Mr. ALEXANDER SIEMENS observed that in America the mode of communication between passengers and the engine was a small cord connected with a bell on the locomotive. The plan was simple, and might, he thought, be adopted on English railways instead of the telegraphic appliances.

Mr. CHARLES DOUGLAS FOX said the Institution was indebted to the Author for again bringing before it the various details relating to American railway construction. It was important that Englishmen should know what Americans were doing, and the Author, from his position as judge, had great opportunities for ascertaining the improvements that had taken place during the last few years. The Paper had, however, produced on his mind the same impression as that which he had received from a careful examination of the mechanical section of the Exhibition in 1876. He had been in America in 1857, and on several other occasions between then and 1876, and it appeared to him, that while there had been an immense expansion during those years in the extent of mechanical industry, in the number and size of the firms employed upon engineering matters, and in the machinery used—an important point to Englishmen, involving them as it did in severe competition—there was a want of novelty; and that, during the last six or seven years at least, the Americans had, with one or two exceptions, adhered very much to their old types. It was well known that, from the commencement they had adopted the bogie truck, long cars with a passage down the middle affording means of communication throughout the train, and locomotives having four wheels coupled with a leading bogie truck; and they still retained the same system, generally speaking. It was true that Mr. Pullman had recently introduced an improvement, the effect of which was to encourage the adoption of what was practically a first-class carriage. Those who had been in America knew the misery of travelling long distances in an ordinary American car. In a first-class 'Pullman,' running from the Atlantic to the Pacific, the passenger was surrounded with every luxury, which he might contrast with the discomforts of some English railways; but, if the traveller happened to wander off the main line, and went to any of the out-of-the-way districts of the Western States in an ordinary car, he would soon wish himself back in the old country. The Westinghouse brake, which he had seen in use on the Pennsylvania Railroad about ten years ago, had also been brought to great perfection. There were one or two points in which the advantages obtained by the Americans were most clearly seen. The greatest weight on the wheel of a locomotive in America

was 4½ tons, as compared with 8½ or 8¾ tons in this country. That was one reason why the American permanent way engineers had easier times than English engineers. There could be no doubt also that the use of the bogie truck had been a great advantage to the Americans on their rough roads, but it appeared to him that the adoption, in combination with the bogie truck, of a long car, supported only at the two ends, was an unmechanical arrangement, resulting in a heavy dead weight, as compared with paying load. The subject had been so thoroughly ventilated in 1874, in connection with another paper read before the Institution,[1] that he hardly liked to touch upon it; but it was an important question in discussing the relative advantages of long and short carriages. The weights given in the Paper were, he thought, somewhat misleading. The sleeping cars were supposed to carry sixty-four persons. That might be true at times, as at the period of the Exhibition (when he had himself had unpleasant experiences of what such a car full of people meant), but that was not the ordinary state of things. In estimating the weight of the cars, not more than half that number of passengers should be taken into consideration, because nearly every one paid for a double berth, of which the Pullman car company had the entire benefit, the railway company only getting the single fare. With regard to the question of cast-iron wheels, it seemed curious that it was impossible to obtain thoroughly good wheels of that kind in this country. Probably English wheel manufacturers had not found a demand for them. If there had been a demand he thought the supply would have followed. He had had considerable experience in the use of cast-iron wheels in the severe climate of Canada, where they proved remarkably good in regard to freedom from fracture and the amount of wear and tear they would bear. In a communication laid before the Institution by a gentleman who was chief engineer of one of the railways in Canada,[2] it was stated that some of those wheels had been running without being touched for 100,000 miles—a wonderful result considering the frost to which they were exposed. While, however, they were adopted in America for economical reasons, they were but poor expedients as compared with the wheels used in England. There were indications in the Paper that the Americans did not think it a good thing to have a rigid mass existing between the tire and the axle, and that some questionable experiments were

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxix., p. 62.
[2] *Ibid.* vol. xlviii., p. 52.

being tried by the introduction of small pieces of wood between the tire and the felloe of the wheel. That was the weak point of those wheels: they were very heavy, very rigid, and, consequently, very severe upon the permanent way; particularly from the fact that, until lately, they had not been turned up, and it was impossible therefore to get them strictly true. During the last few years they had been made in such a way as to be capable of being turned up, and no doubt that was a great improvement, but he believed that a thoroughly well made Mansell wheel (especially if it could be filled up with paper not liable to split and crack with heat) would be far better than the cast-iron wheel, setting aside the question of cost. As to wheels loose on their axles, whenever an attempt was made to use such a contrivance the wheel had a tendency to get out of truth. He had considered the arrangement described as used on the little railway running round the Centennial grounds. For a train running at slow speed, it might answer fairly well; but it did not seem to him to have the simplicity or inherent strength that would be necessary for high speeds. It had often occurred to him that it was dangerous to make wheels for railway purposes loose on their axles. He imagined there was something in the wonderful tendency shown by the gyroscope to resist being moved out of the plane in which it was revolving, that assisted to keep a railway train on the rail; and, if there was anything in that idea, putting loose wheels on axles would diminish that item of safety. The use of centre buffers in America had in a great measure grown out of the employment of very long wagons. With the exception of the Miller platform coupling, which seemed to act well for passenger cars, he had seen nothing in America, nor indeed elsewhere, in combination with centre buffers, that was safe for those who had to couple the wagons, and at the same time satisfactory in the working of the traffic. It was quite true, as the Author had said, that the name of such coupling was 'legion;' but he had failed to see any thoroughly effective details to carry the matter out. The subject was beset with difficulties, and the right thing had yet to be introduced. With reference to the narrow-gauge lines in the Western states, he thoroughly disagreed with the policy of adopting them, where they came into the midst of the 4 feet 8½ inches system, and thus introduced a break of gauge which, as their promoters were beginning to find out, would be fatal to their final success. Some years ago he had been called in to advise as to a railway in that part of the world, where they were anxious to have a narrow gauge, but he had strongly recommended

the adoption of the 4 feet $8\frac{1}{2}$ inches gauge, as being that most likely to come into general use. The narrow gauge, however, was put down, and the company had now the unpleasant duty of altering it, in order to avoid the inconvenience and loss of traffic consequent on break of gauge. But while he could not agree with the policy of a break of gauge, he did not think the cost of transhipment was so great as stated in the Paper, namely, 10*d.* in the case of regular traffic, and 1*s.* 6*d.* where the traffic was slack or intermittent. That might be the cost in Colorado, where everything was paid for at a high rate; but under ordinary circumstances, transhipment could be effected, by proper arrangements, for less than half that amount. It was well for Englishmen to know what Americans were doing, because they were men of expedients, and always trying to employ the often very inadequate means at their disposal to obtain great results. Out of their inventive faculty, and the desire of Englishmen to do everything substantially, he thought a good combination might be formed.

Mr. JOSEPH TAYLOR was surprised to learn the extent to which the American wheels were chilled. When he was at some works in the North of England, where about one hundred wheels a day were cast for coal wagons, the endeavour was to chill them to as small an amount as possible, so as to have it continuous. The chill was no more than about $\frac{1}{16}$ inch or $\frac{1}{32}$ inch. The mixture used consisted of equal parts of cold blast Welsh and Scotch pig and old metal, with a small quantity of white iron added, which was supposed to produce the chill. The wheels were not solid, but with a serpentine spoke, and the hub was divided into four, to allow for the difference in the contraction. After the wheel was made, the hub was wedged up with wooden and iron wedges, and then wedged on to the axle. On one line there were cast-iron wheels running under ten thousand wagons. They were cheap, costing, when pig-iron was 50*s.* a ton, about £1 each; but he believed they had been generally discontinued, in consequence of their liability to break. It was impossible to tell whether the wheel was good till it was broken, and then it was not of much use. He had heard of wheels running under coal wagons for twenty years, and of others that had broken the day they went out. He believed that wheels of that kind had been discontinued except on short lines.

