

Discussion.

Hon. R. C.
Parsons.

The Hon. R. C. PARSONS said that Mr. Shellshear in his Paper had drawn attention to some engines sent out by Messrs. Kitson and Co. to Sydney, and compared their working with some supplied by the Baldwin Locomotive Works, which, he said, worked more smoothly. The cylinder, he added, was so much inclined to the horizontal, as to give the engine an unpleasant movement. He thought that most locomotive manufacturers would admit that the cylinder and connecting-rod of the engine in question were not inclined excessively to the horizontal. The latter was long, more than four times the stroke of the engine. Many locomotives were now made with a stroke of three times, consequently the action produced by the angularity of the connecting-rod to the horizontal was practically of no importance. When the engines were sent to Sydney, three were also sent to Queensland to work on the tramways there; and it appeared from the reports that had been received, that they had been driven up to 20 miles an hour without any difficulty. Messrs. Kitson and Co. had also made other engines of a similar type, and he himself had driven them up to 30 miles an hour on a tramway. The parts, therefore, could not be unnecessarily heavy. It had been stated that the line was broken up several times, and he thought that some of the results produced were due to the joints in the rails being so much out of repair, causing the engines to jolt excessively. It was stated in some of the reports they had received, that the drivers riding on the engines had frequently become sea-sick from the jolting.

Sir Charles
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Gregory.

Sir CHARLES HUTTON GREGORY, K.C.M.G., Past-President, thought that all the members must have been greatly interested in the Papers that had been read. It was asked, "What's in a name?" Very often there was a great deal, and he thought that the misnomers applied to different systems of railway sometimes involved a misleading error. The word "tramways," for example, was applied in a sense far different from its original signification. In Tredgold's treatise on railways published in 1825, they were divided into tramway-roads and railroads, the tramway-road being a road constructed of plates for the north country trams to run upon, with flanges on the plates themselves; the railroad having what was then called the edge rail, with flanges on the wheels. The public had an idea that what were erroneously called tram-

ways were much cheaper than the ordinary system of railway. The nearest approach to the form of a tramway was in some of the earlier rails used in street railways; but it had been found that those earlier forms were so inadequate to the work they had to do, that the details of a road, the mode of laying it, and especially the weight of the rail, had to be materially altered, so that the cost of street railways (as he thought they ought to be called), where there was a large amount of ordinary street traffic running over and across them, was very great indeed. It would be seen from the second Paper, that the cost of the lines in Sydney far exceeded, mile per mile, that of ordinary railways. He thought that railways might be divided into ordinary railroads, in which land and works of all sorts had to be provided for the traffic of the railway proper; common road railways, where there was naturally very much saving in works, and street railroads, abandoning altogether the misleading expression "tramway," which was generally supposed to imply cheapness. In the treatise on railways to which he had referred, he had found an illustration of the saying that there was nothing new under the sun; at page 179 there was a drawing of a railway wagon which Mr. Tredgold proposed should be mounted on two four-wheeled bogies. He thought few were aware of this proposal at so remote a date as 1825.

Mr. E. WOODS, Vice-President, said the Papers would prove of great use to the members when studying the subject of traction on tramways. Mr. Parsons had stated that the steam-tramway cars were first used on the Vale of Clyde Railway. He believed, however, that the late Mr. John Grantham, M. Inst. C.E., was the pioneer in the introduction of steam-tramway cars for traffic. He made an engine which ran for many years on the Wantage tramway, and which he believed was still running, carrying traffic from the Great Western station to the town, on a considerable gradient, over a length of a mile or a mile and a half, the line being laid along the common road. The members could compare the results of English practice, and to some extent of colonial and foreign practice, with the practice of railways in Sydney. The Sydney tramways, he observed, were laid very much like English railways, with cross sleepers, with flat-footed rails, or rails of Vignoles section, simply grooved on the top. That was a form of rail which recommended itself to many engineers in this country. He had recently received a letter from his son in Monte Video, stating that he had been studying the subject of tramways there, and had ascertained that preference was given to the

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Mr. Woods.

Mr. Woods, form of rail which had been recommended in both the Papers, not only for tram-cars drawn by horses, but for steam-motors. With reference to the comparison instituted between the locomotives, Mr. Shellshear had stated that the Baldwin motors, of which there were fifty-seven, were greatly preferred to the English engines. Mr. Woods, however, saw no reason why engines of English manufacture should not be as good as those of American manufacture. He had found that to be the case in his own experience. He had engines constantly in use for years, both from the United States and from many of the leading English houses, and he could certainly state that the English engines compared most favourably with the American. He could not conceive that the cause of the oscillation described as existing in the Kitson engines was that assigned to it, namely, the slight inclination of the cylinders. In the engines at Sydney, the use of condensation had been abandoned. He supposed that the inhabitants of the town, and the municipality, did not care so much as English authorities did about the noise or the nuisance occasioned by the escape of steam from the engines. No doubt the climate had an important effect in rendering condensation in that country of less importance. The degree of humidity was less; the atmosphere therefore took up the steam, and rendered it invisible, so that the nuisance was removed. Mr. Parsons had said that he did not consider it expedient to attempt to condense more than two-thirds of the steam that escaped through the chimney, the remaining one-third being applied in producing blast. Now that the Board of Trade regulation had been amended in favour of the tramway companies, he supposed from Mr. Parsons' statement, and from Mr. Woods' own observation, that the escape of that one-third was comparatively unimportant. Superheating at one time was thought to be essential, but that seemed now to have been abandoned, upon the ground not only of the unnecessary complexity of the parts, but of the largely increased consumption of fuel incidental to the superheating. The comparative statement of the working expenses by the two systems, the Sydney and the English, was of great value. It was stated in Mr. Shellshear's Paper that the Sydney system of steam-tramways was perhaps the most advanced in the world. If so it might be expected that the working expenses would be exceedingly moderate; but, on comparing them with those given in Mr. Parsons' Paper, it would be found that they were much greater. In 1880 the cost per train-mile at Sydney was 38·38*d.*, in 1881 42·12*d.*, and in 1882 36·91*d.*, the mean being about 39*d.*

per train-mile,¹ without any allowance for depreciation and other expenses included by Mr. Parsons, who had taken the case of a railway, the name of which had not been given, where the expenses were only a little over 7*d.* per mile, or, together with what he had put down for depreciation, 9½*d.* as compared with 39*d.* at Sydney. The cost of locomotive-power alone was 21*d.* per train-mile in Sydney, while on the line mentioned by Mr. Parsons it was only 4½*d.* Making every allowance for the high wages paid in Sydney, and also for the increased cost of materials, and perhaps of coal, the difference was he thought too great to be accounted for by those considerations. There had been a falling-off in the percentage of earnings during the three years. In 1880 the percentage of earnings with reference to capital expended in lines open was 12·34, in 1881 it fell to 6·16, and in 1882 it was 6·80. He could not discover why such a great reduction should have taken place, and it might be interesting to have it explained. He also observed that there was a very considerable increase in the percentage of working expenses, which in 1880 was 70·83, and in 1881 and 1882 averaged more than 82 per cent.

Mr. NORMAN SCOTT-RUSSELL observed that Mr. Parsons' Paper was entitled "The Working of Tramways by Steam;" but it seemed to him that the impression must have been produced that steam on tramways was still in an experimental stage, and that the experiments were confined to one type of engine on the Leeds and Birmingham tramways. The fact was that steam on tramways was now regularly employed in Gateshead, Stockton, the Hartlepoons, Tynemouth, Bradford, Blackburn, Burnley, Bury, Rochdale, Stoke, Dewsbury, Batley, Coventry, Brighton, and one or two other towns. In Mr. Shellshear's Paper the Sydney tramways were spoken of as perhaps the most advanced in the world, whereas there was one line in England, the South Staffordshire, 22 miles in operation with thirty-five engines, and another, the Manchester, Bury, and Rochdale, which was probably the longest in the world, with 32 miles open to traffic, 62 miles authorized, and fifty engines. Altogether there were in England 160 miles of tramway open to traffic, worked by two hundred and forty engines made on the Wilkinson, Merryweather, Kitson, and Falcon systems. In bringing those tramways to their present state great difficulties had to be contended with, and engineers had been obliged to purchase their experience. At first the rails were too light, and the engines too heavy; and both managers and drivers

¹ When these remarks were made the details for 1883 had not arrived.—Sec. Inst. C.E.

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had to be trained. With regard to the permanent way, nearly all engineers appeared to have considered the girder-rail described in Mr. Parsons' Paper as the best. He thought, however, the rails might be improved by being made heavier. An addition of 10 lbs. a yard to the weight of a rail would add considerably to its endurance, and only 3 per cent. to the cost. A source of weakness in the rails was of course the butt-joint, and that was more the case in tramways than in railways. Any one who had noticed a tramway would see that the water soaked through, and every time an engine went over it pumped out the water, which afterwards filtered in again, so that the cement not only close to the butt but all round worked out. Many of the fish-joints seemed to him not nearly so strong as they might be. Another defect was to be found in the points and crossings. Mr. Parsons had illustrated a form of siding, but it was not always possible in crooked streets to arrange the crossings in the way desired. He had seen tramways in which the leads into the crossings were perfectly straight, and in which, nevertheless, cars had gone the wrong way. He believed that some mechanical points had been made, and he thought that method would have to be adopted or a self-acting spring point. The gradients in tramways were sometimes very steep; he thought that any above 1 in 16 or 1 in 17 ought to be avoided. Some were as steep as 1 in 11, but such gradients were so near the limit of adhesion as to be dangerous. The power required to draw cars up steep gradients increased rapidly with the steepness. Up to 1 in 40, and even 1 in 30, there was not very much difficulty, but beyond that gradient the necessary power increased greatly. He should like to point out the work to be done in making engines to draw cars on tramways. The usual car weighed about 4 tons, and carried sixty passengers, weighing another 4 tons; the engine to draw it weighed about 9 tons, making a total of 17 tons. The actual HP. necessary to take 17 tons up a gradient of 1 in 20 was 38; and to show that that was not very much out, he might mention that on one line an engine hauling $18\frac{1}{2}$ tons, which theoretically required 42 HP., was found, by taking diagrams from it, to absorb 48 HP., or an addition of 6 HP., which was not unreasonable when allowing for the friction of the mechanism. In regard to the steam tram-engine, however, the power was enormously disproportionate in comparison with what was done every day with horses, where two horses were able to drag a car up considerable inclines. He thought he could explain some part of that peculiarity. Of course there was great absolute loss in

that half the power was required to take the engine alone, leaving 18 HP. to drag the car up the incline. A great deal of that was due to the HP. needed for the speed required with steam, which was much greater than with horses. Still there remained something to be explained, and he was sorry to have to upset one of the idols which had been set up from the time of Watt, and to say that the 33,000 foot-lbs. HP. which had been regarded with so much reverence was not HP. A tram-car horse actually took up something like 65,000 lbs., or nearly double the amount supposed. The engine constructed at the Falcon Works for tramway purposes was shown in Plate 5, Figs. 1 and 2. It was in some respects like that of Messrs. Kitson, with this material difference that the cylinders were inside instead of being outside, and there was also a locomotive boiler. All the mechanism was shut in from below, thus keeping it free from dust and dirt, and it was accessible from above. Considerable attention had been devoted to the brake and governor gear, which was a very serious point on account of the danger in going up an incline. What was called the fifth wheel had been adopted. It was not considered necessary to stop the engine to remind the engine-driver that the brake was in working order. The fifth wheel ran on the rail. It was connected directly by a shaft with a ball governor, which, when it expanded, opened a little valve, putting brakes both on the car and on the engine, and at the same time cutting off steam. Further, by a reducing valve, the driver could put on the steam- and the car-brake at the same time. It was a self-acting valve, which regulated the pressure. With regard to the working cost, it was hardly possible to compare one line with another, in consequence of the difference of the gradients. Assuming that along a level line 1 HP. was required to draw a car each way, or 2 HP. for the complete turn, on a gradient of 1 in 40, it would take 3 HP. to go up an incline, none being required to run down, so that it took 50 per cent. more power to work a gradient of 1 in 40 than it did to work a level line. It therefore took 50 per cent. more coal, and the same thing would apply to all the other expenses of working. The engine, for example, being more heavily strained, would need more repairs, and would use more oil; and the same might be said of another great source of wear and tear on tramways, viz., of the tires. The life of a tire on lines with heavy gradients was about 21,000 or 22,000 miles, which any one acquainted with railways would know to be short. The cheapest worked lines in the kingdom

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were, he believed, the Stockton and the Dewsbury and Batley, which were quite, or very nearly, level. He agreed with Mr. Parsons with reference to the great economy of having spare engines, but the argument was one which directors were slow to accept. There could be no doubt that if an engine were turned out in an unfit condition it would incur more harm in a day than from a month's ordinary work when in good order.

With regard to other mechanical power, he might mention the rope, compressed air, and electricity, the last of which he thought had hardly come within measurable distance of practicability. The rope had been worked with great success in America, and very well in this country, but it was a very different thing in America from what it was in England. Here the streets were tortuous, and there were great difficulties in regard to going deep into the ground. The streets being narrow, single lines and sidings, which were all against the use of wire rope, had to be adopted. For a very steep gradient, however, he thought there could be no doubt that it was the best, in fact the only, means of locomotion.

He desired to make an appeal to engineers, and also to the Board of Trade, in order that some arrangements might be made for a uniform gauge, and also a uniform width of car, as in Ireland. At present there were in England gauges of 2 feet 6 inches, 3 feet, 3 feet 6 inches, 4 feet, and 4 feet 8½ inches, and also different widths of car on the same gauge. On the 3 feet 6 inches gauge, for instance, there were widths of 5 feet 6 inches, 5 feet 9 inches, 6 feet, and even 6 feet 3 inches. He believed the present to be the commencement of a great era in tramways, which would form a network over the country and supplement the great system of railways.

Mr. Harris.

Mr. H. GRAHAM HARRIS said he should like to supplement the statement of Mr. Scott-Russell, as to the importance of tramways and tramway work, by pointing out that, according to a return just issued by the Board of Trade, £11,000,000 had been subscribed for tramway purposes in the United Kingdom alone; that nearly the whole of this capital had been expended; and that from the 30th of June, 1883 to the 30th of June, 1884, the tramways had carried 330,000,000 passengers. Those figures, he thought, were sufficient to show that the subject was an important one, and worthy the attention of the members of the Institution. Further than this the engineering question to be solved, in substituting mechanical for animal traction upon tramways, was not so easy a one as might appear at first sight. It was all very

well to say, "There are thousands of examples of locomotives on *Mr. Harris*. ordinary railways, and all you have to do is to put a light locomotive upon a tramway; the work cannot be very great, two horses usually do it." It was no such easy thing as that. There were many important differences between traction upon the edge rail of a railway, and traction upon the grooved rail of a tramway. One of these was the difference of resistance to traction itself. Upon the edge rail of a railway, at the speed allowed by the Board of Trade Regulations for motor tram-cars, namely, 8 miles an hour, and on a level, the resistance to traction might be taken at 11 lbs. per ton. On the grooved rail of a tramway, at the same speed, it was more than twice as much, amounting indeed to 25 lbs. per ton of load moved, and in bad dirty weather, when the grooves were filled with road refuse, to 45 lbs. per ton. It would sometimes vary between those amounts, almost from hour to hour. He thought he could explain the reason, why the traction upon the grooved rail of a tramway should be so much greater than upon the edge rail of a railway. The tramway groove must be narrow, so that the ordinary street traffic might pass over it. The tramway wheel-flange must be wide, to give sufficient strength, consequently there was not much clearance between the two, and if there was the slightest incorrectness of gauge in the rail, or if the wheels were in the slightest degree out of gauge, there was a large amount of friction upon the sides of the flanges. Worse than that, the tramway groove got filled with road refuse, and the tramway wheel, instead of running upon its tread alone, was often running upon the edge of the flange as well, with the sides of the flange also rubbing against the sides of the groove; now owing to the differences of diameters of these portions of the wheels, they were, when the car was in motion, running at different speeds, and the result was that the resistance was increased, as compared with that upon the edge rail of the railway, where the flanges were clear of everything, from, as he had said, 11 lbs. per ton of load moved to about 45 lbs. per ton in bad weather. When, therefore, the motor for the tram-car was mechanical and was put upon wheels, the HP. required was something astonishing; with the weights given by *Mr. Scott-Russell* it amounted to about 38 indicated HP. With a 9-ton car upon an incline of 1 in 25 (which he took because it was capable of being worked by two horses), and at a speed of 6 miles an hour, the indicated HP. was as much as 25, and sometimes even more, because in the case of curves it was enormously increased. That was one of the troubles that the mechanical engineer who designed a motor tram-car had to deal with.

