Mr. J. GRANTHAM said, as a model of the steam tramway carriage, constructed under his direction, had been submitted to the Meeting, some explanation in regard to it would probably be acceptable. Several gentlemen being desirous to ascertain whether it was admissible to use steam in streets for the conveyance of passengers, had liberally determined to defray the cost of building a carriage, with which certain experiments had been made in private. It was a common tramway carriage, with power applied from the centre. The experiments had hitherto been satisfactory; and the only question now to be solved was whether it would be objectionable in the open streets. One of the tramway companies had granted permission for the carriage to run on a line, at present not in use, where the public could see it. It had a boiler chamber on each side, and the centre passage was preserved intact. There was nothing peculiar about the engines, and they worked under the seats of the carriage. In hot climates, the car would have a canopy provided for the passengers on the roof. The principal fact to which he desired to draw the attention of the Meeting was that the passengers could pass, without any obstruction, from end to end of the carriage, both inside and out. As was usual with tramway cars, the carriage was not turned, but each end became alternately the back or the front. The handles for working the engine were transferred, the gates were opened and closed, the steps lowered and raised, and all the operations reversed, as usual on horse tramways. He would notice the extent to which the experiments had been carried out. The place in which the carriage was built was under a railway arch, and there was sufficient space for it to run about twice its own length; but that was too limited to give any evidence as to the effect of the steam from the funnel. It had been ascertained that there was no heat perceptible to the passengers inside. There were small mirrors at the end of the chambers containing the boilers, and after the steam had been up for 3 hours, or 4 hours, those mirrors were quite cold. There was no annoyance to passengers from smell or from the motion; and it was also clearly shown that the carriage could be started and stopped with greater ease and rapidity than when horses were employed. He hoped shortly to have an opportunity of placing it on a tramway where it could be seen by the public.

Mr. T. AVELING said, the cast-iron wheels of the engine referred to in the Paper as having been tried at Wolverhampton, and as having drawn $3\frac{1}{2}$ times its weight, had no cross bars upon them. The bearing surface of the wheel on the road was perfectly smooth. If the engine had been fitted with cross bars, as wheels were fitted for locomotive purposes, it would have nearly approached—as it had since—the tractive power of the india-rubber tires fitted with cross-bars. He agreed as to the great advantage derived from the use of india-rubber tires upon paved roads. In fact, it was an extremely difficult matter to draw a load on a pavement with a rigid wheel, but on macadamised roads its performance was satisfactory. There was, however, so much expense attending the use of flexible tires, that the benefits obtained from them must be much greater than had yet been shown before their general adoption would be warranted.

A pair of elastic wheels on Adams' system had been made by Messrs. Aveling and Porter for one of Mr. Neville Granville's engines. Mr. Aveling had been told that they had run 500 miles; but it was difficult to keep the outer tire and the inner tire coupled together. The action of the wheel, as far as making it more comfortable for the driver, was no doubt an improvement. The engine could also draw more with wheels fitted in that manner on paved roads, because the contact was more certain at all times. The wheel did not jump from one stone to another; but nevertheless he was not satisfied with that description of wheel. He might add, he had lately tried experiments with spring tires and rigid tires on good macadamised roads, and he had never found that a wheel which flattened itself on the surface of the road could draw the load with the same pressure of steam as a rigid wheel fitted with wrought-iron cross bars. The flexible wheel would require from 6 lbs. to 8 lbs. more steam pressure. On the whole he considered the 'rigid' system to be preferable to the 'flexible' system.

Mr. L. J. Todd considered that if steam tramway locomotion was to be successfully carried on it must be done by a separate engine drawing a car. Any combination of the boiler and machinery with the passenger carriage — like the successive attempts made by Gurney, Hancock, and Scott Russell, in Great Britain, and by Remington, Baxter, and others, in the United States — would prove, more or less, unsuccessful. It would be dangerous to run the car referred to by Mr. Grantham in the streets, as it had two boilers shut up in small spaces, in which the driver could not see what was going on. Supposing it was running on a dark night, and the driver happened to be a little intoxicated, an explosion would probably take place. The passenger engine called the 'Pioneer,' tried in Edinburgh a year or two since, was similarly constructed. It had a single boiler at one end of the car, and below the floor three cylinders coupled to one pair of the wheels; and from the mud and dust it was found impossible to keep the working parts in order when running on common roads—even on those in the best condition—so that in three months, or four months, the whole of the joints and brasses had to be renewed. Again, if the engines were placed below the car, and there was the slightest escape of steam from the glands, it would rise through the floor of the carriage and frighten the passengers, especially if they were ladies. On one occasion the exhaust pipe of the 'Pioneer' burst, when it was taking out the Town Council of Leith for a trip, who, when they saw the steam issuing through the floor, very speedily 'cleared out' and ran off for some distance. That was an accident; but even a little steam coming up from the glands through the floor would frighten ladies in such a way that they would not travel in the car at all. The canopy for the outside passengers alluded to by Mr. Grantham would always be required, as with a short funnel coming up through the roof in the midst of them it would be impossible they could otherwise be kept free from smoke and soot. In the 'Pioneer,' the smoke was carried off at the rear of the carriage by an opening at an angle of 45°, so as to discharge the dust and steam behind, and yet it was found impossible to keep the roof seats clean, and the fireman at the end of each run had to go up and sweep the dirt away. Then, again, in the matter of repairs. It was better to work at an engine in a shop into which it could be taken by itself, and where it would be apart from the passenger car. With the 'Pioneer,' it was found that the fittings of the passenger carriage were very much damaged by the smoke and dirt of the repairing shop; and it would have been much better if the engine could have been repaired by itself, and the carriage have been left free for service. Mr. Todd would repeat that the worst feature of the carriage described by Mr. Grantham was the enclosure of the two boilers in places where they could not be easily inspected, as such an arrangement must sooner or later be the occasion of an accident.