Mr. J. A. LONGRIDGE wished to say a word as to the claim made for a great reduction in the tractive force of the American axles. It was stated in the Paper that, with the Miltimore axle, the tractive force, exclusive of the gradient, was 13·15 lbs. per ton, as

against 17·21 lbs. in the case of the ordinary axle; and in another case the figures were 13·67 lbs., as against 26·55 lbs. He thought those figures were far beyond what was customary in England, where 7 lbs. a ton was certainly not a low estimate of the tractive force of wagons and carriages. He had never heard of anything like 13 or 26, and he thought there must be some mistake in that part of the Paper. With regard to cast-iron wheels, he had been struck with what appeared to be their enormous cost—£8 for a 30-inch wheel, and £12 for a 42-inch wheel. Comparing that with the cost of wrought-iron wheels and steel tires, there could hardly be a claim made for cast-iron wheels on the score of economy. The system of running loose wheels on an axle had never, so far as he knew, been applied to a very high speed, but he had employed it with success on the Mont Cenis railway for a speed up to 25 miles an hour. He had often wondered why the system had not been adopted in England. He had seen the system mentioned by the Author, of using axles cut in two, and it had answered well. The wheels on the Mont Cenis railway carriages were not made in that way; they were bushed, and ran loose upon the axle, which was fixed; and the carriages, which were six-wheeled, ran with greater ease than the four-wheeled carriages under the ordinary system.

Mr. BERKLEY said he had spoken on several occasions on the subject of cars, wheels, and engines, but he desired to bring to bear his own personal experience upon two statements in the Paper. The Author had prudently suggested in cautious terms that American experience might be useful to engineers who were making railways in India and the colonies. Such a suggestion might, without due consideration, lead to error. If the Author meant that in making railways the means should be adapted to the end, and obtained at the cheapest rate, he entirely agreed with him, because that was what ought to be done in every part of the world; but if he meant that the American railroad system was to be imitated in India and the Colonies merely because it had been productive of economy in America he dissented from that view. The Author had truly stated that the characteristic feature of the permanent way in America was the large number of sleepers. Why was that? Because timber was found almost invariably wherever the railway went, and it was wise to use that which was of the cheapest description of suitable material, and which gave a large base for sustaining the rolling load. It was otherwise in India, and in the colony with which he was connected—Natal—where every sleeper had to be transported from England,

iron sleepers being largely used because timber ones were liable to rot from the heat of the climate and other circumstances. It might be said that, if timber was not found, other available materials were at hand and could be used in the construction of railways with economy. But that was not always the case. He once had placed before him designs for a viaduct $\frac{2}{3}$ mile in length, and 60 or 70 feet high, in a country where stone was abundant. The estimate for that work was £400,000; but by sending iron from England the work was constructed for £140,000. This was only one of many examples. The employment of materials at hand was not therefore always productive of economy. It was necessary in all cases to consider the means required to produce the end, and then to ascertain how the needful materials and labour in the locality or abroad could be obtained and utilised most economically.

Mr. COWPER had tried some experiments on the South-Western Railway with reference to the friction of axles. With grease the friction varied, but was about 8 lbs. per ton, and with oil it was about 2·4 lbs. per ton.[1]

Mr. W. ATKINSON said at a discussion at the Institution some years ago on American rolling stock,[1] it was shown that the resistance of the American cars was about 4 lbs. per ton as compared with about 8 lbs. on English railways, the difference being due to the use of oil for the American rolling stock. The cost of the cast-iron wheels was then put down at £3 10*s.* each; he presumed that the price mentioned in the present Paper was that of a pair of wheels and an axle. The adoption of rigid wheels had arisen in America from the freezing of the permanent way, making the road so irregular and hard that it would knock to pieces the wheels ordinarily used in England. The reason why the hard rigid wheel was not so destructive on American railroads was that there was interposed between the body of the car and the rails, a double set of springs; for the bogie truck was composed of a double series of springs, so that there was much greater elasticity, therefore the wheels did not injure the permanent way so much as they would otherwise do. The new points brought forward in the present Paper were the Wharton switch, which was a great improvement on the ordinary American plan, and the attempt at working two wheels disconnected. How far that plan would answer it was difficult to say; it appeared extremely complicated and must be costly. He believed the large size of the carriages

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxviii., p. 360 *et seq.*

had arisen from the peculiarity of the climate. It was necessary to warm carriages in winter, and it was almost impossible to do so with ease and economy if they were divided into compartments.

Mr. W. R. Browne inquired what was the chemical composition of the cast-iron wheels in use in America with regard to the percentage of carbon. He thought they should be regarded rather as cast-steel than as cast-iron wheels. Pure iron with practically no carbon was known as wrought-iron; steel was iron with a certain small percentage of carbon; and cast-iron had a certain larger percentage. A great deal had been done towards getting at steel from the side of wrought-iron by producing what were called homogeneous irons, or steely irons, with a percentage of carbon less than that of ordinary steel, but greater than that of ordinary wrought-iron. Yet little had been done in getting at steel from the side of cast-iron, by reducing the percentage of carbon found in ordinary cast-iron. He imagined that the processes by which the wheels were manufactured must have a tendency to reduce the percentage of carbon, and to make a sort of steely cast-iron, and that that was the explanation (the properties of steel coming to some extent into play) of the great toughness which the wheels appeared to exhibit in addition to the hardness necessary for the chilled surface on which they rolled. It was evident that if a material could be obtained at a moderate price possessing the hardness of chilled cast-iron, and the elasticity of steel, it would be very valuable. He had made some calculations as to the approximate price at which the wheels described could be made in England. He could not see any reason why they should not be made; it was merely a question of buying pig-iron of a high character, comparable to that which the Americans obtained in their own country, but which Englishmen would probably buy from Sweden or Russia. In both those countries charcoal pig-iron was largely made at the present time, and the make could be easily increased (as he knew from personal observation) if there was a demand for it. Towards the close of the last century a firm in South Staffordshire with which he had been connected bought a large quantity of pig-iron from Sweden and Russia in the regular way of their trade: for although there was then a much larger quantity of charcoal pig-iron made in England, yet the manufacture was declining, and English manufacturers of the best wrought-iron seemed therefore to have gone to Sweden and Russia for their supply. Allowing 6 cwt. as the weight of a 36-inch wheel, that would require about 6½ cwt. of pig. Assuming 2 cwt. of this to be charcoal iron at 5*s.* per cwt., and the other

4½ cwt. ordinary first class pig-iron at 3*s.* 6*d.*, that would give 26*s.* 3*d.* for the pig-iron used. Taking labour, coke, and other extras, at 4*s.* per cwt. (which he thought a liberal estimate, there being only one description of castings, and that of a considerable weight), the cost price of each wheel would be 30*s.* 3*d.* The cost of a pair of wheels therefore would be £5, and adding 35*s.* for an axle, the total amount would be £6 15*s.* That would be about £14 a set for the chilled wheels and axles, a price probably somewhat less than the cost of any good system of wrought-iron wheels of the present day, and decidedly less than that of any system of wrought-iron wheels with clip tires. Probably wrought-iron wheels with riveted tires might be bought for that price. There thus appeared to be a saving in first cost, but he could not quite make out from the Paper how long the American cast-iron wheels would run before actually wearing out. If the mileage was no more than from 60,000 to 90,000 miles, that would compare badly with the mileage of wrought-iron wheels, which (as stated by Mr. Harrison in a previous discussion[1]) would run with one pair of tires, and with three turnings up, from 160,000 to 180,000 miles. Fresh tires might be afterwards used, and as long as the journals did not wear out the wheels might be said to last for ever. If the comparison he had given was a correct one there appeared little reason for introducing cast-iron wheels into England.