Mr. Harris. Two forms of car, the detached and the combined, had been described by Mr. Parsons, who strongly advocated the use of the detached car. He had, however, recommended Mr. Rowan's combined car, because, he said, it was possible to detach the body of the car from the engine and put it to another when required, so that the capital represented by the car-body would not be lying idle. At first that appeared to be an important consideration, but when it was remembered that the total cost of the combined car might be taken at £800, and the cost of the car-body itself at one-fifth of that amount, it would be seen that the saving effected by having a car-body capable of being put to two or three engines was very little. When, moreover, this saving of capital and interest, upon which so much stress had been laid, was taken in comparison with those on the detached engine, where it was necessary, according to Mr. Parsons, to have 33 per cent. of the engine-power lying idle, surely it was hardly worth consideration, especially when the question of extra complication which was involved was considered. It reminded him of what he had read in regard to the Great Western Railway. When the line was started, it was thought necessary to have the boilers of the locomotives capable of being detached from the engines, so that the boiler and engine might not be lying idle in the shed at the same time. Several engines of that kind, he believed, were made, but the necessary complication was so great, that it was not thought worth while to continue the system, and it was soon abandoned.

Reference had been made to the value of the cable system for steep gradients. He was himself interested in another mechanical method, the compressed-air system, of Mr. Mékarski, but he did not think that that, or steam, or anything else, would compare with the cable system for very steep gradients like those of 1 in 15 or 1 in 11, which were to be found on tramways. When the roads were in a dirty muddy state, the surface of the line became covered with mud, practically like butter, brought upon it by the ordinary traffic of the road, and upon this mud the sand used by the motor car was of very little use. In such a case, the cable tram, when the traction was not taken through the wheels on to the rails, and where the cable had only to pull the weight of the car itself, and of its load of passengers, was certainly the best that could be adopted. It might astonish the members to learn what the cost of sand sometimes amounted to for mechanical traction. On one line in London, where the steepest gradient was 1 in 25, it happened during one week last winter that the cost of sand for a

single car amounted to two guineas, six loads of sand being used, Mr. Harris. at 7s. a load. That, he thought, was sufficient to prove that London mud at any rate was very difficult to deal with.

He agreed that the cost of working depended to a large extent upon the gradients, so that it was useless to give the cost of working a line without stating what the line was like. As to the cost of working an ordinary line by other systems than steam, he might be permitted to refer the members to the last volume of the Proceedings of the Institution,¹ in which a detailed statement was given as to the cost of working the Nantes line by compressed air on the Mékarski system; this cost would be found to be much less than that stated by the Author for working his ideal line by steam.

Mr. NORMAN SELFE said he had been travelling since last March, Mr. Selfe. and therefore could not give any data on the Sydney tramways gained since Mr. Shellshear's Paper was written; but he had been in Sydney for thirty years, and had been familiar with the tramways ever since their initiation. He had also recently seen the cable roads of San Francisco and Philadelphia, the steam-locomotive roads in Glasgow and Leeds, and horse tramways in many cities. Mr. Shellshear's statements, based on official returns, could not be gainsaid, but there appeared to him to be a disposition to question his remark that the "Sydney steam-tramways were perhaps the most advanced in the world." The speaker, who objected to this claim, had an approving assent from the members generally, especially when he quoted the working expenses at 39·1d., as against 9½d. on his line, without taking earnings into account. Of the Sydney tramways generally, it was never denied that they had proved a great convenience to the travelling public and to the residents in the suburbs. They had been extended so rapidly to meet the absolute wants of the people, that, seeing there was no precedent for the work, much of the road-laying had no doubt been done more than once, and the first cost was relatively much heavier than it was likely to be in the future. The demand for transit had at times been so great that he had seen engines drawing three hundred people instead of the one hundred and eighty for whom sitting accommodation was provided, the upper deck of the cars on such occasions being double-banked, and the footboards crowded. There was, for this reason, but little room for comparison between the Sydney engines doing such work on extremely steep gradients, and the engines

¹ Minutes of Proceedings Inst. C.E., vol. lxxviii., p. 488.

Mr. Selfe. that he had as yet seen in England and Scotland, taking sixty passengers on comparatively level roads. As a friend had remarked to him, the tram-engines in this country were comparatively toys. To complete the comparison of the cost of working in Mr. Shellshear's statements with Mr. Parsons' ideal line of 16 miles, namely, $9\frac{1}{4}d.$ against $39\cdot 1d.$, when it was concluded that the Sydney system was behindhand, he would give the earnings:—

Mr. Parsons' line	$12\frac{1}{4}d.$	Mr. Shellshear's	$49\cdot 96d.$
Train-mile mean profits	$3d.$	„	$10\cdot 86d.$
Earnings per mile of line	£1,660 to £1,675	„	£8,142
Earnings percentage on capital	6·6 per cent.	„	8·43 per cent.

He was not championing Mr. Shellshear's claim, but from these figures it would be seen that, under all the disadvantages of initiating a system of tramways 14,000 miles from the centres of civilization, with no precedents for the work, on steep gradients, and having also in many cases the expense of making and maintaining one-third of the whole roadway, the tramway engineers to the Sydney Government had brought a system into active operation which earned about five times as much per mile of line, and about 2 per cent. more on capital invested, than Mr. Parsons' proposed ideal line. On this account he believed Mr. Shellshear based his statement, and something more must be shown than had yet been done, before his claim could be discredited. With regard to the relative steadiness of rival engines, Mr. Shellshear recorded what he believed to be the fact, and what appeared to be supported by the experience of engineers elsewhere. The statement made by a speaker that the drivers in Sydney sometimes got sea-sick in consequence of the bad roads would, if true, apply to the heavy engines as well as to the light ones, and to those with a high pitch as well as to those with horizontal motion. That statement, however, might safely be passed over. As had already been mentioned, some portions of the line were laid with iron rails that had not much endurance, and, for a short time, no doubt one or two sections were inferior; but now, with concrete foundations, steel rails, and Australian hardwood cube blocks, both the road and the railway in the Sydney streets would safely bear comparison with the road and tramways in other cities. In San Francisco, which perhaps had the best tram service in the world, with both cable and horse-car roads on four separate lines in one street, and with the cars running on the cable roads at intervals averaging 1,700 feet, and often less than 1,000 feet, the roadway between the rails was simply cobble-stones packed in sand, and the

ordinary traffic was allowed to get on the tram rails as much Mr. Selfe, as it could without interfering with the tram traffic; for when on the stones, with holes 2 inches to 6 inches deep, it was subjected to rough jolting, and the stones were very prejudicial to the horses' feet. In Sydney, on the contrary, the blocks of seasoned hard-wood were laid on 9 inches of cement concrete to a smooth surface. In Paramatta Street, where the vibration of the sleepers made the blocks over their ends show a faint wave along the line, men were employed with adzes to keep the line smooth, and so great was the respect paid to the wheels of the buggies and other vehicles, that men were constantly employed making up the roadway level with the rails, where tarred metal or granite cubes were used for the road. There were gradients of 1 in 18 or 1 in 17, and in a 5-mile run there was an average gradient of 1 in 20 for about 1 mile.

Having said so much to show that there was some foundation for the suggestion that the Sydney tramways were "perhaps the most advanced in the world," and that it had not as yet been controverted, he might be permitted to state why experience did not favour the use of steam-locomotives for cities. It must be borne in mind that the connection of a city with its suburbs involved different considerations from those attending the internal traffic of the city itself. In the former case, the use of the steam-locomotive was often admissible, and a service with heavy loads, at less frequent intervals, to run for comparatively long trips, might meet the requirements. The steam and smoke were not in such a case relatively so objectionable, and there was plenty of scope for the future improvement of the steam-locomotive. But for connecting important points within a city itself, through narrow and crowded streets, between lofty buildings, where a service was desirable every two or five minutes, where large cars attached to a locomotive would be a great hindrance to the general traffic, and where, also, there might be a reasonable objection on the part of the passengers and residents to having the atmosphere further polluted by the products of combustion and steam (which, however much disguised to the eye, could always be smelt), there was perhaps more than one system of motive power for tramways better than the steam-locomotive. In May last there were six or seven cable roads in San Francisco, and another was being completed up Telegraph Hill, with a gradient in it, he thought, of about 1 in 3. Admitting it to be true, as stated by authorities in that city, that 50 per cent. of the engine power provided was employed to move the cable alone, and

Mr. Selfe. that the wear and tear were very heavy, still those roads were so successful that they were being copied in other cities, and as they fulfilled the conditions of being clean and noiseless, with the advantage of running often with single cars or short trains, and offered the minimum obstruction to ordinary traffic, no real comparison could be made between the cable system and locomotives for city use. The cable system, however, had some drawbacks. The great first cost, the wear and tear of cable, and other matters, were so serious as to have set American inventors at work, and it had been his privilege when in San Francisco, to be present at some very successful trials of the pneumatic-tramway system, invented by Mr. George Pardy of that city, a system which bade fair to eclipse the cable for ordinary grades, and to supersede the steam-locomotive where cleanliness, frequent trips, light loads, &c., were an object. The Pardy system was only slightly different from others that had been proposed before, but that slight difference made it a practicable one. Under Mr. Pardy's plan, stations were established at certain points adjacent to the tram route, where air was compressed to about 120 lbs. per square inch, and air-mains were laid under the roadway the whole length of the tram route. Only one main, however, was required for a double road. At every stopping-place on the route, and at such other stations and distances as might be desired, a special form of valve was connected to the main, which valve was accessible through a hole in the roadway about 3 inches in diameter, or less. The dummies, or engine-cars were provided with air-reservoirs under the seats, capable of withstanding 120 lbs. pressure per square inch, and had a small pair of engines capable of working the load with perhaps 20 lbs. pressure above the atmosphere, a reducing-valve and chamber being provided for the purpose. In the case of a dummy and reservoir-car being connected, their respective reservoirs were coupled by a flexible tube. The driver was provided with a stand-pipe and handle, the pipe having a flexible connection to the reservoir, and an oblong hole was made in the foot-plate. When the stoppage was made to put down or take up passengers, the foot-plate was brought over one of the openings in the roadway, and the insertion of the conical end of the stand-pipe into such opening through the hole in the foot-plate, opened a valve on the main and another in the stand-pipe itself, when the reservoir was charged up to 120 lbs. in, say, five seconds. On the withdrawal of the charging pipe the valves closed automatically, and the tram proceeded on its way without more time being lost for a re-charge than it took an ordinary passenger to alight or occupy a seat. As

the working pressure in the air-engines was very low, the power which might be saved by expansion from full pressure was not utilized, but all trouble of freezing at the exhaust was done away with; no supplementary fire was required, as with the Mékarski or other compressed-air systems; and the engine on the dummy, as compared with the highly compressed-air tramway locomotives, was simplicity itself. In running the engine-car or dummy alone, the driver could collect the fares, as was done with some of the horse tram-cars; but with a train of two or more cars a conductor was required, making then only two hands instead of the three or more for a steam-locomotive train. He made a number of trips on an experimental dummy built in San Francisco, and the results obtained were so successful that two omnibus companies made contracts for plant and outfit, and were about to open routes on the system, if they were not already started. This low-pressure compressed-air system presented no practical difficulties; no machinery in motion was required underground, and there should be a minimum of wear and tear. It was understood that the patentee expected to realize 30 per cent. of the power put into the compressor; but as much greater economy in coal consumption per HP. could be secured at a large station than was possible in a number of small locomotives, and fewer skilled engineers and other hands would be required than with steam-locomotives, it was just likely that the many advantages which this system possessed, in cleanliness, power of running small loads at frequent intervals, simplicity of repairs, and other features, would justify its adoption if only from 20 to 25 per cent. of the actual power developed in the compressor were utilized in the propulsion of the car and passengers.

The question of power depended, of course, very much on the proportion of dead-weight to passengers carried. On the Sydney tramways, according to Mr. Shellshear's Paper, it was, for an engine and two cars, 265 lbs. per passenger with one hundred and eighty persons seated, and it might be expected to be greater on the same system with smaller engines and loads if the gradients were as steep. He should be glad if Mr. Parsons would supplement his Paper by giving the weight of engine and car in his ideal road and estimate, and the maximum gradients proposed to be worked. In the pneumatic dummies to run $\frac{3}{4}$ mile on one charge, with a speed of 10 miles an hour, and carry twenty passengers, the weight was 6,800 lbs., or 340 lbs. per passenger, the gradient being 1 in 20; but with the addition of a reservoir-car to carry twenty more passengers, and weighing 4,500 lbs., the dead-weight was

Mr. Selfe.

Mr. Selfe. reduced to 282 lbs. per passenger, and the distance increased to $1\frac{1}{4}$ mile on the level. On the Clay Street cable-road in San Francisco the car and dummy, carrying thirty passengers, were said to weigh 5,650 lbs., or 188 lbs. per passenger, and of course had neither reservoir nor engine. It might be that they were made so strong because the gradients were in some cases as steep as 1 in 6, and lighter cars might be used now. The only data given to him of the weights of compressed-air tramway-engines, using a very high pressure, showed an 8-ton locomotive and a 3-ton car to fifty-six passengers, or about 440 lbs. per passenger, which was nearly double that on the Pardy system. The low-pressure compressed-air system had not yet had a long trial, like the more elaborate systems using pressures up to 1,000 lbs., and it would be very interesting to watch its future development. There were many openings for modifications in its use, as, for instance, in the case of a short steep rise, such as occurred in William Street, Sydney, where a small engine could be worked off the air-main to drive a supplementary cable, and help the cars over the difficulty.

