

ELECTRICITY IN LIGHTING.

By Henry Morton.



IT was, we think, in reference to some electrical experiment, that Benjamin Franklin made his often quoted and most suggestive answer to the question, What is the use of it? by another question, What is the use of a baby? and nothing has better illustrated the way in which scientific discoveries, like babies, can grow into usefulness than has electricity in its various developments and applications, among which by no means the least is that to electric lighting.

Indeed this scientific infant, whose birthplace may be said to have been Sir Humphry Davy's lecture-room in the Royal Society, has not only developed into vigorous youth and useful manhood, but has also produced an extensive family of descendants, so wide-reaching and diverse in their characteristics that they must be discussed under numerous heads and various classifications, and have in many cases little in common with the founder of their family, except that electricity is the form of energy which vitalizes them, and that light is the result and evidence of their vitality.

Sir Humphry Davy in 1808 showed on a grand scale, with a galvanic battery of some two thousand pairs of plates, that when an electric circuit, established between two pieces of charcoal, was gradually interrupted by their separation, an arch or arc of dazzling light was developed between the separated pieces of carbon.

The magnificent intensity of this light attracted to it the attention of the world, and dreams as to its utility and applications were freely indulged in by many possessed of lively imaginations, but for many years there seemed little prospect that any of these dreams would be realized.

The radical and fatal difficulty was the cost of the electric energy required. Numerous improvements were made in the galvanic battery, by which its constancy of action and compactness as to bulk and weight were improved; but it always remained, and remains to-day, that the cheapest source of energy available in a galvanic battery is metallic zinc, and that metallic zinc is a costly material, with a low efficiency as compared with other substances, such as carbon or carbonaceous compounds, usually employed in the production of light. Left to the galvanic battery, therefore, the electric light, brilliant as were its capacities, would have been confined to the lecture-room of the professor and an occasional display in the theatre or opera-house, or out-of-doors on rare occasions, such as peace illuminations or national anniversaries.

In one direction much labor was spent and much improvement was made; that is, in the structure of "electric lamps" or "regulators" for the electric light.

When the electric arc is formed between the carbon terminals it causes them not only to glow and actually burn, but also to be vaporized and dissipated, so that they are consumed with considerable rapidity, and this, too, at an unequal rate, the positive terminal consuming much faster than the negative one. To provide for this, means of feeding the carbons (which for this purpose were made in the form of long cylindrical rods of the most compact and refractory kinds of carbon, such as plumbago or gas-coke) toward each other as they were consumed must be provided.

Very ingenious and efficient "lamps" or regulators were constructed at an early date. There is one now in the cabinet of the Stevens Institute of Technology, Hoboken, N. J., which was imported some time prior to 1853, and used in some of my public lectures more than twenty-five years ago. It was designed by the eminent French physicist Foucault, and constructed by the

widely known instrument-maker Duboscq Soleil, of Paris.

Lamps similar in general principle, but different in their mode of operation, were made by Deleuil, Serrin, and Duboscq in France; by Roberts, Slater & Watson, Staite, and Chapman in England; and, indeed, as far as anything that could be done with galvanic batteries was concerned, there was nothing to be desired as regards perfection and efficiency in the electric lamp or regulator of the electric light.

This child of Sir Humphry Davy had reached his full growth and intelligence, and had attained not only a brilliant but a well-regulated manhood. His usefulness to the world at large, however, as I have already pointed out, was limited by the costliness of the apparatus by which his vital energy was supplied. Having thus, after the manner of the novelist, followed one of our characters up to a position of difficulty, we will turn in another direction and look after the other who is to relieve the situation.

Again we have the birth of a great scientific discovery, and this time it is in the laboratory of Michael Faraday at the Royal Institution.

Here magneto-electric induction first saw the light, and it was first demonstrated that an electric current could be produced, without any galvanic or chemical action, by the mere motion of a conductor before a magnet.

The theory and detailed conditions of this action were fully explained by Professor Brackett in the June number of this Magazine (p. 653), and I will therefore say nothing of these, but pass at once to the practical application of this great discovery, which was soon made, and which, through a number of developments, has culminated in the dynamo-electric machine of to-day, which turns the mechanical energy of a steam-engine, of a waterfall, or of any other like motor, into an electric current, and thus enables us to secure electric energy from cheap and highly efficient coal or the like, instead of seeking it in costly and inefficient zinc.*

The first development of Faraday's

* The total efficiency of a pound of zinc is only one-sixth that of a pound of carbon.

discovery was made by Pixii, of Paris, who, in 1832, constructed an apparatus in which a large steel magnet was rotated so that its poles continuously and successively swept past those of an electro-magnet, or U-shaped bar of soft iron whose ends were surrounded with coils of copper wire.

This motion generated in the copper wire rapidly alternating electric currents, which were "commutated" or made to pass out of the machine in a constant direction by a simple "commutator" on the axis of the revolving magnet, which shifted the connections each time the direction of the current was changed.

The machine of Pixii is shown in the accompanying Figure 1.

In this, near the top, are seen the copper-wire coils wound on cores of soft iron like thread on a spool. Immediately below these

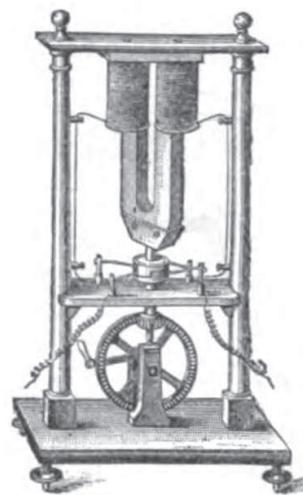


Fig. 1.—Pixii's Magneto-electric Machine—1832.

is the permanent magnet, of a U-shape, and so supported that it can be rapidly rotated about a vertical axis midway between its poles, so that each pole is caused to approach, pass, and recede from, in succession, each of the iron cores of the coils. Immediately below the bend of the U-magnet are the commutator segments, pressed upon by the contact brushes, and below these again is the gearing by which the magnet is made to rotate.

Machines operating on the same principle, but varying in construction (as, for example, by rotating the electro-magnet or coils of copper wire while the steel permanent magnet remained stationary) were brought out by Saxton, of Philadelphia, in 1833; by Clark, of London, in 1834; and by Page, of Washington, in 1835.

None of these machines, however, were of sufficient size to be available for the production of a practical electric light, although they all exhibited a capacity for this effect on a minute scale.

The first magneto-electric machine of a magnitude sufficient to operate a practical electric lamp was that produced by the united labors of M. Nollet, Professor of Physics at the Military School of Brussels, and his assistant constructor, Joseph Van Malderen, under the auspices of a corporation composed of

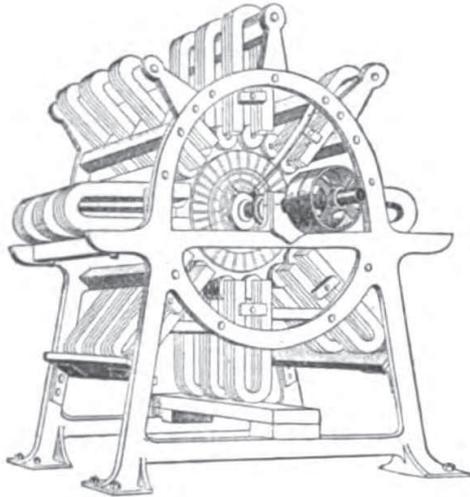


Fig. 2.—An Alliance Dynamo used in the South Foreland Lighthouse, 1858.

French and English capitalists and known as the "Alliance Company."

Strange to say, this machine was built with the absurd object of using it to decompose water and employ the resulting gases in the production of light.

This machine, with some modifications by Mr. Holmes, of England, was, under the superintendence of Faraday himself, introduced into two of the English light-houses, *i.e.*, at South Foreland and at Dungeness. Its preliminary trial was made in 1857. The electric light was first thrown over the sea from the South Foreland on the evening of December 8, 1858, and from Dungeness on the 6th of June, 1862.

Figure 2 shows in outline one of the Alliance machines, as modified by Mr. Holmes, which was long since put in operation at the South Foreland Light-house.

The outer framework supports twenty-four compound steel permanent magnets, and a drum inside carries thirty-two armatures or spools of copper wire wound on iron cores. As these pass from pole to pole between the magnets, currents are developed which are carried off by

commutators on the farther end of the shaft, not shown.

The electric light was not introduced into the French light-houses until December 26, 1863, when it was installed at La Hève, near Havre. It was also used for lighting works of construction, such as the Cherbourg Docks, and on some vessels, for example, on the Lafayette and the Jerome Napoleon.

Although Faraday lived to see the little spark, which he had developed from a magnet and coil of wire in his laboratory, grow into these magnificent illuminators of sea and land, it was not until after many years and numerous new developments that the electric light approached the commercial utility which it to-day possesses.

These Alliance machines, on account of their great size and multitude of parts, were very expensive. Thus the two machines placed in the Dungeness Light-house, with their engines, appliances, and lamps or "regulators," cost £4,760, or nearly \$24,000. The two located at Souter Point in like manner cost £7,000, or about \$35,000, and the machines and accessories for the two lights at South Foreland cost £8,500, or about \$42,500. The same characteristics caused them to be liable to accident and injury and costly in repairs. The world therefore waited for some further development before it could enjoy generally the advantages of electricity as a means of illumination.

The first of these came when Dr. Werner Siemens, of Berlin, constructed a machine in which the revolving coil or armature was made of the form shown in Figure 3, and was entirely enclosed between the ends of the permanent magnets. To construct this armature a long, solid cylinder of soft iron is taken, and two deep grooves are cut on opposite sides through its entire length, so that its cross-section is such as appears at F in

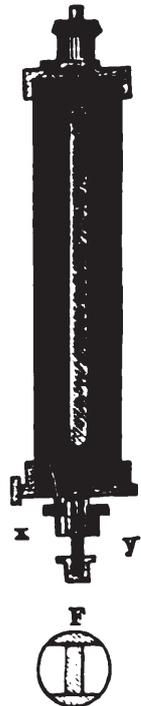


Fig. 3.—Magneto-electric Machine of Dr. Werner Siemens.

the accompanying figure. Insulated copper wire is then wound lengthwise in these grooves, its ends being united to the sections *x*, *y*, of the commutator. Journals on which this armature rotates are provided at either end, and at one end also a pulley by which it may be driven by a belt.

This armature secured a great concentration of action, by bringing the revolving armature into a highly concentrated field of magnetic force and allowing it to have a very rapid angular velocity of rotation. But the chief value of this improvement consisted in its serving as a step toward another, which was most remarkable in its results and excited the liveliest interest all over the world when it was announced. This next step was taken by Wilde, of Manchester.

He took a small magneto-electric machine, such as had been constructed by Siemens, and carried the current from its commutator to the coils of very large electro-magnets, which constituted the field-magnets of a similar machine, which, however, differed from the other, or Siemens machine, both in size and in having its field constructed of electro-magnets in place of permanent magnets.

Figure 4 shows such a combination, in which the first or small magneto-electric machine is mounted on the top of the other, and sends the current from its commutator through the coils of the electro-magnet below, between whose expanded poles another Siemens armature is made to revolve.

Under these circumstances the current developed in the armature of the upper machine, by its permanent steel magnets, will develop a more than tenfold greater magnetic force in the poles of the electro-magnet of the lower machine; and the second armature, rotating in this powerful magnetic field between the poles of this large electro-magnet, will develop a more than tenfold greater current than that of the smaller machine.

