owing to the non-receipt of the manuscript of Col. Owen's paper they had been unable to print and circulate to members the text of that paper, and consequently they were unable, in the absence of an opportunity for members to consider the subject, to discuss the paper at that meeting. It was sincerely hoped that that difficulty would be remedied before the next meeting, and that a profitable discussion would ensue.*

Mr. J. A. Smith, on behalf of the Publication Committee, said they had not yet received the manuscript. He understood the reason was that Col. Owen had been largely out of the State. But they would like members to understand that the manuscript in each case must be (in accordance with the rules) in the hands of the Publication Committee at least a fortnight before the meeting. This would greatly facilitate the work of the committee.

The President said he could supplement Mr. Smith's remarks by making it clear that one of the prime reasons for the rule that the manuscript of papers should be in the hands of the Committee before the meeting was to give members the assurance that when a paper was delivered it could be promptly printed and circulated. Owing to the relaxation of that rule great difficulty was experienced in placing the paper in printed form before members.

Mr. J. H. D. Brearley read a paper entitled, "Notes on Electric Traction."

After the reading the President proposed, Messrs. F. W. Clements and J. A. Smith, supporting, a hearty vote of thanks to Mr. Brearley. The vote was carried by acclamation.

Discussion was opened, and its continuation postponed until the next meeting.

At 10 p.m. the meeting closed.

PAPER.

NOTES ON ELECTRIC TRACTION.

By J. H. D. Brearley.

PART I.—ECONOMICS OF ELECTRIC TRAMWAYS.

The intention in the compilation of these notes is not to attempt any originality in treatment or matter, but rather to put before

* The manuscript has not yet been returned—Publication Com.
members some particulars of the less known considerations that enter into electric tramway design. The desire is to give such members as are interested in traction problems some matter for discussion, and, it is also hoped, some notes that may prove useful in practice. The writer will deal mostly with electric traction as applied to street tramways, and this subject is one likely to become of increasing interest to us all in the near future, as the time is now rapidly approaching when the present system of cable tramways in Melbourne must of necessity undergo conversion to a more effective system.

Surface traction has been effected by various means, such as horses, steam, compressed air, cables, electricity, and internal combustion engines, and, by course of evolution, we find ourselves to-day with practically two forms only left, viz., electricity and internal combustion engines for street transport, and steam remains for railroad use, with an increasing use of electricity and a threatened attack by the Diesel engine type of locomotive.

For the present I propose to refer only to street transport on rails. No modern system of any size now uses steam motors and trailers; it is a dirty, noisy and expensive system. The wear and tear on the track is very great owing to heavy axle loads and bad balancing of driving wheels, and the upkeep of the steam motors or locomotives is very heavy. In isolated cases where only a few trams are required there may be some excuse for steam traction, but there is really no limit to the smallness of a system which will justify electrification.

The writer was associated with the design and installation of the only one-car electric tramway he knows of in Australasia, and that is in Leonora, W.A., where a municipal combined lighting and one-car tramway was installed operating off the same power plant. This installation is unique, and worked so well that the tram-car caused no substantial interference with the lighting service. It disposes entirely of the idea, still tenaciously held, that it is impossible to operate such a combination. I venture to say, where local conditions justify an electric lighting installation in a small country town, and there are also other conditions which justify a one-car tramway, the two can (by a suitable design of plant) operate perfectly together. This consideration should be of value to some of our country towns situated near to mines or other industries absorbing a large proportion of the inhabitants daily at some little distance from the town.
NOTES ON ELECTRIC TRACTION.

and so requiring transport. It is a field so far untouched except in the very backblocks of W.A. some 700 to 800 miles from Perth.

In passing it may be of interest to remark that the result was accomplished by installing a 3-wire 460-volt lighting system for the house and street lighting, and the two outer wires were connected to two trolley wires over the track, which, of course, was not bonded, and was incidentally about the worst bit of track I have ever seen in its original condition under steam. The one trolley car carried a standard two-motor equipment and two trolley poles. The generator was a three-wire one with balance coils, and in order to prevent any interference with the lighting system a buffer battery and double automatic reversible booster were provided. The system was an entire success. It has so far justified its existence by increasing its rolling stock by 100 per cent.

At the other extreme we find no limit to the size of an electric tramway system other than that imposed by the carrying capacity of the main trunk lines where they exist. The great and outstanding advantage of an electric tramway system is this very elasticity and ease of extension, and as the energy can readily be delivered from one or more central power houses with any defined loss to sub-stations located at the most economical point in a given area it is clear that an electric system has immense advantages over cable systems which are inflexible on account of their low-carrying capacity and great expense in extension. One form of electric track, however, suffers from the disadvantage of the cable system with some special troubles of its own added, viz., the electric conduit system. This matter is one of special interest to us in Melbourne, partly because we are all concerned in the aesthetic aspect of the future tramway construction, especially in the city, and also because we have already got a cable conduit laid. There are, however, many reasons why this cable conduit is useless for conversion, and, if it were decided to instal a conduit system in Melbourne, there is no doubt that an entire reconstruction of the conduit would be necessary. Even an electric system of tramways has its limit of carrying capacity, but this is largely a matter of local conditions. For example one might cite Sydney as a system where the conditions are peculiar in that the number of trunk lines is limited, and where such great congestion has occurred that the only relief is to be found by under-
ground or elevated tracks. Melbourne and Adelaide both, fortunately, have a better distribution of traffic over the system, and have well-defined trunk lines of communication in every direction of importance. The carrying capacity of tracks in the city boundary is the only limiting feature here, and one may without any difficulty work any of these with an average heading 10 to 20 seconds between cars or less in crush loading. The real limiting feature is the speed at which the cars can be worked across the intersections, of which Melbourne has at present five of importance in the city.

Electric cars can, of course, be banked in crush loading times even closer than the interval referred to above, the only limit being the capacity of the feeder cables on the section.

Granting the great elasticity of electric traction, which is beyond dispute, the writer considers that we may conclude that it is the only system likely to be worthy of consideration for the next decade, and he proposes to deal briefly with the economics of the subject.

It is of fundamental importance in the consideration of any proposed service or conversion to closely study the financial aspect of the problem, and whilst much has been written on details of construction and equipment not much has been published on the general economics of the subject. In the figures or comparisons to be put before you, the writer will take British and Australian results where the latter are available. British figures are fairly correct, being based on Board of Trade returns, and the Britisher has a travelling habit more akin in some respects to Australians than has the American, who thinks no more of five cents. than we do of a penny, but one must always be careful in drawing conclusions from British figures and in applying them to other conditions such as in Australasia where climate, population, spending power, wages and costs of materials vary so considerably among themselves, and especially in regard to the United Kingdom. A study of British Board of Trade returns reveals some interesting results, and I will briefly refer to those entering into a consideration of a new tramway project or the conversion of an existing system. The first thing that strikes you is what poor dividend earners electric tramways and railways are for private capital. Of 139 companies having an aggregate
NOTES ON ELECTRIC TRACTION.

capital of £150,370,000, including ordinary and preference shares, loans and debentures, the results were as follows:

<table>
<thead>
<tr>
<th>Capital</th>
<th>Ordinary</th>
<th>Preference</th>
<th>Loan &amp; Deb.</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average rate of interest for dividend year 1911-2</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>2.33</td>
<td>3.91</td>
<td>4.44</td>
<td>3.54</td>
<td></td>
</tr>
<tr>
<td>Maximum rate ditto Period 1899-1911</td>
<td>4.3</td>
<td>5.56</td>
<td>4.64</td>
<td>4.65</td>
</tr>
</tbody>
</table>

whilst the number of companies increased from 24 with an aggregate capital of £9,056,000 to 139 companies, with a capital of £150,370,000.

A further study reveals the fact that of the above capital
£20,400,000 earned no dividend or interest,
£84,370,000 earned under 5 per cent. interest,
£45,600,000 earned over 5 per cent. interest.

Turning to some of the most successful of our Australasian privately-owned systems we find that Auckland with a total capital, inclusive of debentures, of £772,000, pays 6 per cent. on preference, 6 per cent. to 7 per cent. on ordinary, and 5 per cent. on debentures. Brisbane, with a total capital of £1,200,000, has increased its dividends on ordinary shares from 2 per cent. in 1906 to 8 per cent. in 1909-10, with 5 per cent. on preference and 4 1/2 per cent. on debentures.

It is always difficult to draw conclusions from the dividends paid by Companies, as many considerations arise in regard to the amounts required for reserves and sinking funds, length of franchise, and the cost of raising the capital which do not complicate the accounts of systems owned by municipal councils or public trusts. I venture to think that, as far as Australasia is concerned, private enterprise will find very little further scope in tramways for cities or towns because of the continual increase in wages and the increasing tendency to reserve public utilities for the administration of municipal or public bodies and the greater ease with which they can finance these proposals. Nor do the figures on the whole prove that electric tramways are a very satisfactory trading field for private enterprise either in Great Britain or Australasia.
A further examination of statistics shows a certain amount of uniformity in the ratio of traffic revenue to capital expenditure and in the ratio of working expenses to traffic revenue. The following table gives the results in some of the best known systems, and where marked "M" the undertaking is Municipal, and where marked "C" is owned by a Company:

<table>
<thead>
<tr>
<th>TABLE I.</th>
<th>Capital Expenditure</th>
<th>Traffic Revenue.</th>
<th>Revenue as per cent of Capital.</th>
<th>Working Expenses.</th>
<th>Expenses as per cent of Traffic Revenue.</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. Glasgow</td>
<td>£3,503,000</td>
<td>£946,000</td>
<td>96%</td>
<td>£533,000</td>
<td>56.3%</td>
</tr>
<tr>
<td>M. Manchester (no power house)</td>
<td>£1,981,000</td>
<td>£799,000</td>
<td>40%</td>
<td>£519,000</td>
<td>64%</td>
</tr>
<tr>
<td>M. Liverpool (no power house)</td>
<td>£1,986,000</td>
<td>£582,000</td>
<td>30%</td>
<td>£398,000</td>
<td>68.3%</td>
</tr>
<tr>
<td>M. London C.C.</td>
<td>£9,469,000</td>
<td>£2,097,000</td>
<td>22%</td>
<td>£1,207,000</td>
<td>57.6%</td>
</tr>
<tr>
<td>C. Dublin</td>
<td>£2,058,000</td>
<td>£290,000</td>
<td>14%</td>
<td>£172,000</td>
<td>57%</td>
</tr>
<tr>
<td>C. Metropolitan</td>
<td>£1,842,000</td>
<td>£394,000</td>
<td>21.5%</td>
<td>£241,000</td>
<td>61.3%</td>
</tr>
<tr>
<td>M. Sydney</td>
<td>£5,664,000</td>
<td>£1,329,000</td>
<td>23.4%</td>
<td>£1,083,000</td>
<td>81.47%</td>
</tr>
<tr>
<td>C. Brisbane</td>
<td>£1,300,000</td>
<td>£222,000</td>
<td>17%</td>
<td>£115,000</td>
<td>50%</td>
</tr>
<tr>
<td>C. Auckland</td>
<td>£842,000</td>
<td>£210,000</td>
<td>25%</td>
<td>£127,000</td>
<td>62%</td>
</tr>
<tr>
<td>M. Adelaide</td>
<td>£1,332,000</td>
<td>£277,000</td>
<td>21%</td>
<td>£181,000</td>
<td>65.3%</td>
</tr>
<tr>
<td>C. Perth</td>
<td>£474,000</td>
<td>£68,000</td>
<td>14%</td>
<td>£39,000</td>
<td>57%</td>
</tr>
<tr>
<td>M. Wellington</td>
<td>£580,000</td>
<td>£133,000</td>
<td>23%</td>
<td>£92,000</td>
<td>66.6%</td>
</tr>
<tr>
<td>M. Prahran-Malvern (no power house)</td>
<td>£182,000</td>
<td>£37,370</td>
<td>20.5%</td>
<td>£24,719</td>
<td>66.3%</td>
</tr>
<tr>
<td>Average of 122 British Companies</td>
<td>£24,525,000</td>
<td>£3,496,000</td>
<td>14.2%</td>
<td>£2,354,000</td>
<td>67.3%</td>
</tr>
</tbody>
</table>
| Average of 174 British Corporations           | £51,147,000         | £9,701,000       | 19.0%                         | £6,147,000        | 63.3%                                  

The variations in capital expenditure are very great, and it is difficult to draw more than general conclusions as so many contingencies may arise involving capital expenditure, but one may safely say that, unless there be some very special reason why the capital expenditure should be reduced, as e.g., by the absence of a power house where energy is purchased, or on the other hand in a private Company where large sums are paid for a concession, or promoters' profits, the gross traffic revenue should amount to from 20 per cent. to 25 per cent. on the capital expenditure. For estimating it is safe as a rule to take 20 per cent.

The ratio of working expenses to traffic revenue, however, shows much more uniformity, and may be taken as about 65 per cent. Any system that operates under 65 per cent. is on a good basis, and any that runs over 65 per cent. needs investigation to ascertain the reason. It is interesting to note also that this
ratio in the case of steam tramways was about 75 per cent. to 80 per cent., and on horse traction 85 per cent. to 90 per cent. Taking the ratio of working expenses to revenue at 65 per cent. and the ratio of the revenue to capital at 20 per cent., it is seen that the working expenses equal about 13 per cent. on the capital expenditure, leaving 7 per cent. as gross profit to provide for interest, depreciation, sinking fund, renewals, etc.

Taking the average of 174 corporation systems in the United Kingdom where the ratios were 19 per cent. and 63.3 per cent. respectively, we get the working expenses as 12 per cent. on capital expenditure and gross profit 7 per cent.

Even if you take a very favourable case of 25 per cent. and 60 per cent. respectively, the gross profit works out to only 10 per cent. on capital expenditure. Out of this gross profit interest has to be paid, or dividend as the case may be, and, if the capital has to be repaid, a sinking fund is necessary to effect the purpose in a given term of years. Public bodies may not always establish a sinking fund, as the system belongs for all time to the people, and if the capital, as is usual, is raised by loans these can be renewed by later generations. In fact it is quite open to argument, whether the obligation of redeeming the capital cost of a publicly-owned system by a sinking fund should be cast on one or more generations for the benefit of the future ones, and it appears to some to be quite sound to provide only out of profits for a renewal fund to restore each part of the system as it wears out. One advantage of a sinking fund, however, is that if provision is thus made for the return of the original capital to the lenders the tramways become entirely the property of the citizens, and no complications can arise with the lapse of time due to obsoletion, new forms of traction or other causes as affecting the value of the security. The writer is personally of the opinion that it is sound policy for all public bodies owning tramways to establish a sinking fund sufficient to extinguish the debentures in, say, 30 years. Such appropriations should be invested either in or outside the undertaking, and if bearing interest at 4 per cent., for example, the debt will be extinguished in 30 years by a sinking fund of 1.78 per cent., or at 4\frac{1}{2} per cent. in 30 years by a sinking fund of 1.71 per cent. Allowing that 4\frac{1}{2} per cent. is a fair rate to pay as interest on borrowed capital, and assuming that the sinking fund is invested in the undertaking at 4\frac{1}{2} per cent., the combined interest and sinking
fund will absorb 5.06 per cent., or practically 6 per cent. per annum. There is, therefore, not a very large margin left from the gross profit to provide for renewals due to wear and tear other than that provided for in working expenses. I refer to renewals of rails, sleepers, overhead trolley wire, car-bodies, and equipments, power-house plant, etc., which gradually wear out or become obsolete. The amount which should be put aside for such purposes is a very variable one, depending so much on the nature of the wear and tear in each case, and its determination is a nice matter of judgment and experience. The first consideration is the effective life to be allotted to each section, and for sake of example the author takes the following values for the life and percentage of capital expenditure in each case for the renewable parts.

**TABLE 2.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Average Life</th>
<th>Per Cent. of Capital Expenditure</th>
<th>Capital Expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Years</td>
<td>%</td>
<td>Average Life</td>
</tr>
<tr>
<td>Permanent Way</td>
<td>15</td>
<td>30</td>
<td>2.0</td>
</tr>
<tr>
<td>Overhead Construction, Cables, Conduits, etc.</td>
<td>20</td>
<td>20</td>
<td>1.0</td>
</tr>
<tr>
<td>Rolling Stock</td>
<td>20</td>
<td>17 1/2</td>
<td>.875</td>
</tr>
<tr>
<td>Power Plant</td>
<td>15</td>
<td>15</td>
<td>1.0</td>
</tr>
<tr>
<td>Buildings, Land, etc.</td>
<td>40</td>
<td>17 1/2</td>
<td>.435</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>5.31</td>
<td></td>
</tr>
</tbody>
</table>

The above figures for the average life of each item are generally accepted, but in calculating the amount of a renewal fund there are several points to be remembered. The assumption in the above table is that the whole of the item—such as permanent way, etc., will require renewal in the time stated. This, however, is not correct, and in each case an allowance should be made for the "residual value" of each item, i.e., the value of such parts as are, at the end of the renewal period, available for further use either for a complete further term or part of it, and this residual value is a substantial item. As the real object in establishing a renewal fund is to annually appropriate and invest, until required, a sum sufficient, with the residual value, in each case, to renew each section as required, and as a renewal fund is in no sense a reserve fund to equalise profits or losses, to disguise profits, or provide for such contingencies as depreciation
in debentures, it is clear that only just such amounts need be set aside as will effect the object of renewals.

In regard to permanent way, it may be assumed that the rails, sleepers, tie bars, and spikes will be useless for tramway purposes, but they have a definite scrap value, and deducting the cost of removal they may be taken as having a residual value of 20 per cent. The above items may represent quite 40 per cent. of the permanent way, so that in these items alone 8 per cent. of the total cost may be considered a fair residual value. A certain amount of ballast, too, is recoverable, but rail welding and all the original labour costs are of course of no residual value.

Probably 10 per cent. would be as much as one could safely figure on as the total residual value of the permanent way. This would therefore mean that 3 per cent. of the total capital value will be available at the end of the term or average life.

In regard to overhead construction, cables, and conduits, the residual value would be much greater. The copper trolley wires, when removed, have a very decided value as scrap, or even for electrical purposes, as conductors, and there is generally a good market for worn trolley wires, and they may be safely allowed a residual value of 1 per cent. of the capital expenditure. Steel poles, where used, and if properly erected and protected at the ground line, should last 40 years, and similarly underground and overhead cables. Conduits are not subject to much actual depreciation, if properly constructed and protected against white ant. Span wires, insulators, ears, frogs and other overhead fittings, however, cannot be safely allowed more than the life shown in the table. The writer considers that a reasonable residual value for the overhead construction, cables, etc., may be put at 50 per cent., or 10 per cent. of the total capital expenditure.

In regard to the Rolling Stock and its electrical equipment the residual value is largely a matter of how carefully the maintenance is carried out. No part of the system is so subject to wear and tear, and it must be borne in mind that unless the electrical equipment, brakes, trucks, and car-body details are properly maintained and kept in first-class order no satisfactory operation can be obtained. During the so-called life of the rolling-stock it is almost certain that bearings, armature coils, and commutators, field coils, brushes, brake shoes and pins,
commutator segments, trolley wheels, etc., will have been renewed several times, as a matter of ordinary repairs. The car bodies will have been repainted and varnished at regular intervals, and all such repairs are usually fully covered by working expenses.

In the writer's opinion, therefore, it may be safely assumed that the "residual value" of the rolling stock is fully 33\(\frac{1}{3}\) per cent., or say 6 per cent. of the total capital expenditure.

In regard to Power Plant, which includes sub-stations, somewhat similar conditions exist. Boilers, to be effective at all, must be kept in good repair in regard to tubes and brick work, also condenser tubes, pump valves, valve seats generally, and packings. Certain portions of generating plant and switch gear require regular repair. In sub-stations the principal item of expense for renewal is the buffer battery, which requires replating about every 7 to 8 years if carefully handled.

It is considered by the writer to be a reasonable approximation to allow also a residual value of 33\(\frac{1}{3}\) per cent. in this case. or, say, 5 per cent. of the total capital value.

Buildings and land suffer very little actual depreciation, and in fact very often the land increases in value, and it is not too much to assume that the residual value may be taken at 10 per cent. of the total capital expenditure.

