ber. This constitutes a good fastening, and the flanges give stiffness to the rail, but the clips cause gaps between the rail and the paving stones, which lead to the formation of ruts alongside the rails. The longitudinal timbers, instead of being laid on cross sleepers, on which the paving does not bed well, are often fixed in cast-iron chairs con­nected by transverse tie-bars. A bed of concrete is always laid under the longitudinal timbers, and should extend to the whole width of the paving. The rails first laid weighed 40 lb per yard, but it was soon found desirable to increase the weight to 60 lb per yard. It is, however, impossible to fish the joints of rails like the above, and it was found that the working of the joints under the passage of the cars loosened the ends of the rails, dislocated the paving, and damaged both the tramway cars and ordinary vehicles. Tramways proved hardly able to withstand heavy street traffic ; and to provide for steam traction a stronger form of rail and a better system of perma­nent way became necessary. Many forms of iron bearings have been devised, the rail being either supported continuously or on chairs at intervals. In the best of these the tram rail can be replaced when worn without disturbing the foundation. In the system used in Liverpool cast-iron longitudinal sleepers weighing 80 and 90 lb a yard carry steel rails of a ┬ section (fig. 4) weighing 40 lb a yard, both sleepers and rails being held down by bolts to jaws anchored in the concrete foundation. The rails can be renewed and the sleepers can be taken up with very little disturbance of the paving.

Steel rails of a flatfooted or a bridge section, and of such a depth as to constitute both rail and sleeper, are also used. In some of the latest and best examples the rail is of a flatfooted section (fig. 5), 6 or 7 inches deep, and 6 or 7 inches wide at the base, weighing 65 to 93 lb per yard. The head has a groove either planed out or rolled in it, giving the usual profile to the upper surface. The joints are fished in the ordinary way, and are as strong as the rail itself. Cross ties are sometimes used, but when the rail is slightly bedded in the concrete foundation they are dispensed with. The paving is set in cement close against the rail, and is bedded directly or in sand on the base of the rail, upon which there is a bearing of 1½ or 2 inches. Such a tramway will stand steam traction and the heaviest street traffic, but the rail, which is of an expensive section, requires entire renewal when the head is worn out. Iron or steel continuous bearings are less elastic, and therefore more jarring and noisy than timber sleepers.

The profile of the upper surface of tram rails has been little altered since the first grooved rail was devised for Birkenhead in 1863, though slight modifications have been made in the form of the groove with the object of lessening tractive resistance. For the sake of the ordinary traffic the groove should not exceed 1 inch in width, and a rounded section with sides splaying outwards facili­tates the forcing out of the mud and dirt. A nearly upright side next the tread or rolling surface with a splay on the inner side throws the mud away from the wheel. The upper corners of the rail should be angular, to make as thin a joint as possible between the rail and the paving. There has been a tendency to diminish the width, and a rail as narrow as 3 inches has been laid. A deviation from the usual profile has been adopted in Liverpool, where the groove is in the middle of a rail 3¼ inches wide.

A tramway must not only afford a good rolling surface capable of bearing the weights running on it, but it must also be able to resist the shocks of heavy vehicles crossing the rails in all directions. The space between the rails, and for 18 inches beyond them, which is repairable with the tramway, is always paved, sometimes in pro­vincial towns and in the suburbs of London with wood, but generally with stone sets in the best manner on a concrete foundation. The sets alongside the rail should be carefully dressed and fitted to make a thin joint. There is much extra wear, and a tendency to form a rut alongside the rail, arising from ordinary wheels using the tram rail, and unless the surface of the paving is kept to the level of the rail the wheels of carriages are caught by the rail, and damage and accidents are caused. To resist the wear near the rails, chilled cast- iron blocks have been used where the traffic is great. On a mac­adamized road there is the same tendency to form a rut along the outer edge of the tramway paving, which is to some extent prevented by giving a serrated edge to the paving. There is always great diffi­culty in keeping the road surface to the level of the paving, and it is better to pave the entire width of a street in which a tramway is laid.

Although cars can be drawn round very sharp curves, the latter should be as easy as possible. A radius of 150 to 200 feet is the least that should be used when there is any choice, but necessity may compel the use of curves of 50 or even 30 feet radius. On such curves, however, the cars are liable to be strained, and the resistance to traction is greatly increased.

A single line of tramway must have passing places for the cars, consisting of pieces of double line of length sufficient to hold two cars at least, with connecting curves and the necessary points and crossings. Where steam or other mechanical power is to be used the passing loops should be at least 200 feet in length. There is inevitable delay and interference with the street traffic at passing places, and where cars are to be run at frequent intervals it is better to lay down a double line if the street is wide enough. It is a great advantage to the ordinary traffic to have the cars moving always in the same direction on the same line of rails.

For horse traction fixed points of chilled cast-iron or steel are sufficient, as the driver can turn his horses and direct the car on to either line of rails. When mechanical power is used, drop points or movable points are required. In the former the groove leading into the road to be taken is of the full depth, and the other groove shallow, so that the engine and cars naturally take the former. On coming out of the shallower groove to the deeper there is, how­ever, a drop encountered which is damaging to the rolling stock, and especially to the engines. Movable points require setting by hand, or they are actuated by a spring or balance weight. In one form of spring point one groove is filled up by a tongue which is pressed down by wheels passing out of a loop, but which forms the side of the groove for wheels running the opposite direction. A spring point of steel, which is forced aside by the flange of the wheel passing out, and shuts close again by its own elasticity, is also successfully used. A movable point on one side of the way is sufficient. Crossings are either built up from rails cut to the required angle, or they are cast solid in steel or chilled iron. Fill­ing pieces of the same material, roughened on the surface for foot­hold, are inserted between the rails at the angles of points and crossings. Both points and crossings wear rapidly, and are trouble­some to maintain in good condition, and when not so maintained are dangerous to ordinary traffic.

The tramcars generally in use in the United Kingdom are con­structed to carry 22 persons inside and 24 outside. They are 16 feet long in the body, or 24 feet including the platforms at each end, and weigh 2½ to 2¾ tons when empty and about 5½ tons when fully loaded. Smaller cars to carry 20 or 14 persons inside, drawn by one horse, are useful to run at short intervals when the traffic is not great, a frequent service of cars being a great element of success. The car wheels are usually of steel or chilled iron, with a flange half an inch deep, and are fitted with powerful brakes. The axles are about 6 feet apart, giving a short wheel-base to enable the cars to pass sharp curves, but with the disadvantage of overhanging ends. Cars to be drawn by mechanical power, espe­cially if outside passengers are to be carried, should have a flexible wheel-base, either by means of bogie frames or radiating axles. In Hamburg and Copenhagen tramcars have wheels without flanges, and a small guiding wheel running in the groove, which can be raised to allow the car to leave the track.

The tractive force required on a straight and level tramway is found to vary from 1/150 to 1/50 of the load, according to the con­dition of the rails. On a tramway in average condition it is about 1/100. The resistance is thus at the best nearly double that on a railway, and sometimes as much as on a good pavement. This is due to the friction of the flange of the wheel in the grooved rail, and to the circumstance that the latter is always more or less clogged with dirt. The 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 a tramway car Tresca 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 very 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 miles, or much less on steep gradients. In London a tram- car horse bought at the age of five years has to be sold at a low price after about four years’ work. On the Edinburgh tramways, in consequence of the steep gradients, the horses last a less time, and they have 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.

The application of steam as a motive power on street tramways is attended with special difficulties, arising from the conditions