DISCUSSION BEFORE THE INSTITUTION, 12TH MARCH, 1914.

Mr. Casson.

Mr. W. CASSON: I think there can be no doubt as to the importance of the question of weight which the author has put before us to-night, and the much more direct effect that it has on the operating costs of electric railways than on those of steam railways. I cannot help thinking, however, that he has gone rather far in estimating the probable effects of small reductions in weight on the maintenance costs, when one considers the rough and ready conditions that obtain in operating. There is one question that I should like to ask. Should not the horizontal scale in Fig. 2 be "time in seconds" and not "speed"? So far as Fig. 3 is concerned, I am not quite sure whether the percentage there is the percentage that the accelerating energy bears to the energy input of the train or to the energy output of the motor. If it be the former it seems to me to be about correct; but if it be the latter I think it is more like 80 per cent with stops half a mile apart. With regard to Fig. 4, I hardly think it would be found in practice that with such a small number of trains as 56 one would get anything like unity for the ratio of the maximum to the mean load. The number of trains on the underground system supplied from Lots-road power station is very much more than 56, and we should be only too pleased if we could get a figure of 1 for the ratio of the maximum to the mean load. Moreover, it is always necessary to provide against the contingency of an unusual number of trains starting at once. That is the kind of consideration that prevents these calculations being carried too far. If that were done we should be liable to have the whole arrangement upset by a slight change in the next month's time-tables. The same thing occurs to me in regard to the question of reckoning maintenance cost per ton of car. It seems to me that there are other considerations, which may be quite small and yet may have such an effect as completely to swamp the consideration of the weight in regard to maintenance, even if the weight is all put in the right place. For instance, the rolling stock on the Central London Railway is much lighter than that on the London Electric Railways; but from causes which I need not go into, its maintenance cost is considerably higher. The first electric rolling stock on the District Railway in which wood and aluminium were used is lighter than the more modern steel rolling stock, but it is more costly to maintain.

With regard to first cost, the original wood and aluminium stock was actually more expensive than the steel stock; it was cheaper, however, than our latest steel stock which is just being put into service, but it is difficult to make a correct comparison owing to the great general advance in the cost of material and labour for rolling stock.

The seating diagrams given by the author are of great interest, especially as showing the different views held by various people on what constitutes adequate seating room. People in the north country are supposed to be built on a larger scale than southerners, but I am quite sure that all our passengers would strongly object if they were placed in the seats that the author has provided on his trains. The seating room on the author's coach compares as follows with that on the District Railway:—

Mr. Casson.

	Mr. O'Brien's Coach	District Railway
Longitudinal seats ...	just under 18 in.	20 in.
Cross seats	approximately 16 in.	19½ in.
Distance between centres of cross seats ...	4 ft. 11 in.	5 ft. 8 in.

I cannot help thinking that with the very large number of stops per mile on the District Railway there would be considerable difficulty in getting the passengers in and out of the cross-seat cars, especially with the comparatively small door openings that are provided. The other day I was told by a traffic superintendent of one of the railways that "railway engineers are much too fond of trying to crowd too many seats into the cars, whether they are comfortable or not. It would be better to have fewer seats, so that they can be made more comfortable." I certainly think that with the arrangement of seats and the small doors shown it would be difficult to handle passengers fast enough for stops half a mile apart. But so far as seating is concerned, as long as we provide the traffic department with floor area it is for them to say how they want to divide it. With regard to the question of vacuum brakes, the simplicity and the low maintenance costs must be admitted, but I do not know of any system operated with vacuum brakes that is running a service of the same sort that there is on the underground railways of London and New York. I do not say that such systems do not exist, but merely that I do not know of any. In any case I think there would be difficulties. I quite agree with the author as to clerestory roofs, and I fancy everybody does at present, but fashion seems to have a lot to do with this question. For rolling stock for use in the Tubes, however, where there is no room for outside ventilators, the elliptical roof introduces some interesting problems in ventilation. The author's remarks about bogie design and construction agree exactly with our experience on the underground railways, particularly as to its not being necessary to use elliptical springs on the bolsters. As a matter of fact one very satisfactory trailer bogie that we use has no elliptical springs at all; it has two helical springs over each axle-box, and helical bolster springs. I agree as to the weight of the equalized type of bogie and as to its being unnecessary for anything like that sort of service. As to its weight, the District Railway bogie, mentioned above, which has cast-steel side frames and a 7-ft. wheel-base, weighs less than an equalized bogie having a much more flimsy construction and only a 5-ft. wheel-base. The 7-ft. wheel-base bogie rides very much better and is far cheaper to maintain. With regard to the question of wheel-base, there is considerable difficulty in practice in reconciling the use of a long wheel-base with the placing of the motor masses near the centre of the bogie. That is one of the difficulties experienced by designers in reconciling the requirements for a satisfactory bogie. The outside frames shown in the author's design are interesting, and where the positive conductor rail is far enough away to give room for the bolster swing links in that position it must be a great advantage. Unfortunately we have not got that. With regard to the question of motor bogies in general, I cannot help thinking that

Mr. Casson. engineers do not take into account to anything like a sufficient extent that they are giving that bogie the work of a locomotive to do; in fact, as far as tractive effort is concerned, it does more work than a good many locomotives. I do not think the motor bogie receives anything like the attention that it ought to do. If we took a lesson from the locomotive engineer and went more on the lines of a locomotive in building motor bogie-frames it would be much better. With regard to the question of cast-steel axle-boxes, I agree with the author, but we do not find cast-steel axle-box slides are very good. They save an almost infinitesimal amount in weight and they wear themselves and the axle-boxes out very rapidly. We prefer cast iron. With regard to the table on page 453, I cannot help thinking it would have added very much to its interest and the amount of information that we get from it if instead of taking the motor car as the unit for comparing weights, we had what I may call the traffic unit, that is to say, the motor car and the trailer car or cars, 1½ or 1¼, or however many trailer cars go with each motor car. For instance, I recognize No. 2 in Table I as the Central London Railway Standard motor car. We have reduced the number of cars per train now since the motor omnibuses became so aggressive, but when these motor cars were originally introduced there were two motor cars to a 7-car train. It alters the whole question of relative weight if that is taken into account. I have here the figures of the latest steel rolling stock on the District Railway which is just being put into operation. They are as follows:—

Trailer cars per motor car	1
Motors per motor car	2
Horse-power per motor	230
Temperature rise at which horse-power is taken for 1-hour run...	135° F.
Gear ratio	3·37
Diameter of driving wheel...	36 in.
Diameter of trailing wheel...	30 "
Weight of each motor	6,100 lb.
Weight per rated horse-power	26·5 "
Bogie wheel-base (motor)	7 ft. 3 in.
Bogie wheel-base (trailer)	7 "
Weight of car complete (motor)	33 tons
Weight of car complete (trailer)	22 "
Weight of motor bogie complete	11·4 "
Weight of trailer bogie complete ...	3·8 "
Weight of motor bogie without motors ...	6 "
Weight of car body complete and equipped (motor)	18·2 "
Weight of car body complete and equipped (trailer)	14·4 "
Weight of equipment complete including motors but not compressors	7·3 "
Length of car	49 ft. 9 in.
Width outside	8 ft. 8 in.
Length of bogie centres	34 ft. 1 in.
Floor area	320 sq. ft.

