first really noteworthy road was that constructed in 1883 at the Giant’s Causeway at Portrush, in the north of Ireland. This line was 6 m. long, and the power was obtained from turbine wheels actuated by a cascade on the river Rush. The method of supply was, curiously enough, the third rail.

In 1883 invention in electric railways seems to have taken a decided advance in America. It was in this year that the conflicting interests of Edison and S. D. Field were consolidated; and at the same time C. J. van Depoele and Leo Daft began their experimental work, which later resulted in numerous commercial railways. Next year E. H. Bentley and Walter Knight opened to the public in Cleveland, Ohio, U.S.A., a railway operated by an open-slot conduit, and for the first time worked in competition with horse traction on regular street railway lines. For the next two years much experimental work was done, but it may be said with fairness that the first of the thoroughly modern systems, in which a large railway was equipped and operated under service conditions by electricity, was the fine built in Richmond, Virginia, U.S.A., by Frank J. Sprague in 1887. This railway had 13 m. of track, and started with an equipment of forty cars. It has been in continuous and successful commercial operation ever since. The original Richmond system was in all its essential particulars the overhead trolley system now in use. Many improvements have been made in the construction of the motors, the controllers, the trolleys and the various details of car equipment and overhead construction, but the broad principles have not been departed from. The success of the Richmond line called the attention of tramway managers to the advantages of electricity as a motive power, and its substitution for other systems progressed with astonishing rapidity.

The pioneer application of electricity to heavy electric traction was that of the Baltimore & Ohio railway tunnel at Baltimore, Md., U.S.A., and the system was put into operation in 1895. This tunnel is about 1½ m. in length and passes under the city of Baltimore. Its route made the expense of ventilation prohibitive, and the smoke and gases from the locomotives made the use of the tunnel impossible without ventilation. The management therefore decided to attempt the use of electric locomotives to haul the trains through, despite the fact that there existed no prior applications of heavy electric motors for even far lighter service than that demanded by the conditions, namely, the propulsion of trains of over 2000 tons up a grade of 42 ft. to the mile. The engineering work and designing of the locomotives were undertaken by Dr Louis Duncan. The locomotives weigh 96 tons and have worked succesfully since they were first put into commission. The electric service has been extended 6 m. from the mouth of the tunnel, making a total haul of nearly 8 m. for these locomotives. In 1907 many heavy electric locomotives using continuous current were constructed for the New York Central & Hudson River Railroad Company to operate a distance of about 5 m. from the New York terminus, and others for practically the same service, hut using single-phase alternating currents, were put in for the New York, New Haven & Hartford Railroad Company.

It has been fully demonstrated that electricity is superior to its competitors—horses and moving cables—for tramway work. It is cheaper and more flexible. The relative cost of operation varies with the local conditions, but a fair average estimate would be that cable lines cost 25% more to operate than electric, and horse lines 100% more. The increased speed of the electric cars and the comfort rendered possible by larger vehicles always increase the receipts when horse traction is replaced by electric, while the latter, as compared with the cable, allows better and easier control of the car and a much greater possible speed variation. The installation of an overhead electric line costs less than a cable system, though the expense of a conduit electric line is about the same. By the extension of the urban tramway systems into the suburbs and the construc­tion of inter-urban lines, electricity has come into competition with steam. Here the conditions are different. For ordinary suburban service, the electric cars, running through the city streets and on the highways, cannot, in speed, compete with steam trains operated on private rights of way. The fact that they run more frequently and can take up passengers anywhere along the line gives them an advantage, and within limited distances they have taken a large proportion of suburban traffic from steam railways. For long-distance service, in order to compete with steam a speed much greater than that used on ordinary tram-fines must be adopted, while owing to the time spent on the car more attention must be paid to the comfort of the passenger. Speed and comfort being equal, the great advantage of electricity is that, when it is used, the most economical way of transporting a given number of passengers between two points is in a larger number of small trains; with steam the converse is true. A frequent service is a great attraction to passengers.

For freight service, especially on railways having heavy grades, electricity also possesses many advantages, due principally to the peculiarity of the electric locomotive, which admits of its maintaining its tractive effort or so-called “ draw-bar pull ” when running at relatively high speeds. This steam loco­motives cannot do. Thus a steam locomotive weighing 100 tons may exert a draw-bar pull of say 45,000 lb at a speed of 6 m. per hour, while at 15 m. per hour the continuous draw-bar pull will not exceed about 25,000 lb. On the other hand, an electric locomotive weighing 75 tons and having a tractive effort of 34,000 lb at 6 m. per hour will exert a pull of about 27,000 lb, at 25 m. per hour. From this it is clear that an electric locomo­tive may pull a heavier train at a fair speed than can a larger steam locomotive. This admits of more rapid movement of freight trains, and thus decreases the hauling cost. Another advantage the electric system has for freight service is the ability to couple several light locomotives in tandem, all under the control of one driver, and thus pull at a high speed larger trains than may now be drawn by steam locomotives of weights commercially admissible. Also, these lighter motors distribute the weight over the track instead of having it concentrated on a few wheels, and the heavy pounding due to the latter condition is obviated and the maintenance of the track and bridges reduced. Other savings arise from diminished fuel consumption, elimination of water and coal stations with their attendants, and greatly reduced repairs on motive power. The chief disadvantage is the stoppage of all trains on a section if the source of current supply should fail. With proper precautions in design and construction this should be a remote possibility, and since electric rail haulage, in any form attempted up to the present, has shown a reduced cost for a given service as compared with steam traction, it is not improbable that the future will witness great activity in the change from steam to electricity for long-distance railway work.

Systems of electric traction may be divided broadly into two classes, the one employing continuous, the other alternating currents to drive the motors. Both of these classes may be further divided with reference to the conducting system employed between the source of current and the motor. The system may also be divided according to operative units into three classes—the single car, the train pulled by one or more directly controlled locomotives or motor cars, and the train operated by two or more motor cars under a common secondary control. This last is called the “ multiple unit system.”

*Continuous-Current Systems.*—The applications of continuous current to electric tractioιr comprise six principal varieties, with numerous modifications and combinations. In all of them the motors are operated under a constant, or approximately constant, potential difference. The system in which cars were connected in series by automatic switches, in limited use in the United States in 1888 and 1889, has now disappeared, and the parallel system of connexion, in which the cars are bridged across between the two conductors of a parallel system, maintained at a substantially constant voltage, has become practically universal.

The overhead conductor and track-return construction is the standard for street railway work in most of the cities where electric traction is employed, though there are some notable exceptions. In its present development the system may be said to have grown out of the work of Sprague in Richmond in 1887. Over the track is suspended a bare