The result therefore is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Residual Value Per Cent. of Total Expenditure</th>
<th>Per Cent. of Total Capital Expenditure for Renewals</th>
<th>Renewal Fund Per Cent. of Total Capital Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent Way</td>
<td>3</td>
<td>27</td>
<td>1.398</td>
</tr>
<tr>
<td>Overhead Cables</td>
<td>10</td>
<td>10</td>
<td>.353</td>
</tr>
<tr>
<td>Rolling Stock</td>
<td>6</td>
<td>11(\frac{1}{3})</td>
<td>.406</td>
</tr>
<tr>
<td>Power Plant</td>
<td>5</td>
<td>10</td>
<td>.518</td>
</tr>
<tr>
<td>Buildings &amp; Land</td>
<td>10</td>
<td>7(\frac{1}{3})</td>
<td>.089</td>
</tr>
</tbody>
</table>

We may assume that the renewal fund can be invested at, say, 3\(\frac{1}{2}\) per cent., and in that case we arrive at the amount of the renewal fund expressed as a percentage of the total capital cost as shown in table 3. It will be observed that the total appropriation necessary on this basis is about 2\(\frac{1}{2}\) per cent. If you were to take from table 2 the percentage in each case obtained by dividing the percentage of capital expenditure by the average life the total would amount to 5.31 per cent. This is the figure usually considered to be the value of the renewal fund necessary.
or what is often called the "depreciation." The writer, however, considers it misleading as a measure of a proper renewal fund, such as should be provided by a municipal or public body desirous of making a reasonable provision for renewals.

Returning now to the question of the net profit available, we have placed the interest and sinking fund at 6 per cent., renewals at 2½ per cent., or say 3 per cent., or in all 8½ per cent. to 9 per cent. It will therefore be seen that there is no great margin left for net profits taking the average figures of 10 per cent. So that, although in some cases a publicly-owned tramway shows a balance which can be properly described as net profit it does not amount to a very large percentage on capital, and it is quite a nice point as to whether such balance should not be devoted to reduction of fares or provision of better services for the public. In this regard it is interesting to note that in 1910-11, 174 corporations or local authorities in the United Kingdom, with a total capital expenditure of £51,147,000, contributed to the relief of rates £302,000, i.e., about 0.6 per cent.

The application of statistical data to the consideration of the possibilities of a proposed electric tramway system gives a reliable first approximation to what capital must be expended on a system to earn a stated revenue. The most important point to determine in all cases is the probable revenue which any proposed system can earn. For the estimation of revenue is needed considerable experience of the effect on the travelling habit of the people served by the provision of a quick, clean, and fairly frequent service, and the consequent increase in the number of rides per capita per annum, and also the effect of improved communication in opening up a district and inducing settlement, especially in the outer areas. It is impossible for anyone without previous experience to realise fully how great is the increase in the travelling habit by the provision of a modern electric service over any other form of traction.

It is of interest to note in this respect that in the United Kingdom during the three periods, viz., horse power (1878), steam period (1898), and electric (1911) the number of passengers carried per annum was about 4.5, 21 and 64 times the population respectively, and the number of passengers carried per mile of route open was 470,000, 806,000, 1,119,000 respectively.
In Sydney during 1899, when there were only 8½ miles of electric route, 4½ miles of steam and 3½ miles of cable tramway, the number of passengers carried was 52,810,000, or about 100 times the population, whereas in 1912 the electric route mileage was 13½, and steam was 22 miles, and the passengers carried were 266,789,000, or about 400 times the population. In Adelaide for 1912 the corresponding figure was 284. This undoubtedly is a most astounding figure for Sydney, and is due to the peculiar conditions there, and the fact that so large a proportion of the population depends almost entirely on tramways for transport.

To arrive at an estimate of the population served it is useful firstly to ascertain the actual population within ½ mile on each side of any route, i.e., within 10 minutes easy walking distance, and one must to this figure add a reasonable allowance for increase in settlement. It is not unreasonable to allow 100 journeys per capita per annum for such population as a minimum estimate. The average revenue, with penny sections, per passenger may be put at 1½d. per journey, i.e., 12/6 per capita per annum. The total cost of a well-constructed system calculated per mile of single track may be put at £15,000 per mile, and allowing that the revenue is 20 per cent. of above this would mean £3,000 per annum per mile of single track. This would require 480,000 journeys per annum at 1½d.—£4,800 per mile of route, or per square mile of area, taking ½ mile each side of the route. Unless, therefore, the population density is likely to be from 4,000 to 5,000 per sq. mile within ½ mile each side of the route a very much cheaper system must be adopted than is represented by an average capital expenditure of £15,000 per mile of single track. As a first approximate estimate of revenue to be earned, therefore, one may take 12/6 per annum as a minimum expenditure per capita for the population per square mile (i.e., ½ mile each side of route). This, however, may go as high as £2 10/- per capita per annum. For Adelaide in 1911-12 the revenue was £2 1/5 per capita per annum.

Electric cars can run 120 miles per day without undue wear and tear, and at an average schedule speed of 10 miles per hour (including stops) a car should earn about 1/- to 1½ per mile, i.e., 10/- per hour, or £6 per day on an average. Assuming 1½d. per passenger the average passengers per car mile should be 8, and this is in practice a very conservative figure, and may be
safely taken for estimating purposes as a lower estimate, and 10 passengers would represent a very satisfactory traffic. This gives 1/- to 1/3 per car mile revenue, and if the annual car mileage be computed it gives us a second method of arriving at the estimated gross traffic revenue. From the returns available the revenue per car mile is as follows in pence:

- Adelaide: 14.4
- Auckland: 18
- Christchurch: 15
- Fremantle: 13
- Perth: 15
- Sydney (per tram mile): 15.3
- Wellington: 14.2
- Prahran-Malvern: 13.2

The average of 296 undertakings in the United Kingdom is 10d., and the number of passengers per car mile is 9.3, giving only an average of slightly over one penny per passenger per car mile.

In order to determine the annual car mileage for any given system a study of the requirements must be made, and a time table prepared for ordinary days, Saturdays, Sundays, and holidays, and from this is easily computed the number of car hours or car miles necessary to give such a time table. There is no other reliable method of arriving at the estimate. It must be always borne in mind that no single line can be worked satisfactorily with a quicker service than 10 minutes, and at about 9 miles per hour schedule speed. If the conditions justify a better service than the above, then, generally speaking, the track should be double.

A third method of estimating the probable revenue is by allowing an earning capacity of from £2,500 to £3,000 per mile of single track. It is a poor system that does not earn £2,000 per annum which may be taken as a minimum.

The average of 269 systems in the United Kingdom is £3,120, and some Australasian figures are:

- Adelaide: £3,260
- Auckland: £5,100
- Brisbane: £3,100
- Christchurch: £2,000
- Fremantle: £2,000
- Sydney: £6,600
Summarised, therefore, we can by these methods arrive at estimate of minimum and maximum earnings by—

<table>
<thead>
<tr>
<th>Minimum.</th>
<th>Maximum.</th>
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<tr>
<td>1. Population served</td>
<td>12/6 per capita p.a.</td>
</tr>
<tr>
<td>2. Car mileage</td>
<td>10d.</td>
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<tr>
<td>3. Revenue per mile at</td>
<td>£2,000</td>
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The margin between the minimum and maximum figures is large, but so are the local conditions, and we must make a careful selection between the above ranges in accordance with experience and the knowledge gained of local conditions. The average of the above figures in each case will be a reasonably safe basis for a preliminary estimate.

Estimates of revenue are always somewhat uncertain, and the necessary data difficult at times to obtain, and it is therefore impossible to obtain in a general consideration of the subject more than an approximation to the values.

In regard to the working expenses of an electric tramway system the writer has taken a ratio to traffic revenue of 65 per cent. This is a variable factor, and by looking at table 1 it will be seen to vary from 81.4 per cent. in Sydney to 50 per cent. in Brisbane, and there are special circumstances, no doubt, in each case to explain the variation from the mean figure referred to above.

It may be of some interest to analyse the working expenses somewhat in order to obtain an appreciation of the more important elements. The total working expenses can be approximately subdivided as follows:

<table>
<thead>
<tr>
<th>TABLE 4.</th>
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<tbody>
<tr>
<td>Item.</td>
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<tr>
<td>Power</td>
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<tr>
<td>Rolling Stock</td>
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<tr>
<td>Permanent Way and Electrical Equipment</td>
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<tr>
<td>Traffic</td>
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<tr>
<td>Buildings, Rents, Rates, Insurance and Miscellaneous</td>
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<td></td>
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The above figures, giving the ratio of each section to the whole, are in very close accord with the average results of about 300 systems covered by Board of Trade returns, and in the last column the writer has shown the values in the basis of a total working expense of 10d. per car mile, this being an easy figure to remember, and easily adjustable to any given case where the actual figures differ from 10d., which even for Australasian conditions is fairly high. Some results are:

- Adelaide: 9.5d. per car mile
- Auckland: 11.2d.
- Christchurch: 9.0d.
- Perth: 8.2d.
- Wellington: 9.8d.
- Sydney: 12.8d. tram
- Prahran: 9.0d. car

In regard to the item of power it may be of interest to consider this in more detail, as many interested people have the idea that the cost of power is a very important factor, depending on whether you use this or that class of coal.

The allowance of 20 per cent. of the total working expenses for power is, if anything, on the high side. The energy consumption per car mile varies from 1 unit per car mile to 1.75 units, and may be taken as about 1.5 units for a mixed car service and measured at the car. Allowing 2d. per car mile for all power charges inclusive of sub-station losses and distribution the cost per unit at the car would require to be 1.33d. Of this about 0.33d. will be sub-station losses and expenses, and distribution losses, and one may put it that 1d. represents the price at the power house. As a matter of fact no small power house, i.e., suitable for, say up to 25 miles of track could turn out energy at this price, and if energy could be bought by such a tramway at from 1d. to 1½d. per unit it would be best to do so, and put in a converter station, as has been done at Malvern. The present price paid by this system is slightly over 1d. per unit, measured at the D.C. bus bars, but not inclusive of battery and distribution losses. For the year ending September 30th, 1912, the power cost was practically 1½d. per car mile, and the number of units per car mile was 1.47, giving the average cost of power as 1.2d. per D.C. unit at bus bars of sub-station. Such a result
is remarkably good, and contrasts well with any system elsewhere of similar size.

In Adelaide, which is a self-contained system, and the most recently constructed, the units per car mile for 1911-12 were 1.65, and the cost per car mile, inclusive of sub-stations, but not inclusive of losses from sub-station bus bars to cars was 1.3d. per car mile, or about .78d. per unit. It is interesting to note that this amount includes:

Fuel ........................................ 0.658d. per car mile, or .4d. per unit.
Other power house costs ..................... 0.367d.  .22d.
Sub-stations and Transmission .............. 0.268d.  .16d.
                                   ________________
                                   1.293d.  .78d.

