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ON SOME

APPLICATIONS OF ELECTRIC ENERGY

TO

HORTICULTURE AND AGRICULTURE;

AND

A CONTRIBUTION TO THE HISTORY

OF

SECONDARY BATTERIES.

Papers read before Section A of the British Association, at the York Meeting, 1st and 5th September, 1881.

BY

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Mem. Inst. C.E.

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APPLICATIONS OF ELECTRIC ENERGY

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By C. Wm. SIEMENS, D.C.L., LL.D., F.R.S.,

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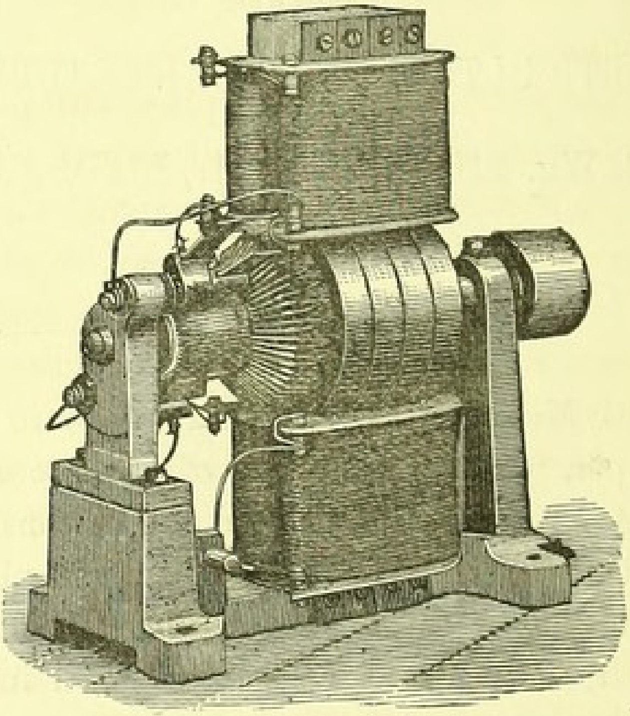
On the 1st of March, 1880, I communicated to the Royal Society a paper, "On the Influence of Electric Light upon Vegetation, &c.," in which I arrived at the conclusion that electric light was capable of producing upon plants effects comparable to those of solar radiation; that chlorophyl was produced by it, and that bloom and fruit rich in aroma and colour could be developed by its aid. My experiments also went to prove that plants do not as a rule require a period of rest during the twenty-four hours of the day, but make increased and vigorous progress if subjected in winter time to solar light during the day and to electric light during the night.

During the whole of last winter I continued my experiments on an enlarged scale, and it is my present purpose to give a short account of these experiments and of some further applications of electric energy to farming operations (including the pumping of water, the sawing of timber, and chaff and root cutting) at various distances not exceeding half a mile from the source of power, giving useful employment during the day-time to the power-producing machinery, and thus reducing indirectly the cost of the light during the night-time. The arrangement consists of a high-pressure steam engine of 6 horse-power nominal, supplied by Messrs. Tangye Brothers, which gives motion to two dynamo machines (Siemens D), fig. 1, connected separately to two electric

Fig. 1.



lamps, each capable of emitting a light of about 5000 candle power. One of these lamps was placed inside a glasshouse of 2318 cubic feet capacity, and the other was suspended at a height of 12 to 14 feet over some sunk greenhouses. The waste steam of the engine was condensed in a heater, whence the greenhouses take their circulating supply of hot water, thus saving the fuel that would otherwise be required to heat the stoves.

The experiments were commenced on the 23rd of October, 1880, and were continued till the 7th of May, 1881. The general plan of operation consisted in lighting the electric lights at first at 6 o'clock, and during the short days at 5 o'clock, every evening except Sunday, continuing their action until dawn. The outside light was protected by a clear glass lantern, while the light inside the house was left naked in the earlier experiments, one of my objects being to ascertain the relative effect of the light under these two conditions. The inside light was placed at one side over the entrance into the house, in front of a metallic reflector, to save the rays that would otherwise be lost to the plants within the house.

The house was planted in the first place with peas, French beans, wheat, barley, and oats, as well as with cauliflowers, strawberries, raspberries, peaches, tomatoes, vines, and a variety of flowering plants, including roses, rhododendrons, and azaleas. All these plants being of a comparatively hardy character, the temperature in this house was maintained as nearly as possible at 60° Fahr.

