the plates, and brings fresh liquid into contact with the zinc and carbon and restores the strength of the battery, when the armature of the magnet, H, will be acted upon, bringing the lever, I, into engagement with the fan, J, and stopping the action of the spring motor until the current is again weakened, when the operation just described will be repeated.

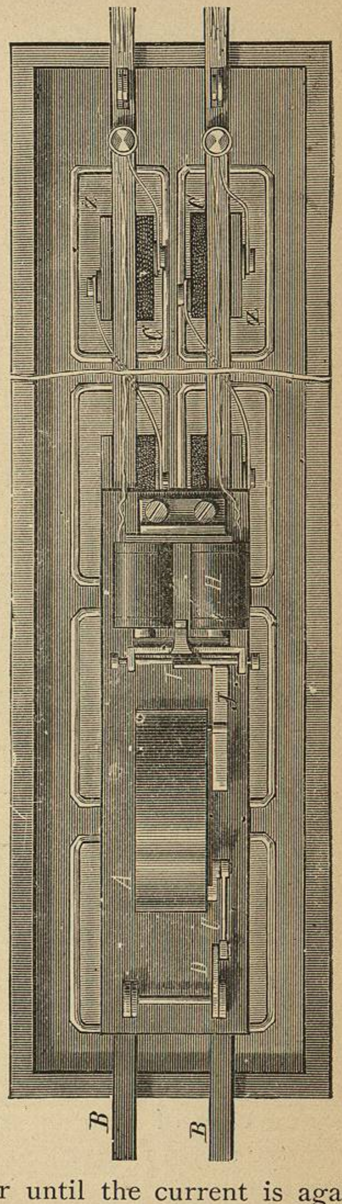


Fig. 412.

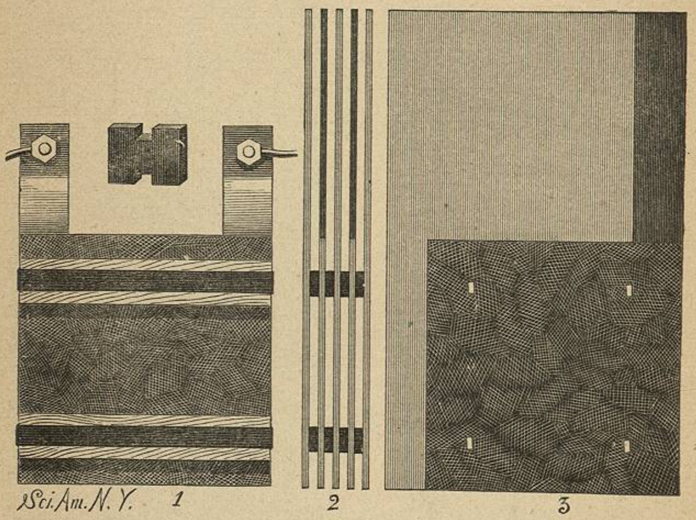
Plan of Depolarizing Apparatus.

In this way the strength of the battery will be maintained within certain limits, until the liquid is exhausted. Of course this system may be extended sidewise or lengthwise as much as may be desired.

All batteries employing mechanical means of depolarization, with, perhaps, the exception of Smee's, are only adapted to uses requiring a very strong current for a limited time.

SECONDARY BATTERY.

FIG. 413.

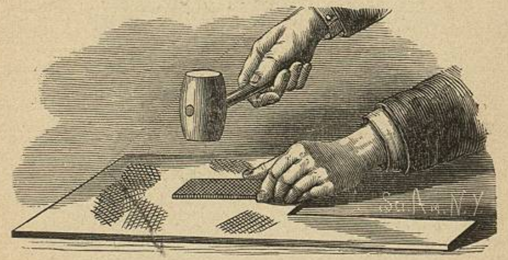


Plates of Secondary Battery.

Probably no secondary battery can be more readily made or more easily managed than the one invented by Plante. It is, therefore, especially adapted to the wants of the amateur who makes his own apparatus. It takes a longer time to form a Plante battery than is required for the formation of some of the batteries having plates to which the active material has been applied in the form of a paste, and its capacity is not quite equal to that of more recent batteries, but it has the advantage of not being so liable to injury in unskilled hands and of allowing a more rapid discharge without affecting the active matter.

