mechanical form by the second, leaving out of consideration frictional losses, which latter need not be great considering that a dynamo-machine had only one moving part well balanced, and acted upon along its entire circumference by propelling force. Jacobi had proved, many years ago, that the maximum efficiency of a magneto-electric engine was obtained when

$$\frac{e}{E} = \frac{w}{W} = \frac{1}{2}$$

which law had been generally construed, by Verdet (Theorie Mechanique de la Chaleur) and others, to mean that one-half was the maximum theoretical efficiency obtainable in electric transmission of power, and that one-half of the current must be necessarily wasted or turned into heat. The lecturer could never be reconciled to a law necessitating such a waste of energy, and had maintained, without disputing the accuracy of Jacobi's law, that it had reference really to the condition of maximum work accomplished with a given machine whereas its efficiency must be governed by the equation

$$\frac{e}{E} = \frac{w}{W} = \text{nearly } 1$$

From this it followed that the maximum yield was obtained when two dynamo-machines (of similar construction) rotated nearly at the same speed, but that under these conditions the amount of force transmitted was a minimum. Practically the best condition of working consisted in giving to the primary machine such proportions as to produce a current of the same magnitude, but of 50 per cent. greater electro-motive force than the secondary; by adopting such an arrangement, as much as 50 per cent. of the power imparted to the primary could be practically received from the secondary machine at a distance of several miles. Professor Silvanus Thompson, in his recent Cantor Lectures, had shown an ingenious graphical method of proving these important fundamental laws.

The possibility of transmitting power electrically was so obvious that suggestions to that effect had been frequently made since the days of Volta, by Ritchie, Jacobi, Henry, Page, Hijorth and others; but it was only in recent years that such transmission had been rendered practically feasible.

Just six years ago, when delivering his presidential address to the Iron and Steel Institute, the lecturer had boldly suggested that "time will probably reveal to us effectual means of carrying power to great distances, but I cannot refrain from alluding to one which is, in my opinion, worthy of consideration, namely, the electrical conductor. Suppose water-power to be employed to give motion to a dynamo-electrical machine, a very powerful electrical current will be the result, which may be carried to a great distance, through a large metallic conductor, and then be made to impart motion to electro-magnetic engines, to ignore the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod 3 inches in diameter would be capable of transmitting 1,000 horse-power a distance of say 30 miles, an amount sufficient to supply one quarter of a million candle-power, which would suffice to illuminate a moderately sized town. This suggestion had been much criticised at the time, when it was still thought that electricity was incapable of being massed so as to deal with many horse-power of effect, and the size of conductor he had proposed was also considered wholly inadequate. It would be interesting to test this early calculation by recent experience. Mr. Marcel Deprez had, it is well known, lately succeeded in transmitting as much as 3 H.P. to a distance of 40 kilometres (25 miles) through a pair of ordinary telegraph wires at 4mm diameter. The results so obtained had been carefully noted by Mr. Tresca, and had been communicated a fortnight ago to the French Academy of Science. Taking the relative conductivity of iron wire employed by Deprez, and the 3-inch rod proposed by the lecturer, the amount of power that could be transmitted through the latter would be about 4,000 H.P. But Deprez had employed a motor-dynamo of 2,000 Volts, and was contented with a yield of 32 per cent. only of the power imparted to the primary machine, whereas he had calculated at the time upon an electro-motive force of 500 Volts, and upon a return of at least 40 per cent. of the energy imparted. He had been anxious, indeed, not to overstate the case, and if he were now asked what size of conductor he would recommend, he should say a 3-inch copper rod. In March, 1878, when delivering one of the Science Lectures at Glasgow, he said that a 2-inch rod could be made to accomplish the object proposed, because he had by that time conceived the possibility of employing a current of at least 1,000 Volts. Sir William Thomson had at once accepted these views, and with the conceptive ingenuity peculiar to himself, had gone far beyond him, in showing before the Parliamentary Electric Light Committee of 1879, that through a copper wire of only ½-inch diameter, 21,000 H.P. might be conveyed to a distance of 300 miles with a current of an intensity of 80,000 Volts. The time might come when such a current could be dealt with, having a striking distance of about 2 feet in air, but then, probably, a very practical law enunciated by Sir William Thomson would be infringed. This was to the effect that electricity was conveyed at the cheapest rate through a conductor, the cost of which was such that the annual interest upon the money expended equalled the annual expenditure in producing the power to be conveyed. It appeared that Mr. Deprez had not followed this law in making his recent installations.

Sir William Armstrong was probably first to take practical advantage of these suggestions in lighting his house at Cragside during night time, and working his lathe and saw bench during the day, by power transmitted through a wire from a waterfall nearly a mile distant from his mansion. The lecturer had also accomplished the several objects of pumping water, cutting wood, hay, and swedes, of lighting his house, and of carrying on experiments in electro-horticulture from a common centre of steam power. The results had been most satisfactory; the whole of the management had been in the hands of a gardener and of labourers who were without previous knowledge of electricity, and the only repairs that had been found necessary were one renewal of the commutators, and an occasional change of metallic contact brushes.

An interesting application of electric transmission to cranes, by Dr. Hopkinson, was shown in operation.

Amongst the numerous other applications of the electrical transmission of power, that to electrical railways, first exhibited by Dr Werner Siemens, at the Berlin Exhibition of 1879, had created more than ordinary public attention. In it the current produced by a dynamo-machine, fixed at a convenient station and driven by a steam engine or other motor, was conveyed to a dynamo placed upon the moving car, through a central rail supported upon insulating-blocks of wood, the two working-rails serving to convey the return current. The line was 900 yards long, of 2-feet guage, and the moving car served its purpose of carrying twenty persons through the exhibition each trip. The success of this experiment soon led to the laying of the Lichterfelde line, in which both rails were placed upon insulating sleepers, so that the one served as the conveyance of the current from the power station to the moving car, and the other for completing the return circuit. This line had a guage of 3 feet 3 inches, was was 2,500 yards in length, and was worked by two dynamo-machines, developing an aggregate current of 9,000 Watts, equal to 12 H.P. It had now been in constant operation since the 16th of May, 1881, and had never failed in accomplishing its daily traffic. A line ½ a kilometer in length, but of 4 feet 8½ inch guage, was established by a lecturer at Paris in connection with the Electric Exhibition of 1881. In this case two suspended conductors in the form of hollow tubes with a longitudinal slit were adopted, the contact being made by metallic bolts drawn through these slit tubes, and connected with the dynamo-machine on the moving car by copper ropes passing through the roof. On this line 95,000 passengers were conveyed within the short period of three weeks.

An electric tramway, 6 miles in length, had just been completed, connecting Portrush with Bush Mills, in the north of Ireland, in the installation of which the lecturer was aided by Mr. Traill, as Engineer of the Company, by Mr. Alexander Siemens, and by Dr. E. Hopkinson, representing his firm. In this instance the two rails, 3 feet apart, were not insulated from the ground, but were joined electrically by means of copper staples and formed the return circuit, the current being conveyed to the car through a T iron placed upon short standards, and insulated by means of insulite caps. For the present the power was produced by a steam engine at Portrush, giving motion to a shunt-wound dynamo of 15,000 Watts = 20 H.P., but arrangements were in progress to utilize a waterfall of ample power near Bush Mills, by means of three turbines of 10 H.P., each, now in course of erection. The working-speed of this line was restricted by the Board of Trade to 10 miles an hour, which was readily obtained, although the gradients of the line were decidedly unfavourable, including an incline of 2 miles in length at a gradient of 1 in 38. It was intended to extend the line 6 miles beyond