The early effects observed were anything but satisfactory. While under the influence of the light suspended in the open air over the sunk houses the beneficial effects due to the electric light observed during the previous winter repeated themselves, the plants in the house with the naked electric light soon manifested a withered appearance. Was this result the effect of the naked light, or was it the effect of the chemical products—nitrogenous compounds and carbonic acid—which are produced in the electric arc? Proceeding on the first-named assumption, and with a view of softening the ray of the electric arc, small jets of steam were introduced into the house through tubes, drawing in atmospheric air with the steam, and producing the effect of clouds interposing themselves in an irregular fashion between the light and the plants. This treatment was decidedly beneficial to the plants, although care had to be taken not to increase the amount of moisture thus introduced beyond certain limits. As regards the chemical products, it was thought that these would prove rather beneficial than otherwise in furnishing the very ingredients upon which plant life depends, and, further, that the constant supply of pure carbonic acid resulting from the gradual combustion of the carbon electrodes, might render a diminution in the supply of fresh air possible, and thus lead to economy of fuel.

The plants did not, however, take kindly to these innovations in their mode of life, and it was found necessary to put a lantern of clear glass round the light, for the double purpose of discharging the chemical products of the arc and of interposing an effectual screen between the arc and the plants under its influence. The effect of interposing a mere thin sheet of clear glass between the plants and the source of electric light was most striking. On placing such a sheet of clear glass so as to intercept the rays of the electric light from a portion only of a plant—for instance, a tomato plant—it was observed that in the course of a single night the line of demarcation was most distinctly shown upon the leaves. The portion of the plant under the direct influence of the naked electric light, though at a distance from it of 9 feet to 10 feet, was distinctly shrivelled, whereas that portion under cover of the clear glass continued to show a healthy appearance, and this line of demarcation was distinctly visible on individual leaves. Not only the leaves, but the young stems of the plants, soon showed signs of destruction when exposed to the naked electric light, and these destructive influences were perceptible, though in a less marked degree, at a distance of 20 feet from the source of light.

A question here presents itself that can hardly fail to excite the interest of the physiological botanist. The clear glass does not apparently intercept any of the luminous rays, which cannot therefore be the cause of the destructive action. Professor Stokes has shown, however, in 1853, that the electric arc is particularly rich in highly refrangible invisible rays, and that these are largely absorbed in their passage through clear glass, it therefore appears reasonable to suppose that it is those highly refrangible rays beyond the visible spectrum that work destruction on vegetable cells, thus contrasting with the luminous rays of less refrangibility, which, on the contrary, stimulate their organic action.

Being desirous to follow up this inquiry a little further, I sowed a portion of the ground in the experimental conservatory with mustard and other quick-growing seeds, and divided the field into equal radial portions by means of a framework, excluding diffused light, but admitting light at equal distances from the electric arc. The first section was under the action of the naked light, the second was covered with a pane of clear glass, the third with yellow glass, the fourth with red, and the fifth with blue glass. The relative progress of the plants was noted from day to day, and the differences of effect upon the development of the plants were sufficiently striking to justify the following conclusions:—Under the clear glass the largest amount of and most vigorous growth was induced; the yellow glass came next in order, but the plants, though nearly equal in size, were greatly inferior in colour and thickness of stem to those under the clear glass; the red glass gives rise to lanky growth and yellowish leaf; while the blue glass produces still more lanky growth and sickly leaf. The uncovered compartment showed a stunted growth, with a very dark and partly shrivelled leaf. It should be observed that the electric light was kept on from 5 P.M. till 6 A.M. every night except Sundays during the experiment, which took place in January 1881, but that diffused daylight was not excluded during the intervals; also that circulation of air through the dividing framework was provided for.

These results are confirmatory of those obtained by Dr. J. W. Draper (see 'Scientific Memoirs,' by J. W. Draper, M.D., LL.D., Memoir X.) in his valuable researches on plant cultivation in the solar spectrum in 1843, which led him to the conclusion, in opposition to the then prevailing opinion, that the yellow ray, and not the violet ray, was most efficacious in promoting the decomposition of carbonic acid in the vegetable cell.

Having in consequence of these preliminary inquiries determined to surround the electric arc with a clear glass lantern, more satisfactory results were soon observable. Thus peas which had been sown at the end of October produced a harvest of ripe fruit on the 16th of February, under the influence, with the exception of Sunday nights, of continuous light. Raspberry stalks put into the house on the 16th of December produced ripe fruit on the 1st of March, and strawberry plants planted about the same time produced ripe fruit of excellent flavour and colour on the 14th of February. Vines which broke on the 26th of December produced ripe grapes of stronger flavour than usual on the 10th of March. Wheat, barley, and oats shot up with extraordinary rapidity under the influence of continuous light, but did not arrive at maturity; their growth having been too rapid for their strength, caused them to fall to the ground after having attained the height of about 12 inches.