Mr. Cotton. Mr. FRANCIS M. COTTON observed that as early as 1872 the late Mr. John Grantham, M. Inst. C.E., introduced a combined steam-tramway engine car, which was constructed by Messrs. Merryweather and Sons of Greenwich; this car was capable of holding forty-four passengers, and weighed, when empty, $6\frac{1}{2}$ tons. It was set to work experimentally on a short piece of railway at West Brompton, traversing the line at an average speed of 11 miles an hour. In 1876 this car was removed to the Wantage tramways, and had since been in constant use. This was quickly followed on the Wantage tramways by one of the Merryweather independent tramway engines, and Major-General Hutchinson, R.E., Assoc. Inst. C.E., of the Board of Trade, stated before a Select Committee of the House of Commons in March, 1877, that this engine was the only one he had then seen which was fitted with appliances having regard for the safety and convenience of the public. On the 17th of the same month, the Select Committee rode from Leytonstone to Stratford Church in a car drawn by one of these engines. In 1876 a steam-tramway engine was drawing five or six cars of passengers at the National Rifle Association Meeting on Wimbledon Common, and then in 1878 the Vale of Clyde Tramways were first worked by steam. In his opinion "the independent type" of engine (Plate 4) would be much improved if the cylinders were placed horizontally instead of at a considerable angle from the horizontal. It was well known that the nearer the cylinders approached the vertical in locomotives the greater would

be the oscillation on the road, especially with outside cylinders, Mr. Cotton, and this well-established truth was fully borne out in tramway practice, but had been ignored by Mr. Parsons. Then again, for hard and constant work he did not like the gear. He thought none of the arrangements, where the motion was derived from the connecting-rod, were so good or lasting as the old shifting link-motion, provided of course the latter was made much stronger, and with larger wearing surfaces in proportion to the size of the engine, than would be used in ordinary locomotive practice, as so much more dust and dirt had to be contended with on tramways than on a railway. He should have preferred to have had the boiler and condenser rather larger, so that when running on the level all the steam would be condensed; in damp weather one-third of the exhaust steam escaping could not fail to be disagreeable. He understood that on some tramways only 50 gallons of water escaped uncondensed on a day's run, and the whole of this steam passed away on the inclines, none escaping on the levels. The most important point about a steam-tramway engine was the rapidity with which it could be brought to a standstill. Mr. Parsons seemed aware of this, for he had furnished his ideal engine with several powerful brakes. Mr. Cotton was therefore at a loss to understand the statement that the steam-engines were in frequent collision. In reply to an enquiry on the subject, he had received from Stockton-on-Tees a telegram to the effect that in the "course of more than three years only two collisions had occurred, and those had been due to drivers of vehicles being intoxicated;" also that no claims had been made. Table No. 1 (p. 115), would be very useful for reference. Although the cost per mile for working the engines was low, viz., 3·28*d.*, it was by no means the best result obtained by tramway companies. He had a record of the half-yearly running and repairs account for the engines (Merryweather's) of the Stockton and Darlington Steam Tramways, which gave 3·12*d.* per mile; and a similar account for the past twelve months of the Dewsbury, Batley, and Birstal Company (Merryweather engines) gave 2·57*d.* per mile run. This included cost of coke, oil and waste, water, firewood, locomotive repairs, drivers, coke, watering and relief man, and cleaners, and was, he believed, the best result hitherto obtained. These figures had been taken from the annual reports of the respective managers of the lines in question, and therefore demonstrated in a reliable and conclusive manner how economically street tramways could be worked. The latter line had been previously worked by horses when the cost was 5*d.*

Mr. Cotton. per mile. With regard to the question of repairs, Mr. Cotton thought that parts were made too light, and with insufficient bearing surface for the extra wear to which they were exposed. He also held that it must be an ill-conducted company that would allow the repairs to be done at midnight, or in the small hours of the morning by a labourer. In view of the approaching introduction of steam on the Metropolitan Tramways, some information as to what was being done in that direction might be of interest. The portion from Ponder's End, Enfield, to Edmonton, was laid; but the section along Seven Sisters Road to Finsbury Park had not been commenced. The North London Tramway Company obtained an Act to use steam-power on these lines last Session, having secured the sanction of the Board of Trade, and of the Metropolitan Board of Works. The line was intended to be worked by fifteen Merryweather engines. The cylinders of those engines were $7\frac{1}{2}$ inches in diameter by 12 inches length of stroke, arranged horizontally inside the frames. The guide-bars and crossheads were of steel, and the crosshead-slippers were of cast-iron, with large wearing surfaces. The valve-motion was of the ordinary shifting-link type, case hardened. The eccentrics and straps were of cast-iron; these were made to a heavy pattern, for by this means the gear would run for eighteen months' continuous working without having to be set up, as had been ascertained in practice, so that the complaint against link-motion for tram-engines was not well founded, when proper proportions were employed. The coupling-rods had solid ends, bushed with phosphor-bronze; the wheels and axles were of steel. The boiler was of the locomotive type, made of mild steel; the fire-box was of copper. In addition to the feed-pump there was an injector which filled the boiler, and returned the overflow water back to the tank, thus economising water. Great attention was paid to the axle-boxes; their lubricators could be reached from the foot-plate whilst the engine was running, and they were fitted with dust-tight covers, so that the weak point in locomotives, namely, hot axles, was prevented. A fender-plate was attached to each end of the engine to obviate the possibility of running over obstacles. At Stockton-on-Tees, on a market-day, it was a common practice to force the engine through the crowd slowly, and no accidents had occurred from this proceeding. The condensers consisted of 1-inch copper tubes placed above the roof, and in addition to the air admitted to the front of the condensers, and made to pass through them, tapering air-passages were provided under the roof, and the air which passed in by these was found to disturb the hot air

which clung to the tubes, thus making the condensers more efficient. Mr. Cotton. A common practice existed of fastening the ends of the tubes by soldering, but in these condensers the ends were secured by ferrules, so that they could be repaired without pulling the apparatus to pieces. The boilers would work at a pressure of 150 lbs. per square inch, and all the requirements of the Board of Trade would be fulfilled. The weight of each engine would be about 8 tons when empty, and 9 tons when in working order, with water, fuel, &c. One of the most fruitful causes of wear in tramway locomotive bearings arose from the sand and dirt pushed or washed into the oil-cups by the driver when oiling; but this had been overcome in these engines, for the oil siphons were so arranged that the act of removing the cover cleared away all dust that might have gathered in the vicinity of the oil-hole. The first of these engines was expected to be at work on the North London line early in the year 1885.

Mr. JOSEPH KINCAID wished to offer a few suggestions, based on Mr. Kincaid. the experience he had had with most of the engines made for street tramways. There were still serious complaints from the local authorities, as to the working of the condensers in certain states of the weather, and it was difficult to say how they were to be completely met. In the Kitson engine, which had given great satisfaction, the condensing was done nearly altogether by an air-condenser; in other engines water alone had been used, which certainly afforded much satisfaction as far as condensing the steam went, but it was very expensive. Great objections were made to it by the local authorities, because it was difficult in the streets to get rid of the hot water used in the condensers. He did not know how far that difficulty could be removed by the improvements made in locomotives. Another difficulty was the immense amount of wear and tear in consequence of the working parts being so close to the dirt, and the necessity of having them boxed in. In crowded towns in bad weather the wear and tear was very serious if the working parts were not carefully boxed in and raised above the roadway. The automatic-brake, as required by the Board of Trade, was accomplished in two ways, by a belt from the driving axle, and by a fifth wheel; but an objection to the belt arrangement was that when the wheels slipped the brake was put on. There were certain advantages in having a fifth wheel, and he should be glad if Mr. Parsons would give his opinion as to the mode of applying the automatic brake in that way. The speed-indicator used was in his opinion an unsatisfactory one. There had been three tramway engines at work

Mr. Kincaid. moved by compressed air, the Scott-Moncrief, Colonel Beaumont's, and the Mékarski. There had not been much experience with the Scott-Moncrief engine. Colonel Beaumont's engine worked at a very high pressure. The Mékarski had been in use for several years in Nantes. The fireless locomotive had been tried near Paris, on the tramway from Rueill to Marly on a severe gradient, and it was charged with superheated water. He did not know that the results had been satisfactory, and he understood that the system had been lately abandoned. He should be glad to know if it had been adopted in other places. Many engineers had been looking forward to electricity as applicable under certain conditions. Most of the members knew the great utility of the tramway in Brighton worked by that agency, which had also been adopted for the tramway at Giant's Causeway, where, however, it was applied in a different way. At Manchester also an experimental tramway was worked by electricity applied in yet another manner. Considerable advance was being made in the application of electricity to tramways, and it was to be hoped that some means might be found whereby it might be used at smaller cost. As to the cable system, of which he had some practical knowledge, especially as applied at Highgate, where the works had been designed and carried out by Mr. Eppelsheimer, he thought that it could be economically used in many places where the locomotive was not suitable. Not one of the systems, however, was of universal application. The cable system could not be economically successful if there was a very small amount of traffic, and on the other hand the steam-locomotive would not be of service in the case of very severe gradients. There was a great difficulty in applying the cable system in places where the roads were narrow and winding, but it might, he thought, be extended, getting rid as it did of the practical difficulty of the movement of a locomotive along public roads. It was hardly fair to compare the working of a tramway at Sydney with that of a tramway in this country, where the Requirements of the Board of Trade were very irksome in regard to the emission of steam and smoke, and that the rails used in a street should have a groove not exceeding an inch in width, necessitating an enormous power in the locomotive. The peculiarity of the Baldwin engine, he believed, was that it had a certain amount of elasticity suitable for very bad roads. That might have been the reason why it was highly valued in Sydney; but he did not know that it was a good reason for its adoption in this country.

Mr. Pritchard. Mr. EDWARD PRITCHARD observed that the engine which Mr.

Parsons had described was working very well ; it met the Requirements of the Board of Trade, and had been advantageously adopted by various companies, judging from the dividends paid to the shareholders. There were one or two points, however, which he proposed to challenge. It had been stated that it was important to have good brakes ; but that was a matter which the Board of Trade had determined. He agreed with Mr. Parsons that it was very desirable that the driver should know when the brake was in perfect order ; but when upon a severe incline the driver's attention had to be directed to the brake fifteen or sixteen times, he thought the service rendered by the brake was not so great as it might be. He would suggest that engine-makers should still consider the best means of putting the brake in operation. With a severe gradient and a slippery road, it certainly did not operate as it should, and it caused excessive expenditure in working the line. On an easy road, or with a clean rail, it only came into operation when the maximum speed was exceeded ; but under other circumstances the result was very different. As to the employment of sand, he might remark, that it was so necessary on one line with which he was professionally connected where the gradients were severe, that he was about to place a small trolley to supply the sand to the rail. Drop-points were no doubt injurious to the life of the engine, seriously affecting the springs, and frequently the wheels themselves ; but that evil, he believed, was in a fair way of improvement by the adoption of a movable toe. There was one method of construction, where the point gave way under the weight of the engine passing upon it, and was replaced by a spring. There was also another, where the point was actuated by the dead weight. How these points might act, he was of course unable to say ; but he believed that the method would be found to be a considerable improvement upon the ordinary drop-point. The question of the cost of working, and the receipts per mile run, had attracted considerable attention ; in fact unless tramways were made to pay, they would not be held in much favour by a certain portion of the population. It had been stated by Mr. Parsons that the cost was 9·33*d.* per mile. He had not given the gradients of the line ; but Mr. Pritchard was acquainted with a line in which those figures closely represented the actual cost. Although there was a length, probably 30 chains, of 1 in 22 or in 23, the cost named had not been exceeded. He had also the experience of another line, where there was a difference of level of 475 feet in 5 miles, giving a prevailing gradient of about 1 in 58. The chief gradients were

Mr. Pritchard. 1 in 15 for 10 chains, 1 in 16 for 12 chains, and 1 in 18 for 20 chains. The Kitson engines succeeded on that line, and that was the line to which he referred in alluding to the erratic action of the automatic brake, and also to the sand arrangements. The cost of working upon that line for the last five months had been 11·1*d.* per mile, and the receipts for the same period amounted to 17·79*d.* per mile. A comparison had been drawn between tramways in Sydney and in England, and a misapprehension, he thought, had existed with reference to the cost per train-mile. The proper course to adopt would be to take the cost and the receipts, and ascertain the surplus. He should be glad to know why in Sydney, where it was supposed that something like perfection had been attained with a much lighter rail than the one used in England, the cost should have been about £15,000 per mile, inclusive of equipment. That was certainly very much in excess of the cost of construction of lines in this country. The percentage of earnings on the capital for 1882 in Sydney amounted to 5·6, but in England there were lines with earnings far in excess of that amount. It was also stated that in Sydney it was common for three hundred passengers to ride upon cars constructed to carry ninety. He had been informed that deaths due to tramway accidents in Sydney were numerous; he should like to know if the death-rate of the city due to such accidents could be given.

Mr. Crampton. Mr. T. R. CRAMPTON was sorry that during a recent visit to San Francisco he had not seen the compressed-air apparatus. The engineer of the cable line took him over the whole of the system, and he could not imagine anything superior; but the cost of it was enormous. The last line was constructed on a gradient of 1 in 8 or in 9, and the company made their own cables, supplying a new one every fourteen months. Everything was of the best quality, and the total cost was \$120,000 per mile. The other systems had not cost so much, but on the tramways to which he referred everything was done in the most substantial manner. The carriages were open and very light, and the people jumped on to them as they pleased in a way that would not be permitted in England. It was not surprising, therefore, that accidents now and then occurred. The Board of Trade would certainly not allow companies in England to carry the same number of passengers. He thought that too much attention was being paid to engines, and not enough to roads. If the roads were made sufficiently good for the ordinary traffic passing over them they would be strong enough for any engines that could be put upon them. It was absolutely

necessary that engines should be kept separate from the carriages, Mr. Crampton. where the traffic was large, and the wheels should be as close together as possible. There was one thing especially against which locomotive engines should be guarded. It had been stated that the Baldwin engines at Sydney ran steadily with horizontal cylinders, and that the Kitson engines did not. This might be so, particularly when the wheel-base was small, and the roads bad. He had no reason to change the views which he had expressed in a Paper presented by him to the Institution in 1849,¹ in which he had discussed at some length the question of the causes of oscillation in locomotive engines. He then showed for the first time how engines could be constructed having every working part without exception within sight, nothing being under the boiler. He also showed the effect of the angle of the connecting-rod in assisting oscillation. He placed the front wheels of an engine constructed upon his system (with driving-wheels behind the fire-box) on a weighing machine, the others remaining on the road, when, turning on full steam, the weight on the front wheels was relieved of 6 cwt. only, and on treating an ordinary engine having driving wheels in the centre in a similar manner, a load of 24 cwt. was taken off. This alternating weight tended to cause oscillation, which increased when the locomotive ran on bad roads; therefore, where convenient, the connecting-rod should be as long as possible, and the vertical thrust should be directly under the centre of gravity of the engine. Engines should be constructed to work steadily on bad roads. It had been stated that high engines ran more steadily than low ones. He imagined when such results were noticed that a well-constructed high engine was travelling on good roads, and a badly-constructed low engine on bad roads. It could hardly be seriously contended that high engines would not swerve more than low ones, the condition of the roads being the same. He should not wish it to be understood that he thought the Kitson engine would not answer its purpose well. Engineers had many circumstances to take into consideration in designing engines, and they could not in all cases adhere to strict principles.

Mr. R. PRICE-WILLIAMS said Mr. Parsons had stated that the first Act for the construction of tramways on public roads was so recent as 1870; whereas an important Act had been passed ten years earlier for Ireland, which had served as the basis of a great deal of subsequent legislation in connection with the subject under

Mr. Price-Williams.

¹ Minutes of Proceedings Inst. C.E., vol. viii., p. 233.

Mr. Price-Williams. discussion and as there were some special features in connection with this Act of 1860, he would briefly advert to it. Powers were given under the Act to the Grand Juries in the Counties in Ireland to facilitate the construction of tramways, and Joint Stock companies were authorized to deposit plans in the ordinary way, and to submit them to the Grand Juries, who were empowered to inquire into the merits of the schemes, and could give their approval and make "presentments" to the Lord-Lieutenant, who might by an Order in Council give it the sanction of law, subject to the obtaining of an Act of Parliament. Compulsory powers were also given to acquire land within 30 feet from the centre of the roads, and altogether great facilities were afforded for the construction of tramways. Unfortunately, however, the requirement of an Act of Parliament, after the sanction of the Lord-Lieutenant had been given, was fatal to the measure. In the next year an Act was passed removing the necessity for applying to the Imperial Parliament for a confirmation. Nothing, however, resulted from this Act for some time; but in 1871, four years prior to the period mentioned by the Author as the time when mechanical power was first authorized for English tramways, authority was given by an Act to employ mechanical power on these tramways; the speeds were limited to 6 miles an hour on roads, and 3 miles an hour in towns. Another Act in 1881 followed, which gave power to increase the speed to 10 miles. But after all this legislation, little progress was made until some advance occurred in England. In 1883, however, a great departure was effected, and power was given to the Grand Juries in Ireland, under a short Act passed at the end of last session, to give guarantees; the Imperial Government also contributing something like 2 per cent. of the cost. Under the influence of that Act, during the last year or year and a half, a considerable mileage of light railway had received the sanction of the Grand Juries, and in some cases the sanction of the Lord-Lieutenant or Order in Council. He particularly referred to the subject, because he thought the time had come when an Act of this kind was urgently wanted in England. The late Mr. Vignoles, Past-President, in his inaugural address in 1870, laid stress upon the fact that there were 160,000 miles of metalled roads in the country, and Mr. Price-Williams found, from a reference to returns made in 1831, that there were about 25,000 miles of public roads and turnpike roads. Many of those turnpike roads ran parallel with and close to the great arterial lines of railway, but at least 12,000, or 15,000 miles, which traversed important agricultural districts at a considerable

distance from any railway, were in every way adapted for the construction of light railways; and if the same powers were given in England for facilitating the construction of light railways and tramways as were given in Ireland, there would, he thought, be a new and important means afforded of supplementing the great arterial lines of communication in the country by valuable tributaries. The distinction in Ireland between a light railway and a tramway was simply this, that a tramway was considered to be entirely on a public road, and a light railway on private ground. If a tramway was constructed on a public road or highway more than 18 feet from the side of the road, it was free from all restrictions of the Board of Trade with regard to levels, and land could be acquired compulsorily except where domains were passed through. If similar powers were granted in England, large districts at present entirely without railway communication would be put directly in connection with the trunk lines, and the new lines would serve as valuable feeders to the branch lines. With regard to the question as to whether they would pay, he might mention that of the 260 miles of light railways and tramways in Ireland, with which he was concerned as consulting engineer, about 100 miles had already been sanctioned by the Grand Juries, and the whole of the capital for their construction found, the average cost not exceeding £4,200 per mile. Table I. (pp. 151, 152) was a statement showing the full particulars of the cost and other details, including the probable revenue. As regarded the paying character of light lines, in all cases in Ireland it had been necessary to satisfy the Grand Juries that there would be a fair prospect of their proving remunerative, because, notwithstanding the great inducement to the employment of capital (chiefly English), afforded by the Imperial and Baronial guarantees, the Grand Juries were very sceptical as to the paying character of the lines. Under his advice, the promoters of the lines had employed a staff to ascertain the amount of traffic in the district. With the view, however, of checking the estimates made by these observers, he had adopted a novel plan, which he thought would commend itself as being safe and reliable, and which he had found of great use. Fortunately there existed in Ireland what was wanting in England, namely, most accurate statistics in regard to the population and rateable value of every parish, township, and barony throughout the country; and it had occurred to him, that, in order to test the amount of traffic in a district unserved by a railway, population might afford a good basis. He had, therefore, accurately defined the gathering-ground of each district.