Mr. I. Lowthian Bell, M.P., feared that some apology was due from him for venturing to offer any remarks on this occasion, as many of the members were necessarily much better acquainted with matters belonging to railways than he could pretend to be. Having, however, had an opportunity of travelling in America, from the Atlantic ocean as far as the valley of the Mississippi, and from the shores of Lake Superior nearly to the Gulf of Florida, he had been able to form some kind of a traveller's opinion, at all events, upon the position of railways in the United States. In addition to this inducement Mr. Browne had referred to a matter in which he felt a little more at home, namely the chilled wheels of which the Author had given so lucid an explanation. He desired in the first place to record his opinion that the invention which, more than others, had tended to promote civilisation where it existed, and to extend it where it was absent, was that of railways. Looking at the conspicuous position which this country had occupied in the formation of railways and

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxviii., p. 400.

in their elaboration, he thought The Institution of Civil Engineers might feel proud of its position in connection with that great movement; but while drawing a picture a little flattering, perhaps, to national self-love, engineers should be careful not to fall into the error of imagining that no other nation had done anything to advance that great system of inter-communication. As that view was opposed to his own general impression, from what he had seen in America, he might be excused for stating the ground upon which he had formed this opinion. There were many things connected with railway carriages in America which commended themselves to his own mind. In the first place, they afforded great accommodation and convenience to passengers on long journeys. He spoke with some hesitation on the subject, but he could not help thinking that a structure, unbroken as it was by door openings, must possess greater strength than those constructed on the English principle. Mr. Fox had compared the convenience and comfort of American cars with the convenience and comfort of English carriages; but he had fallen into error in comparing what were in America practically the representatives of English third-class carriages with first-class carriages in this country. He did not know whether Mr. Fox referred particularly to the kind of company to be met with in the omnibus carriages in the United States; but having travelled at least 30,000 or 40,000 miles in America, and often in that class of carriage—there being upon many lines no others—he could testify that the company he had met with had been the reverse of disagreeable. Indeed, he did not know that he could have met with less objectionable company in first-class carriages in England. Certainly it would compare favourably with what one was in the habit of meeting in third-class carriages in England. With reference to the question of chilled wheels, Mr. Browne was entirely mistaken in attempting to classify that kind of iron with steel in any shape. He believed he was correct in saying that charcoal-iron instead of containing less carbon than that which was manufactured from coke, contained generally rather more. It might be supposed that some great chemical change was exercised upon the condition of iron from the fact of its being chilled; that, however, was a mistake. He was at issue with the Author in regard to the supposition that the carbon which in iron in its grey condition was in the graphitic, or uncombined state, was converted into what was called combined carbon, by the mere action of chill. It was a fallacy to suppose that the difference between white and grey iron always consisted in the carbon being combined in the one case and

uncombined in the other. The fact was there was no grey iron that did not contain carbon in both those conditions; and his own experiments tended to prove that white iron frequently contained quite as much carbon in the uncombined as it did in the combined state. There was practically little or no difference, and the circumstance of iron being grey was, in his opinion, a mere question of heat. In order to satisfy his mind upon this point, he had not only converted grey iron into white, but had reversed the action by mere alterations in the temperature at which the iron was melted, and thus changed white iron into grey. There was, therefore, no reason for supposing that the change induced upon the iron by chill was any more than that due to the comparatively instantaneous refrigeration and solidification of the iron, which prevented the molecules of the iron grouping themselves in that crystalline form, upon the faces of the crystals of which carbon was extruded at the moment of cooling. The Author had given the composition of the iron, and he did not wish to say that it was not of good quality; but he desired to point out that in speaking of extremely pure irons, such as Swedish, no iron could be called good which contained 0·169 per cent. of phosphorus, or 0·107 per cent. of sulphur. The ordinary so-called hematite iron of this country, which was so useful for steel-making purposes, contained no more than half that quantity of phosphorus. The silicon was stated to be 0·667 per cent., which did not indicate anything very peculiar or excellent in the quality of the iron. The iron might be very good when compared with pig-iron made from ordinary clay iron-stones; but when it was compared with the pig from which the best Russian or Swedish irons were made, it did not call for any particular remark. A previous speaker, in alluding to the want of novelty in chilled irons, had referred to the old chilled wheels made in the colliery districts of Northumberland and Durham many years ago. His former partner, Mr. William Losh, was one of the patentees of the method employed in the North of England; and under his own superintendence many thousand wheels of that kind were made; but the chill did not extend more than $\frac{1}{4}$ inch. The great recommendation of the American wheels was the careful manner in which they were annealed. The Author had not mentioned an essential circumstance connected with the way in which they were kept hot for a considerable time. The wheels were placed in pits 15 or 20 feet deep, one on the top of the other, and then covered with sand so as to prevent the convection and radiation of heat. The result was, that they were all kept red-hot for some time and were

allowed to cool at a very slow rate. The rim in casting was rapidly cooled, by which the rest of the wheel was thus brought into a state of tension, but the gradual cooling allowed the molecules of iron to arrange themselves in a way which preserved the structure when in use. With regard to the cost of the wheels, Mr. Longridge had expressed the opinion that they were very dear; and so they were when compared with the wrought-iron wheels used in England. The comparison ought, however, to be made between cast-iron wheels in America and wrought-iron wheels in America. As Mr. Browne had pointed out, if charcoal pig-iron was brought to England at the price at which it could be easily obtained, cast-iron chilled wheels could be made at a much lower price than wrought-iron wheels. It had been stated that the American wheels were not circular, entailing, it had been said, about 8 lbs. tractive power instead of 3 lbs. or 4 lbs., the inference being drawn that the running upon an American railroad must necessarily be a distracting and distressing operation. All he could say was that, having travelled many thousands of miles upon American railroads, either from the shape of the carriages or from the character of the springs or some other circumstance, he had never travelled more easily. Although his firm were pig-iron makers on a large scale, and had steel and iron in every shape at their doors, members might be surprised to hear that for their slag wagons, which were exposed to a good deal of hard work from the usual roughness of the appliances about a large iron-works, and the melted slag they were occasionally immersed in, they had had some difficulty in getting any material to stand. They had tried cast-iron, wrought-iron, and then cast-steel; but the substance which they had found to exceed any other in durability was that of the chilled wheels brought from the United States. With regard to the locomotive engine, many years ago the government of Brazil ordered twenty locomotive engines from the house of Messrs. R. Stephenson and Co. of Newcastle; but from that day to the present they had ordered their locomotive engines from the United States. There were one hundred and fifty engines now building in the United States which would be carried past the shores of the United Kingdom, and be landed at St. Petersburg. Those circumstances, he thought, should be taken as an indication that the Americans knew something about the construction of locomotive engines. English railway locomotive builders, he believed, adhered to copper fire-boxes; but in America fire-boxes were now all made of steel. No doubt copper had its advantages, but it also had its dis-

advantages. It was not nearly so strong as steel, and it was necessary to make up in thickness for the deficiency in strength. The heat of the fire could penetrate much better through a thin steel plate than through a thicker one of copper. Mr. Browne was certainly mistaken in his attempt to draw a distinction between steel and cast-iron. There was no absolute line of demarcation between steel and cast-iron or between wrought-iron and steel; but between cast-iron and steel there were substances which being neither steel nor cast-iron were useless for the purposes for which steel or cast-iron were employed. There was one other matter to which he desired to direct attention, as it was important to those who, like himself, were dependent on railways for the carriage of minerals. He referred to the question of cost. When business was in a state of depression, as at the present time, every augmentation of cost weighed heavily upon all industries. If the railways of the country had been constructed upon more economical principles, some relief might have been expected in the matter of carriage to the industries of the country. Pig-iron made in his own district paid above 7*s.* a ton for carriage; and seeing it was selling at the low price of 40*s.* a ton, any diminution in the cost of carriage would be most gladly received by the iron manufacturers. The railroads in the United States had cost only about one-half the amount for which they had been constructed in this country; and although some of them were paying no dividend, and others were scarcely paying their working expenses, the average profits upon American railroads were almost, if not quite, equal to those of English railways. Mr. Childers, M.P., had desired it to be stated on his behalf that he thought there were many useful lessons to be learnt in the matter of railways, by Members of The Institution of Civil Engineers, from a journey to the United States.

