PART I.

PAPER ON TRAMWAYS

CABLE VERSUS HORSE OR OTHER MOTIVE POWER.

BY CAPTAIN F. C. ROWAN.

Mr. President and Gentlemen,

The subject which I have been asked to introduce to your notice to-night, is that of Cable Traction versus Other Motive Power for the Haulage of Traffic on Street Tramways, and it is undoubtedly a subject at the present moment, not only of great technical importance, but also of great public interest.

I could have wished that some gentleman of large engineering experience, and whose utterances could claim a right to more attention than can possibly any of mine, should have been asked to open up the discussion on so important a matter. It may be, however, that we shall ultimately obtain that information which we hope to elicit, in a more clear and crystallised form, by hearing the opinions of such experienced gentlemen expressed separately and definitely upon each subdivision of our subject as it arises, than if a thoroughly detailed and critical dissertation were undertaken on all forms of haulage collectively at first. To deal in an opening paper thoroughly, with all the different forms of traction recommended for tramway use by different experts, would be manifestly confusing and impossible. The subject is a large and a complex one, and it demands a systematic treatment from the outset if we are to produce any definite and useful result as an outcome of the discussion, which I think not only we, but a good many outside friends, are looking forward to with so much interest.

Before, however, attempting to touch the technical portion of my paper, it may, perhaps, be considered not inappropriate to dilate slightly upon the advantages, or the reverse, which may accrue to this Association in particular, and to the public in general, from the initiation of discussions upon this and upon other cognate subjects at these periodical meetings of our body.
It was considered by the Council, and I think with reason, that there are at the present juncture several questions before the public which are connected with engineering, and the proper carrying out of which would be benefitted by that thorough ventilation of them, in their various aspects, which might be expected to take place in a discussion carried out on definite lines by a body of technical men.

There can be no doubt, I think, that such discussions, whether they be upon compilations of useful information collated from outside sources, or upon original papers written by competent members of our own body are, if properly conducted, of benefit from most points of view.

The present moment seems a particularly appropriate one for initiating such a discussion on tramways, and we hope that it will enable us, from the accumulated stores of information which we may reasonably hope to find among our members, to form some idea of the practical results as regards different forms of traction which have been obtained both in these colonies and in other countries.

We cannot, I think, except in one particular direction—viz., that of cable traction—hope at present to learn much from practice in these colonies as to what system to follow, though we may easily see in different places a good deal that ought to be avoided.

This is hardly to be wondered at when we remember that the undertakings which have been gone into in these colonies, in the way of tramways, have all so far been on a comparatively small scale, and, if we except the so-called tramways of Sydney, which were built and which are worked by the Government, but which are practically street-railways, they have been nearly all injuriously affected in their inception by an insufficiency of funds for construction.

It seems, therefore, probable that in order to enable us to arrive at some definite conclusion from the discussion to which I am asked to give the initial impetus this evening, we can only hope, in the natural order of things, to receive communicated or compiled information which has been derived from sources outside these colonies.

If the information communicated to us, however, be of such a nature, and from such sources as to enable us to feel confident that due care has been taken in ascertaining its reliability, before passing it on, and if we proceed to our discussion upon definite and preconcerted lines, there can be little doubt that we ought to arrive ultimately at some definite and useful conclusion.

The title of the subject, as it was given to me, was—
Tramways.

Tramways.—Cable versus Horse or Other Motive Power.

Now, I need hardly say that dealing with such a subject as this in a general way opens up an enormous field for argument and debate.

To deal properly with such a topic in general terms, to discuss fairly the different forms of motive power which have been and are still upon their trial, would involve the employment of an amount of time and research which, I think, we hardly have at our disposal.

I prefer, therefore,—taking into consideration the spirit of the intention with which the Council suggested the initiation of these discussions, and the fact that we want to arrive at some practical results to the benefit of our fellow-citizens, to assume that the question which we have to consider is rather: What form of traction for street-tramways—cable, horse, or other, is the most suitable for use on the Melbourne tramways? and here I may point out at the outset that it is not my intention to-night to advocate any one particular system for universal or general application.

The more one investigates the question of tramway traction the more one finds that the conditions which affect it are always many and varied, and that what is admirably adapted to one place is very likely utterly unsuited to another. For instance, it is held by many people who have devoted much time and attention to the matter, that there is nothing in the world which, on the whole, can compare with horse-traction, and they have doubtless in many instances strong reasons for their belief; at the same time I have reason to believe, from the results which I have actually seen, and from information which I hope will be duly communicated to us, that several forms of mechanical traction are more economical in nearly every sense of the word than horse-traction under many very ordinary conditions, if not generally preferable to it in other respects also.

Again, the advocates of compressed-air have claimed universal superiority for their method of haulage, and here again, under certain conditions, they may be right; in fact every kind of traction which I shall presently proceed to enumerate has its warm partisans and advocates who will, as a rule, be found able to give some sound and weighty reasons for the opinions held by them.

The practical engineer, however, who has to deal with these subjects, and who has not only to construct lines, but to devise paying methods of working them, finds in the course of his practice that in this, as in other matters, circumstances alter cases; under certain conditions horse-traction undoubtedly
answers admirably, but so does wire-cable under certain others; similarly, also, with steam and with compressed air; so also, possibly, with fireless engines of different kinds, with gas or with electricity; in fact it seems that out of the hundreds of different methods which have at different times been proposed for using applications of mechanical force, one exponent or so, of almost each species, or system, has some really practical advantages to recommend its employment, under certain special conditions.

Now, sir, I think that our aim must be to study systematically what those conditions are, and then to try to ascertain which of those conditions predominate here in Melbourne. The time at our disposal is, I fear, too limited to allow of our expecting to get to the end of our discussion in one, or even in two or three nights, and I think it will be agreed on all hands that in discussing a subject of such magnitude, and such a many-sided one as this promises to be, a little time is well spent at the commencement in clearing the ground, and in formulating some definite plan of procedure.

To revert, then, to what I have previously said, it would naturally follow that in planning a comprehensive tramway system, when we come to the question of how to provide for the haulage of our tram-cars, we may naturally expect to find a considerable list of methods available to choose from.

I propose now, with your permission, and as an introduction to discussion, to enumerate the principal of these methods. In so doing I will ask leave to set horse-traction first, because in practice and for purposes of enumeration or discussion it is generally found more convenient to divide tramway traction into two broad classes, animal and mechanical; also because horse-traction becomes naturally first on the list, in virtue of seniority and of its more general, although possibly decreasing employment.

I shall then follow on with those modes of haulage by mechanical power, including wire-cables, which may be admitted, under proper handling, to comply almost or entirely with certain conditions, to be hereafter enumerated, and which should, in my opinion, be insisted upon, with regard to any form of mechanical traction, before the sanction of the Legislature can be reasonably demanded as a step towards its introduction.

This will, probably, I think, occupy fully as much time as I can fairly expect you to accord me this evening, and this meeting might then elect either to proceed at once to a discussion of the various systems enumerated, or it might, as I trust it will, prefer to await a further introductory development in another paper. In such a subsequent paper I should hope to be allowed to set
forth, as briefly as possible, those general conditions which will, I trust, be admitted as universally worthy of insistence, no matter what the system of haulage may be, but without complying with which no system of tramways ought to be tolerated. I would then put forward my view of those conditions which any and every mechanical device ought to be shown to fulfill before it is allowed to put forward any pretension to justify its introduction or adoption for street traffic.

It would then, I think, be advisable to describe the general physical characteristics of the Melbourne streets, and to give some details as to the longitudinal sectional configuration of the tramway routes as proposed in the Act of Parliament. I should prefer, myself, to see the discussion commence after this, taking the different forms of traction in the order in which they shall have been enumerated, and debating the merits and demerits of each one in turn, with regard to its fulfillment of the necessary conditions, and its employment in Melbourne streets.

To enable the discussion as to each method of haulage to proceed on well defined lines, and to give both its supporters and its opponents an equal opportunity of bringing forward the best and latest evidence at their command, I would suggest that the Council might be asked to formulate general rules for the guidance of those participating in those debates.

With this suggestion I now proceed to details, and, as already indicated, the first class of tractive power which we come to is that of horse-traction. This particular kind of tramway has, owing to many reasons, by far the greatest amount of mileage to show in actual work up to the present time.

It was stated in a number of the Scientific American, last year, that a return of the National Street Railway Association showed that there were then, at least, 415 Tramway Companies in the United States and Canada. These companies are said to own a length of 3000 miles of tramway lines, to employ 35,000 men, and to possess about 18,000 cars. They use daily over 100,000 horses, which require somewhere about 150,000 tons of hay, and 11,000,000 bushels of corn annually. During the last few years the number of passengers conveyed amounts to about 1,212,000,000, and the capital that is invested in all these lines is not far from £30,000,000.

This will serve to give some idea of the number of people, and also of the variety of the callings, or trades, who may have a direct pecuniary interest, quite independently of anything connected with engineering, in the question of how this or that tramway is to be worked.

Again, in a letter from a corresponding engineer who visited America last year for the special purpose of examining into the
Tramways.

Tramway question, I learn that there are over 800 miles of tramways in New York alone. These are, nearly, if not quite all, horse-tramways.