Each cell of the battery consists of 16 lead plates, each 6×7 inches and $\frac{3}{32}$ inch thick, placed in a glass jar 6×9 inches, with a depth of $7\frac{1}{2}$ inches. Each plate is provided with an arm $1\frac{1}{2}$ inches wide and of sufficient length to form the electrical connections. The plates are cut from sheet lead in the manner indicated at 3, in Fig. 413, *i. e.*, two plates are cut from a sheet of lead $8\frac{1}{2}$×14 inches. This method of cutting effects a saving of material. The plates after being cut and flattened are roughened. One way of doing this is shown in Fig. 413*a*. The plate is laid on a heavy soft-wood plank, and a piece of a double-cut file of medium fineness is driven into the surface of the lead by means of a mallet. To avoid breaking the file, its temper is drawn to a purple. After the plate is roughened on one side, it is reversed and treated in the same way upon the opposite side. If a knurl is available, the roughening may be accomplished in less time, and with less effort, by rolling the knurl over the plate. Half of the plates are provided with four oblong perforations into which are inserted H-shaped distance pieces of soft rubber, which project about $\frac{1}{8}$ inch on each side of the plate. The perforated and imperforate plates are arranged in alternation, with all of the arms of the perforated plates extending upward at one end of the element and all of the arms of the imperforate plates similarly arranged at the opposite end of the element.

FIG 413*a*

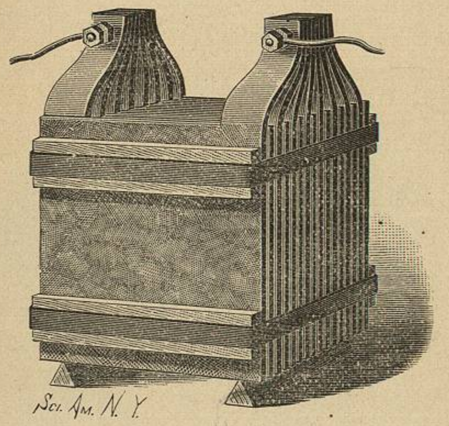


Roughening the Plate.

The plates are clamped together by means of wooden strips—previously boiled in paraffine—and rubber bands. The strips are placed on opposite sides of the series of plates at the top and bottom, and the rubber bands extend lengthwise of the strips.

The arms of each series of plates are bent so as to bring them together about 3 or 4 inches above the upper edges of the plates. They are perforated to receive brass bolts, each of which is provided with two nuts, one for bending the arms, the other for clamping the conductor.

Fig. 414.

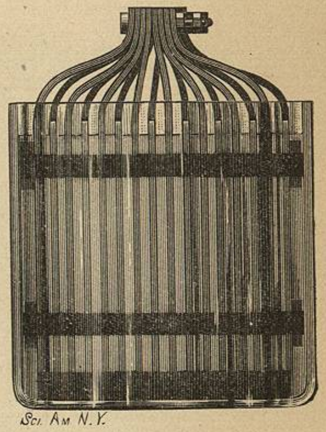


Plates Connected.

This element is placed in a glass cell, on paraffined triangular wood supports, and the formation is proceeded with. To hasten the process, the cell is filled with dilute nitric acid (nitric acid and water equal parts by measure), which is allowed to remain for twenty-four hours. This preliminary treatment modifies the surface of the lead, rendering it somewhat porous, and, in connection with the roughening, reduces the time of formation from four or five weeks down to one week. The nitric acid is removed, the plates and cell are thoroughly washed, and the cell is filled with a solution formed of sulphuric acid 1 part, water 9 parts.

The desired number of cells having been thus prepared, are connected in series, and the poles of each cell are marked so that they may be always connected up in the same way. The charging current, from whatever source, should deliver a current of ten amperes, with an electromotive force ten per cent. above that of the accumulator.

Fig. 415.



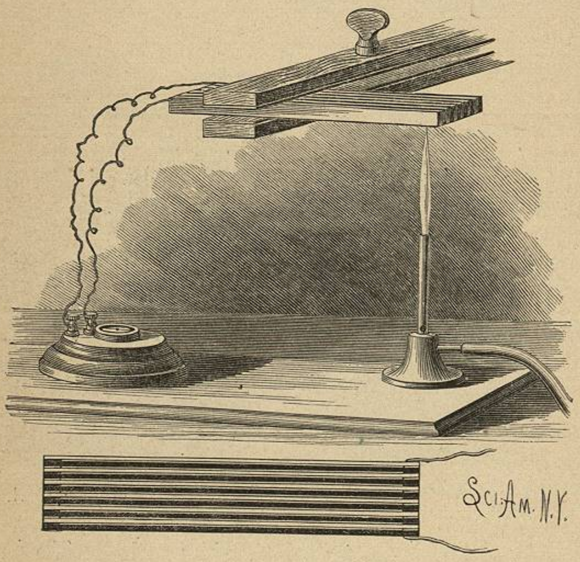
Complete Cell.