Mr. Thomas Ashbury said Mr. Browne had already referred to the American chilled wheels, and he need only add that English wheels of the same size might be made with steel tires at almost the same price as that stated by the Author. When it was considered that the life of a steel tire was about three times that of the American chilled wheel, he thought in the matter of economy the English ordinary wrought-iron wheel was able to hold its own. An American second-class car, such as that referred to in the Paper, 45 feet long, and seating fifty-four passengers, gave an average dead weight per passenger of 577 lbs. An English third-class carriage 29 feet long, with interior fittings equal to the American second-class car, and seating fifty passengers, gave

an average dead weight per passenger of 394 lbs. An American first-class car, 45 feet long, and seating fifty-six passengers (the first class was said to carry two passengers more than the second, although only of the same length and width), gave an average dead weight per passenger of 535 lbs. An English first-class carriage of the ordinary type, with four compartments, about 29 feet long, and seating twenty-four passengers, gave an average dead weight of 868 lbs. per passenger. The cost of the second-class American car would be about £1,100, or £20 7*s.* 4*d.* per passenger; the cost of a corresponding English carriage, seating fifty passengers, would be about £325, or only £6 10*s.* per passenger. The cost of the American first-class car would be about £1,600, or £28 11*s.* 5*d.* per passenger; whereas the cost of the English first-class carriage would be about £568, or £23 7*s.* per passenger. With reference to accommodation, the seat space allowed for each passenger in both the American cars referred to would be about 1 foot 9 inches; but those cars were exceptionally wide, namely, 10 feet, the average width being 9 feet 4 inches, which would reduce the space to 1 foot 7½ inches per passenger. The space in English third-class carriages carrying fifty passengers was 1 foot 6 inches, and the space in English first-class carriages, seating twenty-four passengers, was 2 feet 5 inches. No reference had been made in the Paper to the drawing-room cars in America. These were sumptuous, and magnificently fitted up; but he thought if they were brought into comparison with English carriages the cost and weight per passenger would compare very unfavourably. English carriages were much more advantageous for passengers getting in and out than American cars. English carriages seating fifty passengers would have five doors on each side for ingress and egress, thus giving a door for egress in case of collision to every five passengers. If the doors on one side were locked, passengers, in cases of sudden emergency, would not hesitate to get out through the window, for which there was ample space. English first-class carriages, seating twenty-four passengers, had four doors on each side, giving a door to every three passengers. In the American cars the only means of ingress and egress was through the two end doors, the falling lights in the windows not being sufficiently large to pass through. If the carriages on the Metropolitan railway had only two end doors for ingress and egress, as in the American cars, the delay at the stations would be so serious, that it would be impossible to run anything like the present number of trains. One objection to American cars arose from the carriages being invariably draughty

in consequence of the open compartment, and the doors being at each end; and each window being at the will of the individual sitting against it might be made an annoyance to other passengers who desired less ventilation. The cost of working American passenger trains per mile was greater than that of English trains, on account of the larger number of officials who were compelled to travel by each train. With regard to bogies, he had an indistinct recollection that bogie carriages were made, tried, and ultimately abandoned at an early date in the history of one of the railways south of the Thames. The wheel base of a third-class carriage was about 18 feet as compared with 6 feet for four-wheel bogies, and 10½ feet for six-wheel bogies. Loose wheels had been repeatedly tried in England and abandoned. In reference to brakes, the Americans had introduced some advantageous features; but he did not think English engineers would be behind them, for he was of opinion that the time was not far distant when brakes superior to any in America would be in daily use in this country. With respect to wagons, the American box-freight cars, 29 feet long and 9 feet wide, on two four-wheeled bogies weighed 18,000 lbs., and their carrying load was 20,000 lbs., or 1·1 lb. carried to 1 lb. dead weight. English covered goods wagons 16 feet 6 inches long, and 8 feet wide, on four wheels weighed 12,880 lbs., and their carrying load was 17,920 lbs., or 1·4 lb. carried to 1 lb. dead weight. He believed English trains ran more quickly than American trains. While Englishmen had several things to learn with reference to American stock, it should not be forgotten that the Americans had adapted their stock to their own peculiarities, and that in like manner the peculiarities of this country ought to be taken into consideration. He believed that on the whole England would maintain its own, and that English engineers need not be afraid of any innovations from America.

Mr. GEORGE FINDLAY remarked that the Paper was of great interest to all who, like himself, were actively engaged in the working of English railways. Notwithstanding the various differences described, the mechanical principles adopted on English and American railways were the same, whether with regard to the engines, the carriages, or other rolling stock, the different necessities of the countries having developed the different types employed. Some fifteen or twenty years ago he went to the South Kensington Museum with Mr. John Ramsbottom, the late locomotive superintendent of the London and North-Western Railway, who showed him with great interest the old 'Rocket'

engine, which, he said, combined as nearly as possible all the mechanical principles prevailing in the construction of the present locomotive engine. On the subject of engines he was not competent to speak with much authority, but he might be permitted to say that at Crewe the London and North-Western Company had, many years ago, adopted as an experiment steel instead of copper fire-boxes, and since the visit of Mr. Webb a few years ago to America, they had adopted them to a much greater extent, and were increasing their use. For the tenders now employed on the London and North-Western Railway they were using wheels with cast-iron frames and steel tires; they were worked with goods engines, and he believed with economical result. No doubt the conditions of railway traffic in America, an immense country comprising an area of 3,600,000 square miles, with a comparatively sparse population of forty millions, must have called for a cheap construction of railroad for the purpose of colonising the more distant provinces. But for cheaply constructed railroads that great country would not have been opened up so soon. The conditions of traffic necessitated a comparatively low speed, averaging not more than 20 miles an hour for the longer distances towards the far west; though in some of the eastern provinces the traffic was worked as expeditiously as in this country. With reference to rolling stock, the Midland Railway Company had adopted day drawing-room and sleeping Pullman cars between England and Scotland, but he was bound to say, partly from his own observation and partly from the admission of the Midland Company, that they had not been a great success, and were not particularly adapted to the requirements of English traffic. The cars which had run for some months in the summer of last year between Edinburgh and Perth, had afterwards been discontinued as unprofitable. Other companies had adopted special types of cars for the comfort of travelling. The London and North-Western Company had day saloons, night saloons, invalid carriages, and family carriages, fitted up with lavatories and closets in a way to promote the comfort and convenience of passengers, and the Author might travel on the North Western line with as great comfort as when travelling in America. Reference had been made to the refrigerator cars for the conveyance of dead meat. The London and North Western Railway Company had carried thousands of tons of American meat from Liverpool to London during the last two or three years in ordinary covered cars, with ventilating holes, and the meat was delivered in a perfectly good condition, after a journey of ten to twelve hours. Meat was