If such be the case in America, a country which is supposed by many to be the chief source of mechanical invention and ingenuity, as well as that where the people are among the readiest to experiment, and to take up and try new ideas and methods of working, we might almost, at the onset, consider the matter as settled, and declare at once that if horses were found to be in an overwhelming majority in America, it must be because no satisfactory method of mechanical traction had yet been anywhere devised.

Such an assumption would, however, I opine, not stand the sifting of careful investigation, and we might find that there are several reasons why, except in one or two particular ways, mechanical traction on tramways has not hitherto made much headway in America.

That it has not made anything like such headway as it has in Great Britain and on the continent of Europe is an undoubted fact, however, and may be, I think, in part accounted for by the magnitude of the vested interests concerned in the perpetuation of the method of traction by horses. These interests had grown up and had attained an enormous development before the question of possible traction by mechanical motors had assumed very serious proportions, and I have no doubt that, indirectly, they have combined to divert both capital and inventive talent from expending themselves in this direction.

However this may be, it appears a fact beyond question that if length of mileage and the number of hands employed were to determine the issue, the judge's fiat would have to be, to paraphrase a sporting term, horse traction first—the rest nowhere!

But numbers alone are not argument, and cannot be received as the sole determining factor in so many-sided a question. Various other points, sooner or later, prompted engineers, both in America and elsewhere, to enquire whether, after all, sundry difficulties which working with horses gave rise to could not be avoided by substituting mechanical power for animal traction. Among the difficulties which first prompted inquiry, and then stimulated invention in America and elsewhere, but more especially in Great Britain and Europe, were the difficulties of keeping up the supply of suitable horses. It was found, just as in ordinary omnibus traffic, although in a less degree, that the severity of the straining effort required to start a car full of passengers told so severely on the horses that from thirty to twenty-five per cent. of the horseflesh had to be renewed yearly after the first three or four years. This fact also stirred up the subject
from a humanitarian point of view, which was not without its influence among thoughtful, educated men. One or two epidemics of disease among omnibus or tram-horses also had their effect in drawing attention to possible inconveniences, as had also difficulties connected with stabling, attendance, and the price of forage.

The result has been that during the past twenty years or more, many hundreds of inventions have been patented, and many thousands of pounds have been spent in endeavouring to find some satisfactory method of drawing tram-cars through streets by mechanical power, which should be free from the inconvenience of horse traction, and at the same time cheaper to use. Most of these inventions have belonged to one or other of the classes which follow. How far the cable, or any one of them, can make good its claims to be advocated as suitable for employment on Melbourne Tramways, so far, at least as this Association is concerned, must depend on the inherent qualities of each system, and upon how far its advocates are able to bring out its good points, and to defend it from attack in the debates which, I hope, will now ensue.

Second on our list, we may place the underground cable system, which is freely spoken of outside as practically already adopted for several of the Melbourne tram routes.

The supporters of this system do not claim that it is cheap in first cost; but the main point which they insist on is that the large prime outlay necessary is more than compensated for afterwards by the great saving in working expenses. It will be for those who advocate this system to establish the truth of this position. Just at present, I believe, a strong conflict is going on in New York between the advocates of the cable system on the one hand, and those of the elevated railroads on the other. We may possibly learn a good deal if we can manage to follow the arguments, pro and con, which are evolved in the New York struggle. I have not brought the system of elevated tramways or railroads into the list for our consideration, because Melbourne streets are so wide that there is not the same reason to fear an excess of traffic over space to anything like the same extent as has occurred in older towns.

Third on the list, and next to the cable in importance, we may place steam used in engines where it is generated by fire carried on the engine itself. This may surprise many whose knowledge of steam on tramways is confined to the snorting monsters of Sydney, but will not surprise those among us who have studied the question at all carefully, and who have followed the development of steam-motors in various countries. The record of what steam has done, and can do, will be, I dare say, well brought out
by its advocates, while there are no lack of accounts of badly-made engines and of injudicious attempts, resulting in failure, to gladden the souls and strengthen the arguments of its adversaries.

Steam may be otherwise utilised, however, than in such engines as will come under class three; and under No. four I propose to class FIRELESS ENGINES, whether they be like Dr. Lamme's or Francq's hot water engines, worked with super-heated steam, or like that most interesting and ingenious invention of Herr Moritz Honigmann, which has been lately patented in these colonies, and which utilises sundry natural and chemical effects of heat and saline solutions in a most surprising manner. Lamme's engine which was an American invention, is hardly ever heard of now. It was found, I believe, that the loss by radiation was extravagant, and that there was a great loss in transmitting the pressure from the fixed boilers to the machines, the loss from this cause alone being put down at as much as 30 per cent. Francq's locomotive system consists of a reservoir with ordinary small locomotive engines and working gear. I will endeavour, when we reach this class in our debates, to give a fuller description of the manner in which the engines are charged from the reservoirs, and as to the results obtained.

As regards Herr Honigmann's invention, it is also most interesting, and several engineers look to find in it a solution for all the difficulties which have hitherto beset the working of tramways by mechanical power. It is claimed for it that it works without any loss of steam whatsoever, as the engine is being continually fed and heated by its own exhaust steam. This sounds paradoxical, but I shall hope on a future occasion, and when more time is available, to give such a description of this engine, with a few diagrams, as will make quite clear how these very wonderfully-sounding results are obtained.

In Class five, I think we may place GAS ENGINES, which have been tried at various times and by various inventors, but without I think, ever obtaining any very extensive support. Possibly however, the stimulus lately given to the gas industry by the competition of electricity, may have evolved some fresh inventions and if so, doubtless we shall hear of them.

In Class six, we come to COMPRESSED AIR, and we may hope for able advocacy and also for a good debate on this. Without further alluding to talent that we know of among our own members, I may mention the compressed air-engines of Col. Beaumont, of Moncrieff, and of Mékarski at Nantes, while in America also most important experiments have been carried out at enormous pressures. Col. Beaumont, of the R.E., whose name is well known to most engineers in connection more especially with this particular subject, claims to have obtained most satisfactory
results, and that by the expenditure of from $\frac{3}{4}$ lb. to 1 lb. of coal he can take three tons one mile on an ordinary level railway, or develop six horse-power for one minute under a dynamometer. In his latest form of engine, heat is supplied to the air during expansion, whereby he claims that the store of energy received from the original source is supplemented. He further claims for his engines that they are noiseless, smokeless and cleanly; that they offend neither the ear, the eye, nor the nose; and also that they offer greater facilities than does, for instance, steam, for overcoming the difficulty of combining engine and car together in a satisfactory manner. All these points, together with the objections to be set down per contra will, no doubt, be plainly developed to our minds as we proceed.

Seventhly, and lastly, we come to electricity, and I place it last, though not least in importance, because it certainly, in its most improved form, is the most modern and the least understood of the various developments of energy hitherto experimented with.

It is not long since we saw a miniature railway worked by its means, and heard from one of our members something of what had been done in this direction. We shall now hope to hear from its advocates what further developments have taken place, while its opponents will no doubt tell us of its weak points and its dangers, past, present, and future. On this head then, also, we may, I hope, anticipate some lively and instructive discussion.

Even this introductory sketch, Mr. President, has drawn me on to greater length than I anticipated when I commenced, and I must postpone the further development of my introductory remarks to our next meeting.
In my previous paper I promised to set forth those conditions which I believe to be generally accepted now as worthy of insistence, when commencing to regulate the haulage arrangements for any and every system of street-tramways. If these conditions are shown to be of general application, it follows that unless we can show special cause why an exception should be made in the case of Melbourne, we must accept them for our guidance in this discussion, and put on one side, as out of court, any methods of haulage which ignore or contravene them.

I would, however, wish it to be clearly understood that, in laying down these conditions, I have no pretensions to think that they must, of necessity, be accepted for the guidance of the debate. If any member disagrees with the views which I now enunciate, Mr. President, I sincerely hope that his objections may be urged with all possible force and clearness, for I take it that one object in starting these discussions is that, through the workings of many minds, we may arrive somewhere near the truth as regards the practical experience about tramway traffic, which has been obtained in various localities.

I shall have, bye-and-bye, a few words to say as to the roadway upon which our cars are to be pulled in some manner yet to be determined; meanwhile, we come to the conditions before alluded to, and which have, of course, for their main object, that of regulating the adoption of any form of mechanical traction.

As regards animal traction, very little further regulation is necessary than already exists, and the advocates of this form of haulage will, no doubt, lay due stress on that fact; but when we come to speak of mechanical tractions, it is quite another matter.

On railways, which are fenced in and protected from the public, speed and economy are our main objects; but it must be manifest to all that it would never do to allow railway trains to run promiscuously through our streets. So far, in Melbourne, our experience of mechanical traction in streets has been confined to the Corporation steam-rollers, and to the occasional slow trains crawling on the very rough track along Flinders-street, which connects the Spencer-street Station with the suburban lines of railway. As was pointed out in my previous paper, mechanical traction may be applied in various forms; in all of them I submit that the following conditions should be rigidly insisted upon:

Firstly.—Each car, or combination of cars, should only occupy a reasonable amount of street space; say as much as an ordinary two-horse tram-car with horses attached.
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Secondly.—All moving or working parts should be so far concealed from view as not to frighten horses nor to annoy passers by.

Thirdly.—The weight per wheel should not exceed that allowed in good horse-cars.

Fourthly.—The tractive force available per car should be greater than that of two horses, for it should be sufficient to take fifty people or more up considerable gradients.