The whole of this is passenger space, except that in the front car of the train a space 3 ft. × 8 ft. is shut off for the motorman. The space available for passengers is thus 99·1 per cent of the total floor space in an 8-car train. Mr. Casson.

Square feet per ton for motor and trailer car ...	11·6
Square feet per ton for motor car only	9·7
Square feet per ton for trailer car only	14·5
Horse-power per ton of train	8·4

The most severe continuous service on which these trains operate is about 17 miles per hour schedule speed with stops about ½ mile apart.

Mr. H. W. FIRTH: The author emphasizes on page 445 the importance of the question to which Mr. R. T. Smith * recently called attention in connection with locomotives, and to which I also referred in the discussion, namely, the characteristic curve of the motor. Mr. O'Brien shows that that is again important, not only in connection with the question of locomotives or the utilization of suburban rolling stock on non-suburban services, but even in suburban traffic where a certain amount of non-stop running is necessary. He refers to the question of strength as regards collision, and his remarks seem to show the importance of keeping down to the lowest possible limit the weight on the underframe—that it is much more important to keep that down than to keep down the weight on the bogies. If that be so, it certainly seems to show that single-phase equipment, which requires very heavy apparatus on the underframe, would be less satisfactory in this respect than systems which place most of the weight on the bogie. The author also gives the capital cost of motor coaches as £70 per ton, and of trailer coaches as £45 per ton. I take it that the difference is entirely accounted for by the electrical equipment. I should like him to tell us whether this is so or whether it costs more per ton to build a motor car than to build a trailer car, excluding the equipment. The light car design which the author has shown is very interesting, but I think it does not give as great a seating capacity as side-door compartment cars do. Thus, the light trailer car of the Lancashire & Yorkshire Railway, if my figures are correct, provides a seating capacity of 1·62 seats per foot-run of train, whilst a side-door compartment car gives a seating capacity of at least 1·8 seats per foot-run of train; moreover, this light car gets that seating capacity per foot of train (which is less than that of the side-door compartments) only by increasing the width of the car to 10 ft., or at least 1 ft. more than usual. I should like to know whether these 10-ft. wide coaches are operated over the same road and at the same platforms as ordinary narrower stock. If this be the case, how are the platforms arranged so as to deal with both types of coach? The author makes a point that the gauge of the rolling stock should not be restricted to the limiting point of the loading gauge of the line. That is all right in case the limiting point of the loading gauge is in some out-of-the-way portion of the line, but there are a large number of places in the very centre of the heaviest suburban traffic in London where 10-ft. cars could certainly not be run. I think the seating capacity per foot-run of this car does not show up as favourably as I thought it might compared with the side-door arrangement. As regards the weight per seat, or number of seats per ton, Mr Firth.

* R. T. SMITH. Some railway conditions governing electrification. *Journal I.E.E.*, vol. 52, p. 293, 1914.

Mr. Firth. this car is, so far as I know, far ahead of anything that has ever been built. The author points out that the side-door car is much less inherently strong than the end-door car. I should like him to tell us the time that it takes to empty a full car of this description on its arrival at a terminus. I think it will be found that quite a long time is taken to empty one of these cars. It may be all right with the frequency of service with which these cars have to contend, but in some cases the frequency of service is so great that the utmost speed is required in loading and unloading passengers. I notice in Fig. 6 that the author shows two designs with additional doors in the sides of the car as well as those at the ends. Does not this increase the weight of the car over the weight of those with end-doors only? Also, is there any advantage from the point of view of the passenger in this arrangement over the arrangement shown in the first two diagrams? It seems to me that they can be unloaded more quickly, but I wonder whether the author can give us any results from actual operation. With regard to the question of bogies, I notice the wheel-base of the new bogies is 10 ft. I think I am right in saying that the original Lancashire & Yorkshire bogies had an 8-ft. wheel-base. Has this increase in wheel-base been due solely to considerations of providing satisfactory running for light cars? In a paper * read last month by Mr. Willox before the Institution of Civil Engineers the very great importance of wheel-base in regard to the question of rail wear has been pointed out. I wonder if the author could give us any information as to rail wear with relative wheel-bases, and tell us whether the question of rail wear influenced the choice of wheel-base. Or was it chosen solely with a view to improving the riding of the cars?

Mr. Sparks. Mr. J. B. SPARKS: In discussing methods of reducing the weight of motor coaches, the author presents much information of value, but I consider that the calculations which he gives on page 447 largely exaggerate the importance of such a reduction in weight, and, moreover, are worked out on a wrong principle. The author has assumed that the costs of energy, and of repairs, maintenance, etc., vary *pro rata* with the weight of the coach, but I submit that these costs will not vary in any such proportion, and that the cost per ton will increase for any reduction in the total weight. Further, I believe I am right in saying that the weight of all types of electric rolling stock has largely increased since electric traction was first introduced, it having been found that the more substantial construction obtained with an increased weight reduced the maintenance. Provided the required strength is obtained, it is certainly advantageous to avoid excessively heavy cars, but I submit that it would not pay to increase the cost of rolling stock by 10 per cent in order to save 4 per cent in weight, as the author suggests. With regard to the importance of weight reduction as affecting energy consumption, I have made the following estimate as to what reduction in total cost of working a railway would result from reducing the weight of the motor coaches by as much as 10 per cent. Taking the cost of locomotion (that is the cost of operating the trains) as 30 to 40 per cent of the total cost of operating the railway, and the cost of energy as 50 per cent of the cost of locomotion, the energy accounts for from 15 to 20 per cent of the total cost of working the railway. Owing to the various losses in the electrical system and the energy required for overcoming wind resistance, etc., we may assume that a reduction of 10 per cent in the weight of the rolling stock will only reduce the energy consumption by 5 per cent. This saving of 5 per cent in energy consumption would probably reduce the generating costs by not more than $2\frac{1}{2}$ per cent. As stated above, the energy cost amounts to from 15 to 20 per cent of the total cost of operating the railway, so that if this be reduced by $2\frac{1}{2}$ per cent the reduction on the total cost of operating the railway amounts to only 0·375 or 0·5 per cent. This reduction of less than 0·5 per cent in the total cost does not seem to bear out the author's figures. I should like to know if I am right in assuming that he takes the expenditure on energy consumption, maintenance, etc., *pro rata* with the weight of the coach. [Mr. O'BRIEN: Yes, that is quite correct. I estimate that if the weight of the coach be reduced from 10 tons to 9 tons the cost of repairs should be reduced from £50 to £40 per annum.] I submit that this is a wrong principle on which to estimate this saving, and that the reverse to what the author suggests is more likely to occur.

