THE ANGLO-AMERICAN BRUSH CORPORATION'S ELECTRICAL ENGINEERING WORKS.

We recently paid a visit to the factory of the Anglo-American Brush Electric Light Corporation at Lambeth, with a view to the following descriptive account, which we feel sure will be of much interest to our readers. It is scarcely necessary to say that there are very few electrical engineering enterprises in this country which can be compared either in importance or magnitude with that carried on by the Anglo-American Brush Corporation. From a technical and an engineering point of view the operations of this company have been characterised by a long and unbroken series of successes, which reflects the highest possible credit upon the technical staff, whose inventive genius and mechanical skill deserves, as it has indeed received, a wide recognition. From a commercial point of view, the history of the company has been of a chequered and somewhat remarkable character, but the present board of directors, with their able staff, have made great and by no means unsuccessful efforts to establish the company on a sound and permanent basis. Of the extent to which the foundation—and something a good deal more than the foundation—of a career of prosperity has now been laid our readers will be better able to judge after reading this description.

The works in Belvedere-road, Lambeth, cover an area of about 28,000 square feet, and consist of three separate main buildings, each of three floors, besides an iron building containing drawing and works manager's offices. The first of these is devoted to the offices of the board and the staff. The second contains the dynamo and arc lamp factories; to this there is also attached a smithy, an erecting shop, and a building of one story where the greater part of the testing work is carried on. In the third building chiefly women and girls are engaged in the manufacture of incandescence lamps. It would be a mistake to suppose that all the secrets of lamp making have been disclosed during the late proceedings in the Court of Chancery, and for that reason our lips are sealed with regard to the contents of this building. We return, therefore, to the second department, where there is enough of interest to be seen in the various processes of manufacture of the Brush and Victoria dynamos, the Mordey alternator and transformers, the Brush and Brush-Sellon arc lamps, together with motors, projectors, switches and minor fittings innumerable. It is not, however, our present purpose to enter upon any description of these apparatus, which at various times have all been described and illustrated in *The Electrician.** We have now to do chiefly with the machinery and with the organisation by which they are produced.

The heavy tools are placed on the ground floor of one of the three-story buildings already mentioned. Here there is every appliance for dealing with the large masses of iron with which modern electrical machinery is built up, including a powerful traveller, which passes overhead along the whole shop. At one end is a horizontal Galloway engine of about 150 horse-power, which supplies motive power to the whole of this building. Steam is generated in a couple of Galloway boilers, placed in the adjoining boiler house. The principal tools in this shop are large planing machines, shaping machines, some very fine radial drills, and a substantial row of heavy lathes, together with numerous milling machines and other tools; lastly, though not least interesting, we find here some special tools adopted in the factory for building up the iron cores of the modern Brush armature. As our readers are aware, the Pacinotti projections of this armature consist of a very large number of various-sized stampings of sheet iron. By means of special jigs, the apparently difficult operation of building up this structure with the necessary uniformity and rigidity is easily and rapidly accomplished. This shop is lighted all day by electricity. For this purpose a large Brush dynamo, driven by the engine already mentioned, supplies 55 arc lamps in this and other parts of the building. Every lamp has its own switch, and as the current from the same machine is employed in the adjacent lamp factory, and also for some of the testing work, the load on the dynamo is very variable. But by means of the Brush automatic regulator—which, it will be remembered, consists of a variable carbon shunt upon the field—the lamps burn with remarkable steadiness, and the current is maintained almost perfectly constant at 10 amperes. At the time of our visit many tons of wrought and cast iron were being planed and turned up for the construction of dynamos.. Every portion of these dynamos, of whatever size, from 1,500 up to 75,000 watts (which happens to be the largest size at present in progress), is made to template, so that all the parts are interchangeable. The largest possible number of machines of the same type is put through at the same time, so as to economise the work of the factory to the utmost. Unfortunately for incandescent machines, so many different voltages, outputs, and speeds are demanded that it is impossible to carry out this principle to the fullest extent. It is much to be hoped that dynamo makers will shortly see their way to adopt some united course of action in this respect.