This method of multiplying or creating magnetic force was a wonderful discovery, and, combined with the use of electro-magnets in place of permanent magnets for the production of the mag-

netic field, gave an important increase in power and efficiency to the machine; for, as compared with permanent magnets, the power of electro-magnets is vastly greater.

This advance, made by Wilde on April 13, 1866, was quickly followed by another, made almost simultaneously in Europe by Varley, Siemens, and Wheatstone, and nearly a year earlier in this country by Mr. M. G. Farmer, whose work in another department of electric lighting we shall have occasion to mention farther on.

This development may be indicated by the term "self-exciting," and consisted in the discovery that if the commutator is so connected with the coils constituting the field magnets that all, or a part of the current developed in the armature will flow through these

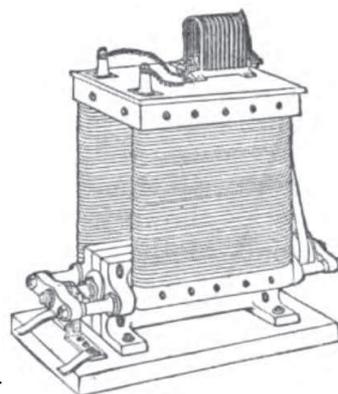


Fig. 4.—The Wilde Machine.

Small machine or feeder, with permanent magnets on top; large machine, with electro-magnets yielding available current below.

coils, then all permanent magnets may be dispensed with, and the machine will excite itself or charge its own field magnets without the aid of any charging or feeding machine such as the little one shown in Figure 4.

There is in all iron, unless special means have been taken to remove it, a little magnetic force. This small magnetic force, called "residual magnetism," in the iron cores of the field magnets will produce a little current in the armature when it is revolved. This current flowing through the coils of the field magnets will increase their magnetic force, and thus cause them to develop more current in the armature, which in turn, flowing through the coils of the

field magnets, will further increase their magnetic force, and so on until a maximum, determined by the structural conditions of the machine and the amount of driving force applied to the pulley of the armature, is reached.

In practice such machines are each complete within themselves. When started they develop for a few moments only very feeble currents, but within a few seconds they "wake up" by degrees, and reach their maximum in less time than it takes to read this paragraph.

One other radical improvement in dynamo-electric machines remains to be recorded, namely, that due to the French inventor Gramme.

The essence of this lay in the structure of the armature. While previous to Gramme all armatures had been constructed either like spools of cotton or like balls of yarn wound on blocks, he made his armature by starting with an iron ring (itself consisting of a coil of soft iron wire) and winding the copper wire on this by passing the end of the wire again and again through the ring. A Gramme armature ring, cut and bent out partly, and with some of its copper coils removed, is shown in Figure 5.

The cut ends of the iron wires constituting the ring-core are shown at A, and B shows a portion of the copper-wire coils wound around this ring-core. The copper wire is continuous through-

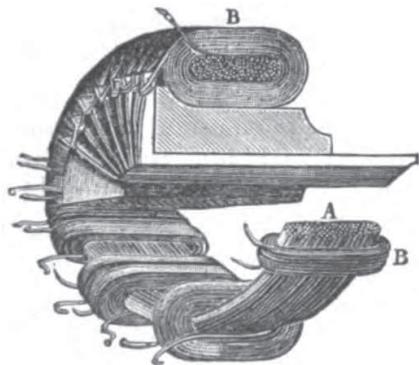


Fig. 5.—Section of a Gramme Armature Ring, showing its construction.

out as regards its electric connection, but at frequent intervals a loop of this wire is carried out and attached to a segment of the commutator.

This armature being rotated in a magnetic field (*i.e.*, between the poles of powerful field magnets) tends to deliver

a substantially continuous current to "brushes" touching the commutator segments at points midway between the poles of the field magnets.



Théophile Gramme.

It will be remembered that the iron ring constituting the core of the Gramme armature was made of iron wires, and not of a solid piece or ring of iron. The object of this was to prevent the formation of electric currents in this ring-core itself, commonly called Foucault currents, which would be a cause of inconvenience by heating the armature and of loss by wasting energy in the useless production of this heat.

The Siemens armature had no such provision, and accordingly very serious difficulties were experienced in the running of machines using such armatures, by reason of the intense heat there produced. Arrangements were in fact made in many machines to relieve this symptom by running cold water through the armature, made hollow for that end; but this did not cure the disease, or prevent the loss of efficiency caused by the conversion of the driving energy into useless heat in place of useful current.

The desirable end was, however, soon secured by "laminating the armature core," that is, making it up out of a great number of thin sheets of iron insulated from each other and held together by one or more bolts. The building up of such an armature core is illustrated in Figure 6.

The merit of this invention appears

to have been assigned by the U. S. Patent Office to Mr. Edward Weston, of Newark, N. J., who on September 22, 1882, filed an application in the U. S. Patent Office describing such a laminated armature core, for which two patents were granted, April 16, 1889, being Nos. 401,668 and 401,669.

We have given above all of the radical steps or improvements by which the dynamo-electric machine of to-day has been developed from the earlier constructions of Pixii, Clark, Saxton, and Page, or, in fact, from the experiment and discovery of Faraday.

There were, however, during the same time, a multitude of minor modifications of structure and arrangement introduced by various inventors, some useful and some useless, and when the world had been startled and interested by some of the wonderful developments, such as those of Wilde and of Gramme, it was found that in some forgotten patent or other publication some description might be read more or less completely anticipating these important discoveries.

We have not attempted to follow out the subject in this relation, which, however important in its legal consequences, as affecting the rights of patentees, is not a part of the general history of the actual development of the electric light which we have attempted to write.

An endless variety has also been given to the forms and arrangement of the more recent dynamo-electric machines manufactured by the various companies, but these it would likewise be impossible for us to discuss within the limits of a magazine article.

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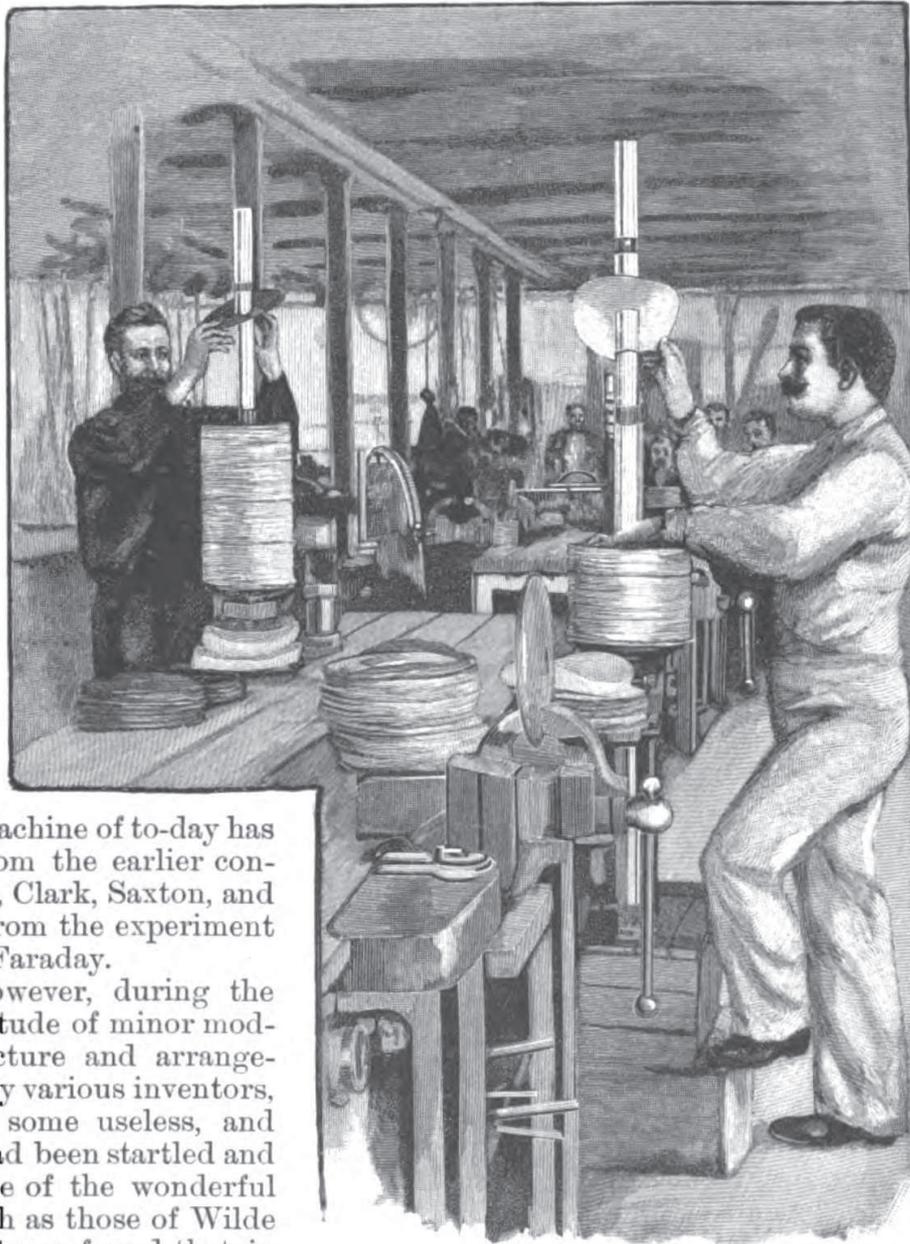


Fig. 6.—Workmen Building up the Armature Core of a Modern Dynamo.

I will therefore select a typical case, and give some account of its mode of construction.

The most difficult and important part of the structure is the armature, and in building this the first thing is the laminated iron core. For this purpose an immense number of thin disks of sheet iron are cut out, each having a central hole to admit the shaft, and several other holes for the bolts which are to hold the series of disks together, so as to make of them a solid drum. These disks are then piled one upon another around the iron shaft which is to form the axle of the armature, as shown in

Figure 6, and thick iron end-plates are applied at either end and bolted together by iron bolts going through from the successive sections of the commu-



Fig. 7.—Winding an Armature.

end to end. The drum or cylinder thus formed is then mounted in a lathe and turned to a smooth surface, except for such projections as may be left for guides in winding-on the copper wires.

This is the next operation to be performed, and is shown in Figure 7, which represents the winding of a large armature intended to produce a very heavy current, and therefore wound with thick wire.

The workman in front is drawing the insulated copper wire down from a drum overhead and passing it lengthwise around the armature-core, which is supported by its axis in a lathe, while another workman assists him in pressing the wire accurately into place and keeping it close to the core. This wire is not wound on continuously, but in a number of short sections whose ends

tator which is presently to be passed over the end of the shaft, appearing at the left.

Figure 8 shows just such an armature as that in Figure 7, but finished and turned the other way, so that though the position of the observer is reversed he still sees the commutator end of the armature turned toward him. The numerous radiating lines at the nearer end of the drum are parts of the commutator-sections, which are attached at their outer ends to the successive coils of wire on the armature. At their nearer ends these radial bars bend at right angles, so as to pass along the surface of the shaft, being insulated from it and from each other by mica or other appropriate substance.

The workman in this figure is engaged in putting on the last turns of

binding wire, which is wound in several bands, as shown, around the armature, not for any electric action but to hold the coils, which run lengthwise round the drum, firmly in place and prevent them from being spread outward by centrifugal force when the armature is in use. These binding wires are made of German silver, a bad conductor for a metal, and are thoroughly insulated from the copper wires of the armature.