The fuel cost is about half the total cost of the power, or assuming that the power represents 20 per cent. of the total operating expenses the cost of fuel is about 10 per cent. of the total operating expenses. These results are of much interest to us in Melbourne, where we are promised cheap power supply from some source or other, but I would point out that this is only to be obtained by increasing the output of the power station, and thus reducing the cost per unit, more particularly for stores, wages, maintenance, etc., but the fuel cost per unit is limited by the efficiency or steam consumption of the generating plant and the evaporative efficiency of the boilers. The fuel consumption can be reduced by improved plant and larger units, and although a station like Adelaide burns 3 lbs. of coal per unit it is now possible to get down to about half this amount. Taking even 1½ lbs. of coal per unit with coal at 12/- a ton, as may be reasonably expected at Yarraville for Wonthaggi coal, the fuel cost would be reduced to practically .1d. apart from the other charges, which come down very rapidly with a large output. Probably .125d. per unit is not too low a figure to hope for as a generating cost. To this must be added the fixed charges for interest, etc. It may be reasonably assumed that such a station as is proposed for the railways or any other similar station for central supply in bulk would require to sell under such circumstances at .25d. to .33d. in order to cover all charges, and make a small profit. This figure, however, is only put forward
as an approximation to what may be achieved, and in order to get an idea of what the possibilities are in the savings due to cheap energy. Whether it would be better for a system such as the Melbourne tramways will develop into to buy its energy is a point requiring a careful consideration of the amount of energy it would need, but it is a very important consideration because a big central power plant can offer great inducements, and as the cost of power is about 15 to 20 per cent. of the total working expenses, a saving of one-half of this expense even is a great consideration, as there is the further saving in capital cost of power plant and fixed charges on same.

A consideration of the traffic expense, which is 45 per cent. or more of the total working expenses, shows how vitally tramway systems are affected by increase in wages. Ten per cent. increase in traffic wages means 4½ per cent. to 5 per cent. increase in the total, or over 3 per cent. increase in the ratio of working expenses to revenue. This is equal to over ¾ per cent. on the total capital expenditure which, as shown above, is in itself a large proportion, and almost all the net profit. There appears to be no doubt that wages are, if anything, increasing, and it therefore is essential for tramway authorities to closely watch for every opportunity to reduce the working expenses in other directions. This can be done by careful design and installation of the system initially, and the adoption of numerous devices, which reduce running costs, and increase the life of wearing parts. The purchase of power in bulk, where possible, also gives in some cases a saving both in actual working expenses, original capital, and fixed charges thereon. The detail economics that are obtainable cannot very well be covered by the limits of this first part, but will probably be embodied in a later paper dealing with operation.

DISCUSSION.

The President said those who knew how busy a man Mr. Brearley was must have been impressed with the enormous amount of research work and close analysis that had been applied in compiling the paper. He did not suppose for a moment that Mr. Brearley expected them to accept without close scrutiny many of his claims, or that he would resent their expressions of dissent from the principles laid down in the paper. But they could not fail
to be impressed with the vast amount of labour and patient thought he had placed before them, and the excellent review of Australian conditions which he had given, which should prove a valuable addition to the literature of the subject of electric traction. He formally moved a very hearty vote of thanks to Mr. Brearley for his paper.

Mr. F. W. Clements said the Institute ought to be very grateful for the paper they had heard. It was a very excellent paper, and in his opinion it did not suffer from the fact that it was purely on economics. They too seldom had papers of that kind put before them, and he thought the paper therefore was probably of very much more value than the papers that were promised, because whilst they had a great deal of literature upon traction, there was a very small amount upon the economics of electric traction. He had also been struck with the enormous amount of information got together in the paper, and would look forward to an opportunity of reading it quietly, and making notes, and possibly having something further to say on the matter later on.

Mr. Jas. Alex. Smith said Mr. Clements had anticipated him in regard to several matters. They had had many papers on the technical side of engineering; very few indeed from the point of view of economics, and when all was said and done in regard to these installations the ultimate justification for them was would they pay? That was really the governing engineering question, and they had had too little reference to that in the past.

Mr. J. H. D. Brearley thanked the members for the vote of thanks. It had been a pleasure to him to write those few notes. It was a subject he was very fond of, and of which he had had some little experience. He thought it was in regard to such matters they should come forward and contribute to the Proceedings of the Institute, because they each worked along their own lines, and at times got some information that was of value to the other members. He sincerely hoped that when his remarks had been printed and circulated there would be a full discussion. All the points in his paper left plenty of room for discussion; there was almost room for another paper with separate information from every member of the Institute. There was nothing that gave
more opportunity for divergence of opinion than statistical information, and the deductions drawn from it. He had drawn his deductions, and left them with the members to form their conclusions as to their reasonableness or otherwise. If the paper provoked a good discussion no one would be more pleased than he.

The President said he thought by reason of the lateness of the hour and the real complexity of the paper and its statistical character no one would desire at present to embark upon an actual discussion, before the paper was printed and circulated. But there were a few moments left, and if anyone wished to ask questions or suggest any fresh view of the matter he was sure Mr. Brearley would be glad to answer.

Mr. J. A. Smith said that, with a view to facilitate the coming discussion he would like to have the author’s definition of two matters. In respect to the “car mile” what seating accommodation had Mr. Brearley assumed? What was the carrying capacity of the car? Upon the uniformity of the unit of comparison the issues depended. Also what was the definition of the word “residual” used in the expression “residual value?” Did it imply the actual market or selling price at a given date?

Mr. J. H. D. Brearley said in regard to the unit of the car mile that was the usually accepted unit in compiling tramway statistics, and they had to take it as meaning the average car. The seating capacity, of course, was a great deal in excess of the average number of passengers carried. It usually varied, but he supposed they might take the average seating capacity as 50 passengers. Anything above that was a big car; anything below that was a small car. Sydney had cars with a seating capacity of about 80. They were the biggest he knew of. Of course their carrying capacity was a very different thing. He had known a car for 32 to carry 136 passengers.

The residual value he had allowed was the actual value to the undertaking of what was available of each item at the end of the term; that was to say, its actual value at that date as if it had to be purchased. It was the real cash value at the time of the section or article as the case might be.

The President said he gathered that the percentage in the last column of Table 3 had been calculated on a compound interest basis.
Mr. Brearley.—Yes.

Mr. F. W. Clements said as to the compound interest basis the usual way of providing for depreciation was simply to take the life of the plant and divide the amount by the life, and set aside so much a year. Mr. Brearley had adopted the compound interest method of doing it. Of course that was a method which had often been proposed, and sometimes adopted, and he much questioned whether it was the proper way. Because a plant had been on the property a certain time the bottom did not fall out right away. It was simply the average period, and during that time of course they had to draw on the depreciation account a good deal. Take the permanent way. Supposing they based it on a period of 15 years. It was a well-known fact that the rails on the curves required renewing sooner—in five or six years. Then they had to dip into the depreciation fund. Immediately they touched that they knocked the compound interest principle on the head altogether, and so it was not altogether splitting hairs if they said that principle was not theoretically quite correct. But it was a very valuable theory, because the other theory could not be followed, and seeing they could not do what they would say was the proper thing, the next thing to do was to put their heads in the sand, and take some method that would make them look logical.

The President thought that was one of the most interesting phases of the paper. It required more scrutiny than they could give it while sitting there to follow, but there was a great deal to say for and against that method. He would like an opportunity of thinking it out, and stating his views on another occasion.

Mr. J. Barbour thought the period mentioned as the life of the power house—40 years—was enormously too much.

Mr. Brearley said with regard to the question of the renewal fund he agreed with the President that it was one of the most interesting questions in the economics of tramway work, and upon which a great deal could be said on both sides. He had developed it a little more than usual somewhat as a protest against the methods usually adopted of writing off the depreciation on the basis of dividing the value by the term of years. Of course he recognised the difficulty set out by Mr. Clements of dipping into the depreciation fund.
With regard to the life of the building he could not claim any originality for the term of 40 years. It was a figure frequently quoted as a reasonable life for buildings. It must also be remembered that in considering the question he had taken what he called the residual value of the building, and assuming that the building was of ample capacity, he saw no reason why it should not stand for over 40 years, and he did not think 40 years an unreasonable figure. As land and buildings were included in the same item he took it that 40 years as a basis of computation was not unreasonable. As to whether the building was large enough was not the point. But given a building that was suitable for a given system and 40 years was generally accepted as a reasonable figure.

The President said the question referred to the power house. Mr. Brearley had carefully separated plant from building, and he took it the author was not referring to the case of a building becoming obsolete through enlargement of the plant.

Mr. Brearley said that was so.

Mr. Barbour said the point he had wished to bring out was that in 15 years the plant would have become larger and heavier, and the building would have to be remodelled accordingly.

Discussion adjourned.
The President said the first item on the notice paper was the discussion of Mr. J. H. D. Brearley's paper on "Notes on Electric Traction." The paper had been circulated, and he knew Mr. Brearley was present at considerable inconvenience, and under the disability of not feeling well. He hoped advantage would be taken of Mr. Brearley's presence to deal with the discussion promptly, and give Mr. Brearley the opportunity of replying to the criticism.

Mr. A. L. Hargrave said Mr. Brearley had given 1.5 lb. of coal per unit. What evaporation did he estimate to get from—say—Wonthaggi coal? He did not think it was possible to get more than 8. That would mean 12 lbs. of steam per unit generated. He thought 11 lb. was the testbed-record at the present time.

Mr. Jas. Alex. Smith said he had hoped to have been able to give considerable attention to the paper. He had, however, been able only to peruse it that evening.

He had had considerable responsible experience in the compilation and analysis of traction and transportation statistics, and knew the extreme difficulty of arriving at rigorous comparisons of different systems upon published figures, the basis of which was unknown, arbitrary, or incomplete. Whilst fully appreciating Mr. Brearley's work he was, however, of the opinion that it was difficult to predicate from generalised figures with commercial accuracy, the future of any particular case. It was necessary to consider each proposition as a particular case. One per cent. might make all the difference.

Taking a few of the points in the order of their sequence, he noted, in reference to the capacity of electrical street systems, that it was stated that cars could be run at 10 or 20-second intervals, or even more closely under conditions of stress. He took it that that was an enunciation of a higher, but possible, limit of the capacity of local surface systems. But he did not think that result would be possible in Melbourne unless the thoroughfares were given up to the cars. Ten-second intervals, at the 10-miles per hour specified, would mean only about 120 feet between cars, or five cars on each line per block. It would also
mean a speed exceeding 20 miles per hour at the acceleration peak.

Bearing in mind that those routes were streets of intense general traffic, intersected by other streets of equally intense general and tram traffic, he thought it would not be found possible to work the two modes of traffic simultaneously at that rate. Either the general traffic or the tram traffic would require to be eliminated. He thought that that traffic capacity could not be based upon the capital value of a surface system, but would necessitate here, as elsewhere, the added capital cost of undergrounding.