Mr. Burnett. Mr. R. H. BURNETT: A similar subject was discussed at the Institution of Civil Engineers only the other day when a good deal was heard about the great wear of rails, although nothing was said about the tyres. I fancy there must also be a great wear of tyres. In the papers that were read before the Institution of Civil Engineers the authors had investigated most carefully—I may say microscopically—the proper composition of rails to withstand the wear that takes place. I ventured to point out in the discussion on those papers that I thought the ingenuity displayed in determining the chemical composition of rails might be better expended in investigating the cause of their wear, as in my opinion it was due to a very great defect in the gear through which the electric force is transmitted to the wheels. I will confine my remarks to-night to only a few points, and I may start by mentioning that my experience of 40 or 50 years ago on the Metropolitan Railway enables me, I think, to speak on the very points that are being raised by the paper to-night, because of my having had charge for eight years of the rolling stock and the permanent way in steam locomotive days. We did not then work the length of line that is being operated now; the total length of the Metropolitan Railway, the District Railway (which we also operated and maintained), and the other branches of the Metropolitan Railway, was then only 25 miles; but I had some experience of what I may call the intense traffic that is peculiar to electric traction, because of the short distances between the stations, and such questions as starting and stopping quickly, rounding curves, etc., were even then very much to the fore. I wish in the first place to emphasize Mr. Casson's remarks with regard to the need for solidity of the bogies through which the electric force is transmitted to the rails. My observation of the rolling stock of the Metropolitan and District Railways has made me feel that in the attempt possibly to get lightness the very large amount of work that is being done by these bogies has not been taken into account. Taking the analogy that the first speaker made about the bogies of steam locomotives, although they have no driving to do they would soon go to pieces if they were constructed in the more or less—I do not like to use the phrase—flimsy way that I observe. It is very important

* W. WILLOX. Rail-steels for electric railways.

Mr. Burnett. that the bogies should be substantial in view of the enormous force that is given out in propelling the train. I think any saving in the weight of the bogies themselves is quite a mistake. The direction in which one should go is rather to make them more solid to stand the wear and tear upon them. Another important question is the length of wheel-base. To my mind the wheel-base is too short. Theoretically a short wheel-base is the right thing, because it tends to reduce what I may call the "scissor" action between the guiding flange and the high rail. I watched very carefully the action of the various types of bogies running over the Metropolitan Railway in my time, because the wearing away of the rails and flanges was a very important question, and I am satisfied that a long wheel-base is infinitely better in practice than a short one, because it compels the bogie to set itself more correctly to the curve and reduces the flange friction and the wear on the side of the rail. I notice that various figures are given in the table on page 454 for the bogie wheel-base, under the heading of "Trailer cars." I am glad to see that the bogie wheel-base in No. 1 is 10 ft. as compared with 5 ft. in No. 2, and 5 ft. 6 in. in No. 6. I am quite sure that the bogie with a 10-ft. wheel-base is better than a bogie with a 5 ft. or 5 ft. 6 in. wheel-base; in fact I think one need not be afraid of going up to 12 ft. With 40-ft. carriages we had a 20-ft. steadying wheel-base—a most important feature for ensuring steady running on the *straight* portions of the lines—and the cars went round the curves with perfect ease when properly guided by radial axles in front and without any wear on the wheel flanges.

The other point that I should like to mention is the diameter of the wheels. The larger it is the better. Mention was made at the Institution of Civil Engineers the other night of the sacrifice of seating accommodation if larger wheels are used. We had wheels 3 ft. 6 in. in diameter and did not sacrifice any seating capacity. I really do not understand why at least 3 ft. 6 in. wheels should not be used on electric rolling stock. Even if it meant sacrificing some seats I believe it would pay. Who would ever think of running a locomotive—of course there is the reciprocating action with it which I admit does not occur in electric traction—with small wheels like those under an electric train? Such a locomotive would knock itself to pieces in no time. It is therefore very important to use wheels as large as possible even if it means sacrificing some seats or raising the floor of the carriages. What does it matter if people have to step a few inches higher than they have to do at present? Another point emphasized in the paper read before the Institution of Civil Engineers was the difficulty of carrying the motors on springs. I am not an electrical engineer and it is not for me to suggest how the thing should be done; but why not attach the motors to the bodies of the vehicles and drive the axles of the carriages through gearing or in some other way, the weight of the motors being carried, not on the axles, but on the body of the car? The weight would then be carried on the springs, which cannot be the case when the motors are attached direct to the axles of the driving wheels.

Mr. Mason. Mr. C. L. MASON: As a representative of the carriage department I have been very much interested in this paper. In particular I was astonished to see the figure that was given for the saving that is effected by doing away with the superfluous weight of carriages. The trend of modern carriage design is always towards a heavier vehicle, and I think the reason for this is that a lighter coach built on the present lines will not stand up to modern traffic conditions. Secondly, the public demand greater comfort, which means less seating capacity per vehicle or greater weight per passenger, and there is also the steadier riding that is obtained by a heavier vehicle. In designing a lighter coach the carriage superintendent would have to be careful not to increase unduly either the first cost or the cost of maintenance, as it is by these figures that he is judged. The saving in haulage, etc., effected by reducing the weight, referred to by the author, does not show in the balance sheet as such, and would not perhaps be so apparent to the general manager and the directors, and by them credited against the increase in first cost. Naturally, therefore, if the carriage superintendent finds that the lighter vehicle causes the maintenance charges to increase, he is apt to build a heavier vehicle in order to make sure of keeping down his departmental costs. I should like to ask a question with regard to the paragraph at the bottom of page 447, to which a previous speaker has referred. I have not been able to follow the statement that "it becomes therefore a commercial proposition to spend as much as £185 per motor and £145 per trailer in labour and material in order to save a ton in weight." As I understand it, it should be the total saving per annum by omitting this ton of weight, multiplied by the life of the coach; that is to say, so much is saved in first cost, so much in the wear of the permanent way, and so much in hauling the vehicle, and the annual saving multiplied by the life of the vehicle will give the amount that might be spent in getting rid of the unnecessary ton. If we take, say, the £19 per trailer and divide it into the £145, or the £25·5 and divide it into the £185, it gives a figure of somewhere about 7 or 7½, which from my reasoning would appear to be what the author assumes the life of the electrical coach to be, so that I can only presume I have misunderstood his calculations somewhere. Further, he says on page 446: "It is not a difficult matter so to design the ends of the underframe as to prevent over-riding of one underframe upon another." I should like to ask him whether he knows of a suitable device that will prevent the over-riding of an underframe fitted with buffers, such as we have to use on the London & North-Western Railway.

Mr. Bowden. Mr. J. BOWDEN: Comments have been made on this paper by locomotive, carriage, and electrical engineers, which suggests that this series of papers on electric railway work is bringing together that combination of experience in the development of electric rolling stock which has hitherto been rather conspicuous by its absence. On page 454 the author states that "it will be realized that the question of weight has not had the same attention given to it as the question of equipment." There can be little doubt of this, mostly due to the new conditions and problems raised by electric traction apart from the design of motors and control gear. The design of rolling stock for heavy electric working has been largely a question of trial and error; this paper points out a better way and also the importance of weight saving, to which the remarks of previous speakers suggested opposition. Surely the factor of intrinsic strength which the paper so strongly emphasizes has escaped their notice. We cannot be content with anything but rational design, and we are led thereby to use