The armature, having been thus constructed, is now ready to be mounted in the framework of field magnets, which has been constructed in another department of the factory.

This is shown in Figure 9, and consists of a massive framework of cast-iron, portions of which are surrounded with coils of insulated copper wire so as to make the central parts of the upper and lower horizontal masses respectively north and south poles.

It is in the cylindrical hollow between

off from it the current generated in the armature, are then attached to the sides of the bracket which carries the nearer end of the shaft, and the machine is substantially complete, the driving pulley being of course attached, when needed, on the farther end of the shaft.

Figure 10 shows this same machine completed in all respects, with the armature inserted, the brushes in place, and the driving pulley on the farther end of the shaft.

The dynamo-electric machines of Weston, of Edison, of Brush, of Thomson-Houston, of Westinghouse, and a dozen others are all constructed (with considerable variations in form and detail), in the manner above described, and by their aid mechanical energy can be transformed into electric energy with an economy entirely unparalleled by any transformation heretofore known to the arts. Thus in the steam-engine we may, under very favorable conditions, trans-

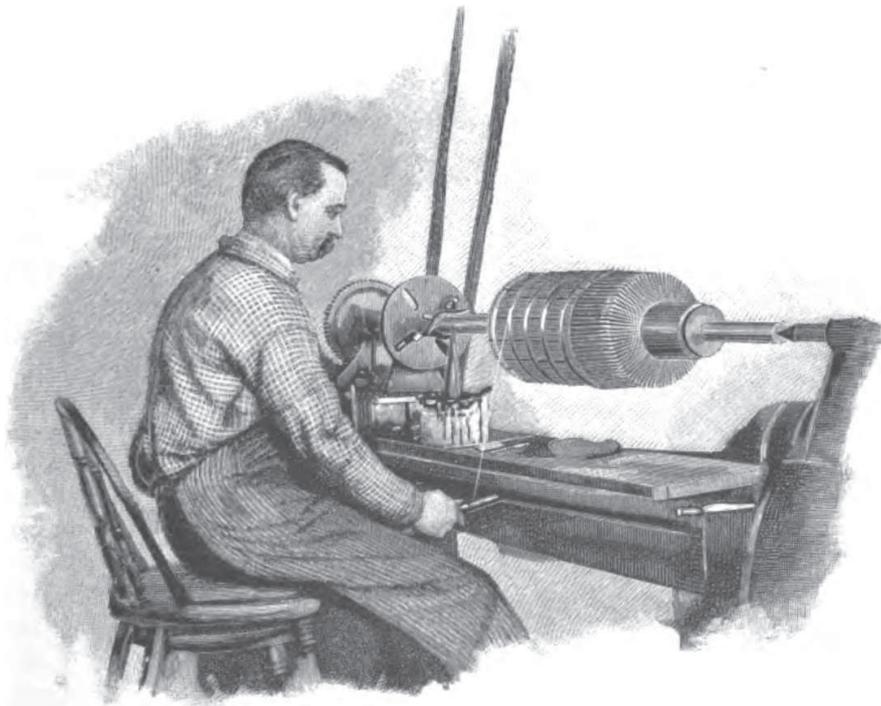


Fig. 8.—Finishing an Armature.

these that the armature rotates, one end of its shaft being supported in the journal-box seen at the right, while the other end is supported in a journal-box out of view on the other side of the machine.

The adjustable supports to hold the brushes, or elastic strips of copper which press against the commutator and take

form ten per cent. of the energy of the fuel into mechanical energy, but under the average working conditions we only secure about five per cent., the other ninety-five per cent. being lost.

In the dynamo-electric machine, on the other hand, it is very common to secure a transformation of eighty per cent.

of the mechanical energy, applied to the driving pulley, into electric current, and in many cases as much as ninety per cent. is so transformed and only ten per cent. is lost.

Cheap electricity having been thus secured by the development of the dynamo-electric machine, the electric regulator or lamp acquired a new importance, and new demands were made upon the inventive genius of the world on its account.

As long as expensive batteries were the only sources of electric energy, it was considered quite enough to operate one lamp at a time; but when the great capacities of the dynamo-machine were to be realized, it became clear that for economical working many lamps must be operated from one machine, and, if possible, in a single circuit or one after the other. For this the old regulators

As soon, therefore, as the burning away of the carbon poles causes an increase in the resistance of the arc or space between them by increasing its length, the resulting diminution of the current causes the electro-magnet to release or actuate the feeding device, until the poles are brought near enough to diminish the resistance of the arc to its normal amount.

With a single lamp in circuit this is all that is required, but it will be manifest that anything which causes a diminution in the current will cause the carbons to be brought nearer. Now suppose that two such lamps are arranged in series so that the current flows first through one and then through the other, and that, as must always be the case, one mechanism is a little (no matter how little) more sensitive than the other; then, when either pair of carbons burn away enough to diminish

the total current to the point at which the more sensitive mechanism will act, that mechanism will so act, and will bring its carbons toward each other, until the resistance is diminished far enough to restore the normal current, and this will happen without the less sensitive mechanism being brought into action at all. This operation will then go on; the carbons of the less sensitive lamp burning

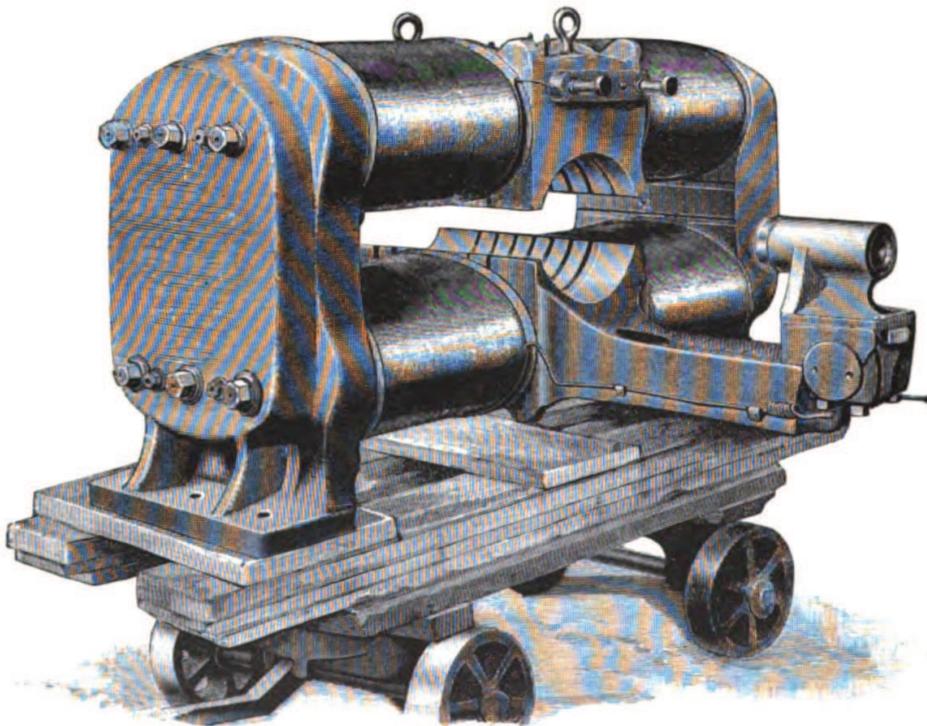


Fig. 9.—Field Magnets and Frame, without armature.

were not adapted. They all operate in the following general method:

The current which supplies the lamp passes through an electro-magnet which controls a clock-work or other mechanism which allows or causes the carbon poles to approach each other whenever the strength of the current is reduced.

away farther and farther, and their increase of resistance being made up by the approach of the carbons of the more sensitive lamp until the latter is extinguished by the actual contact of its carbon poles and the less sensitive lamp has secured an excessively long arc which is absorbing the entire energy of the circuit.

The same thing would happen with any number of such lamps in series. The most sensitive of the lamps would

United States, being very inferior in efficiency and economy to lamps arranged on the Brush or other similar systems.

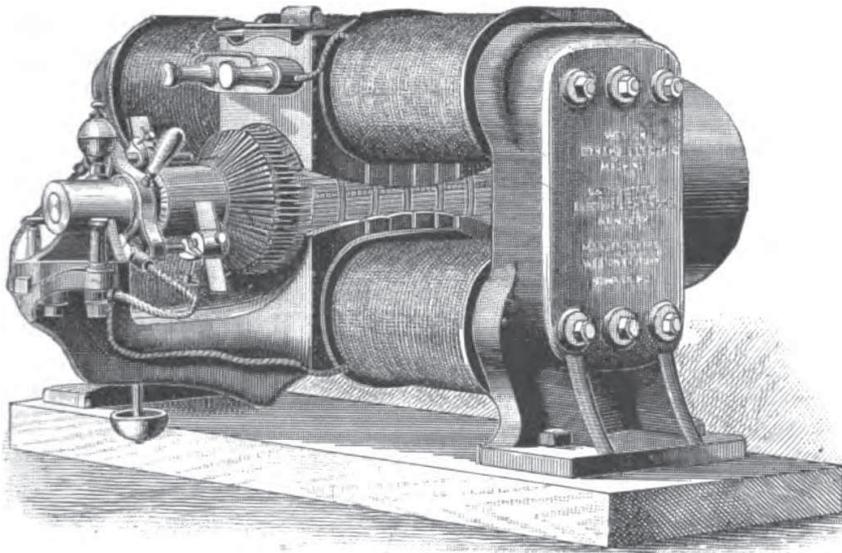


Fig. 10.—A Complete Dynamo—armature in place.

do the adjustment for all the rest, until its poles were brought into contact, and then the next in order of sensitiveness would take its turn, and thus one after the other would be thrown out of use, and the entire energy of the circuit would be concentrated in an abnormally long and probably destructive arc in the least sensitive lamp. Numerous plans were suggested to meet this difficulty, but the only ones which have reached any general practical success are those of Jablochhoff and of Brush.

Jablochhoff substituted for the lamps whose carbons were moved by mechanisms of some sort his electric candles with immovable carbons. In these the two carbon rods were placed side by side, vertically, very near to each other, the space between being filled with plaster-of-Paris.

An arc having been established between the upper ends of the carbons by a thin strip of carbon which was quickly burned away, the same continued as the carbons consumed, because the plaster-of-Paris between them melted and volatilized as fast as the carbons were consumed. (Figure 11.)

These Jablochhoff candles were used to a considerable extent in Europe in the early days of electric lighting, but never made much progress in the

traverses the arc of the lamp, but the other magnet or coil is traversed by a current branching from the former where it enters the lamp, and rejoining it where it passes out, but not going through the arc. This last-named coil has a higher resistance than the other, and normally transmits but a small fraction of the current as compared with that passing through the arc and the other coil.

If, now, by the burning away of the carbons, the resistance of that circuit is increased, two things happen at once: the current through the other coil, which is not in circuit with the arc, is increased at the same time that the current through the arc and its coil is diminished, so that the total current through the lamp remains substantially unchanged, and therefore

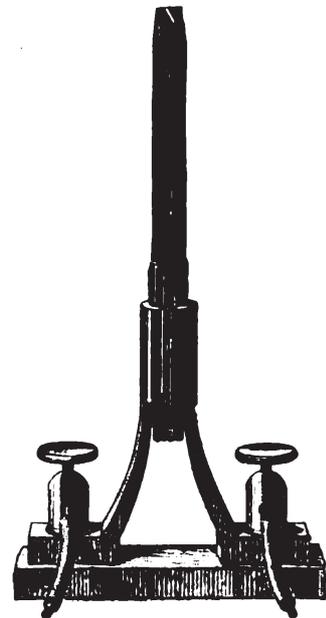


Fig. 11.—The Jablochhoff Candle.

nothing which happens in one lamp has any effect on the circuit at large or on any other lamp. Also the opposite magnetic effects in the two coils cause a rapid readjustment of the carbon electrodes and a consequent restoration of the arc to its normal length.