Fifthly.—The cars must be drawn, if necessary, round curves of fifty or forty-five feet radius.

Sixthly.—The brake power must be strong, simple, and effective.

Seventhly.—No steam must be shown, neither must any smoke be visible.

Eighthly.—There must be no puffing nor other objectionable noise audible.

Ninethly.—Not more than two attendants should be required by any one car and its motor.

If these conditions can be adhered to it seems to me simply a question of humanity and of economy in working, whether animal or mechanical traction is to carry the day.

It is manifest that if we are to give due attention to the foregoing conditions, we must know what routes we have to follow in our working, and what gradients there are to be overcome. The substructure of our roadway, too, whatever system is adopted, must be more or less affected by the nature of the soil. From what I have been able to learn, although on this point I would like to be better informed, I gather that along many of the selected routes, the subsoil is of a clayey nature, and retentive of wet. Whether it be so or not, the proper drainage of the substructure is a matter of the very greatest importance, particularly if cable traction is to be provided for. As regards the routes to be followed, and the ruling gradients on those routes, I am able, thanks to the courtesy of the engineer to the Tramways Trust, to give you accurate information on that head.

On Main Line No. 1, which we may call the Spencer-street Railway Station and Fitzroy Line, and which has a length of 3 miles 61 chains, the maximum gradient occurs in Bourke-street, and ranges from 1.17 to 1.21 for about 20 chains.

There are a number of branches proposed from this line; some eight altogether. Of these

Branch No. 1 is 11 chains in length, with gradients varying from 1.33 to 1.47.

No. 2 is the Collingwood and Clifton Hill Branch, and it is 2 miles 39 chains in length, with gradients ranging from 1.16 to level.
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No. 3 is the Simpson’s Road Branch, and is 2 miles and 50 chains long, with a maximum gradient about 12 chains long of 1·19 to 1·21.

There is a sub-branch to this line about 19 chains long.

No. 4 is the Brunswick Branch, and is 4 miles 18 chains in length, on which the maximum gradient is 1·34 for about 18 chains.

No. 5 is the Hotham Branch, and is about 2 miles 5 chains long, with a maximum grade about 2 chains long of 1·17.

No. 6 is the West Melbourne Branch, and is 1 mile 12 chains in length, with a maximum gradient in Lonsdale-street of 1·16 to 1·21 for about 7 chains.

No. 7 is the Lonsdale-street Branch, and is 74½ chains long, with a maximum grade 23 chains long of P19.

No. 8 is the Nicholson-street Branch, 1 mile 50 chains long, with a maximum grade, 7 chains long, of 1·21 to 1·23.

Main Line, No. 2, is the Hobson’s Bay Station and Carlton Line, and is 8 miles 18 chains long. The maximum grade on this line is about 10 chains in length of 1·21 to 1·24.

There are three Branches proposed from this line—

No. 1 is the Richmond Branch, 2 miles 60 chains long, with a maximum grade in Wellington Parade of 1·19, about 4 chains long.

No. 2 is the Flinders-street Branch, 71 chains long, with a maximum grade in Spencer-street of 1·18 about 50 links long.

No. 3 is the North Carlton Branch, 55 chains long, with a maximum grade of 1·39 about 1 chain in length.

Main Line No 3, is the South Yarra and Prahran Line (to St. Kilda Esplanade), and is 5 miles 40 chains long. The maximum grade on this line is 1·19 to 1·23 in Toorak-road about 3½ chains in length.

There are 2 branches proposed from this line—

No. 1 is the Toorak Branch, and is about 1 mile 27 chains long, with a maximum gradient in Toorak-road of 1·15 to 1·22 for a length of 18 chains.

No. 2 is the St. Kilda Branch, and is 2 miles 46 chains long, with a maximum grade in High-street of 1·17 to 1·24 for a length of 18 chains.

Main Line No. 4 is the Sandridge Line, and is 2 miles 38 chains long. The maximum grade on this line is 1·22 to 1·26 in Moray-street North about 5 chains long.

There are 2 Branches proposed from this line—

No. 1 to the stables.

No. 2 is the South Melbourne Branch, and is 1 mile 61 chains long, with a maximum gradient in Park-street of 1·45 for a length of about 11 chains.
There is a sub-branch to this line 21 chains long. Main Line No. 5 is the Hawthorn and Kew Line, and is 1 mile 34 chains long. The maximum grade on this line is 1.17 for a length of 7 chains in Power-street.

These details are sufficient to permit of some estimate being made of the amount of power likely to be required in carrying the traffic on these routes; but there is yet another point which requires consideration, and which is intimately connected with tramway haulage, and that is the nature of the roadway on which the cars which carry the travelling public have to run. And it is not the travelling public alone, or the shareholders of the company only, who are interested in this matter, and who have a right to consideration; but we should consider the general public also, and especially those who dwell or have shops, &c., along the lines of route.

Upon this point I find nothing to alter in the opinions which I have already once or twice expressed when writing upon this subject, viz.:—

That before tramways are fairly set working, it behoves us to inquire how far the public safety and convenience are borne in mind by those who are to construct them. Not only companies and corporations, but the members of the general public also, are far more interested, and have far more right to a voice in the matter, than is generally conceded to them. If a company constructs a railway badly, either from mistaken ideas of economy, or from defective professional advice, it is the company who suffers, and the loss falls upon the right shoulders; but, in the matter of street tramways, faulty construction of the roadway entails loss and inconvenience to everyone, more or less, along the line of route, besides immense extra wear and tear to private vehicles, hindrance to traffic, and, frequently, serious danger to life and limb. These points have, as far as I am aware, been ignored or carelessly overlooked in many tramway acts that have been passed. I hold the view, however, that every tramway bill should contain a clause putting it beyond the power of anyone, either director or engineer, either Government or Corporation, to adopt any system of tramway construction in which the true interests of the ratepayers, and of the public who use the streets, do not receive due attention.

It is perfectly well known to students of tramway history that certain recognised principles are now generally accepted by good tramway engineers as obligatory and necessary, if a really good tram roadway is to be secured.

Now, without going into the details of the defects of many of the existing tramways throughout these colonies, it will suffice to point out the leading conditions that should be insisted upon in
all street tramways. I say insisted upon, because it is manifestly wrong that the streets, which are the citizens' property, and their special means of inter-communication, should be cut up, or blocked up, or interfered with one single atom more than is absolutely necessary for the general convenience.

It is manifestly wrong that a body of directors, or an engineer, should have the power to put down a roadway which must inevitably require frequent repairs and renewals, to get at which the streets must be picked up, the general traffic interfered with, and an extra amount of dust and dirt created, which must prove not only damaging to shop goods, but injurious to health as well.

This being so, it is manifestly right that the leading principles of a really good roadway should be definitely formulated, and not only so, but that they should be embodied in a clause which should be compulsory in every Tramway Act that is to be passed. I am far from claiming that perfection has been attained; but certain progress has been made towards perfection, and no retrogression should be allowed.

The construction of street tramways always does, and always must, bring some evils and some slight inconveniences in its train; but these should be reduced to a minimum, and it is unpardonable to allow these evils to be increased by the employment of an inferior or a faulty system of roadway. Continual repairs, such as we see going on on most street tramways, wherever there is a heavy ordinary traffic, are a pest and a nuisance to all, and any system which involves picking up the street for ordinary repairs or renewals of rails, must be looked upon as reprehensible.

When the streets are paved with stone or wooden setts, I believe all cross-sleeper systems to be objectionable, because, for one reason, they entail too much excavation in the body of the street; for another, they inevitably offer obstacles to a good union with the street paving, a point of much importance. Wooden cross-sleepers are especially objectionable, because, it is held to be wrong in principle to imbed a perishable material such as wood in an imperishable foundation such as concrete, to support a track made of durable metal. It is an incongruity which has frequently been adopted simply for the sake of the sleepers acting as tie bars to keep the gauge. As foundations, where there is already a good concrete foundation, they are useless; and all first-class tramways should have concrete foundations, because, over all first-class tramways, that is to say, over all tramways which have to carry a large number of passengers through busy streets, there is a considerable ordinary street traffic as well, and good paving becomes a necessity. It becomes
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a necessity in nearly all cases in order to save expense by protect- 57. ing the roadway from the effects of ordinary street wear and tear, and more especially in the case of horse-tramways, because of the additional wear and tear resulting from the tramway horses themselves.

If a concrete foundation be not used, and especially if the drainage be not very perfect, sooner or later the vibration imparted to the cross-sleepers produces little boggy patches underneath them, and the track gives way with the adjoining pavement.

All the best tramways are now adopting a continuous bearing for their rails. Wooden continuous bearings, in the form of long beams, such as were used with the box-rail, where the rail- joint came on the wood itself, or on a joint plate, are no longer in favour except for very light traffic.

Many systems have been devised of so-called girder-rails, which form practically a rail and continuous support in one; but in order that the rail may rest on a firm foundation with the pavement, it must be at least as deep as the paving setts. This necessitates a heavy weight and corresponding cost, while, when the rolling surface is worn out, the street must be pulled up to get the rail out, and a large amount of metal goes to the scrap-heap. Some of these systems, too, are rolled with outward sloping sides or flanges, so as to get a broad base. This means that the paving setts adjoining the rail must be more or less wedge-shaped, so that vibration soon loosensthem, and then also those adjoining them. No matter how good a system may be in other respects, it should be rejected if it appears at all probable that the pavement, or the adjoining roadway will have to be disturbed for the purpose of tightening up fastenings or of renewing rails, and any system which involves frequent disturbances, whether of pavement, of asphalte, or of macadam, is, therefore, to be avoided.