Adjoining this shop, and on the same floor, is the erecting room, where the machines are erected and finished ready to be sent out after being thoroughly tested. Here also is a travelling crane driven by high-speed rope gear, by means of which parts of dynamos or the entire machines are rapidly placed in any required position. Amongst a large number of machines here approaching completion we noticed a 40-unit Mordey Alternator of the type recently introduced by the Brush Corporation. This machine has abundantly fulfilled the expectations formed of it, and since its description in this journal the only improvement it has been found desirable to make consists in the substitution of porcelain for wood in the flat sector-shaped cores on which the armature coils are wound. Another interesting machine which attracted our attention was a low-tension Brush dynamo, designed for train lighting on the London, Brighton and South Coast Railway, and also in use on several other lines. These machines are driven by a belt from the axle of the guard's van, and are used in connection with an accumulator of about 25 cells. The machine gives a constant E.M F. over a wide range of speed, so that no regulating device of any kind is needed. The brushes are brought to bear on the commutator, by an automatic arrangement, as soon as the train is running at a speed of 10 miles per hour. Two sets of brushes are fitted, which come into use alternately as the van runs backwards or forwards. On the London, Brighton and South Coast Railway and the Great Northern Railway these machines have been in use for some years. The dynamo and accumulators are placed in a locked compartment of the guard's van, and are found to be quite capable of taking care of themselves upon the journey. Here also we noticed a 15-unit Victoria machine, ordered by the War Office for installation in a certain fortification, for which purpose over 30 similar machines have already been supplied.

Ascending to the first floor, which is the light turnery department, we found some seventy or eighty men engaged, chiefly on lathe work, turning out the transformers, brass fittings, arc lamps, projectors, switches, lamp-holders, &c., &c. The projectors made by the Brush Corporation are largely employed for military and naval purposes, and for navigating the Suez Canal, and doubtless their use will extend in the mercantile marine for navigating other narrow channels at night. An ingenious but simple dioptric electric side light for steamers, of quite recent design, was here undergoing completion. An incandescent lamp is placed in the focus of the lantern, and by means of an electro-magnet whose armature retains a spring-catch, if the lamp burns out, not only is a second lamp immediately lit up, but it at once replaces the first in the focus of the lens. This practically does away with the objection which has hitherto been felt against the electric side lights. Considering the scale upon which the manufacture of the Brush arc lamp is now carried on we need hardly say that every part of the lamp is made to template, but our readers will perhaps

* *See* the following numbers of *The Electrician*:—The Brush dynamo, February 3rd, 1883, p. 271; March 3rd, 1883, p. 379; August 9th, 1884, p. 304, Vol. XV. (Exhibition Record, p. 29); January 7th, 1887, p. 198. The Victoria dynamo, February 16th, 1884, p. 315; January 7th, 1887, p. 199. The Mordey Alternators, May 25th, 1888, p. 81. The Mordey Transformer, February 10th, 1888, p. 346. The Brush Company's portable electric light apparatus, March 4th, 1887, p. 371.

be surprised to learn that so great is the accuracy with which some portions of the apparatus are turned out that an inaccuracy of $\frac{1}{2000}$ inch determines their rejection. In order to secure this extreme nicety the greater part of the work is carried out by specially designed tools, most of which are automatic in their action. We cannot, of course, enter upon any description of these appliances, some of which are extremely beautiful and ingenious, and are the results of a great deal of thought and mechanical skill.

For cutting spur and bevel gearing for the projectors and arc lamps, an automatic tool is used, which was also designed in the works. The iron plates for the Mordey transformer are stamped out on this floor by a power press, attended by a boy, which works at the rate of twenty-five strokes per minute. Another boy then slips the outer and inner stampings alternately through and over the long coil, and the transformer is thus quickly and cheaply put together. A special and somewhat dirty compartment on this floor is occupied by the "buffing" machinery, where the highest polish is given to the work requiring it.

On the third floor are the pattern and the winding shops. The iron cores of Brush and Victoria dynamos which were seen in course of construction on the ground floor here receive their copper coils. Some surprise is often expressed that the coils of high tension dynamos so very seldom give rise to insulation troubles. But while watching the operation of winding a large Brush armature designed for an E.M.F. of 3,000 volts, we perceive that the greatest possible care is taken with every inch of the conductor, and the work is only entrusted to those men who by long experience and skill are thoroughly qualified for the task. In the Victoria armatures, all the larger sizes are wound with copper strip, and the details of the old style of Gramme winding are somewhat departed from. Instead of winding each coil separately and connecting its own end to the commutator—which involves a considerable twist in the wires—the whole core is wound continuously with one length, and the commutator bars are connected by separate wires which are securely fastened to the armature conductors.