As to profits. On page 39 there was a statement of the ordinary share, preference share, and debenture percentage earnings of British systems, together with the average net profits (3.54 per cent.) on capital. From this it was deduced that those systems, as a whole, were not highly remunerative. But, unless he was in error, the average quoted was simply the arithmetical mean of the rates upon the specified component kinds of capital. It was necessary to know before it could be definitely stated that a system was, or was not, paying, not only the percentage returns upon each class of capital, but, also, the amount of each class invested.

For instance, for the purpose of illustration, assume such a case as this:—Loan capital, 99 per cent.; ordinary and preference together, 1 per cent.; earnings on loan, 6 per cent.; earnings on ordinary and preference, nil. That would, in effect, be a six per cent. proposition, although, on the basis of the arithmetical mean, it would appear to be earning only 2 per cent.

Considering the matter further in the light of table 1:—It was stated that the capital of the London County Council system was £9,500,000, and, upon the other figures of the table, there was a gross profit of 9.33 per cent. Taking the author's estimate of 5.96 per cent. to cover interest (4.25 per cent.) and sinking fund, that left 3.37 per cent. to cover unspecified costs.

On those figures—he had not verified them—that might not necessarily imply an un lucrative scheme. The citizen had an effective service. The charges, in view of competition, were, presumably, moderate, yet they would, on the figures, suffice to establish a sinking fund to eventually meet the debentures, and, in the interim, the debenture-holders received 4.25 per cent.
Again, several of these large municipal ventures did not aim at anything in the way of a net profit. When their revenue showed a surplus over all expenditure it was their policy to make concessions, in decreased fares or increased sections, to the public, or to carry out extension or developmental services that, for a time, were non-remunerative.

Private corporations, too, might be content, for a time, to sacrifice profits to eliminate or meet rival traction modes, or to develop traffic, trusting to the future to repay them.

He wished to emphasise the fact that, although, in Britain, the Board of Trade required certain returns to be made, yet a skilled actuary or accountant could cause them to convey much what he desired them to convey. None of those bodies—and certainly not similar bodies or governments locally—would "take the roof off their houses" in this matter. It required an expert with inner knowledge, as Mr. Brearley would admit, to read between the lines.

He was sure the author would agree with him that it was a popular fallacy to assume that a low working cost necessarily implied efficiency. They would find that assumption very widely diffused indeed in many Australian Parliamentary papers. An illustration might be drawn from Table 1. The working expenses of the Brisbane lines were given as 50 per cent. of the traffic revenue—lower than any other city, local, or British, quoted—that of Glasgow as 56.3 per cent. Yet if they went a little further and considered the proportional revenues earned by these expenditures they would find that Glasgow would lose £40,000 per annum were it run on the Brisbane ratio of working expense to revenue, and revenue to capital. The percentage earning of each unit of capital would be less.

Low working expenses might connote economy or they might not. In the limit, if a system were closed they would cease, but the standing charges must still be met.

With regard to the residual value of buildings alone, he doubted whether the life could be assessed at 40 years. Structurally they might then be sound. They might be sufficiently extensive and adequate now, and in relation to present modes, but, unless inordinate provision were made now, it was unlikely that that condition would obtain nearly half-a-century hence. He agreed with Mr. Barbour that they would probably have been remodelled or completely rebuilt, ere that date.
The author referred to the growth of the "travelling habit" as a source of prospective revenue. It was shown that the proportion of travellers in Sydney had increased fourfold during the past twelve years, and that it was now equivalent to the whole population carried 400 times per year. That would mean, allowing for infants and those not within the traffic areas, probably at least two journeys per day for the whole remaining populace. The argument was being used very freely as a justification of estimates of prospective profit.

In so far as increased travelling was necessary or beneficial travelling, which had been deferred owing to the lack of clean, rapid, and effective facilities, it was good. But simply as a luxury, as an indirect mode of raising revenue, or as a result of providing costly schemes for the investment of capital, the fostering of the "habit" was not in consonance with the higher economics.

The author based many broad deductions upon the "car-mile" as a unit. In so doing he adopted a recognised system which had almost become standard. Nevertheless it might be held that that system was fallacious. The same thing obtained in many—but not in all, or in the largest—railway returns, where the "train-mile" was adopted. Comparisons could only be decisive when the unit was the "passenger-mile" or its equivalent, unless all conditions of each system were very similar. It would be found, in railway working, frequently, that no distinction was made between a mile on a 1½ ft. and a mile on a 5½ ft. gauge. Similarly, Mr. Brearley had, in answer to a question, stated that car capacity might vary from 30 to 80.

It might thus be possible to show that a system running an excessive mileage of almost empty small cars was costing less per "car-mile" than another system running an adequate mileage of fully occupied large cars. Obviously this would be entirely misleading as a gauge of the efficiency or of the profit-earning capacity.

He wished to make it clear that whilst Mr. Brearley had used a recognised mode of comparison, the unit used was open to question when very diverse systems were under review.

He was fully in accord with the author when he exposed the popular fallacy that the cost of power was the chief item of expenditure. It was important, certainly, but not in a prim-
ary sense. Any possible saving in cost in respect to this or that mode of steam production or use was, relatively, an insignificant matter.

The author appeared to favour the purchase of electricity in bulk when such supply was available. If such a supply were available at the times of use; if the requirements were not large; if the capital for an independent supply could not be commanded; if the supplier were content with a narrow margin of profit over cost, then a purchased supply would clearly be indicated. But if the user's demand was large and permanent, and if he could command capital, then, quite obviously, he could provide his own supply at a rate less than the outside suppliers' by the amount of the latter's profit. If the supply were Government or municipal, there was always the possibility that possible reductions would not be made, or that there might, in times of stress, be increases.

He would again express his appreciation of Mr. Brearley's communication, again, however, pointing out the difficulty, or impossibility, of directly predicing with anything like the commercial accuracy—1 per cent. or so—the performance of local systems upon the basis of the published figures—usually as favourable as possible to them—applying to systems abroad.

Mr. C. E. Wolff said Mr. Brearley had referred to a one-car system in Western Australia. He was sorry he had not heard the paper read, but he would like to know the cost of that system compared with an ordinary petroleum or petrol driven motor. It seemed to him that in the single-car system the capital expenditure would be abnormal compared with the internal combustion motor. He did not like the internal combustion motor himself, but it seemed to him the extreme limit to run a one-car service. The capital expenditure must have been very high.

The President said he had only a very few observations to add. Mr. Smith had dealt with several points that he intended to address himself to, and he had little of importance to add. He had also had very little time for a full study of the paper, having by an accident only received it a couple of days previously. He was again impressed with the large amount of research and careful analysis which the author had brought to bear on the subject. The whole question of street transportation had in recent years come to the forefront, and there
was no branch of engineering upon which so much attention had been focussed. There was an immense volume of experience gathered in the older systems of the world, and if the problems became acute here they would only have themselves to blame if they did not profit very fully by the experience of other countries. Such a paper as they had heard would aid investigators, and open a path for other investigators in studying a very important feature of the whole question—the economics of it.

He thought from the point of view of economics the paper was extremely logical, and one or two quite novel suggestions had been made.

He had not realised before with such force as Mr. Brearley had shown what poor profit earners electric tramways were; and he thought Mr. Brearley had made out this case at any rate, that under Australian conditions it would be a very poor field indeed for the investment of private capital, and the Australian public would do very well if it could secure electric street tramway transportation at actual cost. It was not doing that now universally, and one large system in Sydney seemed to suggest that after making proper provision for the actual working expenditure, interest and sinking fund, it was running at a loss. Mr. Smith had said that if a publicly-owned utility of that kind did succeed in making a profit a very proper policy would be to devote such profit for the direct benefit of the public by increasing facilities, and reducing fares, and lengthening sections. Surely if that policy was correct the converse was equally true, that if a great public system was found not to be leaving enough residue of profit on working expenses to pay the whole burden for renewals, etc., then the logical position was that charges upon the public would have to be increased. They could hardly accept the one proposition without the other, and it seemed to him unavoidable that unless extraordinary economies could be effected in working, the time would come when tramway managers would have to face the question of increasing revenue either by increasing fares or by shortening sections.

Coming to some of the details of the paper, he was glad to see that Mr. Brearley spoke in such unequivocal terms on the question of the conversion of the Melbourne cable tramways when he said it was beyond all question that no conduit system could be seriously considered, and that even if it were the Mel-
bourne conduits were unsuitable. It was astonishing how prevalent was the opinion among laymen in Melbourne that when the cable lease terminated it was going to be a simple matter to use the cable conduits as they are. Every second man in the street would affirm that position. Quite the reverse was the case, and the evidence taken recently before the Traffic Commission in Melbourne included a large amount of valuable expert testimony, which showed it was rarely possible to have an efficient underground system; in Melbourne it was quite impossible, and the Melbourne conduits were quite unsuitable.

Mr. Brearley appeared to be in a little doubt as to whether in making financial provision for a tramway system provision should be made for redemption, or whether it should not be left for future generations to carry their share of the burden. There was hardly any enterprise where the necessity for redemption was so potent as in this. Take the case of the cable tramways, which were not yet 30 years old. It would never have done to have started with the proposal that they would only pay the interest on the capital borrowed, because they would have found themselves left with an obsolete and useless system, and faced with the burden of the whole debt. No man could say that in 30 years from now the electrical tramway system would not be equally obsolete. And the only possible policy in regard to the raising of the money for tramway construction was to provide a proper annual charge for sinking fund, so that the whole debt would be extinguished in a limited term. He would like to see a 25 years' redemption term.

Mr. Brearley's suggestion of taking into calculation a residual value for several fundamental parts of the system was a very good one, and he did not remember having met it before. He had also introduced another element, which was not so acceptable, and that was the system of calculating by compound interest the annual sum to be set aside to make good the renewals that were found to be necessary. Theoretically it might be all right. Practically there were immense difficulties. It was not possible to foresee exactly when the renewals would take place; they took place progressively. They could not assume that at a given time the whole sum would be available at a given rate of interest. At every stage of that process the investor would lose, and he did not think there was much wrong with the rough
and ready method in vogue of treating the annual allowance for renewals as a simple interest percentage.

The President then called on Mr. Brearley to reply.

Mr. Jas. Alex. Smith thought there were several members who wished to take part in the discussion who were not present. He would suggest, subject to Mr. Brearley's assent, that the discussion be postponed. One meeting was hardly sufficient for such an important matter.

The President said the suggestion was before the meeting. Mr. Brearley could respond to what had been said, the discussion could be adjourned, and further discussion invited, and also by correspondence, and it could be left to Mr. Brearley to reply to the discussion by correspondence or personally.