Mr. Bramwell said, the subject of which the Paper treated was one of great interest to him, and had been so ever since his apprenticeship, when he became acquainted with the well known Walter Hancock, the most successful maker of common road locomotives, and was frequently with him at his manufactory at Stratford.

The scope of the Paper was very extensive. It included the self-propelling passenger carriage for high speeds; the high speed traction engine; the slow speed traction engine for goods; the self-moving engines for ploughing, and for other agricultural purposes; the self-moving tramway car, or the traction engine for such cars; and it also included steam road rollers. It thus opened out a wide field of discussion; but Mr. Bramwell would not weary the Meeting by attempting even to touch upon the whole of those matters, but would confine his remarks almost entirely to one division, namely, to the quick traveling, self-propelling passenger coaches. The Author alluded to the names of Gurney and Hancock, but there were other names which might be mentioned, such as Ogle, Maceroni, Dance, and Church.

With the exception of the steam ploughing locomotive, which was worked in the field, and not upon roads, and the steam roller commonly used on roads which were for the time closed against horse traffic, the question whether or not locomotives could be employed on common roads depended in a great measure upon whether or not horses would be frightened by them. Mr. Hancock for many months used to run his steam carriage regularly from Paddington to the Bank and back, and in the other direction from Cornhill to Whitechapel, among the ordinary omnibuses. For the first week or two after the steam omnibus started the horses along the road showed signs of inquietude, but after the running had continued about a fortnight the ordinary omnibus horses on the road paid no attention to the steam. When strange horses went by there was frequently some sign of restlessness, but not much. Mr. Bramwell thought a great deal of this indifference on the part of the horses to Hancock's steam coach arose from the care which had been taken to make it in a shape that should be "reasonably agreeable" to horses. One of Hancock's earliest steam carriages was called the 'Infant.' Some years after its construction he built another and larger carriage, called the 'Automaton,' of the same general form; another, called the 'Era,' which had an ordinary coach body; and another, called the 'Autopsy,' with an omnibus body. All those were built more or less like ordinary coaches and omnibuses, and, being so, they did not appear to offend the susceptibilities of the horses. Further, Mr. Hancock took care that there should be no moving machinery visible. With the exception of the driving wheels there was not a particle of moving machinery to be seen; and there was no smoke, because coke was used; neither was there any noise. The waste steam was blown into a box, and issued by a number of holes into the fire, and escaped quietly, and any steam from the safety-valves was dealt with in the same manner. In that way the steam coaches passed along, and neither by the sight of moving machinery, nor by the sounds of waste or escaping steam, did they cause alarm. Mr. Bramwell thought, if similar care were taken in

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the present day to conceal the moving machinery, and if the noise of exhaust steam and that of steam whistles were dispensed with, there would be little if any trouble with regard to horses.

Further, in his opinion, after the engineer had paid all the attention he could, to make the construction of those engines as little offensive as possible, the matter was one of such importance that—if horses were still to some extent alarmed—the proper course would be not to settle the question by forbidding the use of such engines on common roads, but to solve it by educating horses to pass steam carriages without being frightened by them, as they were now educated to pass military bands and railway bridges, or to pass other things which were sources of annoyance. It was well known that horses about railway stations paid no more attention to a locomotive than to another horse alongside them. There would be no difficulty in thus training horses if it were worth while—and he thought it was.

Mr. Bramwell believed that Mr. Hancock, between 1830 and 1840, did more to show what was practicable on common roads with steam locomotives than any other person had done before or since. In each of Hancock's carriages the engine was in one with the body of the coach, but the objections to that mode of construction which had been raised by Mr. Todd did not apply, inasmuch as the boiler was placed at the hinder part of the coach. The engine was in a separate room. The water-tanks were placed under the passengers' seats; and the blowing-fan was under the ash-pit. The boiler, the soul of such machinery, was ingeniously constructed. It was stated in the Paper that:—"The boiler was about 2 ft. square and 3 ft. high, and was made with flat chambers, 2 in. wide and $\frac{1}{8}$ in. thick, covered with bosses, arranged in such a manner that the bosses of one chamber touched the bosses of the neighbouring chamber, thus forming abutments, and at the same time increasing the heating surface."[1] It was rather an inaccurate phrase to say that the boiler was made with chambers, for the chambers formed the boiler. The principle on which each chamber was made was very simple, namely, the same principle as that on which an ordinary biscuit-bag was made. The sheet of iron was bent in the middle until the two portions were brought parallel, the one to the other, in the same way that a sheet of paper was folded to make the two sides of a bag; then the edges of the sheet of iron were brought together, and were united by being riveted up the two edges and along the top. Thus there were no rivets at the

[1] *Vide* ante, p. 48.

bottom of the chamber – the part which was placed immediately over the fire. In that way there was formed a flat chamber 2 in. wide; a number of those were put side by side, with spaces between each; the spaces were also about 2 in. wide, and through those spaces the fire played. Evidently no form could be more improper for withstanding a high pressure of steam than that of a flat chamber, but Mr. Hancock got over the difficulty in the following manner:—The sides of the chambers were covered with hemispherical bosses, and when the chambers were put together side by side the summits of the hemispheres—if he might use the word summit to a hemisphere—impinged one upon the other, and thus every chamber was the support of the chamber on each side of it. In this way the boiler was self-supporting until the two outside chambers were reached; those required further support. That was given by a thick wrought-iron plate the full size of the outside chambers which bore on their hemispheres; outside those plates strong girders were put in three places, and bolts outside the chambers passed through the ends of the girders and braced the boiler together, aided by two other tie-bolts, which passed, one along the lower part, and the other along the upper part of the boiler. In the centre of each chamber there was a vertical plane raised to the same height as the hemispherical bosses, so that when the chambers were placed together those raised planes nearly touched each other from top to bottom all the way down the middle. Further, there were introduced into each of the chambers two rings of gun-metal as wide as the chambers in those raised parts were broad, namely, about 4 in.; those rings had a number of small holes passing radially through their circumferences, while through the large central hole passed one of the tie-bolts; that bolt was much smaller than the central hole, and thus there was an annular space between the outside of the tie-bolt and the inside of the ring. Then there was a ring of copper wire between each chamber, and pressure being applied by the bolts, the whole was screwed up tight. Thus not only was the boiler held together by those bolts and ring washers, but they formed an annular tube at the bottom and another at the top, the bottom one serving as the feed tube to all the chambers, and the top one as a steam-pipe from all the chambers.

