Batavia, Java, for some years. The motive power was obtained from water heated under pressure to a very high temperature in stationary boilers and carried in a reservoir on the engine, where it gave off steam as the pressure and temperature\* were reduced. Two tons of water heated to give a steam-pressure of 250 lb to the square inch served for a run of 8 or 10 m., more than 9/10 of the water and a pressure of 20 to 25 lb above the atmosphere being left on returning to the boiler station. Large boiler-power was required to reheat the engine reservoirs quickly, and this could be afforded for only a few engines; hut, when worked on a sufficient scale, the tireless engines were claimed to be economical, the economy resulting from the generation of the steam in large stationary boilers.

*Compressed Air.—*Compressed air as a motive power offers the advantage of having neither steam nor the products of combustion to be got rid of. In W. D. Scott Moncrieff’s engine, which was tried on the Vale of Clyde tramways in 1876, air was compressed to 310 lb per sq. in., and expanded in the cylinders from a uniform working pressure to that of the atmosphere. There is a considerable loss of heat during the expansion of the air which is attended with a serious loss of pressure, and in L. Mekarski’s system, which was in use for the propulsion of tramcars at Nantes for a number of years, the loss of pressure was considerably lessened by heating the air during expansion. The air, at a pressure of 426 lb per sq. in., was stored in cylindrical reservoirs beneath the car, and before use was passed through a vessel three-quarters full of water heated to 300° F., by which it was heated and mixed with steam. The heat of the latter was absorbed by the air during its expansion, first to a working pressure which could be regulated by the driver, and then to atmospheric pressure in the cylinders. At Nantes the average cost for three years of propelling a car holding thirty- four persons was about 6d. per mile. Owing to the heat losses in compressing the air, and other considerable losses incident to its use, the compressed-air systems of traction have been found inefficient and have nearly all been replaced by the more flexible and efficient electric motor.

*Cable Traction.—*Moving steel cables, propelled by steam engines, have been used for traction. The street railway cars running from New York to Brooklyn, over the Brooklyn Bridge, were for many years propelled by a cable to or from which the cars could be attached or detached at will, and, though electric motors are now used on this line, the cables are still kept in place as a reserve in case of breakdown of the electrical system, and are used whenever an accident to the electrical plant occurs. Before the advent of electric traction, the tramways using cable propulsion were numerous and of great size, as at San Francisco, Chicago, Washington, Baltimore, Philadelphia and New York in America, at Highgate Hill (London) and Edinburgh in the United Kingdom, and at Melbourne in Australia. The Glasgow Subway is so equipped.

In the usual form, the motive power is transmitted from a station- ary engine by a rope of steel wire running always in one direction, up one track and down the other, in a tube midway between the rails, on pulleys (fig. 4) which are arranged so as to suit curves and changes of gradient as well as straight and level lines. Over the rope is a slot ¾ in. wide, in which travels a flat arm of steel connecting the dummy car with the gripper (fig. 5) which grasps the cable. the flat arm is in three pieces, the two outer ones constituting a frame which carries the lower jaw of the gripper, with grooved rollers at each end of it, over which the cable runs when the gripper is not in action. The upper jaw is carried by the middle piece which slides within the outer frame, and can be depressed by a lever or screw, pressing the cable first on the rollers and then on the lower jaw until it is firmly held. The speed of the cable, which is generally 8 to 10 m. an hour, is thus imparted to the car gradually and without jerk. The arrangements for passing the pulleys, for changing the dummy and cars from one line to the other at the end of the road, for keeping the cable uniformly taut, and for crossings and junctions with other lines, are of considerable ingenuity. When the cars are cast off from the cable they must be stopped by hand brakes which, on steep gradients especially, must be of great power.

*Gasolene Engine Traction.—*Explosive engines using gasolene (petrol) have been used for motive power, and this is the principal form employed in the road motor car. Certain railways in Eng- land and America have experimented with cars having a gasolene engine placed in one end to propel the car, the greater part of which is left clear for the accommodation of passengers. These cars are intended for short runs and may in effect be classed as belonging to extended tramway service. They have yielded en­couraging results.

*Electric Traction.—* Electric traction, as treated here, will refer to the operation of vehicles for the transportation of passengers and goods upon tracks, as distin- guished from what are known as telpherage systems on the one hand (see Conveyors), and automobiles intended to run on common roads on the other (see Motor Vehicles).

Possibly the first elec- tric motor was that made by the Abbé Salvatore dal Negro in Italy in 1830. As early as 1835, Thomas Daven­port, a blacksmith of Brandon, Vermont, U.S.A., constructed and exhibited an automobile electric car, operated by batteries carried upon it. Robert Davidson, of Aberdeen, Scotland, began experimenting about 1838 with the electric motor as a means of traction, and constructed a very powerful engine, weighing five tons and carrying a battery of forty cells. This locomotive made several successful trips on Scottish railways, but was finally wrecked by jealous employés of the railway whiIe it was lying in the car sheds at Perth. In 1840 a pro­visional patent was granted in England to Henry Pinkus, which described a method of supplying electric energy to a moving train from fixed conductors. A little later, in 1845, French and Austrian patents granted to Major Alexander Bessolo described practically what is to-day the third-rail system. In 1847 Professor Moses G. Farmer, of Maine, U.S.A., built a model locomotive operated by electricity, which he exhibited at Dover, New Hampshire, and later at other places in New England. Shortly afterwards Professor C. G. Page, of the Smithsonian Institution in Washington, constructed an electric railway motor, which made a trip on the 29th of April 185r, from Washington, D.C., to Bladensburg, Maryland, over the Baltimore & Ohio railway. This machine carried 100 Grove’s cells, and attained speeds as high as 19 m. an hour. Perhaps the beginning of modern electric traction may be said to date from 1879, when the firm of Siemens & Halske put in operation the first electric railway at the Industrial Exposition in Berlin. In America it was not until a year later that real work began and T. A. Edison built an experimcntal line near his laboratory in Menlo Park, New Jersey. In 1880 a locomotive driven by accumulators was constructed and operated at a linen-bleaching establishment at Breuil-en-Auge, in France; and in 1881 a similar car was worked upon the Vincennes tramway line. On the 12th of May 1881 the first commercial electric railway for regular service was opened for operations at Lichterfelde, in Germany. The