Mr. Price-Williams.

Mr. Price-Williams.

TABLE I.—TRAMWAYS and

Name of Line.	—	Length in Miles.			Estimated Cost including Equipment.	Estimated Cost per Mile.	Area of District.
		M.	F.	Ch.	£.	£.	Sq. Miles.
Wexford and New Ress .	T. & L. Ry.	32	7	3	144,975	4,405	292
Galway, Oughterard, and Clifden (including Roundston Branch) .	Light Ry.	53	4	0	210,000	3,925	821
Athboy and Castle Pollard	T. & L. Ry.	18	2	9	73,783	4,017	160
Portarlinton and Mountmellick	„	9	0	6	38,546	4,249	58
Maryborough and Stradbally	Tramway	7	1	6	29,143	3,848	65
Mountrath	T. & L. Ry.	3	1	8	15,726	4,483	43
Ballybrophy and Rathdowney	Tramway	4	0	4	19,658	4,700	43
Craughwell and Loughrea	T. & L. Ry.	7	1	0	23,777	3,338	126
Carrick-on-Suir and Callan	Tramway	14	6	4	64,652	4,369	149
Castle Comer and Athy .	T. & L. Ry.	18	6	2	75,825	4,050	155
Virginia and Ballyjamesduff	„	12	0	9	62,660	5,200	144
Foxford and Ballaghadareen	Tramway	26	1	7	94,994	3,700	313
Dromkeen, Cappamore, and Doon	T. & L. Ry.	7	0	3½	33,103	4,729	67
Nenagh and Thurles .	Tramway	23	0	0	94,282	4,100	157
Nenagh and Shannon .	„	10	0	0	43,370	4,337	51
Kilmainham and Bailieborough	„	10	3	7	60,000	5,736	107
		258	1	8½	1,084,494	4,200	2,751
Total of Irish Railways, 1882		2,465	0	0	34,962,665	14,184	32,524

LIGHT RAILWAYS (IRELAND).

Mr. Price-Williams.

Population of District.		Rateable Value of District.	Railway Traffic Value of District.		Estimated Traffic Receipts of Proposed Light Railway and Tramway.				
Total Population Served.	Population per Sq. Mile.		Annual Value.	Per Mile per Week.	Annual Gross Receipts.	Per Mile.		Annual Net Receipts.	Interest on Cost of Works and Equipment of Line.
						Per Annum.	Per Week.		
Number.	No.	£.	£.	£.	£.	£.	£.	£.	Percent.
43,841	150	127,300	25,460	14·9	12,730	387	7·44	8,487	5·85
87,846	107	125,480	25,096	9·1	16,730	319	6·12	11,153	5·30
17,418	108	82,570	16,514	17·6	8,257	458	8·80	5,505	7·46
6,732	117	20,125	4,025	8·5	2,683	296	5·68	1,788	4·64
8,005	123	28,515	5,703	13·3	2,852	345	6·63	1,901	6·52
3,879	90	12,208	2,442	14·6	1,221	379	7·29	814	5·18
4,225	99	18,825	3,765	18·0	1,882	470	9·00	1,255	6·38
10,495	83	31,621	6,324	17·1	2,108	296	5·69	1,405	6·00
19,711	132	73,497	14,700	17·3	7,350	450	8·66	4,900	7·58
19,893	129	65,170	13,034	12·4	6,517	323	6·21	4,345	5·73
24,891	173	67,005	13,401	21·3	6,700	553	10·63	4,467	7·14
46,850	149	56,431	11,286	8·3	7,524	287	5·52	5,016	5·28
8,780	132	22,600	4,520	12·3	2,260	321	6·17	1,507	4·55
17,749	113	58,151	11,630	9·7	7,753	337	6·48	5,170	5·48
5,155	101	14,160	2,832	5·4	1,888	189	3·63	1,259	2·90
18,791	175	44,106	8,821	16·2	4,411	222	8·11	2,941	4·90
344,252	125	847,764	169,553	12·7	92,866	362	6·06	61,913	6·07
5,412,377	166	13,420,022	2,772,585	21·5	..	..	..	..	..

Mr. Price-Williams.

TABLE II.—DEPRECIATION OF LINE. ROLLING STOCK.

	First Cost.	Annual Depreciation.	Period of Sinking Fund, 3 per cent. compound interest.	Annual Cost per Train-mile.	Ordinary Maintenance Cost per Train-mile.	Total Maintenance and Depreciation per Train-mile.	Total Annual Cost.	Annual Cost per Engine and per Carriage.	Money Life.
	£.	£.	Years.	d.	d.	d.	£.	£.	£. Years.
Line	72,000	2,160	23	0·99	0·15	1·14	2,471	..	$\frac{72,000}{2,471} = 29\cdot14$
Buildings	4,000	100	26½	0·05	$\left. \begin{matrix} 0\cdot29 \\ 0\cdot09 \end{matrix} \right\}$	0·43	932	..	$\frac{4,000}{932} = 4\cdot29$
Engines	19,500	1,950	8¾	0·90	0·80	1·70	3,684	147·36	$\frac{780}{147\cdot36} = 5\cdot28$
Cars	6,250	625	8¾	0·29	0·26	0·55	1,192	47·68	$\frac{250}{47\cdot68} = 5\cdot23$
Tools	2,000	100	16	0·05	nil.	0·05	108	..	$\frac{250}{47\cdot68} = 5\cdot23$
	103,750	4,935	16½	2·28	1·59	3·87	8,387	..	$\frac{103,750}{8,387} = 12\cdot37$

TABLE III.—THREE PER CENT. SINKING FUND FOR RENEWALS.

	First Cost after deducting Scrap Value.	Period of Sinking Fund, 3 per cent. compound interest.	Sinking Fund, 3 per cent. compound interest.	Cost per Train-mile.
	£.	Years.	£.	d.
Line and works ¹	52,736	25	1,446	0·67
Buildings	4,000	40	53	0·02
Engines (less 15 per cent. scrap)	16,575	15	891	0·41
Cars (less 10 per cent. scrap)	5,625	10	491	0·23
Tools	2,000	5	376	0·17
	80,936	18¾	3,258	1·50
¹ Average cost of line per mile (see Table, p. 114)	£. 4,521			
Deduct—				
Excavation	£. 717	s. 10	d. 0	
Scrap value of permanent way, 127 tons at £4	508	0	0	
	1,225	10	0	
	1,225			
		Miles.	£.	
		3,296 × 16 =	52,736.	

He found, however, that the population basis was not reliable; and that the rateable value, as indicating the commercial activity of a district, would be more likely to be the gauge of what the actual traffic would be. He had ascertained, in the first place, that the ratio of the entire rateable value throughout Ireland to the entire railway traffic receipts in Ireland was roundly about 5 to 1, and that this ratio was of a very constant character. In other words, given the rateable value of a district at present served by a railway, the railway traffic receipts in that district would be about one-fifth of such rateable value; and he might mention that he had been able practically to test the reliability of this rule, by ascertaining the rateable values of certain well defined areas, such as those served by the Dublin, Wicklow, and Wexford, Cork and Bandon, and Dublin and Meath, railways.

Mr. Price-Williams.

He was glad to have an opportunity of bearing testimony to the way in which the Kitson engines worked; they were eminently suitable for street traffic. With reference to the inclination of the cylinders, although Mr. Crampton was theoretically right, practically the matter was of no moment. He need not go further than the Metropolitan Railway close at hand, where the system was generally adopted. With reference to the plan of condensing steam, he could also bear testimony to the complete way in which that was done; he had had an opportunity of testing Mr. Wilkinson's engine for superheating it, and so far as getting rid of the steam was concerned, it entirely effected its purpose. He exhibited a table to show that Mr. Parsons was in error, in including in his depreciation fund the entire cost of the line and works, and that in such items as permanent-way and rolling stock, subject to wear and tear, and for the renewal of which provision should be made in the early years of the working of a line, credit should be allowed for the scrap value. The total sum for which a sinking fund had been provided by Mr. Parsons was £103,750 (p. 113), and the total annual amount allowed for a sinking fund was £4,935, which at 3 per cent. compound interest, would provide for the renewal of the entire line, buildings, engines, and rolling stock generally, in the short average period of sixteen years and a half (Table II.), the annual amount set aside for the renewals of the engines and rolling stock being sufficient to renew them entirely, irrespective of the credit value of the scrap, in the short period of eight years and three quarters. If in addition to the sinking fund, the amount per train-mile provided under the head of ordinary maintenance was added, it would be found that the total annual sum provided would represent an average "money

Mr. Price-Williams.

life" for the whole of the undertaking (exclusive of the cost of the land) of only twelve years and four months (12·37). In other words, the annual amount provided for the sinking fund and for ordinary maintenance would represent its first cost in that short period; the "money life" in the case of buildings, amounted to the exceedingly short period of four years and a quarter, and only five years and a quarter in that of the engines and rolling stock; whereas the average money life of engines on the principal lines of railway in England and Wales during a long period of years was about ten years.¹ The amount allowed for depreciation was obviously excessive. In Table III. (p. 154) Mr. Price-Williams had shown, that after deducting the cost of constructing the line, and making allowance for the scrap value of the old materials of the engines and rolling stock, the amount of the items, subject to depreciation, would be reduced from £103,750 to £80,936; and that the period over which the sinking fund would operate, would be extended, in the case of the engines, from eight years and three quarters to fifteen years, and to ten years in the case of the cars. The cost per train-mile of the whole of the items included under the head of depreciation, as given by Mr. Parsons, was 2·28*d.*; this would be reduced to 1·50*d.* per train-mile (Table III., p. 154). In the case cited by Mr. Parsons, the amount of the train-mileage was very large, and Mr. Price-Williams thought there was nothing so unreliable as train-mileage, when not considered in connection with all the circumstances of the particular traffic. In this case its effect as a very big divisor on these items of depreciation made their cost appear very small, whereas in reality, as he had shown, they were excessively large.

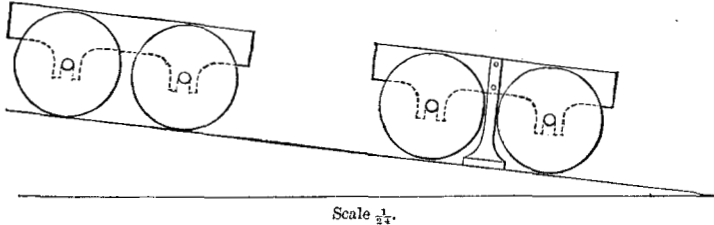
Mr. Wilkinson.

Mr. WILLIAM WILKINSON desired to offer a few observations on three matters,—the motive-power, the "drop-off" point (this destructive element to engines), and the slipper-brake. He had been trying some experiments with the slipper-brake. He had a model with the wheels and axles accurately turned up and made as frictionless as possible, and taking this model with the wheels skidded, tried the following experiments. At what he termed the angle of repose, the machine would neither slide nor be quite steady; if it was touched or blown, it would move $\frac{1}{4}$ inch, and then come to a state of rest. That was at a gradient of 1 in 8. At a gradient of 1 in 7·75, it would gradually slide down hill. Applying the slipper-brake, Fig. 7, in the same way, the results were similar. He, therefore, contended that the advantages generally

¹ Minutes of Proceedings Inst. C.E., vol. xxx., p. 151.

thought to follow from the application of the slipper-brake did not exist; indeed, he believed it to be an element of danger. With

FIG. 7.



SLIPPER BRAKE.

reference to points, he had brought an illustration of a single spring point on the Wigan tramways (Fig. 8). It was a piece of steel riveted fast to the point plate, and as the engine went over, it was sprung open and immediately snapped to again. It had been working for some time at Wigan without the slightest mishap, no engine ever having gone the wrong way. With the drop-off points the engine frequently went one way and the car the other, with very bad results. The simplicity of this point was its principal recommendation. He thought he was the

FIG. 8.



SPRING POINT ON WIGAN TRAMWAYS.

first to attempt to ascend such steep gradients as 1 in 13, and 1 in 12, and 1 in 11½ by steam power, so that he could speak with some little authority on the subject. An engine of his had been before the public for three years, and since then one hundred and fifty of these engines had been built, and were working in various parts of the kingdom, from Gateshead in the North to Plymouth in the South, with some measure of success. That success had been mainly in proportion to the care taken with the engines and the skill brought to bear in the management of the mechanical department on the various tramways on which they had been adopted. Where there was a surplus of engines, so that they could be repaired and kept clean, they had worked very well, but in other places where there had been a deficiency of engines they had failed. He had had considerable experience of the shortcomings of this engine, and he thought there was plenty of room for improvement in working

Mr. Wilkinson, steep gradients at low speeds according to the Board of Trade Regulations. The result was that he had designed another engine to which he now directed attention (Plate 5, Figs. 3 and 4). He had departed widely from the ordinary method of locomotive engineers by adopting a worm-gear, of which it had been prognosticated that it would be an utter failure; but he was proud to say that it was not an engine on paper alone, but one that had been built and which was giving very satisfactory results. It was prophesied that when the steam was shut off from the steam-pistons the worm and the wheel would lock and the engine slide on the rails, but no such thing had happened. A gradient of 1 in 70, which was considered slight in tramway practice, would propel the worm round by the force of gravity. It had also been prognosticated that there would be an undue amount of friction, but that, too, had proved erroneous. No doubt with the old cast-iron worms and worm-wheels there would be, but now that better materials were available, such as phosphor-bronze and steel of various kinds, the case was different. The worm he had used was constructed of Siemens steel, and the worm-wheel ran in an oil bath, so that there was constant lubrication, the oil being carried to the worm and back into the bath with very little waste. To show that there was no undue friction, he might state that the engine would draw a loaded car, weighing 3 tons and as many passengers as could be crowded into it, on a level or nearly level road with the valves in mid-gear, after it was once started. The steam was cut off at one-eleventh of the stroke. Another strong point in its favour was that the cylinders, slide-bars, valve-gear, foundation-plate, worm, plummer blocks, &c., could be all removed from the engine as a whole machine in about two hours by taking away six bolts; and a duplicate engine could be put in its place in the same time by screwing up the same number of bolts. The engine could be left on the workshop floor for repairs, and then go out again to do its duty with the duplicates, instead of having to remain idle.