Other matters worthy of notice were considered by Mr. Hancock. One was that instead of placing the driving wheels direct upon the crank shaft he placed them upon a separate straight axle driven from the crank shaft by means of a chain and pitched pulley. The relative distance between the two shafts was always, notwithstanding any rise or fall, preserved by horizontal radius rods. That enabled him to use perfect carriage-springs for the driving wheels without interfering with the action of the crank shaft of the engine. In those days neither donkey engines nor injectors were known, and thus driving as a second motion afforded great facility for working feed-pumps when the coach was not running. All that was necessary was to throw out the clutch from the chain pulley, and then the engine could be worked as might be desired for the purposes of pumping, or of urging the fire by the fan-blast.

The wheels were not rigidly attached to their driving axle, but were loose upon it, and were worked by clutches. Those clutches had a large amount of clearance; so that the carriage, when steered on any short easy curve to pass another carriage, could obey the steersman with facility, because the driving wheel which was on the outer side of the curve could overrun its driving clutch, and thus keep true pace with that of the inner wheel. Moreover, when it was required to turn the coach in its own length, that was effected by throwing out of gear the clutch of one of the wheels, which then became the pivot on which the coach turned.

There was another question which was worthy of notice—that was, with respect to the fire bars. Two sets, coupled up, were provided, and were so arranged that when one set were slid into the fire the other was outside; thus when one set of bars became clinkered they could be withdrawn, and another clear set could be put in, and when the clinkers were scaled off the first lot of bars they were ready to be put in again. The steering arrangement also was well thought out: it consisted of a chain and wheel; and the peculiarity was that the driver, with a pedal, could hold the fore wheels in any required position without strain on his hands, which were only employed when the pedal was relieved preparatory to its being required to alter the direction of the carriage.

Much had been said in the Paper in reference to the great trouble of road locomotives—the driving wheels. That trouble was no new one; for Mr. Bramwell remembered Mr. Hancock had said to him:—"You will be surprised to hear that the point in which I found most trouble is one that seems the most simple: that is, in the tire of the driving wheels, owing to their great wear." In Hancock's carriages the wheels were made of wood. As regards their felloes and spokes, which had radiating ends secured into cast-iron plate bosses, although the spokes were straight, that is, were not 'dished' at all, the material — wood — afforded a certain amount of elasticity, which enabled the wheels to stand the work for many months. It should, however, be borne in mind that the engine was not one of those ponderous machines which were now employed for traction on common roads, weighing from 8 tons to 11 tons. For instance, the weight of the 'Infant' was only about $3\frac{1}{2}$ tons, although it conveyed 16 passengers, besides the steersman.

Mr. Bramwell thought that, of late, sufficient attention had not been paid, in the science of common road locomotives, to the possibility of making light engines. With such engines of course the power to draw heavy loads could not be obtained, but for passenger carriages containing the motive power within them, where there was nothing but the load of the vehicle and of the passengers to propel, there was every inducement to make the weight as small as possible. It must be remembered that although greater weight gave greater adhesion it required greater power, and greater power required greater weight, so that the increase might go on indefinitely, as in the contest between big guns and thick armour plates. That the great weight was not necessary for quick passenger traffic they knew from Mr. Hancock's experience. Neither was great weight a necessary accompaniment of great power. On this point he would wish to instance that which Mr. Thorneycroft had done in engines for river navigation. He had produced 70 I.H.P., with a weight of only 4,900 lbs., including the water in the boiler and the weight of the propeller, with its shaft. Those who had devoted attention to the subject would bear Mr. Bramwell out in the statement that light engines could be made, and he was certain when that was done the great destruction of the wheels spoken of in the Paper would not take place.

He would mention that Mr. Hancock was one of the first to discover that the way to keep the boiler from priming was to cause the steam to come through an extremely small steam-pipe—namely, $1\frac{1}{4}$-in. steam-pipe for a pair of 10 in. cylinders in the 'Automaton;' and he was one of the first to use the eccentric rod with inclined horns and a 'gab' on each side to get reversal of motion. The ability and skill showed by Mr. Hancock in the mechanism of his common road steam coaches so long ago as 1835 would do credit to the most talented Engineer of the present day.

With respect to traction engines, the Author had shown the effect of putting the load upon an india-rubber tire, namely, that it threw out the tire in advance of the wheel, and that it caused the tire to assume different thicknesses in different parts. On reflection it might be perceived that the action of a load upon such a tire advancing over a surface was very much that of a rolling mill, and that the tire was being thinned at the part below the middle of the wheel. This of necessity forced out the accumulation in front, and caused the tire to slip round to bring the material again into its proper position. Mr. Bramwell must say he had entertained a very high opinion of those india-rubber tires, first, because they appeared to afford a spring in the place where the spring was best situated; that was, in the nearest point to the road; and, second, because of the great adhesion they gave on paved and on other road surfaces. He feared, however, the elasticity of those tires was not perfect, and that they absorbed power in the continuous change of form. He was led to that conclusion by the fact, that, after some amount of working, there was a considerable generation of heat within the substance of the tire, which was indicative of work put into it, and was inconsistent with perfect elasticity. That development of heat was accompanied by a strong smell of sulphur. As to the great powers of traction possessed by india-rubber tires upon ordinary roads there could be no doubt.