Mr. Bowden. only such materials as make for weight reduction. If strength efficiency be thereby sacrificed, the design is not rational. Materials have so far progressed during the last 10 years that alloys of steel and bronze can now be made with such physical properties, that but for their use the hulls of large ships like the *Mauretania* could not have been built within the tonnage limits now common to that class of ship. On similar lines the operating costs of electric traction can be economized. I am in accord with Messrs. Burnett and Casson as to the desirability of following locomotive practice in regard to design, materials, and workmanship of trucks. Early locomotive engineers soon found it necessary to construct frames which, in addition to being suitable as a carriage, were sufficiently rigid to take the stresses of the engine itself and of starting and stopping. The motor truck mentioned in the paper is equipped with two motors of 250 h.p. normal rating, and capable, no doubt, of 50 per cent overload on occasion. Thus the truck may have to stand stresses incidental to 750 h.p. at starting, and equally heavy stresses on stopping. For such service a mere carriage truck is not sufficient, and failure to appreciate this has proved expensive, as many of us know. Judged by the heavy service conditions which obtain in London the truck shown in the paper appears to be light. The vacuum brake is used, and this affirms the suggestion. I would ask the author whether that brake retards so heavily as is required for the Metropolitan and District Company's services where short runs and 20-second station stops are required to meet the time-tables of to-day. The large vacuum reservoirs suggest difficulty in this respect. In truck details I notice that the journals are without button heads, side thrust being taken on the ends of the axles by bearings provided with means of adjustment. This arrangement is comparatively new in this country, though common in Continental practice and in America, but without the adjustment. As Mr. Burnett said, the longer wheel-base eases the side pressure on axles, and end wear is particularly troublesome on short-wheel-base trucks. The gear wheel is bolted to an extension of the wheel boss—I presume in halves. [Mr. E. O'Brien: It is pressed on.] If bolts are used why not take advantage of split gears and avoid pulling off wheels when renewing gears?

Seating and door arrangements have been discussed at some length, and I would refer to experience of both car and compartment stock working together. Car stock only was installed on the electrification of the Metropolitan Railway, and later Mr. C. Jones converted several existing compartment trains built for steam service and of comparatively recent construction; the trailers were fitted with train lines and the end vehicles were mounted on new underframes and motor trucks; fireproofed compartments were provided for control gear and motormen. These trains are greatly appreciated by the traffic department and travelling public alike. Compared with car trains, even those fitted with centre doors, the side-door train loads and unloads faster, the public prefer the privacy, there is less difficulty with draught, and the doors being fitted with slam locks and suitably hung give no trouble or delay in opening and closing. These compartment coaches are easier and quicker at stations than the car trains working on the same service, and the superiority of the old side-door arrangement has been fully demonstrated on the Metropolitan Railway. There is, moreover, the advantage of utilizing existing stock which by obsolescence might become a heavy charge against electrification. Mr. Bowden.

Dr. Smith. Dr. S. P. Smith: On page 445 the author draws attention to the very important matter of the different services for which motor coaches have to be equipped, such as low-speed city traffic and high-speed suburban traffic, which makes it troublesome to obtain the best conditions for both classes of traffic in one and the same vehicle. The result is that a compromise has to be accepted both in the motor characteristics and in the gear ratio. Now this is probably the cause of a lot of the trouble that is experienced on the suburban service, owing to the excessive strains that are set up thereby. It would be far better if there were more elasticity in the method of speed control, for we could then suitably meet the various conditions of working. At present the standard method is to use the series-parallel method of control and quickly bring the train up to a fairly high speed; it is then allowed to coast a certain distance, depending on circumstances, and is finally brought to rest as quickly as possible. This is doubtless rather bad for the equipment, but as long as we are limited to the series-parallel method of control we cannot well avoid working in this way. If, however, we can get more elasticity into the speed control we can get characteristics which are more suitable for both low and high-speed traffic. The recent developments in the design of traction motors tend to show that instead of having only two economical running speeds we can have any desired number, though probably only three or four would be used owing to the complications of the controller. This elasticity is obtained by means of field control produced either by placing the poles in parallel or by diverting the field current. The possibility of field regulation is a consequence of the introduction of interpoles in traction motors. So long as interpoles are not used, one of the most important things that the designer has to bear in mind is commutation, which practically determines the flux; but as soon as the interpole is introduced he can vary the flux as he pleases. The result is that the same heavy starting is no longer necessary to produce a high acceleration, because a much stronger field can be used. It is then possible to run up to whatever speed is suitable and to remain at that speed for a longer period, instead of running to a high speed and then coasting. In this way there are not the same heavy demands on the station either when starting or running. On reaching the suburban line the driver can then notch up to a higher speed when required. By thus taking full advantage of the interpoles, which at present seem to be advocated chiefly for producing good commutation, it is possible to improve the service very considerably by increasing the number of economical speeds; at the same time the starting losses, the maximum electrical demands, and the mechanical stresses will all be reduced. The future will probably show that series-parallel control alone is but one step in the right direction.

Mr. F. W. Carter: There are only a few matters that I wish to mention in connection with the paper. The first has reference to Fig. 1, which shows the resistance to motion of a two-coach train. Train resistance is a subject on which no two people ever seem to agree, and I must Mr. Carter.

Mr. Carter. say that I consider the curve given in the paper is very high. At 35 miles per hour the resistances are shown as approximately 18½ lb. per ton; I think this is higher than would be expected even for a single coach of 40 tons' weight. I wish therefore to ask the author what is included in the train resistance, because there are practically two train resistances that appear in electric railway work. One is train resistance when power is on, and the other the train resistance when the train is coasting. In the latter, the motors are being driven, and in addition to the true train resistance there is axle-bearing friction, gear friction, armature-bearing friction, brush friction, and wind friction in the motors, all of which appear as resistance to the motion of the train. This may amount to a large percentage of the whole, and in one case that I recently investigated, viz. that of a heavy interurban car of the American type, weighing about 25 tons, having a 4-motor equipment, and running at about 20 miles per hour, the effect of the friction due to the motors when the car was coasting was about 4 lb. per ton. If, then, the train resistance as deduced from the slope of the coasting curve is, say, 16 lb. per ton, only about 12 lb. per ton of this is true train resistance, and the rest is friction which only appears when the car is coasting, since all this friction is attributed to the motor when power is "on." It would not be practicable to attribute the motor friction to train resistance when power is "on," as the gear losses necessarily depend on the power that is passing through the gears. I wish, therefore, to ask the author whether in Fig. 1 the motor friction has been subtracted, leaving the true train resistance, or whether the motor friction is included, which may account for the curve being so high.

I have long contended that unnecessary weight should be saved in trains intended for suburban services, and am therefore gratified to find that the author takes the same view. The value of the saving does not amount to much for long-distance services, as it is only the fact that frequent stops are made that makes a saving in weight result in a commensurate saving in energy. As I read the paper I do not think the author is suggesting that weight should be saved at the expense of strength in the coach, as many speakers seem to have assumed. I am sure the author fully realizes that the saving must not be such as will diminish the strength, but must be effected by more careful choice of material, or by cutting down weight where it is not necessary for strength. Any saving in weight that can be obtained in this manner is justifiable and good economy, but a saving which results in a sacrifice of necessary strength would probably cost more in maintenance than is saved in power. In common with several other speakers, I do not quite appreciate what the author intends to convey by the paragraph at the bottom of page 447, on the subject of the yearly saving due to a saving of weight. It seems to me that it is not right to take maintenance at so much per ton when the question of weight itself is under consideration, because the saving in weight will not necessarily result in a saving in the cost of maintenance. I should say the only saving to be expected would be the power saving of £12 10s. per annum. The only other point to which I wish to make reference is in connection with motor weight. This is a matter that has come forward during the last few years, and it is now usual to design motors with this feature strongly in view, and to arrange induced ventilation to carry away the heat in order that as light a motor as possible for the power may be obtained. This is done with the special object of doing away with unnecessary weight, and it is quite in accordance with the author's views on the subject. Mr. Carter.