also brought from Aberdeen, a distance of 600 miles, the journey occupying about thirty hours. An ordinary truck covered with tarpaulin was sufficient for the purpose. The refrigerating cars used in America were therefore not necessary in England, where the journeys were not so long, or the variations in temperature so great. With reference to the question of continuous brakes the idea had strongly possessed the public mind, and it was encouraged by the Board of Trade, that continuous brakes were the only means of preventing railway accidents. No doubt a continuous brake was a great adjunct to fall back upon in cases of emergency; but he was sure that under the present conditions of working railway traffic in England, with a system of signals and block telegraphs, there was no urgent necessity for the immediate adoption of a continuous brake such as there would be if railways were worked under the conditions prevailing in America. There the brake was adopted first, and to the present day the interlocking and signal arrangements existing in England had not been adopted. He had no doubt that with the skill of English engineers and the long purses of some railway companies, sooner or later a brake would be developed that would be adopted generally; but to attempt to enforce by legislation the use of any particular brake at the present moment would be a great mistake, and an obstacle in the way of further improvements. With reference to the heating of carriages, he believed that great improvements might be made upon the present crude system of hot-water tins. If anything could be done to warm a train throughout without disturbing the passengers, it would be a great advantage.

Mr. BRAMWELL said he gathered that the Author was of opinion that English railway travelling would be improved by the general adoption of saloon carriages similar to the long American cars. He could not help thinking that the kind of carriage required to promote comfort in travelling depended very much upon the temper of the traveller; and as it was impossible to have a carriage to suit the temper of every passenger, it was desirable to fulfil the requirement as far as possible, and the only way to accomplish this was to consider the general temper of the nation. The general temper of the English nation in regard to railway travelling, as compared with that of other nations, might, he thought, be ascertained by looking at the passengers on a railway platform, and observing their behaviour in the selection of a carriage. If such observation were made at an English railway station it would be noticed how carefully every man went

along the train to find an empty compartment; and if he could not find an empty one he would get into a compartment where there was only one passenger; and if he could not find that he would get into a compartment where there were only two passengers. Englishmen were not gregarious. They did not like the sort of sprightly conversation that pleased some foreign nations, but preferred solitude. At the risk of being sneered at, as one who could not bear his fellow-creatures, he would put forward, in support of the reasonableness of this behaviour, a supposition. If twenty-four persons were travelling on a railway the probability was that one out of the twenty-four would be a person whom the other twenty-three would consider disagreeable. Now, if those twenty-four persons were in one compartment, the one disagreeable man was the fly spoiling the whole ointment; the whole in this case being represented by twenty-three. Let the compartment be separated into two equal parts, and the nuisance was not imported into the additional compartment; twelve persons were saved the nuisance, and it annoyed only eleven. If it were separated into four compartments, the troublesome man annoyed only five. He was afraid that this supposition had a jocular air about it; yet he did not mean it as a joke, but as affording an explanation. Why each passenger tried to find a compartment to himself was so much of the temper and genius of Englishmen, that the introduction of the long American carriages would not be acceptable. He had had experience in American railroad travelling, and he agreed with Mr. Bell in what he had said about the company. He had never, except on one occasion, met with the slightest inconvenience or rudeness from any passenger, the company contrasting favourably with that of third-class carriage company in England. Nevertheless he should be sorry if the American system were imported into England. If a man travelled with his wife and family he preferred a compartment to themselves. Whenever he saw a Pullman car he carefully eschewed it. Instead of paying an extra price to ride in it, he would pay an extra price to ride out of it. Rather than adopt the Pullman carriage he should prefer to revert to the plan adopted in the mail carriages on the London and Birmingham railway when it was first opened, in which the separate compartments placed upon an under frame, contained only four persons, so that each man had his corner. With respect to practical working of trains, what could be worse for rapidity of traffic than having simply the ends of long cars for the exit of forty or fifty passengers? One could well understand that in

America at a time when railway stations were unknown except at the large towns, and when platforms were not used, it would be desirable to have some contrivance to enable the passengers to get to the ground by means of steps at the ends of the carriage. It would be inconvenient, expensive, and cumbrous to have such steps at a number of side doors. But he did not think it would be possible to conduct traffic with rapidity, or give passengers a feeling of security in the knowledge that they could get out quickly in the event of an emergency, if they were restricted to an end delivery. It had been said that the long carriages were easy to travel in, and probably there was something in that statement; but he saw no reason why there might not be—as there actually was on some lines—the same length of under frame, the same under-carriage in every respect, coupled with those separate compartments, which were more suited to the English taste than all the 'drawing rooms' afforded by the through-car system. He hoped that the Institution would agree with him, and that it would not go forth as the opinion of the Institution that it was desirable to introduce into England the American through cars, whether of the Pullman or any other form.

Mr. ROCHUSSEN desired to call attention to the fact that while the American cast-iron wheel was represented as having a life of 60,000 miles, the steel wheel which had been used in Germany for eighteen years had a life exceeding 400,000 miles. He believed that orders had been taken for wheels to be used in Russia for which a life of 500,000 miles had been guaranteed.

Mr. CLAYTON had no doubt that cast-iron wheels had answered the purpose of American engineers very well up to the present time. In the first instance they had been compelled to resort to them because they had not appliances for making wrought-iron wheels such as existed in this country, and they had been much favoured by the specially good class of iron of which the wheels were made, and the improvements from time to time introduced into the manufacture. The cost of the ordinary 42-inch carriage wheel was upwards of £6 per wheel. In England the best class of wheel, commonly known as the Mansell wheel, could be made for less money. The weight of the cast-iron wheel was about $7\frac{3}{4}$ cwt., while that of the Mansell wheel was $6\frac{3}{4}$ cwt. The life of the cast-iron chilled wheel was said to be from 60,000 to 90,000 miles. It had been found difficult to obtain the exact mileage of carriage wheels in England, owing to the intricacies of the working of the traffic. During the last two or three years, however, Pullman cars, and other special carriages had been fitted up on the Midland

Railway, and having been kept for particular districts, the mileage could be better ascertained. Under a number of those vehicles different classes of tires were placed. Under one end there might be two wheels with the best Yorkshire iron tires, and at the other end Bessemer steel tires might be used; under other vehicles there might be Siemens' tires or cast-steel tires and crucible steel tires. The mileage of all of them was recorded, so that it would be possible to ascertain the best class of tire to be employed in future. Some of the vehicles were carrying a greater weight than the maximum stated in the Paper, and the mileage of some of the wheels had already reached 168,000, the tires not having been re-turned. Calculating from the present diameter of the wheels, it seemed probable that before the tires had been reduced to 1 inch thick they would have reached 600,000 miles. When the tire was considered to be too weak to carry a load, it could be renewed for about 50*s*., and then the wheel was almost as good as new.

Mr. CRAMPTON thought that too little attention had been paid to the axle-boxes of railway rolling stock. He wished to know from the managers of railways how it was that the oil-boxes had been given up, seeing that they were thought some years ago to be in every respect superior to grease-boxes. Captain Galton had stated that the American car had run 9,000 miles with a pint of oil. That was a long distance, but it appeared that with the Beuther axle-box 33,000 miles had been run with the same quantity of oil. Under those circumstances it seemed extraordinary that the English railway companies had gone back to the use of grease.