The Author had alluded to some experiments made by Mr. J. Easton and by Mr. Bramwell, in which, fortunately, they were able to try the very same carriage with india-rubber tires and with plain cast-iron wheels. They also tried them in competition with another traction engine which had cast wheels, with a sort of cellular pattern on the tread—not with ribs across, as was stated in the Paper. On good hard road the proportions were:—for india-rubber, a tractive force of 45 per cent. of the insistent weight; for cast-iron wheels, with a cellular pattern on their treads, 35 per cent.; and for small smooth-faced cast-iron wheels, 25 per cent. No doubt on ordinary roads the india-rubber had great advantage in tractive force, but when those engines were used on wet land the conditions were not so favourable for india-rubber. The same engines had been tried over a farm after 24 hours' very heavy rain, and then the cast-iron wheels succeeded in drawing loads through most difficult places with remarkable ease. The india-rubber wheels, unhappily, did not succeed. The clay was spurted up from under the wheels, and entered between the india-rubber and the iron rim round which the india-rubber was placed, and so lubricated the parts that there was a revolution of the iron rim within the india-rubber. Notwithstanding this failure on wet clay soil he still had a very high opinion of india-rubber tires for road purposes. He was rather alarmed, however, at the statement made in the Paper that the old india-rubber tires were of very little value. The late Mr. Thomson, the inventor of the india-rubber wheel, used to urge that the tires could be worked up again, and re-used, and that a considerable sum could be allowed for old tires; but, according to the present statements, that was not so. That, as Mr. Bramwell had said, alarmed him, because it made the expense of those tires very great. For instance, Lieutenant Crompton estimated that a set of tires which cost £234 would run only 8,000 miles; thus making the working cost of the india-rubber tires about 7*d.* per mile, and such a cost as that was nearly prohibitory of their use. Allusion was made in the Paper to the contrivance adopted by Messrs. Aveling and Porter between their motive power and the driving wheels, namely, that of Holdsworth's 'jack-in-the-box'—invented to be used in cotton-spinning machinery—whereby the engine could turn round any corner without throwing the wheels out of gear; but there was one difficulty about that, which was, that when one of the wheels got into a hard place, or, rather, into a slippery place, the whole energy of the engine could be devoted to turning the wheel round over that slippery place without any forward movement at all; but he believed Mr. Aveling had lately devised means whereby he was able to throw out the compensating arrangement, and thus to make the wheels for a time as though they were rigidly connected, so that the ill effects Mr. Bramwell had alluded to might not take place.

Mr. G. A. C. Bremme said the past history of the traction engine, as recorded and explained in the Paper, seemed to furnish ample evidence that the want of suitable propellers or driving wheels had been the primary and chief cause of the failures and disappointments hitherto experienced. Instead, however, of occupying time by reviewing the various propellers which had already been before the public, he would, with the permission of the Meeting, state a few facts relating to a class of steel tire wheels not so well known. The pair of wheels mentioned in the Paper as being now under trial at Chatham had been at work, attached to one of the Royal Engineer 6-H.P. steam sappers, since the 15th of January last, and had now run an aggregate distance of 150 miles. They were flexible, and would, therefore, in future, and in accordance with the Author's classification, be called 'flexible steel tire wheels.' The Royal Engineers had not as yet reported on them, but the results of private experiments confirmed Mr. Bremme's opinion that, for the sake of economy and safety, the flexible steel tire wheel would ultimately be generally and exclusively used for tractive purposes on the common road. The pair of wheels in question weighed 46 cwts., which was about the same as that of a pair of india-rubber wheels of equal size and capability, and their circumference was 206 in. The weight of the pair of rigid wheels belonging to the steam sapper was about 16 cwts., and their circumference was 189 in. From empirical data he found that a pair of steel tire wheels, specially adapted to the 6-H.P. steam sapper used, need not weigh more than 30 cwts. The flexible tires were made of ordinary sheer steel, and were untempered. Their actual deflection when working was not quite one-fourth of that admissible before permanent set began, and the steel tire might therefore be considered indestructible. The weight of steel in each tire was 4 cwts., and its cross-sectional area was 8 square inches. An equivalent india-rubber tire would have necessitated a cross section of at least 60 square inches. It might be assumed that in the construction of elastic tires 80 lbs. of steel was equal in efficiency to 100 lbs. of india-rubber. The wrought-iron tread pieces or shoes were 6 in. broad, perfectly smooth, and close together. The positive and peculiar connection between the tire and the central part in those wheels obviated two material defects peculiar to, and unavoidable in, the india-rubber wheels, namely:—1, loss of power through the slip of the central part; 2, excessive intensity of pressure and consequent friction and wear at some point or other of the wheel. To remedy those defects in india-rubber wheels would seriously affect their qualities of flexibility and elasticity. In working the sapper with the steel tire wheels, the attendant riding on it felt no vibrations. The wheels in hauling a load on paved or macadam roads, although perfectly smooth, did not slip; their adhesion, therefore, was purely frictional, and—not being dependent, as in the case of rigid wheels, on any projections entering and lacerating the face of the road—was always reliable. In an experiment made on the 18th of January last the steel tire wheels took a 5-ton gun up an incline of 1 in 8, near Melville Hospital, Brompton, with 80 lbs. boiler pressure, and a gross load of 11½ tons. The load on the drivers was 85 cwts.; the allowance for gravity and road friction was 34 cwts.; the indicated coefficient of adhesion 0·4, and the actual average coefficient was estimated at 0·5. A pair of rigid wheels of the same weight and circumference would have required 94 lbs. boiler pressure, or 14 lbs. more than that required by the steel tire wheels. This difference was due to the fact that the road friction of the steel tire wheels was considerably less than that of the rigid driving wheels. As regarded the saving of first cost arising from the use of the steel tire wheel, it might be sufficient to state that the difference of cost between an india-rubber tire and a steel tire was also the difference of cost between the respective wheels. This difference represented a large saving, as, for instance, in the case of the wheels of the 'Ravee,' it amounted to from £180 to £200.

