In seasons of good normal rainfall, the railways were benefited by The Author. increased internal and foreign business; in periods of local scarcity, they still found that the misfortunes of the land brought them large receipts, it being a cardinal principle that rates should not be lowered, but the movement of food-grains left to the natural requirements of trade. Visitations of plague alone seemed to affect the railways adversely. Therefore, weighing the railways in the balance of general usefulness to the country and fair return on capital, might not those who were responsible for the railway-gauges of India feel, while admitting errors in the past, that a good record could be shown, and that the yearly increasing necessity for higher speeds, and for greater comfort and conveniences, would gradually bring about uniformity? England waited nearly 50 years before the Great Western railway, after having a mixed gauge for some time, finally abandoned the 7-foot gauge. Then the United States and Canada followed suit. South America and Australia were still considering the cost, and waiting like India until the advantages of a uniform gauge would be forced on them by commercial necessities.

Correspondence.

Colonel G. F. O. BOUGHEY, R.E., observed that modern conditions and Col. Boughey. practice had shown that the assumed much heavier cost of standard-gauge lines, which had been the reason for introducing metre-gauge lines into India, was largely, if not entirely, a fallacy; for in easy country standard-gauge lines had recently been constructed at a cost little more than that of metre-gauge lines. The Southern Punjab railway, for instance, upwards of 400 miles in length, in exceptionally easy country, had been built at a cost, excluding land and rolling stock, of little more than £3,000 per mile, or, including everything, say, £4,000 to £4,500 per mile. This was but little above the cost of a metre-gauge line in similar country; and yet the Southern Punjab railway was capable of carrying, at a moderate speed, goods-vehicles with a gross load of 12 tons per axle, which could run over trunk-lines to the ports. Uniformity was desirable, but, looking to the future, a country of such immense distances and great prospects, and wherein the principal trunk-lines serving the ports and coal-fields were already laid on the standard gauge, was no place for lines of inferior speed and carrying-capacity. What had to be aimed at, therefore, was a system of double lines on the standard

Col. Boughey. gauge, beginning at the ports and coal-fields, and running backwards as far as the amount of traffic would justify it. The delay and consequent cost of dealing with heavy traffic on a single line was considerable, and this must be taken into account in deciding when and how far a double line on the standard gauge should be laid, which was a matter that could not be determined by any mathematical formula. The cost of transshipment was exceptionally low in India, and the necessity for it did not form any practical impediment to the free flow of traffic from the extreme limits of the metre-gauge lines to the ports, or any appreciable addition to the cost of transport from the place of origin to the European market. There seemed, therefore, to be no substance in the claim that because the metre-gauge lines had originated a fairly substantial traffic, it should be carried through to the ports on the metre gauge, merely to save the cost of transshipment. Still less did it seem right that heavy expenditure should be incurred in constructing long lengths of line solely, or mainly, to save the cost of transshipment. Where the amount and cost of transshipment was considerable, there was a clear indication that the standard gauge should be carried farther back. The port of Marmagao, now served exclusively by the metre gauge, might perhaps continue to be served by single, or as far as necessary double, lines on that gauge, for it did not seem that traffic was likely to flow to that port from such considerable distances as to the other ports. Madras was also in some respects exceptional. It already had lines of both gauges running into it, and it was alone in the fact that rail-borne traffic was loaded into boats, so that it was not necessary to intermix the gauges in order to serve any particular vessel. If, therefore, the facilities of the port were such that the two gauges could continue to be conveniently and separately accommodated, and if the traffic of the South Indian system could be adequately dealt with by doubling the metre gauge as far as necessary, there seemed to be no reason why that gauge might not be retained for that system. With these possible exceptions, he ventured to deprecate strongly the introduction of the metre gauge into any other port. The metre gauge must either be mixed up with the standard gauge, so as to give it equal access to every vessel, or it must be placed behind the existing standard gauge—a position which it would not likely occupy for long without complaint, involving as it would costly and difficult arrangements for passing all its traffic across. The cost of transshipment at an up-country station was as nothing compared with the cost, delay, and confusion inevitable from the introduction of a second gauge into the busy scene and limited space available at the ships' sides at a port. On this point he wrote

with some experience of the actual work of dealing with export and import traffic at the port of Karachi, and with some knowledge of the same work as carried out at Calcutta and Bombay. In short, the great and growing export traffic should flow into each port in one broad stream, and not by each separate trickle finding its own way down. Col. Boughey.

Mr. J. FORREST BRUNTON regretted that the Author nowhere gave Mr. Brunton. expression to his own views, or even an indication of his opinion as to the necessity of having now, or at some future date, one gauge only for the railways of India. The Author's position as chairman of the Railway Board in charge of Indian railways might be the cause of this reticence, but as that position had not prevented him from bringing the subject before the Institution, it was a pity if it had prevented him from expressing his views for or against conversion. In Mr. Brunton's opinion, conversion from the narrow, or metre, to the standard, or broad, gauge must come eventually, and, as every year's delay added to the number of lines to be converted, and increased the expenditure that would ultimately have to be incurred in order to rectify an error that ought never to have been committed, the sooner it came the better. The metre-gauge lines were originally intended—or it might be more correct to say that those who were responsible for their introduction said they were intended—to be only feeders for the main standard-gauge lines. That they would be allowed to extend into large and important independent systems had never been contemplated officially, although, no doubt, those who had given the subject due consideration had seen the danger of their so extending, and this danger was, equally without doubt, one of the reasons why their introduction had been opposed by many of those best able to form an opinion on the subject. Since its introduction, the metre-gauge extension had more than kept pace with the extension of the standard gauge. When the first metre-gauge railway was opened in 1873, the standard-gauge mileage amounted to 5,576½ miles.¹ At the end of 1904 the mileage was: standard gauge 14,733, and metre gauge 11,562 miles.² Thus, in the 31 years which had elapsed since the introduction of the metre gauge, 11,562 miles had been laid on that system, against only 9,157 miles of standard gauge. That the metre gauge was still extending practically twice as quickly as the standard gauge could be seen by a comparison of the mileage of 1899 with that of 1904. During this period the

¹ Minutes of Proceedings Inst. C.E., vol. xevii, p. 107.

² "Administration Report on the Railways in India for . . . 1904, by the Railway Board," p. 1. Simla, 1905.

Mr. Brunton, extension of the standard gauge had been a little less than 3 per cent. of the mileage open on the 31st March, 1899, while the metre-gauge extension was a little less than $6\frac{1}{4}$ per cent. The importance of the question raised by the Author could therefore hardly be exaggerated, as the evils of a dual gauge were daily becoming more acute. It was not a question of the relative value of particular gauges. It was possible that a metre gauge might meet all the traffic requirements of India, or that it would have been wiser to have originally fixed on a metre, or 4-foot 6-inch, or 4-foot $8\frac{1}{2}$ -inch gauge, instead of a 5-foot 6-inch. But this was not the question to-day. The standard gauge of India had been fixed at 5 feet 6 inches more than 50 years ago, and there were now nearly 15,000 miles of open line on this gauge. Was it seriously proposed to convert it to the metre gauge? If not, there could be no object in altering it. Its conversion to any other gauge would not remove the evils of a dual gauge, unless the metre gauge were also converted, in which case the metre gauge could as easily be converted to the standard 5-foot 6-inch gauge as to any other. The important question was, was India always to be saddled with the evils of a dual gauge? If not, the sooner steps were taken to stop further construction on the narrow gauge, and to gradually convert that gauge to the standard gauge, the better. A glance at any railway-map of India showed only too clearly the evils that a dual gauge had already caused. Thirty-five junctions between standard- and metre-gauge lines could easily be counted, at each of which there was experienced the inconvenience, delay, and cost that were inseparable from the transshipment of passengers and goods. Was it not time, then, to put a stop to any increase in the number of these barriers to the free transport of passengers and goods, and to arrange for their gradual removal? So long ago as March, 1889, Major-General (now General Sir E. C. S.) Williams stated that, with more than 5,000 miles of narrow-gauge line, the objection to break of gauge cut both ways when extensions were contemplated.¹ Those who favoured the narrow gauge probably thought that this argument had been greatly strengthened with 11,562 miles of metre-gauge railway now open. But Mr. Brunton ventured to think that if the necessity or advisability of adhering in the future to one gauge were admitted, few would prefer the metre to the standard gauge. There could be no doubt that, viewed merely as a means of transport, the standard-gauge railway was superior to the metre-gauge. A metre-gauge line was capable of carrying a heavy traffic at a fair speed, and it was by no means the toy some considered it; but it could

¹ Minutes of Proceedings Inst. C.E., vol. xcvi, p. 165.

not compete with a standard-gauge line in either carrying-capacity Mr. Brunton. or speed, and it was not reasonable to expect it to do so. Consequently the rational course appeared to be to retain the 5-foot 6-inch gauge as the standard, and to give up the metre gauge. The comparison of first cost given by the Author in Tables I and II, while no doubt correct as far as it went, was misleading, as it did not clearly bring out the fact that the standard of construction of the metre-gauge lines was so inferior to that of the standard-gauge, that no fair comparison could possibly be drawn without making liberal allowance for this. In the Paper the Author admitted that at no time had there been any serious attempt to lay down an inexpensive standard-gauge line equipped with suitable light rails, rolling stock and station-accommodation; but the fact that the metre-gauge railways had generally been built on cheaper lines than the standard-gauge was not elsewhere alluded to. Mr. F. J. Waring, in 1889, showed¹ that, on the standard-gauge lines then open, the cost of the larger bridges alone increased the cost per mile by nearly Rs.11,600, while on the metre gauge the increased cost on this account was only Rs.1,416. Taking the rate of exchange at 2s. per rupee, as it probably was when the greater part of the works referred to were made, this meant that the cost of the large bridges, excluding cost of heavy approach-works, had in 1899 enhanced the cost per mile of standard-gauge lines by more than £1,000 per mile over metre-gauge lines. In addition to this the standard gauge was made to bear the cost of rails 70 per cent. heavier than those on the metre-gauge lines; and, further, the very heavy expenditure necessarily incurred on the pioneer lines of India, and on the frontier lines such as the Peshawar and Quetta branch of the North Western railway, was all included in the figures given in Table I. A fair comparison should exclude all these charges from the standard-gauge figures, when it would probably be found that for lines built to the same standard, having the same weight of rails, and capable of carrying equal axle-loads at equal speeds, the standard gauge would cost less than £1,000 per mile more than the metre gauge. If, therefore, the 11,562 miles of metre gauge which had been constructed since 1873 had been made on the standard gauge, but of lighter construction, the extra cost would have been less than £11,562,000—not an exorbitant sum to pay for the advantage of uniformity of gauge. This extra expenditure would have involved no positive loss; it would merely have reduced the return on capital from 6 to 5 per

¹ Minutes of Proceedings Inst. C.E., vol. xcvi, p. 114.

Mr. Brunton. cent. It was true that a standard-gauge line with light rails, etc., made lighter engines and lower speeds necessary over the section so constructed; but surely this would be immeasurably less inconvenient and less costly, and would involve less delay, than the transhipment of passengers and goods; and obviously the cost of bringing such a line at any time up to standard conditions was nothing compared with the cost of converting a metre-gauge into a standard-gauge line, to say nothing of the delay to traffic and the general inconvenience that would be caused during the conversion.