If it were a point of contention merely as to whether longitudinal or intermittent supports were to be allowed, no doubt many cases might be quoted where intermittent supports have done good service; but when we see that Kincaid, for instance, has found it necessary to extend the bearing surface of his chairs, so as to obtain what is practically a longitudinal sleeper, but having the rails supported at intervals only, it seems strong presumptive evidence in favour of a continuous bearing surface.

Again, if we look at Barker's system, we find a continuous bearing surface which, with the rail, amounts to 244 tons of metal per mile. But, in either of these systems, and I quote them because they have both been much used, to get at the fastenings it is constantly found necessary to pull up the road-
way alongside the rails. Deacon's system, which is in use in Liverpool under very heavy traffic, gets over this objection, and remains at the same time one of the best roadways now in use in England, but it is very expensive and troublesome to lay.

The conditions laid down by the well-known Liverpool city engineer may be fairly adopted as embodying the practical outcome of tramway experience. and—for the colonies, where we have to import our rails—leaves only one additional point to be desired, viz., a reduction in weight. The gentleman in question, Mr. Dunscombe, whose opinions are confirmed by those of other experienced engineers, both English and foreign, maintains with regard to first-class tramways—

1. That the foundation should be concrete.
2. That the support to the rails should be practically continuous.
3. That the rail, with its support, should be held or anchored down to the concrete foundation by suitable fastenings.
4. That we should be able to remove and replace a rail, or to tighten up fastenings, without disturbing the pavement; and
5. That the longitudinal sleepers or supports for the rail must present laterally a true vertical face, free from all projections, so as to admit of close paving on each side of the rail.

If these general conditions are firmly insisted upon, minor details such as material, weight of rails, width of groove, depth of paving sets, &c., may fairly be left to the engineer's decision in each particular case. Where, however, metal-work has to be brought some 16,000 miles, freight is an item of considerable importance; if the item of duty has to be superadded, and with freight and landing charges, has to be taken into consideration by the shipper, cost f.o.b. at home, becomes correspondingly increased, and looking at the great weight of the continuous, or almost continuous, iron sleepers in use in Liverpool, it must be held that some superstructure which will combine the good points of Deacon's system with a notable reduction in weight is much to be desired.

The Gowan and the Barker rails are perhaps the most extensively used patterns, and they illustrate the two principles of renewable wearing surface only as opposed to a general renewal. Both are heavy and costly. In Europe, owing to the present low prices of metal, and to the saving in trouble which it effects, the Gowan rail is being more and more universally adopted. A glance at the section shows that as regards strength, it not only suffices, but largely exceeds any demands which can possibly be made upon it. In all grooved rails, however, of course the duration of the rolling surface is limited by the depth of the groove, and some time or other renewals
become necessary. Should the price of metal rise, it might therefore become a very serious matter for shareholders; while in any case, at this distance from manufacturers, the item of freight is always to be considered.

The troubles caused by repairs and renewals have hitherto been one of the greatest sources of loss to and prejudice against tramways, and I will therefore just mention two systems in which the pavement need never be disturbed after the rails have once been properly laid down.

These are the Deacon and the Channel-rail systems. The Deacon rail has stood the test of the heaviest traffic in England—that of Liverpool; it is doubtful, in fact, if any tramway in the world, except perhaps that in Tenth Avenue in New York, has to stand heavier shocks and jars from the ordinary street traffic. It may here be appropriate to remark that it is not only the traffic of the tram-cars themselves that tells upon the roadway, although that may be terribly severe if a system of haulage be permitted where very heavy loads have to be moved rapidly by mechanical means. The wear and tear resulting from such a traffic as is carried daily, for instance on the rails in Elizabeth-street, in Sydney, is something which must be seen and studied to be realised; but this kind of wear and tear can nearly always be reduced by a judicious reduction of speed, and of the moving load allowed. The wear and tear which tramway proprietors dread most comes from ordinary heavy-wheeled vehicles, such as drags, waggons, and lorries driving over and along the line. It is this which renders it necessary to expend so much money and ingenuity in securing strength and solidity in our roadway.

A glance at the drawing which represents the so-called Channel rail will make it clear, however, that strength and solidity may be secured, together with all the other advantages of the Deacon system without having to pay freight on such a considerable weight of metal.

The Channel rail has not yet received a sufficient trial to warrant my speaking with absolute certainty as regards its lasting qualities, but I can see no reason to doubt them. I am, however, personally interested in it, and I therefore prefer reserving any further statements regarding its qualities for some more suitable occasion, when I may feel freer to advocate what I believe to be its claims to take a premier place in any first-class tramway system.

I have now, Mr. President, to the best of my ability carried out my promise to introduce the subject of haulage on the Melbourne Tramways. I feel deeply how imperfectly I have treated my subject, and I can only reiterate what I said at the
that of the iron only, and many reasons were assigned for the failure, of which I place a few in rotation:—

(1) That the material and workmanship were defective.
(2) That the tube, instead of being built absolutely horizontal, had been built with a camber.
(3) That the flanges had been improperly put on not at right angles to the tube, and that the injury had been caused in screwing them up to make the joints.
(4) That the joints had been destroyed by the expansion and contraction of the suspension rods.
(5) That the flanges were fractured by the turning round of the tube in the saddle rollers.

It was proved, however, that the material and workmanship could not be found fault with, and that the tube had not been constructed with an excessive camber. The camber at time of construction would appear to have been about 2-in. in the centre.

It was shown also that the tube had been made in 3-ft. lengths adjoining the flanges, with turned butt ends, and that the flanges were riveted on truly at right angles to such 3-ft. lengths, and that no undue strain had been used to bring the joints together by bolting; and it was proved that the upper joints were all tight, and some of them excessively so, whilst the lowest joints were in some cases from \( \frac{1}{2} \)-in. to \( \frac{3}{4} \)-in. open.

These facts having been satisfactorily demonstrated, there was no conceivable force at work to destroy the tube but that of the expansion and contraction due to change of temperature, and it was necessary that should have adequately occurred between the 6th and 8th of February, 1883.

Even then it did not appear why the peculiar results shown by the excessive fractures in the joints adjoining the stone piers should have occurred.

Whilst engaged on this case, however, I plotted the line of pipes as shown by the levels taken in June, 1883, and roughly drew the line I imagined the pipes would assume on a change of temperature with such a result that the work was re-performed in a more accurate manner, leading me to the, in my opinion, irresistible conclusion that the alteration of temperature I assumed of \( 85^\circ \) would account for the whole injury.

Inquiry was made at the Observatory, when it was found that between the 6th and 8th February, 1883, the variation of temperature amounted to \( 110^\circ \).

Had the tube been of similar construction throughout, as in the case of those previously mentioned as across the Yarra and Merri Creek, the alteration of temperature would have caused a regular alteration in the curvature of the tube, no part being
Deacon's Way, as laid by Mr. Dunscombe, Liverpool.

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more strained than any other; but in this case, as the tube in the 23-ft. lengths was incapable of deflection, and far stronger than the angle iron flange joints, the effect of a fall in the temperature raising the central suspended rollers was to tilt up the ends of the 23-ft. pipes towards the centre, and thus to depress the end of the length sustained on the fixed stone piers, resulting, inevitably, in the fracture of the joints of one end of the length so sustained.

That the upper joints are tight whilst the lower are open, is explicable on the ground that the alternate rising and falling of the suspended rollers loosened all the joints at some time, and whilst nothing could occur to tighten the lower joints again, the weight of the pipes themselves would tend to keep open the lower and tighten the upper portions of the circle.

It might well have happened that attention enough should not have been given to such extreme alterations of temperature as 110° occurring in 24 hours; but this result should guide us to so design works, that extreme alterations should be provided for in such manner as only to affect the work as a whole, and be distributed evenly throughout, instead of being allowed to find weaker portions such as these joints, upon which to expend the power exerted.

In this case, however good the material and workmanship, the result must have been the same, for, even after the water had been admitted, although the tube itself would have maintained a fairly even temperature the suspension rods would have remained susceptible to the variations which, for a difference of 100° of temperature, represent a rise and fall of the suspended rollers of $3\frac{3}{4}$ inches.

Appended are the calculations showing—

1. The strength of the flanges for a span of 46 feet.
2. The angular opening of the joints near the southern pier caused by a rise of the suspended central rollers.
3. The effect on the tie-rods of alterations of temperature and alteration of camber.
4. The effect of torsion in turning round the pipe.

These calculations show that if from any cause the tube so varies from the horizontal that beam action comes into play the flanges are incapable of resisting the tension brought upon the lower portion of the angle iron, and a certain amount of that action must have arisen from the unsupported weight of the half length of tube at each end, destroying the principle of balance upon which the tube was evidently designed.

And a further calculation shows that the effect of a rise in the central rollers of $3\frac{3}{4}$ in. would produce an opening in the lower
portion of the flange of the joint adjoining the pier of about ¾ in.,
to counteract which there is but the ¾-in. thick flange which has
collapsed under the strain.

Sketches showing the principle of construction of the tube,
and diagrams of the altered positions of the lengths at different
temperatures, and of the condition of the tube when examined
in June are attached, to enable the foregoing to be more readily
followed.