Mr. R. J. Quelch said, he concurred in the idea that horses would soon become so familiar with steam carriages in ordinary use on the public highways as to be driven past them without fright or danger. That such would be the case he inferred from the quiet behaviour of horses at work in and about railway stations, and also from the fact that all animals grazing alongside the lines, though at first scared by the sights and sounds of locomotive traffic, very soon became so accustomed to it as to be oblivious to what was going on around them.

With reference to the use of a canopy over the roof of the steam passenger carriage alluded to by Mr. Grantham, it was evident that unless it was imagined the question of perfect combustion had been satisfactorily solved, or as long as the chimney was placed just above the roof of the carriage, the passengers must necessarily be subject to a continual shower of unburnt carbon and ashes. Mr. Quelch, however, considered that there was not the slightest difficulty in designing a light wrought-iron roof capable of sheltering the passengers from all possible annoyance. It had also been alleged that passengers would never consent to travel in such dangerous proximity to the boiler of the engine, and would be frightened by the slightest escape of steam through the floor of the carriage. Now this objection was utterly meaningless, for passengers on board river steamers could be there observed daily sitting in the closest proximity to the boiler, without apparently noticing either the escape of steam or even betraying the slightest fear while sitting directly over the boiler itself.

Until the Act of Parliament was altered so as to place steam carriages on a similar footing to other vehicles, the question before the Meeting would not be satisfactorily solved. Practical engineers were not likely to spend their valuable time in working out designs which could never be carried into execution; but when the existing absurd restrictions were rescinded, they would be found both willing and able to deal with the mechanical difficulties involved.

Mr. H. Gore thought that those who had recently devoted their attention to this question—as exemplified by the Paper and the drawings before the Meeting—were endeavouring to follow too closely some form, or modification of form, of the ordinary locomotive engine. That he considered a mistake. He had given much consideration to the mode in which tramways were to be worked, and he had come to the conclusion—more particularly with regard to those abroad—that it was essential for their success that they should be enabled to use to a certain extent locomotive power upon them. It appeared to him that the designers of steam tramway carriages had forgotten an essential point, namely, that they were not dealing with railways. In dealing with tramways which had to pass through populous streets, and to turn round corners on curves of very short radius, with rails that did not admit of super-elevation, engineers were restricted by the grooves of those rails to a very peculiar mode of traction, all or most of which conditions seemed to be lost sight of by the designers of tramway locomotives or tramway steam carriages. He alluded especially to the systems of Mr. Todd and of Mr. Grantham. With regard to the former it was evident, in the case of a curve of 30 ft. radius with an engine and detached carriage, the engine would probably pass round, but the carriage would most certainly slip off the tram, and perhaps run into the centre of the road. He had traveled behind tramway locomotives in America, and he knew from personal experience the results. So long as they ran on long straight lines, or on curves of 150 ft. radius, the steam cars did very well, but with curves of 30 ft. or 40 ft. radius it was a different matter. In Baltimore, with an engine and detached carriage, the latter became placed in the middle of the road on going round a curve. With Mr. Grantham's steam carriage it would be impossible to pass round short curves, owing to the distance between the bearing points of the wheels being so great. There were, on many existing tramways, curves, of 32 ft. and 33 ft. radius laid with grooved rails on both sides. A carriage of the description proposed by Mr. Grantham, would go off the first time it was attempted to pass it round such curves. Knowing the difficulty of getting the ordinary horse car on to the line again, it might be imagined what trouble and delay would attend that operation when it had to be performed with a heavily weighted steam tramway carriage. But there was another great difficulty which had not been taken into consideration. How was a steam car to be guided round such curves? Those connected with tramways knew that on a curve of small radius as a matter of course the horses were drawn off the curve towards its inner part in order to give a tendency to the carriage similar to that produced with a super-elevation of the outer rail; but how could that be done with any of those arrangements? Hancock's carriage—which Mr. Gore believed engineers must eventually adopt, if they ever attempted to apply steam to tramway locomotion—could go round such curves. He had traveled by it round the sharp curve at the 'Angel' at Islington, and another at London Wall, and it went round both with great facility. It was most important that inventors or designers of steam tramway carriages should adapt them as closely as possible to some existing form of carriage; and in his opinion the engine and carriage should be self-contained. Trials in the United States pointed in that direction; and he believed that, out of the many experiments that had been made, the only carriage which was feasible was that designed by Messrs. Gray and Hunt, of Baltimore; and that was, to all intents, a modification of the arrangements of Hancock's steam carriage applied to tramway purposes.[1]

Mr. David Greig said, the subject might be divided into three heads:—1, the effect of legislative enactments; 2, the adhesion of the wheels; 3, the capacity and durability of the roads in reference to a heavier and more wearing character of traffic. At present the state of legislation was such as to keep inventive minds from studying the question of steam locomotion on common roads. No man with capital was inclined to embark in an undertaking that was liable to be stopped at the caprice of any nervous individual. If the legislative enactments were satisfactory the arrangements might be safely left to the engineers; and therefore he did not propose to enter very fully into that branch of the subject. The mechanical arrangements should not be too ingenious. If an engine was constructed as lightly as had been proposed, it would be likely to go to pieces even if made of the best steel. His experience had convinced him that the fewer parts that were put into a traction engine the better.