Mr. Cardew. Mr. C. E. CARDEW remarked that the use of the term "standard" gauge savoured of political affectation. It was never used in India by railway-authorities outside Government official circles; in ordinary speaking and writing the term was always "broad," or "5-foot 6-inch" gauge. The Author asserted that the narrow-gauge lines did not in general serve metre-gauge lines, but had been built as feeders to standard-gauge lines. A noticeable exception to this rule was the Darjiling-Himalayan 2-foot line, which had been planned as a feeder to the Northern Bengal metre-gauge railway. Recently it had been proposed to build a 2-foot 6-inch line into the Southern Shan Hills in Upper Burma as a feeder to the metre-gauge lines of that country. If this break of gauge were really justifiable, it would be hard to defend the introduction of the larger of the two small gauges, a saving of merely $9\frac{3}{8}$ inches. So long as this sort of thing was permitted, it was useless to deplore, as done by the Author, that no serious attempt had been made to preserve uniformity of gauge by building inexpensive broad-gauge lines equipped with light rails, rolling stock, and station-accommodation. Historically, however, he was not quite accurate, as the Oudh and Rohilkhand railway had been originally built very lightly—so much so that the neighbouring East Indian railway, about 30 years ago, declined to accept its wagons in interchange. This, of course, had resulted in their being replaced by wagons of ordinary heavy build. As to private ownership of railway-wagons, no responsible railway-official with experience of traders' wagons in the United Kingdom and in other countries where they were permitted, would ever willingly admit them into India, as they always tended to become a serious source of difficulties in working. The schemes for their introduction referred to by the Author had deserved to fail, for they had been proposed not by the actual traders needing them (such as colliery-owners and grain-dealers), but by certain companies, to be incorporated as public carriers, which owned the wagons and hired them out. Under such a system of private ownership, compared with that of traders' wagons as hitherto practised, the difficulties of the railways would be

greatly enhanced. In referring to the broad gauge as being more Mr. Cardew efficient than the narrow in respect of carrying-capacity, the Author clearly used the term "more efficient" as synonymous with "larger"; for it was universally conceded that a metre-gauge wagon could always be built of greater efficiency in its tare-to-load ratio than a broad-gauge wagon. This was due solely to the permissible relative overhang in the former being so much larger than in the latter; in fact, on the Indian 5-foot 6-inch gauge the permissible width of car-body was no greater than on the Canadian 4-foot 8½-inch gauge. He had pointed out what the metre-gauge was capable of in this respect 2 years ago, in the discussion on Steel Railway-Wagons.¹ In remarking that, so far, all the metre-gauge lines were single-tracked only, the Author had overlooked the Burma railways, which at present had 16¼ miles of double track, and 1 mile of treble track; while a much larger extension of double track was to be provided in the near future. With reference to the Author's remark that it was significant that the metre gauge carried the larger average passenger train-load, this was probably due merely to the broad gauge having a more frequent train-service, the rigid economy practised on the metre gauge (which generally comprised the poorer lines of the country) tending to the crowding, not to say overcrowding, of the trains. In his anticipation of little difficulty in converting existing rolling stock from the metre to the broad gauge when necessary, the Author would scarcely be supported by engineers having any knowledge of the actual difficulties to be overcome. So far no such conversion had been attempted except in a few isolated cases, where for merely temporary purposes the bodies of a few passenger-vehicles had been put on broad-gauge underframes. In stating that the cost of transshipment between the two gauges was equivalent to an extra haulage of 20 miles, the Author omitted to state on which gauge the haulage was to be reckoned; but in the evidence given before the Parliamentary Committee of 1884² regarding the extension of railways in India, the Consulting Engineer for State Railways to the Secretary of State for India (Sir A. M. Rendel, K.C.I.E., M. Inst. C.E.) estimated the cost as being approximately equivalent to having an additional 10 miles added to the Rajputana-Malwa system, which in that year had three transshipment-stations (Ahmedabad, Agra, and Khandwa). This mode of expressing the cost seemed to be better than that in terms of haulage merely.

¹ Minutes of Proceedings Inst. C.E., vol. clvii, p. 175.

² "Report from the Select Committee on East India Railway Communication," p. 368. London, 1884.

Mr. Egerton. Mr. R. W. EGERTON considered that the two questions asked by the Author on p. 196 should be answered in the negative. After pointing out how the policy of confining the metre-gauge railways to certain defined areas has not been adhered to, with the result that that gauge had spread over the country, and in some cases had become competitive with the standard (5-foot 6-inch) gauge, the Author went on to state that this competition had, on the whole, been of benefit to the country and to trade. But Mr. Egerton ventured to point out that in a country which was still undeveloped and was crying out for railway-extensions, the construction of competitive lines was not called for, and should not be encouraged. Moreover, it must be remembered that the Indian Government was, practically speaking, the owner of all the lines and had control of all the rates. Such being the case it would appear that, if the Government exercised its control for the benefit of the people, the necessity for competitive lines disappeared. Indian railways of the present day presented a somewhat melancholy object-lesson in railway economics. It might naturally be asked why, when Government was practically the owner of the metre-gauge lines, it had been unable to withstand their demands for access to large centres of trade. The answer was that the working of the lines had been given over to companies who had deposited a fixed sum of money, on which Government had guaranteed a certain rate of interest plus a certain percentage of surplus earnings. The ratio of this deposit to the capital cost of the lines varied of course on different lines, but in no case did it exceed a quite small fraction. The companies were represented by boards whose offices were in London; and it was due to the pressure exercised by these boards that the demands were granted. It was thus that competitive lines had come into existence. Some of these lines had no *raison d'être* whatever, except for the purpose of linking up two metre-gauge systems; and sometimes there was not even that excuse. A very instructive example was the Cawnpore-Burwhal metre-gauge link, which was laid on the same formation as the Oudh and Rohilkhand railway between those points for practically the whole distance of 80 miles. The Lalkua-Kashipur line, in the United Provinces, now under construction, and the Benares-Allahabad line, now under survey, were further examples of unnecessary lines; and it might safely be predicted that, unless some definite policy with regard to metre-gauge extensions was formulated and adhered to, there would be many more examples of unnecessary metre-gauge lines in the future. There could be no doubt, too, that metre-gauge administrations would never be satisfied until they obtained access to the ports of Bombay, Calcutta,

and Karachi. The expense attendant on such a course, in the construction of unnecessary lines, would go far towards paying for the conversion of these lines to the standard gauge. It remained to consider, therefore, the three suggestions for conversion given by the Author. The idea of converting all 5-foot 6-inch gauge lines to the metre gauge might be abandoned at once. First, because the cost of conversion would be a capital charge, and it would be economically unsound to substitute an inferior means of transportation for a superior one, at the same time increasing the capital cost of the undertaking. Secondly, because the metre gauge, on account of the low limit of speed attainable, was an unsuitable gauge for large trunk-lines. The second suggestion, that the metre-gauge lines should be converted to the standard gauge, had something to recommend it. The policy to be adhered to, if such a course were decided on, would be to rigorously exclude the metre-gauge lines from all the three ports enumerated above, and to gradually convert all existing metre-gauge lines directly the volume of traffic justified the conversion; and, in order that there might be no opposition from the boards of the metre-gauge companies, a clause providing for this conversion should be added to all their contracts when these contracts came to be renewed. Only by some such measures as these would it be possible to control metre-gauge construction in India, and make that gauge what it was originally intended to be, the handmaid of the standard gauge. But the Author's third suggestion, namely, the conversion of both gauges to the English gauge had most to recommend it. Its advantages were clear. The claim, often justly raised, that the cost of the 5-foot 6-inch gauge was so high that the metre gauge should be accepted on certain lines, would disappear. India would reap the incalculable advantage of being able to adopt all that was best in the designs of locomotives and rolling stock, station-machinery, etc., which English practice had evolved and perfected. The cost of all kinds of rolling stock would also be less. The work of converting 30,000 miles of railway was at first appalling in its magnitude; but, after all, what did it amount to? As regarded regauging the 5-foot 6-inch lines, an alteration in the tie-bars of the pot-sleeper road and a respiking of the rails or chairs on the wooden-sleeper road were practically all that was required, and on the metre-gauge lines the same, with perhaps in some cases renewal of the wooden sleepers. The whole difficulty, indeed, was tied up in the question of the conversion of the rolling stock; and the locomotive problem was the most difficult of all. But this difficulty could be overcome in the same way as the Great Western railway had overcome it at home some years ago. The

Mr. Egerton. designs of all locomotives and rolling stock in the future should be such that the conversion could be easily effected, and then, when the time came—say, 10 years hence—the conversion should begin from some fixed point, Tuticorin, for example, and be gradually extended year by year till the whole scheme was completed. The more this thorny question of gauges was contemplated, the more did the conviction grow that it was only by the adoption of the English 4-foot 8½-inch gauge that the gauge difficulty in India was to be solved.

Mr. Godfrey. Mr. G. C. GODFREY observed that the Author's interesting account of the struggle of the gauges in India threw much light on what to an outsider would appear to be the grave mistakes of the earlier railway-authorities in India. That there should be four different gauges in a country like India, where the Government had control over the whole of the railways by its powers of sanction and veto, seemed absurd; but the Author showed how the apparent absurdity had grown up, and that there were good reasons for it. The broad-gauge line cost two-and-a-half times as much as the metre gauge; therefore, had the Government of India pinned its faith to the broad gauge, there would now have been at least 7,000 miles less line open for traffic, for the same capital expenditure. On the other hand, the capacity of the broad gauge was shown to be about double that of the metre gauge, and the broad-gauge single lines were in most cases working nearly up to the limit of their capacity; therefore, had the Government of India adhered to the metre gauge only, the trunk-lines would have had to be doubled, and in some cases even quadrupled, while the trade of the country would have suffered from delays in transit, and from the actual incapacity of lines to carry the traffic until doubled. The great mistake had been made at the beginning in allowing two gauges, and in adopting either such an expensive and heavy gauge as 5 feet 6 inches, or such an inefficient one for heavy traffic as the metre. An intermediate gauge, the English 4-foot 8½-inch for choice, would have served all purposes, it could have been used with greater ease and far less cost than the broad gauge for hilly country, and its carrying-capacity would not have been 25 per cent. less; while as compared with the metre gauge its efficiency would have been at least 75 per cent. more. The saving in cost as against the 5-foot 6-inch gauge would have assisted in meeting excess in cost over the metre gauge. But the question for discussion was not so much the mistakes of the past as the line of policy to be adopted in the future. Mr. Godfrey considered that both the Author's questions (p. 196) should be answered in the affirmative, but that the last sentence of question No. 2 should be omitted. His reasons

were briefly the following:—The open-line mileage for 1904 was Mr. Godfrey. 14,733 miles of 5-foot 6-inch gauge, 11,562 miles of 3-foot $3\frac{3}{8}$ -inch gauge, 942 miles of 2-foot 6-inch gauge, and 328 miles of 2-foot gauge, and in addition there was sanctioned for construction, 306, 212, 251, and 81 miles, respectively. The cost of conversion of 15,039 miles of broad gauge to the metre gauge, or of 11,774 miles of metre gauge to the broad gauge, or of 26,813 miles of both gauges to the 4-foot $8\frac{1}{2}$ -inch gauge would entirely absorb all the money available for expenditure on railway-construction in India for some years, and in the meantime the trade and progress of the country would suffer severely from the want of new lines to develop the large areas not yet served by railways. The conversion of the metre gauge to the 5-foot 6-inch gauge would over-capitalize many of the metre-gauge lines, and the owning companies would naturally object to the loss of profit. Moreover, the conversion of either gauge to the other, or of both to the 4-foot $8\frac{1}{2}$ -inch, would, as the Author showed, have to be carried out gradually, the main line of a system being taken in hand first and converted section by section: this would lead to great confusion at branch junctions, owing to transshipment, and traffic towards the sea-coast would probably have to undergo transshipment two and even three times while conversion was in progress. It should now be finally recognized that there were three gauges, the 5-foot 6-inch, 3-foot $3\frac{3}{8}$ -inch, and the 2-foot 6-inch gauge, and that any scheme for bringing about uniformity was impracticable. The small 2-foot gauge should be discountenanced except for tramways; there was only 409 miles of such line in existence or under construction, and these lines were generally small feeders and tram-lines or hill railways as such. These did no harm to the railway-system of India; but no new lines on this gauge should be sanctioned as railways except for short extensions of existing 2-foot lines; and it should be the policy of the Government to convert all the 2-foot lines to the 2-foot 6-inch gauge, whenever that course was possible without increasing the capital to such an extent as to render the line incapable of earning a fair return on its capital. The broad- and the metre-gauge systems should be regarded as two complete and independent systems, each to be fed by branches of its own gauge where possible, or by branches of 2-foot 6-inch gauge where the physical nature of the country and its promise of traffic rendered the cheaper gauge necessary; but as a rule the 2-foot 6-inch gauge should be restricted to feeders for the broad gauge, and only under very special circumstances, such as mountain railways, should it be permitted for feeders to the metre gauge. Further, on all new 2-foot 6-inch gauge feeders to broad-gauge lines the masonry

Mr. Godfrey. of bridges should be built to dimensions suitable for conversion to the broad gauge, and the smaller girders up to 6 feet span should be of the broad-gauge type. To render the metre-gauge system complete, it should be given every facility for its traffic to reach the ports of Calcutta, Bombay and Karachi, without actually receiving direct access. The first step as regarded Calcutta would be the bridging of the Ganges at or near Sara Ghat: transhipment between the broad and the narrow gauge could then be effected at a minimum tax on traffic; and, in view of the expense of laying a double gauge on the Port Trust railway and connections in Calcutta, it would be necessary to retain permanently the transhipment-station at the river, and, when required by traffic, to lay an additional broad-gauge line into Calcutta. This principle applied in the same way to the ports of Bombay and Karachi. Transhipment was a very small tax on traffic, provided platforms and sidings were suitably arranged; the average cost at Ahmedabad had been shown to be $5\frac{1}{2}d.$ per ton, and this should be capable of considerable reduction; but even at that figure, the equivalent extra lead of 20 miles was not much on traffic which was being carried 400 miles or more to the coast, and the interest on capital outlay in bringing the second gauge to the port, and the extra expense of working two gauges at the port, would probably constitute a tax on trade equal to or greater than $5\frac{1}{2}d.$ per ton. In order to connect the northern and southern systems the link mentioned by the Author between Khandwa and Hotgi should be started at once, and a branch should be made from the point of junction with the Haidarabad-Godavari line (probably Sailu) through Ahmadnagar to a junction on the Great Indian Peninsula railway, such as Kalyan, where transhipment would take place for Bombay. This would be an expensive branch, owing to the crossing of the Western Ghats, but it would be necessary as an outlet for traffic to the seaport from the new Khandwa-Hotgi link and from the Haidarabad-Godavari Valley line. The latter line was at present entirely isolated from its own gauge, and should never have been sanctioned as a metre-gauge line; but since it was in existence, the southern portion of it would serve as a feeder to the two extensions advocated above, and, when the Sailu-Kalyan branch was ready, affording easy access to Bombay, it would probably be found necessary to convert the northern portion between Sailu and Manmad to the broad gauge, as it would no longer be of any use as an outlet for the Godavari Valley produce from the country south of Sailu towards the sea-coast. In all other cases where rivers intervened at points of transhipment between the gauges, bridges should be built; a programme for this could be prepared arranging the bridges in order of importance, and allowing for

one or two, according to the cost, being started each year. In the future no isolated metre-gauge lines should be constructed; the only extensions permitted on that gauge should be feeders to or extensions of the existing metre-gauge systems.

