rolling stock by new, & the unsuitability of the system generally to existing lines as worked by steam, have rendered the use of a locomotive of the utmost importance in all applications to railroads where steam has been used.

CITY AND SOUTH LONDON ELECTRIC RAILWAY.

This railway has 3¼ miles of double line. It is driven by electric locomotives, each of which has 2 motors, giving in all 100 horse-power. A third rail is used for the electric conductor. This was the first electric railway introduced in London, & its operation has been studied by engineers & railroad men with great interest.

The remarkable economy of operating the Liverpool Overhead Ry. has surprised all those whose experience in electrical traction has been limited to street railways. The reasons for this excellent performance lie partly no doubt in the cheapness of fuel & of labor, but far more in the good quality of the track & the care taken in designing & supplying efficient machinery.

The examples chosen must not be looked upon as an exhaustive list of cases where electric traction has been successful in competition with steam. They are typical cases, each illustrating some point which it is desirable for the public interested to have knowledge of. There has been no example of a long trunk line worked electrically, but, from the examples already given, it can be taken as thoroughly established that this is not due in any way to want of capability in the electric locomotive. The reason why trunk lines have not been worked by electricity is that, rightly or wrongly, those who have had the matter to decide have considered the cost of transmitting electric power too great. There would be nothing experimental in carrying out such a work, & the estimates of cost can be made out with the greatest accuracy. In an article like the present, intended for business men, as well as technical experts, such estimates should not be introduced ; but it is necessary to draw attention to the fact that, in a great deal that has been written on the subject, it has been assumed that the electric pressure upon the feeders is only some 600 or 700 volts. Without assuming to advance any new idea upon the subject, I may cite as indisputable the fact that the feeders may be supplied with current at 10,000 volts or more, which may be in the form of continuous current, but which is more manageable as an alternating current. At different stations along the line it would be reduced in pressure by means of transformers, & converted into continuous current by means of a commutating machine. It is in this point that machinery for working the proposed system has been the least developed. The commutating machine now on the market, introduced first by Mr. Shuckert in Germany, & applied in various factories at the Niagara works, is usually called a rotary transformer. It does its work admirably, but it is expensive, cumbrous & requires continual attention. This last fact renders it impossible to lay such machines along a trunk line at distances of a few miles. But I have prepared the designs for a transforming & commuting machine free from all the defects referred to, which can be manufactured at small cost. For years I have impressed upon manufacturers the desirability of such a machine, & it is only a matter of time when they will find that it is to their own interest to provide it. Viewed in the light of the adoption of very high electric pressures, the cost of transmitting the power electrically is not at all the serious matter that it has been considered, but, in spite of this fact, human inertia may prevent rapid progress in the direction of working trunk lines electrically. After wide experience & a laborious study of the whole question, my opinion is that, as a rule, electric locomotives, with the power developed by steam, would, if the work were carried out on proper lines, be cheaper than the steam railroad up to a distance of between 40 & 50 miles from the power station. If water power were available for generating the electricity, the distance at which steam power would begin to be the cheaper on a busy line is several hundred miles. These statements are the result of calculations with coal at $1.50 a ton. This economy arises from the well-known fact that in the best trial tests of locomotives 5 lbs. of coal are required for the horse-power hour, & from the fact equally well known, that so good a result is rarely attained, in nearly every case the consumption of coal being several times as much as that indicated. These conclusions, however, do not give much encouragement for the substitution of electricity for steam, except in special cases. A time may come when special railroads will be built over long distances to be worked electrically, & in that case there are advantages of a totally different character which will favor electricity, depending upon the fact that the locomotive will be abolished & power applied to every axle of the train.