Mr. Brearley said he would like to do that which would please the members. He would prefer that the discussion should be postponed, because he thought there were some men interested whose opinions they would like to have. He was sure that the Institute would welcome the attendance of the chairman of the Prahran Tramways Trust, who took a keen interest in tramway economics. He also had hopes that at a later date they would have the opinion of Mr. Goodman, of Adelaide, who was also interested in the matter. He knew those two gentlemen would be glad to contribute to the subject. In that case he would prefer to postpone his reply to the remarks already made.

Discussion adjourned.

PAPERS.

NOTES ON INSULATION FOR COLD STORAGE.

By Professor Henry Payne.

(Member of Council).

Cool storage has become essential to the welfare of every country, in connection with the preservation of its food supplies, no matter whether the country be itself a producer or a consumer. By the aid of refrigeration the production of food supplies can be more equally distributed throughout the year, thus individually benefiting both producer and consumer; the pro-
MR. F. W. CLEMENTS (Chairman) said there had been some previous discussion, and no doubt there were some members who would like to say something further on the subject. He might say Mr. Cameron, Chairman of the Prahran-Malvern Tramway Trust, was present. Mr. Cameron was full of figures, referring to the economics of traction, and possibly he might see his way to give some information.

Mr. J. T. N. ANDERSON forwarded the following contribution:—

"The writer would be indebted for any light on the real reason why in so many countries—e.g., New Zealand, and in some of the British Acts—corporations are restricted as to their investment of sinking fund to the extent that they are prohibited in investing in their own debentures. Personally the writer must confess an inability to understand why this is, and even more difficulty in knowing why some acts require the sinking fund to accumulate practically without re-investment, and practically at simple interest.

The writer has usually advised the retirement of the debentures by arrangement at par annually to the full amount of the sinking fund. This does not seem to have an adverse effect on the price the loan can be floated at, and it automatically acts like a compound interest investment, by reducing the interest payable every year—and it has the great advantage of simplicity, and the definite assurance that the debt will be paid off at the exact date intended.

One other question: Are the London electric tramways referred to as representing an invested capital of nine and a half millions exclusively street tramways—or do they not also include a certain amount of "tube" traffic? A useful illustration of the futility of trying to improve nett revenue by raising fares can be seen in the history of the London Metropolitan (underground) railways. After the conversion of these to electric traction—the capitalisation was too heavy—and the low fares charged, on the same basis as the Yerkes Tube, showed a loss. The effort to convert this into a profit by raising fares had the reverse effect.

In the early history of tramways it will be seen that splendid returns were earned for the shareholders. But the experience
has been that on the conversion to electricity this has been entirely changed. The explanation of why, in spite of this, the investment of capital on these undertakings has continued to grow to an enormous extent, notwithstanding this discouraging experience, is no doubt due to the magnificent indirect benefits earned by the rise in the value of all adjacent land and house property, due to the increased transit facilities. Shareholders get their return by being interested in these properties, and corporations similarly are impelled for the same reason to gladly shoulder a slight loss on the electric tramways."

Mr. A. L. Hargrave said there was an omission in what he had said at the last meeting—that he did not think it was possible to get more than 8 as an evaporation. That should have been for the whole year. That was rather important, as probably a good deal more than 8 could be obtained on test with a full load on the boiler, but when they took into account the light loads, and with the tramway system no load at all at night, 8 would be a very fair evaporation.

Mr. M. E. Kernot said he had not come prepared to discuss the matter. Mr. Brearley had put a lot of time and work into his paper. It was the summation of a large amount of experience. He had looked through it, but he did not think he could add anything to the profit of the discussion. But one point had just struck him. Mr. Brearley spoke of the limit of traffic on electric tramways as to 10 to 20 seconds. He had not seen traffic work as closely as that. For instance, in George-street, Sydney, which was said to be carrying all the traffic it could carry, the number of cars per minute was a good deal less than 6; he thought it was less than 3.

Mr. Alex. Cameron, Chairman of the Prahran-Malvern Tramway Trust, said he regarded it as a compliment that he had been invited to take part in the discussion. He professed no greater knowledge than a layman who had taken a very deep interest in tramway economics, and as the paper dealt with a number of somewhat recondite engineering problems, he proposed to pass them over. He made no claim to engineering knowledge whatever.

He had been aware that Mr. Brearley was going to read a paper on "Electric Traction," and knowing Mr. Brearley as he had known him for a number of years, and having close business
relations with him, he had expected very high things of his paper, and had not been disappointed. As a summary of tramway economics he did not think he had ever read a more informative paper. He thought it would be of immense value at the present juncture, as they were dealing with the problem of the installation of a complete electric tramway system. There could be no more valuable source of information than Mr. Brearley’s paper. He knew only one book on the subject which was at all comparable with it, the book by Prof. Smith on Electrical Traction, written some seven or eight years ago, and consequently its information was out of date to some extent. He knew of no other source of getting such valuable information as he found in that paper, and he felt that no praise was too great for it as a generalisation on that important subject.

He had been through Mr. Brearley’s paper somewhat hastily. He had not had time to make a critical analysis of it, but it seemed to him that the deductions throughout were sound and convincing. He was not going to discuss the question of tramway traction or the problem which lay before them in Melbourne with regard to the conversion of the cable tramway into an electric tramway, or as to whether conduits or overhead wires, or any other system should be adopted. It was a very difficult matter, and one that required a great deal of thinking about. He did not think that up to the present one could say a thoroughly satisfactory solution had been offered. He would now just take the paper in the order in which it was written.

The first important thing to be considered in setting about the installation of a tramway system was to determine whether it would pay, and to what extent installation could be made. As far as his experience went the important considerations were first of all the density of population per mile of track, and while, perhaps, the square mile was rather an arbitrary method of determining the density of population, he thought it was about as satisfactory as any, because for purposes of uniformity they had to take some figure, although they knew that the effective drawing power of a tramway varied very greatly according to the district. Taking the square mile—half-mile on either side of the track—under Melbourne conditions, he had, as a result of a very close analysis of figures, come to the conclusion that it usually required 4,000 people per mile of route to support a
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tramway giving a minimum service of 15 minutes. Of course that largely depended not only on the population of the area served, but also on the non-residential population abutting on it, and on the extent of the network of tramways. That was well illustrated on their own local experiment at Prunran-Malvern, where they started three years ago with a tramway of only 4 1/2 route miles, and 6 1/2 miles of track in a population estimated at 35,000 people. That line was remunerative from the beginning. It provided interest and working expenses, i.e., maintenance, power, wages, and administration, and a sinking fund of 2 1/2 per cent. upon the actual cost of the undertaking, exclusive of the cost of the land, and left a surplus over to go in relief of rates. At the end of the first year's operations they were able to distribute about £3,650 between the two municipalities out of a gross revenue of £26,314. In the next year in the same area, with just the ordinary increase of population, the revenue rose to £38,000, and in the third year to £48,000, but in the third year they extended the route mileage by 2 1/2 miles with double track.

Then he wanted to point out that the increase of earning power was due, first of all, to the increase of population; secondly, to the increase in the travelling habit; thirdly, the increase due to the extension of the network of tramways, and therefore they had a much more useful system. They had formed a connection at St. Kilda Road with the Melbourne cable tramway, and therefore they had a large infusion of non-residential passengers. The result had been that, although at the commencement the journeys of the population were 80 per annum, they had now risen to 150 journeys. Going back to 'bus days, they saw what an enormous increase had taken place in the number carried, which under that system was about 300,000. The Melbourne Tramway Co. estimated that with a quarter-hour service under electric traction, it would increase to 800,000. They proposed to offer a fare of 2d., and asked for a concession of 50 years without any proviso to terminate the concession on any terms whatever. Ultimately it was not deemed advisable to accept their offer. When the line was actually built, though not quite under the same conditions, because the route had been somewhat varied, and although the area served was only very slightly increased, instead of receiving £6,700 a year, they received in the first year £23,000, and in-
stead of carrying 800,000 passengers in the first year they carried over 3,800,000, and on the same lines to-day over 6,000,000, leaving out the passengers on the Dandenong Road line—amounting to another 1½ millions. On the line now open, the number of passengers had gone up to an average of ten or eleven millions per annum, and the revenue had risen to an annual average of £76,000, so that in considering the question of tramways one must take into account that in a growing district, and particularly where there was a large metropolitan population, and the network of tramways increased, and facilities for passing from one district to another increased, there would be found a rapid rise in the travelling habit take place.

The next important question was to arrive at some estimate of what the population would spend per head. An examination of Australian figures showed that, roughly speaking, the spending power of suburban transportation was something from £2 to £2 10/- per head. Taking the railway and tramway traffic in Melbourne at the present time an approximate figure would be £2 5/- per head. A few years ago, when he had looked into the matter, the figure for Melbourne was £2 3/-, and for Sydney £2 5/-, talking the tramway and railway traffic together, but there was a different distribution. In Melbourne the railway earned about £1 3/- and the tramway £1. In Sydney it was about 30/- on the trams, and 15/- on the railways. Of course it had to be remembered that Melbourne had a much larger railway system, which carried half the travelling population. In Sydney the proportion was vastly different. In Melbourne the railways carried about 100 millions per annum, and the trams 90 millions. In Sydney two years ago they carried 48 millions on the railways, and over 300 millions on the tramways. That made a great difference in determining the earning power of the tramway in a district where there was a railway, and in one where there was none. In Prahran-Malvern the amount earned per head had risen from £1 2/6 to 15/4, and taking the original lines for the last six months, the amount stood at 10/2 per head of population.

He thought these were the important factors to consider:—First of all, what was the population, what was the spending power per head of population, how far was the tramway competed against by existing railways, and what facilities the district offered in the way of giving cross connections. The larger the network the more profitable it would be.
The next point he would touch upon was the cost of construction. They had constructed something like 40 miles of track for a total expenditure of £450,000. That would give a figure of about £11,000 per mile of single track. Taking small systems with a limited track mileage, he thought that the figure of £13,000 a mile was more accurate, allowing for an average service of 1½ cars per mile of track.

An important feature in determining the service was that they could not have a successful system with less than a 15-minute service. That was the absolute minimum that would justify the building of an electric tramway, and in order to do that it must earn £3,000 per mile of route. Of course, with a double track one looks for an earning of £6,000 per mile. It needs a service of something like 60,000 car miles per mile of track per annum to give this result.