Returning to the ground floor, and passing through the erecting shop, we arrive at the testing room. In this room there are racks provided with dark glasses for testing and adjusting arc lamps, and as many as eighty lamps are sometimes tested at the same time upon a single circuit. Motive power is furnished in this room by a couple of 70 horse-power engines and boilers. These engines drive on to a counter-shaft, which is fitted with a claw clutch, so that one or both engines can be used in the same work, or each engine may be used separately on its own half of the counter-shaft, so that various operations demanding different speeds may be carried out at the same time. When large dynamos have to be tested whose output exceeds the joint power of the engines, a portion of the current from the machines is carried to an electro-motor whose pulley is belted back on to the counter-shaft. This modification of Dr. Hopkinson's method of testing is often useful in enabling heavy work to be economically dealt with even when the full power of the engine is not exceeded by that of the dynamos. For power tests for motors, or dynamos, there is provided a transmission dynamometer, designed in the drawing office of the works. The apparatus may also be used as an absorption dynamometer, by attaching a friction brake to one of the pulleys.

In the adjoining courtyard we come to another small engine house, which contains a "Brush" vertical engine, driving a 10-unit Victoria dynamo by means of the Raworth friction gearing. This forms an excellent combination for use where it is desired to supply a small installation with the minimum amount of trouble and attention to the engine, the advantage being that the friction pulley enables the dynamo to be driven at the required speed by means of a comparatively slow running engine of the simplest possible type, one which can be put into the hands of the most ordinary mechanic or engine driver with the certainty that he will find no point in its management beyond his skill. This machine is compounded (as most of the Victoria machines are) exactly to suit the special conditions under which it is working—that is to say, it maintains a constant potential difference at the end of its leads through any variation of load, and also corrects for the 5 per cent. irregularity of speed which is permitted by the governor of the engine. We may add that for ship lighting a very large number of these sets has been supplied, it being found that their simplicity and reliability admirably adapt them for use on long voyages. We were informed that one, supplied to an Orient liner, had just returned into port after a voyage to Australia and back, the total stoppages amounting to only 23 hours, and this due to the ship being in port and not requiring any lights, and not to any mechanical or electrical necessity. It is in this department of ship-lighting that some consolation has been found for the slow development of land work, but now that Lord Thurlow's Bill has become law, and the electrical atmosphere cleared in other respects, we fully anticipate that the electric light will become at least as common on shore as afloat.

At this point we may also refer to the fact that the Brush Corporation has for some time been devoting special attention to the subject of the electrical transmission of energy, and particularly to electric traction. An arrangement has just been concluded by which they will have an opportunity of showing what can be done in this direction upon a large scale. We are unable to go into details at the present moment, but we may say that the scheme contemplates the use of electric traction upon a tramway some 10 miles in length, traversing a very hilly district, with grades and curves of the most severe character. An overhead conductor will be employed, and each motor will be constructed to develop more than 20 horse-power. We have every confidence that the scheme will be brought to a highly successful issue.

As an illustration of the extent to which the machinery and appliances which we have now briefly described is capable of dealing with a very large amount of work in a remarkably short time, we may quote an instance which has quite recently occurred. On the 23rd February an order was received from the Australasian Electric Company for 1,000 Brush arc lamps, 40 Brush dynamos, and 7 Victoria dynamos each of 3,000 20 candle-power lamps capacity, a condition being made that a guarantee should be given that the whole of the plant would be shipped within two months, it being required for the lighting of the Melbourne Exhibition. It so happened that very few Brush lamps were in stock at the moment, owing to demands for the exhibitions at Glasgow, Brussels and elsewhere, and of the Brush machines required only six or seven were then in stock. The order was, however, immediately accepted, and duly carried out within the specified time, and the plant is now at work lighting the Melbourne Centennial Exhibition. It will be evident to all that to obtain such results as these demand not merely adequate mechanical appliances, but also a highly skilled and intelligently organised staff, accompanied by the most careful supervision of detail. It is to the perfection of these minutiæ, and the development of the commercial side of its organisation, that this company has devoted itself during the comparative lull of the past few years.