Mr. W. A. A. BURGESS (*communicated*): Although the author has dealt rather fully with the reduction of dead weight, he does not refer to the importance of reducing to a minimum the proportion of the motor weight that is directly borne by the axle. This proportion of course very considerably affects the hammering action at rail joints and crossings, and therefore the upkeep of both track and tyres, and to a less extent that of the rolling stock as a whole. The "wheelbarrow" method of motor suspension shown in Fig. 8 is undoubtedly preferable to suspending the whole of the motor weight from the axle, but even so more than half the weight of the motor has still to be carried by the axle. It appears very desirable therefore to aim at the suspension of the motor from the sole plates at a point as near as possible to its centre of gravity, and even though this is by no means easy owing to the necessity for keeping the motor as far as possible below the underside of the car floor, I consider that it will be found practicable in many cases. As the sliding movement of the motors would be doubled by this method, owing to the radius being halved, it would probably be found most satisfactory to suspend the motor by pivoted links which would allow this movement to take place without the necessity for a special bearing sliding in guides on the sole plates. As to the ventilation of coaches, an objection to the method of introducing fresh air at the bottom of the coach and there warming it is the amount of dust that would be kept in suspension in the air; for as users of some of the types of domestic radiators now on the market are painfully aware, there is always an impalpable dust which only the frequent use of a vacuum cleaner can keep down, and which is very perceptible in the rising current of warm air from radiators standing directly on the floor. I therefore suggest that the process be reversed and the air extracted from the carriage at the floor level, fresh air slightly warmed and properly diffused being admitted at the top of the carriage. The heat required by varying outside temperatures should preferably be provided by heaters suitably distributed under the seats or in the footboard and controlled by the passengers. With reference to carriage lighting, owing to the proximity of the roof to the level of the eye, semi-indirect lighting seems particularly suitable, and with a matt-white roof-surface a plain inverted conical shade of white opal glass suspended directly below the lamps will be found to give a pleasing effect with lamps of moderate candle-power. Mr. Burgess.

Mr. W. Y. LEWIS (*communicated*): In my paper before the Society of Engineers in May, 1912,* I emphasized the desirability of (1) low weight of rolling stock per seat provided; (2) graduated acceleration and deceleration so as to permit of mean accelerations and decelerations several times greater than was customary; (3) regeneration during deceleration. I welcome Mr. O'Brien's paper as dealing with (1), and hope that forthcoming papers relating to electrification problems will discuss the evidently more promis- Mr. Lewis.

* W. Y. Lewis. Intermittency: its effect in limiting electric traction for city and suburban passenger transport. *Society of Engineers, Transactions for* 1912, p. 121.

Mr. Lewis. ing fields, (2) and (3). It seems a pity that the author has not summarized the possibilities in the field that he had explored, by indicating, if only approximately, the extent of the weight reduction attainable by resort to the refinements described. Perhaps he would in his reply state this for the case of the latest Lancashire & Yorkshire Railway train comprising, say, two motor and two trailer cars, which presumably would be capable of the 30 miles-per-hour schedule speed with one stop per mile service mentioned in the paper. It would also be useful if the tables were amplified, especially as regards average weight per seat in a given train with or without refinements. From the paper one might expect that a saving of at least 10 per cent in dead weight per seat is attainable; but this is misleading. The allowance of only 4 sq. ft. per passenger is too low to ensure the comfort which the public demands and which engineers should strive to give. Recently the Midland Railway introduced a new train on the Southend service having six-seats-per-side compartments on approximately this basis, and the patrons of the line are strongly protesting against this bare allowance. If the wide coaches suggested would involve track slewing and platform widening, the capital cost thereof might easily become a sufficiently serious consideration to outweigh the advantages to be gained by saving weight. Analysing the paper, I have found it difficult to account for anything like a 10 per cent saving of weight by the refinements set forth. Assuming that the advantages of extra wide coaches be offset by track widening, etc., I deduce the following results:—

Item	Weight Saved	Extra Cost
Al. roof instead of steel ...	0·5 ton	£60
Al. panels instead of steel	0·5 "	£36
Al. seats instead of cast iron	0·75 "	£70
Special steel underframe	1·00 "	£48
Sundries, say	0·25 "	£25
Totals	3·0 tons	£239

Against this there is the possibility of an increase of dead weight on account of bows, double brake-blocks, etc., amounting to at least $1\frac{1}{2}$ tons and involving extra cost; but other items not included above, owing to insufficient data being given in the paper, may possibly balance these. Assuming this to be the case, it seems therefore that in the 67-ton Lancashire & Yorkshire motor coach costing £70 per ton the dead weight could be reduced to 64 tons (a $4\frac{1}{2}$ per cent weight reduction) at an extra capital cost of say £220 (4·7 per cent extra), allowing £19 for the saving in labour cost due to lighter material. This means an increase of the cost per ton from £70 to £77, or 10 per cent. The author appears to suggest that the saving of 3 tons of dead weight would warrant an increase in capital expenditure from £70 per ton to—

$$\frac{(67 \times 70) + (3 \times 185)}{67 - 3} = £82 \text{ per ton}$$

(*i.e.* a 17 per cent increase). His argument taken in the case of a trailer car is even more startling, since a similar 3-ton saving of weight would, according to the paper, warrant an increase of the rate per ton from £45 to £71 (*i.e.* 57·5 per cent). The deductions on page 447 do not seem to be sound, and it is to be hoped that they will be satisfactorily explained or modified in the author's reply. The tendency in the design of electrically operated rolling stock is towards increased rather than decreased weight, and it is significant that the latest example of Lancashire & Yorkshire rolling stock described in the paper and presumably tabulated in column 1 of the tables is exceptionally heavy. It remains incumbent upon traction engineers to reduce both the weight and the capital cost. To reduce only slightly the dead weight and thereby considerably increase the capital cost will not help matters at all. In conclusion, I may perhaps be allowed to point out that the prospect of much improvement in the direction of weight-saving cannot make one very hopeful of finding the better solution of traffic problems in the electric train system. I have indicated in the above-mentioned paper that by resorting to the continuous plan of operation (or, if need be, semi-continuous plan) as against the present intermittent plan, the weight per seat can be reduced from 1,200 or 1,400 lb. (as instanced in the Lancashire & Yorkshire rolling stock) to about 400 lb. in the electro-mechanical system recently put forward by me. As to this, I may say with Mr. Hobart, who had deeply investigated it, that a schedule speed of 30 miles per hour with one station per mile in the outskirts and a 16-miles-per-hour schedule speed with 4 stops per mile in urban districts, can be far more easily and cheaply attained than by the electric train system.