Seeds of wheat, barley, and oats planted in the open air and grown under the influence of the external electric light produced, however, more satisfactory results; having been sown in rows on the 6th of January, they germinated with difficulty on account of frost and snow on the ground, but developed rapidly when milder weather set in, and showed ripe grain by the end of June, having been aided in their growth by the electric light until the beginning of May. Doubts have been expressed by some botanists whether plants grown and brought to maturity under the influence of continuous light would produce fruit capable of reproduction; and in order to test this question, the peas gathered on the 16th of February from the plants which have been grown under almost continuous light action were replanted on the 18th of February. They vegetated in a few days, showing every appearance of healthy growth. Further evidence on the same question will be obtained by Dr. Gilbert, F.R.S., who has undertaken to experiment upon the wheat, barley, and oats grown as above stated, but still more evidence will probably be required before all doubt on the subject can be allayed.

I am aware that the great weight of the opinion of Dr. Darwin goes in favour of the view that many plants, if not all of them, require diurnal rest for their normal development. In his great work on 'The Movements of Plants' he deals in reality with plant life, as it exists under the alternating influence of solar light and darkness; he investigates with astonishing precision and minuteness their natural movements of circumnutation and nightly or nyctitropic action, but does not extend his inquiries to the conditions resulting from continuous light. He clearly proves that nyctitropic action is instituted to protect the delicate leaf-cells of plants from refrigeration by radiation into space, but it does not follow, I would submit, that this protecting power involves the necessity of the hurtful influence. May it not rather be inferred from Dr. Darwin's investigations that the absence of light during night-time involved a difficulty to plant life that had to be met by special motor organs, which latter would perhaps be gradually dispensed with by plants if exposed to continual light for some years or generations.

It is with great diffidence, and without wishing to generalise, that I feel bound to state as the result of all my experiments, extending now over two winters, that although periodic darkness evidently favours growth in the sense of elongating the stalks of plants, the continuous stimulus of light appears favourable for healthy development at a greatly accelerated pace through all the stages of the annual life of the plant, from the early leaf to the ripened fruit. The latter is superior in size, in aroma, and in colour to that produced by alternating light, and the resulting seeds are not, at any rate, devoid of regerminating power. Further experiments are necessary, I am aware, before it would be safe to generalise, nor does this question of diurnal rest in any way bear upon that of annual or winter rest, which probably most plants, that are not so-called annuals, do require.

The beneficial influence of the electric light has been very manifest upon a banana palm, which at two periods of its existence—viz. during its early growth and at the time of the fruit development—was placed (in February and March of 1880 and 1881) under the night action of one of the electric lights, set behind glass at a distance not exceeding two yards from the plant. The result was a bunch of fruit weighing 75 lb., each banana being of unusual size, and pronounced by competent judges to be unsurpassed in flavour.

Melons also remarkable for size and aromatic flavour have been produced under the influence of continuous light in the early spring of 1880 and 1881, and I am confident that still better results may be realised when the best conditions of temperature and of proximity to the electric light have been thoroughly investigated.

My object hitherto has rather been to ascertain the general conditions necessary to promote growth by the aid of electric light than the production of quantitative results; but I am disposed to think that the time is not far distant when the electric light will be found a valuable adjunct to the means at the disposal of the horticulturist in making him really independent of climate and season, and furnishing him with a power of producing new varieties.

Before electro-horticulture can be entertained as a practical process it would be necessary, however, to prove its cost, and my experiments of last winter have been in part directed towards that object. Where water-power is available the electric light can be produced at an extremely moderate cost, comprising carbon electrodes, and wear and tear of and interest upon apparatus and machinery employed, which experience elsewhere has already shown to amount to 6*d.* per hour for a light of 5000 candles. The personal current attention requisite in that case consists simply in replacing the carbon electrodes every six or eight hours, which can be done without appreciable expense by the under gardener in charge of the fires of the greenhouses.