After this arrangement had been developed by the Brush Electric Co. some old patents were discovered in which the same principle was to a greater or less extent set forth, but as in the case of the Pacinotti article and the Gramme machine, these do not seem to have had anything to do with the practical development of the art of electric lighting prior to Mr. Brush's invention.

As with the dynamo-electric machines, so with the regulators or electric lamps for arc lights, their varieties of construction are endless, but they all come under the general description of holders for the carbon rods, whose motions are controlled by feeding mechanisms

failure in operation is almost unknown to the ordinary observer. Irregularities, such as are incident to the unequal burning away of the carbon points, of course frequently occur; but the extinction of a light through any failure of the mechanism of the lamp is of the rarest occurrence even where the lights are placed in the most exposed and inaccessible positions. A striking example of this was furnished in the lights erected and maintained for some time by our Light-house Department at Hallett's Point for the purpose of lighting up the difficult channel of the East River, known as Hell Gate, illustrated in Figure 13. These lights, nine in number, arranged so as to form about three-fifths of a circle, were supported at a height of two hundred and fifty feet by a light iron tower. Each light gave, by actual measurement, an amount of light equal to three thousand standard candles, or about four times the light given by the

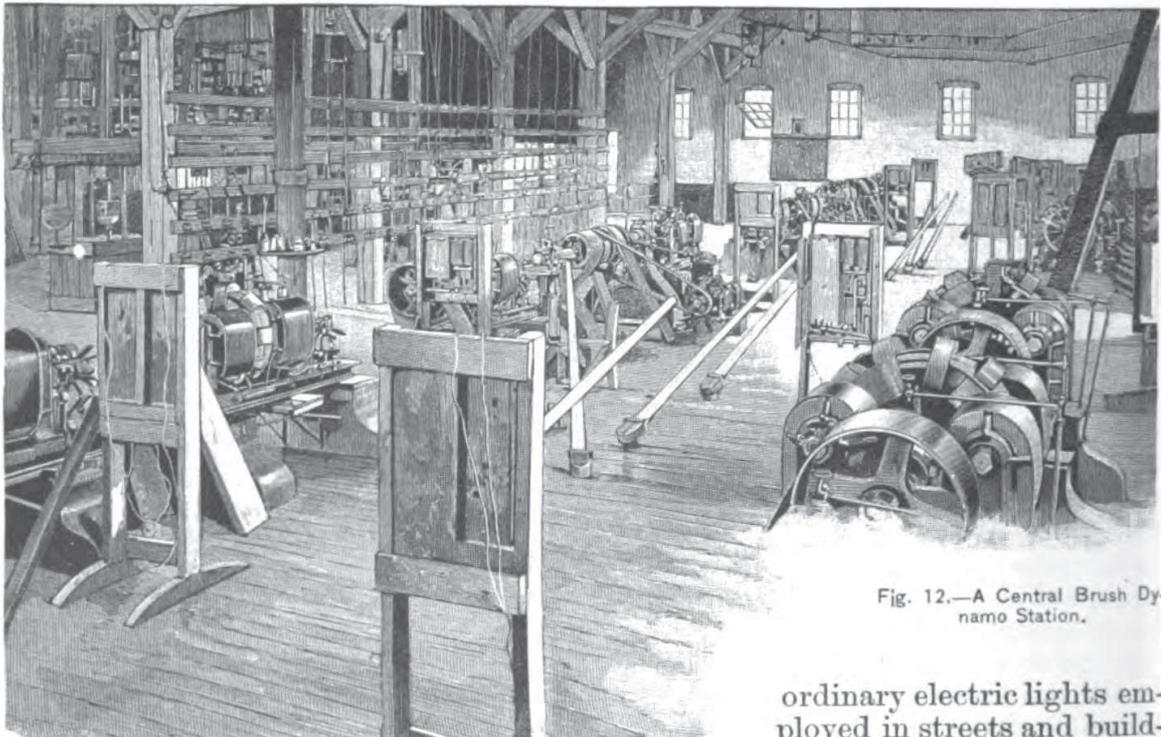


Fig. 12.—A Central Brush Dynamo Station.

ordinary electric lights employed in streets and buildings.

which are in turn controlled by electromagnets through which the operating current flows.

Such structures have reached a marvellous perfection as regards their regularity and certainty of action. Among the thousands of lamps which light our streets and stores night after night, a

These lights were put in operation on October 20, 1884, and produced a magnificent effect, lighting up the whole surrounding town of Astoria and the adjacent channel. After several years of use it was, however, decided that they did not afford the expected aid to navigation, and they were removed in 1888.

During all these years, however, there was no failure caused by the mechanism of the lamps.

The number of arc lamps which are nightly operated by the different electric lighting companies in the city of New York is probably over five thousand, and throughout the United States it probably reaches seventy-five thousand. Assuming that these lights are worth to their users the moderate rental of fifty cents a night, this represents an output of light having a value of \$11,250,000 each year of three hundred days; all earned by this one branch of the family directly descending from the baby spark born from a magnet in the laboratory of Michael Faraday.

Admirable as is the system of electric-arc lighting, for use in streets and open spaces, and in workshops or large halls, it is entirely unfit to take the place of the numerous lights of moderate intensity, employed for general domestic illumination.

For this purpose it was at a very early period perceived that the incandescence or heating to luminosity of a continuous conductor by an electric current was the most promising method. It was also at a very early period perceived that the conductor to be used for this purpose must be one which would admit of being raised to a very high temperature without being melted or otherwise destroyed. The first material which was thought of in this connection was platinum, or one of its allied metals, such as iridium, which have the highest melting-points among such bodies, and are besides entirely unacted upon by the air at all temperatures. In 1848 W. E. Staite took out a patent for making electric lamps of iridium, or iridium alloys, shaped into an arch or horse-shoe form.

One of the most serious difficulties, however, even with these materials, was that, to secure from them an efficient light, it was necessary to bring them so near to their fusing-points that a very minute increase in the current would

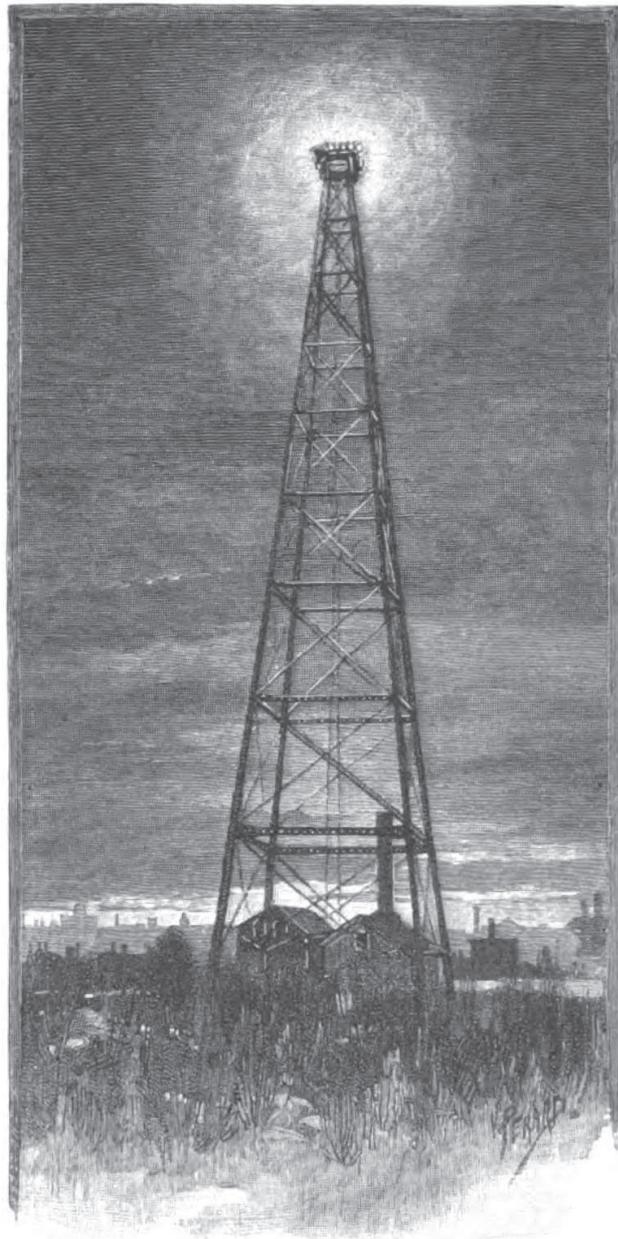
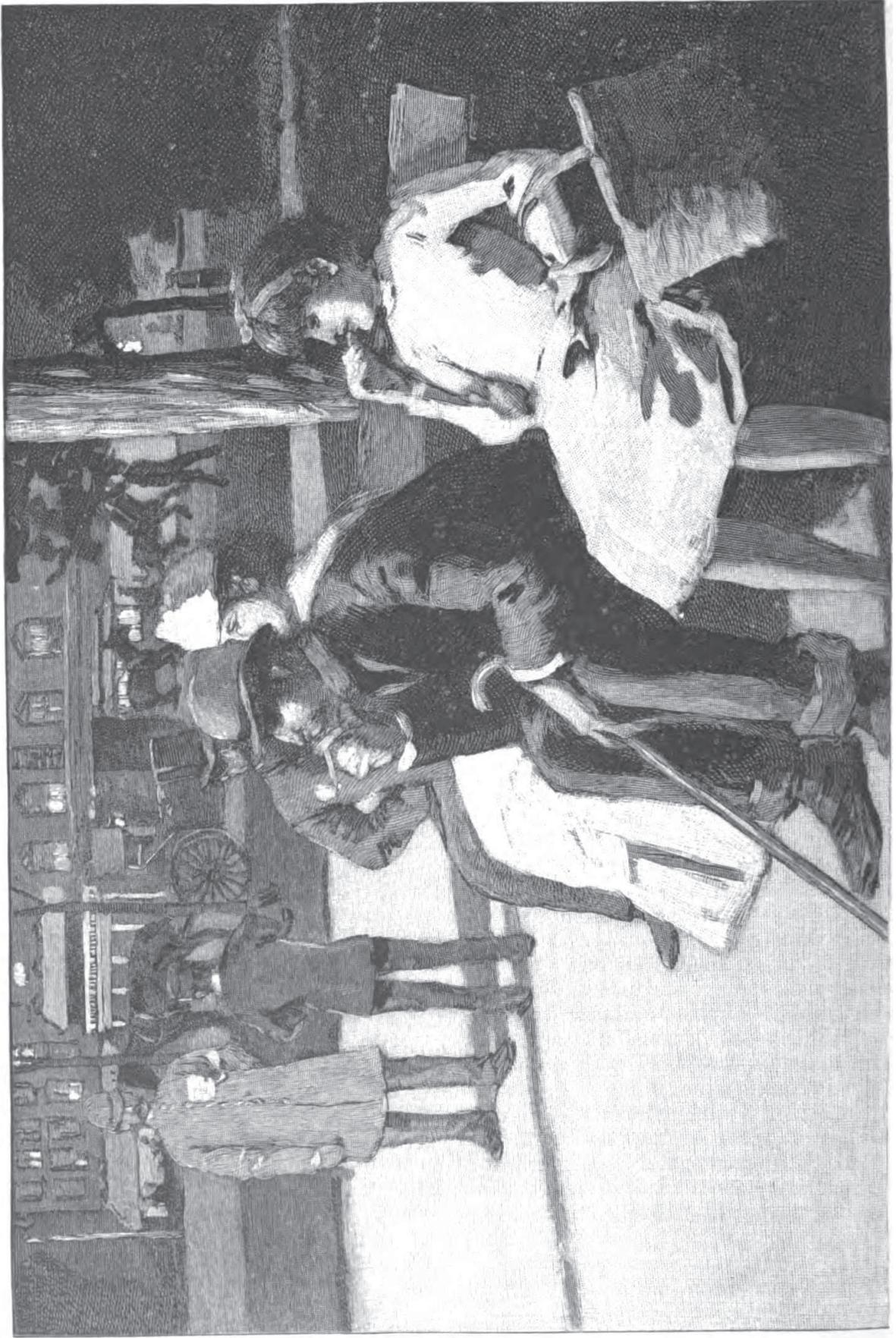


