THE APPLICATION OF ELECTRIC POWER ON TRUNK-LINE RAILWAYS.

By George Forbes.

In accepting the invitation of the Editor to write an article upon electric traction with special reference to its probable extension to trunk lines, it is not my purpose to instruct engineers in the duties of their profession, or to suggest to manufacturers any new directions in which to work, but simply to give those who are financially interested in railways the results of disinterested and careful study and extensive calculation. After casting a retrospective glance over what has been accomplished I will endeavor to indicate the directions in which electric traction is advancing, & to state in broad & general terms the conclusions that I have arrived at as to the cost of works & facility of carrying them out.

In dealing with this subject, it must be borne in mind that circumstances differ. The street railway has developed to a marvellous extent in America, whereas in some European countries it has not found general favor. The cause of this lies largely in the differing circumstances. Countries are also affected in varying degrees by the amount of their suburban traffic, while the introduction of electric traction must also depend on the amount of underground communication in large towns. And other special features arise, such as the facility of obtaining water power for generating electricity, or the difficulty of getting water for the generation of steam.

The first town to be thoroughly equipped with electric street railways was Richmond, Va. (in 1878, on the Sprague system), & from that date their development has been by leaps & bounds. Moreover, it has been continuously in the same direction, &, while competitive systems have at various times come forward & may prevail at some future time, yet the overhead trolley system has so far almost monopolized the field. The consequence is that the general methods of working have remained tolerably uniform, although there have been decided improvements in the details of machinery. In the U. S., where this development has been most rapid, the systematizing of methods has become as complete as in the case of steam railways, & this applies to construction as well as equipment. The figures showing the present state of development are startling to those who have not yet realized them. It is impossible at present to get details of what has been done up to the present moment; the following figures are for 1895, up to which date sufficiently correct estimates have been prepared. At the end of 1895 in the U. S. there were 12,583 miles of electric street railways in operation. The capital invested in electric street railways at the same time was $1,400,000,000; the net gross receipts, $164,250,000; expenses, $113,500,000; number of passengers carried, 3,000,000,000. These figures alone are sufficient to impress anyone accustomed to deal with the development of large industries.

A good many years ago I was in attendance at a meeting of electrical engineers in New York, & after numerous statements had been made about the progress of electric street railways in the United States, I was invited to give information as to what was being done in England. I then confessed that progress in electric tramways on the other side of the Atlantic had been very slow, but I described the principal development of electric traction which had taken place, & characterized it as being on new lines, saying that possibly this single instance might turn out to be almost equal in value to the street railway work which had already been described. I referred to the City & South London Railway, which cannot be looked upon as a tramway in any sense of the word, but is a solid railroad properly constructed, its great distinction from the electric tramways being in the fact that the trains were hauled by electric locomotives. Several of my brother engineers in America grasped this fact at once, & were quite prepared to admit that, in the development of the electric locomotive, of which this was the first step, there might be a future worthy of comparison with what had been done in the propulsion of individual cars on street tramways. No assertion was made that the adoption of the locomotive was opening a new era; the statement was simply that the London experiment was one of great interest to all electrical engineers who wish to have a hand in moulding the future of this department of engineering. Since that date electric locomotives have been used on many railways. The facts are not generally known to the public, & it is not out of place here to refer to special cases.

NIAGARA FALLS PARK AND RIVER RY.

This railway is 12 miles long, of double-track, resembling in every way the standard adopted by the Canadian Pacific Ry. The maximum speed attained is 30 miles an hour. Trolley wires are used. There are 2 motor houses: one at the falls, worked by water-power; the other a small auxiliary station at the Queenstown end of the road, with steam plant. There is 15 minutes headway between cars, the average speed, including stoppages, being 13 miles an hour. Locomotives, in the ordinary sense of the term, are not used, but 22 motor cars supply this service, & are followed by trailers, etc. Some of the cars, when fully loaded with passengers, weigh more than 20 tons. There are 8 regular stopping-places along the line, furnished with platforms.