Adhesion was a matter obviously intimately connected with the structure of the wheel. No wheel would take a load with the same resistance as one with an india-rubber tire, or occasion so small an amount of destruction of the road. Although he had expended much time and money in perfecting this class of wheels, he was still sanguine as to their ultimate success. At present the trials had shown that they were the most efficient, and that the locomotives mounted upon them could traverse ground inaccessible to others. But, on the other hand, the cost, especially as regards repairs, was so great

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[1] *Vide* also "Propulsion of Carriages on Common Roads by power other than animal power." 8vo. London, 1873.—H.G.

as to impede their more general adoption. The results of the trials at Wolverhampton did not give a fair idea of the capabilities of the india-rubber tire, as it slid round like a locomotive on greasy rails, whereas it should have been held securely as in a rigid wheel. The power was not, therefore, applied upon the periphery of the wheel.

The capacity and durability of the roads was limited to the weight and adhesion which they would stand. It was not a matter of the power which the crank shaft would give, but of the adhesion of the periphery of the wheel, and that was limited. The result of his experience had tended to prove that small engines with light loads, driven at a moderate speed, were most available. He did not approve of the use of high speed road locomotives, as he believed that their use would endanger the other traffic. With high speed, the steering would be difficult and a collision might occur, and any inequality in the road would occasion a sudden, perhaps dangerous, shock to the engine. On a tramway, a speed might be allowed which could not be allowed on an ordinary road, where a stone only ½ in. thick would occasion a sensible jar to a carriage traveling at a high velocity.

Mr. J. GRANTHAM said, the steam engines used on common roads were generally called 'road engines,' in contradistinction to those on tramways, which were styled 'tramway engines.' Having watched for thirty years the progress of road engines, he had come to the conclusion that past experience indicated failure rather than success. No doubt there were circumstances where the common road engine might be useful; as, for instance, for military and agricultural purposes; because the same engine which worked machinery could be used for transporting the carriage itself. But he felt that nothing had hitherto transpired to warrant their adoption for ordinary purposes of traffic, for passengers and the conveyance of goods. A hard and uniform surface was an essential element in the use of the road steam engine. Tramways were being introduced rapidly, and might be employed to a much greater extent if steam could be applied in the place of horses. The use of steam engines would afford an opportunity for the introduction of tramways into small towns and other places where the traffic was not sufficient to warrant the construction and working of railways at a large cost. He considered there were three essentials in the construction of steam tramway carriages, namely:—1, they should have a short wheel base; 2, they should be so constructed as to be capable of being driven from either end, and of being worked both ways —backward and forward—without being turned; 3, there should be a clear passage for passengers from one end of the carriage to the other.

The other question, of whether steam tramway carriages would make such a noise as to preclude their use in crowded towns, he was happy to say was on the verge of being tested in a full-sized carriage built for that purpose. In a long carriage a short and narrow wheel base was essential to turning round sharp curves. A bogie frame with four wheels formed even a better angle with regard to the rails than the short wheel base of the present tramways. As it was necessary that, under any circumstances, the wheel base should be short, it was equally essential that the weight should be disposed as much as possible in the centre of the carriage. With regard to passengers inside a steam carriage, experiment had shown that they would be as comfortable as with horse traction, and perhaps more so. It had also been ascertained that the starting and stopping of a steam tramway carriage was more easily effected, and the vehicle was under better control than with horses. He was not prepared to give an opinion as to how far the anticipated annoyance in the streets from the chimney would be overcome. Various means had been suggested with a view to protect the outside passengers from being powdered with dust from the chimney. He had been recommended to put the chimney at the end of the carriage, and to turn it in different directions. It had been suggested also that a traction engine drawing an ordinary passenger car would cause less annoyance; but he considered that by such arrangements the passengers would be more exposed to the smoke and dust. If the chimney was in the centre of the carriage, in nine cases out of ten the dust would fly clear ; at any rate its annoyance would be small. An opinion had been expressed, to the effect that there was danger in having the boiler in the middle of the carriage, and something had been said about its bursting. It was well known that tubes used in boilers, like that proposed by him, when they burst, would not blow up the carriage and the people in it. They only made a spluttering noise and put out the fires. He had witnessed such an occurrence in the carriage he had referred to. A joint in the steam pipe, being badly made, burst; but it caused no inconvenience to the people inside the carriage; in fact, no one but the engineer was aware of it. No doubt the objections and difficulties urged against the use of steam passenger tramway carriages would eventually be surmounted, like those opposed to the introduction of locomotives on railways.

Mr. R. C. Ransome said, he saw, four years, or five years ago, in Baltimore, a steam tramway carriage at work, between the city and the People's Park, a distance of 4 miles or 5 miles. The form of the carriage was similar to that of an ordinary London omnibus or tramway car, with an engine at the end; and it appeared to answer well. The starting and stopping was done with great facility, and the motion was easy; the heat was not unpleasant, and there was none of the dust mentioned by previous speakers. The thorough mechanical practicability of that plan of steam traction for tramway purposes might, therefore, be considered as established; and, so far as the engineering or mechanical part of the subject was concerned, the steam tramway cars might at once be run in London without the necessity for designing fresh rolling-stock. But it was a very different thing to run from Baltimore to the Park to what it would be to run in narrow thoroughfares, crowded as those of London, where the difficulties spoken of must exist. He ventured to say the Legislature would never give its sanction that steam tramway carriages should run in crowded and narrow streets mixed up with the general traffic; and he was sure popular opinion would be against it. If it was desired to convey business men to and from the suburbs by steam carriages, at a rate of 10 miles per hour, it would be much more practicable to do so by bridging over the present streets with a series of columns and girders—which would carry the rails and the traffic above the heads of persons in the street, without much obstruction of light and air—than to attempt to do it by tramways on the level of the ground. For the hauling of heavy loads, the engines for steam ploughing made by Mr. Fowler, Messrs. Aveling, and other manufacturers were very perfect and useful. But for the general carrying purposes of a farm—such for instance as carrying crops, manure, &c., or for thrashing grain—an engine especially adapted and strong enough for ploughing and cultivating could not be employed to advantage. The engine which contained power enough to break up land would be too heavy for the purpose of conveying produce off the land, and for the other uses for which it would be required in an old country like England. But in a new country, such as the American prairies, and the steppes of Russia, and in India, something forcible might be said on the opposite side of the question; although in such countries the difficulties of providing the skilled workmen required for the repairing shops, together with a regular supply of coals and water, would have to be taken into consideration. As far as England was concerned, he thought there was no room for a medium between the systems of traction already adopted, namely, by horses on common roads and by locomotives on railroads. He considered that in places where steam traction on common roads was admissible, the maximum of success had been obtained; indeed, it might be asserted that very little progress had been made in the conveyance of passengers by steam at high speeds on common roads since the time when Hancock's steam carriage was introduced.