In my case no natural source of power was available, and a steam engine had to be resorted to. The engine, of 6 nominal horse-power, which I employ to work the two electric lights of 5000 candle power each, consumes 56 lb. of coal per hour (the engine being of the ordinary high-pressure type), which, taken at 20*s.* a ton, would amount to 6*d.*, or to 3*d.* per light of 5000 candles. But against this expenditure has to be placed the saving of fuel effected in suppressing the stoves for heating the greenhouses, the amount of which I have not been able to ascertain accurately, but it may safely be taken at two-thirds of the cost of coal for the engine, thus reducing the cost of the fuel per light to 1*d.* per hour; the total cost per light of 5000 candles will thus amount to 6*d.* plus 1*d.*, equal to 7*d.* per hour.

This calculation would hold good if the electric light and engine power were required during, say, twelve hours per diem, but inasmuch as the light is not required during the day-time, and the firing of the boiler has nevertheless to be kept up in order to supply heat to the greenhouses, it appears that during the day-time an amount of motive power is lost equal to that employed during the night. In order to utilise this power I have devised means of working the dynamo machine also during the day-time, and of transmitting the electric energy thus produced by means of wires to different points of the farm where such operations as chaff cutting, swede slicing, timber sawing, and water pumping have to be performed. These objects are accomplished by means of small dynamo machines, placed at the points were power is required for these various purposes, and which are in metallic connection with the current-generating dynamo machine near the engine. The connecting wires employed consist each of a naked strand of copper wire, supported on wooden poles, or on trees, without the use of insulators, while the return circuit is effected through the park railing or wire fencing of the place, which is connected with both transmitting and working machines, by means of short pieces of connecting wire. In order to ensure the metallic continuity of the wire fencing, care has to be taken wherever there are gates to solder a piece of wire buried below the gate to the wire fencing on either side.

As regards pumping the water, a 3 horse-power steam engine was originally used, working two force-pumps, of 3½ inches diameter, making 36 double strokes per minute. The same pumps are still employed, being now worked by a dynamo machine weighing 4 cwt. When the cisterns at the house, the gardens, and the farm require filling, the pumps are started by simply turning the commutator at the engine station, and in like manner the mechanical operations of the farm already referred to are accomplished by one and the same prime mover.

It would be difficult in this instance to state accurately the percentage of power actually received at the distant station, but in trying the same machines under similar circumstances of resistance with the aid of dynamometers as much as 60 per cent. has been realised.

In conclusion, I have pleasure to state that the working of the electric light and transmission of power for the various operations just named are entirely under the charge of my head gardener, Mr. Buchanan, assisted by the ordinary staff of under gardeners and field labourers, who probably never before heard of the power of electricity. Electric transmission of power may eventually be applied also to thrashing, reaping, and ploughing. These objects are at the present time accomplished to a large extent by means of portable steam engines, a class of engine which has attained a high degree of perfection, but the electric motor presents the great advantage of lightness, its weight per horse-power being only 2 cwt., while the weight of a portable engine with its boiler filled with water may be taken at 15 cwt. per horse-power. Moreover, the portable engine requires a continuous supply of water and fuel, and involves skilled labour in the field, while the electrical engine receives its food through the wire (or a light rail upon which it may be made to move about) from the central station, where power can be produced at a cheaper rate of expenditure for fuel and labour than in the field. The use of secondary batteries may also be resorted to with advantage to store electrical energy when it cannot be utilised. In thus accomplishing the work of a farm from a central power station, considerable savings of plant and labour may be effected, the engine power will be chiefly required for day-work, and its night-work, for the purposes of electro-horticulture, will be a secondary utilisation of the establishment involving little extra expense. At the same time the means are provided of lighting the hall and shrubberies in the most perfect manner, and of producing effects in landscape gardening that are strikingly beautiful.