Mr. Baker. Mr. C. A. BAKER (*communicated*): The author refers on page 447 to the question of a railway company producing its own electrical energy, and he puts forward some reasons in favour of its doing so. I should like to remind members that in the recent paper by Mr. Roger T. Smith it was pointed out* that "the generation of electrical energy and its supply is a business in itself," continuing generally to prove that it is more advantageous for a railway company to purchase than to generate electrical energy. I entirely agree with Mr. Smith's opinion, and would condemn the establishment of the two new generating stations now under construction for London railway companies as being encumbrances for many years to come upon their respective proprietors. In neither case has it been possible to select a site that may be considered ideal or even mediocre; electrical energy could be purchased in any quantity that the companies might respectively require, from established undertakings which have reputations for reliability and economy, and at prices that, with the available diversity factor, must be better than those at which a solitary station can in the long run produce. No better object-lesson is necessary than the case of London with its 50 or more generating stations which 15 or 20 years ago were established with the guidance of the most enlightened expert advice and commercial knowledge that could be obtained, and now the question arises what is to be done with them. History will for ever repeat itself, developments in electrical generation have been and will be rapid, and unless it is impossible for a railway company to purchase the energy that it requires, there can scarcely be sufficient justification for the equipment

* R. T. SMITH. Some railway conditions governing electrification. *Journal I.E.E.*, vol. 52, p. 297, 1914.

Mr. Baker. of a generating station and the establishment of a new staff in connection therewith. The author further adds that "the operation of generation, etc., falls naturally within the province of the Chief Mechanical Engineer's Department"; here again I disagree with him. The electrical department should be independent and in charge of a responsible electrical engineer with the right to put forward his own views from his own standpoint, having primary regard to the utmost efficiency of the undertaking unhampered by considerations which a mechanical engineer, who is dealing primarily with duties of another character, may or may not see fit to endorse. As to "the changes of policy that occur with municipal stations" to which the author refers, I fail to recognize what undertakings he has in mind, those stations of the classification suggested in and around London having nearly all progressed most favourably from their earliest days.

Mr. O'Brien. Mr. H. E. O'BRIEN (*in reply*): Mr. Casson suggested that in Fig. 2 the horizontal scale should be "time in seconds" instead of "speed in miles per hour." That is quite right, and the suggestion will be carried out. In Fig. 3 the energy is the energy input into the car and not the output from the motors. With regard to Fig. 4, Mr. Casson suggested that an even load would not be obtained when there are 56 trains running. I must admit that he is correct in that. It would be possible to have 1,000 trains and not obtain a level load. What I wished to indicate was that when one gets as many as 56 trains on a system one is beginning to approximate to a level load if batteries are not used. He is quite right in raising that point, and I should have added that explanation to the paper. Mr. Casson and various other speakers have queried the propriety of basing the cost of repairs on the tonnage. Different engineers have different experiences, but our experience in the North of England has tended to show that the repairs do depend very largely on the tonnage of the cars.

Replying to Mr. Mason at the same time on that point, I should like to say that I speak as a carriage and wagon man and as a locomotive man more than as an electrical engineer, and taking the period of the last seven or eight years the very light cars have shown themselves to be exceedingly economical in maintenance, and the heavier cars, even though the design has been strengthened, have proved heavier in maintenance. It is to a certain extent a matter of design. One designer places his material in one position and another designer in another position, better results perhaps being obtained in one case than in the other. I quite understand that under certain special conditions it may be otherwise, as for instance on the Central London Railway.

Generally speaking, the maintenance does depend entirely on the weight; and the weight of the body is the most important part of the weight of the car, because on it depends the weight of all the other parts. I agree that as far as the body itself is concerned a very heavy rigid body will require less maintenance than a very light flexible body, but a light body can be designed which will still be very rigid, and the maintenance of which will be practically the same as that of the heavier body.

Supposing that the weight of a car is increased from 30 tons to 40 tons, in the first place the axle loads are increased; that means to say that larger bearings are necessary. Even if the bearings are enlarged so as to obtain the same bearing pressures, they will only run the same length of time as the smaller bearings, and when they are renewed it is a larger bearing that has to be renewed. The same remark applies to the tyres. Mr. O'Brien.

The cost of tyre renewals will increase even more in proportion, because the tyre has practically line contact with the rail, and consequently the greater the intensity of pressure (we are limited practically to four wheels per coach on an electric coach) the quicker the tyres wear out. When it is necessary to re-tyre, the old tyre has to be scrapped, so that the cost of repairs increases more than proportionately. The same remark applies to the armatures. There is a larger coach and a larger motor, consequently a larger armature with more copper in it. The life of the insulation will be just the same in both cases; but when it comes to rewinding, larger coils and more insulation have to be renewed, so that I do not feel inclined to recede from the position that I took up, namely, that the cost of repairs is very nearly proportional to the weight of the cars.

In the next place Mr. Casson complained of the small seats provided in Fig. 6. I think it is a good point that where passengers are getting in and out every one-third or half a mile a little more knee room is probably required than when the stoppages are further apart; but I hope Mr. Casson will pay us a visit in the North. It is a rather out-of-the-way place and difficult to get to, but I think if he will get into these cars he will find that they are not as uncomfortable as they seem. I consider 16 in. is quite a reasonable accommodation for anybody, and I think that if the 4 ft. 11 in. centre is actually tried it will be found that it allows one to sit quite comfortably.

Mr. Firth pointed out that the side-door car gives greater seating capacity. That is perfectly correct. I think that about 20 per cent more seats are obtained in a side-door car; but if passengers are to be taken 20 to 25 miles out from the terminals, which is what is wanted if possible, as Mr. Roger Smith recently pointed out in his paper, I do not think the side-door car is suitable. It may be suitable in certain districts—it certainly is not suitable in the North of England, with an exposed coast like the Lancashire coast, and it is found that when once accustomed to it the public prefer the corridor car; so much so, that we actually have complaints when corridor cars are removed from a service for repairs and compartment stock has had to be substituted. The circumstances are different in the South, and it is possible there, with the shorter distances between stations, the milder climate, and the shorter runs, that the side-door car would give satisfaction from the point of view of comfort.

It certainly does not give the management of the railway satisfaction as regards the platform staff that they have to keep, because if there are 8 doors per car to open and shut every time, unless this is left to the passengers, it involves keeping a considerable number of men on the platforms for the purpose of doing that work. The time taken to empty one of these corridor cars with end doors when it is crowded is a smaller time than it takes for the motorman to get out of his compartment at one end and walk to the other to reverse the train; and unless the traffic has become so dense that a motorman will be waiting on the platform to step into the other end of the train—that may be the case in London, but it is not the

Mr. O'Brien.

case as yet with us in the North—unless that point has been reached, the train can be emptied without involving unnecessary delay at the termini.

It was stated that the doors in these corridor coaches were too narrow. The doors are not narrow but exceptionally wide—sufficiently wide, in fact, to allow two people to enter or get out abreast. The door opens in the direction of the exit traffic, and the results obtained in practice are very satisfactory.

The question of the vacuum brake was raised by several speakers. There is no reason—if there is, I should like to know what it is—why the same retardation should not be obtained with the vacuum brake as with the Westinghouse brake; and the retardation on the Liverpool & Southport line is actually greater than on the London lines.

