pressure of several millimeters of mercury, it happens not only that the blocks of light termed entities by Mr. De La Rue, are formed, but also that these entities travel along the tube from the immediate neighborhood of the positive terminal to a finite distance in the direction of the negative, and then disappear. It would seem not unreasonable to suppose that ball lightning is due to conditions not dissimilar to those of such tubes—namely, to a discharge occurring in the upper regions of the air, at an elevation of, perhaps, 20 miles, more or less, where the pressure is very moderate—that is to say, greater than that under which an auroral-like display could take place, and yet less than that which would give rise to a true spark or ordinary flash of lightning. We have not unfrequently present in regions at moderate elevations, say from 20 to 50 miles, all the conditions necessary for the production of an auroral display. And not only so, but our experiments enable us to determine, at all events approximately, some limits of elevation within which this phenomenon can occur, and thereby to check the very divergent estimates of those who have observed it. Estimates of the altitude at which the auroral discharge takes place have been made from simultaneous observations at different points, and these have ranged up to 50 or 60, and even to 281 miles. But even the lowest of these appears to be improbable. The pressure at which the resistance of air is least is a little less than 0·4 of a millimeter of mercury; and the corresponding elevation is about 38 miles. A vacuum tube measured by hundred thousandths of an atmosphere would correspond to an elevation of a little more than 81 miles. Through a hydrogen vacuum at this pressure Mr. De La Rue failed to obtain a discharge with 11,000 cells; and he adds that, "it may be assumed that at this height the discharge would be considerably less brilliant than at 38 miles, should such occur." It seems to me a well ascertained fact that in high latitudes there are fewer thunderstorms and more auroras than in lower latitudes. This fact points to the conclusion that, after a disturbance, the redistribution of atmospheric electricity is effected by one process or by the other, according to, or rather in consequence of, the meteorological differences between arctic, temperate, and tropical regions.

ELECTRICAL HORTICULTURE.

ON SOME APPLICATIONS OF ELECTRIC ENERGY TO HORTICULTURAL AND AGRICULTURAL PURPOSES.*

By C. Wm. Siemens, D.C.L., LL.D., F.R.S., Memb. Inst. C. E.

On the 1st of March, 1880, I communicated to the Royal Society a paper "On the Influence of Electric Light upon Vegetation, etc.," 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 color could be developed by its aid. My experience also went to prove that plants do not, as a rule, require a period of rest during the 24 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 six horse power nominal, supplied by Messrs Tangye Brothers, which gives motion to two dynamo machines (Siemens D), connected separately to two electric lamps, each capable of emitting a light of about 4,000 candle power. One of these lamps was placed inside a glass house of 2,318 cubic feet capacity, and the other was suspended at a height of 12 feet 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 23d of October, 1880, and were continued till the 7th of May, 1881. The general plan of operations 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 inside 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 effects 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, carbonic acid and nitrogenous compounds, 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 demarkation 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 shriveled, whereas that portion under cover of the clear glass continued to show a healthy appearance, and this line of demarkation 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 these 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 conclusion, viz., under the clear glass the largest amount of and the most vigorous growth was induced; the yellow glass came next in order, but the plants, though nearly equal in size, were greatly inferior in color and thickness of stem to those under the clear glass; the red glass gave 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 shriveled leaf. It should be observed that the electric light was kept on from 5 P.M. to 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* in his valuable researches on plants 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 put in about the same time produced ripe fruit of excellent flavor and color on the 14th of February. Vines which broke on the 26th of December, produced ripe grapes of stronger flavor 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 had 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 Mr. Darwin goes in favor of the view that many plants, if not all of them, require diurnal rest for their normal development, and it is with great diffidence and without wishing to generalize, that I feel bound to state, as the result of all my experiments, extending now over two winters, that although periodic darkness evidently favors growth in the sense of elongating the stalks of plants, the continuous stimulus of light appears favorable 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 color 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 generalize, nor does the 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 pounds, each banana being of unusual size, and pronounced by competent judges to be unsurpassed in flavor. Melons also remarkable for size and aromatic flavor 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 realized where 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 to 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 toward that object. Where water power is available the electric light can be produced at an extremely moderate cost, comprising carbon electrodes, wear and tear of and interest upon apparatus and machinery employed, which experience elsewhere has already shown to amount to 6d. per hour for a light of 5,000 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 six nominal horse power, which I employ to work the two electric lights of 5,000 candle power each, consumes 56 pounds of coal per hour (the engine being of the ordinary high-pressure type), which, taken at 20s. a ton, would amount to 6d., or to 3d. per light of 5,000 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 1d. per hour; the total cost per light of 5,000 candles will thus amount to 6d.+1d.=7d. 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 daytime, 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 daytime an amount of motive power is lost equal to that employed during the night.

In order to utilize this power I have devised means of working the dynamo-machine also during the daytime, 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 where 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 insure 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 three horse power steam engine was originally used, working two force pumps of 3½ inch 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 sixty per cent. has been realized.

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 laborers, who probably never before heard of the power of electricity.

Electric transmission of power may eventually be applied also to thrashing, reaping, and plowing. 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 labor 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 labor than in the field. The use of secondary batteries may also be resorted to with advantage to store electrical energy when it cannot be utilized.

In thus accomplishing the work of a farm from a central power station considerable saving of plant and labor 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 utilization 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.

New Method of Assassination.—A merchant of Santanda, Central America, was lately murdered by a new and ingenious use of dynamite. The charge was placed in the large lock of his store door, with the exploder arranged to be set off by the door key. He was instantly killed on attempting to unlock the door.

* Paper read before Section A, British Association Meeting, York.

* See "Scientific Memoirs," by J. W. Draper, M.D. LL.D., Memoir X.