This railway has been referred to, not because of any special merit which it possesses, but because it is not a street railway, & because it shows a method of working. In fact, reference is made to it partly to draw attention to the extremely objectionable feature of it. When water power was available, it was not good policy to use steam power at a distance of 12 miles. Of course, if the electric pressure were only 500 to 600 volts, there would be a great waste of energy or an enormous expenditure of copper in carrying the current to even that short distance; but there would have been no difficulty in transmitting electrical power at high pressure, transforming it down, & converting it into a continuous current. This would have saved nearly the whole expense of working the steam plant. It is important to give attention to this matter of the use of water power on trunk railways. There has been an absurd hesitation to undertake the transmission of power to great distances. If engineers who have had experience in the transmission of power & in the conversion of alternating into continuous currents would look into this question they would be convinced that where water power is available it is generally economical to transmit electrical power hundreds of miles for working railways. As an example it can be proved that, if the railway companies of Scotland were to combine to work their trunk lines by means of electric motors, the electric current being developed by the water power which exists in that country, then the whole of that service might be carried on without the use of steam locomotives.

Another lesson to be drawn from a careful consideration of the subject is that the waste of coal on steam locomotives is not by any means compensated by the extra cost & loss of power in electrical transmission. Estimates have been prepared which show that not only is the cost of copper prohibitive, but that the efficiency of the electric system renders the consumption of coal with stationary engines about as great as with locomotives. This is certainly not the case. The cost of electric transmission, when properly affected, is not comparable with what it is as calculated on the lines adopted in the past; &, on the other hand, the efficiency of dynamos & motors has not been sufficiently considered in street railway practice in the U.S. A very large part of the success of the Liverpool Overhead Ry. is due to the high efficiency of the electrical machinery.

THE BALTIMORE TUNNEL.

This is a section of the Baltimore & Ohio Railway which it was found desirable to work electrically. The tunnel runs under Baltimore city, & is 7,339 ft. long, 27 ft. wide, & 22 ft. high. There is a steady grade of 0.8% from south to north. The passenger trains are pulled through the tunnel, & the freight trains are pushed the entire distance, steam locomotives in the latter case assisting them in the open. The calculations were for a maximum weight of 500 tons per passenger train, including locomotive, with a speed of 35 miles an hour; for freight trains, a weight of 1,200 tons & a speed of 15 miles an hour. The locomotives have 4 gearless motors, 2 to each truck. All the freight & passenger trains are run through the tunnel by electric locomotives. The following are examples of what has been done on this line: A train weighing 1,125 tons was hauled up a gradient of 42 ft. to a mile by the electric locomotive. At the end of 1 minute the train was moving at 10½ miles an hour. In another case, with a total weight of 1,068 tons, the electric locomotive gave a drawbar pull of 25,000 lbs. as measured by a dynanometer; with a speed of 11⅛ miles per hour, & a train of 1,600 tons, the drawbar pull was 45,000 lbs. On another occasion a train weighing 1,900 tons was started in the tunnel, & the maximum drawbar pull was 60,000 lbs. at 12 miles an hour. This case is cited as showing that electric locomotives are capable of doing all that can be done by steam locomotives. The first locomotive has been running steadily since Aug. 4, 1895.

NANTASKET BEACH ELECTRIC RAILWAY.

The electric railway is a branch of the New York, New Haven & Hartford Ry. It is 7 miles long, with some sharp curves, & there is a gradient of 34 ft. to the mile. There are stops about every quarter of a mile. Motor cars are used with trailers, with a drawbar pull amounting in some cases to 8,000 lbs. Further extensions of this railway in the same direction have been made, with the use of a third rail between the ordinary rails as a conductor for electricity. These extensions are from New Britain to Berlin & from Hartford to New Britain. There are 22 grade crossings, at each of which the third rail is replaced by underground cable. This electric railway is cited as the first instance of the supplanting of steam by electricity on a standard American railway.

LIVERPOOL OVERHEAD RAILWAY.

The length of this line is 6¾ miles, of standard gauge. A third-rail conductor is laid between the ordinary rails. There are 2 motors on each train, 1 at each end, each motor being of 40-horse power. This line was designed with the utmost care. The machinery was not taken from stock patterns, but specially designed to give high efficiency, the benefits from which have been thoroughly appreciated. This line deserves consideration as comparable with the one next to be considered, & as illustrating the advantage of applying motive power to the wheels of the train instead of to a locomotive, wherever possible. It can be shown that the greatest advantages are attained when the electric power is applied to every axle of the train, & this is the direction in which engineers 10 or 15 years ago expected that electric traction on railways might be developed. The inconveniences & expense, however, of replacing the whole of the old