Fig. 13.—Hell Gate Light, New York, before it was abandoned.

carry the temperature beyond this and destroy the lamp by fusing the conductor. An escape from the difficulty was offered by the use of hard carbon, such as that employed for the electrodes of arc lamps, but here the compensating drawback was encountered, that this substance, when highly heated, was attacked by the oxygen of the air, or, in other words, burned. To meet this, plans were devised for the replacement of the consumed carbon conductor and for its protection from the air by enclosing it in a non-active gas or in a vacuum.



Under the Electric Light.

Thus in 1845 a patent was taken out in England by Augustus King, acting as agent for an American inventor named J. W. Starr, for an incandescent lamp, the important parts of which are represented in Figure 14.

Here a platinum wire is sealed through the top of a small glass chamber constituting the upper end of a barometer tube. This platinum wire carries at its lower end a clamp, which grasps a thin plate or rod of carbon, and also a non-conducting vertical rod or support, which helps to sustain another clamp, which grasps the lower end of the carbon strip and connects it by a wire with the mercury in the barometer tube below.



Fig. 14.—The Starr-King Incandescent Platinum Lamp, 1845.

By passing a current through the platinum wire, and thence through the upper clamp, carbon strip, lower clamp, wire, and mercury, the carbon strip could be made incandescent, and was to a certain extent protected by the surrounding vacuum.

Though this lamp produced a brilliant light it proved in various respects unsatisfactory, and was abandoned after numerous trials.

Other inventors, as, for example, Konn, of St. Petersburg, continued to work with rods or pencils of hard carbon and achieved a limited success, but the irregularity and brittleness of the material seem to have been an insuperable objection and drawback, and the problem of commercial electric lighting by incandescent conductors yet remained without a solution.

This was the state of affairs even up to the fall of 1878, when, as is claimed, Mr. William E. Sawyer, in combination with Mr. Albon Man, after many preliminary experiments, produced their first successful incandescent lamp with an arch-shaped conductor made of carbonized paper. In their application for a patent, filed January 8, 1880, these inventors use the following remarkable

language in their fourth claim: "An incandescing arc of carbonized fibrous or textile material." This indicates that they realized the importance of what seem to be the common features of the present electric incandescent lamps, namely, the arc or arch or bow or loop form, and the carbonized fibrous or textile material. They also specially refer to carbon incandescent conductors made from paper.

After a long and hotly contested interference the United States Patent Office has granted them a patent in which these points are broadly stated, and the merits of this patent are now actively litigated.

The lamp brought out by Messrs. Sawyer and Man, soon after their application for a patent, and described and shown in that application, was a rather large and complicated structure; and had no improvement and simplification of this structure been made, the present immense development in electric lighting would no doubt have been unattained.

It is to Mr. T. A. Edison, without doubt, that we owe many of the simplifications and modifications which, by cheapening the lamp and diminishing its weight, have extended its range of use and its usefulness to a remarkable degree.

On his return in the fall of 1878 from the Far West, where he had gone in company with Dr.

and Mrs. Henry Draper, Dr. George F. Barker, and the present writer, to observe the total solar eclipse of that year, Mr. Edison visited the shops and laboratory of Mr. William Wallace, at Ansonia, Ct., where

many experiments with electric-arc lights and dynamo-machines were in progress, and while studying these, was impressed with the desirability of producing an incandescent electric lamp.

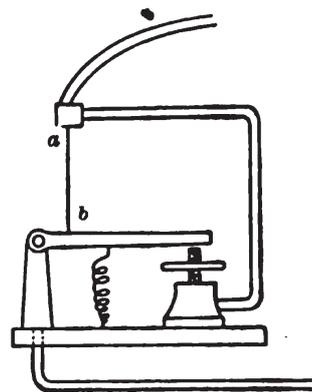


Fig. 15.—Edison's First Incandescent Platinum Lamp.

Like so many before him, he first turned to platinum and platinum alloys, and devised a form of lamp admirable for its simplicity, but, unfortunately, open to a fatal objection. This first lamp of Edison's is shown in Figure 15, in which *ab* is the incandescent platinum wire.

The announcement of a new system of electric lighting, made by Mr. Edison and his friends on the foundation of this device, attracted universal attention, and even caused a serious fall in the value of "gas stocks" in this country and abroad. It is, indeed, amusing now to look back upon the extravagant assertions and predictions made at that time, and widely circulated, when we realize how more than frail was their foundation. In fact, Mr. Edison very soon found out that this simple device was entirely insufficient for the purpose proposed, because the heated platinum wire gradually stretched by its own weight, and thus was constantly getting out of adjustment, and finally would become attenuated and break.

It also happened that, though the secret of this great invention was carefully guarded, some inkling of it escaped, and this enabled those who were familiar with such subjects to perceive the close similarity between this Edison lamp and

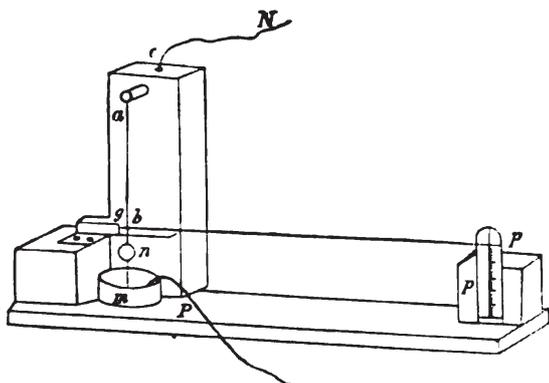


Fig. 16.—Dr. J. W. Draper's Plan for an Incandescent Platinum Lamp, 1847.

ab is the incandescent platinum wire or strip, supported above by the brass pin at *a*, which runs into a cavity, *e*, filled with mercury and is thus connected with the battery wire *N*. The other end of the platinum wire or strip is attached to a delicate lever, *gp*, turning about the fulcrum *g*; a little weight, *n*, tends to keep the wire stretched, and communication is made through it by a copper wire with the cup *m* filled with mercury, into which dips the other battery wire *P*.

a similar device constructed and used by Dr. J. W. Draper prior to 1847, and described and figured in articles pub-

lished by him during that year in *The American Journal of Science and Arts*,

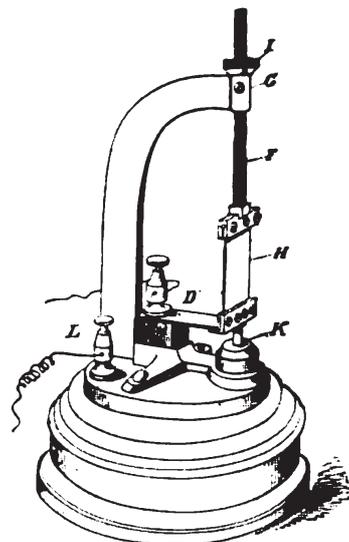


Fig. 17.—Maxim's Incandescent Platinum Lamp.

H is a strip of platinum, adjustably supported by means of the screw *F* and nut *I*, from the standard *GL*, from which it also receives an electric current which normally passes out through *D*; but when, by excessive heat, the platinum strip is elongated unduly, a short circuit is closed at *K*, which diverts the current from the standard and platinum strip, and so prevents the fusion of the latter.

The London, Edinburgh, and Dublin Philosophical Magazine, and *Harper's New Monthly Magazine*. This apparatus of Dr. Draper is shown in outline in Figure 16. It was used by Dr. Draper as a source of light or lamp with which he determined the relations between temperature and luminosity. At the conclusion of his article Dr. Draper says: "An ingenious artist would have very little difficulty, by taking advantage of the movements of the lever, in making a self-acting apparatus in which the platinum should be maintained at a uniform temperature notwithstanding any change taking place in the voltaic current."

It also appeared that precisely the same idea had occurred to another inventor, Mr. Hiram S. Maxim, who has recently developed such a marvellous improvement in magazine or repeating guns, and who, on December 22, 1879, filed an application for a patent which, after an interference litigation with Edison, was finally issued to Maxim on September 20, 1881, for the form of electric lamp shown in Figure 17.

It has also been shown that in 1858

Mr. M. G. Farmer, one of the veteran electricians of America, to whose work in connection with the dynamo-electric machine allusion has been made before, lit a room in his house at Salem, Mass., for several months, with platinum lamps of similar structure controlled by automatic regulators.

During 1878 and 1879, however, Mr. Edison was most diligently at work, and, perceiving the imperfections of his first ideas, sought in every way to overcome them. It thus came to pass that by December 21, 1879, at which date he made his first revelation to the public, in the pages of the *New York Herald*, he had perfected a platinum lamp which is shown in outline in Figure 18, as well as some other forms substantially like it.

But these platinum conductor lamps were not the only outcome of Mr. Edison's work between the fall of 1878 and December, 1879. As this *Herald* article also related, Mr. Edison, like many before him, having experienced the insuperable difficulties present in metallic con-

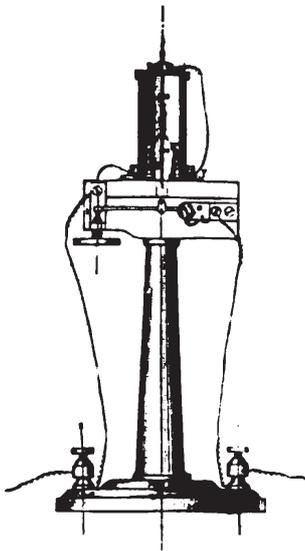


Fig. 18.—Edison's Platinum Lamp on Column Support, 1879.

The incandescent wire of a platinum alloy is supported by a metallic rod about which it is wound and whose expansion serves to operate a shunting contact below, by which an inconveniently high temperature is avoided.

ductors, had turned his attention to carbon in various forms; and, like Sawyer and Man, had found fibrous textile materials, when carbonized, to be most convenient, and paper especially to be, in the

first instance, the most available substance. Like Sawyer and Man he had also found the arch or horseshoe form to be the most desirable.