In the course of the investigation into the causes of the
failure a suggestion was made that it might have been prevented
had inclined compensating planes or wedges been introduced
under the tube on which the suspended rollers would run,
constructed to such an angle that the change in vertical height
of the suspended roller would be compensated by the different
thickness of the plane or wedge, but as the height to provide for
reaches 4 in., whilst the variation in length of the horizontal tie
between the suspended rollers to only 0.0322, it follows that the
angle of the inclined plane would be so very steep that it is
doubtful if such compensating arrangement could be made to
answer the purpose.

It appears to me that the only method by which the tube can
be rendered satisfactory is to construct it of equal strength
throughout its length, which might be effected by means of
thimbles and rings, but that no attempt to continue the system
of bolted flanges will prove efficent.

R. H. SHAKESPEARE.
STRAIN ON FLANGES.

Weight of 23-ft. pipe not water loaded, 2 tons 7 cwt., the greatest deflection for a span 46ft. = 0.036in. if the joints were iron to iron, or practically nil; thus all deflection is in the compressibility of the india-rubber joints.

If the india-rubber insertion compresses on top, a far greater strain is thrown on the lower bolts. If beam action comes into play, and if the compressibility were continued, all strain would be in tension on the bottom bolts and flanges.

As the india-rubber does compress, this must partially be the case.

If the tube did not follow the rollers, or remained rigid, so as to be lifted off the pier rollers, so as to render the tube a beam with a span of 92-ft., collapse would immediately take place, for the strain on lower web of angle iron near the root, would rise to nearly 70 tons per square inch. This, however, could but partially arise.

STRAIN ON FLANGES ON END SPANS BETWEEN PIERS AND ABUTMENTS.

One end not balanced, and the other end, owing to the great camber due to the original camber added to rise due to alteration of temperature, and not treated as a continuous beam, but as a beam supported at both ends and uniformly loaded to extent of weight of metal only.

Span 46·0 \( W = 5 \) tons \( w = 0.11 \) tons per foot \( x = 11.5 \) feet.

\[
\text{Moment} = - \frac{w}{2} \left( \frac{L^3}{4} - x^2 \right) = 0.055 \times 397 = 21.88 \text{ tons.}
\]

The tube being cylindrical and bolt diameter 81-in., and compressible packing between flanges, take the five lowest bolts as supporting the strain:

Diameter 2-ft. 6-in., tension on bottom \( \frac{21.88}{2.6} = 8.4 \) tons.

Bolt centre 1\( \frac{1}{4} \)-in. from line of pressure near root of angle-iron, web 8\( \frac{8}{16} \)-in. thick.

Leverage \( 1\frac{1}{2} = \frac{24}{16} = \frac{3}{16} \) or 8 to 1.

Tension at root = 8.4 \( \times \) 8 = 67.2 tons.
Distance between bolts, 8·125-in.
Notes on the Merri Creek Tube.

To resist this the area of iron is—

\[
5 \times 3.125 \times 3/16 = 2.93 \text{ square inches.}
\]

\[
\frac{67.2}{2.93} = \text{nearly 23 tons per square inch.}
\]

Even if seven bolts be accepted as sustaining the strain, the area of angle-iron is but 4.1 square inches, and strain over 16 tons per square inch; and this strain is placed on angle-iron which, through rolling and bending, is deteriorated, and in addition, the stress is across the line of fibre of the iron.

MERRI CREEK TUBE
(as per Diagram.)

Assume a change of temperature of from a summer day at, say 142° to a winter day at, say 57°: or a total change of 85°. The difference in rise of the suspended rollers will be 24 inches, and vertical change at joint, No. 9, 1\(\frac{1}{8}\) inches in 11 feet 6 inches, or \(\frac{1}{8}\) inch.

\[
\sin \theta = \frac{11}{23} \times 12 = 0.005 \theta = 0°20'\]

Opening of joint DB = DA \times \tan \theta

DA or outer diam. of flange of pipe = 3 feet.

DB = 36 \times 0.00581 = 0.209 of an inch, or \(\frac{1}{8}\) of an inch opening of the flange for a change of temperature of 85°.

It must be remembered, however, the extreme alteration of temperature exceeds this by quite 15°, and thus the joints will have opened to full half an inch.

EXPANSION AND CONTRACTION.
Notes on the Merri Creek Tube.

Expansion for $100^\circ = \frac{100}{180} \times 0.00122 \times 98.084 = 0.0665.$

$46^\circ + 14^\circ = x^2 = 2312 \quad x = 48.084$

$\text{CB - expanded} = 48.084$

\[ \frac{0.0665}{48.15} \quad (1) \]

Expansion on BD $= 23 \times \frac{100}{180} \times 0.00122 = 0.0156$

$\text{BE} = 46 - 0.0656 = 45.9344.$

$\text{EC} = 48.150^2 - 45.9344^2 = 14.27$

Rise on suspended rollers for $100^\circ = 0.27\text{ft.} = 3\frac{1}{4}\text{-in.}$

or, $1\frac{3}{4}\text{-in.}$ for $50^\circ$ alteration.

or, $2\frac{1}{4}\text{-in.}$ " 75° "

The expansion on half the length of the tube between the piers, due to a change of temperature of $85^\circ = 46 + 23 = 69$ feet.

$69 \times \frac{85}{180} \times 0.00122 = 0.040\text{-ft.}, \text{or nearly} \frac{1}{2}\text{-in.}$

CAMBER.

If the tube were built at a temperature of say, $142^\circ$ summer noon with a camber of $2'$, the increased camber for a difference of temperature of, say $60^\circ$, would be $2\frac{1}{8}''$; or total camber on a winter noon, $4\frac{1}{4}''$; or at a temperature of $32^\circ, 6\frac{1}{2}''$.

The actual camber in July was $4\frac{3}{4}''$, as measured by Mr. Dowden; and thus it would appear that the camber, when the tube was built in February, could not have exceeded $2\text{in.}$, the amount directed by the Engineer.

TORSION.

The pole used was 16-ft. long, projecting 2-ft. over centre of tube and 1-ft. beyond the fastening.

Tube, 2' or 3' diam.

Leverage \[ \frac{19.0}{2.3} \; \text{say 6 to 1.} \]

The utmost weight that the four men employed to turn the tube round could exert would be

$4 \times 11 \times 14 \times 6 = 4082 \text{ lbs.}$

which would be the utmost shearing force upon the tube if it were fixed and could not turn round.
Notes on the Merri Creek Tube.

The shearing resistance of the angle iron flanges—
10 angle irons \( \times 2 \times 3'' \times \frac{3}{8} \times 2 = 45 \) sq. inches.
Safe shearing strain 3 tons per square inch or 185 tons, or the resisting safe limit was about seventy times the force four men could apply if distributed over all the joints. If, however, the force be assumed as affecting two joints only the resistance would still be fourteen times the power exerted. It is therefore impossible that these four men in turning round the tube in the rollers could have broken the flanges.

The power required to turn the tube in cylindrical rollers, three feet diameter, would be as follows:—Angle of repose 10°, versed sine 0.276, or the vertical height necessary to raise the tube so as to slide round. Sine = 3" or the horizontal distance. At the point 3", distant horizontally from the perpendicular through bottom of tube, and 0.276 above it, the tube will turn. Total weight of tube = 23.5 tons to be raised, 0.276 feet in a minute = 1185 lbs. raised one foot high in a minute, equivalent to four men at end of the pole, each exerting a force of 50 lbs. with leverage of 6 to 1.
PART I.

PAPER ON TRAMWAYS

CABLE VERSUS HORSE OR OTHER MOTIVE POWER.

By Captain F. C. ROWAN.

Mr. President and Gentlemen,

The subject which I have been asked to introduce to your notice to-night, is that of Cable Traction versus Other Motive Power for the Haulage of Traffic on Street Tramways, and it is undoubtedly a subject at the present moment, not only of great technical importance, but also of great public interest.

I could have wished that some gentleman of large engineering experience, and whose utterances could claim a right to more attention than can possibly any of mine, should have been asked to open up the discussion on so important a matter. It may be, however, that we shall ultimately obtain that information which we hope to elicit, in a more clear and crystallised form, by hearing the opinions of such experienced gentlemen expressed separately and definitely upon each subdivision of our subject as it arises, than if a thoroughly detailed and critical dissertation were undertaken on all forms of haulage collectively at first. To deal in an opening paper thoroughly, with all the different forms of traction recommended for tramway use by different experts, would be manifestly confusing and impossible. The subject is a large and a complex one, and it demands a systematic treatment from the outset if we are to produce any definite and useful result as an outcome of the discussion, which I think not only we, but a good many outside friends, are looking forward to with so much interest.

Before, however, attempting to touch the technical portion of my paper, it may, perhaps, be considered not inappropriate to dilate slightly upon the advantages, or the reverse, which may accrue to this Association in particular, and to the public in general, from the initiation of discussions upon this and upon other cognate subjects at these periodical meetings of our body.
It was considered by the Council, and I think with reason, that there are at the present juncture several questions before the public which are connected with engineering, and the proper carrying out of which would be benefitted by that thorough ventilation of them, in their various aspects, which might be expected to take place in a discussion carried out on definite lines by a body of technical men.