Mr. TOMLINSON said Mr. Crampton was correct in stating that the Beuther axle-boxes had run 33,000 miles with a pint of oil on the Metropolitan Railway. The secret of the axle-box was in his opinion the shield at the back of the journal which effectually kept out the dirt. There was nothing more in the feeding than was done in many other boxes, but the same result could not be obtained, as the dirt could not be kept out. There were four boxes running on the Metropolitan Railway, and they had been in use since before he joined the railway in 1872, and the same brasses were still in. He did not think the box as in use on the Metropolitan Railway would be safe to work on a main line, as if by any accident the journal began to heat there was no means of getting in any more oil. This had not happened on the Metropolitan, and as the journey was only 11½ miles, should any signs of heating appear, the box could be got rid of before any serious damage was done. The box exhibited showed a provision to meet the case referred to.

Mr. LONGRIDGE remarked that the figures quoted by Mr. Crampton had been obtained from the average of nearly eight years' working of the boxes on the Metropolitan Railway. On the North British Railway a set of the boxes had been put on in 1875, to an express first and second class composite four-wheel carriage, which ran every day for twelve months (except Sundays) from Glasgow to Edinburgh and back. The total distance run in that time was 29,000 miles, and the consumption was rather less than a pint of oil for each box. No accident had happened from their getting dry, although thirty thousand boxes had been at work.

Captain GALTON in reply said the gist of the observations which had been made seemed to be a sort of bill of indictment against him for bringing before the Institution the Railway Appliances of America. When he went to America as one of the judges on Railway Appliances, Sir John Hawkshaw had suggested that it would be desirable to place any information he could obtain on this subject before the Institution, and he had accordingly done so —though not as an advocate of everything he had described. Several points of interest in the Paper had not been alluded to in the discussion. No remarks had been made on the Wharton switch. This switch had not been introduced into England; but if any railway engineer was desirous of trying it, Mr. Wharton was willing to send over a switch complete, with drawings, so that it might be fixed for experiment. Mr. Fox had said that he viewed with apprehension the placing of loose wheels upon an axle, because he considered that the wheels and axles, as fixed at the present time, acted very much like a gyroscope, keeping the train upon the line. He thought that view might be open to question. Indeed if Mr. Fox were right in this assumption it might perhaps be contended that the fixed wheel and axle, in acting like a gyroscope, would rather tend to carry the train off the line at every curve that it met, because the gyroscope action would tend to keep it in the plane in which it was moving, and a curve in the line would conduce to turn it from that plane. Mr. Longridge had stated that the resistance mentioned in the experiments on the Miltimore axle was much in excess of the ordinary resistance in English trains. He had not witnessed those experiments, but he would observe that the experiments were made upon curves, and not upon a straight line, and that the resistance mentioned was that upon the curve. Mr. Longridge had also directed attention to the high cost of the chilled wheels. But the price which Mr. Longridge had quoted was that of the paper wheel with a steel tire, and not of the cast-iron wheel. The cost of the cast-

iron wheels in America was from $2\frac{1}{2}$ or $2\frac{3}{4}$ to $3\frac{1}{2}$ cents. per lb., which for a wheel of 800 lbs. would amount to £4 10*s.* or £5 in paper money. The cost of the Canadian wheels of the same size, of which the price was given in gold, was $12\frac{1}{2}$ dollars, or from £2 10*s.* to £3. It was impossible to give any satisfactory data as to cost, because so many disturbing elements interfered; for instance the protective tariff was very high in the United States; and the difference between the value of paper currency and gold was subject to continual fluctuations. With regard to the question of carriages, he held very strongly the opinion that if instead of an old stage-coach (which seemed to be the *beau idéal* of Mr. Bramwell) railway companies had started on the principle of a steamboat saloon, the public would have had a greater convenience in travelling than they now possessed. He did not mean that that was as important in England as it was on the continent of Europe, where the conditions of travelling much more resembled those in America, the distances being equally long, and the trains running for several days before reaching their destination. The American idea of a steamboat saloon had necessitated a long substructure for the carriage. This would not move on curves without the bogie truck. The large substructure of itself afforded facilities for conveniences in the passenger arrangements, and means for passengers to move about in the trains without remaining cooped up in one place for the whole journey. He did not contend for an entire absence of compartments if such were preferred; but he did contend for a means of communication between the compartments, and for a means of locomotion throughout the train, as well as for people's convenience. And he would add that if the idea he had mentioned had been acted upon, the companies would not have required the expensive station appliances that had been introduced, and great economy would have resulted. No allusion had been made in the discussion to the Miller coupling, to the way in which the passenger carriages were coupled together, nor to the springs that had been introduced, although all these appliances presented features of peculiar novelty. American engineers had had to deal with the same questions as English engineers, but they had begun from an almost opposite standpoint. They had commenced with the idea of having to make the most of the appliances that lay to their hand, and to effect as much as they could with a small sum of money. European engineers, on the other hand, had had at their disposal large sums of money, and the European public had looked upon railways as a luxury instead of a necessity; the result no

doubt had been that the European railway was, in many respects a more complete machine than the American. The Americans, however, had introduced many appliances which might be adopted with advantage in England, and with still more advantage on colonial and Indian railways.

Mr. BATEMAN, President, said the Author had not brought this interesting Paper forward so much to instruct English engineers how to make railways, as to show them what the Americans were doing. Having like most engineers to spend a good deal of his time on railways, he always avoided the saloon carriage, and chose a compartment in which there were the fewest passengers. He looked upon a railway as a place of rest, and was glad to have nobody to talk to. Travelling in a carriage that held twenty-four persons, one could not help being disturbed by the conversation of others. He had spent many nights in travelling, and it was a great advantage to be able to sleep comfortably without being disturbed.

Mr. R. MAITLAND BRERETON remarked, through the Secretary, that an impression appeared to prevail in England that American engines were too light and flimsy for general work, and would not last more than six or seven years. The mileage and life of the best American engines compared, however, most favourably with those built in the United Kingdom. Engineers sent by various European Governments to report on American railway plant, preferred the best American types of locomotives to the English. The 'Railway News' gave the average mileage of engines for the year 1873 as follows:—

ENGLAND.	Miles.	AMERICA.	Miles.
London and North Western	15,415	Boston and Albany	24,500
Midland	18,808	Erie	27,550
North Eastern	17,290	New York Central	26,933
Great Western	18,320	Pittsburg, Fort Wayne, and Chicago	31,737
Total	69,833	Total	110,720
Average	17,458	Average	27,680

This showed an average of 10,222 miles more for the American engines than for the English, or 58 per cent. greater duty obtained on inferior tracks, in a more severe climate, over steeper gradients and sharper curves, and with heavier loads. English engines attained a greater average speed than American engines, yet they failed to give an equal average mileage for

the year. In 'Engineering' for the 10th of November, 1871, it was stated that the average mileage of engines on twenty English railways for six months was 9,160 miles; that was 18,320 miles for the year. In the same journal on the 11th of May, 1877, the average mileage on twenty-two English railways for the year 1876 was stated to be 17,934. In the discussion upon Mr. McDonnell's Paper on "The Repairs and Renewals of Locomotives,"[1] it appeared from a tabular statement as to the results of working on twenty English railways for the half-year ending July 1876, that the engines had run on an average 881,207 train miles, or 17,625 miles per engine. There was also given[2] the mileage of one hundred and seventy-six engines on the Great Southern and Western Railway of Ireland, which showed an average for ten years of only 13,926 miles a year, and it was inferred that these one hundred and seventy-six engines would last 11·95 years, running 20,000 miles a year. But it was afterwards stated[3] that the average age of the Great Western engines was 6·1 years, and on the same occasion the President, Mr. Stephenson, said,[4] "Many engines had been killed earlier than they ought to have been, especially during the last few years, because the traffic had increased to such an extent that the companies could not maintain the engine-power to keep pace with that increase." Referring to the North-Eastern Railway, he also said,[5] "that Company had scarcely a spare engine. The engines were at work night and day." If these engines were really worked so hard, it was difficult to understand how they had such a low average mileage as from 17,000 to 18,000 train miles per annum, especially as the loads were light, the road good, and the speed high.