Though working with the same materials and form, Edison produced a structure very different in appearance from that of Sawyer and Man, as will be seen by reference to Figure 19, which represents one of Edison's paper carbon lamps, which was the first one whose

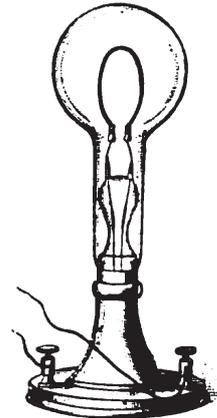


Fig. 19.—Edison's Paper Carbon Lamp.

electric properties were accurately measured, these measurements having been made at the Stevens Institute of Technology, early in 1880, by the present writer, acting in his capacity as Chairman of the Committee on Scientific Tests of the United States Light-house Board, that body desiring information as to this new light, and deputing the work of investigation to this committee.

In this lamp the carbon conductor is supported on platinum wires and held in minute platinum clamps at the ends of these wires, which are sealed through the walls of the pear-shaped enclosing tube in the manner which had been familiar for twenty years in the construction of the beautiful electric toys known as "Geissler tubes."

The interior of this glass vessel had likewise been exhausted and hermetically sealed in the manner usual with many Geissler tubes and with the radiometers of Dr. William Crookes.

Indeed, as was subsequently made apparent, the wonderful results obtained by Dr. Crookes, in the production of very perfect vacua, were of essential importance to the development of the incandescent electric lamp. Several of the instruments produced by Dr. Crookes in the course of his researches were in fact incandescent electric lamps, consisting of coils of platinum wire enclosed in glass vessels exhausted to a very high degree, the coils being heated to brilliant luminosity by electric currents. One of these is shown in his paper in the "Phil-

osophical Transactions for 1876," vol. xlvi., Part II., page 351.

Further experience proved to Edison and others that *paper* carbons were not the best for the conductors of electric lamps, and many other substances have been, or are now, employed for this purpose. Among these may be mentioned silk, hair, parchmientized cotton thread, tamodine or reduced celluloid, and last, but not least, bamboo, which is used to a very large extent.

The making of these electric lamps is carried on in a number of large factories, such as that of the Edison Co. at Harrison, near Newark; those of the Westinghouse Electric Co. at Newark and at Pittsburg; that of the Consolidated Electric Co. at West Twenty-third Street, New York; that of the Thomson-Houston Co. at Lynn, Mass.; that of the Brush Co. at Cleveland, O., and a number of smaller establishments elsewhere. The daily output of all these factories taken together is about fifteen thousand lamps, or four and a half million a year.

The methods of manufacture are substantially alike in all, and I will therefore describe one only as an example.

Sheets of tamodine (or celluloid from which the nitric constituent has been removed) are cut by a machine into delicate strips or filaments, which are collected in small bundles and bent so as to lie in U-shaped grooves in iron plates. These, packed with carbon powder, are enclosed in large black-lead crucibles, carefully closed, and heated in a Siemens furnace to an intense white heat. After cooling, the crucibles are opened, and the now carbonized filaments, looking like delicate wires or threads of steel, are removed. They have now the U-shape into which they were bent before carbonizing, but are so elastic that they can be stretched out straight without breaking. Their ends are next thickened by a remarkable process devised by Messrs. Sawyer and Man, and which is conducted as follows: Each U-shaped fibre is grasped by two clamps, one holding it by the extremities or ends, and the other at a little distance above. The loop and clamps are then plunged in a vessel of high-

boiling petroleum-oil, like the well-known "astral oil," and a powerful electric current is passed from the clamps through the short portions of the filament, near its ends, which are grasped between them.

By this means these portions are intensely heated and decompose the hydrocarbon liquid in contact with them, so as to plate themselves with compact carbon like that deposited from the gas in the necks of gas-retorts. A few seconds' action suffices to make this deposit of carbon thick enough to answer the desired purpose.

We will next turn to the glass-blowing department, where hundreds of girls are employed in all the delicate and skilful manipulations involved in the glasswork of these lamps.

The first step is to take two minute pieces of platinum wire, one end of each having been shaped into a little socket capable of holding the enlarged end of the carbon filament; and, after mounting them in a small lathe-chuck, to wind melted glass from a glass rod, heated in a glass-blower's lamp, around these platinum wires until they are for some distance embedded in glass and formed into a structure such as is seen at the lower part of the ordinary incandescent lamps. Into these glass and platinum supports are then inserted the enlarged ends of the carbon filaments.

In the meantime small glass flasks, made by the thousand at the glass-works, are passed through a variety of manipulations by which a small glass tube is attached to what would be the bottom of each flask, and its neck is shaped so as to receive the glass socket carrying the platinum wires and carbon filament. At the proper time this socket is dropped into the prepared flask, and by manipulation with the glass-blower's lamp and a sleight of hand which is simply marvellous, the glass socket, with its carbon filament and connecting wires, is sealed, by fusion of the glass itself, into the neck of the flask.

This operation is shown in progress in Figure 20, where the girl in the foreground holds in her left hand the glass flask by the glass tube which has been attached to it, and in her right hand the

shears with which she at times holds and shapes the glass socket and neck of

When a good vacuum has been reached, the current is passed through



Fig. 20.—Sealing the Glass Socket and Carbon Filament into the Flask of an Incandescent Lamp.

the flask. The blow-pipe flames, constituting what is called the "glass-blower's lamp" or "fire," are seen as pointed tongues of light between the hands of the operator, who is supposed at the instant represented to have just raised an electric lamp, finished (so far as her work is concerned) from the flame.

The next thing to be done with the lamps is to exhaust them. For this purpose they are attached by the small glass tubes before mentioned to radiating glass connectors, and these are in turn attached to the pumps, while at the same time electric connections are made so that currents can be sent through the filaments of the lamps while they are being exhausted by the pumps. These pumps are themselves entirely composed of glass, and operated by the flow of mercury back and forth within them, and their operation is so nearly automatic that a few attendants can keep a large number of them in steady operation.

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the lamps and they are then kept at a brilliant incandescence for some hours, in order to drive out any gas which might be occluded in the carbon filaments or adhere to the interior surface of the glass. This process of exhaustion and a series of pumps and lamps in operation during the process are shown in Figure 21.

After the complete exhaustion of the lamps it then only remains to "seal them off," that is, to melt the small glass tube attached to each so that its sides close together, and it becomes a little knob of glass, and to attach the brass caps by which they are to be subsequently connected to their sockets.

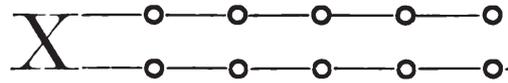
The uses of these lamps are so countless and so familiar to everyone that we have only selected one unusual one for illustration, namely, the lighting of the Hoosac Tunnel, which has recently been carried out by this means in the face of great difficulties encountered in securing adequate insulation, in such a

situation, for the wires carrying the current to the lamps. The lamps are attached to the rock or to the stone lining of the tunnel in the manner shown in Figure 23, (p. 196) and produce when in operation the effect shown in Figure 22.

As we have seen so often already, the solution of one problem always opens up another, and thus it is not surprising that the cheapening of electricity and increased efficiency of incandescent lamps brought to the front the problem of an economical method for carrying the electric current from the generator to the lamps.

monly known as the "series" and the "parallel" systems.

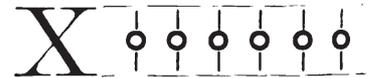
The "series" system is that always and necessarily employed whenever more than one arc light is used on the same circuit, and may be likened to the arrangement of disks on the chain of a chain-pump, or illustrated by the accom-



panying diagram, in which X represents a dynamo-machine and o, o, o, o, etc., represent a series of lights connected by the circuit wires —, —, so as to form a single chain from the machine through all the lights in succession back to the machine again.

This was the usual arrangement of the telegraph instruments at the various stations on a line.

The "parallel" or "multiple arc" system was one which might be indicated by a ladder or by the accompanying diagram, where, as before, X represents the dynamo.



from whose poles proceed two main conductors between which the lamps o, o, o, etc., are placed in cross connections.

This was a method commonly employed in central telegraph offices for operating the sounders by means of the large "local" battery. It is also described in the United States Patent to H. Woodward for improvement in electric lights, granted August 29, 1876, as well as in many other places.

The first method has certain drawbacks which are specially important in the case of incandescent lamps, where, for economy, a large number should generally be operated on a single circuit:

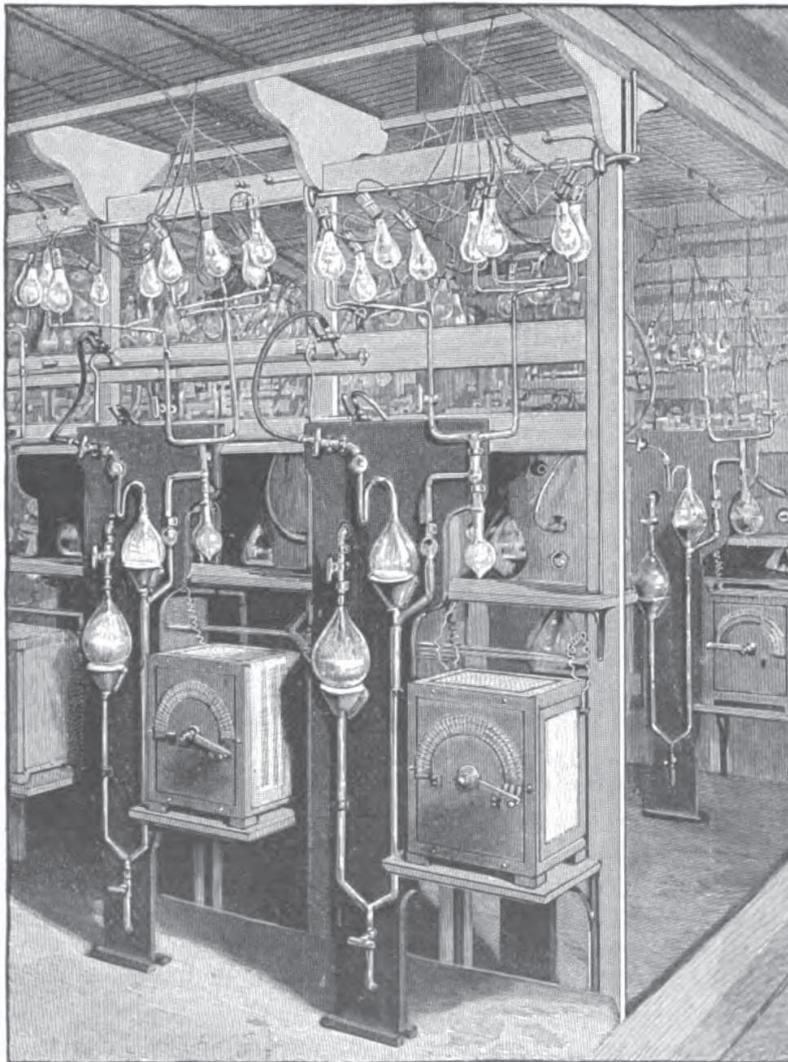


Fig. 21.—The Process of Exhausting the Air from Incandescent Lamps.