In the case of the vacuum brake a lower pressure, 11 or 12 lb. per sq. in., is used. It is purely a matter of cylinder diameter. In the case of the vacuum brake one has a 21-in. brake cylinder, compared—I am not familiar with the dimensions of the Westinghouse brake—with probably an 8-in. cylinder in the case of the Westinghouse brake. The question of the rapid production of the vacuum is certainly a difficulty. That is why I said that there was a field for a high-speed vacuum pump. The vacuum pumps that are used at present are low-speed and more or less inefficient machines, but even with them it is quite possible to produce a vacuum on a 5-car train within 15 seconds so that 20-second stops are quite practicable. The rapid raising of the vacuum is effected partly by the use of the high-speed valve on the train pipe—which incidentally ensures graduated application of the brakes—and also by having vacuum reservoirs to which the pump is connected while the train is running between the stations, the vacuum in the reservoirs being then used for re-creating the vacuum in the train pipe.

The table on page 453 would have been very much more useful if the names of the railway companies had been given: I was anxious to give those names, and received a general consent with one exception; consequently I had to leave the table as it stands.

Mr. Firth drew attention to the importance of the motor characteristic. I am very glad that he did so because it is one of the things that wants to be very carefully considered in designing rolling stock for suburban services, where it is very difficult to meet the varying requirements.

Then as to the question of collisions, the weight of the underframe should be a minimum. I do not think it is possible to prevent telescoping, but it is possible to go a long way towards preventing it by providing very strong pillars at the ends of the underframes, and by so doing the effect of the telescoping will in many ways be minimized. Collisions at high speeds, I believe, will always cause telescoping, no matter what we do; all that I wished to point out was that the rational way to meet the possibilities of collision was not to increase the weight of the whole car, and thus introduce a perpetual charge, but to try and design ends so that the underframes would not lift over one another, as far as could be done without seriously increasing the weight; and also to do what is being done in America, that is, fasten the underframe on to the bogies so that part of the energy of the collision will be absorbed in tearing away the bogie from its attachment to the underframes. As to the saving effected by weight reduction, I said "it becomes therefore a commercial proposition to spend as much as £185 per motor and £145 per trailer in labour and material in order to save a ton in weight." I think I should have omitted the word "commercial." I should have said "no loss will be involved if one spends as much as £185." I look at it from this point of view: that one could borrow £185 at 5 per cent and could provide a 5 per cent depreciation fund for renewing that £185 in approximately 17 or 18 years. That would cost £18·5 per annum, which was exactly the saving which would result by reducing the weight by one ton. Of course it would not really be profitable to spend £185, but one would not lose by spending that sum.

Mr. Mason suggests that the life of a coach should be taken into account, but he will see that it is done when the transaction is looked at in this particular way.

Mr. Sparks seemed to say that because the saving effected was only a small percentage of the total cost of traction, it was therefore not worth considering. That of course is a proposition to which nobody engaged in the practical maintenance of rolling stock could assent. It is only by grasping at every little economy which can be effected at not too great a capital cost that the cost of operation could be reduced in such a way as to produce satisfactory results.

In answer to Mr. Firth, the 10-ft. rolling stock operates over the same roads and platforms as all other stock, and there is no difficulty in effecting this.

Mr. Firth and Mr. Burnett mentioned the long wheel-base. The 10-ft. bogie of which a drawing was given in the paper was designed partly to minimize the rail wear and partly to provide for larger motors. Those objects were not entirely attained by that bogie, because the greater weights of the motors negatived the increase in the wheel-base; and the wear on the tyres, and also presumably on the rails, with that particular bogie was just as great as on the shorter wheel-base bogie that preceded it.

Another speaker criticized the bogie as being apparently of too light a construction. It is difficult to judge from a drawing, but actually the bogie is of too heavy a construction. It is quite correct as an example of design as far as it is shown in the paper, but it is not correct in the matter of weights; that is to say, the frames, the transomes, and the bolsters, could all have been made much lighter, and will be made lighter in subsequent bogies. This bogie was constructed throughout with the ordinary mild steels hitherto employed in bogie construction; but by the use of high-tensile alloy steels, properly heat treated, a saving in weight of probably not less than 25 per cent could have been effected.

In order to design a satisfactory electric bogie, as was pointed out by one speaker, it is not a matter of getting a heavy bogie, it is a matter of placing the material in the right place. What is wanted is to get ample bearing surfaces on the journals and ample bearing areas on the faces of the axle-boxes, so that there will be no heavy wear on the horns. It is a question of using one of these high-tensile steels and placing the material in the right place, seeing that the bogie is well trussed and that proper diagonal pieces are introduced so as to secure its rigidity.

I quite agree with Mr. Burnett that the bogies must be of strong construction and that the wheel-bases should

Mr. O'Brien. be as long as possible. There is no doubt that the larger the diameter of the wheels the better.

Though it is not referred to in this paper, I do not see why in the case of electric locomotives the bogies should not have wheels as large as 4 ft. 6 in. or 5 ft., or even a little larger. It is practically impossible to have such large wheels on passenger stock, because the loss of seats would be serious. The wheels would interfere with the body of the coach to such an extent that I think more revenue would be lost by the lack of seats than would be gained in maintenance with the large wheels. But with the electric locomotive I see no reason why the bogie wheels should not be very much larger than they are at present.

One of the speakers asked how much of the cost of the cars was due to the electric equipment and how much to the actual coaches, *i.e.* he wanted to know whether the trailer coach cost as much as the motor coach to construct. The motor coach is more expensive to construct than the trailer coach, because it is necessary to provide accommodation for the tractors, attachments for resistances, and heavier bogies; but as far as the actual carriage work is concerned, the cost is approximately the same.

Dr. Smith pointed out the objection to series-parallel control, and suggested that by using field control the peaks on the power station could be very largely reduced. I am not a motor designer, but I thought that we already used practically as strong a field as was possible during the acceleration period, and it certainly had not occurred to me that by the use of interpoles we could enormously strengthen the field and reduce the starting current correspondingly.

The proposal to make the motor cars more flexible, that is to say more adaptable to different services by means of field control, is worth considering, and in many cases it will pay to adopt it.

Mr. Lewis suggests that there is a more promising field in graduated acceleration and regeneration during deceleration than in reducing the weight of the rolling stock. He further suggests that weight reduction is attained by resorting to refinements. I cannot admit that the plain straightforward substitution of lighter and stronger materials is in any way a refinement; it is merely proceeding on rational lines. He is mistaken in assuming that I have stated that the actual instances which I have given where weight could be saved meant a saving of 10 per cent. It is not stated in the paper that 10 per cent in weight can be saved in this manner, and, as a matter of fact, in constructing the trailer car there is no difficulty in saving considerably more than 10 per cent by the methods indicated.

In replying to Mr. Carter, I should like to say that I am much obliged to him for drawing attention to that point about the resistance of the motors. The curve is not obtained by means of readings of the speed, but from the readings of a pendulum in the dynamometer car, which gives the total actual resistance of the train in a very much more correct way than it can be obtained by the speed readings. It is the total resistance, so that if he is correct in his figure of 4 lb. per ton for the resistances, which might properly be attributed to the motor itself, and which are absorbed in the motor when running, that would bring that curve down to a figure which approaches the curves with which we are more familiar.