Mr. E. A. Cowper said, the earliest locomotive steam engine for common roads, he believed, had been made in 1769, by a Frenchman of the name of Nicholas Joseph Cugnot, who was born at Void, in Lorraine, on the 26th of July, 1729, and died at Paris in 1804. Mr. Cowper had seen the model in the Conservatoire des Arts et Métiers in Paris, and afterwards the engine itself, laid up in a repository for old machines in connection with the Conservatoire.[1] The machine traveled on three wheels, one in front and two behind, and was furnished with steering tackle to the front wheel. It was composed of two parts, the fore part being supported by a single driving wheel. They were united by a pin and a toothed sector, fixed on the framing of the front part; the hind part was merely a carriage on two wheels, intended to convey the load, and was furnished in front with a seat for the conductor. The fore part carried a copper boiler, having a furnace inside, with two small chimneys, and two single-acting brass steam cylinders, which were provided with four-way cocks, communicating with the boiler by a pipe and with machinery for communicating the motion of the pistons to the driving wheel. The conductor could turn the carriage at an angle of from 15° to 20°, by means of a set of cog-wheels, the last of which worked on a toothed sector, and the first of which was turned by a spindle furnished at the top with a double handle in front of the seat. Running upon three wheels only, with the weight of the boiler and engine overhanging in front, it was by no means a steady machine, and in passing along a street in Paris, near where the church of the Madelaine now stands, it overbalanced itself while turning a corner, and the inventor was forthwith locked up in prison, and the machine as well. A number of trials were, however, made in the presence of the Duc de Choiseul, then Minister of War, General Gribeauval, First Inspector-General of Artillery, and other eminent persons; but it was found that the engine could not travel faster than 2¼ miles per hour when carrying 4 persons, and the boiler not being large enough, it could not keep going longer than 12 minutes or 15 minutes at a time. Those trials were made fifteen years before the engine of Murdock was brought forward; and, so

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[1] *Vide* also "Institution of Mechanical Engineers. Proceedings, 1853." Birmingham. Page 33.

far as Mr. Cowper knew, Cugnot's engine was the first locomotive ever made.

After Cugnot there were several persons whose names should be mentioned as having suggested the use of steam for locomotion, namely:—Watt, in 1784; Oliver Evans, in 1786; Professor Robinson, in 1795; and lastly, Trevithick and Vivian, in 1804, who not only ran a locomotive steam-engine, but laid down rails for it to run on, at Merthyr Tydvil, in South Wales; and from that time the improvements introduced in locomotives and railways had been almost incessant.

Mr. Henry Chapman said, the Author had omitted to mention in his Paper the last improvement which had been made in applying steam to traction on common roads; and Mr. Chapman was the more surprised at the oversight, as the system was being applied on a large scale, in a populous town, with steep gradients, and severe curves, by the Lisbon Steam Tramway Company (Limited). One of the engines was tried a short time time ago on an experimental line near London and gave complete satisfaction. The system was invented by Mr. Larmanjat, and consisted of a single rail laid in the middle of the track; the driving wheels of the engine, bearing nearly the whole weight, ran upon the ordinary road, the guiding wheels only running on the rail. The wagons and carriages had 4 wheels, of which 2 bore on the rail and the other 2—carrying just weight enough on them to steady the vehicle—on the road. The distribution of the weight of the vehicles was thus made in the reverse way to that of the locomotives; thereby obtaining an increased adhesion for the driving wheels of the locomotive, and a reduction of resistance in the traction of the wagons and carriages. The use of one rail almost entirely obviated the difficulty of going round curves.

The engines, made by Messrs. Sharp, Stewart, and Co. for the Lisbon Tramway Company, were from the designs of Mr. Trevithick. They weighed 13½ tons, and had smooth wrought-iron tires to the driving wheels; but Mr. Chapman had seen one last year running on an experimental line in Paris, weighing only 5½ tons. It had Thomson's india-rubber tires, and was one of a number to be used on a canal in Burgundy, where Mr. Larmanjat had the concession for the haulage. Mr. Chapman thought the system was especially applicable in such cases, where the banks were not sufficiently secure to allow of a heavy traction engine on the towing-path. The central rail had the further advantage of preventing the engine sliding into the canal, to which there was always a tendency in consequence of the angle at which the boats were drawn.

As to the effect on horses of steam engines on high roads, he thought the danger had been much exaggerated. Of course no one anticipated steam engines being used in Fleet Street or Cheapside; but at Nantes, a town intersected by canals, the railway ran along one side of the canal, on a level with the principal streets, and only divided from it by a small low fence, and he had never seen a horse frightened, although there were trains constantly running, and no warning of their approach, except the ordinary screech signal with the whistle. The experiments with Thomson's engine, in one of the crowded and fashionable parts of Paris, had been similarly successful.

Mr. Francis Trevithick, through the Secretary, stated, that Mr. Richard Trevithick designed his high-pressure steam locomotive in 1796, and during the following three years, or four years, constructed as many working models, one of which was in the Kensington Patent Museum. In 1800, his full-size locomotive was being constructed at Hayle, and made its first memorable trial on Christmas Eve, 1801. The following report appeared in the newspapers of the day:—"A carriage has been constructed containing a small steam engine, the force of which was found sufficient, upon trial, to impel the carriage, containing several persons, amounting at least to a ton and a half weight, against a hill of considerable steepness, at the rate of four miles an hour. Upon a level road it ran at the rate of eight or nine miles an hour."