There was another point in the boiler to which he should like to direct attention. A few years ago the late Mr. Dewrance of Liverpool tried a series of experiments with a multitubular boiler 66 inches long. He divided it transversely into sections each 1 foot long, except the first section against the fire-box tube-plate which was only 6 inches. He found that the first 6 inches of tube, including the fire-box tube-plate, evaporated more water than the whole of the 60 inches length of tubes besides. Acting upon that Mr. Wilkinson designed a short locomotive boiler with tubes only 1 foot long. His object was not to interfere with the water-level

in the boiler in going up such gradients as 1 in 11, 1 in 12, 1 in 13, Mr. Wilkinson. or 1 in 14, as it had been interfered with in the case of the long locomotive boilers. Owing to the trouble that had been experienced in torpedo-boat boilers, with the leakage of the tube-plate through the large range of expansion or contraction in the tubes, he knew that straight tubes would not do, and he therefore put the tubes into a reversed curve so that they would be able to yield a little. He conveyed the exhaust steam from the engine into a condenser which had between 200 and 300 square feet of effective cooling surface. He drew all the atmospheric air to support combustion through those tubes into a closed ash pan. He did not know whether the method was original; he was inclined to think that he had been anticipated in it. All the steam that was not condensed passed into a super-heater with tubes exactly coincident with the boiler tubes, and the gases passed through the super-heater into the smoke-box. When the engine was running on a level with a heavy load and working in mid-gear as nearly as possible, there was such an amount of expansion that the condenser condensed the greater portion of the steam. There was scarcely any steam left of sufficient tension to give the artificial draught required to support combustion. He had, therefore, designed a variable blast pipe, somewhat different from others that had preceded it. These had a cone inside the pipe, by raising or lowering which the annular space was reduced or increased. That would not do, and he had designed a cap, fitting over it like a valve. It was worked from the outside of the smoke-box with a lever. Under a high rate of expansion the cap could be closed, and the area of the blast-pipe reduced to about one-half of its original sectional area, so that what little steam was left increased the blast slightly, and supplied about the right amount of steam. He had also introduced "Field" tubes between the stay girders, or the roof bars of the fire-box. It was no doubt well known that the "Field" tube was very effective for the generation of steam. With reference to slipping on steep gradients, when engines of the ordinary type slipped, they really did slip. He did not say that his engine would not slip, but it slipped slowly; such a rate of piston-speed could not be got up as would make the wheels fly round; the steam was kept on all the time, and by a little sand the slip could be easily arrested. With the ordinary locomotive on a steep gradient, if the steam was shut off to arrest the slip, the engine stopped, and could not start again. Another point had been argued, namely, that there would be an excessive rate of piston-speed in the engine; but at

Mr. Wilkinson, the regulation speed of 8 miles an hour, the piston-speed was only 436 feet per minute, and there was scarcely any express locomotive that did not run at considerably more than twice that speed. He had driven the engine 16 miles an hour in order to test it. He had paid attention to accurate balancing with favourable results. He had further increased the diameter of the driving wheels, up to and above 36 inches, as against the ordinary standard type of tramway-engine wheels. That increased the life of the tires, which was an important item in the working of tramways, owing to the extremely dirty state of the roads, as compared with the clean raised road of an ordinary railway. Again, the increased radius of the wheel, owing to the increased diameter, had a beneficial influence on points and crossings. The less the diameter of the wheel, and the smaller the radius, the more likely it was to take off the tips of the points in crossing.

Mr. Greig. Mr. ALFRED GREIG said that Messrs. John Fowler and Co., of Leeds, had decided a few months ago to manufacture steam tramway-engines. In designing the tramway-engines to meet the Board of Trade Regulations, they had found that there were innumerable difficulties to overcome, of which the two principal were how to maintain a sufficient chimney draught in the absence of exhaust steam, and how to get rid of the exhaust steam without noise, or without its being visible. The first of these conditions had been dealt with by Mr. Parsons, who had stated "about two-thirds of the steam which escapes from the engine is condensed in this way, and the remaining one-third is allowed to pass into the chimney to improve the draught." He quite agreed that one-third would help to maintain the draught; but he could not understand how steam would not show itself in cold or damp weather, however little might escape. Mr. Greig had been compelled to seek some other means of creating the draught, which he had succeeded in doing. Condensing was, he thought, a more difficult thing to get over. Mr. Parsons had stated: "Efforts have been made to economize the consumption of steam in tramway-engines by compounding the cylinders, and in this way not only to reduce the consumption of fuel, but also to avoid to some extent the difficulty of rendering the exhaust steam invisible. The results of experiments so far have not been very successful, and the Author is of opinion that little economy can be effected with an arrangement of this kind. There is also considerable difficulty in starting a compound tramway-engine quickly. To obviate this several ingenious contrivances have been invented; but on the whole a simple high-pressure engine, like the one

already described, meets the requirements most satisfactorily." Mr. Greig. He should like to know on what grounds Mr. Parsons based this opinion. The engines now being constructed by Messrs. John Fowler and Co., for the Brighton Tramway Company, were provided with compound cylinders, not only to economize the fuel, but to aid in dealing with the exhaust steam. He might not have made that departure from the usual practice had it not been for his experience during the last four years with compound traction-engines, of which some hundreds were at work in England and abroad. There was a saving with those engines of from 25 to 30 per cent. in the fuel as compared with single- or double-cylinder engines. As to the starting of the compound engines no complaints had been received; on the contrary they had been found more easy to get out of holes than others. He had made two compound locomotives and had had no difficulty whatever in starting them. His father, who had lately returned from Australia, had seen in Sydney the compound tramway-engines, manufactured at the Baldwin Locomotive Works, Philadelphia, having four cylinders, one high- and one low-pressure at each side placed tandem, and they were doing their work satisfactorily. From recent experiments with air-condensers applied to compound agricultural engines, he had found the exhaust steam much easier to deal with than with the ordinary high-pressure engines. A third difficulty to be overcome, in order to meet the Board of Trade Regulations, was one which cost manufacturers no little trouble, namely that they were required to fit their engines with an automatic-brake which could not be tampered with by the driver. To overcome that difficulty, as far as manufacturers were concerned, and also to remove the excuse so frequently made by the driver, the failure of the automatic-brake, he would propose to reverse the regulation and place something on the engine that would tamper with the man. Having met all the Requirements of the Board of Trade, manufacturers had next to take into consideration the wear and tear which tramway-engines were subjected to. From his experience with agricultural traction-engines and road-locomotives, he was of opinion that in order to reduce the wear and tear to a minimum, not only should the wearing parts be kept as far from the rail as possible, but the wearing surfaces should be excessive, almost twice as large as in an ordinary locomotive. Taking into account the extra expense incurred by having to comply with the Board of Trade Regulations, and considering the extraordinary conditions under which the engines were worked, he thought that tramway com-

Mr. Greig. panies should regard the first cost as a secondary consideration, and allow the makers a sufficient sum to permit them to supply an engine suitable for tramway traffic. That would be a much less costly method of dealing with the wear and tear than by having a large percentage of spare engines, necessitating large buildings, and also extensive repairing shops.

Mr. Lewis. Mr. W. B. LEWIS said it might be interesting to the Institution to know, that light railways in Sydney, with the tram-cars running at 10 miles an hour through the streets, could not exist without some danger to the public. He had seen the Government Report for the year 1882, alluded to in Mr. Shellshear's Paper, and he had found that in that year on the 22 miles then in operation, eight persons had been killed and forty-eight injured. Of the killed, one was a servant of the company, a conductor who was accidentally knocked from the tram-board by a passing dray; three were passengers who contributed to the loss of their lives by attempting to enter or leave the cars when moving; and four, two children and two men, were run over. Of the forty-eight injured, five were servants of the company, twenty-eight were passengers, and fifteen were described as "others." That was a state of things which the Board of Trade would not permit in England. He rather objected to the passage in Mr. Shellshear's Paper, wherein it was stated that the steam-tramways in Sydney were "perhaps the most advanced in the world"; because their cost had been very great, and their construction was not yet satisfactory. The Paper did not give the total cost, for he had found that there was a sum of £14,325 which would have to be added to that named by Mr. Shellshear, who took only one-seventh of the cost of the last steel rails, which had been substituted for the two former sets of rails that had failed. With that addition he found the total amount spent was £426,886, or at the rate of £19,404 per mile—a large sum for railways in the Colony. In New South Wales at the end of 1882 there were in existence 1,268½ miles of railway, which had cost on an average £12,490 per mile, and in Victoria there were 1,562 miles of railway, which had cost £13,757 per mile, the cost of the tramways having been more than either. Some of the railways were double and some single, but the majority were single. On the railways in New South Wales the earnings per train-mile were 7s. and the expenses 3s. 10¼d. In Victoria the earnings were 6s. 8d. per train-mile, and the expenses 4s. 5½d.; on the tramways the earnings were 3s. 9d. and the expenses 3s. 1d. It might be true that train-mileage was a fallacious basis of comparison, but it

seemed to him remarkable that there should be such a large Mr. Lewis. sum as 45*d.* per train-mile earned on a tramway, by a little load consisting of a single carriage with passengers. One fact, which bore on what Mr. Price-Williams had said, was that where there was a population on either side of a road wishing to get up at one point and down at another, tramways paid admirably, but in a sparsely-peopled district he doubted whether they could be made to pay. The secret seemed to be to get a district with a thick population like those places to which Mr. Parsons had referred. With reference to the method of construction adopted in Sydney, it appeared that the road had been laid and relaid three times, and yet the result was not satisfactory, for the engineer of the Colony, in reporting to the Government, wrote, "The repairs and renewals have been very great, but the roads are now mostly in a fair working order. There is great difficulty in keeping the joints good, in consequence of the weakness of the fishing, which cannot be strengthened in consequence of the shallow depth of the rail. Also the creeping of the rails running the joints past the sleepers. This will, I am afraid, always be a source of annoyance and expense, unless a different rail with a continuous iron sleeper be adopted." It seemed rather formidable that in three years three systems of permanent way should have been put down, and that the engineer should be reporting that another was needed, when £19,404 per mile had already been expended upon the work. He had been told, by persons conversant with Sydney, that a great deal of public annoyance was occasioned by the tram-cars running through the streets, some of which were narrow, so that a person in a hansom cab hearing one of the engines approaching was apt to feel nervous. He made these remarks in no adverse spirit; engineers were always glad to obtain experience from the Colonies or elsewhere, because it was only by experience that they could be guided in their practice; but he was afraid that Sydney, however advanced, was not leading in a way that English engineers would like to follow.

Mr. W. EPPELSHEIMER observed that he had been connected with Mr. the cable system from its beginning, having in 1873 built the Eppelsheimer. first successful cable-tramway in the world—the Clay Street Hill Tramway in San Francisco; and since then he had been identified with the system, making it in fact a speciality. He might also mention that he had acted as chief-engineer in connection with the construction of the Highgate Hill Cable Tramway. It was generally agreed that the cable system was an excellent one for tramways on steep gradients, but he ventured to say

Mr.
Eppelsheimer.

that it was equally good for level lines, as had been shown in Chicago, provided there was a frequent service of cars, either at regular intervals or at periods when a great augmentation of the carrying capacity was required. It must be borne in mind that a rope moving in a tube in a tramway track was a movable transmitter, which would carry the power to any point of the line, where the rope was running, and where the force might be required. Instead of any of the surplus power produced by the gravitation of the cars in going down hill being absorbed by the friction of the brakes, it would be received by the cable and transmitted to such section of the line where power was needed, thus relieving the engine. The extra effort required for the starting of a car would, by the help of this transmission, be taken from the common source of motion, and only in such quantity as was absolutely necessary. It would no doubt be observed that this was the only mechanical system by which such an equalization could take place, except, perhaps, electricity, which, however, was not purely mechanical, and could be used only under limited circumstances. Allusion had been made to the enormous cost incurred in the construction of cable-tramways in America, and he was well aware that this system more than any other gave opportunities to the engineer to expend injudiciously a very large amount of money; but he had also found that cable-tramways of proper lengths, say of 2 or more miles, and with a double track, would compare very favourably with lines of any other system when properly equipped for a five-minutes service. Moreover, a cable-line could provide a one-minute service without additional cost, except for cars. As an illustration of the cost, he would give a few figures relative to the lines that he had constructed. The Clay Street Hill Cable Tramway, constructed in 1873, was a double line 3,300 feet in length, and, with land, buildings, and rolling-stock consisting of six cars and six dummies, had cost £17,100, or about £13,800 per mile of single track. The Geary Street Cable Railroad, built in 1879-80, was a double track 13,100 feet in length, or 26,200 feet of single line. The rolling-stock consisted of twenty-six cars and twenty-six dummies, and, with land and buildings, the line had cost £60,000, or about £12,000 per mile of single line. Included in this £60,000 was a sum of £3,000 which had to be paid to two other tramway companies for the right of way over 3,000 feet of their lines, and now those companies drove horse-cars over the cable-track for the distance he had mentioned, the cars following each other about every five minutes. Besides having to join the tracks of the cable-road

with those of the two other companies at the corners for the incoming cars, and at other corners for the outgoing cars, he had to cross three other horse-tramways and one cable-tramway, thus showing the adaptability of the system to crowded thoroughfares. The Highgate Hill Cable Tramway, which was the first of its kind in Europe, was constructed in a district where the Local Boards and the inhabitants were opposed to tramways. It was situated in three different parishes, and the local authorities had been very exacting. The line was only 3,780 feet long, and the track was double for 2,700 feet, the remaining 1,080 feet forming a single line, with two passing-places. The line proper, with the paving specified by Act of Parliament, and with five cars and three dummies, had cost, irrespective of land and buildings, £18,111. The engine-house had been very expensively constructed, owing to the requirements of the landlord, and, together with the lease, cost about £6,000. The engine-power was in excess of that at present wanted, in order to allow for a future extension of the line at the upper end. With regard to the wearing of the ropes and pulleys, which had been referred to as serious, his experience in the matter led him to the conclusion that the cost on that head would be about £180 per mile of rope per annum, which he did not think was a high figure, comparing it with the items of cost either in horse or steam-tramways, for additional wear and tear and sanding of the tracks.

Mr. R. C. RAPIER wished to say a few words respecting a system of tramway-engines that had been very successful on the Continent. It had been alluded to previously in a tone almost implying that it had only been tried as an experiment. He referred to the fireless engines of Mr. Francq, of Paris. These had been at work, more or less, for six or seven years, and at present there were twenty-one such engines in successful operation at Lille; and others employed at Marly, near Paris. They had been continuously in use for some years, and the general result was that, as compared with an engine carrying its own fire, there was an economy, under equal circumstances, of about $2\frac{1}{2}d.$ per mile. He had before him the particulars of the actual expenditure at Lille, as returned by the Company. The engines ran, on an average, 70 miles each per day, which was a good day's work for a tramway-engine, taking into account the number of times that it had to stop and start again. The mileage of each engine was nearly 20,000 per annum. The total number of kilometres run per day by all the engines was 852, and the Company was so well satisfied that they had already discontinued the use of engines

Mr. Eppelsheimer.

Mr. Rapier.