In 1876 the Illinois Central Railroad had two hundred and two engines, which averaged 27,819 miles each in the year. In 1875 the Central Pacific Railroad had two hundred and three engines, which averaged 27,960 miles each. In 1876 the Missouri, Kansas, and Pacific Railroad engines averaged 37,811 miles. In 1873 the seven hundred and eighty-six passenger and freight engines of the Pennsylvania Railroad averaged 25,263 miles each. One of these engines, No. 133, on the Middle Division, ran 83,820 miles in the year on passenger trains, in addition to 2,904 miles on freight trains. This was equal to 237½ miles a day for every day in the year. Taking 17,500 miles as the average run of English

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlviii., p. 66.
[2] *Ibid.* Table 10, facing p. 34, and p. 39.
[3] *Ibid.* p. 47. [4] *Ibid.* p. 72. [5] *Ibid.* p. 73.

engines, the above mileage showed that this No. 133 engine did five years' average work in one year. A freight engine, No. 215, on the same division, ran 48,012 miles in the year. In 1876 one of the passenger engines on the Central Pacific Railroad took a special fast train from Ogden to San Francisco, 880 miles, in less than thirty hours. According to the Annual Report of the Reading Railroad Company of Pennsylvania for the year 1874, the weights and average mileage of the passenger engines were :—

No.	Class.	Weight in Tons.	When first run.	Miles run.	
				In Year 1874.	Total to date.
23	1st	26·9	July 1852.	24,780	410,733
44	„	26·2	May 1857.	25,484	438,541
45	„	23·8	June „	27,428	422,222
49	„	25·2	August „	28,595	475,733
57	„	25·2	June 1859.	35,407	426,071
58	„	25·2	„ „	35,142	455,428

These locomotives were selected as being among the best, and had been running from fifteen to twenty years. The table showed that they did a large duty in 1874. Taking the average of English engines at 17,500 train miles a year, these engines had been doing a duty equivalent to a life of from twenty-three to twenty-six years.

Mr. Juland Danvers's report on "Railways in India for the years 1876–77" showed that the 6,948 miles of completed railways were served by thirteen hundred and fifty-two engines, and as these engines ran 21,609,411 train miles in the year, this gave an average of 15,983 miles per engine. The East Indian Railway had four hundred and fifty engines on the main line; the Great Indian Peninsula, three hundred and thirty-one; the Madras, one hundred; and the Bombay and Baroda, sixty-four. The engine mileage on these railways had been :—

	Miles.
East Indian	14,737
Great Indian Peninsula	17,000
Madras	23,334
Bombay and Baroda	19,149
Total	74,220
Average	18,555

Mr. Augustus Morris, Executive Commissioner to the Philadelphia International Exhibition of 1876 for the colony of New South Wales, reported to his Government that American locomotives, provided with copper furnaces and tubes, instead of the more commonly used steel ones, could be delivered in Sydney for

about £2,000 each, or nearly £1,000 less than those contracted for in England, and that the boilers could be caulked on the concave method, which would increase their strength 25 per cent. In 1876 a Commission made a report to the Government of Victoria on the prices, &c., of all their locomotives, in which it was stated that the engines built in England cost, when erected in Melbourne ready for service, from £2,352 to £3,032, compared with from £2,939 to £3,571 for those built in the colony. The cost of the American engines ordered by the Government of the Rogers Locomotive Works, at Paterson, New Jersey, when erected in Melbourne, was £2,132 each. Mr. T. Higinbotham, M. Inst. C.E., Engineer-in-Chief of the Victorian railways, in a "Report of Observations on Railways made during a tour in 1874 and 1875, undertaken by direction of the Government of Victoria," stated that American locomotives were better adapted for the light lines of railways in that colony than any others he had seen.[1]

In 1877 the Rogers Locomotive Works furnished the Government of Brazil with some of the best types of eight-wheel passenger engines and tenders at the following prices :—

	Inches.	$		$
With cylinders	15 × 22	8,850;	boxing	500 extra.
„ „	16 × 24	9,250	„	„ „
„ „	17 × 24	9,500	„	„ „
Eight-wheel Mogul freight	16 × 24	10,100	„	„ „
Eight-wheel „ „	17 × 24	10,350	„	„ „

Ten-wheel engines at the same price as the Mogul engines.

The above prices were in United States currency, payable in cash when the engines were ready for shipment. The furnaces were of steel, the boilers were of the best Pennsylvania iron, and all materials and workmanship were of the best quality. These engines were either for the 4 feet 8½ inches or for the 5 feet 6 inches gauge. For copper furnaces the extra cost of copper over steel was an additional charge. The prices of some of the best engines for narrower gauges of 2 feet 6 inches, 3 feet, and 3 feet 6 inches, were as under :—

	Cylinders. Inches.	$		$
Four-wheel tank engine .	9 × 16	6,500;	boxing	350 extra.
Eight-wheel Mogul „ .	15 × 16	9,000	„	„ „
Double-ender „ .	12 × 20	8,500	„	„ „
„ „ „ .	11 × 16	8,000	„	„ „
Tank engine	11 × 16	8,000	„	„ „

[1] *Vide* Report, p. 22.

The Baldwin Locomotive Works of Philadelphia, as well as the Rogers Locomotive Works, had built most of the American engines for Europe, Australia, and New Zealand. Recently, at the former works, forty engines were built in sixty days for the Russian Government, and the company had facilities for building one locomotive a day if necessary. The great object of the American master mechanic was to arrive at interchangeability of parts. On the Pennsylvania Railroad one hundred and twelve patterns were required for one engine, but only one hundred and eighty-seven patterns were required for all the seven classes of engines in use on that extensive line.

In India the locomotive depôts were generally placed about 100 miles apart, and the average engine duty was estimated at 100 miles a day, that was 36,000 miles a year. Deducting from this 20 per cent. for repairing days, the actual engine work should be from 28,000 to 29,000 miles a year. It was evident that the engines in India must either be standing idle for want of work or else they must consume 50 per cent. instead of 20 per cent. for repairing days. In either case this was scarcely consistent with that paragraph of Mr. Danvers's report which stated that "The want of locomotives and wagons has been a great check, and I am afraid that goods have, in consequence, sometimes been damaged by delay and exposure" (page 29), and also with the passage: "The lines have been well maintained, and the rolling-stock and locomotives, to which considerable additions will have to be made, have been kept in good order" (page 46).