Mr. F. A. LART observed that one point brought out very clearly by the Paper was the decided relative superiority of the metre gauge in every particular. This in itself was a strong argument against the broad gauge. He thought the 5-foot 6-inch gauge stood self-condemned, and that had the gauge been 5 feet there would not have been the discrepancy, either of first cost or—much less—of general efficiency, between the two gauges; and, incidentally, conversion of one gauge to the other would have entailed less difficulty and less cost. As things stood at the present time, and with the impending unknown development of the Indian railways, which would apportion itself between the two gauges—perhaps equally, but possibly to a larger extent on the metre gauge—and looking at the intricate network of broad- and metre-gauge lines, it might be prophesied that no general conversion of either system to a standard gauge, broad or metre, was either probable or indeed possible, as the cost would be prohibitive, even to the growing prosperity of India; and that India was therefore doomed to the dual system of railway-gauges, with all its disadvantages. That unfortunate state of affairs was aggravated by the existence of two minor gauges, namely, the 2-foot 6-inch and the 2-foot, which served as feeders. If these were looked upon as pioneers of the broad gauge, and not adopted in connection with the metre-gauge lines, the discrepancy between the two, and the difficulty, if not impossibility, of conversion, considering the nature of the country they were said to occur in, was obvious. Given any trunk-line or connected system such as a country like India afforded plenty of scope for, the development of narrow-gauge lines to act simply as feeders to the trunk-lines was logical and desirable. But when railways were put down in such a country not on any well-defined plan of extension or combination, and with two or more gauges connecting and even intermixing, confusion and difficulty were the inevitable result. It would seem that any scheme of conversion, whether local or general, would absorb so much time and so much money as to hinder seriously the natural development of the Indian railways. If any plan of conversion were seriously needed and entertained, the decision should be made and acted upon forthwith. His own opinion was that the broad gauge should give way to the metre gauge, which should become the standard; it would suit India better than the excessive gauge of 5 feet 6 inches, despite all the possibilities of the

Mr Lart. future. He thought that the analogy of the Great Western dual gauge would hold good in regard to these two Indian gauges. But whereas in England the discrepancy between the two gauges had been roughly, 35 per cent., in India it was, roughly, 60 per cent.; and if in a highly-developed country like England such a discrepancy was found inadmissible, the 7-foot gauge excessive, and the conversion of the narrow gauge to the broad gauge impracticable (not solely on account of the broad gauge being an isolated minority), then surely the moral was that the Indian broad gauge should give way to the metre gauge, the lower cost of which would enable a double line to be put down. There were many practical reasons in favour of this, apart altogether from the question of capital cost. India was probably not a country that called for rapid travelling. It had been, and could be, europeanized up to a certain point; but still it had remained, and must ever remain, an eastern country conducted on eastern lines of life; and therefore the metre gauge would be sufficient in point of speed, especially as very fair maximum and average speeds were quite feasible. As the Author showed, the average speeds of the metre-gauge lines were very little less than those of the broad-gauge lines. Indeed, the efficiency of the metre gauge in every respect—including carrying-capacity—was very little less than that of the broad gauge, and relatively it was considerably higher. For some time Mr. Lart had had charge, under the consulting engineers, of the construction of large numbers of broad- and metre-gauge locomotives for the Indian railways, and he had been struck with the relatively low and high powers and efficiencies of the broad- and metre-gauge engines, respectively. Of course there was much greater scope for development in the case of the broad-gauge locomotives; but surely that pointed to the gauge being excessive for the requirements of the country. The cost of conversion from metre gauge to broad gauge in one of the instances cited by the Author, namely, £2,867 per mile, seemed to him rather low. The several items were not easy of analysis; but the cost of the rolling-stock conversion, £667 per mile, seemed rather small, as it represented, necessarily, new locomotives and new carriages and wagons for that particular length of line. The cost of, say, five locomotives for working the 50 miles referred to would be about £17,500 complete on rails, leaving £15,850 for new carriages and wagons; while the value of the old locomotives, carriages, and wagons would be little more than scrap value, say £3,000. Similarly, conversion from broad to metre gauge would involve considerable loss in value of stock broken up, and not much less expenditure for new rolling stock. It was difficult to understand why, with conversion from the metre to the broad gauge presumably

in view, the tunnels alone had been built to suit the broad gauge, Mr. Lart. while the station-dimensions and loading-gauges generally had been retained on the dual system; because the expense of increasing the capacities of station-buildings alone would perhaps be as much per mile as the extra cost of the larger tunnels. The question of bridges and their replacement, strengthening, or widening for broad-gauge traffic was a serious one. Indeed, only in a few favourable instances would strengthening or widening of bridges be possible. In the case of a single track, no doubt a metre-gauge bridge would take a broad-gauge track so far as width and clearances were concerned. But the carrying capacity was another matter; and with the development of the broad-gauge locomotive the general capacity of even the existing broad-gauge bridges was already in question. It looked as if all the Indian railways were marking time, each waiting for the others to begin the task of conversion. But any conversion that was decided upon would have to be general, and indeed compulsory; for the existing confusion would be increased indefinitely if some systems were converted to the broad gauge and others to the narrow gauge. Considering the gradual acquisition by the Government of India of all the railways, it was not difficult, studying the railway-map presented in the Paper, to devise a complete scheme of trunk-railways, by co-ordinating the existing lines of the broad or the narrow gauge, and frankly accepting the tributary lines as mere feeders, their gauges remaining unaltered. Looking at the problem in this light, the relative existing mileage of broad and of metre gauge was not perhaps of so much importance as the Author suggested; the chief difficulty would seem to lie in the fact that certain towns had developed from minor to first-rate importance, and were developing—as others also would do in time—simply by reason of the railways that served them. Of these towns Marmagao was instanced by the Author, the importance of which port would seem to require, in connection with the existing through communication between Bombay, Madras, and Calcutta on the broad gauge, the conversion to that gauge of the Poona-Marmagao-Bangalore, and the Marmagao-Guntakal-Bezwada metre-gauge lines; also the conversion of the metre-gauge Karachi-Agra and Ahmedabad-Delhi lines to the broad gauge, thus linking up Karachi and Calcutta, Bombay and North-West India. The existing metre-gauge lines north and east of the Hooghly and Ganges rivers might be left as they were. But any re-arrangement of this kind would be a temporary solution of the problem of trunk-line intercommunication, if the lines so converted, and all others built in the future, whether broad or metre gauge, were not made double. This doubling should be taken in hand simultaneously with the conversion, thus

Mr. Lart. dealing with the difficulty in a drastic and permanent fashion, to the ultimate saving of considerable trouble and expense and of general disorganization of the railways affected. The question of cost was naturally a very serious one; but the circumstances of the Indian railways and the present needs of India were such as to demand, to justify, and to provide whatever finances might be required, in the certain knowledge that, as in the case of the heavy expenditure on public works in Egypt and the Sudan in recent years, a speedy and bountiful return of general prosperity was assured, since the economic development of India, as it had arisen from the railways of the country, was also entirely dependent upon them.

Mr. Molesworth.

Mr. HENRY B. MOLESWORTH observed that the Author put forward three proposals for securing uniformity of gauge, the cheapest of these involving an expenditure of £2,500 per mile in converting 11,400 miles of metre-gauge railway to the broad gauge, or a sum of £28,500,000 at the lowest estimate. This could hardly be put forward seriously, as a practical suggestion. If the quantity of goods transhipped from the metre gauge to the broad gauge at all the transshipment-stations in India were assumed at 1,000,000 tons annually—which was probably much above the actual amount—and if the cost of transhipment were taken at 9*d.* per ton, there would be a yearly expenditure of £37,500, whereas the interest on £28,500,000 at 3½ per cent. would be £997,500. Uniformity of gauge was very desirable, but it was possible to pay too dearly even for desirable things. The initial mistake of introducing a break of gauge had been made, and the result had been that in 30 years the metre-gauge systems had assumed such dimensions that a drastic and wholesale policy of conversion to the broad gauge was beyond the range of practical financial achievement. The remedy for the break of gauge in India was not to be found in wholesale conversion, but in accepting the present state of things, and in taking each case on its merits and making the best of it. On p. 206 the Author said that when the circumstances of trade demanded it the metre-gauge lines might be allowed access to the ports of Bombay, Calcutta and Karachi. The metre-gauge lines in Eastern and Northern Bengal were separated from the broad-gauge lines by a defined boundary, the Ganges and Brahmaputra rivers, and when the Northern Bengal and Tirhut railways were made in 1870–75 this obstacle was an insuperable one. Now, however, there was a probability that a bridge would shortly be built at Sara, and if this were done these two gauges would be connected. A proposal in which he was interested had recently been submitted to the Bengal Chamber of

Commerce for bringing the metre gauge into Calcutta by bridging the Ganges at Sara, and constructing a metre-gauge line crossing the Eastern Bengal railway at or near Halsha, running through a densely-populated and fertile country by Jhanidah and Naldanga to Jingergatchi on the Bengal Central railway, which railway would be converted to the metre gauge, and, if necessary, doubled. The scheme also proposed a metre-gauge line from Nowapara on the Bengal Central railway to Paterdi on the Torki River, and a steam-ferry to convey metre-gauge rolling stock between Narainganj on the Dacca and Maimansinh railway, Chandpur on the Assam-Bengal railway, and Paterdi. There need be no fear as to the conversion of the Bengal Central railway to the metre gauge; the traffic on this line had never been remunerative, as it had never seriously competed with the communication by water. The disposal of the metre-gauge rolling stock at Calcutta presented great difficulties, owing to the complexity of the Port Commissioners' sidings. The third rail was probably inadmissible; transfer-trucks might be used, or the overhead transporters suggested by the Author; but the development of Calcutta as a first-class port would probably lead at no very remote date to the canalization of the Mutla River, when access to the docks on the metre-gauge could be arranged. The cost of the new works would be approximately £1,750,000; the capital cost of the Bengal Central railway was approximately £1,000,000 more. This proposal presented a simple and practical method of minimizing the disadvantages of the present break of gauge in one province, and was not so costly as to preclude a fair return on the capital expended.

Mr. SIDNEY PRESTON thought that reference might usefully have been made in the Paper to the further complication of the problem of the railway-gauges of India by the introduction of the 2-foot 6-inch and 2-foot gauges. The latter might perhaps be ignored, as at the close of 1903 there were only 262 miles open and 113 more under construction or sanctioned; at the same time it was a matter for regret that there should be two gauges which differed by so little as 6 inches. The 2-foot 6-inch gauge, of which at the close of 1903 there were 796 miles open and 575 miles under construction or sanctioned, could not, however, be ignored. It would have been useful if the Paper had contained a statement showing where the lines of this gauge were situated. So long as they were confined to lines in the hills, such as the Kalka-Simla, or Darjiling railways, exception could probably not be taken to them, as such lines must necessarily be feeders to main lines in the plains. But the case of lines in the plains was on a different footing, and it was a pity that

Mr. Molesworth.