It would, however, be of little avail for a firm to keep in touch with scientific progress if its organisation were such as to render the economical execution of contracts impracticable, and this is just what the officers of the Brush Corporation have so fully recognised. What may be called the economics of electric engineering find full application in the establishment of the Brush Corporation. This is exemplified by the fact that the volume of the Corporation's transactions is now nearly three times greater than it was five years ago, while the aggregate expenses of management have been reduced by over 40 per cent. This absolute reduction in the expenses of the establishment is the more surprising and creditable when it is considered what a large amount of work has been done which has not been remunerative in the past, and which has been incurred solely with the object of facilitating future operations, and making them more profitable. The records in the possession of the Brush Corporation show that the company has, during the past few years, laid open much new ground in various important branches of the electrical industry, and it naturally looks forward to reaping a good harvest now that the conditions of the business have improved, while the careful analysis of cost of manufacture of a large variety of articles will enable the company to enter into close competition for orders without any uncertainty as to the result. The processes of manufacture are carried out in a systematic and economical manner, and there is much in the methods adopted for registering material and labour which is both instructive and interesting.

What strikes one more especially is the general thrift and absence of extravagance, and this is attributable in a large measure to the *esprit de corps* existing among all the *employés* of the Corporation. We have before us a striking evidence of this in the form of a neat set of rules for the Sick Benefit Club for the workmen, which has been spontaneously formed by the officers acting in concert with the men. We understand that there are close upon 200 regular subscribers to this club, and a reserve fund which has been created entirely by voluntary contributions by the staff and directors amounts to a very respectable figure, and affords a guarantee that in no case of sudden demand upon the funds of the club will there be serious risk of claims not being satisfied.

Another interesting feature is the adoption of the principle of participation in profits, which was sanctioned by the shareholders some little time back, upon the recommendation of the directors. This is not merely a scheme by which a few favoured officers receive commission corresponding to the business done, but is an instance of the true principles of co-operation being put into practice. Every officer who qualifies himself under certain general rules is eligible to be nominated as a participant. The arrangement is that a sum equal to 10 per cent. of the dividends is set aside as a fund to be divided in proportion to salary among the officers from time to time nominated by the Board. In this way the interests of the staff are made identical with those of the proprietors, and the experience of the past affords every reason for satisfaction with the operation of the plan.

The Brush Corporation, it will be seen, has shown much commercial enterprise and initiative, not only in the direction above indicated, in the admission of pupils and apprentices into the factory, or other internal affairs, but also in their efforts to develop the electrical industry in this country.

It is well known that the first practical steps taken with a view towards amending the Electric Lighting Act were initiated by the Brush Corporation, and that the Bill which has just received the Royal assent was successfully piloted through Parliament by the chairman of the Corporation.

Another reform which has received less attention, but which will be of much pecuniary advantage to electrical firms generally, namely, the re-classification of railway freights, was also largely brought about by the efforts of this company.

The introduction of the purchase hire system into this business has also done much to promote the extensive adoption of electric lighting. Firms who have been deterred from expending capital in introducing the new illuminant were enabled to do so by the facilities thus afforded them, and in this way the electric light has been more extensively advertised, and increased demands for it have arisen. We can only express surprise that other firms have been so slow to follow the example thus set them.

It would be impossible for us to dwell upon these and other matters at greater length, but we felt that a sketch of the company's work and resources for undertaking large contracts would not be complete without some notice of the important commercial features of its organisation which have so largely contributed to placing the Corporation in the position it now occupies.

Auckland, N.Z.—The Thomson-Houston Electric Company of Boston appear to be anxious to secure a footing in New Zealand. They are now endeavouring to promote a local company in Auckland, with a capital of £12,000, under the title of the Grey-Brumner Electric Company, to light the wharves and streets of that city.

ON THE THEORY OF LIGHTNING-CONDUCTORS.*

BY PROF. OLIVER J. LODGE, D.SC., LL.D., F.R.S.