In 1881, in the course of some correspondence from the Paris Electrical Exhibition to the London Times, I drew attention to the possibilities of electric traction on railways. That article was really the summary of a lecture which had been delivered before Anderson's College, in Glasgow, in 1879. In that article I drew attention to the remark made by Captain (now Sir) Douglas Galton, in the concluding paragraph of his report on experiments conducted by himself & Mr. Westinghouse on the air-brake when used with trains going at high speed. In that report Sir Douglas Galton said : "The advantage which thus evidently ensues from utilizing the adhesion of every wheel of a train suggests the further consideration as to whether it would not be a more scientific arrangement, as well as more economical in regard to the permanent way of railways, to utilize the adhesion of every wheel of a train for causing a train to move forward, instead of depending for the moving force upon the adhesion of one heavy vehicle alone—namely, the locomotive." I then pointed out that this fertile suggestion might be carried out by the employment of electric motors on the wheels or axles of each carriage. I further pointed out that such a system would result in a saving of wear & tear of the permanent way, a diminution of shocks & injuries to passengers & goods, & a facility in going around curves. Besides this, the wheels would not slip when going up steep inclines, &, in starting from a station, speed could be obtained in a small fraction of the time now required. As a secondary advantage, the construction of the permanent way would be very much less costly. This is undoubtedly the way in which an electric railway should be worked. It was supported by able engineers, & many of us can remember the admirable writings of Mr. Sprague upon the subject, in which he made it abundantly clear that such a system of traction would be beneficial in every way.

Although the method of working just described is ideal, it can be applied only to a trunk line about to be constructed in total independence of existing steam railroads. If anything is to be done on a large scale with trunk railways, it must be by means of locomotives, & the advantages of an electrical system using locomotives are not nearly so great as in those cases in which electricity is applied to every axle of the train. It is owing to the great importance of these considerations that so much money has been spent on, & attention devoted to, the Heilmann locomotive, in which steam is generated on the train for the purpose of creating an electric current to be applied to motors driving all the wheels of the train. Without saying that this complicated system has proved a success, still there is no doubt that those who have invested capital in the experiment have been satisfied that there is enough advantage in this method of propulsion to justify the carrying on of extensive experiments. The whole of the advantage lies in the fact that power is delivered to every wheel of the train, no advantage being gained from the cheaper use of fuel at a stationary engine.

The examples given, while they indisputably show that electric traction, under certain conditions, is well able to compete with steam, are not sufficient to overcome the natural conservatism which holds to existing methods.

Hitherto reference has been made chiefly to the great trunk lines, but special attention must be given to the conditions of suburban traffic. Most of us remember, not so very many years ago, the surprise with which we learned that several short steam railways were having to give way to the electric tramways which had been started. In later years it is the great steam railway companies which have been noticing with alarm that their receipts are being largely diminished by the competition with electric tramways for suburban traffic. That this competition is so successful is due to several causes. One is that the natural roads & streets have been employed for the purpose, so that little or no purchase of land has been necessary. But, perhaps, the most important cause is the rapid succession of independent cars which becomes possible under this system, affording a great convenience to the travelling public, & enabling them in many cases to start from their places of business in town & be landed at the doors of their houses in the suburbs. These are very serious matters from the point of view of the railway companies, because many of the companies are really dependent for their profits upon suburban traffic, &, if this source of revenue is to be taken away, it will seriously endanger the financial position of the railroads as a whole. These matters have become more evident in the U.S. than in any other country.

At the first glance it seems almost impossible for a railway with fixed railway stations to be able to compete in convenience with an electric tramway, passing along the ordinary thoroughfares, picking up & letting down passengers at all parts of the journey. Most persons, however, who know the conditions of traffic in the neighborhood of large towns in the U. S., will probably agree that this matter of convenience does not apply to every householder, & that householders wants, so far as this point is concerned, would be fully met if the stopping places on the trunk line were in direct communication with the local street railways of the place.

A great deal has been written upon the comparative cost of working the suburban traffic upon trunk lines by steam & electricity. The question of a slight difference in cost one way or the other is of far less importance in the matter than the question whether it is possible for the suburban lines to run independent trains at a shorter headway—a system practically impossible with steam locomotives, but advantageously workable from a central electric power station. If the public felt certain of being able to find a car or train ready to take them along the well-laid trunk railroads to their destination, so that they would never have to wait more than a few minutes at the station, there is no doubt that a great preference would be shown for travelling along these well-equipped lines. This appears to be the only solution that affords the railway companies a hope of escape from the competition which they now have to face.

It must not be forgotten that there are some cases where electric traction is perfectly certain to take the place of steam, but, as a rule, there are special cases. Such super-