There can be no doubt, I think, that such discussions, whether they be upon compilations of useful information collated from outside sources, or upon original papers written by competent members of our own body are, if properly conducted, of benefit from most points of view.

The present moment seems a particularly appropriate one for initiating such a discussion on tramways, and we hope that it will enable us, from the accumulated stores of information which we may reasonably hope to find among our members, to form some idea of the practical results as regards different forms of traction which have been obtained both in these colonies and in other countries.

We cannot, I think, except in one particular direction—viz., that of cable traction—hope at present to learn much from practice in these colonies as to what system to follow, though we may easily see in different places a good deal that ought to be avoided.

This is hardly to be wondered at when we remember that the undertakings which have been gone into in these colonies, in the way of tramways, have all so far been on a comparatively small scale, and, if we except the so-called tramways of Sydney, which were built and which are worked by the Government, but which are practically street-railways, they have been nearly all injuriously affected in their inception by an insufficiency of funds for construction.

It seems, therefore, probable that in order to enable us to arrive at some definite conclusion from the discussion to which I am asked to give the initial impetus this evening, we can mainly only hope, in the natural order of things, to receive communicated or compiled information which has been derived from sources outside these colonies.

If the information communicated to us, however, be of such a nature, and from such sources as to enable us to feel confident that due care has been taken in ascertaining its reliability, before passing it on, and if we proceed to our discussion upon definite and preconcerted lines, there can be little doubt that we ought to arrive ultimately at some definite and useful conclusion.

The title of the subject, as it was given to me, was—
Tramways.—Cable versus Horse or Other Motive Power.

Now, I need hardly say that dealing with such a subject as this in a general way opens up an enormous field for argument and debate.

To deal properly with such a topic in general terms, to discuss fairly the different forms of motive power which have been and are still upon their trial, would involve the employment of an amount of time and research which, I think, we hardly have at our disposal.

I prefer, therefore,—taking into consideration the spirit of the intention with which the Council suggested the initiation of these discussions, and the fact that we want to arrive at some practical results to the benefit of our fellow-citizens, to assume that the question which we have to consider is rather: What form of traction for street-tramways—cable, horse, or other, is the most suitable for use on the Melbourne tramways? and here I may point out at the outset that it is not my intention to-night to advocate any one particular system for universal or general application.

The more one investigates the question of tramway traction the more one finds that the conditions which affect it are always many and varied, and that what is admirably adapted to one place is very likely utterly unsuited to another. For instance, it is held by many people who have devoted much time and attention to the matter, that there is nothing in the world which, on the whole, can compare with horse-traction, and they have doubtless in many instances strong reasons for their belief; at the same time I have reason to believe, from the results which I have actually seen, and from information which I hope will be duly communicated to us, that several forms of mechanical traction are more economical in nearly every sense of the word than horse-traction under many very ordinary conditions, if not generally preferable to it in other respects also.

Again, the advocates of compressed-air have claimed universal superiority for their method of haulage, and here again, under certain conditions, they may be right; in fact every kind of traction which I shall presently proceed to enumerate has its warm partisans and advocates who will, as a rule, be found able to give some sound and weighty reasons for the opinions held by them.

The practical engineer, however, who has to deal with these subjects, and who has not only to construct lines, but to devise paying methods of working them, finds in the course of his practice that in this, as in other matters, circumstances alter cases; under certain conditions horse-traction undoubtedly
answers admirably, but so does wire-cable under certain others; similarly, also, with steam and with compressed air; so also, possibly, with fireless engines of different kinds, with gas or with electricity; in fact it seems that out of the hundreds of different methods which have at different times been proposed for using applications of mechanical force, one exponent or so, of almost each species, or system, has some really practical advantages to recommend its employment, under certain special conditions.

Now, sir, I think that our aim must be to study systematically what those conditions are, and then to try to ascertain which of those conditions predominate here in Melbourne. The time at our disposal is, I fear, too limited to allow of our expecting to get to the end of our discussion in one, or even in two or three nights, and I think it will be agreed on all hands that in discussing a subject of such magnitude, and such a many-sided one as this promises to be, a little time is well spent at the commencement in clearing the ground, and in formulating some definite plan of procedure.

To revert, then, to what I have previously said, it would naturally follow that in planning a comprehensive tramway system, when we come to the question of how to provide for the haulage of our tram-cars, we may naturally expect to find a considerable list of methods available to choose from.

I propose now, with your permission, and as an introduction to discussion, to enumerate the principal of these methods. In so doing I will ask leave to set horse-traction first, because in practice and for purposes of enumeration or discussion it is generally found more convenient to divide tramway traction into two broad classes, animal and mechanical; also because horse-traction becomes naturally first on the list, in virtue of seniority and of its more general, although possibly decreasing employment.

I shall then follow on with those modes of haulage by mechanical power, including wire-cables, which may be admitted, under proper handling, to comply almost or entirely with certain conditions, to be hereafter enumerated, and which should, in my opinion, be insisted upon, with regard to any form of mechanical traction, before the sanction of the Legislature can be reasonably demanded as a step towards its introduction.

This will, probably, I think, occupy fully as much time as I can fairly expect you to accord me this evening, and this meeting might then elect either to proceed at once to a discussion of the various systems enumerated, or it might, as I trust it will, prefer to await a further introductory development in another paper. In such a subsequent paper I should hope to be allowed to set
forth, as briefly as possible, those general conditions which will, I trust, be admitted as universally worthy of insistence, no matter what the system of haulage may be, but without complying with which no system of tramways ought to be tolerated. I would then put forward my view of those conditions which any and every mechanical device ought to be shown to fulfil before it is allowed to put forward any pretension to justify its introduction or adoption for street traffic.

It would then, I think, be advisable to describe the general physical characteristics of the Melbourne streets, and to give some details as to the longitudinal sectional configuration of the tramway routes as proposed in the Act of Parliament. I should prefer, myself, to see the discussion commence after this, taking the different forms of traction in the order in which they shall have been enumerated, and debating the merits and demerits of each one in turn, with regard to its fulfilment of the necessary conditions, and its employment in Melbourne streets.

To enable the discussion as to each method of haulage to proceed on well defined lines, and to give both its supporters and its opponents an equal opportunity of bringing forward the best and latest evidence at their command, I would suggest that the Council might be asked to formulate general rules for the guidance of those participating in these debates.

With this suggestion I now proceed to details, and, as already indicated, the first class of tractive power which we come to is that of horse-traction. This particular kind of tramway has, owing to many reasons, by far the greatest amount of mileage to show in actual work up to the present time.

It was stated in a number of the Scientific American, last year, that a return of the National Street Railway Association showed that there were then, at least, 415 Tramway Companies in the United States and Canada. These companies are said to own a length of 3000 miles of tramway lines, to employ 35,000 men, and to possess about 18,000 cars. They use daily over 100,000 horses, which require somewhere about 150,000 tons of hay, and 11,000,000 bushels of corn annually. During the last few years the number of passengers conveyed amounts to about 1,212,000,000, and the capital that is invested in all these lines is not far from £80,000,000.

This will serve to give some idea of the number of people, and also of the variety of the callings, or trades, who may have a direct pecuniary interest, quite independently of anything connected with engineering, in the question of how this or that tramway is to be worked.

Again, in a letter from a corresponding engineer who visited America last year for the special purpose of examining into the
tramway question, I learn that there are over 800 miles of tramways in New York alone. These are, nearly, if not quite all, horse-tramways.

If such be the case in America, a country which is supposed by many to be the chief source of mechanical invention and ingenuity, as well as that where the people are among the readiest to experiment, and to take up and try new ideas and methods of working, we might almost, at the onset, consider the matter as settled, and declare at once that if horses were found to be in an overwhelming majority in America, it must be because no satisfactory method of mechanical traction had yet been anywhere devised.

Such an assumption would, however, I opine, not stand the sifting of careful investigation, and we might find that there are several reasons why, except in one or two particular ways, mechanical traction on tramways has not hitherto made much headway in America.

That it has not made anything like such headway as it has in Great Britain and on the continent of Europe is an undoubted fact, however, and may be, I think, in part accounted for by the magnitude of the vested interests concerned in the perpetuation of the method of traction by horses. These interests had grown up and had attained an enormous development before the question of possible traction by mechanical motors had assumed very serious proportions, and I have no doubt that, indirectly, they have combined to divert both capital and inventive talent from expending themselves in this direction.

However this may be, it appears a fact beyond question that if length of mileage and the number of hands employed were to determine the issue, the judge's fiat would have to be, to paraphrase a sporting term, horse traction first—the rest nowhere!

But numbers alone are not argument, and cannot be received as the sole determining factor in so many-sided a question. Various other points, sooner or later, prompted engineers, both in America and elsewhere, to enquire whether, after all, sundry difficulties which working with horses gave rise to could not be avoided by substituting mechanical power for animal traction. Among the difficulties which first prompted inquiry, and then stimulated invention in America and elsewhere, but more especially in Great Britain and Europe, were the difficulties of keeping up the supply of suitable horses. It was found, just as in ordinary omnibus traffic, although in a less degree, that the severity of the straining effort required to start a car full of passengers told so severely on the horses that from thirty to twenty-five per cent. of the horseflesh had to be renewed yearly after the first three or four years. This fact also stirred up the subject
from a humanitarian point of view, which was not without its influence among thoughtful, educated men. One or two epidemics of disease among omnibus or tram-horses also had their effect in drawing attention to possible inconveniences, as had also difficulties connected with stabling, attendance, and the price of forage.