There were two well-known systems which had been often used in other applications of electricity, and, indeed, even described and patented for use in electric lighting, namely, what are com-

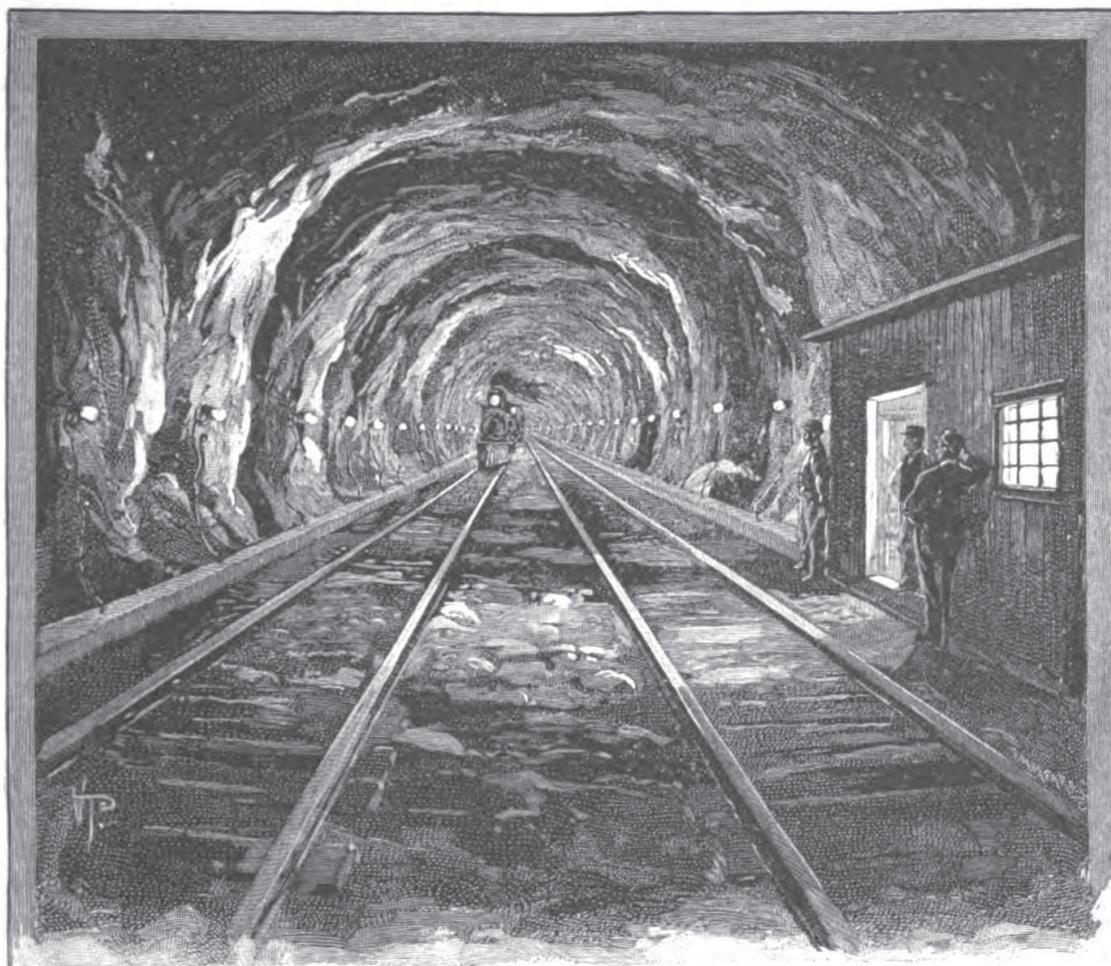


Fig. 22.—The Hoosac Tunnel Lit by Glow Lamps, after the plan of the Marr Construction Company.

1. The extinction of one lamp means the extinction of all, unless some more or less complicated mechanism is provided to restore the connection around the lamp which has failed or has been turned out.

2. The electro-motive force, or electric pressure, needing to be multiplied in direct proportion to the number of lamps in the circuit, soon becomes inconveniently high.

Both of these difficulties being avoided in the "parallel" system, this last has been generally adopted by all the companies using incandescent electric lights for most of their work. This is, however, by no means universal, for the Edison Co., in what they call their "Municipal system" (used mostly for street lamps in small towns and villages), run incandescent lamps in series. Other companies often run their lamps in a combination of the two systems, and the Heissler Co. run their lamps in "series" exclusively.

In avoiding the difficulties of the "series" system mentioned above, the parallel or multiple-arc system encountered others, the chief of which was the great size and cost of the conducting wires, if the distance between the dynamo and the lamps was considerable. Suppose that a group of lamps was placed one thousand feet from a dynamo, and the wires used were of such a size that their resistance to the flow of the current caused them to waste ten per cent. of the energy developed. Now let us suppose that this group of lamps is moved away one thousand feet farther. This would, of course, mean doubling the length of the wires, which alone would double their cost; but it would also mean doubling their resistance, if they were not made larger than before, and so wasting twenty per cent. of the electric energy generated by the dynamo.

To avoid this loss we must make the wires twice as heavy per running foot,

and if we do so we can then reduce the loss at two thousand feet to ten per cent. as before, but clearly we have four times the weight of copper to pay for in our conductors. If the lamps are removed to a total distance of three thousand feet we shall have three times the length of wire, and to keep down its resistance to that producing a loss of only ten per cent., we must make the wire three times

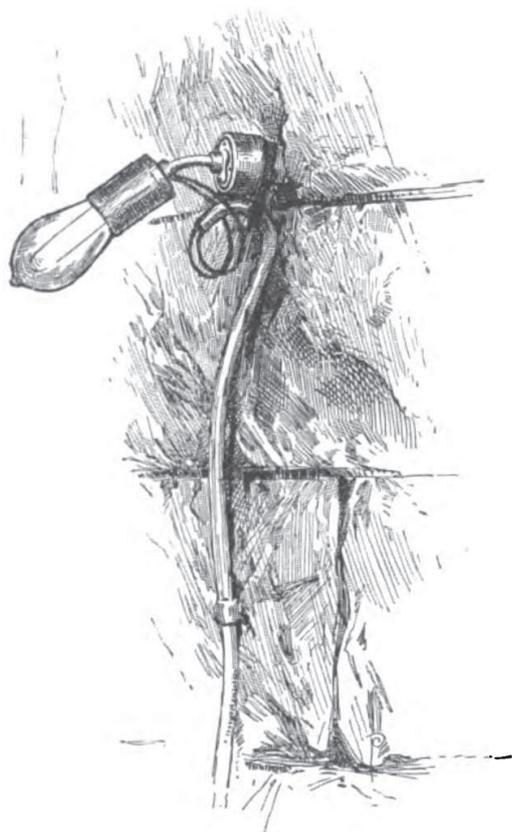


Fig. 23.—Method of Attaching Glow Lamps to the Walls of the Hoosac Tunnel.

as heavy per foot, or, in all, we shall require nine times as many pounds of wire to operate the lights at a threefold distance. The law evidently is, that the weight and cost of the wire will increase as the square of the distance.

This difficulty is mitigated to a considerable degree by what is known as the "three-wire" system, first indicated by Mr. Brush in his patent No. 261,077, issued July 11, 1882, and developed in two different directions by Mr. Edison, in his patent No. 274,290, issued March 20, 1883, and by Mr. H. M. Byllesby, of the Westinghouse Co., in his patent No. 345,212, issued July 6, 1886, so that the loss can be reduced to three-eighths or

even to five-sixteenths of what it would otherwise be by a moderate increase in the complication of the arrangements.

The outstanding loss has, however, led to the development of a radically new and very interesting system, known as the secondary or transformer system, chiefly represented in this country by the Westinghouse Electric Co.

The principle on which this system operates is indicated by Professor Brackett at pages 654 and 655 (June) of his article, and may be briefly stated by saying that if we have two conducting wires parallel to each other, and pass an interrupted or reversed (*i.e.*, alternating) current through one of them, there will be produced a similar, but always alternating current through the other, without there being any conducting contact at all between the wires.

This may be very beautifully shown by the following experiment:

We have upon a table an oval coil of fine copper insulated wire, through which is passing the rapidly reversing or alternating current obtained from a dynamo-machine which is working without a commutator. (Fig. 25, p. 199.)

If, now, we hold above it just such another coil, in whose circuit is included an incandescent lamp, this lamp will light up and glow to its full intensity as we bring the second coil near to the first, and will die out as the coil is moved away. This will operate just as well with a plate of glass between the two coils.

This action is greatly intensified by enclosing both coils in a mass of iron whereby magnetic influence is brought into play; and accordingly the converters or transformers used in this system are made, as will appear from inspection of Figure 24, by enclosing the two coils in a mass of iron made up of thin sheets, so cut that they can be sprung in, one at a time, around the coils.

The relative character of the currents in the two coils, depends substantially on their lengths and consequent resistance; that which is shorter and thicker having a current of larger volume and less pressure or electro-motive force, and that which is longer and thinner having less quantity or current strength and more electro-motive force or pressure.

Now a current of high electro-motive force and small quantity, can be carried a long distance on a small wire with very little loss.

If, then, we pass this current through a coil of long fine wire, in a converter whose other coil is relatively short and thick, we shall obtain in the latter a current whose quantity is great and whose electro-motive force is low. In other words, we can thus transmit such a current as goes easily on a small wire, from the central station to the house

where the lights are to be used, and there transform it into the kind of current most desirable for the operation of incandescent lights. In practice the Westinghouse Co. send out their currents with an electric pressure of one thousand volts or units of electro-motive force. A quantity of this current equal to one ampère, or unit of current strength, running through the fine wire of one of their converters will develop in the coarse wire a current of twenty ampères quantity but of only fifty volts pressure.

Such a current, however, would be just what was wanted to run twenty incandescent lamps in "parallel" series, which is the most convenient way, as each is then entirely independent of all the others.

The problems of cheap production of electric energy, of cheap and efficient regulators or arc lamps, of cheap and efficient incandescent lamps, and of economical methods of distributing the electric energy from the electric generators to the lamps having been solved so thoroughly, as has been here indicated, there seemed little yet to be desired. One thing, however, was *not* provided for,

and that was the storage or accumulation of electric energy. The method of

its production by the dynamo requires an absolutely constant activity and a literally sleepless vigilance. If the steam-engine stops or relaxes its speed, the light goes out or becomes dim; or if a belt breaks or slips off, or any part of the dynamo becomes disarranged, the light is gone in an instant and without warning.

This lack of storage capacity was often referred to, and was a serious

reproach to the systems of electric lighting as compared with other methods of illumination. This reproach has been to some degree removed by the labors of M. Camille A. Faure, and of those who have followed up, and to a greater or less extent improved upon, his invention.



Moses G. Farmer.

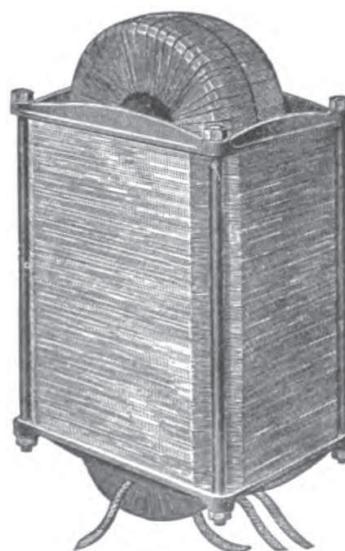


Fig. 24.—Converter or Transformer Used with an Alternating Current.

The "state of the art," as regards the storage of electricity prior to Faure, may be fairly expressed and summa-

rized by a statement of what was done by Gaston Planté* in 1860.