Coming to the question of operating expenses, Mr. Brearley had given some interesting figures, and denoted 10d. per car mile as something like a fair figure to estimate upon, exclusive of interest. He thought that was a very full figure indeed for a system of any reasonable dimensions. They had a similar system, and before the increase of wages, their operating expenses came to about 8½d. per car mile. For the last 18 months, until the increase in the wages came into effect, he thought the actual figure was 8.548d.; it had now risen to 9.6d. Included in the increases were those for motormen and conductors, amounting to an increase of 4d. per car mile. The increase in wages obtained through the Arbitration Court had made that difference, and other incidental expenses, including the greater use made of bogie cars, made a difference of 1.33d. per car mile. Owing to the increase of wages, and the fact that a minimum rate must be paid to what were termed casual motormen and conductors, and the fact that the latter had to receive £2 2/- per week, and that during the afternoons and evenings there was twice the density of traffic than during the rest of the day, making it difficult to find full employment for the extra men who worked the extra cars during the rush period, a tramway manager was hard pressed to keep the wages within a reasonable compass. Therefore he thought Mr. Brearley's figure, particularly in a small system, was not excessive.

There had been a rather interesting discussion on the question of power costs. They had no generating station.
of their own in connection with the Prahran-Malvern system, but they had a very satisfactory arrangement under which power was supplied by the Melbourne Electric Supply Company, and their figure for daily current at the D.C. 'bus bars was 1.086d., on an output of a little more than a million units. That compared very favourably with a much larger system like Adelaide, where he believed the cost worked out at somewhere about 1.025d., and it fully justified the wisdom of Mr. Brearley's advice to buy their current in bulk instead of erecting their own generating station under existing conditions.

Mr. Brearley had given a very interesting table of the ratio of working expenses to expenditure, and he fully agreed with those figures, that a fair average amount was 65 per cent. He saw, however, that Mr. Brearley mentioned 66 per cent. in the case of the Prahran-Malvern system. He thought that must have been based upon some early figures. The actual figure for the last 18 months was 63.439, so that they were well within the average. That was a figure that varied very largely owing to varying conditions. In their case they were in a period of transition, where they had to debit to their ordinary expenditure interest and charges in regard to extensions of buildings and plant not brought fully into use. That made a very considerable difference. In that connection they had in their system what he thought obtained in no other. They undertook the whole lighting of the track. That was a very considerable item. Track lighting cost something like £1,400 a year, and that exaggerated the working expenses. Then another thing which exaggerated the working expenses was the fact that they had to pay a very heavy interest bill on a large sum of money, £13,000, for the regrading of railway lines, and on something like £24,000 for altering water mains and sewers, manholes, and railway bridges, and a sum of £5,000 towards road improvement. All those items were debited against their capital expenditure. These facts should be borne in mind when criticising their local figures.

Another important matter he would like to refer to was the question of sinking fund, renewal fund, or a fund for depreciation, and obsolescence. They set aside 2½ per cent. per annum on the capital cost of everything except the line as renewal fund only. That fund had now accumulated to over £14,000 in three years. It was invested in their own undertaking. It provided
for renewal of track only on the assumption that there was no obsoletion. No provision had been made for repayment of capital. He thought in a municipal undertaking it was necessary. If they provided for renewal, and renewed the whole thing, it left matters in the same position as when they commenced, apart from obsoletion. As an instance of the necessity of a fund for obsoletion probably the best instance they could take was the existing cable tramway. Assuming, as he believed it to be, that it was in excellent condition, and had many years of effective life as a cable tramway, yet it might have to make way for the newer and more elastic form of traction, which had resulted from the developments in electric traction during recent years. He did not think a renewal fund only would be sufficient to meet such a case as that. There ought to be some further provision. Apart from the form of motive power, however, he did not think a more perfect form of traction could be devised than on rails. He could hardly think rails would be superseded. Rolling stock—the electric part of it—and these were subject to sudden changes, were fortunately mostly provided out of maintenance. As the Prahran and Malvern Tramway Trust had no power station, and the only things to grow obsolete were the cars, probably the fund they had provided would make very reasonable provision for their requirements in this respect. Then, of course, they were also aware of the fact that they were going to be absorbed very soon into a Greater Melbourne Tramways Trust, or some such similar body.

There was one other point, upon which he did not profess to speak with any authority, but simply as it appealed to him as to its practical application. It had been raised by Mr. Smith in discussion as to the use of the car-mile as the unit of calculation. He thought they could find many objections to the car-mile if they tried to make it of universal application to all purposes. They could easily see that by increasing car-miles and reducing car-mile cost they made their traffic costs per car-mile look magnificent, but would not find the revenue going up correspondingly. The car-mile, however, served a very useful purpose, especially where they had to find a common method for determining the rights and interests of municipalities associated together. Take, for instance, Prahran-Malvern. In Prahran they had a dense population in a very small area. The whole depth traversed by tramways of Prahran was two miles. It had behind it a large
district in Malvern and Caulfield. To establish a tramway in Prahran, confining the distribution of profit on the basis of passengers carried, or on route miles within its boundary or any other method, the tramway would have been a failure. It would not penetrate far enough to collect passengers, because for the first half-mile of the route the people would not get into the habit of travelling at all. They would mostly walk. On the other hand, if Malvern carried the system through its territory, it became a very valuable feeder. If the revenue boundary was to be drawn at the municipal boundary there would not be the amount of population to support their portion, and the result would be probably a loss to both municipalities. But with the two working together the success in each municipality depended on the success of the whole. Therefore, for purposes of obligation they should treat the tramways as a joint concern, and the car-mile was then a most useful basis for ascertaining their joint rights and obligations. The cost of wages, power, and of maintenance was proportional to the number of car-miles run. Certainly it was not a sound factor as regarded interest or a sinking fund for repayment of capital. These were some of the reasons why the figure did substantial justice to the transaction, and why no other figure as a common basis for the calculation would be so effective. It all depended on the use they made of it. He thought it would be found on examination to be the most convenient basis upon which municipalities establishing a joint relationship with each other should base their mutual rights and obligations.

He was afraid he had taken up a lot of time, and had not been able to give as much light on those very important matters as they may have deserved. He had only endeavoured to give them the personal experience he had gained in connection with their local electric tramways, in the hope that perhaps what he had given might be of some use in elucidation and support of the very highly instructive paper by Mr. Brearley.

Mr. J. A. Smith said there was one matter arising out of Mr. Cameron's speech. It was in connection with the car-mile. The position he had taken in discussion was that the car-mile had its use, that comparisons could be made between systems that were somewhat similar, but that it could not be accepted as a standard
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in relation to every city and every system. To compare Paris or London, or New York or Petersburg, with Melbourne or Brisbane, or other systems widely removed, on the car-mile basis was liable to cause grave misapprehension.

Mr. F. W. Clements said he had not had much time to study the paper, but he had a few remarks to make. He would first of all like to express his admiration of the marvellous memory of Mr. Cameron. Possibly some might have thought Mr. Cameron was reading from notes. It was not so. He had simply been reeling off figures that he had in his mind. It was one of the things that he envied Mr. Cameron for.

There was no need to go into the conduit controversy, because it had been so often mentioned, but he would say that he agreed with the various remarks that it was hopeless to imagine that they were going to do anything with the conduits. The man in the street thought nothing was easier than to put a couple of wires in the existing conduits, but he forgot that the rails were too light, and there was such a lack of accommodation in the tunnels. In fact, the whole of the conduits would have to be rebuilt. He did not mind predicting that Melbourne would follow all the other cities, and not be ashamed to use the overhead system. It certainly was not very pretty, but it was a very practical system.

With regard to the tramways being bad profit-earners, it was a very unfortunate fact. He thought they would find in going through statistics that in England very few towns under 50,000 inhabitants paid at all. That appeared to be the limit, especially in England, which gave any reasonable chance of making a tramway pay. Of course in Australia they had smaller tramways—Launceston and Hobart, Bendigo and Ballarat, on the 50,000 line, Geelong and other tramways running down to 20,000 inhabitants. Because these were connected more or less with supply undertakings, they could be made to pay to a certain extent, but it was with great difficulty. The difficulty had been recognised in England, and it was so serious that there had actually been a suggestion made two or three years ago that a special tramway coin of one and one-fifth penny be struck, which would have put everybody on the sound footing. He thought the reason why some small companies were non-paying concerns was very well shown in Mr. Brearley's table, where he showed that 122 British
Companies averaged 14.2 per cent. revenue to capital, whereas the corporations averaged 19 per cent. That was not due to the fact that the companies were more philanthropic than the corporations, but the corporations were running bigger towns. Small towns were on the whole probably responsible for the bad paying qualities of electric tramways.

With regard to the term of depreciation for generating plant alluded to, only 15 years could be allowed. They had recently heard of an old beam engine in Melbourne being thrown out which must have been running for 50 or more years. It would look like retrogression that modern power plants could not do equally as well. It was purely a question of obsolescence, not depreciation. In his experience he did not think he ever remembered any powerhouse machinery which had existed more than 15 years. It was nearly always thrown out for something better or larger, although the plant had been quite good. It was not a question of depreciation at all.

He would like to ask Mr. Brearley whether the figure of 0.78d. given as the Adelaide cost of the unit on page 50 included capital charges, or whether they were purely operating charges. Mr. Brearley said in his paper they were not inclusive of loss from 'bus bars to consumer. He therefore assumed it was the operating cost of the unit at the 'bus bars.

Mr. Brearley said that was correct.

Mr. Clements had assumed that; otherwise it would be too creditable a figure. In giving the figure of 1.082 for the Prahran-Malvern Tramway, he believed they were being supplied under a sliding scale, depending upon coal costs, etc., and if that was the case, probably, with an increased consumption, the price might be reduced.

With regard to the question of coal and fuel cost which Mr. Brearley mentioned on page 50, and to which Mr. Hargrave had referred, he must agree with Mr. Hargrave that 1.5 lb. of coal per unit was a very low figure. If they took the evaporation at 8 lb. year in and year out, it would be excellent. With Wonthaggi coal they got a consumption of about 12 lb. per unit at the generator terminals. That was extremely low, without allowing for auxiliaries, and also for light load losses of machines, which rarely ran above .8, and so on. In fact it brought it down to what was the testbed figure, and that could not be obtained
throughout the year. He should rather be inclined to put it down at 2 lb. of coal as the irreducible minimum, i.e., taking the average steam consumption at 15½ lbs. of steam per unit it would amount to about 2 lbs. of fuel per unit. That would work out at 0.13 lbs. per unit at the price taken by Mr. Brearley—12/- per ton.

