of St Petersburg, who propelled a boat on the Neva in 1839 by an electromagnetic engine driven by a battery of Grove’s cells. The inefficiency and bulkiness of early electromotors, and the cost of producing electric energy when a galvanic battery was the source, made it impossible for electricity under such conditions as these to compete with other methods of traction. A good battery using zinc as the active metal consumes from 1 to 2 lb of zinc per hour per horse-power developed ; a good steam-engine consumes from 2 to 3 lb of coal in doing the same amount of work, and the cost of zinc is about fifty times that of coal. Hence, notwithstanding modern improvements in electro­motors, the cost of producing mechanical power by means of electricity, when a zinc-consuming battery is the source, is still prohibitive.

The earliest practical electric railway was constructed at the Berlin exhibition of 1879 by Dr Werner Siemens. At one station was a dynamo driven by a steam-engine. The ■current was conducted to the moving car through a special rail placed between the ordinary rails and insulated from the ground by blocks of wood. From this rail it passed through a motor-dynamo on the car, and the ordinary rails completed the circuit. Electrical contact with the ordinary rails was made by the wheels, and with the central rail by a pair of brushes made of copper wire which rubbed against its sides. Spur-wheels were used to connect the motor shaft with the wheels and to effect a suitable reduc­tion of speed. The line was half a mile long and of 2-feet gauge. The motor developed about 3½ horse-power, and was carried by a separate truck, forming a locomotive which drew a car with 20 passengers at a speed of from 4 to 7 miles an hour.

The success of the Berlin experiment was complete, and Messrs Siemens followed it up in 1881 by the construction of a permanent electric tramway, 1½ miles in length, at Lichterfelde, which has now (1887) been in continuous operation for six years. At Lichterfelde the ordinary rails, insulated by wooden sleepers, are the only con­ductors. Where roads cross the line the rails are cut out of circuit, and the current is carried past the gap by underground cables, but switches are provided by which the current can be sent into the insulated sections if re­quired. Each car takes 24 passengers, and runs at a speed of 12 miles an hour. There is no separate locomotive, the motor-dynamo being on the car itself. In 1882 Messrs Siemens constructed an electric tramway in the mines of Zankerode, in Saxony, and built for it a locomotive able to draw 8 tons at a speed of 7½ miles an hour. Overhead conductors were employed, consisting of a pair of insulated ˩-shaped rails fixed to the roof of the workings ; the current was conveyed to and from the locomotive by means of a pair of contact carriages sliding on these conductors, and connected with the car by short flexible cables. A similar line was opened in 1883 at the Hohenzollern col­liery in Upper Silesia.

The same year witnessed the completion of another pioneer undertaking of the first importance, an electric tramway 6 miles long connecting Portrush and Bushmills, in the north of Ireland. Here the insulated conductor is a special rail, carried alongside of the line on wooden posts at a height of 1½ feet above the ground. Contact is made by springs shaped like carriage-springs, which project from one side of the car at both ends, so that the length of the car enables continuous contact to be maintained at cross­roads, where there are gaps in the conducting rail, past which the current is taken by underground cables. The ordinary rails serve as return conductors. The dynamos are driven by turbines at a station nearly a mile distant from the line; they supply a current of 100 amperes with an electromotive force of 250 volts. The motors are placed on passenger cars ; their speed is regulated by means of resistance coils, which the driver of the car switches into the circuit. A similar tramway, 3 miles long, connecting Bessbrook and Newry, was opened in 1885; there also water-power is made use of to drive the generating dynamos. On these lines the train usu­ally consists of a motor car with passengers, followed by two or three goods waggons, and the whole working ex­penses are from 3d. to 4d. per train-mile. The speed is 10 miles an hour.

Amongst early electrical railways Mr Volk’s short line on the beach at Brighton deserves mention. There the rails themselves act as conductors, and are insulated only by wooden sleepers lying on the shingle. The line has been in operation since 1883, with a working expense of only 2d. per car-mile.

Other English and Continental lines will be referred to later; it is, however, in America that electrical traction has hitherto found its widest development. In 1880 Mr Edison ran an electric locomotive on an experimental track near his laboratory at Menlo Park. Soon after the Chicago exhibition of 1883, at which an electric railway was shown in action, a large number of permanent lines were estab­lished. There are now more than twenty electrical tram­ways at work in the United States, under the patents of Edison, Field, Daft, Van Depoele, Sprague, and others. Many more lines are projected, and experiments are in progress on the application of electrical traction on a large scale to the elevated railways of New York.

In all the instances which have been referred to above, electricity is employed as a means of transmitting power as it is wanted from a generating station to the cars, through a conductor extending along the track. Another method of effecting electric traction is to carry a store of energy on the car or on a special locomotive, by using secondary batteries which are charged from time to time at the generating station. This system, which was introduced in England by Mr Reckenzaun and on the Continent by M. Julien, has been successfully employed on several lines.

The system of storage, by means of secondary batteries, has the great advantage over the system of transmission through a con­ductor that it makes each car independent and that it is applicable to ordinary tramway lines. As regards economy of power, we have in the storage system a more complex series of transformation of energy, and therefore a larger number of items of loss. In both systems alike we have a certain loss of energy at the dynamo and at the motor. A secondary battery yields in the electrical form only about 70 per cent. of the energy given to it. In comparing the two methods, the loss which this involves has to be set off against that which occurs in the transmission system in the process of conduc­tion, an item which may be very small in favourable cases, but which becomes large when there are many cars to be driven, when the line is long, and when, owing to the use of an exposed conductor, the electromotive force has to be kept low. Under average con­ditions it is probable that the conductor system has a slight ad­vantage over the other in this respect, but the difference is not material, especially as the cost of power is a comparatively small part of the whole working expense of a line. The difference is slightly affected by the fact that in the storage system there is an extra weight to be carried—namely, the batteries—amounting to about ¼ or 1/5 of the whole weight, and the tractive force required to overcome friction is increased in a corresponding degree. A serious objection to the storage system is the probable cost of renewing batteries. In respect, however, both of durability and of power (in relation to weight) secondary batteries have of late undergone a marked improvement; and it is likely that the storage system will prove the most applicable to tramways in city streets, where conductors on the level of the road are impracticable and overhead conductors would not be permitted.

The existing methods of electrical traction as applied to tramways may be classified as follows:—

I. Motor driven by storage batteries, the batteries and motor being carried either (*a*) in the car itself or (*b*) on a separate truck forming a locomotive. Reckenzaun’s and Julien’s cars, in which the batteries are under the seats, are examples of the first plan, which is in operation on lines at Antwerp, Hamburg, Brussels, and New York. Mr Elieson’s tramway locomotive working in London on the North Metropolitan tramways is an example of the second plan. It is obviously preferable, when space can be found on the car itself for the motor and batteries, to place them there rather than on a separate truck. When a separate locomotive is used it