A CONTRIBUTION

TO THE

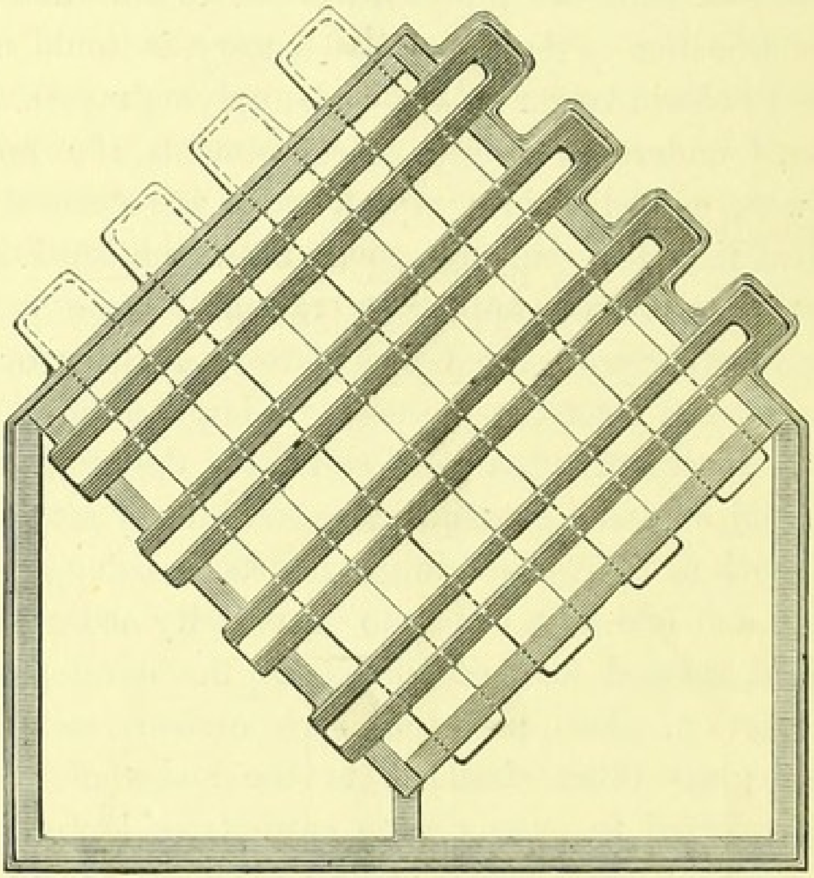
HISTORY OF SECONDARY BATTERIES.

THE surprising effects realised by Faure give particular interest at the present time to the general subject of secondary batteries, and it may not be uninteresting to the members of this Section to put before them an account of some early attempts in this direction with which I have been connected.

The earliest and, as regards its principle of action, the most perfect and admirable form of secondary battery is, I venture to think, that proposed by Sir William Grove as early as 1841. It consisted, as is well known, of two test tubes with a strip of platinised platinum suspended in each from an electrode passing through the tube, the two tubes dipping with their open ends into a trough filled with acidulated water. In passing a galvanic current through such a pair hydrogen is developed in the one tube and oxygen in the other in the well-known proportions, and if the battery be disconnected, and the electrodes be connected by means of a wire, with a galvanometer of high resistance, it will be found that a continuous current is produced, exceeding a Daniell element in electro-motive force, which current continues to flow until the whole of the gases accumulated previously in the tubes by means of the galvanic current have recombined. The current so produced necessarily equals that by which the decomposition was effected, barring only losses by resistance, which, in the case of Grove's gas battery, admit of the utmost reduction. The drawback to any practical use that could be made of the Grove gas battery is that the active surface of triple contact between the metal, the acidulated water, and the gas is exceedingly small, and consequently that the amount of current to be got from such a battery in a given time is also too small for practical use.

In the year 1852 the problem was put to me whether, by some modification of the Grove gas battery, it would not be possible to obtain larger effects, and, applying myself to the question, I undertook a series of experiments, the results of which were embodied in a report, which was deemed satisfactory at the time, but has never been published. Now, however, these results appear to reassume some practical value. Starting with the Grove battery, I endeavoured to obtain a form of electrode presenting a large surface of triple contact. Platinum appeared ill suited for the attainment of such an object, and I consequently directed my attention to carbon, such as is deposited in gas retorts, as being a cheaper material, and one that, owing to its porosity and roughness of surface, seemed well calculated for the development of surface action. Two pieces of such carbon inserted into inverted glass tubes similarly to the strips of platinum already referred to, gave rise to currents of larger quantitative effect, although somewhat inferior in intensity to those produced by the platinum strips. The intensity, however, was greatly increased by subjecting the carbons previous to use to a process of platinisation, or galvanic deposition of pulverulent platinum on their surfaces. The next step was to put carbon into the shape of tubes open at one end and closed at the other. A number of these tubes were inserted in a square box of guttapercha in rows traversing the box alternately in one direction and the other, the box being ultimately placed edge-ways and connected with two chambers covering respectively the open ends of the two series of tubes, fig. 2. By filling these two chambers, the one with oxygen, the other with hydrogen gas, and filling the square box containing the tubes with acidulated water, I succeeded in converting the entire carbon surfaces into surfaces of triple contact of carbon, acidulated water, and oxygen and