Each cell of this battery has an electro-motive force of two volts, and the voltage of the series of cells would be the number of cells × 2. It is a simple matter to determine the amount of current required to charge a given number of cells. For example, a battery is required for supplying a series of incandescent lamps. It has been found uneconomical to use lamps of a lower voltage than 60. It will, therefore, require a battery having an E. M. F. of 60 volts to operate even a single lamp. This being the case, at least 30 cells of battery must be provided, and on account of a slight lowering of the E. M. F. in use, two extra cells should be added. It will, therefore, require 32 cells for a small installation, and the machine for charging such a battery should be able to furnish a current of ten amperes, with an E. M. F. of 75 volts. To form the battery, it is placed in the circuit of the dynamo and kept there for thirty hours continuously, or for shorter periods aggregating thirty hours. It is then discharged through a resistance of 20 or 30 ohms, and again recharged, the connections with the dynamos being reversed so as to send the current through the battery in the opposite direction. The battery is again discharged through the resistance, and again recharged in a reverse direction. These operations are repeated four or five times, when the formation is complete. It will require from five to seven hours to charge the battery after it is thoroughly formed. It must always be connected with the dynamo as connected last in charging. Although amateurs may find pleasure in constructing and forming a secondary battery, there is no economy in securing a battery in this way. It is less expensive and less vexatious to purchase from reliable makers.

THERMO-ELECTRIC CURRENT.

Professor Seebeck, of Berlin, discovered in 1821 that an electric current could be produced by the direct application of heat to a conductor consisting of two metals soldered together, the heat being applied to the junction of the two parts of the circuit.

FIG. 416.



Thermo-Electric Series.

A simple thermopile for illustrating this phenomenon is shown in Fig. 416. It consists of a series of brass and German silver bars, alternating in position and separated by strips of mica, except at a short interval at one end of each pair, at which point the bars are connected

by soldering. The soldering occurs alternately at opposite ends, as indicated in the plan view in the lower part of the cut. The battery is thus formed of a continuous conductor of dissimilar metals. The terminals of the series being connected with a galvanometer of low resistance, heat applied to one end of the series will cause a current to flow. This will be indicated by a deflection of the galvanometer needle. The current will continue to flow so long as a difference of temperature of the ends of the series is maintained.

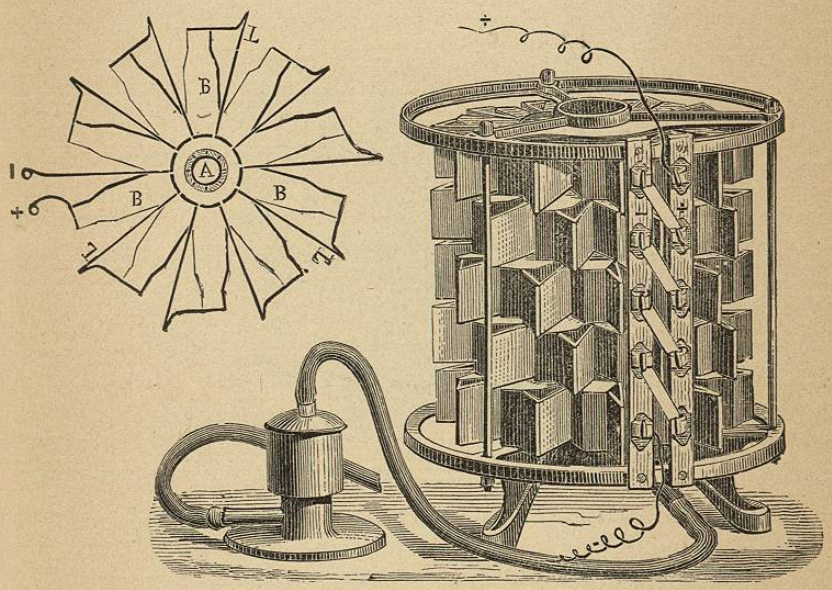


FIG. 417. FIG. 418.

Clamond's Thermo-Electric Battery.

Nobili's thermopile, constructed on this principle from a large number of small bars of bismuth and antimony, used in connection with a delicate galvanometer, constitutes one of the most sensitive indicators of change of temperature known.

Clamond's thermo-electric battery, which is shown in plan in Fig. 417, in perspective in Fig. 418, and vertical section in Fig. 419, has been used for telegraphic purposes and