The result has been that during the past twenty years or more, many hundreds of inventions have been patented, and many thousands of pounds have been spent in endeavouring to find some satisfactory method of drawing tram-cars through streets by mechanical power, which should be free from the inconvenience of horse traction, and at the same time cheaper to use. Most of these inventions have belonged to one or other of the classes which follow. How far the cable, or any one of them, can make good its claims to be advocated as suitable for employment on Melbourne Tramways, so far, at least as this Association is concerned, must depend on the inherent qualities of each system, and upon how far its advocates are able to bring out its good points, and to defend it from attack in the debates which, I hope, will now ensue.

Second on our list, we may place the UNDERGROUND CABLE system, which is freely spoken of outside as practically already adopted for several of the Melbourne tram routes.

The supporters of this system do not claim that it is cheap in first cost; but the main point which they insist on is that the large prime outlay necessary is more than compensated for afterwards by the great saving in working expenses. It will be for those who advocate this system to establish the truth of this position. Just at present, I believe, a strong conflict is going on in New York between the advocates of the cable system on the one hand, and those of the elevated railroads on the other. We may possibly learn a good deal if we can manage to follow the arguments, pro and con, which are evolved in the New York struggle. I have not brought the system of elevated tramways or railroads into the list for our consideration, because Melbourne streets are so wide that there is not the same reason to fear an excess of traffic over space to anything like the same extent as has occurred in older towns.

Third on the list, and next to the cable in importance, we may place STEAM used in engines where it is generated by fire carried on the engine itself. This may surprise many whose knowledge of steam on tramways is confined to the snorting monsters of Sydney, but will not surprise those among us who have studied the question at all carefully, and who have followed the development of steam-motors in various countries. The record of what steam has done, and can do, will be, I dare say, well brought out
by its advocates, while there are no lack of accounts of badly-made engines and of injudicious attempts, resulting in failure, to gladden the souls and strengthen the arguments of its adversaries.

Steam may be otherwise utilised, however, than in such engines as will come under class three; and under No. four I propose to class fireless engines, whether they be like Dr. Lamme's or Francq's hot water engines, worked with super-heated steam, or like that most interesting and ingenious invention of Herr Moritz Honigmann, which has been lately patented in these colonies, and which utilises sundry natural and chemical effects of heat and saline solutions in a most surprising manner. Lamme's engine which was an American invention, is hardly ever heard of now. It was found, I believe, that the loss by radiation was extravagant, and that there was a great loss in transmitting the pressure from the fixed boilers to the machines, the loss from this cause alone being put down at as much as 30 per cent. Francq's locomotive system consists of a reservoir with ordinary small locomotive engines and working gear. I will endeavour, when we reach this class in our debates, to give a fuller description of the manner in which the engines are charged from the reservoirs, and as to the results obtained.

As regards Herr Honigmann's invention, it is also most interesting, and several engineers look to find in it a solution for all the difficulties which have hitherto beset the working of tramways by mechanical power. It is claimed for it that it works without any loss of steam whatsoever, as the engine is being continually fed and heated by its own exhaust steam. This sounds paradoxical, but I shall hope on a future occasion, and when more time is available, to give such a description of this engine, with a few diagrams, as will make quite clear how these very wonderfully-sounding results are obtained.

In Class five, I think we may place gas engines, which have been tried at various times and by various inventors, but without I think, ever obtaining any very extensive support. Possibly however, the stimulus lately given to the gas industry by the competition of electricity, may have evolved some fresh inventions and if so, doubtless we shall hear of them.

In Class six, we come to compressed air, and we may hope for able advocacy and also for a good debate on this. Without further alluding to talent that we know of among our own members, I may mention the compressed air-engines of Col. Beaumont, of Moncrieff, and of Mekarski at Nantes, while in America also most important experiments have been carried out at enormous pressures. Col. Beaumont, of the R.E., whose name is well known to most engineers in connection more especially with this particular subject, claims to have obtained most satisfactory
results, and that by the expenditure of from 3lb. to 1lb. of coal he can take three tons one mile on an ordinary level railway, or develop six horse-power for one minute under a dynamometer. In his latest form of engine, heat is supplied to the air during expansion, whereby he claims that the store of energy received from the original source is supplemented. He further claims for his engines that they are noiseless, smokeless and cleanly; that they offend neither the ear, the eye, nor the nose; and also that they offer greater facilities than does, for instance, steam, for overcoming the difficulty of combining engine and car together in a satisfactory manner. All these points, together with the objections to be set down per contra will, no doubt, be plainly developed to our minds as we proceed.

Seventhly, and lastly, we come to electricity, and I place it last, though not least in importance, because it certainly, in its most improved form, is the most modern and the least understood of the various developments of energy hitherto experimented with.

It is not long since we saw a miniature railway worked by its means, and heard from one of our members something of what had been done in this direction. We shall now hope to hear from its advocates what further developments have taken place, while its opponents will no doubt tell us of its weak points and its dangers, past, present, and future. On this head then, also, we may, I hope, anticipate some lively and instructive discussion.

Even this introductory sketch, Mr. President, has drawn me on to greater length than I anticipated when I commenced, and I must postpone the further development of my introductory remarks to our next meeting.
In my previous paper I promised to set forth those conditions which I believe to be generally accepted now as worthy of insistence, when commencing to regulate the haulage arrangements for any and every system of street-tramways. If these conditions are shown to be of general application, it follows that unless we can show special cause why an exception should be made in the case of Melbourne, we must accept them for our guidance in this discussion, and put on one side, as out of court, any methods of haulage which ignore or contravene them.

I would, however, wish it to be clearly understood that, in laying down these conditions, I have no pretensions to think that they must, of necessity, be accepted for the guidance of the debate. If any member disagrees with the views which I now enunciate, Mr. President, I sincerely hope that his objections may be urged with all possible force and clearness, for I take it that one object in starting these discussions is that, through the workings of many minds, we may arrive somewhere near the truth as regards the practical experience about tramway traffic, which has been obtained in various localities.

I shall have, bye-and-bye, a few words to say as to the road-way upon which our cars are to be pulled in some manner yet to be determined; meanwhile, we come to the conditions before alluded to, and which have, of course, for their main object, that of regulating the adoption of any form of mechanical traction.

As regards animal traction, very little further regulation is necessary than already exists, and the advocates of this form of haulage will, no doubt, lay due stress on that fact; but when we come to speak of mechanical tractions, it is quite another matter. On railways, which are fenced in and protected from the public, speed and economy are our main objects; but it must be manifest to all that it would never do to allow railway trains to run promiscuously through our streets. So far, in Melbourne, our experience of mechanical traction in streets has been confined to the Corporation steam-rollers, and to the occasional slow trains crawling on the very rough track along Flinders-street, which connects the Spencer-street Station with the suburban lines of railway. As was pointed out in my previous paper, mechanical traction may be applied in various forms; in all of them I submit that the following conditions should be rigidly insisted upon:

Firstly.—Each car, or combination of cars, should only occupy a reasonable amount of street space; say as much as an ordinary two-horse tram-car with horses attached.
Secondly.—All moving or working parts should be so far concealed from view as not to frighten horses nor to annoy passers by.

Thirdly.—The weight per wheel should not exceed that allowed in good horse-cars.

Fourthly.—The tractive force available per car should be greater than that of two horses, for it should be sufficient to take fifty people or more up considerable gradients.

Fifthly.—The cars must be drawn, if necessary, round curves of fifty or forty-five feet radius.

Sixthly.—The brake power must be strong, simple, and effective.

Seventhly.—No steam must be shown, neither must any smoke be visible.

Eighthly.—There must be no puffing nor other objectionable noise audible.

Ninthly.—Not more than two attendants should be required by any one car and its motor.

If these conditions can be adhered to it seems to me simply a question of humanity and of economy in working, whether animal or mechanical traction is to carry the day.

It is manifest that if we are to give due attention to the foregoing conditions, we must know what routes we have to follow in our working, and what gradients there are to be overcome. The substructure of our roadway, too, whatever system be adopted, must be more or less affected by the nature of the soil.

From what I have been able to learn, although on this point I would like to be better informed, I gather that along many of the selected routes, the subsoil is of a clayey nature, and retentive of wet. Whether it be so or not, the proper drainage of the substructure is a matter of the very greatest importance, particularly if cable traction is to be provided for. As regards the routes to be followed, and the ruling gradients on those routes, I am able, thanks to the courtesy of the engineer to the Tramways Trust, to give you accurate information on that head.

On **Main Line No. 1**, which we may call the Spencer-street Railway Station and Fitzroy Line, and which has a length of 3 miles 31 chains, the maximum gradient occurs in Bourke-street, and ranges from 1.17 to 1.21 for about 20 chains.

There are a number of branches proposed from this line; some eight altogether. Of these

**Branch No. 1** is 11 chains in length, with gradients varying from 1.33 to 1.473.

**No. 2** is the **Collingwood and Clifton Hill Branch**, and it is 2 miles 39 chains in length, with gradients ranging from 1.16 to level.
No. 3 is the Simpson's Road Branch, and is 2 miles and 50 chains long, with a maximum gradient about 12 chains long of 1:19 to 1:21.

There is a sub-branch to this line about 19 chains long.