Mr. Preston

Mr. Preston. a third gauge had been introduced to further complicate the already sufficiently difficult problem. For instance, the North-Western railway at Saharanpur and the East Indian railway at Shahdara were standard-gauge lines. Was it not a pity that they should be connected by a 2-foot 6-inch gauge line? Further, Shahdara was only 8 to 10 miles from the great junction of Delhi. Now it was not unreasonable to think that in the near future the Saharanpur-Shahdara line would, if the traffic developed as was anticipated, claim to enter Delhi, so as to transfer its traffic direct into the metre-gauge wagons of the Rajputana railway system. Should this be conceded there would, at some future date, be the complication of three gauges entering Delhi; or, if it were not conceded, the traffic from the Saharanpur-Shahdara line for the metre-gauge system, would be subjected to two changes of bulk in a distance of 8 to 10 miles. Neither of these alternatives could be viewed with equanimity. The disadvantages were so obvious that it would be interesting to know the reasons which had influenced the Government in sanctioning a 2-foot 6-inch gauge for the Saharanpur-Shahdara line. Mr. Preston understood that it was due to the fact that it was to be constructed under the Tramways Act, and not under the Railway Act. He was not sufficiently conversant with the details of these two Acts to say anything regarding them, but he believed that one of the advantages of the former was that local governments could sanction lines as "tramways," while railways must be included in the programme of the Government of India, and be sanctioned by them. This necessarily caused delay, and the sanction was not so easily obtained. The construction of the Saharanpur-Shahdara line as a tramway might therefore be satisfactory from the promoter's point of view, but it was questionable whether it was wise of the Government to invent or authorize a system which, as far as could be seen, must still further complicate the question of the railway-gauges of India. Whether there were other lines similarly situated Mr. Preston was unable to say, and for this reason he regretted the absence of a Table for the 2-foot 6-inch gauge, similar to Tables I and II for the standard and metre gauges. If there were other similar lines, either existing or contemplated, it only emphasized the objection to a third gauge. He could not but think that the Saharanpur-Shahdara line should be built on either the standard or the metre gauge. The former would be the same as the gauge of the two lines it would connect, while the latter would allow of the line being connected with the Rajputana system if necessary. Having no personal interest in any of the railways referred to he merely offered these remarks in the interests of the general railway-system of India.

Mr. F. E. ROBERTSON observed that most discussions on the gauge question had been vitiated by the implicit assumption that all the dimensions were geometrically similar, and by the omission to remember that speed was a commodity which was sometimes worth money. When it was considered that some narrow-gauge lines possessed heavier rolling stock than lines of considerably wider gauge, and that generally the body-width bore no fixed ratio to the gauge, it would be seen that the actual distance apart of the rails was, within limits, scarcely worthy of serious discussion. Probably, if the railway world could begin again, a normal gauge of 5 feet and a narrow gauge of 2 feet 6 inches would be chosen, and these two, with the great variations in cost and carrying-capacity which actually existed on the same gauge, would fully meet all requirements. One at least of the alternatives suggested in the Paper, namely, alteration of both the broad gauge and the metre gauge to the English gauge had, in Mr. Robertson's opinion, nothing to recommend it. The running dimensions of the broad gauge would remain unaltered, and it was difficult to see what would be gained by putting the rails a few inches nearer together, either on existing lines or on those to be built. Nor could there be any serious discussion of the abolition of either the broad or the metre gauge as an ultimate object. It might perhaps be regretted that a 2-foot 6-inch gauge had not been chosen for local lines, but the metre gauge had undoubtedly come to stay, and the decision in any particular case whether to double or to widen a metre-gauge line which had attained its limit must depend upon the circumstances; the question was not susceptible of any general answer. One of the first considerations would naturally be the prospect of the construction of other lines which might take off any surplus of traffic by direct communication with the terminus, or which, if built as branches, would still further increase the flow of traffic on the main route. One argument in favour of pushing back the point of junction up the metre gauge was the speed question. The longer the line and the heavier the traffic, the more was speed required, and the better could it be afforded; but even here a direct answer was difficult to get. For the comparison would be between a single broad-gauge and a double metre-gauge track, and the superior speed of the former in actual running might be seriously handicapped by the delays inevitable in single-line working. The difference in running-speeds between the two gauges was not really known, for the broad-gauge was in this respect usually worked in such a leisurely way that the metre gauge had no difficulty in keeping fairly close to it. As to the minor gauges, the difference was so small as to mean nothing, and the 2-foot 6-inch gauge should prevail, simply because there was more of it

Mr. Shadbolt. Mr. E. I. SHADBOLT remarked that, having regard to the Author's general conclusion that a line of 5-foot 6-inch gauge had double the capacity of a metre-gauge line, and that a double line of either gauge had five times the capacity of a single line, no further arguments were required to show that, if a single gauge were adopted as the standard for India, it should not be the metre gauge. In reviewing the three possible methods of attaining uniformity of gauge, it was assumed in the Paper that the ultimate limit of capacity was proportional to the gauge when that limit was reached. This was not quite correct. The ultimate capacity for goods-traffic, at least, was rather proportional to the dimensions of the loading-gauge—or what were known in India as the “standard moving dimensions”—combined with speed. A glance at Figs. 8, Plate 2, showed that these dimensions, as adopted in India, were by no means proportional to the gauge. In the one case there was an outside width of 10 feet 6 inches on a gauge of 5 feet 6 inches, while in the other there was a width of 8 feet 6 inches on a gauge of 3 feet $3\frac{3}{8}$ inches. The size of the loading-gauge was relatively much larger on metre-gauge lines than on 5-foot 6-inch lines; and while this was an advantage so long as low speeds were maintained, it was fairly well agreed among engineers in India that any appreciable increase of speeds on the metre gauge was impracticable, as stability would be endangered thereby. While, therefore, the speeds of metre-gauge trains shown in Table IV would never be greatly exceeded in practice, those of 5-foot 6-inch lines, shown in the same Table, did not nearly approach the limits that might be attained if circumstances should render it worth while. From the experience of England, America, and most of the countries of Europe, with railways of the 4-foot $8\frac{1}{2}$ -inch gauge, it was fairly well known what those limits were. The speeds conveniently attainable were certainly more than double those shown in the Table, and if only double those speeds were adopted in India, the carrying-capacity of the 5-foot 6-inch lines would work out to four times that of the metre-gauge lines; while, so far as passengers were concerned, the facilities and conveniences afforded would be more than double those of metre-gauge lines. In the foregoing remarks the conditions which obtained with regard to the English gauge were assumed to be practically identical with those of the Indian 5-foot 6-inch gauge. This was really the case, for, as already indicated, capacity was proportional to the loading-gauge adopted, and not directly to the gauge of the rails. The loading-gauge for the 5-foot 6-inch gauge was practically that of English railways, and somewhat smaller than on American railways. When railways

were first introduced into India, the English practice was followed Mr. Shadbolt, with little variation, the only difference being in the greater width apart of the wheels. This modification was considered necessary owing to a fanciful apprehension of the effects of high winds upon the stability of vehicles. Having once been adopted, the loading-gauge was limited by the fixed dimensions of tunnels, bridges, and other structures. Neither could be modified to any considerable extent. It might be accepted, therefore, that all the advantages possessed by the 5-foot 6-inch gauge, as compared with the metre gauge, were equally possessed by the 4-foot 8½-inch gauge so far as related to actual carrying-capacity. But the English gauge had further advantages, in that it allowed of the construction of a better and more economically proportioned vehicle, with shorter axles for the same body. It also admitted of more flexibility in laying out a railway, as sharper curves could be employed. Above all, it had been adopted by all the leading commercial countries of the world, and the full sum of their great experience in design and working was thus at the disposal of those who were wise enough to follow in their steps. The Paper truly intimated that it was not necessary, in this Institution, to demonstrate the advantages of uniformity of gauge, and all the arguments that were set forth in favour of uniformity in one country applied, though in varying degrees, to uniformity in many countries. The advantages of general standardization in engineering matters had been much discussed, and were now fully accepted. Such as they were, they existed equally in the case of the standardization of railway-gauges. England had shown its adhesion to this principle by the conversion of one of its two gauges, and America by the conversion of the dozen or so of various gauges that existed prior to 1885. The conclusion might be accepted with absolute confidence that there should be one gauge in India, and that this gauge should be the gauge of 4 feet 8½ inches adopted in England, in America, on the continent of Europe, and in other countries. The reference in the Paper to questions of cost and difficulty of conversion applied only to the 25,000 miles of railway existing in India, and practically took no heed of the developments that must necessarily occur in the future. It was said that India had not now a clean slate to start on. No doubt a precisely similar remark would have been made 20 years ago when there were 11,000 miles of railway, or 30 years ago when there were only 6,000 miles. But everything seemed to indicate that the railways of India would be steadily added to until the whole country was covered with a network of lines perhaps 50 miles apart, perhaps even 25 miles apart. The progress would certainly not be checked until 100,000 miles

Mr. Shadbolt. or more had been constructed: the development would be continuous, and this mileage might be completed in a period of 50 or 60 years. Relatively speaking, therefore, India *had* a clean slate, because the existing mileage was insignificant in comparison with the mileage that would ultimately be attained, and ought now to be considered. It must be remembered that the disadvantages of break of gauge had hitherto been scarcely felt. Where traffic had been on a moderate scale, the mere cost of transshipping goods had been found to be equivalent to about 20 miles of haulage. But if the two gauges were ever brought together into seaport towns, or into coal-fields or other large centres of traffic, the expense, the difficulties, and the confusion, would be multiplied a hundred-fold. Experience had shown that the administrations of lines of different gauges did and would press for equal rights and facilities in such cases, not in any way to the benefit of the country, but merely for the sake of securing a favourable position with regard to competition. It was difficult for the Government to resist such demands, although in the great majority of cases the work had to be carried out at the expense of the tax-payer, for unassisted private enterprise in India was practically non-existent. About four-fifths of the railways were owned by the State, and the small working-capital provided by companies, to whom the working of many of the lines had been entrusted, was furnished by them under a guarantee of interest. In such cases the private enterprise did not differ essentially in character from the enterprise of depositing money in the Post Office Savings Bank. Clearly it was the future and not the present that should be taken into consideration. If action were delayed, it might well be that a future generation would look back with amazement at the timidity which led to the evasion of the problem at a time when only 25,000 miles of road had to be dealt with. The cost of converting a metre-gauge road to the 5-foot 6-inch gauge was shown in the Paper to be Rs.38,750 to Rs.43,000 per mile. In both the cases quoted, about half the expense was due to the substitution, for the light permanent way of the metre-gauge line, of the heavier permanent way necessary for the increased traffic expected on the 5-foot 6-inch gauge. But there were many railways in India which had been constructed for administrative reasons or with a view to protection from famine, and on which the traffic was very light. On such lines there was no reason why the light metre-gauge rails should not be retained for the wider gauge—at least for a time—and the expense of heavier rails be avoided. Perhaps it was fair to assume that the conversion of one-half of the metre-gauge lines in India would cost Rs.40,000 per mile, and that of the other half

less than Rs.30,000 per mile. It must not be forgotten that on Mr. Shadbolt, metre-gauge lines where traffic was increasing, considerable expenditure would be necessary for increasing the strength of rails, girders, and other works, whether conversion took place or not. There was no record of the cost of converting a 5-foot 6-inch line to a gauge of 4 feet $8\frac{1}{2}$ inches, but where traffic was small it would be trifling. On a busy line a temporary mixed gauge might be necessary to avoid a stoppage of traffic, and the cost would then be higher; but the same materials would be used, and there would be no outlay for stronger rails or girders. There had been one or two instances in which a 5-foot 6-inch line had been converted to the metre gauge. This operation had been performed on a section of railway not far from Karachi, extending from Haidarabad (Sind) to Shadipalli, a distance of 50 miles. It was a cheap line, laid with flat-footed rails on wooden sleepers, and having a few openings spanned by plate girders carrying wooden transverse sleepers. The conversion had involved little more than moving in one rail to a new position on the sleeper. It had been carried out by the ordinary maintenance-gangs at the rate of a station-to-station length of 8 to 10 miles daily, the trains of the two gauges meeting end-on at a station, and passengers moving from one to the other. The total cost had not exceeded a few hundred rupees per mile, and the engineer-in-charge had asserted that the value of the ends sawn off the long sleepers had paid for the whole operation. The conversion of a 5-foot 6-inch to a 4-foot $8\frac{1}{2}$ -inch road would present even fewer difficulties, and on wooden-sleeper roads generally the cost might be taken at not more than Rs.1,000 per mile. Many roads in India, however, were laid with cast-iron sleepers connected by tie-rods, or with pressed-steel sleepers. In such cases the cost of conversion might amount to Rs.5,000 per mile. On busy lines, where a temporary mixed gauge would be required, the ultimate cost might come to Rs.20,000 per mile. With regard to rolling stock, if the conversion were spread over a term of years, the present rolling stock could be largely used on lines of existing gauges during the transition period. By the time conversion was complete, much of the stock would be worn out, and only the remainder would have to be dealt with. There would be some expense, but the item would not be a serious one. Reference was made in the Paper to the "confusion" which would accompany conversion; but a difficult operation was not necessarily attended by confusion. Whether an operation was simple or complex, it was only necessary that arrangements should be made to suit the circumstances. The large body of experienced railway-engineers in India would be quite equal to doing