With regard to the cost of 0.25d. to 0.35d. per unit, at which the author stated current might be sold in bulk, if they allowed 3 per cent. for station and transforming-up losses, an average of about 7 per cent. for transmission losses and about 17 per cent. in converting to direct current for traction purposes, but assuming no battery losses, the cost for fuel alone would be about 0.17d. per unit. This fact, however, would still allow of Mr. Brearley’s figures being correct, assuming that they applied to a supply of extra high tension current untransformed at the delivery end.

He would like to ask Mr. Cameron if the £2 to £2 10/- per head which he mentioned was income per head of population served or of the total population of the town?

Mr. CAMERON said he had taken the whole metropolitan population of each place, taking Melbourne as 620,000 and Sydney as 670,000.

Mr. Clements said it seemed to him that that was a reasonable basis of calculation, which ought to provide quite as good a method of estimating returns from a tramway as the usual half-mile radius method.

He was surprised to hear the increase per car-mile which an apparently small increase in wages made. 4d. per car-mile on an average cost of 8d. to 10d. was a big increase.

The CHAIRMAN then called on Mr. Brearley to reply.

Mr. J. H. D. BREARLEY said he would like to express his thanks for the way in which his paper had been received, and he would try and respond seriatim to the remarks that had been made. He did not think anything which occurred at the first meeting called for much in the way of reply, so he would pass on to Mr. Hargrave’s remarks.

In quoting 1½ lbs. of coal per unit, which was a point Mr. Clements had also raised, he must admit that he had perhaps claimed a little too much for plants as now operating, and his remarks should have been somewhat qualified by stating that
the amount quoted was one that was likely to be realised within a few years in view of the continued reduction in steam consumption, by improved design of prime movers, by the increased use of high superheat, and by the better economy of heat throughout the whole cycle of generation from coal. As to the evaporation with Wonthaggi coal, from the information he had, and assuming that 12/- was a fair price, also that a good class of coal and not slack would be available to the railway supply station, there should be no difficulty in getting 8 lbs., and over, of actual evaporation. But the point he wished to make—although perhaps he had not made it as clearly as he might have done—was that even after allowing for a somewhat ideal condition, in which 1½ lbs. of coal per unit were obtainable, under those favourable conditions the fuel cost would be 0.1d. Mr. Clements had placed it at 0.12d., an advance of 20 per cent. He was prepared to accept that in lieu of his own, but he thought his own might stand as a standard when they took into consideration what his object was, and with other necessary charges it was quite obvious that the least energy could be supplied for would be ¾d. per unit. One might therefore conclude that there was no great advantage in concentrating the whole power supply in one station. That was his object in pointing out that under the most ideal conditions they could not arrive at a figure for the supply of energy less than the dimension suggested, or one would put other generating stations out of the question.

In reply to Mr. J. A. Smith's remarks he would say that his object in giving generalised figures was rather to apply them as a first approximation in any given case and, if a more general consideration had deduced a value for any proposed system, a further detailed consideration would be essential dealing with the particular merits in each case. He would be the last to claim that a generalisation could be applied to every specific case, but he certainly had found in his own experience that there were certain generalisations in relation to electric traction that were very useful in a preliminary consideration as a first approximation to the results of any given system.

As to whether a 10-second interval was impracticable, he would say, in reply, that such a capacity was quite possible, and actually existed. Within his own knowledge closer than a 10-seconds' interval was observed for many years in Sydney.
the same time he did not claim that a 10-seconds' interval was a desirable condition of things, but it was one that might exist under crush conditions. His only object was to point out the great elasticity of an electrical service, and the limit of carrying capacity of the system was only the carrying capacity of the feeders. However, few systems would be justified in attempting 10 seconds' intervals as a general thing.

As to the arithmetical average having been taken of the rates of interest in the table on page 39, he would say that that was not so, although the figure—3.54—was, more by accident than anything else, the arithmetical mean of the others. But in each case the amount and the rate earned thereon had been taken into account. The second line on that page could not be used from that point of view, because in each figure quoted he had taken the highest result obtained over that period of years. The consecutive figures did not refer to one year, but were the highest results gained throughout that period.

He was quite in accord with Mr. Smith as to working expenses, and did not claim that a low rate of working expenses in proportion to revenue necessarily meant a satisfactory system.

In reply to Mr. Barbour and Mr. Smith as to buildings, he thought they could only assume that the item to be renewed would be of the same character and extent. The dimensions of the building were another question altogether. He had not dealt with the aspect of obsoletation, and thought it should be separated from the consideration of the renewal fund.

Obsoletation of plant or alterations to a system on account of growth were difficult matters to provide for.

He was not prepared to agree with Mr. Smith that comparisons based on the car-mile unit were fallacious. It was true that the passenger mile was a very sound unit in comparison of results, but in a given system the car-mile was a definite and determinable quantity. As soon as the requirements had been estimated the car-mile could be determined. It was a quantity in respect of which many of the operating costs varied. The wages of conductors, consumption of energy, wear and tear of track, were almost all proportional to the car-mileage. The relation of the variables taken on a passenger mile basis was not, to his mind, quite so clearly defined as on the car-mileage basis.

In reply to Mr. Wolff he might say, in reference to Leonora, that there were several reasons for adopting the one-car system.
Apart from the question of cost there was no practicable form of petrol car available. The council had decided to have its own lighting system, and it required but a small extra capital cost to carry out the conversion from the steam car to the electric car.

With regard to the remarks made that evening, he would take first Mr. J. T. N. Anderson’s contribution. The question as to the restriction of the investments of sinking fund had frequently cropped up, and he thought there was some justification for the Legislature insisting that a sinking fund should be invested outside the undertaking. The object of the sinking fund was to replace the original amount advanced for the system. If money was invested in the system it took the risk of that system, whereas if it was invested in outside securities it took none of those risks, and the interests of the people who put their money into the concern were safeguarded.

With regard to the suggestion in relation to the question of redeeming the sinking fund from time to time, and also the question as to whether the sinking fund should be credited with simple interest or otherwise, he thought the remarks on the point were sound, and the practice one that should be adopted. It was a business proposition.

Mr. Anderson had referred to the item of the investment of £9,000,000, and asked if that amount were exclusive of tube tramways. He might say it did not include any tube tramways. It referred exclusively to surface tramways.

Mr. Anderson’s remarks as to the effect of transport facilities in increasing the value of investments in the case of electric traction, and thereby making investors more content with a lower rate of interest, he had noted with interest, but his own experience with regard to tramways had not shown that, even prior to electric traction, tramways were a particularly remunerative form of investment. Of course they had to take almost every case on its own merits, but as far as electric traction was concerned, he had given results in which he had brought out the maximum results earned in any year, varying from 3.6 per cent. to 5.56 per cent.

He had noted Mr. Hargrave’s further remarks, but he thought he had answered that criticism as far as possible.

Mr. M. E. Kernot had referred to the service of less than three cars to the minute in Sydney, but he had in his own experience of traffic there, for seven or eight years associated with the Department, to deal with a greater density of traffic than that, al-
though it was not a condition of affairs desirable, but still it was possible; he only mentioned the condition as one to show the extreme elasticity of electric traction, and then only in the heart of the system, because the conditions could not obtain over any length of track.

He had been very pleased indeed that Mr. Cameron had been able to attend and contribute something to the discussion, on account of his very considerable research in that interesting field. He might mention also that he had a letter from Mr. Goodman, of Adelaide, thanking the Institute for the invitation extended to him through the President to contribute to the discussion, but unfortunately he was a victim to influenza, and was unable to do anything in the way of contributing to the discussion. Mr. Dix also was unable to be present. He must thank Mr. Cameron for his flattering remarks with regard to the paper, and also more particularly thank him for the interesting additional information he had been able to give the Institute, which would form a very admirable addition to the generalisations he had put forward in the paper.

He was particularly interested to hear the results of Mr. Cameron's inquiry as to the approximate population density per square mile that would make a tramway payable, and it came rather as a surprise to him to see that Mr. Cameron, by his own independent investigation, considered that about 4,000 per mile were necessary, while he himself had put it down at from 4,000 to 5,000.

Another very noticeable figure put forward by Mr. Cameron was the increase in the travelling habit, from 80 to 150 per annum in three years. As bearing on that point and on Mr. Clements' subsequent remarks as to small systems not being payable propositions, he would like to offer a few figures he had obtained from Mr. Cameron, which were very interesting. Out of more than 40 American systems—and they would remember he had been careful to exclude American systems from consideration on account of certain differences in conditions—but under American conditions a system with up to 25,000 population, the travelling habit was about 68 per annum, that was to say the population was carried 68 times per annum. In cities of 100,000 population the travelling habit was 109 per annum. Up to 500,000 it was 184; over 500,000 it was 236 per annum. So that in the smaller cities the number of journeys per capita per annum was very much smaller, and therefore it explained to a
large extent the reason why the small systems were not as profitable as the larger ones. He was also interested to note that the average revenue per capita per annum in Prahran and Malvern had gone up from 12/6 to 15/4 and 19/2, which confirmed his own estimate as to the earning capacity of the system.

The further information Mr. Cameron had given as to what he was paying for power, he thought should be particularly interesting to members. He observed Mr. Cameron was now buying energy on the D.C. system at 1.086d. per unit. That compared even more favourably than he had anticipated with the cost of production in a self-contained plant. He would reply to Mr. Clements that the figures he had given for Adelaide, viz., 0.78d., did not include capital charges. He thought a tramway system should be congratulated if it could purchase energy at that price, paid in Malvern, and avoid the capital cost and wear and tear of a generating station.

He was sorry that in the figures published in his paper the latest with regard to the Prahran system were not included. He had pencilled the figures, but they did not get into the manuscript. The ratio of working expenses to capital given by Mr. Cameron was very satisfactory indeed, and more particularly in view of the large amount of capital on which interest had to be paid in constructing the line, regrading, alteration of mains, sewers, etc.

He was very pleased to hear Mr. Clements' endorsement, and also that of the President, of his remarks on the question of the conversion of conduits in Melbourne, and also that he found from wide experience of the subject that the period of 15 years was reasonable as the life of the power plant.

With regard to Mr. Clements' criticism as to the generating cost of energy in a large central power station, he thought he had already replied to that matter in answer to Mr. Hargrave. He was quite prepared to accept Mr. Clements' figures as being something that could be now obtained, but he still maintained that his object was served by that, viz., to show that there was no prima facie argument in favour of having the whole of the power supply for Melbourne concentrated in one power plant.

That concluded the remarks he had to make, and he would like to take the opportunity of thanking members for the way in which the paper had been received, and the interesting discussion evoked.

Discussion closed.
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