Several speakers seem to think that it was suggested in the paper that the strength of the car should be diminished as the weight was diminished, but that is not the intention. As Mr. Carter pointed out, I thought we ought to save unnecessary weight, and that where we could use stronger and lighter materials without any sacrifice of strength, that should be done, but that it did not seem to have been carried out. Mr. O'Brien.

Coaches have very generally up to the present time been built of mild steel, or mild steel and wood, and little attention has been paid to the importance of closely investigating the possibility of reducing their weight. It can be conclusively shown that to introduce unnecessary weight is to throw money away in perpetuity; and I should like again to emphasize the fact that the body which carries the passengers is the most important part to consider from the point of view of weight-saving. But the weight of the body reacts throughout the whole equipment. A light body and underframe means light bogies to carry them: light bogies mean light motors: light motors again mean that the electrical equipment which has to be carried on the body will be light, which again in its turn permits of a slightly lighter body. Our knowledge of the strength of materials has greatly advanced in the last 10 or 15 years, and it is most important that we should turn that knowledge into advantage in connection with rolling stock construction.

Mr. Bowden notes that in the bogies the journals are without button heads: this arrangement has proved very satisfactory in practice. The gear wheel is not split because the solid wheel is both cheaper and stronger. The average life of the gears on the Liverpool–Southport line is over 250,000 miles, and consequently it is not worth while making a special arrangement for renewal purposes.

In answer to Mr. Burgess, the "wheelbarrow" method of suspension has survived as being the simplest and cheapest. As to ventilation, I agree that a downward movement of the air produces the most sanitary results, but it is a very difficult system of ventilation to carry out in a railway carriage. The system described produces fairly good results.

Where a bulk supply of current can be purchased cheaply I agree with Mr. Baker that it is far better for a railway to purchase its electrical energy. On the North-East Coast waste-heat stations and a varied load with a magnificent diversity factor make it possible to supply energy so cheaply that no municipality or railway company could hope to do the same. Elsewhere, however, small stations with a poor diversity factor are universal, and while this is so railway companies do well to build their own generating stations; for a railway load has an excellent diversity factor of its own, and the magnitude of the load is such—on a successful scheme it will seldom be less than 20 million units per annum—that the standing charges per unit will be less than in the case of municipal stations which are notable for their extravagance in buildings and plant. The changes in policy which occur in municipal stations are partly due to the fact that the latter are controlled by political parties and partly to the fact that the poor salaries paid by the corporations cause perpetual changes in the staff. Liverpool, Manchester, Newcastle, and the London County Council are all cases in point.

Mr. O'Brien. The directorate and chief mechanical engineer of a railway company change infrequently, and the policy is continuous. The problems connected with the generation of electricity are mainly mechanical; the chief mechanical engineer is usually a man of broad views and wide experience, and in the ordinary operation of his department he has the assistance of experts in each particular branch—electricity, marine engineering, cranes, stationary boiler plant, etc. He is therefore eminently fitted to deal with the problems of a power station. The railway will already possess a staff for dealing with coal analyses and purchase properties of oils, and water, etc., and for testing purposes, and hence a generating station can be operated with an economy unknown among municipalities or in most companies. I do not dispute Mr. Baker's contention that the 50 generating stations in London are wasteful and that it is a problem to know what to do with them; on the contrary, I am pleased that he should have adduced this argument to prove the wisdom of the policy adopted by the London & North-Western and London & South-Western Railways. It is of course a matter for regret that there is not a central supply authority for the whole of London; as soon as such an authority is in being no doubt the railway companies will be in no two minds about purchasing their current. I should like to say further in answer to Mr. Baker that in my opinion in order to get the best results in a very large organization like a railway company it is essential that the whole of the mechanical engineering and transport problems should be grouped under one authority. Many hard things have been said recently about the Great Eastern Railway, but the Company has shown very great wisdom in appointing an engineer as general manager, who will be able to co-ordinate the various mechanical problems now divided between departments.

DISCUSSION ON

"SOME RAILWAY CONDITIONS GOVERNING ELECTRIFICATION." *

SCOTTISH LOCAL SECTION, 17TH FEBRUARY, 1914.

Mr. Lackie. Mr. W. W. LACKIE: The main point in this paper about which I wish to speak is the statement that the electric tramways compete directly with the railway services in many large towns, and that railway companies have been obliged to reduce their fares owing to tramway competition. I thought it was quite agreed that a tramway is a distinct benefit to a railway, in so far as the tramway acts as a feeder to the railway and increases its traffic. It is true that the tramway undertaking uses the streets, but it also bears the cost of paving in a very substantial manner, viz. to the extent of two-thirds of the area of those streets, an expense that would otherwise fall upon the rates. The tramway department further pays rates on the full value of its permanent way, whereas the railway companies only pay rates on one-third of the value of their permanent way. The extension of tramway lines to suburban areas has had the effect of stimulating the building trades in those areas, and of developing a residential population, both of which results undoubtedly react beneficially on both goods and passenger railway traffic. It has been shown on the railways in several districts that the traffic has increased when the tramways have been extended. The motor omnibus acts similarly in favour of the railway. The author indicates in the paper that what is wanted in suburban traffic on electric lines is either an increase in the fares or the ability to purchase electrical energy at ½d. per kilowatt-hour. It seems to me that the running of a railway is very much like the operation of an electricity supply undertaking, inasmuch as standing charges are an important feature in both. In my opinion, instead of being increased, the fares should be reduced. Our experience in Glasgow is now well known. Instead of carrying a passenger half a mile for ½d., the Corporation increased the distance to 1 miles for ½d. The increase in revenue from this cheaper fare has more than covered the cost of the reduction. Would it not pay the railway companies to reduce the first-class fares and so increase the number of persons who travel first-class? In the case of the Glasgow Electricity Department, which showed a deficit of £4,000 on one year's working, the tariffs were reduced and the deficit was turned into a surplus in the following year. The author states that cheap coal is a hindrance to the electrification of the railways; but the price of coal in America, where electrification has been adopted, was only half the price of coal in this country. It is stated that the difference between the heat value of the coal in the bunkers and the work done at the draw-bar of the electric locomotive is only 6 per cent. I do not see why this should not be 12 or even 15 per cent. It may be of interest to recall that in February, 1909, I read a short paper * before this Local Section in which I gave an account of an experimental electric locomotive which was run between Glasgow and Edinburgh as early as 1837.

Mr. Cockburn. Mr. C. E. COCKBURN: Whilst I am in favour of electricity as a motive force, I do not think the time is yet ripe for its introduction for long-distance traffic. There is a considerable difference between the working of electric tramways and underground electric railways in London and the operation of the steam-worked overhead railways. With regard to the difficulty of handling long-distance and short-distance traffic in the limited area inside big terminal stations such as those in Glasgow and London, I consider it to be better for the railway companies to leave the local traffic in short-distance areas to the electric tramways, and to concentrate their attention on the long-distance traffic, which can be more successfully dealt with for the present by steam railways. As an example of the difficulty of handling traffic to places on the Clyde, in the case of a steamer capable of carrying 1,000 or 1,500 people, with the

* Paper by Mr. Roger T. Smith (see pp. 293 and 368).

* W. W. LACKIE. Early experiments in electric traction. *Journal I.E.E.*, vol. 42, p. 626, 1909.