Mr. Shadbolt. whatever might be required, without causing any confusion or appreciable dislocation of traffic. The rate of conversion would become merely a question of cost, and would depend on the circumstances of each case. A line could be converted in a Saturday-to-Monday interval if it were worth while to complete the operation in so short a period. To sum up, the conclusions Mr. Shadbolt arrived at were:—That a uniform gauge should be adopted for India; that this should be the 4-foot 8½-inch gauge; that not another mile of any other gauge should be laid, but that all lines now under construction should be completed to the new standard gauge; that conversion of existing gauges should be begun on State-worked lines; that in new contracts with working companies whose existing contracts would shortly expire, provision should be made for conversion. Probably it would not be practicable to force conversion on companies having contracts with some years to run; but if the steps indicated above were taken, most of them would probably be prepared to come into line in their own interests. So far as they refused to do so, the worst that could happen would be that conversion might possibly be delayed till the termination of their current contracts.

Mr. Spring. Mr. F. J. E. SPRING considered that the Paper confirmed the opinion at which he had long ago arrived, that it would be folly to attempt now to bring about uniformity of railway-gauge in India. The abolition of the numerous existing breaks of gauge would doubtless serve to oil the wheels of trade to some appreciable extent. But practical administration could not hearken to counsels of perfection which—however useful they might have been 30 or 35 years ago—were now quite outside the scope of action. The theory that break of gauge was an intolerable evil had originated with the military advisers of Government on the north-west frontier, where considerations of facility for transporting troops and war-materials must necessarily outweigh all other considerations, and where it was so important that in time of war there should not be a break of gauge that it was considered worth while to keep hundreds of miles of railway, even during years of peace, doing perhaps only one-half or one-quarter of the work which they were capable of doing, and no more than might perfectly well be done by a railway of narrower gauge costing only half the money. But these considerations, which so influenced the northern railway-administrations, did not altogether apply to other lines. It was often forgotten that most of the evils of break of gauge were going on daily and hourly in scores of places all over India, without traders being conscious of them, or any attention being paid

to them: he referred to the unloading of foreign wagons, in order that they might be returned, when they arrived too lightly loaded on lines other than their own. The Author gave $5\frac{1}{2}d.$ per ton as the cost of transshipment, or the equivalent of about 20 miles of haulage, but Mr. Spring had evidence of its costing much less than this. When in charge of the Madras Government Railway Department a few years ago, he had found it necessary to tender advice to district boards (county councils) in that Presidency, which, as the result of certain new legislation, had had to consider the question of light local railways. On the subject of transshipment he then wrote—

“From evidence supplied to me by four traffic experts, all working in Southern India, it would appear that from 1 to $1\frac{1}{2}$ annas (pence) per ton is a fair price for transshipping from one gauge to another, while it may run up to $3\frac{1}{2}$ annas (pence) for specially bulky and troublesome goods, and may cost, for such goods as grain, as little as half an anna per ton. . . . On the Morvi Railway the average sum received in ten half-years for the carriage of *one ton of goods one mile* was about $1\frac{1}{4}$ anna, or a penny-farthing.

“A not unimportant item of cost of transshipment consists of payments by the railway administration of claims made by consignors or consignees on account of damage occasioned to goods by being handled. But the public soon get to recognize that, when their goods are carried by carts or by canal boat, there is practically no possibility of recovering anything on account of damage done in transit; while in dealing with railways such recoveries are made in the ordinary course of business.

“As an ordinary charge for railway freight of average goods is from 3 to 6 piers (one farthing to one halfpenny) per ton-mile, and as the cost of transshipment is from 1 to $1\frac{1}{2}$ annas (a penny to three halfpence) per ton, it follows that the cost of transshipment is equivalent, according to class of goods handled, to haulage over from three to six miles of railway. This cost the merchant of course pays, but he pays it indirectly, for the general run of rates throughout a railway system is regulated by the management so as to cover *all* incidental charges, of which transshipment is one. It may safely be predicated that the cost and delay of transshipment at the junction of a railed road with the main line of which it is a feeder, when added to railway freight charges, will usually be considerably better for the consignor than the cost and delay incidental to carriage by country cart.”

The managers of Indian railways—whether State or companies’ lines—naturally and rightly looked upon certain territories and cities as peculiarly their own scene of action for earning-purposes, and they resented seriously the advent of rival companies athwart or into their territory. Indeed, the battle of the gauges in India had become for the most part a battle between the traffic-managers of rival railways of different gauges. The 5-foot 6-inch gauge, being for the most part the older line in a given territory, and its management having in the past been at times somewhat conservative, not to say hidebound, in the matter of branches and extensions, it had naturally followed that here and there the cheaper and more modern metre-gauge had

Mr. Spring. pushed its way gradually into the territory of its older and less vigilant neighbour, often right into centres of trade, *e.g.*, Bangalore, Cawnpore, Lucknow, etc., which the broad-gauge lines had got into the habit of counting as their peculiar trading-territory. Hence much of the acrimony which characterized the rivalry between the two gauges. Such rivalry was seldom exhibited between lines of similar gauge—at least, not in so acrimonious a form. Such a spirit, though right and proper between the partisans of the several gauges, would be totally out of place if exhibited by the advisers of Government, who were, or ought to be, and ought to consider themselves as being, the trustees of a voiceless mass of tax-payers whose interests were the sole or the chief interests to be taken into account, directly and indirectly. What the Indian tax-payer wanted, and what he would ask for were he only articulate, was railways, and more railways, so long as he could earn from them at least as much—say 4 per cent.—as, all told, the money cost him which directly or indirectly he spent on them. He wanted a means of transport which would carry his field-produce to market 80 miles in a night instead of 8 miles, and at not much greater expense for the 80 miles than for the 8 miles. The town merchant wanted to find the villages of India—parishes they would be called in England, only with the houses grouped instead of scattered—within a 10-mile walk, or even a 20-mile tramp, of a railway-station—a state of things which as yet was far from being the case. He wanted to buy and carry off the villager's field-produce, and to give him in exchange the things he could not grow but which were produced by other parts of India or even by foreign countries. All concerned wanted to be able to get about more easily and quickly, for they were keen travellers when they could afford it. But they did not care so much about speed, for, compared with the 2 miles per hour of the paternal bullock-cart that had served them for untold generations, the 15 or 20 miles per hour of a metre-gauge or even 2-foot 6-inch railway was a giddy whirl to be talked of for long after it was first experienced. Also, they liked to get out and loiter at the stations, and they felt that they were being cheated of half the joys of the journey if whisked off again before their smoke and general wash-up were finished. Had these people a voice—and it should always be remembered that they owned the railways—that would say: "Give us 200 miles instead of 100 and 2,000 instead of 1,000, if it can be done at the same cost; but don't trouble to give us European speeds and luxuries of travel, for we don't value them." The town merchant did not want to be able to trade only with Agra, Jhansi and Allahabad, or only with Madras and Calicut; he wanted also to trade with Ajmere and

Gorakhpur, or with Marmagao and Masulipatam. He knew nothing Mr. Spring. about gauge, but he wanted to feel that as many routes as possible had termini in his town, so that his goods might go through without complication. These were the things that a wise trustee, who was not a mere railway partisan, would try to give the people of India—more railways, the maximum mileage for the available money consistently with suitability for the probable traffic, and the freest access of all neighbouring railways, or failing that, of both the main gauges, into the chief centres of trade. As compared with all this, the inconvenience to India of mere break of gauge was the veriest trifle, and insistence on the extension of the standard gauge without reference to local conditions indicated, to Mr. Spring's mind, a lack of the wisdom which might be looked for in a statesman. The Paper brought out certain facts which it seemed desirable, in the interests of clearness, to recapitulate. These were:—

(1) The mileage of the 5-foot 6-inch or Indian standard gauge was only about 15 per cent. in excess of that of the metre and other gauges.

(2) It cost about twice as much to build a 5-foot 6-inch line as to build a metre-gauge line. Yet in India both gave about the same return on the capital expended, the chief reason for this being that the broader gauge had been first in the field in the richer countries.

(3) The general capacity of the 5-foot 6-inch gauge was about double that of the metre gauge.

(4) For rough purposes it might be accepted that it would cost about £2,500 per mile to convert a line of metre gauge to the 5-foot 6-inch gauge, including rolling stock.

(5) It would apparently cost about £3,400 per mile to double a piece of metre-gauge line, including rolling stock.

(6) Transhipment from one gauge to the other appeared to cost about $5\frac{1}{2}d.$ per ton, or the equivalent of about 20 miles of haulage. This, however, Mr. Spring believed to be over-estimated for most parts of India.

(7) When a metre-gauge line was found to be overworked, the expenditure on it of £2,500 per mile for its conversion to the 5-foot 6-inch gauge would about double its carrying-capacity; but the expenditure on it of about £3,400 per mile for doubling it without altering its gauge would quadruple its capacity. In view of these figures and of the facts and arguments put forward in the Paper, and in the light of over 30 years of close connection with most parts of the Indian railway-system, during a period in which that system was expanding from about 5,000 to about 30,000 miles, he thoroughly endorsed the conclusion at which Mr. Upcott had arrived, namely

Mr. Spring. that: "For many years to come India needs all the money she can get for fresh lines, and will have little or nothing to spare for adopting a counsel of perfection. India has not now a clean slate to start on, and she must needs by compromise make the best of each case as it arises."

Mr. Sykes. Mr. C. F. SYKES considered that the experience and example of all the great countries of the world put the question whether there should be a uniform gauge for railways throughout India practically beyond discussion; and that the question for consideration brought out in the Paper was really confined to the merits or demerits of the existing gauges, particularly as compared with each other, on the assumption that the practical method of obtaining uniformity was by the conversion of either gauge to the other. All comparisons hitherto made between the capabilities of metre-gauge and standard-gauge lines appeared to be based on the initial cost and cost of working of single-track "pioneer" lines. Relative to the standard-gauge lines in India, metre-gauge railways were essentially light railways. The maximum axle-loads were about one-half of those obtaining on the standard gauge, the relative weight of rails being about two-thirds. It might be laid down as a principle that, for traffic within the limits of its capacity, any single-track light railway would compare favourably, in first cost and cost of working, with a railway built to a heavier standard; and that traffic beyond that limit would never be dealt with by duplication and reduplication of light lines, but by concentrating loads on single tracks to the utmost they would bear, the single track of the greatest load-capacity combined with the greatest speed being the most efficient—whatever the gauge might be. The true criterion in this case, therefore, was not the merits of the two gauges for pioneer lines (a light line could be constructed equally well on the standard gauge), but the capability of dealing with the maximum gross traffic ultimately to be developed. It was not too optimistic to assume that, if the railways were retained on the standard gauge, all the trunk-lines would be doubled within the next decade, or two decades, and would be quadrupled on the sections leading into the seaports. In fact the necessity for quadrupling had already arisen in some instances. Any claim to make the metre gauge universal must therefore be based on its capability to deal with the traffic which this implied. From the data in the Paper it seemed fair to assume, for this purpose, that the gross carrying-capacity of a single standard-gauge track was equivalent to that of a double-track metre-gauge railway, and it would be necessary, therefore, to substitute a four-track metre-gauge railway for each double standard-gauge railway, and six

or ultimately eight metre-gauge tracks for a quadruple standard-gauge railway. The relative cost on this basis could not be properly estimated from the cost of existing lines, which, as noted in the Paper, had been constructed at different periods over half a century, and under widely varying conditions; but it might easily be seen by comparing the works under the following different heads:—

Formation.—The relative widths of formation would be—

	Feet.	Inches.
Standard-gauge single-track	20	0
Metre-gauge double-track	28	6
Standard-gauge double-track	34	0
Metre-gauge quadruple-track	53	6
Standard-gauge quadruple-track	62	0
Metre-gauge sextuple-track	78	0
„ „ octuple-track	103	0

Tunnels.—A double-track metre-gauge tunnel 30 feet wide would be required in place of a single-track tunnel 17 feet wide on the standard gauge, or two such tunnels for each double-track standard-gauge tunnel.