That a condenser discharge is oscillatory has been known ever since 1858, when Sir William Thomson's great Paper "On Transient Currents" appeared. Quite recently it has been recognised, first quite explicitly perhaps, by Mr. Heaviside, in *The Electrician* for January, 1885,† that rapidly alternating currents confine themselves to the exterior of a conductor ;‡ and Lord Rayleigh (*Phil. Mag.*, May, 1886) has developed an expression of Maxwell's so as to give the real resistance and inductance of a conductor for any frequency of alternation.

I propose to apply these considerations to the case of a lightning-flash.

A lightning-flash is the discharge of a condenser through its own dielectric, and is more analogous to the bursting or the overflow of a Leyden jar than to any other laboratory phenomenon. The condenser-plates may be two clouds, or they may be a cloud and the earth. The discharge occurs mainly through broken-down air, but a lightning-rod may form a part of its path.

The particular in which lightning transcends ordinary laboratory experiments is difference of potential or length of spark. The quantity of electricity is very moderate, the capacity of the condenser is quite small, but the potential to which it is charged is enormous. Flashes are often seen a mile long, and there is said to be a record of one seven miles long. Allowing 3,000 volts to the millimetre, a mile-long spark means a potential of 16 million electrostatic units.

The capacity of a condenser with plates a square mile in area and a mile apart is roughly about ⅔ of a furlong, or, say, 10^4 centimetres.

The energy of such a condenser charged to such a potential is enormous, being over 10^{20} ergs, and there is no need to assume that so much as a tenth of this is ever dissipated in any one flash.

We may not be far wrong if we guess the capacity emptied by a considerable flash as about 10 metres, or one-thousandth of a microfarad. The total *charged area* is commonly much greater, but it is not all well connected, and it does not discharge all at once.

[The author proceeds to calculate the self-induction of the discharge under certain probable assumptions. We know first that the discharge will be of an oscillatory character§ if the total resistance of the path be not greater than L/S, L being the self-induction coefficient and S the capacity, or, as Mr. Heaviside calls it, the permittance. It is then shown that the critical resistance R_0 below which the discharge is oscillatory may be approximately expressed by

$$R_0 = 120\frac{h}{b}\sqrt{\left(2\log\frac{b}{a} - 1\right)} \text{ ohms} \quad . \quad . \quad . \quad (1)$$

where h is the height of the cloud, b the radius of the area which is discharged by the flash, and a the radius of the channel occupied by the flash. If the path is a metal rod, then a is the sectional area of the rod.]

And inasmuch as in practice h is likely to be much greater than b, and b much greater than a, this is a big resistance, which is not likely to be exceeded by the discharger. For if the line of discharge is a metallic conductor, a is moderate, but then so is R ; whereas if the flash occurs through air, and it is not easy to say what the equivalent R is, then a must be considered extremely minute.

Suppose h to be a mile, b 50 metres, and a a millimetre ; R_0 comes out about 15,000 ohms.

I think we shall be right in saying that this far exceeds any reasonable value that can be attributed to the resistance met with by a disruptive discharge. It is generally supposed, indeed, that

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* Abstracted from the *Philosophical Magazine*, August, 1888.

† See also *Phil. Mag.*, August, 1886, *et seq.*

‡ It is not possible, I think, to give Mr. Heaviside the credit of the original discovery of this theorem (though, doubtless, he discovered it for himself), for it had been virtually anticipated by so many persons. Not counting a wide general mechanical theorem of Sir William Thomson, which may be held to include this as a special case, a great part of it is clearly indicated by Clerk-Maxwell in his Paper in the *Phil. Trans.* for 1865. It then reappears in a more or less developed form in several Papers of Lord Rayleigh, specially perhaps that in the *Phil. Mag.* of May, 1882 ; and it is clearly stated for electrical oscillations in a spherical or cylindrical conductor by Prof. Horace Lamb (*Phil. Trans.*, 1883). There are also several papers by Oberbeck, the references to which I am unable to give just now. It is certain that all these philosophers had the data at command, and could at any time have constructed the completely explicit statement ; but it may be held that none of their *actual* statements were quite so explicit as that of Mr. Heaviside in 1885. It is well known that some ingenious experiments of Prof. Hughes first excited public interest in the matter and quickened the mathematical abstraction into life.

§ The student may be referred to Dr. Fleming's exposition of this subject in *The Electrician* of May 11th, page 6.