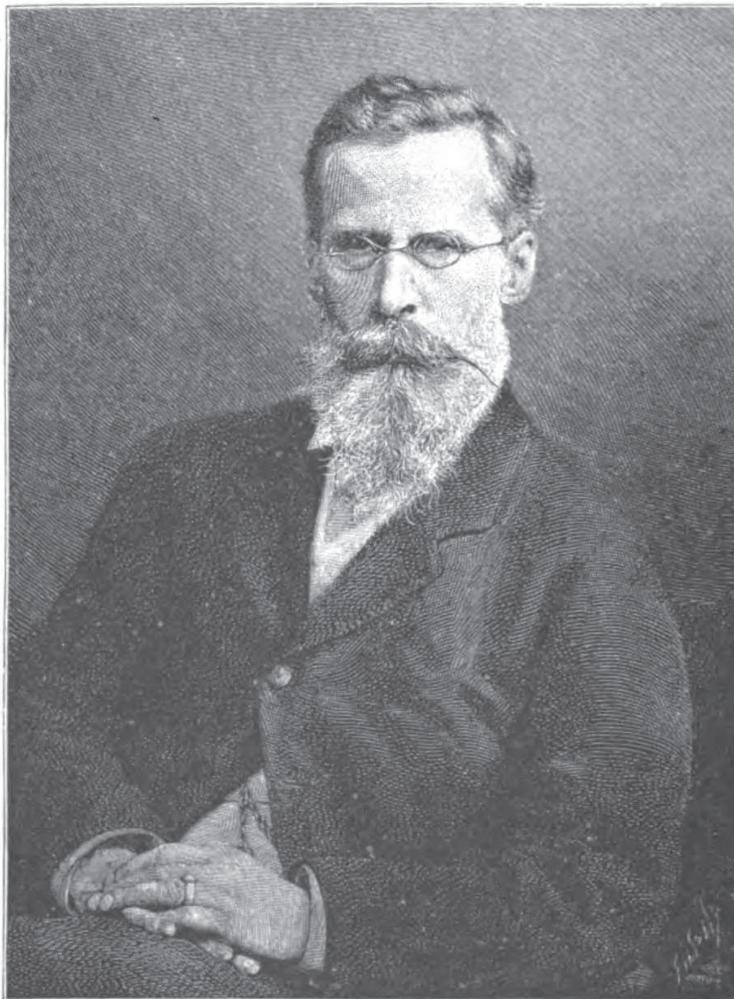
This experimenter took a series of lead plates, immersed in a vessel containing diluted sulphuric acid, and coupled or joined them so that they were united into two groups, each alternate plate constituting one group and the intermediate plates being connected so as to form the other group. He then passed the current from a couple of battery cells, arranged in series, into this structure, by joining the positive pole of the battery to one of these groups and the negative

pole to the other. When the action of the battery had continued for a long time, he found that on removing the battery, he could get an electric current from his two groups of lead plates; this current being opposite in direction to that developed by the battery and capable of yielding a greater flow for a shorter time. The knowledge already accumulated had explained the cause of this, which was as follows: The plates of lead, even before immersion, were coated with a film of oxide, and on immersion, at all events, would soon acquire a coating of sulphate of lead. The passage of the battery current between these plates would convert the oxide or sulphate, on one side into metallic lead, and on the other side into peroxide of lead.

* The news of Planté's death, early in June, is received while this article is in preparation.

Now, metallic lead and peroxide of lead, as was well known, are substances well fitted to develop a galvanic current

in the same way that such a current is developed by an ordinary galvanic battery made with plates, for example, of zinc and copper—the metallic lead taking the place of the zinc. There was, however, one important difference, that whereas in the zinc battery the zinc went into solution, in the lead battery nothing was dissolved, and therefore everything kept its original position, so that the original cycle of action could be indefinitely



Dr. William Crookes, F.R.S.

repeated. Planté, in fact, found that by repeatedly charging his lead plates from an ordinary battery, and discharging them again, and also by reversing the direction of the charging current, the capacity of his lead plates, or the amount of electric energy which they could be made to absorb and redevelop, was greatly increased. Indeed, the maximum capacity secured by this treatment was only reached after about six months of such charging and discharging. The reason of this also was not far to seek. By these repeated actions the surfaces of the leaden plates was corroded or honey-combed, and thus a greater amount of the material was in condition to be converted into metallic lead and peroxide by the battery current, and again to return to

protoxide and sulphate during the discharge.

To obtain any considerable capacity in this way, however, required months of treatment (called "forming"), and a heavy expense for the charging currents, and soon after a battery was fully formed it began to deteriorate by a continuance of this corrosive action, which caused the porous material to scale off and the plates themselves to break up.

Planté's batteries were therefore of no commercial value, on account of their high cost and limited capacity.

Matters stood thus when, in 1881, the world was astonished by the accounts of what Mr. Faure had done in the way of improving this Planté secondary battery, into his electrical accumulator or storage battery.

His plan was a very simple one, but wonderfully effective. He took a quantity of litharge or of red lead, or a mixture of the two, both being oxides of lead, and making this into a paste with dilute sulphuric acid he coated the lead plates with this mixture. When the plates so coated were plunged in dilute sulphuric acid, and an electric current was made to pass between them, the thick coating of oxide-paste on one side began at once to be converted into a spongy mass of metallic lead, and on the other into a like spongy mass of peroxide of lead.



Camille A. Faure—inventor of a storage battery system.

In this way no time was lost in the "forming" process, and the capacity of the plates was very much greater in proportion to their weight than in the most perfectly formed plates of Planté. An improvement on this plan was made by Swan, of England, and others, which consisted in so perforating the plates that the paste of oxide would fill the apertures, like a series of rivets with conical heads, by which it would hold itself in position.

The Faure and Swan patents and some others were taken out in this country by the Electrical Accumulator Co., who established a large factory at Newark, N. J., where these batteries have been made for many years. Figure 26 shows the interior of the

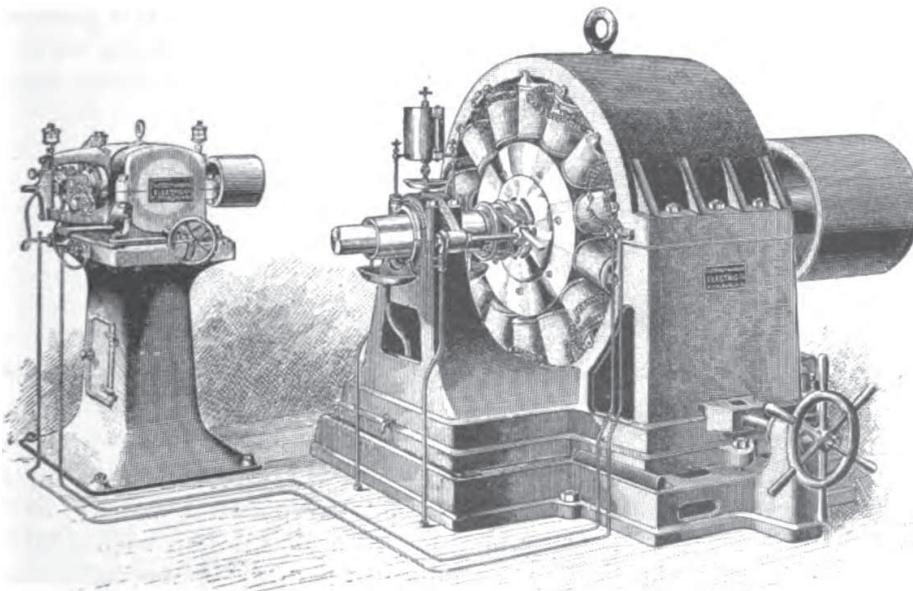


Fig. 25.—An Alternating Current Dynamo and Exciter.

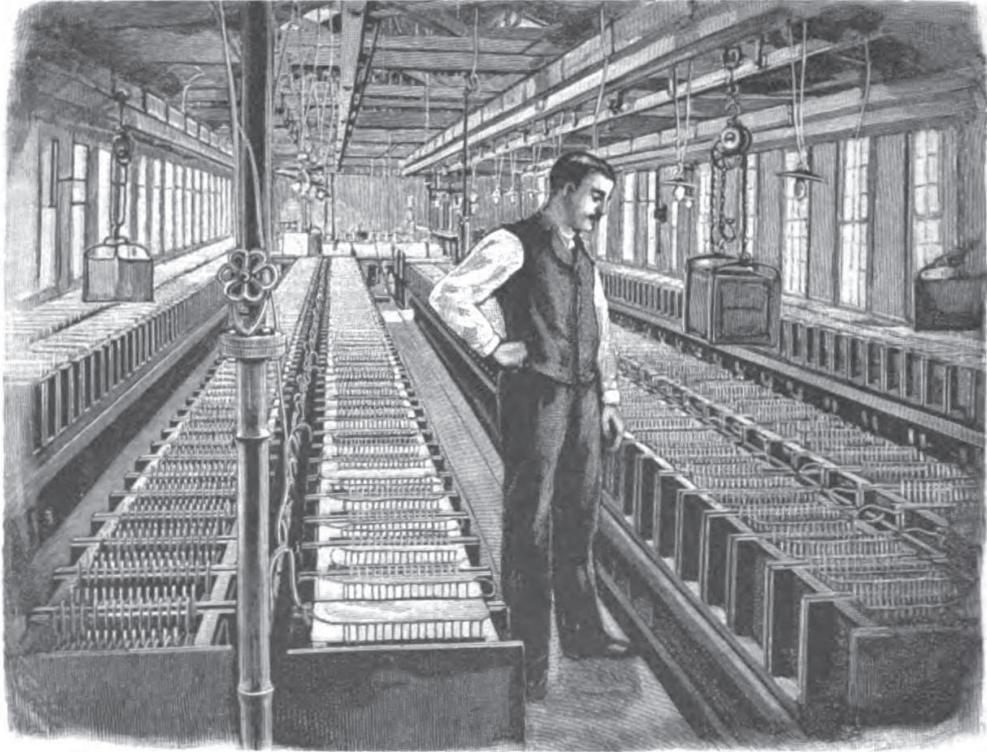


Fig. 26.—Room in the Factory of the Electrical Accumulator Company. The groups of battery plates, such as are shown hanging from the travelling pulleys, are immersed in tanks of dilute acid, and charged by electric currents.

principal work-room in this factory. These batteries only *store electricity* in a metaphorical sense. What they actually do is to transform the active energy of an electric current into the potential chemical energy of separated chemical substances, which are able, by their reunion, to develop again an electric current such as that which produced them. In other words, the charging current each time decomposes the oxides and sulphates of lead formed by the chemical action of the battery during its discharge, so as to develop me-

tallic lead on one set of plates and peroxide on the other. This having been done, this metallic lead by combining with oxygen and sulphuric acid on the one hand, and the peroxide by combining with hydrogen on the other, develop an electric current, as does any ordinary galvanic battery.

As these successive changes can be repeated an indefinite number of times, the effect and appearance are the same as if the electric current had been in fact stored up or accumulated in the storage battery.

A PAGAN INCANTATION.

By Hjalmar Hjorth Boyesen.

HAROLD OLYPHANT'S face was lighted up, by the glow of the fire, with a Rembrandt-like effect. You could see that it was a delicate face; perhaps you might even pronounce it a handsome one, but you might not discover at once, in that rosy illumination, that it was the face of a sick man. Whatever beauty it had was that of intelligence,

refinement, and sensibility. It was not obtrusively handsome; nor obtrusively anything. Such gravely observant blue eyes, such thin, wavy, blond hair, such gently accentuated features, we see every day among professional men with a taste for scholarship; and, if we take the trouble to interpret them at all, we conclude that they indicate inherited cult-