Bridges.—The cost of barrels of culverts and of piers and abutments of girder-bridges, apart from the wings, would be increased in proportion to the width of formation. For small girder spans up to 60 feet two pairs of girders would be required for each pier on the standard gauge, with an increase of about 50 per cent. in cost. For large bridges the comparison would be the same as for tunnels.

Permanent Way.—The following was a comparison between the weights of the rails in use on the two gauges:—

	Metre Gauge.	Standard Gauge.
Light lines	41 lbs. per yard.	62 lbs. per yard.
Ordinary standard . .	50 „ „	75 „ „
Heavy „	60 „ „	90 „ „

That was to say, the gross weight of rails on a double-track metre-gauge railway would be 33 per cent. greater than the equivalent single-track standard-gauge line. The cost of sleepers would be about the same, but on the metre-gauge line they would require about 50 per cent. more ballast than on the standard-gauge line.

Signals, etc.—The cost of signals, etc., would be much the same for either a single- or a double-track railway, but as between a double-track and a four-track railway the cost would be doubled, and the cost of interlocking probably more than doubled.

Stations, etc.—In large goods-yards, assuming that accommodation had to be provided for the same gross bulk of goods standing in wagons at one time, three metre-gauge tracks occupying a width of 36 feet

Mr. Sykes. would be required in place of two standard-gauge tracks occupying a width of 27 feet. The cost of land and maintenance-charges would also be increased in proportion.

These facts formed the basis of the principle first laid down. Other considerations, such as speed and general convenience and the comfort of the travelling public, were still more adverse to the metre gauge. Journeys in India on the standard gauge extended to 2,000 miles or even more, the time taken being 2 to 3 days for a single journey without a break. Substituting the metre gauge would mean a reduction of about 30 per cent. in the average speed, or an increase of about 50 per cent. in the time occupied. For long journeys, existing metre-gauge routes were shunned, wherever practicable. Mails and passengers from Bombay for the Punjab made the detour by Jhansi and Agra, and similarly mails and passengers from the west for Northern Bengal and Assam proceeded via Calcutta. In the face of these considerations, the idea of uniformity throughout India on the metre gauge was hardly conceivable. A principal factor which had brought the metre-gauge systems into being was the practical prohibition of the construction of light railways on the standard gauge. Assuming the ordinary metre-gauge standard of construction, with 50-lb. rails and corresponding weights of locomotives, the factors governing the difference in cost of construction of a light railway on the 5-foot 6-inch gauge to the same standard of construction were:—(1) The formation-width would be increased by 2 feet; (2) The cost of sleepers would be increased by about £200 per mile. Against this would be a saving on transshipping-arrangements, and on rolling stock; for such a line would be able to carry the ordinary four-wheeled coaching- and goods-stock of the standard gauge at low speeds. No light line of this kind existed, nor, as standards were fixed at present, was permitted to exist; and all comparisons of cost between metre-gauge and standard-gauge lines or feeders had been made hitherto, not as between lines constructed up to the same standard of construction or carrying-capacity on each gauge, but on the basis that a railway of 5-foot 6-inch gauge must necessarily be constructed to a much heavier standard. In India, a light railway and a narrow-gauge railway had come to be synonymous terms; and this had brought about the introduction of yet another gauge—the 2-foot 6-inch gauge—in situations where a light railway on the same gauge as the main line would be preferable and ultimately more economical. The cost of conversion of such a light line would, on the whole, be nearly the same as the conversion of a narrow-gauge railway, with the important exception that the rolling stock would not be scrapped. The conversion, however, would

be carried out more gradually in the ordinary course of renewals. Mr. Sykes. In advocating a policy for the conversion of all railways in India to the standard gauge, it would be necessary, therefore, to include provision for the construction of light feeder-railways on the standard gauge. Though the gross cost of conversion appeared large, it might really be considered, for the greater part, as deferred expenditure, which would have been incurred earlier if the lines had been constructed on the standard gauge even as light railways; and it would be largely reduced, in effect, if the conversion were carried out under a well-considered comprehensive scheme, whereby a large portion of the recovered material and the rolling stock might be utilized for the construction of light feeder-lines or for metre-gauge extensions in Assam and Burma. It would not be difficult to show that the net expenditure involved would be much less than the cost of paralleling existing standard-gauge lines, constructing connecting links, and duplicating the terminal arrangements at the principal ports and industrial centres on the metre-gauge—an undertaking which might be regarded as the natural outcome, if the present ruinous system of independent development under two gauges were permitted to continue.

Mr. CAMPBELL THOMSON remarked that, in endeavouring to form Mr. Thomson. an opinion which would be of any value on the questions raised by the Author, it was essential that the data employed should be as accurate as possible. Tables I and II in the Appendix to the Paper were supplied by the Author for the purpose of showing the comparative capital cost of metre- and standard-gauge railways; and although it was pointed out that, for various reasons mentioned, an exact comparison could not be drawn between them, it was claimed that so far as statistics could help to solve the problem, they afforded “a fair basis for comparison of the relative merits of the standard- and metre-gauge systems.” No doubt they did so in some particulars; but it would be found on examination that in the matter of capital cost they were very misleading, and that a much closer approximation could be obtained by rearranging the Tables so as to limit the comparison to railways which had been constructed under somewhat similar conditions. For this purpose the East Indian, Eastern Bengal, Great Indian Peninsula, and Bombay, Baroda and Central India railways should be omitted from Table I because they had been constructed at a time when, for various reasons, the cost of constructing railways in India was generally much greater than when the metre-gauge lines in Table II, with which they were compared, were constructed. On the other hand, the metre-gauge Jodhpur-Bikaner railway should be omitted from Table II, because

Mr. Thomson, it had been constructed under conditions differing in every respect from those of any of the standard-gauge lines in Table I, being to all intents and purposes a surface line through an exceptionally easy country with little bridging; in fact this item amounted to but little more than 2 per cent. of the total cost, as compared with 16 per cent. on the adjoining Rajputana-Malwa railway. The Rohilkhand-Kumaun railway should also in fairness be omitted, as it had been constructed under much more favourable conditions than any of the standard-gauge lines with which the comparison was made. The effect of these modifications was shown in the following Table:—

Metre Gauge.		Standard Gauge.	
Railway.	Cost per Mile.	Railway.	Cost per Mile.
	£		£
Bengal and North-Western	5,300	Oudh and Rohilkhand .	7,800
South Indian	4,600	North-Western . . .	9,600
Burma	6,200	Bengal-Nagpur . . .	8,900
Eastern Bengal . . .	6,200	Madras	9,100
Southern Marhatta .	5,600		
Rajputana-Malwa . . .	5,000		
Averages	£5,483	..	£8,850

The ratio of cost, it would be seen, was 1 to 1·61, instead of 1 to 2·50 by the Author's Tables. The difference was large, but the ratio 1 to 1·61 was undoubtedly more nearly correct. It was possible, however, to obtain a still closer approximation by comparing individual lines constructed under conditions more nearly similar than the grouping in the Tables afforded. A good example was obtained by comparing the Rajputana-Malwa metre-gauge line, costing £5,000 per mile, with the Bengal-Nagpur standard-gauge line. In order to render the comparison as fair as possible, the expensive extension of the latter from Sini to Calcutta was omitted, the cost of the remaining 1,067 miles (£6,100 per mile) being taken from the Railway Administration Report for 1898. As this cost, however, did not include an equipment of rolling stock equivalent to that included in the £5,000 per mile of the Rajputana-Malwa railway, £600 per mile was added to provide for this and get a fair comparison, namely, £5,000 to £6,700, giving a ratio of 1 to 1·34. Another suitable example was obtained by comparing the same portion of the Bengal-Nagpur railway at £6,100 per mile with the Nagpur-Chhatisgarh railway before its conversion from metre to standard

gauge. As a metre-gauge line it had cost £4,700 per mile, which, Mr. Thomson. compared with the £6,100 per mile for the Bengal-Nagpur, gave practically the same ratio as in the last example, namely, 1 to 1.3. In Mr. Thomson's opinion this ratio (or, say, 1 to 1.33) might be accepted as practically correct in all comparisons where permanent way of the "standard" types (41½-lb. and 75-lb. rails for metre and standard gauge respectively) and an equivalent equipment of rolling stock were used, and where the physical conditions of the country were alike. The Author claimed that the question of cost of conversion from metre to standard gauge was not one of estimate, as actual figures were available; but as the cost must vary with the physical and other conditions (as in the case of new lines), "actuals" of one or two cases could not, in Mr. Thomson's opinion, be applied generally. From the Paper it was seen that, in one case, rolling stock and bridges cost respectively Rs.10,000 and Rs.1,500 per mile, and in another, Rs.4,800 and Rs.5,730 per mile—differences which alone showed the incorrectness of the Author's contention. Probably the best way of stating the cost of conversion for general application would be as a percentage of the original cost of the line before conversion. In the case of the Nagpur-Chhatisgarh railway, the original cost of which was £4,700 per mile, the cost of conversion (£2,583 per mile) amounted to 55 per cent.; and as this was an instance in which the two lines were constructed and equipped to a corresponding standard, this percentage might be accepted as a close approximation for general use. The cost of doubling metre-gauge lines must also necessarily be a matter of estimate, and would vary (as in the case of construction or conversion) with the conditions, no fixed rate per mile being applicable to all cases. The cost would also be best expressed as a percentage of the cost of the line before doubling. This might be arrived at approximately by estimating separately, for each main head of account of any metre-gauge railway, the proportionate increase due to doubling in accordance with the standard dimensions, and thus obtaining the required percentage. In the case of the Nagpur-Chhatisgarh railway this was shown in the following statement:—

	£ per mile.
Land	50
Formation	340
Bridges	640
Ballast	360
Permanent way	1,350
Rolling stock	450
General charges	70
Stations	100
Total , , ,	<u>£3,370</u>

Mr. Thomson. This represented 75 per cent. on the original cost of the single line (£4,700), and might be regarded as a fair approximate proportion for general application. It would be observed that the rate per mile corresponded very closely with that in the estimate for doubling given in the Paper ; but apparently the rate for land taken therein was an error and should be reduced by at least £400, making the Author's estimate £2,930. The following ratios of cost were therefore obtained as data to work from in cases in which conditions were in all respects similar :—

(1) First construction of metre-gauge to first construction of standard-gauge, 1 to 1·33.

(2) Metre-gauge to same converted to standard-gauge, 1 to 1·55.

(3) Metre-gauge to doubled metre-gauge, 1 to 1·75.

If, as he believed, these data were fairly accurate, it would seem at first sight that there could be little or no justification for the adoption by the Government of India of the metre gauge to anything like the extent to which it had been adopted. In order to judge the question fairly, however, it must be considered from the point of view of the proprietor (in this case the Government of India), whose first consideration, apart from political or military necessities, must be : “Which will pay best ?” This could best be answered by comparing the financial results of a line of each gauge on the same “location,” their relative cost being known ; and if the latter were taken as 1 to 1·33 it would certainly not be placing the standard gauge at a disadvantage in making the comparison. In working out such a case the results would be found to be largely in favour of the metre gauge ; so much so as probably to surprise anyone who had not made the comparison before. In order to show the results in a convenient form the Table on p. 317 had been prepared as an example, exhibiting the comparative results progressively in 3-year periods for 30 years ; and, although a hypothetical case, the results would apply, *ceteris paribus*, in all similar cases, in so far as they represented the proportionate advantage of the metre gauge over the standard gauge as a commercial investment. For this Table the gross earnings were assumed as beginning at £420 per mile per annum, rising to £840 per mile ; the working-expenses at 50 per cent. ; the capital borrowed by the Government at $3\frac{1}{2}$ per cent. ; and the loss or surplus profits (as the case might be), after payment of the interest on borrowed capital, accumulated at $3\frac{1}{2}$ per cent. compound interest. The results for the metre gauge shown in the Table, good as they were, were no better than, if equal to, the actuals obtained by one of the existing metre-gauge lines (the Rajputana-Malwa), on which the gross receipts for the year 1898,

Mr. Thomson.