In 1802 Trevithick fully described his inventions in his patent, and constructed an improved locomotive, which made several runs on common roads at Camborne. In 1803, another locomotive constructed by him, with larger driving wheels, ran for many days in the streets of London, attaining a speed of 8 miles or 9 miles per hour. In 1804, he completed a tramway locomotive at Penydarran, of which he wrote:—"We carried ten tons of iron, five wagons, and seventy men, the whole journey, above nine miles." In 1805, he took an improved tramway locomotive to the Wylam colliery, and explained its construction to George Stephenson, then employed on those works. A notice of it, dated 1805, might be seen at the Kensington Patent Museum, which stated:—"I saw an engine this day upon a new plan: it is to draw three wagons of coal, each weighing about $3\frac{1}{2}$ tons, at an expected speed of four miles per hour."

In 1808 Trevithick constructed a railway in London, and in describing it wrote as follows:—"About four or five days ago I tried the engine, which worked exceedingly well; but the ground was very soft, and the engine (about 8 tons) sank the timbers under the rails, and broke a great number of them. I have now taken up the whole of the timber and iron, and have laid balks of from 12 to 14 inches square on the ground." A well-known Engineer, Mr. Hawkins, in reference to this engine also wrote :—" I rode on it, with my watch in hand, at the rate of twelve miles an hour. The engine was exhibited at one shilling admittance, including a ride; it ran for some weeks." It was, therefore, evident that Trevithick, after ten years, or twelve years of herculean single-handed labour, was the man who first conveyed the public by steam for hire.[1]

Mr. W. F. Batho, through the Secretary, said, the first self-propelling roller made in England was designed by him, in 1863, for the municipality of Calcutta, at the suggestion of their Engineer, Mr. W. Clark. About seventy rollers of that type were constructed, under licences from the inventors, by Messrs. Aveling and Porter during the last four years, or five years. The date of the patent of the French roller was nearly a year later than that of Messrs. Clark and Batho. The French Engineers had, however, demonstrated the advantage and economy of rolling by steam power, even with an inferior machine. Mr. Batho had found it a hopeless task to endeavour to get the road authorities in England to take up the subject before the French had proved its utility and efficiency. So strong was previously the prejudice against it, that an eminent English road contractor had told him that the machine should be called a 'road destroyer,' and not a 'road roller.'

A new type of roller had been proposed for use in narrow and crooked places and for new road making. It might be necessary to have a narrower machine than had hitherto been made, but the arrangement of a pair of conical wheels carried by a vertical spindle, with the bearing at a distance from the resistance, appeared to be most unmechanical; and could hardly be considered an improvement on the turntable arrangement hitherto in use. The conical wheels would both grind the metal and themselves, on account of the varying speeds traveled by the different parts of the cones; and the undue strain thrown on the boiler by the leverage of the vertical spindle was very objectionable.

He found that from $2\frac{1}{2}$ tons to 3 tons per foot width of roller was the weight best suited to make a good road, and that a machine 9 ft. wide was the most economical. With it the same labour only was required as for driving a narrower machine and less water and fuel in proportion; besides, it had the advantage of being able to

[1] *Vide* also "Life of Richard Trevithick, with an Account of his Inventions." London, 1872.

accomplish a larger area in a shorter time. With this class of roller an average of 3,000 square yards per day could be rolled.

Mr. HEAD, in reply, said, he considered that it would be some time before tramway engines would come into use in towns; but there could be no doubt as to their applicability to suburbs and outskirts. It must be borne in mind that the tramway companies had a large stock of cars now running, and they would not be in a position to use new cars with enclosed engines, however much such a combination might come into use at some future period. As regarded the wheel base, it was desirable that it should be narrow for engines which ran in towns. In the outskirts the roads were wider, and the curves might be of greater radius; and under those conditions there would be no difficulty in making an engine capable of passing round any moderate curve.

With respect to the employment of traction engines and road locomotives for agricultural purposes, he did not agree with Mr. Ransome, that the number employed must be limited, but Mr. Head thought the demand for such machines would largely increase in proportion as the price of labour augmented. It would probably be found that farmers would use light engines. Engineers should therefore devote their attention to making the machinery as light as possible, so that engines could be used both for hauling and tilling. The best form of wheel for such a use was Aveling's, or Fowler's, wrought-iron wheel, with wrought-iron bands fitted with holes for spuds. Sufficient adhesion was thus afforded for ordinary roads. The only difficulty of using the locomotive on some farm roads was on account of their narrowness, and the rough and sandy nature of their surface.

Crops would most likely be generally harvested by the use of wire ropes on the plan adopted by Mr. David Greig; namely, the crop would be collected in the field, and placed upon wagons which would be hauled to the headland by a wire rope attached to a fixed engine placed on the headland, and from thence transported by a light traction engine to the homestead or to the place where the crops would be stacked.

With respect to the tramway engine for the Lisbon and Cintra line, mentioned by Mr. Chapman, Mr. Head believed it was designed that the driving wheels should run on a tramway made of wood. He did not think it possible to make an engine which would run with one set of wheels on a single rail in the middle of the tram, while the driving wheels were running on an irregular surface like a common road.

In pursuance of the notice on the card of the Meetings, it was proposed, and resolved unanimously :—

> "That in order to insure a fuller attendance of Members than could be obtained on Easter Tuesday, the Meeting be adjourned until Tuesday evening, the 22nd of April."

April 22, 1873.

T. HAWKSLEY, President,

in the Chair.

The discussion upon the Paper, No. 1,370, "On the Rise and Progress of Steam Locomotion on Common Roads," by Mr. J. Head was continued throughout the evening to the exclusion of any other subject.