Mr. Rapier. with fires, and next summer they proposed to extend the working of the fireless engine from 852 kilometres per day to 1,300 kilometres, an increase of 50 per cent. With such results the members would not be surprised to hear that the Academy of Sciences at Paris had awarded their Grand Prix Montyon to Mr. Francoq for his improvements in tramway-engines. The condition of the prize was that it should be given to the most worthy inventor in the different useful instruments for the progress of agriculture, the arts, or sciences. The engines obtained their motive power from a large reservoir of hot water, at a very high temperature. That reservoir, when it contained 2 tons of hot water, was enough to serve for a distance of about 8 or 10 English miles. Of the engines at Lille, ten or twelve were in use at a time; and at the end of every trip their reservoirs were connected by a pipe with stationary boilers for the water to be re-heated. They arrived home with perhaps a pressure of 20 or 25 lbs. above the atmosphere, and were charged up to about 250 lbs., and then started again on the road. In the course of the journey they had to mount gradients of 1 in 20, and at Marly of 1 in 18, for a length of 3 furlongs. The system had not made more rapid progress because, to work the engine advantageously, the temperature of the water had to be raised very quickly, and that could only be done where there was a very large boiler-power at the depôt; and this could not be afforded unless there were a good many engines. With twenty engines in use, one would come in about every four minutes, and with two or three large boilers a small engine could be easily re-heated in two or two and a half minutes. But where there were only one or two engines the result was unfavourable, because there would be only one moderate-sized boiler at the depôt, and it would take, perhaps, a quarter of an hour to warm up each engine in turn. That was a tedious process, and on a small scale the system was not profitable. But the fireless engine, worked on a sufficient scale, was a very economical machine. It possessed all the advantages claimed for compressed air and electricity, by admitting the use of inferior coal in big boilers and getting a better evaporation, while with the hot-water engine there was no necessity for any steam-engine at home, nor for air-compressing pumps, nor for dynamos, all of which were troublesome to deal with in the hurry of tramway traffic. Then came the point where the fireless engine was apt to fail. If a small engine, built for an 8 miles journey, was required to run 20 miles, it would fail. But if everything was properly proportioned to the end in view, and to the local circumstances, there

was no difficulty. The quantity of water to be carried was not excessive, having in view the duty to be done. The steam-boiler depôt should be as near the lowest level of the line as possible, and so placed that the latter end of the trip should be on the level or down hill, free from steep gradients. It was obvious that if an engine was required to surmount a gradient of 1 in 20 at the end of its trip, the conditions would not be so favourable as they would be if the engine mounted the gradient first and did the easy work last. Another advantage of the fireless engine was that it did not suffer so much from an imperfect permanent way as small sensitive locomotives. Every jolting caused by the permanent-way damaged the boiler. With the fireless engine the reservoir was simply a large and strong plain cylinder set upon two saddles mounted on the frame. Subjoined was a Table giving the working expenses for the month of November, 1884, on the Lille tramways; also another Table containing particulars of the same tramways.

LILLE TRAMWAYS.

Expenses of Traction for the Month of November, 1884.

Francq's system.

Nature of Expense.	Amount.	Miles Run.	Per Mile.	Observations.
	£. s. d.		d.	
Wages: machinists, stokers, &c.	108 15 10	15,872	1·71	At Lille the cost of coal is 15s. per ton. Wages are very high. The gross cost of the fireless engine is 5·3d. per mile. At Rouen, St. Etienne, Lille, and Paris, traction by steam is worked under nearly the same conditions by ordinary tramway locomotives at a cost of 11·36d. to 16d. per mile. In Paris traction by horses costs 8d. to 10·56d. per mile per single omnibus. The cost of traction by fireless locomotives is therefore much less than the cost of any other system of working, whether by steam or by horses. The saving per day is at least £1 5s. per engine.
Fuel	98 15 0	15,872	1·55	
Other stores	13 2 6	15,872	0·207	
Maintenance	117 4 2	15,872	1·846	
Total cost per month	337 17 6	15,872		
Cost per train per mile . . . . .	..	..	5·104
Cost per carriage per mile . . . . .	..	..	2·656
Cost per ton per mile . . . . .	..	..	0·2737
Cost per seat per mile . . . . .	..	..	0·064

Mr. Rapier. PARTICULARS of the TRAMWAYS at LILLE on which the "FRANCO" FIRELESS ENGINES are at WORK.

Length of line	7 miles.
Length of track with Vignoles' rails	1·8 "
Length of track with Marsillon rails } placed in the paving }	5·2 "
Gauge	4 feet 8½ ins.
Curves { Radius, minimum	65 " 8 "
{ Radius, maximum	2,625 feet.
Maximum gradient	53 in 1,000.
Weight of train with locomotive	25 tons.
Speed per hour, maximum	12·5 miles.
Duration of the journey between Lille } and Roubaix }	50 minutes.
Weight of the engine, empty	7·3 tons.
" " " in working order	9·8 "
Pressure, on leaving dépôt	15 atmospheres.
" at end of journey	5 "
Total train-mileage per annum (20 } minutes interval between each journey) }	276,600 miles.
Number of engines in service and in } reserve }	15
Approximate value of the engines	£12,500
Number of boilers in use and in reserve	6
Total heating surface of boilers	2,368 square feet.
Cost of boilers and fittings	£3,000
Average length of continuous service of } engines without interruption for repairs }	82 days.
Length of run between the limits of } 15 and 3 atmospheres pressure, with } two carriages and a total rise of 315 } feet in the whole journey }	14·2 miles.

Mr. Morris. Mr. W. MORRIS (Westminster) desired to refer to a statement in Mr. Shellshear's Paper as to the engines from the Baldwin Locomotive Works being superior to those of English make. The cause of that would be found, as had been suggested by Mr. Kincaid, to be due more or less to the imperfection of the permanent-way; and it also arose in part from the manufacture of the engines themselves. When visiting America and engaged on Colonial railways he had found great prejudice against the adoption of English locomotives, being informed that they were not suited to a rough and uneven permanent-way. He consulted a locomotive manager who was working with English and American locomotives, and his statement was that the American engine was preferred because the various parts were not so accurately fitted as similar parts in the English engine, that there was more play between the working parts, and that they were therefore more suitable for a rough permanent-way. The English engine did not adapt itself to the

unevenness of their roads. The American locomotives that he Mr. Morris. examined had light frames, and were altogether much lighter than those used in England. The manager further stated that in point of strength the English engines were far superior to the American, and that where an American locomotive would, in case of accident, be broken up, an English engine under similar conditions would be but little damaged. In 1882, when passing through San Francisco, he had the opportunity of carefully examining the working of the cable-system, the results of which he had submitted to the Institution.¹ He was much impressed with the way in which the system overcame such very steep gradients as 1 in 6, and also with the success which attended the brakes that were adopted to guard against accident. He had made a few calculations with regard to the working of tramways by this system as compared with steam. Taking the line referred to, he would assume, as Mr. Parsons had done, that there was a ten-minutes service; this would require twenty-five engines on a double line 8 miles in length. Twenty of the engines would have to be in constant work, the remaining five being spare engines in the shed. These twenty engines would probably require a staff of seventy men—drivers, stokers, cleaners, &c. On the cable-system, as compared with working by steam, there would be a saving in wages of sixty men, which, at 4s. a day, would amount to about £4,380 per annum. A saving in the cost of fuel, repairs and stores, would be 1½*d.* per car-mile as against 3·28*d.*, giving a further saving of £3,250. There was another item of saving on account of depreciation, which he had taken at ¾*d.* per car-mile, and that would amount to about £1,625. The total of the three items came to £9,255, to which must be added the £6,501 placed to dividend by Mr. Parsons; this would give a total net revenue of £15,756. The cost of the tramway mentioned was £6,600 per mile. It had been stated that £10,000 was a fair sum per mile for a cable-road, so that the total cost of 16 miles would be £160,000, the result of the increased revenue being a 9¼ per cent. dividend on the above amount, as against 6·6 per cent., or an increase of 50 per cent. in favour of the cable system of working, notwithstanding its extra cost.

Mr. ROBERT H. BURNETT said, as he had been in Sydney during Mr. Burnett. the first three years of the use of tramways, and had been locomotive engineer of the Government railways in that colony, he desired to draw attention to one or two points relative to the Sydney tramways. In the first place, if the extra cost for

¹ Minutes of Proceedings Inst. C.E., vol. lxxii, p. 210.

Mr. Burnett. maintaining the permanent-way for 1882, amounting to £14,000, referred to by a previous speaker, were added to the cost given in the Appendix, the result of the working in that year would be a little over 2 per cent. interest on the capital account, and the return for the whole of the four years of working—1879–80–81–82—would stand thus: that when in 1879 a length of $1\frac{1}{2}$ mile was in operation, the working cost would be 51·59 per cent. on the earnings, and the rate of interest 33 per cent.; in 1880, with 4 miles open, the cost of working would be 70·83 per cent., and the interest on the capital 12·34 per cent.; in 1881 with $9\frac{1}{2}$ miles open, the cost of working would be 83·31 per cent., and the interest 6·16 per cent.; and in 1882, with 22 miles open, the cost of working would be 93 per cent., and the interest 2·12 per cent., so that as the lines extended the returns gradually diminished—a result that was not at all satisfactory. The cost of the locomotive department of these tramways appeared to be very high, considering the work that was done. The average for three years was nearly 21*d.* per mile, while the cost of working the trains over the most expensive sections of the railways of the Colony for the same period was only 17 $\frac{3}{4}$ *d.* As regarded the work done on the Sydney tramways—although it was a misnomer to call them “tramways” as they were essentially light railways—it was true that two cars, capable of carrying together one hundred and eighty passengers, were used on the trains running on some portions of the lines, and that they were crowded at certain hours of the day, and on holidays, yet the average number of passengers carried, even at the highest computation, was much below the capacity of even one car, as might readily be ascertained by multiplying the number of passengers annually carried by the distance over which they individually travelled (which Mr. Shellshear gave, as a maximum, at 2 miles), and then dividing the multiple by the number of train-miles run in the year. This, it would be found, gave the average number of passengers carried as forty-nine for the year 1880, forty-eight for 1881, and forty-five for 1882. Full particulars as to the number, steepness and length of the gradients were not given, and therefore it was not possible to determine exactly the amount of extra work which they involved. The steepest gradients, it was stated, were 1 in 18, and on one road there was a gradient of 1 in 23 “for a considerable length.” It was also stated that on the heaviest section there was a ruling gradient of 1 in 20 for about a mile. These steep gradients, however, bore, he believed, a small proportion in point of length to the total

length of lines open; and though they doubtless limited, to a Mr. Burnett. certain extent, the loads on the lines on which they occurred, they could not be taken as alone sufficiently accounting for the high cost of locomotion. One of the gradients of 1 in 18 was on the original line of tramway, and was little, if anything, more than $\frac{1}{8}$ mile in length.

The traffic on the railways was, on the other hand, of a very heavy character. It necessitated the use of engines of the most powerful description, with cylinders 18 inches and 19 inches in diameter, by 24 inches and 26 inches length of stroke, with 11 to 12 tons per axle on the coupled wheels, the total weight of the engines with tenders in working order being from 55 to 60 tons. The main lines ascended the mountain ranges to a height of 2,500 and 3,500 feet respectively above the sea, with constantly recurring gradients of 1 in 40 and 1 in 50. On one main line there were gradients of 1 in 30 for 3 miles, and of 1 in 33 for $1\frac{1}{2}$ mile. On the other main line there were inclines of 1 in 30 for a total length of nearly 2 miles, and of 1 in 33 for over 16 miles, with frequent curves of 8 chains radius for an aggregate length of 5 miles. There were also curves of from 8 to 12 chains radius for an aggregate length of 20 miles.

To enable a comparison to be instituted between the cost of working these undertakings in the Colony and in this country, it might be stated that the rate of wages in the former was from 80 to 100 per cent. higher, and the cost of materials used in repairs from 25 to 33 per cent. more than in this country, which, one thing with another, might fairly be taken as adding 66 per cent. to the cost of similar operations in this country. The converse of 66 per cent. on English cost was, of course, 40 per cent. off colonial cost. Therefore, to reduce the figures in the Table in the Appendix to the standard of this country, 40 per cent. should be deducted.

Next, as to the permanent-way expenses, it would be seen from the Table already referred to, that the average cost of maintaining the permanent-way per train-mile, taking the figures as there given, was 7·29*d.*, and, if corrected to include the whole of the expenditure in re-laying the lines in 1882, the average would be 8·95*d.* This was no inconsiderable amount for a "tramway," and was, in fact, more than the cost, per tram-mile, of maintaining for the same period the permanent-way of the suburban district of the main line of railway centering in Sydney, and which, with their far greater weight of trains and engines, amounted to only 7*d.*

Mr. Burnett.

The popularity of the Sydney tramways with those who had occasion to use them, as affording an expeditious and pleasant means of transit, was unquestionable, and the energy with which the system had been developed and managed, and the success which, from some points of view, had attended their working, must be acknowledged. The circumstances which led to the introduction of steam-tramways in Sydney were, however, exceptional. The system was hurriedly introduced in the first instance, and, as the results showed, it had been extended faster than the later experience of its working warranted, either financially or from a mechanical point of view. Owing to the form of the rail, practically an ordinary "railway" rail with a movable guard, the absence of a proper and substantial road-formation contiguous to the rail, and the consequent difficulty experienced in maintaining the road-way at the requisite level, the ordinary road vehicles were greatly inconvenienced in using or in crossing the streets along which the tram-lines were laid; while, in consequence of the high speed at which the motors ordinarily ran, which ranged from 10 to 15 miles an hour (and he had often known it to exceed even the latter speed) all other traffic had practically to give way to them. If confined to the suburbs they might not be very objectionable, but running as they did into the heart of the city, they were a public nuisance to ordinary street traffic, and it might safely be asserted that in few equally civilized and populous cities would such a system of steam-railways be tolerated—certainly not within the outskirts of the town. One anomaly noticeable in these trains coursing the streets was, that while the whole of the railway lines, even in the most secluded parts of the country, were carefully fenced, the public, including the infirm and children, were left, even in the most crowded thoroughfares of the city, without the slightest protection of that kind.

It might, no doubt, be said that the system had been sanctioned by the legislature, the representatives of the popular will, and that that was sufficient justification for its having been adopted. Those who were conversant with public affairs knew, however, that in these colonies Acts of Parliament were not always obtained on their merits. It could readily be shown, by reference to public documents, that the Acts authorizing and providing the sum of £600,000 for the construction, not only of the 22 miles of tramway, referred to in Mr. Shellshear's Paper, as completed at the end of 1882, but of several other routes not then constructed, were passed early in 1880 under special pressure brought to bear on the Government of the day. This was done by large and influential

deputations representing suburban interests, "including repre- Mr. Burnett.
sentatives," to use the words of the Commissioner of Railways in his report to the Minister, "of no less than twenty-two suburban municipalities," and also under the stimulus of the exceptional profits which the special traffic of the Sydney International Exhibition brought upon the original line, and which the official report on the working of the tramways, published up to the end of 1879, showed, in the absence of the heavy charges for repairs and renewals which had since arisen, to have yielded a return of interest on capital equal to 33 per cent. ! The result was that the rights of the city were sacrificed to the interests of suburban municipalities.

Further, if the railway terminus, as constructed twenty-five years ago, had not been inconveniently placed in the outskirts of the city, so as to render it impossible to properly and conveniently connect these suburban municipalities with the business portions of the city, these steam-tramways would never, he believed, have come into being ; and notwithstanding their existence and all the advantages claimed for them, it had been decided, only a few weeks ago, to bring the railway terminus into the heart of the city, a distance of nearly 2 miles, at an expenditure of £450,000.

The heavy and increasing expenditure on the working and maintenance of the rolling-stock and permanent-way, and the consequent falling off in the rate of interest yielded, could hardly be regarded as a satisfactory result at the end of four years' experience of the Sydney steam-tramway system. Nor was it clear how the evil was to be met, for there appeared, by the report of the Select Committee of the Legislative Assembly—lately appointed to inquire into and report upon the purchase of rolling-stock and materials for the tramways, which had just been issued—that there was a great want of unanimity in the tramway department, as to the proper form of motor and vehicle necessary for the economical working of the traffic. By that report it transpired that the combined motors and cars, which Mr. Shell-shear referred to as having been introduced from America, in the hope of greatly reducing the proportion of dead weight to paying load, had not proved satisfactory, and the abandonment of that system was therefore recommended by the Commission.

Mr. W. Lyster Holt said in 1878 he had made some remarks on Mr. Holt.
tramway-engines before the Institution of Mechanical Engineers,¹

¹ Institution of Mechanical Engineers. Proceedings, 1878, p. 434.

