clearance between the flange and the groove is necessarily small, as the former must have sufficient strength, and the latter must be narrow. The least inaccuracy of gauge, there­fore, causes extra friction, which is greatly increased on curves. By removing the flanges from two of the four wheels of the tramway car H. E. Tresca (1814-1885) found that the resistance was reduced from 1/100 to 1/148 of the load. The resistance due to gravity is of course not lessened on a tramway; and if 1/100 of the load be the tractive force required on the level, twice as much, or 1/50 of the load, will be required on a gradient of 1 in 100 and three times as much on a gradient of 1 in 50. To start a tramcar, four or five times as great a pull is required as will keep it in motion afterwards, and the constant starting after stoppages, especially on inclines, is destructive to horses. Horses employed on tramways are worked only a few hours a day, a day’s work being a journey of 10 or 12 m., and much less on steep gradients. In London a tramcar horse bought at the age of five years had to be sold at a low price after about four years’ work. On the Edinburgh tramways, in consequence of steep gradients, the horses lasted a less time, and had to be constantly shifted from steep to easier gradients. The cost of traction by horses is generally 6d. or 7d. per mile for two horses, and more when the gradients are steep (see also Tramway) .

*Steam Traction.—*The most universally used form of motive power is the steam engine, which has been constructed to work on ordinary roads, on tramways and on railways. The road or traction engine comprises a boiler mounted on wheels, and a steam engine usually placed on top of the boiler. The front axle is pivoted so that it may be moved by means of a steering wheel geared to it, and the rear wheels are geared to the engine. The wheel rims are made wide to prevent them from sinking in loose earth or muddy roads. The whole arrangement is similar to the ordinary wheeled portable boiler and engine with the addition of the steering wheel and a gear connexion from the engine to the rear wheels. The tractive power of these engines is high, but their speed low—usually 4 to 6 m. per hour.

A peculiar form of road motor is made by equipping the axles of a traction engine with the so-called “ Pedrail ” invented by B. J. Diplock. This is an arrangement whereby circular pads or “ feet,” fastened around the periphery of a wheel, come successively in contact with the ground, the motion approximating to a smooth, even stepping or walking along. Fourteen of these feet are placed around a wheel, and each is attached at the end of a spoke, free to slide radially toward and from the hub of the wheel. Each spoke has fastened to it a helical spring which tends to draw it inwards. On each spoke there is also a roller, which bears against a cam-shaped piece placed inside the periphery of the wheel. The engine is suspended by springs from the cam and is supported by it. The lower edge of the cam is practically straight and horizontal, the length of this straight portion being great enough to subtend an angle equal to the spacing of three spokes, or about 70°. By this means three of the feet are always resting on the roadway and support the engine, which really slides along on the rollers that are at any instant under- neath the flat portion of the cam. The feet take successive positions on the ground as the movement of the engine proceeds, and the engine itself rolls along on the rail portion of the cam which rests on the rollers beneath it. Ball and socket joints are used to connect the feet to the spokes so that they may rest on any conformation they may encounter. This machine has shown a remarkable ability to pass over obstacles and rough roads, and even to climb roadless hills. It gives a maximum of adhesion of the drivers, and it is claimed that it will pass over rough roads with the expenditure of less energy than will an ordinary wheeled traction engine. Its speed is necessarily low—about 4 m. per hour.

The Hornsby “ Chain Track Tractor ” (fig. 2), patented by Mr David Roberts, is provided with two endless chains, one on each side, which constitute the track on which the machine travels. Each chain is carried on two sprocket wheels, placed at the extreme ends of the frame, and is formed of a number of links (fig. 3) so connected that it is free to bend in one direction, as required to pass round the sprocket wheels, but is locked into a rigid bar by pressure acting in the opposite direction. On their outer surfaces these links bear pads or feet, while their inner surfaces compose a track upon which roll the middle or weight-bearing wheels. Power applied, to one of the sprocket wheels exerts a pull on the chain, but this being held fast by the weight of the engine pressing the feet to the ground, the effect is to roll the engine along the track, arid as this happens the feet at the rear end are one by one lifted off the ground, carried round the sprocket wheels, and relaid at the front of the machine. This construction not only renders the whole weight available for adhesion, but also provides a long supporting base and thus enables the machine to pass over soft ground, loose sand, morasses, &c., in which an ordinary traction engine would certainly sink. Steering is effected by retarding or stopping the motion of the sprocket wheels on the side towards which it is desired to turn.

For tramway work steam is scarcely used at all now, though small locomotives—usually having their engines geared to the driving-wheels, instead of the connecting-rods being coupled direct to them—have been used in the past for this work. They were compactly designed and equipped with mufflers to deaden the sound of the exhaust, with other devices to decrease noise and smoke. In some instances, the engine and boiler were placed in the forward end of a car, a partition separating them from the main body of the car in which the passengers were carried.

For description of steam railway engines see Railways: *Loco­motive Power,* and Steam Engine.

*Fireless Engines.—*Fireless engines were first tried in New Orleans, and were in successful use on tramways in France and