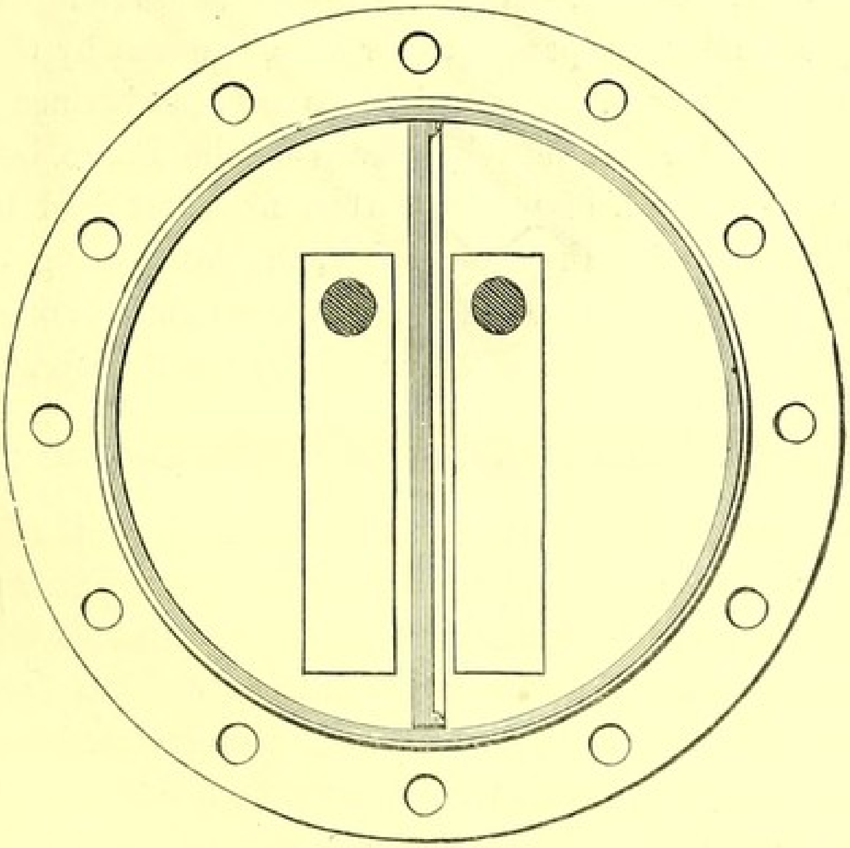
Fig. 2.



hydrogen gas respectively, owing to the porosity of the material of the tubes; and it was only necessary to connect the upper closed and protruding ends of the tubes by means of wire in order to constitute the arrangement a gas battery of considerable power. Nevertheless, the current was insufficient for my purpose, though care had been taken to platinise the tubes.

With a view of increasing the potential of the currents, I directed my attention to the peroxides of metals, and soon found that peroxide of lead was the one giving the greatest promise of results. The tubes were plunged, after drying, into a strong solution of acetate of lead, they were then redried and heated to a dull redness, and again immersed in the lead solution. After repeating this process several times, they were placed in position, and a strong battery current was passed through them, by which the lead was converted into peroxide. The increase of current resulting from this mode of treatment was so remarkable that I was able to effect the decomposition of water by means of one such carbon-lead gas battery by connecting it to a voltameter. No reliable methods of ascertaining the potential of the current were available at that time, but, judging by the results, the power of two volts must have been reached.

Fig. 3.



It was, however, found difficult to obtain a supply of carbon tubes of the right degree of porosity, and I therefore fell back on a simpler form of battery, consisting of two bars or rods of dense carbon, upon each of which a long series of thin laminæ of porous carbon, pierced laterally by holes to admit the carbon rod, were strung, a certain distance between the laminæ being ensured by washers of the same material. Two such bars of carbon with their laminæ were placed side by side in a cylinder of guttapercha with a dividing diaphragm of porous clay, and constituted, when impregnated with peroxide of lead, a powerful galvanic cell, fig. 3. The power of the cell depended more, however, on the power and time of application of the exciting current than upon the gases admitted into the cylinder, showing that it was chiefly due to the presence of the peroxide of lead formed by the exciting current.

These exciting currents produced by a Grove nitric-acid battery were, however, too expensive to render the secondary battery available for practical purposes, whereas by the use of dynamo currents, results might have been obtained comparable to those obtained by means of the Faure battery. By the substitution of porous carbon for sheet lead in the secondary battery of the present day, the intervening layers of felt might be dispensed with, and a large amount of active surface be aggregated in a comparatively small space.

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