Mr. Holt. and also before a Select Committee of the House of Commons,¹ and now with seven years' additional experience he had not changed his views much with regard to the motor that ought to be used on tramways. Hitherto only the manufacturers' and not the practical side of the question had been broached. With reference to the fireless engine, no doubt in some situations it would be suitable; but Mr. Rapier had not explained how he would prevent the visible escape of steam, which was contrary to the Board of Trade Regulations. As to the compressed-air system, the difficulty was, that if anything happened to the engines compressing the air the whole system would fail, and that would equally apply to the cable system. He agreed that for such gradients as 1 in 8 the cable system might be used, but in crowded cities like London, Manchester, and Birmingham, what would the public say if the cable failed for a single day? Their feelings would be very similar to those of the London public if the Metropolitan Railway were stopped for a like period. With reference to the Board of Trade Rules relating to tramway engines, he concurred with Mr. Parsons that as a whole they were a great safeguard to the public, but he thought, with the experience gained in working, that some of them might now be relaxed or modified, and others substituted of an equally stringent nature, with advantage to all concerned. Take, for example, the governor or speed-regulator, a delicate piece of machinery and very liable to get out of order; the Rules stipulated that this should be so constructed that it "cannot be tampered with by the driver," and it had been suggested that because these were in some cases boxed in that they complied with the Regulation; but as the mechanism was ultimately connected with the brake, he thought any driver could prevent their proper working, and it would only be according to all precedent that he would do so if, say, the governor applied the brake unnecessarily with the engine slipping badly on a stiff incline. His idea was that the automatic brakes should be done away with, and the personal responsibility of the driver increased. If the engine- and car-brakes proved insufficient, or failed to act on an emergency, he would make the cylinder-covers and movements strong enough to resist the strain, and would utilize the cylinders for obtaining extra brake-power. There was another stipulation, viz., that "arrangement shall be made enabling the driver to command the fullest possible view of the

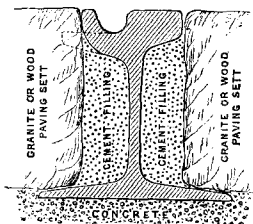
¹ Minutes of Evidence taken before Select Committee on Tramways (use of Mechanical Power) Bills, 1878, p. 33.

road before him," and this, though excellent in itself, might, in a few years, when the boilers became worn, be a source of danger; he alluded more particularly to those engines on which, to comply with this stipulation, the driver was compelled in one direction to be at the smoke-box end of the engine, and when consequently for half-an-hour or forty minutes at a time he never saw the fire-box. Mr. Parsons had spoken of Kitson's variable expansion-gear; but unfortunately drivers of tramway-engines seldom made use of the reversing lever except to reverse the engine, and he would recommend as an inducement that a quick-threaded screw should be used for actuating the expansion-gear and for reversing, as giving greater facilities and nicety of adjustment. Mr. Parsons was of opinion that a compound engine would not be an improvement, but referring to what Mr. Wilkinson had stated, Mr. Holt thought it was a very good system. If, for example, a driver was compelled, in consequence of a vehicle being in the way, to stop on a gradient of 1 in 12, and he could put live steam into a cylinder 16 inches in diameter, he could get over the difficulty of re-starting. As, in England, it was not permitted to show any steam, if by the compound system the steam could be emitted from the large cylinder, say at 6 lbs. above the atmosphere instead of 25 lbs., the difference in temperature of the steam would be nearly 40° , so that there would be this less amount of heat to get rid of in the condenser. There was another advantage also in the compound system. In the case of a line that was level, except for a small length where there was a gradient of, say, 1 in 12, instead of having a heavy engine to do the work, a lighter compound engine, with high-pressure steam admitted into the large cylinder on the gradient, would be sufficient. As far as his experience went, he had never known any engines or cars perform, for any length of time, the mileage suggested by Mr. Parsons, and it would be found in the return of the Board of Trade, that, taking all the cars on steam-tramways, their total mileage did not average more than 27 miles per car per day, while those worked by horse attained over 45 miles per day. Tramway engines did not average more than $33\frac{1}{2}$ miles per day, and, on the authority of Mr. Price-Williams, locomotive-engines did not average more than 20,000 miles per annum. The reciprocating parts of a tramway engine having to work much more frequently than those of a locomotive in the same distance, it could hardly be expected to attain the same mileage for any length of time, and if a tram-engine could be made to perform an average of 10,000 miles a year, that, he thought, would be as much as could be

Mr. Holt. expected. He happened to know that the figures mentioned referred to the Birmingham and Aston Tramways. Now, in the first half year's report the repairs to the engines were quoted at 0·25*d.* per mile run, but in the next year, when the tramway had only been working eighteen months, they amounted to 0·80*d.* per mile. From his experience in Paris, working twenty engines by steam every day, he unhesitatingly said that after five years, tramway-engines would cost from 3*d.* to 4*d.* per mile, and tramway companies therefore ought not to allow a less depreciation than 20 per cent. per annum. The proper place for a speed-indicator, if anywhere, was in the car where the public could see it. An experienced driver knew well enough what was the speed; it was the public who ought to be informed upon that point, as a check on the driver. It would be easy to get a speed-indicator to act as a tell-tale. A tramway engine, in his opinion, ought to have large wheels, if only to lessen the wear and tear on the motion, and the cylinders should be large because, whether the engines had a link-motion or any other expansion gear, by having large cylinders (the size of the boiler need not be altered) they could then advantageously be worked expansively, and there would always be surplus power on a pinch. With regard to sand, his opinion was that if used at all, it should only be to check engines going down inclines. After an engine had passed over sand, the sand was ground into mud, which made it much worse for the engines that followed. On the tramways in Birmingham the rails were 103 lbs. per yard, being heavier than on many lines of railway. Engines to surmount steep gradients must have weight to give plenty of adhesion. Years ago it was a common thing for firemen on railways to be always sanding, but now, except in very slippery weather, they did not do so, because the weight of the locomotive had been increased in proportion to the heavier gradients and loads, and the same thing ought to be done with tramway-engines to work successfully and economically. A tramway-engine should always be run with the fire-box in front, and at every terminus the presence of a triangle, or some other means of allowing the engine and car to turn without uncoupling, should be compulsory. Not only would that be a great saving to the company, because many couplings were broken in shunting, but the driver would be in front of the engine, always near the fire-door and gauge-glass, ensuring more careful firing, and consequent diminution of smoke, whilst duplication of starting, reversing, and brake-gear would be unnecessary.

Mr. F. C. WINBY observed that it was very difficult to make a Mr. Winby. comparison in the cost of working tramways, unless all the conditions were known. One line might be practically level, and another might have many steep and dangerous gradients throughout the whole length of the line. In the one case the cost might be 2*d.*, 3*d.* or 4*d.* per mile, and in the other three or four times as much. The same might be said with regard to the rate of working-expenses at a percentage of the receipts, and also with the maintenance of the permanent-way. Five years ago tramways were a nuisance to the ordinary vehicular traffic, in consequence of the construction of the permanent-way then adopted. The nuisance was not so much in the groove in the head of the tram-rail as in the exposure of the side of the rail to ordinary street traffic, consequent upon the paving setts next the rail being forced below the level of the rail. The rails then used were generally inverted channel iron or T iron, with a groove rolled in the head, and laid on chairs or longitudinal wooden sleepers, 4 inches in width. The strongest of these sections would scarcely support a load of more than 30 cwt. on bearings 1 yard apart, and was altogether unfitted to sustain the rolling-load of a locomotive engine of, say, 10 tons on four wheels. The annexed sketch (Fig. 9) represented not only a very strong rail, but a rail and sleeper in itself, which supported on the bottom flange the granite setts,

FIG. 9.



thus making it practically impossible for them to be forced below the head, and thereby maintaining a level surface. A steel rail of this section, weighing 65 lbs. per yard, would bear 30 tons upon bearings 1 yard apart without appreciable deflection, and being laid upon a continuous bed of concrete, was capable of supporting the heaviest locomotive. It would be seen, by those who had a practical knowledge of the subject, that this section could not be produced by the ordinary mode of rolling rails, and the production was at one time considered impracticable. Hence the many combinations and modes of constructing tramways with the peculiar sections of rails in vogue, on account of the difficulty in rolling a groove in the head of a properly-constructed rail. Mr. Winby had overcome this difficulty by rolling the lip forming the groove parallel with the bottom flange, and then turning it up as it passed through the last groove of the finishing rolls.

Mr. Winby. With reference to points and crossings, the method shown in Fig. 4, p. 111, to acquire a straight lead through the points was wrong, as the engine and car coming from a double to a single line passed unnecessarily to the opposite side of the street, and contrary to the rule of the road. The principle upon which a straight lead through the points should be effected was shown in

FIG. 10.

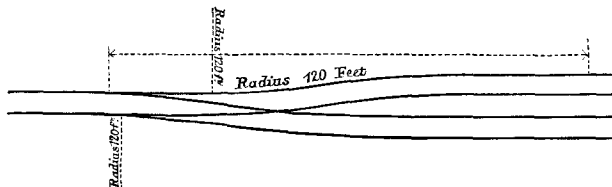


Fig. 10. It would be seen that this was made on the centre line of the roadway, and before diverging therefrom.

Now that all difficulties in constructing a permanent-way had been overcome, there should be none in providing a locomotive equal to the light work of tram-cars; but gradients steeper than 1 in 13 were a serious and dangerous element in working locomotive engines. He had seen, on a gradient of 1 in 13, an engine weighing 9 tons, with a car and freight weighing about 7 tons, with great difficulty keep in position, even with the use of plenty of sand. A car with all the wheels locked, under a slight impetus, would slip down a gradient of 1 in 10, which he considered the angle of repose. A pair of cylinders, with a large range of expansion, acting on an intermediate crank-shaft, placed well above and out of the dirt, and easy to be got at, connected by coupling-rods to wheels of large diameter, and bearing-surfaces of extra large dimensions, well protected, were the principal features to be considered in the design of tramway locomotive engines. He had also suggested the use of mechanical ventilation, to get rid of the heat from the atmospheric condensers, as he had found that one set of tubes acted as a jacket to the others. Simplicity of construction, strength of parts, and anything to obviate trifling repairs, should be the first thought in designing.

Hon. R. C. Parsons. The Hon. R. C. PARSONS, in reply, said he proposed to deal *seriatim* with the remarks that had been made during the discussion. Mr. Edward Woods drew attention to the enormous cost of working the tramways in Sydney as compared with those mentioned in his Paper. He had looked carefully into the various items of cost of working tramways in Sydney. Only two engines had been supplied

by Messrs. Kitson & Co., and the largest number had been furnished by the Baldwin Locomotive Works, of Philadelphia, U.S. As had been pointed out, the cost of $4\frac{1}{2}d.$, which had been stated in his Paper as against nearly $39d.$, showed a very great difference. The engines for light railways in Ireland, supplied by Messrs. Kitson and Co., had the same power as those sent to Sydney, and they were working on lines with very heavy gradients, and drawing loads comparable to those on the Sydney tramways. He had that day received a letter from Mr. John Barton, M. Inst. C.E., the engineer of one of the lines in Ireland, stating that the various expenses of those engines were:—wages, $2\cdot3d.$; oil, $0\cdot35d.$; coal, $1\cdot8d.$; repairs, $0\cdot3d.$, making a total of $4\cdot75d.$ per mile. The expenses of the smaller engines mentioned in his Paper were $3\cdot28d.$ per mile, showing that the large engines cost about $1\frac{1}{2}d.$ more than the smaller engines, and the total expenses of working the line were $1s. 2d.$ per mile. That was only about $2d.$ more than for the smaller engines, and did not amount to anything approaching the expenses in Sydney. Mr. Barton further stated that these engines were frequently driven at 12 miles per hour, and were admitted by all to run very smoothly. He thought the reason why the expenses on the lines in Sydney were so much greater than on the lines in this country might be accounted for, to a great extent, by the extreme roughness of the Sydney line, which was stated in Mr. Shellshear's Paper to have got out of repair several times, and the rails were so imperfectly fished that the joints became very defective, and the engines jolted tremendously. The first effect of engines jolting was that the springs gave way, and after that the various parts of the machinery got out of repair, so that the renewals became very heavy; but in Mr. Shellshear's Paper the items of expenditure were not mentioned, and it was difficult to go more fully into the cause of the excessive cost. He hoped that Mr. Shellshear would supply the Institution with some further information respecting the comparative cost of the working of the Sydney engines. Mr. Scott-Russell had pointed out what he considered to be a defect in Mr. Parsons' Paper, namely that it appeared to deal with a subject which was only in an experimental stage. He thought that the explanation of this misapprehension was very simple. The Paper was written entirely with a view of placing on record what he considered to be the best and most economical form of motive power for tramways. The great advantage of reading a Paper of that kind before the Institution was that it admitted of free discussion, and any one who had information to impart could put it

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forward; and thus there was a chance of arriving at a correct conclusion with regard to the best and most economical system. That was especially the case with regard to steam tramways, which dealt with a motive power that had been coming very much into use during the last few years. Mr. Scott-Russell also drew attention to the fact that the rails mentioned in the Paper were rather light. These rails were 92 lbs. per yard. Even on railways with engines weighing, say 40 tons, that was a heavy section, and he thought that if the rails were increased in weight beyond that it would be merely capital expended without any beneficial result. The joints were fished in the same way as on railways, and from the small wear and tear he thought that the joints had been as perfectly fished as possible. Mr. Scott-Russell next went into the question of HP. required to work the engines. It was difficult to follow his deductions in this matter, as he seemed to omit the question of time. First of all he assumed that 33,000 foot-pounds per minute was less than a HP. It was known that Watt made some careful experiments with regard to the strength of London horses. The London horses were above the average of the country horses, and Watt made out that 33,000 foot-pounds per minute continued for eight hours was the power of these horses. French HP. was below that, being 32,550 foot-pounds per minute, while the estimate made by Professor Rankine, who was one of the most careful experimenters, was below even that amount, and went down to 25,920 foot-pounds. He therefore thought Mr. Scott-Russell was mistaken when he said HP. should be assumed to be 65,000 foot-pounds. On tramways horses only worked a few hours in the day. A horse had done its work after a journey of from 10 to 12 miles, and on steep gradients the distance was sometimes much less. He thought that Watt was not very far out when he computed the strength of London horses at 33,000 foot-pounds per minute. Mr. Scott-Russell next stated that the power of taking a car along a road was 1 HP., and there and back 2 HP. That did not convey any idea to Mr. Parsons' mind. The time was neglected, and Mr. Scott-Russell's computation in that direction did not add much information. The wear and tear of tires on tramways was very great, especially on steep gradients. Mr. Scott-Russell estimated the life of a tire at from 21,000 to 22,000 miles, but a hard steel tire would last as much as 25,000, and he had even known it to last 30,000 miles without being worn out. He did not think there was any chance of arriving at a uniform gauge for tramways, which were generally constructed in towns. Unless

they were laid to the railway gauge there was not much to be gained by uniformity. On the other hand in light railways, as in Ireland, great advantage was obtained by the uniformity of the gauge, namely 3 feet, which had been adopted. Mr. Graham Harris made some remarks with reference to compressed air. He stated that the friction on tramways was very great, even reaching 45 lbs. per ton. Mr. Parsons had never known it attain those figures. He thought that the engine must be very much out of gauge for the friction to reach 45 lbs. per ton, but he had known it as high as 30 lbs. in sticky weather, when the groove became full of mud, which was very incompressible. That was the time when friction reached a maximum. With respect to the combined engine and car he only mentioned that the best system was that introduced by Mr. Rowan, and which was also mentioned in Mr. Shellshear's Paper. Messrs. Kitson and Co. built the one alluded to by Mr. Shellshear, and sent it to Sydney; and he believed it had worked satisfactorily ever since. The chief advantage of a combined engine and car was that a lesser combined weight of engine and car would take a given load up a steep incline. Mr. Harris, he understood, had devoted a great deal of time to the question of compressed air, and he was sorry that the Institution had not been favoured with the results of the experiments, which he believed had been most exhaustive. Attention had, however, been drawn to the working expenses of the tramways at Nantes, as set forth in the Minutes of Proceedings.¹ By reference he found that the expenses of wages, fuel, oil, lubrication, maintenance and sundries amounted to 5·67 pence for one year, and 6·25 pence for another year. That was for an engine with cylinders $5\frac{1}{4}$ inches in diameter, and $10\frac{1}{4}$ inches length of stroke, cutting off at one-third of the stroke. That was a much smaller engine than the one described in his Paper, which had cylinders 8 inches in diameter and 12 inches length of stroke, and cut-off from seven-eighths down to three-eighths. That engine evidently would give out greater power than the one on the Nantes tramway; and from experiments he had made from time to time with compressed air, and from calculations of this form of power, he could not but think that although compressed air was preferable to steam, as it emitted no fumes or anything of that kind, the working expenses of compressed air would not at present compare favourably with those of steam. The economy would be much lower. Mr. Norman Selfe

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¹ Minutes of Proceedings Inst. C.E., vol. lxxviii., p. 488.