Periods (Three- Yearly).	Metre-Gauge Railway, costing £8,000 per Mile.			Standard-Gauge Railway, costing £8,000 per Mile (a Ratio of 1·33 to 1 as compared with the Metre-Gauge).		
	Net Earnings per Mile (50 per Cent. of Gross Earnings).	Loss (-), or Surplus Profits (+), per Mile of Line after paying Interest at 3½ per Cent. on Capital Cost.		Net Earnings per Mile (50 per Cent. of Gross Earnings).	Loss (-), or Surplus Profits (+), per Mile of Line after paying Interest at 3½ per Cent. on Capital Cost.	
		Per Annum.	Accumulated at 3½ per Cent. Compound Interest.		Per Annum.	Accumulated at 3½ per Cent. Compound Interest.
1—3	£ 210	£ Nil	£ Nil	£ 210	£ - 70	£ - 217
4—6	240	+ 30	+ 93	240	- 40	- 365
7—9	270	+ 60	+ 290	270	- 10	- 435
10—12	300	+ 90	+ 600	300	+ 20	- 420
13—15	330	+120	+1,039	330	+ 50	- 311
16—18	360	+150	+1,618	360	+ 80	- 96
19—21	390	+180	+2,352	390	+110	+ 235
22—24	390	+180	+3,166	390	+110	+ 601
25—27	420	+210	+4,161	420	+140	+1,100
28—30	420	+210	+5,264	420	+140	+1,655

NOTE.—With the assumed traffic the metre-gauge line would be able, out of surplus profits, in 24 years to pay for conversion to standard gauge or in 28 years to pay for doubling.

17 years after opening for through traffic, were £836 per mile. In view, therefore, of the undoubted advantages, as commercial undertakings, of metre-gauge over standard-gauge railways, in a great many cases in India, it seemed that the only conclusion that could be arrived at was, that each case should be dealt with on its merits, bearing in mind that, from a financial point of view, there could be no justification for constructing a railway on the standard in preference to the metre gauge, unless a reasonable prospect existed that within a moderate period the traffic would be beyond the capacity of a metre-gauge line, or that, as an extension or connection of existing standard-gauge lines, or for military or other State reasons, the adoption of the broader gauge was imperative.

Mr. F. WOLLEY-DOD remarked that as the primary object of the Paper was to obtain opinions as to the best policy to adopt in the immediate future in order to abate the evil of two principal gauges in India, it seemed desirable to ascertain how the existing state of affairs had come about, and what grounds there were for the preference generally shown for a metre-gauge line rather than a light line of standard

Mr. Wolley-
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Mr. Wolley
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gauge. When the 5-foot 6-inch gauge was first introduced into India, about 1850, the carriages were 8 feet 6 inches wide over the body, the roof projecting on each side, as a protection from the sun, to a width of 10 feet 6 inches. The lamp-covers and engine-funnel extended to a total height of 13 feet 6 inches. The coping of platforms was 5 feet 3 inches from the centre of the track, and the width over the footboards of vehicles was 10 feet, the width over open doors being nominally limited to 13 feet. The tracks were spaced 13 feet 6 inches between centres in stations, and 12 feet elsewhere, and the fixed structures generally were arranged to give suitable clearance to an open door; but on lines used only for goods-traffic the lateral distance from the centre-line was in some cases only 5 feet 6 inches to 6 feet. There had been no great difficulty in subsequently increasing the width over body and floor to 9 feet, raising the roof a little, and carrying lateral sunshades down from the eaves for a depth of about 3 feet. More recently the width over body had been increased to 9 feet 6 inches, but the width at the floor of passenger-vehicles remained 9 feet, and the rest of the space up to the gauge-line of 10 feet 6 inches was reserved for door-fastenings, hand-rails, lamps, etc., a detail not noted on the diagrams which accompanied the Paper. A few years ago one railway constructed, on the strength of a similar diagram, a number of wagons 10 feet 6 inches wide over body, but some of the older lines refused to accept them, and they were rebuilt to the narrower width. These "moving dimensions" were considerably less than the gauge might carry, but they could not be appreciably increased without altering existing structures, tunnels, etc., on the older lines. When the metre gauge was introduced, about 1870, a much higher ratio of loading-dimensions to gauge was adopted, the width over roofs and sunshades being 8 feet 6 inches, over body and floor 7 feet, and over footboards 8 feet 2 inches; dimensions which allowed metre-gauge vehicles to use the same platforms as the standard-gauge by inserting a third rail, though the floor-level was then 15 inches to 18 inches lower. The width over body was subsequently increased to 7 feet 9 inches, the width at floor remaining feet; and the rest of the space between this and the gauge-line of 8 feet 6 inches was reserved for hand-rails, etc., as in the standard gauge. The actual overhang beyond the gauge was therefore $1\frac{1}{2}$ inch to $2\frac{3}{4}$ inches more on the metre than on the standard gauge. The result was that while the standard gauge carried only five passengers on each third-class transverse seat, the metre gauge carried four, and had corresponding relative advantages in the carriage of bulky goods. On standard-gauge railways recently constructed the fixed dimensions had been arranged to admit of some enlargement

of the present limited loading-gauge ; but little had been done in this direction on the older lines. Improvement of these conditions on the standard gauge would tend to reduce the preference for the metre gauge. With regard to the standard of weight, it had frequently been pointed out that this depended not on the distance apart at which the rails were laid, but on their strength and on that of the bridges. There was doubtless a limit to the weight possible on any gauge, but in practice this limit was seldom likely to be reached in the near future. At the time the metre gauge was first introduced, the maximum load on a pair of wheels of the goods-stock of standard gauge was 9 tons ; but this maximum was very seldom reached, and few vehicles exceeded 8 tons on a pair of wheels. The rails first used on the metre gauge weighed 36 lbs. per yard ; had they been placed 5 feet 6 inches apart instead of 3 feet $3\frac{3}{8}$ inches they would certainly have carried fully-loaded standard-gauge vehicles at low speeds. The 36-lb. rails were soon superseded by 40-lb. iron and $41\frac{1}{4}$ -lb. steel rails, which were quite equal to carrying standard-gauge vehicles. The weight per lineal foot of these standard-gauge wagons was 0·8 ton, less than the equivalent live load for which metre-gauge girders, except those of large span, were then designed ; so that with suitable engines, the same girders as were then used on the metre gauge would have carried low-speed broad-gauge trains. Now the maximum load on a pair of wheels of the goods-stock of standard-gauge was 12 tons (except in very special cases), while the ordinary metre-gauge rail weighed 50 lbs. per yard on main lines and $41\frac{1}{4}$ lbs. on branches. The latter could at low speeds carry standard-gauge wagons, though the former would be preferable. It would no doubt be more economical in the long run to lay heavier rails, say, weighing 55 lbs. per yard, which was an increase of $33\frac{1}{3}$ per cent. over $41\frac{1}{4}$ lbs. The maximum weight per lineal foot over buffers of standard-gauge goods-stock was 1·2 ton, which was less than the equivalent live load for which metre-gauge girders of small span were now designed, and not greatly in excess of that for long spans. There was no difficulty in designing a standard-gauge engine to come within these limits ; in fact, some had been built within the last 6 years, and many older ones were still running. It was, therefore, possible now to make a standard-gauge line, suitable for carrying fully-loaded vehicles, using the present metre-gauge rails and increasing the length of sleepers by 2 feet 3 inches only, or about 37 per cent., and the width of formation by about 2 feet 6 inches, the average cost of which would certainly not exceed 1,200 rupees or £80 per mile. But in most cases it would be wiser to increase the weight of the rails by $33\frac{1}{3}$ per cent., to increase the scantling as well as the length of

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Dod. sleepers, thus doubling their cost, and to add about 10 per cent. more ballast. Taking the usual prices of these articles on the metre gauge, this addition would increase the cost of permanent way and ballast by about 45 per cent. The formation would be widened 2 feet 6 inches, which, under average conditions, would increase its cost about 8 per cent., and the girders would be designed to carry about 25 per cent. more live load, which, coupled with the wider formation, would increase the cost of all bridges, including arches, by less than $12\frac{1}{2}$ per cent. on the average. It was not to the point to compare a standard-gauge railway built 40 years or 50 years ago, when all materials were much more expensive, and engineers had less experience of construction by methods suitable to India, with a metre-gauge line recently constructed. What was wanted was to find out what the latter would have cost had it been made as a cheap standard-gauge line. An existing example might therefore be taken, details of which could be found in the Railway Administration Report for 1903. For comparison the metre-gauge Bengal and North-Western, and the standard-gauge Oudh and Rohilkhand railways might be selected. The Bengal and North-Western system included (a) the Tirhut State railway, of which 277 miles were constructed by the State between 1874 and 1890, to which 240 miles, mostly constructed through the agency of the Bengal and North-Western railway, had since been added, and (b) the Bengal and North-Western railway proper, begun in 1882, with 376 miles open in 1890, and 813 miles in 1903: the total length of the system being thus 1,330 miles. The more important parts were laid with 50-lb. and the less important with $41\frac{1}{4}$ -lb. rails, and except as regarded price of materials, there was no great difference between the older and more recent parts of the system, and there were no curves which could not readily be traversed by any broad-gauge stock. The Oudh and Rohilkhand system consisted of 694 miles taken over from the old "guaranteed" company in 1889, most of which was constructed between 1864 and 1876 in the style and with the absence of regard for economy usual at that period; since 1890 additional lines constructed by the State had increased the total length to 1,101 miles. Nearly the whole was now laid with 75-lb. rails. The actual cost per mile under each head was shown side by side in the Table on p. 321, in thousands of rupees. The first five of these items were unaffected, or affected only to a very small extent, by the gauge of the line; but they had cost 31·52 thousand rupees per mile on the Oudh and Rohilkhand, against 21·81 thousand on the Bengal and North-Western, a difference of 44 per cent. Again, as regarded the quantity of bridgework, on

	Bengal and North-Western. Metre Gauge. 1,330 Miles.	Oudh and Rohilkhand. 5-Foot 6-Inch Gauge. 1,101 Miles.	Mr Wolley- Dod.
	Thousand Rupees.	Thousand Rupees.	
Preliminary expenses	0·70	1·22	
Land, general charges, telegraph and sundries	9·08	10·69	
Fencing	1·72	3·07	
Plant	2·25	2·80	
Stations and buildings	7·86	13·74	
Formation	5·69	4·65	
Rolling stock	14·48	19·81	
Bridges	17·04	31·50	
Ballast and permanent way	21·01	37·48	
Total, thousands of rupees or £	79·83 5,322 per mile.	124·96 8,331 per mile.	

the Oudh and Rohilkhand there were 22,240 lineal feet in nine large bridges—five of them over the Ganges—which had cost 1,643·85 thousand rupees, or about 15 thousand rupees per mile, against 14,400 lineal feet in five bridges on the Bengal and North-Western, costing 1,184·07 thousand rupees, equal to a little less than 9 thousand rupees per mile, a difference of over 6 thousand per mile on this head alone. There was very little difference between standard and metre gauge in the cost of bridges of this class. Adding the percentages previously indicated to the cost of the metre gauge, the following figures were obtained:—

	Thousand Rupees.
8 per cent. on formation	0·46
12½ per cent. on bridges	2·13
45 per cent. on ballast and permanent way	9·45
Total (about 15 per cent. on total capital cost)	12·04

making the total cost per mile 91·87 thousand rupees, for a standard-gauge instead of a metre-gauge line; and the difference of 33 thousand rupees (£2,200) per mile between this figure and the actual cost of the Oudh and Rohilkhand railway was due to the difference in character of the country, in the standard of line and equipment provided, and in the prices paid for materials and work. When the working-expenses of the two lines were compared, differences in many of the items became at once apparent, which were not due to the difference in gauge. The conditions on the Oudh and Rohilkhand railway, which had no less than six important junctions with the through main line of the East Indian and North-Western

Mr. Wolley-Dod. railways, at most of which a comparatively frequent service of fast trains was required, did not conduce to economy of working. The

figures for working-expenses applied also to certain branches worked but not included in the capital cost, so that the mileage worked in the Table on p. 323 was greater than that to which the previous Table applied. If the nature of the services, rates, etc., on the two lines were the same, most of these items would be nearly proportional to the gross earnings, while others would increase in a smaller ratio than the gross earnings; anything over and above this difference was due to a more economical method of working and an inferior service, as well as to difference of gauge, which did not in any way affect most of the items. Other figures in the Administration Report enabled an analysis to be made of the item fuel. These figures showed that the average cost on the Oudh and Rohilkhand railway of coal (reckoning $\frac{2}{3}$ of the weight of wood fuel as the equivalent weight of coal) was 35 per cent. higher than on the Bengal and North-Western railway, due chiefly to greater distance from the collieries. Adding 35 per cent. to the cost of fuel gave Rs. 466 per mile, which, divided by 7,780, the gross earnings per mile excluding the steam-boat service, showed the amount of coal used per rupee of gross earnings on the Bengal and North-Western railway to be about $5\frac{1}{2}$ per cent. more than on the Oudh and Rohilkhand railway, although the average speed of the trains was less, and the ratio of paying load to dead load was actually higher. The Table on p. 324 showed that the two systems ran about the same number of passenger-trains. The Oudh and Rohilkhand railway provided a train for every 135 third-class passengers, whom it carried 3.49 in each compartment constructed to hold 10; while the Bengal and North-Western railway only provided a train for every 203 passengers, whom it carried 3.79 in a compartment constructed to hold 8. The former was a better service from the passenger's point of view, and likely to yield the railway less profit, even though the fares were higher. The figures from the returns of goods-traffic on p. 324 indicated a probability of better returns on the Bengal and North-Western railway. Revenue stores and materials for construction on home line, which made up nearly the whole of the rest of the traffic, were carried nominally at cost price. All the foregoing figures showed that the difference in capital cost, and the larger percentage of profit on gross earnings per mile, were due not so much to difference in gauge as to other causes; while the quantity of fuel per unit of gross receipts was larger on the metre than on the broad gauge, though the speed was less, and the receipts per ton-mile of goods-traffic and per train-mile of passenger-traffic were larger. The metre gauge

COMPARATIVE TABLE OF WORKING-EXPENSES FOR 1903, OF THE BENGAL AND NORTH-WESTERN AND OUDH AND ROHILKHAND RAILWAYS.