Mr. Alan Macdougall remarked, through the Secretary, that the permanent way of railroads in Canada was usually laid on sleepers at the rate of two thousand six hundred and forty to the mile. The common size was 9 feet long by 8 inches wide by 6 inches thick; joint sleepers were wider. The best woods were tamarac, hemlock, and cedar. The high cost of white oak was a bar to its general use, and it was employed only on bridges and for joint sleepers. Hemlock was generally used, as it was the most easily obtained. It made a capital sleeper, but had the disadvantage of being readily influenced by frost. This told on the life of the sleeper, and on the condition of the road bed in spring. It lasted from four to five years. Tamarac made a lasting tie; it was somewhat like larch in the grain. It was only obtainable in certain districts, and commanded a higher price than hemlock. A tamarac sleeper lasted from five to seven years. Cedar had been introduced in some cases on main lines, where the gradients were easy. The Great Western rail-

way company were the first to introduce it largely on their main line; along with black ash and elm it had been in use for some time on sidings. If all the sleepers were dressed to one uniform width, it would make a considerable difference in their service. At present it was cheaper to allow the sleeper to exceed its specified size than dress off the superfluous timber. This inequality of width told on the road bed in spring, when the frost was leaving the ground, as the wider sleepers retained the frost longer, and heaved more than the narrower ones. This necessitated "shimming," or putting pieces under the rail where too low, and the adzing of the higher sleepers, both which operations injured the wood. The rails were fished in the ordinary way with a pair of fish plates and four bolts. On some of the railway systems an oak plate was placed alongside the iron plate on the outside of the rail against which the head of the nut was screwed. This had been found to make the joint more rigid and lasting. The rails were usually joined on a sleeper; the Northern and the Great Western railway companies made this sleeper 12 inches wide. The Grand Trunk railway company had lately improved the joint by placing a plate of oak, 2 feet long by 9 inches wide by 2 inches thick, under it, and supporting the plate on two sleepers placed close together, and sunk below the level of the others. This seemed to make a good joint, as there was not much jolting in passing over it. The Great Western railway company had introduced a steel joint plate, which was fastened to the end of the rail like a clip, and was driven off and on. It was about 9 inches square, and was fastened to the sleeper by four spikes. It was in use on the main line between Hamilton and London about two and a half years ago. The narrow gauge railway companies employed fang bolts for the joint; but this plan had been abandoned, owing to its inconvenience in frosty weather. The introduction of a narrow gauge in a young country was a doubtful advantage. There might be a primary saving of cost, but this was more than counterbalanced by the inconvenience and extra cost of handling the traffic afterwards. The difference of gauge between the trunk lines of the American and Canadian railroads told against the latter as trade relations grew more intimate. It led to the laying of a third rail, for the American cars, on the Great Western, and finally to a change of the whole Canadian railway system to the 4 feet 8½ inches gauge. Shortly after the railways on the 3 feet 6 inches gauge had been started, the same promoters worked up two additional schemes, the Victoria, and the Credit Valley railways; but these railways were brought out on the standard gauge, as the difficulty was probably foreseen

that was then arising from the difference between the American and Canadian gauges. The experience of the Canadian 3 feet 6 inches gauge had shown that, so long as it was used merely for local or passenger traffic, the gauge answered, but where the freight was intended to enter into competition at a distant market, the delay of transhipment and cost of breaking bulk was against the gauge. These remarks referred to the Toronto, Grey and Bruce, and the Toronto and Nipissing railway companies. The Prince Edward Island railway was the only one in that island, and the only one that had the characteristics of a "light" railway. The two former lines had abandoned nearly all the points they started upon. The rail had been increased in weight to that of the Northern or Midland Company (56 lbs. per yard); their engines were nearly as heavy as those of the wider gauge, and the diameter of the car wheels had been increased. Placed in rivalry with the wider gauge, they were unable to compete successfully, and this had led the Toronto, Grey, and Bruce railway company to determine to increase the gauge of their line to 4 feet 8½ inches. A correspondent of an American scientific paper had made a comparison between the cost of working the Intercolonial railway of 4 feet 8½ inches gauge on the mainland, and the Prince Edward Island railway of 3 feet 6 inches gauge. Both railways were under the same direction, the Government of Canada, and nearly under the same parallel of latitude. The advantage was drawn in favour of the standard gauge, as it was shown that for fuel consumed, and wages paid, the Intercolonial railway did more work and at a cheaper rate. This did not agree with the statements contained in Mr. Wragge's Paper,[1] but the determination of the company to widen their gauge to the standard was an admission of the fact that the 3 feet 6 inches gauge had not succeeded in Canada. Where snow had to be contended with the light gauge was powerless. The Toronto, Grey, and Bruce railway had suffered severely from snow blockades.

Mr. R. E. MIDDLETON observed, through the Secretary, that the American car was much longer than those in use in this country for the number of passengers carried, and if employed here would be longer still in proportion, as the same width could not be allowed. For this reason station platforms would have to be increased in length. If in long journeys a drawing-room car was run for day service, and a sleeping-car for the night, two cars would have to be hauled for the number of passengers which one would

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlviii., p. 252.

carry. If the sleeping-car was run for both day and night service, from the construction of the berths there was no support for the back, during the day, higher than in an ordinary chair, and the fatigue of travelling was much increased; and for the same reason, there was no accommodation for small parcels, coats, &c., except under the seat of each passenger. Openings at the end, in cases of collision, were liable to be entirely blocked, and exit would be nearly if not quite impossible. For these reasons, besides others mentioned in the course of the discussion as peculiar to this country, and from the increased dead weight per passenger, he did not think it would be advantageous to introduce the American cars into Europe.

Mr. C. P. SANDBERG stated, through the Secretary, that Swedish iron for the manufacture of car-wheels was not as pure as the general class of Swedish iron used for the manufacture of steel, the latter being almost entirely free from phosphorus and sulphur. There existed, however, in Sweden an iron mine called Farola, yielding iron of a sulphuric and silicious character, which melted with charcoal under cold blast, and produced an extremely strong iron for foundry purposes. Guns were still made from it, both for the Swedish and foreign Governments, at Finspong. This iron had also been tried for car-wheels at the Arboga foundry in Sweden, and some of these wheels had been running with good results for several years on the branch lines of railway, where the maximum speed was 15 to 20 miles an hour; but no one would think of putting them on the State lines, where double that speed was attained, since steel tires and wheels were now so cheap. Almost every country had its special type of wheel. In America, there was the cast-iron wheel; in England, the wooden disc wheel; in Germany, the disc wheel of wrought-iron or of cast-steel; and in the rest of Europe, a wrought-iron spoke wheel with cast-steel tires. The American wheel had had a fair trial in Russia on the St. Petersburg and Moscow line, where it had been abandoned. The wooden disc wheel had been fairly tried both in Sweden and in Russia, but it had not given satisfaction; and this must depend partly on climate, and partly on local circumstances. As for the Wharton switch, one from the Philadelphia Exhibition had been put down on the Swedish State line at Malmö station; but as the authorities were satisfied with the old type of switch, he was not in a position to say that the experiment would conduce to the adoption of the Wharton switch. The permanent way, as represented by that used on the Pennsylvania line, had, however, found support on the Swedish State lines, where the fishplates or splices had been adopted. A year or two ago,

experiments on a large scale had been made on the State lines on different modes of fishing the rail, the old plan being found too weak, causing the joints to sink. Both deep and angle fishplates on one side, with a corresponding plain fishplate on the other, and deep and angle fishplates on both sides of the rail, were tried under similar circumstances. This had led to the adoption of the angle fishplate on one side, like that used on the Pennsylvania system, and it was now being introduced on all the Swedish State lines. The deep fishplates were also excellent, but in lifting the joints, and in regulating the line and keeping the gauge, the platelayers had found the angle fishplate preferable. The Sealand Railway Company, in Denmark, had gone farther still in adopting the angle fish on both sides of the rail, to prevent the early failure of the rail ends as experienced in Sweden. This had led him to construct new standard sections for steel rails, applying to them the improved fishplates for general adoption on the Scandinavian railways. These fishplates had been made both in iron and steel, in Wales and on the continent, at little or no extra cost per ton beyond that of ordinary fishplates. On the English railways, with double-headed rails, it had already been found necessary to strengthen the rail joint by deep fishplates. This plan aimed at the same result for flange rails, and there was no doubt that the small extra cost of, say, 4 or 5 per cent. of fishplate weight to the rail, was money well spent.

March 19, 1878.

JOHN FREDERIC BATEMAN, F.R.SS. L. & E., President, in the Chair.

The discussion on the Paper No. 1,522, "Notes on Railway Appliances at the Philadelphia Exhibition of 1876," by Mr. DOUGLAS GALTON, occupied the entire evening.