Hon. R. C. Parsons, had made some remarks with regard to the Sydney tramways, and threw a good deal of light upon the question, but he only admitted that the lines were slightly out of repair. But that alone would not account for the immense amount of money spent from time to time on those lines. Mr. Selfe also mentioned the system of Mr. Pardy. It was an ingenious contrivance for taking in compressed air on an incline or along the road, and that was the only way in which he thought compressed air could be adopted with economy. It was worked at a low pressure, but he doubted whether a fresh charge of compressed air could be taken in so short a time as five seconds, which Mr. Selfe seemed to think possible. In this country the engine would have to wait more than five minutes to get a fresh charge. It was surprising how inefficient compressed air was when severe gradients had to be surmounted. The weight of the reservoirs was so great that the compressed air was soon exhausted, and a fresh charge had to be supplied. Mr. Cotton had directed attention to the question of no steam being allowed to go up the chimney of the tramway engine, and seemed to advocate the Merryweather engine. That was an engine he had had considerable experience of, and had seen it on various inclines, when steam was emitted freely from the chimney. Steam was allowed to go up the chimney, for the purpose of accelerating the draught and working with a lighter boiler. If no steam was allowed to go up the chimney, the boiler would have to be excessively large, and the engine proportionately heavy. A small amount of steam going up the chimney was generally not visible, except on a very cold, damp day; a very small amount of steam, if emitted, would be visible. The Board of Trade Regulations, as stated in his Paper, had been considerably modified during the last two years, and a small amount of steam at the present time was allowed to be emitted, unless it was proved to be a definite annoyance to the public. For the economical working of a tramway, this advantage, which had been wisely allowed by the Board of Trade, should be made use of, and the engines proportionately reduced in weight. Mr. Cotton mentioned that, on the Stockton and Darlington tramways, the working expenses were much lower than those he had quoted. Mr. Parsons had obtained the last report of those tramways, and he found that the working expenses were within 0·03*d.* of those mentioned in his Paper, or practically the same. Further on that line the receipts had been so low during the last year that even the Secretary had foregone £40 of his salary, showing that the working expenses must have been reduced to the very minimum. On that line also

the cars were made to carry only from thirty to thirty-five passengers, while the cars on the line described in his Paper carried sixty passengers, and were generally fully loaded. The receipts on the Stockton and Darlington tramways showed that only six or seven passengers, on an average, were in the cars, and he thought that the working expenses on the Birmingham and Aston tramways, were far lower than on the Stockton and Darlington. Mr. Cotton also stated that, on the Dewsbury and Batley line, the working expenses were 2·57*d.* per mile. He had worked an engine on that line, and found his expenses there would, approximately, be the same as stated in his Paper, and as to reducing them down to 2·57*d.* per mile, he believed it was practically impossible. Mr. Joseph Kincaid next gave an account of the present position of the tramway question, and it was very fair in every way, except that it was stated that the engines described in his Paper had no water condensation. They had a water-tank, which absorbed a considerable amount of the steam which escaped uncondensed, and in very bad weather it was most useful. Mr. Pritchard drew attention to the question of a fifth-wheel, and the automatic brake being worked by means of it. Now the fifth-wheel actuated the brake without any connection with the wheels of the engine, and it had the advantage of not shutting off the steam when the driver allowed the engine to slip. In some ways, the automatic brake attached to the wheels was a safeguard against a careless driver allowing the wheels to slip round and round, and thus prevented the tires becoming worn out sooner than if no arrangement of this nature was attached. Mr. Crampton referred to the question of the oscillation of the engines, due to the outside cylinders being placed at an oblique angle to the line. He had made some experiments since the Paper was read, and he found, when the steam was admitted to the cylinders, there was no oscillation whatever. This effect could not be detected in any position of the crank, and he thought it could not produce any appreciable unsteadiness. The question of compound engines was a most important one, as economy of steam consumption was one of the first items to be considered, and Mr. Greig stated that the economy he had obtained from compound-engines as compared with simple ones amounted to from 25 to 30 per cent. Unfortunately the Royal Agricultural Society of England had not as yet undertaken trials of compound *versus* simple engines; but valuable experiments had been made in Germany with a view to ascertain what was the advantage of the former over the latter. Those experiments had been published

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Hon. R. C. Parsons. in a German periodical,¹ and an abstract had appeared in the Minutes of Proceedings.² The two engines that had been compared were, one a simple engine constructed by Wolf of Buckau, and the other manufactured by Messrs. Ruston, Proctor and Co. The result was that the gain in economy of the compound-engine amounted to 10 per cent. That was a very small advantage for a compound-engine, and he thought the extra complication which was introduced into a compound-engine as against a simple engine was greater than the resulting economy was worth. Mr. Lewis had given some valuable information with regard to the question mentioned in Mr. Shellshear's Paper of doing without a condenser, and allowing an engine to puff through the streets. It appeared that forty-eight persons had been injured and several killed in the streets of Sydney during the year, and this showed that the Board of Trade Regulations were necessary to protect the public from injury. Mr. Rapier mentioned that the economy of the hot-water engine over steam was $2\frac{1}{2}d.$ per mile. If that was subtracted from the working expenses, as shown in his Paper, there would remain only $\frac{3}{4}d.$ per mile to pay the driver, and nothing for any other expenses, and it would be very difficult to find a driver for $\frac{3}{4}d.$ per mile. A hot-water engine therefore could hardly be worked at as cheap a rate as Mr. Rapier had stated. Mr. Holt considered it would be a great advantage to reduce the number of parts in a tramway-engine, and make it more simple. He thought the Board of Trade had very wisely imposed the various restrictions. They were for the benefit of the public, and though Mr. Holt seemed to object to the automatic brake, he regarded it as a protection to have one on an engine.

Correspondence.

Mr. Aspinall. Mr. J. A. F. ASPINALL remarked that a short branch of light railway was being worked by the Great Southern and Western Railway Company of Ireland. The branch in question left the Kerry branch of that railway at Gorbaltea, and ran to Castle Island, a distance of $4\frac{1}{2}$ miles. It was laid to the standard Irish gauge of 5 feet 3 inches. It had been constructed under the "Regulation of Railways Act, 1868," 31 & 32 Vict., c. 119, which in clause 28 enacted that :—(1.) "The weight of locomotive-engine, carriages,

¹ "Der Civilingenieur," 1884, p. 237.

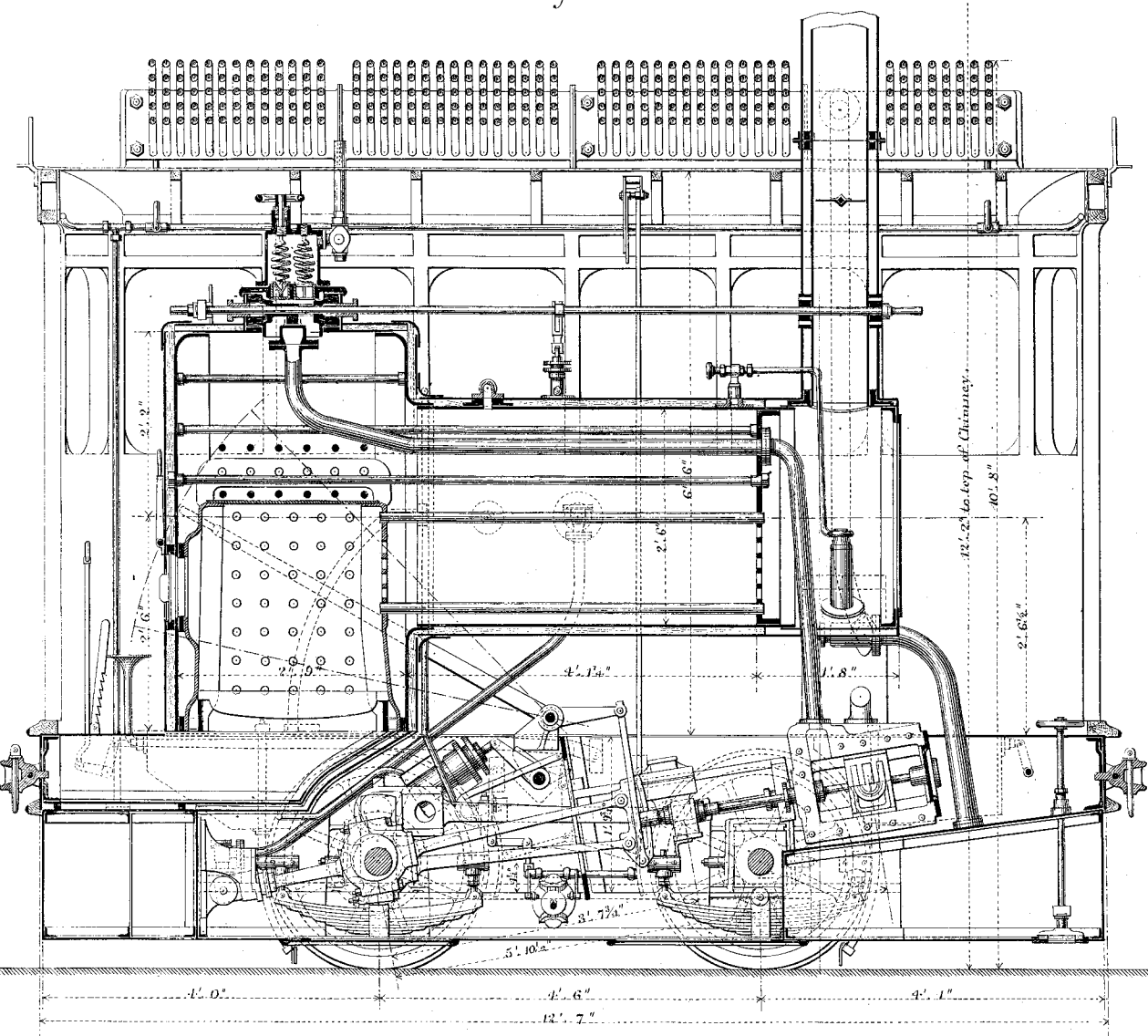
² Minutes of Proceedings Inst. C.E., vol. lxxviii., p. 507.

Fig. 1.

Fig. 2.

Fig. 3.

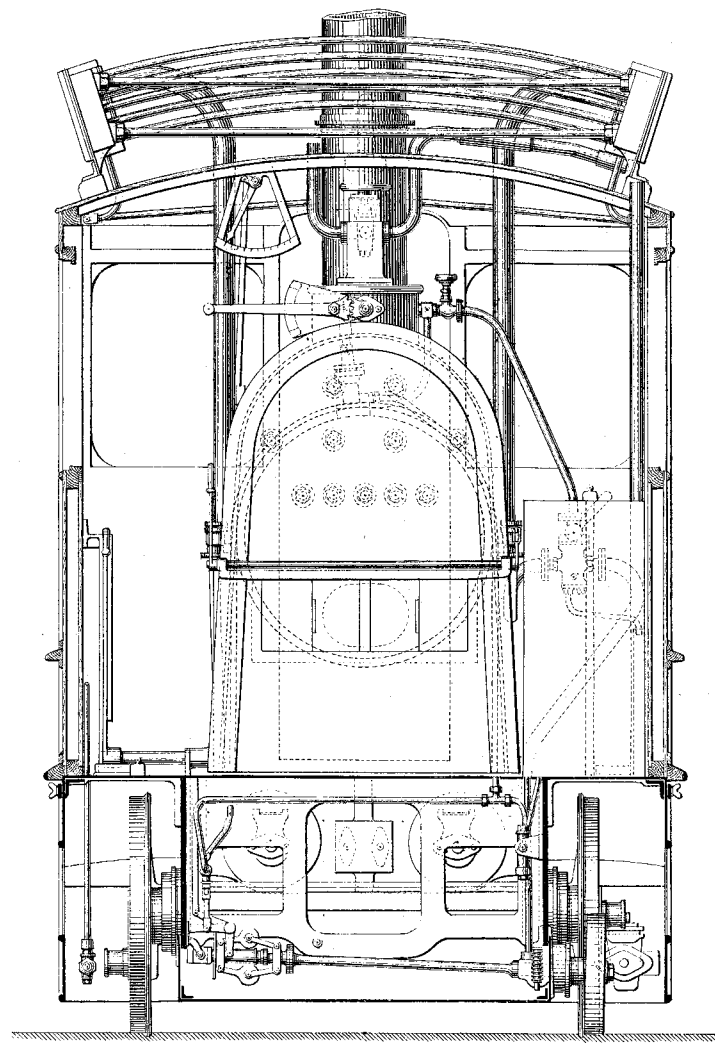
Fig. 4.



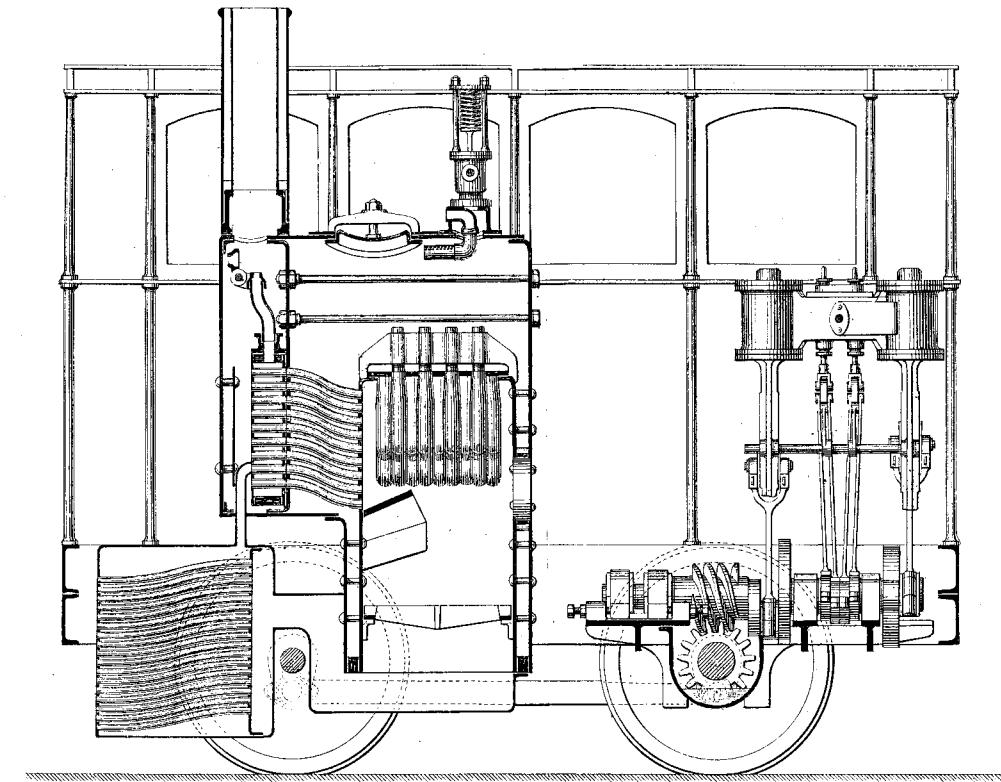
SECTIONAL ELEVATION.

THE FALCON ENGINE WORKS TRAMWAY LOCOMOTIVE.

Scale, 1/2 Inch = 1 Foot.
 Ins. 0 1 2 3 4 5 6 7 8 9 Feet.



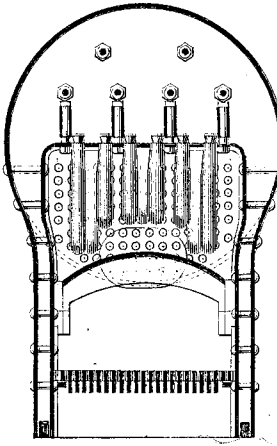
CROSS SECTION.



SECTIONAL ELEVATION.

THE WILKINSON WORM-GEARED TRAMWAY LOCOMOTIVE.

Scale, 3/4 Inch = 1 Foot.
 Ins. 0 1 2 3 4 5 6 7 Feet.



CROSS SECTION.