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	Bengal and North-Western taken on 1,348 Miles worked.	Oudh and Rohilkhand taken on 1,213 Miles worked.
	Rs. per Mile.	Rs. per Mile.
General superintendence, engineering	191	259
Permanent way { Wages	179	275
{ Materials	223	410
Repairs of bridges, etc.	144	200
Conservancy of rivers	13	10
Repairs of stations and buildings	95	186
Items not allocated	91	176
Total engineering expenses	936	1,516
General superintendence, locomotives	75	121
Wages of drivers, firemen, cleaners, etc.	165	245
Fuel	338	685
Water	30	26
Oil, tallow, etc.	37	55
Maintenance and renewal { Locomotives	167	273
{ Machinery	4	27
Items not allocated	75	338
Total locomotive-expenses	891	1,770
General superintendence, carriage and wagon	26	27
Repairs and renewals { Coaching-vehicles	59	265
{ Goods-vehicles	77	91
{ Machinery	4	9
Cleaning and oiling	50	76
Items not allocated	-12	3
Total carriage- and wagon-expenses	204	471
General superintendence, traffic	115	145
Station staff	293	532
Train staff	83	171
Fuel, lighting and stores	75	123
Clothing	13	20
Printing, stationery, etc.	39	63
Delivery and collection of goods	23	3
Items not allocated	19	56
Total traffic	660	1,113
Total general and miscellaneous	652	777
Grand total, excluding steam-boats	3,343	5,647
Cost of steam-boat services	254	0
	3,597	5,647
Gross earnings per mile	8,383	11,969
Deduct for steam-boat service	603	0
Gross earnings, excluding steam-boat service.	7,780	11,969

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Dod. PASSENGER-TRAFFIC ON THE BENGAL AND NORTH-WESTERN AND OUDH AND
ROHILKHAND RAILWAYS.

	Total Number carried.	Rupees received. Thou- sands.	Average Fare per Mile.		Average Distance tra- velled. Miles.	Average Number in each Train.	Ratio of Number to Capacity hauled. Per Cent.	Average Number of Vehicles in a Coaching Train.
			Pies.	Pence.				
<i>Bengal and North-Western Railway.</i>								
First-class passengers}	17,800	52	12·24	1·02	46·25	0·42	2·61	1·70
Second-class passengers}	37,700	62	5·65	0·47	55·48	0·95	4·19	1·50
Intermediate passengers}	169,300	118	2·99	0·25	44·96	3·46	9·41	1·66
Third - class passengers}	11,850,100	4,655	2·00	0·167	37·76	203·33	47·43	14·79
Special tickets	1,700	1	3·79	0·316	40·00	..	..	..
Total or average . . }	12,076,600	4,888	2·05		37·92	208·16	..	22·09

<i>Oudh and Rohilkhand Railway.</i>								
First-class passengers	34,600	207	11·81	0·98	97·14	1·32	4·43	1·34
Second-class passengers	116,200	282	5·22	0·435	89·34	4·07	15·85	1·15
Intermediate passengers	804,700	566	3·03	0·250	44·61	14·08	27·89	1·45
Third-class passengers	7,946,400	4,338	2·44	0·203	43·36	135·11	34·91	7·08
Total or average . . .	8,901,900	5,443	2·65		44·29	154·58	..	11·02

GOODS-TRAFFIC ON THE BENGAL AND NORTH-WESTERN AND OUDH AND
ROHILKHAND RAILWAYS.

	Bengal and North-Western Railway.	Oudh and Rohilkhand Railway.
General merchandise carried . . Thousands of tons	1,327	1,421
Average rate per ton-mile {	6·33 pies = 0·53d.	5·52 pies = 0·46d.
Average distance a ton of goods travelled . . Miles	127·24	109·14
Average percentage of freight on capacity hauled } Per cent.	45·34	41·94

might have been made standard gauge for 15 per cent. more than its original cost, making no allowance for the saving in rolling stock due to uniformity of gauge, or in transhipping-arrangements. In the earlier days of the line the saving in working-expenses would probably not have covered the whole of this 15 per cent., though the public would have benefited; but the time would come, if it had not already arrived, when the saving would more than cover it. The standard-gauge line once made, its permanent way could be increased in strength when the traffic demanded it, to enable more powerful engines to be used, and heavier trains to run at higher speed, the ultimate capacity being practically double that of a metre-gauge line. Either to convert metre-gauge line or to double it would cost considerably more than if it had been made originally as a light standard-gauge line.

The AUTHOR, in reply, thought that Colonel Boughey was correct in saying that the original reason for the two gauges being adopted was that of expediency. His remarks on the transshipment question might be accepted as correct where the traffic was fairly light, but when it became heavy two remedies presented themselves. One was the alteration, to the gauge serving the port, of the entire narrow-gauge system behind, which might sometimes have many times the length and importance of the gauge entering the port; the other alternative was the admission of the inland system of different gauge to the port, as an independent line. It appeared to the Author, as had been shown already, that the second alternative was the correct remedy to apply. Transshipment at the port itself, from a line at some distance from the quay-wall, had been successfully carried out in America and elsewhere by transporters, and the Author saw no insuperable objection against it in India. Mr. Brunton's statement that delay in adopting uniformity of gauge meant extra expense might certainly be true in one sense, but if it was possible to effect a change at a reasonable cost, and if it was justifiable on the score of traffic, when it could be shown that it would pay, and could be carried out in detail, his objection to the necessity for immediate action would seem to be met. Mr. Cardew, the Author thought, wrote without full knowledge of the case when he assumed that the Southern Shan line was to be on a 2-foot 6-inch gauge. As regarded his remark that certain portions of the Burma railways were of double track, 16½ miles in a total of 12,000 miles was quite negligible. In speaking of the conversion of rolling stock, the Author depended on facts supported by the eminent locomotive engineers who had undertaken the conversion of the existing stock. In reply to Mr. Cardew's question, on which gauge the extra

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The Author.

The Author. haulage was calculated the Author explained that it was the metre gauge. As the Author had expressly ruled out the 4-foot 8½-inch gauge as the one to be adopted in any conversion, it was refreshing to find in Mr. Egerton an advocate who believed in it; but it was the cost which was the governing factor of conversion, and not the trouble or difficulty of converting rolling stock, permanent way and works, etc. The object of constructing the Cawnpore-Lucknow and other links on the metre gauge, which was so much deprecated by Mr. Egerton, was to allow goods and passengers to be carried from one system of metre gauge to another without break, and this was making the best use of the isolated systems of lines. Mr. Lart was incorrect in his views as to the need of rapid travelling in India. India, the Author was quite sure, was like every other country, and had progressive ideas of speed, comfort and safety, and the Railway Administrations would have to meet these needs for all classes. Whatever might be the merits of Mr. Molesworth's scheme for bringing the metre gauge into Calcutta, it was evident that when made it would have to embrace the whole of the metre-gauge system north of the Ganges and not one portion only. Mr. Preston's claim for favourable consideration of the 2-foot 6-inch lines, if confined to the hills, had some justification. The Author agreed that they should have no permanent place on the plains of India. But, as pointed out, these lines having been constructed under the Tramways Act, it was subsequently cheaper to increase their efficiency on the original width rather than to adopt a new gauge; hence their continued existence. Mr. Robertson was probably correct that 5 feet and 2 feet 6 inches represented the ideal gauges. The Author hoped that Mr. Robertson's caustic remarks on the speed of the 5-foot 6-inch gauge would in future be inappropriate. The criticisms of Mr. Shadbolt were allied to those of Mr. Egerton as far as his preference for the European gauge was concerned, and the Author found the same disregard to financial considerations which must govern the railway policy of India. Mr. Spring's conclusions were quite sound, as he based his arguments on the needs of the traffic of the country that had to be met by a limited purse. Mr. Sykes reasonably drew attention to the construction of light lines on the standard gauge being a necessary preliminary to uniformity, but he was inaccurate in calling the present system of independent development of two gauges ruinous. The surplus profit from the railway systems of India was a sufficient answer to this indictment. The Author referred Mr. Campbell Thomson to the reply to the oral discussion as to the elimination of certain railways in arriving at a fair basis of comparison. Mr. Wolley-Dod

was correct in pointing out that the loading-gauges of the two The Author. gauges did not vary in the ratio of the distance apart of the rails, but his remark that to convert or double the metre gauge would cost more than if the 5-foot 6-inch gauge had been originally adopted was rather beside the point when dealing with the existing problem. The Correspondence, taken as a whole, seemed to the Author to lead to the general conclusion that the necessities of the country's trade would be the ruling factor in bringing about uniformity.

6 February, 1906.

Sir ALEXANDER RICHARDSON BINNIE, President,
in the Chair.

It was announced that the Associate Members hereunder mentioned had been transferred to the class of

Members.

ROBERT ADAM.	EDGAR PURNELL HOOLEY.
JOHN WEMYSS ANDERSON.	ARTHUR JAMES KNOWLES, B.A.
JOHN COWAN.	(<i>Cantab.</i>)
MICHAEL ELLIOT.	ALBERT DE LINDE.
CLARENCE NOËL GOODALL.	FREDERICK HOWARD LIVENS.
JOHN HALLIDAY.	GEORGE TROTTER LYNAM.
WALTER ANDREW HARPER.	PAUL LE JUGE DE SEGRAIS.
GEORGE WALKER HERDMAN, M.A.,	GEORGE WATSON.
B.Sc. (<i>Edin.</i>)	

And that the following had been admitted as

Students.

KRISHNA CHANDRA RAY CHOWDRY.	WILLIAM REGINALD McLAUGHLIN.
JOHN FREDERIC CRAIG.	ELI MARSDEN.
JOHN HENRY DARE.	WILLIAM THOMAS PARRY, B.Sc.
ALICK DARBY DRAPER.	(<i>London.</i>)
GEORGE HALSTEAD, B.Sc. (<i>Manchester</i>).	JAMES EDWARD PIERCY.
GILBERT STANLEY HEATHCOTE, B.A.	GEORGE EDWARD SCOTT.
(<i>Cantab.</i>)	EDWARD WARNANT.
PERCY HOWARD.	FRANZ WORKMAN.
FRAMJEE PESTONJEE KHAN, B.A.	EMANUEL HENRY WORMS.
(<i>Cantab.</i>)	WILLIAM GEORGE YEAMAN, B.Sc.
ERNEST CHENEY LAUGHTON.	(<i>Glas.</i>)

The Candidates balloted for and duly elected were: as

Members.

ROBERT ARTHUR DAWBARN.	JOHN LYLE HARRINGTON, B.Sc., B.A.
RICHARD MOUNTFORD DEELE.	(<i>Kansas</i>).
HARRY EARLSTON GWYTHYR.	HENRY CHARLES KIDD.