No. 4 is the Brunswick Branch, and is 4 miles 13 chains in length, on which the maximum gradient is 1:34 for about 18 chains.

No. 5 is the Hotham Branch, and is about 2 miles 5 chains long, with a maximum grade about 2 chains long of 1:17.

No. 6 is the West Melbourne Branch, and is 1 mile 12 chains in length, with a maximum gradient in Lonsdale-street of 1:16 to 1:21 for about 7 chains.

No. 7 is the Lonsdale-street Branch, and is 74½ chains long, with a maximum grade 23 chains long of 1:19.

No. 8 is the Nicholson-street Branch, 1 mile 50 chains long, with a maximum grade, 7 chains long, of 1:21 to 1:23.

Main Line, No. 2, is the Hobson's Bay Station and Carlton Line, and is 3 miles 13 chains long. The maximum grade on this line is about 10 chains in length of 1:21 to 1:24.

There are three Branches proposed from this line—

No. 1 is the Richmond Branch, 2 miles 60 chains long, with a maximum grade in Wellington Parade of 1:19, about 4 chains long.

No. 2 is the Flinders-street Branch, 71 chains long, with a maximum grade in Spencer-street of 1:18 about 50 links long.

No. 3 is the North Carlton Branch, 55 chains long, with a maximum grade of 1:39 about 1 chain in length.

Main Line No. 3, is the South Yarra and Prahran Line (to St. Kilda Esplanade), and is 5 miles 40 chains long. The maximum grade on this line is 1:19 to 1:23 in Toorak-road about 3½ chains in length.

There are 2 branches proposed from this line.

No. 1 is the Toorak Branch, and is about 1 mile 27 chains long, with a maximum gradient in Toorak-road of 1:15 to 1:22 for a length of 13 chains.

No. 2 is the St. Kilda Branch, and is 2 miles 46 chains long, with a maximum grade in High-street of 1:17 to 1:24 for a length of 18 chains.

Main Line No. 4 is the Sandridge Line, and is 2 miles 38 chains long. The maximum grade on this line is 1:22 to 1:26 in Moray-street North about 5 chains long.

There are 2 Branches proposed from this line—

No. 1 to the stables.

No. 2 is the South Melbourne Branch, and is 1 mile 61 chains long, with a maximum gradient in Park-street of 1:45 for a length of about 11 chains.
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There is a sub-branch to this line 21 chains long.

Main Line No. 5 is the Hawthorn and Kew Line, and is 1 mile 34 chains long. The maximum grade on this line is 1.17 for a length of 7 chains in Power-street.

These details are sufficient to permit of some estimate being made of the amount of power likely to be required in carrying the traffic on these routes; but there is yet another point which requires consideration, and which is intimately connected with tramway haulage, and that is the nature of the roadway on which the cars which carry the travelling public have to run. And it is not the travelling public alone, or the shareholders of the company only, who are interested in this matter, and who have a right to consideration; but we should consider the general public also, and especially those who dwell or have shops, &c., along the lines of route.

Upon this point I find nothing to alter in the opinions which I have already once or twice expressed when writing upon this subject, viz.:—

That before tramways are fairly set working, it behoves us to inquire how far the public safety and convenience are borne in mind by those who are to construct them. Not only companies and corporations, but the members of the general public also, are far more interested, and have far more right to a voice in the matter, than is generally conceded to them. If a company constructs a railway badly, either from mistaken ideas of economy, or from defective professional advice, it is the company who suffers, and the loss falls upon the right shoulders; but, in the matter of street tramways, faulty construction of the roadway entails loss and inconvenience to everyone, more or less, along the line of route, besides immense extra wear and tear to private vehicles, hindrance to traffic, and, frequently, serious danger to life and limb. These points have, as far as I am aware, been ignored or carelessly overlooked in many tramway acts that have been passed. I hold the view, however, that every tramway bill should contain a clause putting it beyond the power of anyone, either director or engineer, either Government or Corporation, to adopt any system of tramway construction in which the true interests of the ratepayers, and of the public who use the streets, do not receive due attention.

It is perfectly well known to students of tramway history that certain recognised principles are now generally accepted by good tramway engineers as obligatory and necessary, if a really good tram roadway is to be secured.

Now, without going into the details of the defects of many of the existing tramways throughout these colonies, it will suffice to point out the leading conditions that should be insisted upon in
all street tramways. I say insisted upon, because it is manifestly wrong that the streets, which are the citizens' property, and their special means of inter-communication, should be cut up, or blocked up, or interfered with one single atom more than is absolutely necessary for the general convenience.

It is manifestly wrong that a body of directors, or an engineer, should have the power to put down a roadway which must inevitably require frequent repairs and renewals, to get at which the streets must be picked up, the general traffic interfered with, and an extra amount of dust and dirt created, which must prove not only damaging to shop goods, but injurious to health as well.

This being so, it is manifestly right that the leading principles of a really good roadway should be definitely formulated, and not only so, but that they should be embodied in a clause which should be compulsory in every Tramway Act that is to be passed. I am far from claiming that perfection has been attained; but certain progress has been made towards perfection, and no retrogression should be allowed.

The construction of street tramways always does, and always must, bring some evils and some slight inconveniences in its train; but these should be reduced to a minimum, and it is unpardonable to allow these evils to be increased by the employment of an inferior or a faulty system of roadway. Continual repairs, such as we see going on on most street tramways, wherever there is a heavy ordinary traffic, are a pest and a nuisance to all, and any system which involves picking up the street for ordinary repairs or renewals of rails, must be looked upon as reprehensible.

When the streets are paved with stone or wooden setts, I believe all cross-sleeper systems to be objectionable, because, for one reason, they entail too much excavation in the body of the street; for another, they inevitably offer obstacles to a good union with the street paving, a point of much importance. Wooden cross-sleepers are especially objectionable, because, it is held to be wrong in principle to imbed a perishable material such as wood in an imperishable foundation such as concrete, to support a track made of durable metal. It is an incongruity which has frequently been adopted simply for the sake of the sleepers acting as tie bars to keep the gauge. As foundations, where there is already a good concrete foundation, they are useless; and all first-class tramways should have concrete foundations, because, over all first-class tramways, that is to say, over all tramways which have to carry a large number of passengers through busy streets, there is a considerable ordinary street traffic as well, and good paving becomes a necessity. It becomes
a necessity in nearly all cases in order to save expense by protecting the roadway from the effects of ordinary street wear and tear, and more especially in the case of horse-tramways, because of the additional wear and tear resulting from the tramway horses themselves.

If a concrete foundation be not used, and especially if the drainage be not very perfect, sooner or later the vibration imparted to the cross-sleepers produces little boggy patches underneath them, and the track gives way with the adjoining pavement.

All the best tramways are now adopting a continuous bearing for their rails. Wooden continuous bearings, in the form of long beams, such as were used with the box-rail, where the railjoint came on the wood itself, or on a joint plate, are no longer in favour except for very light traffic.

Many systems have been devised of so-called girder-rails, which form practically a rail and continuous support in one; but in order that the rail may rest on a firm foundation with the pavement, it must be at least as deep as the paving setts. This necessitates a heavy weight and corresponding cost, while, when the rolling surface is worn out, the street must be pulled up to get the rail out, and a large amount of metal goes to the scrap-heap. Some of these systems, too, are rolled with outward sloping sides or flanges, so as to get a broad base. This means that the paving setts adjoining the rail must be more or less wedge-shaped, so that vibration soon loosens them, and then also those adjoining them. No matter how good a system may be in other respects, it should be rejected if it appears at all probable that the pavement, or the adjoining roadway will have to be disturbed for the purpose of tightening up fastenings or of renewing rails, and any system which involves frequent disturbances, whether of pavement, of asphalte, or of macadam, is, therefore, to be avoided.

If it were a point of contention merely as to whether longitudinal or intermittent supports were to be allowed, no doubt many cases might be quoted where intermittent supports have done good service; but when we see that Kincaid, for instance, has found it necessary to extend the bearing surface of his chairs, so as to obtain what is practically a longitudinal sleeper, but having the rails supported at intervals only, it seems strong presumptive evidence in favour of a continuous bearing surface.

Again, if we look at Barker's system, we find a continuous bearing surface which, with the rail, amounts to 244 tons of metal per mile. But, in either of these systems, and I quote them because they have both been much used, to get at the fastenings it is constantly found necessary to pull up the road-
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way alongside the rails. Deacon’s system, which is in use in Liverpool under very heavy traffic, gets over this objection, and remains at the same time one of the best roadways now in use in England, but it is very expensive and troublesome to lay.

The conditions laid down by the well-known Liverpool city engineer may be fairly adopted as embodying the practical outcome of tramway experience. and—for the colonies, where we have to import our rails—leaves only one additional point to be desired, viz., a reduction in weight. The gentleman in question, Mr. Dunscombe, whose opinions are confirmed by those of other experienced engineers, both English and foreign, maintains with regard to first-class tramways—

1. That the foundation should be concrete.
2. That the support to the rails should be practically continuous.
3. That the rail, with its support, should be held or anchored down to the concrete foundation by suitable fastenings.
4. That we should be able to remove and replace a rail, or to tighten up fastenings, without disturbing the pavement; and
5. That the longitudinal sleepers or supports for the rail must present laterally a true vertical face, free from all projections, so as to admit of close paving on each side of the rail.

If these general conditions are firmly insisted upon, minor details such as material, weight of rails, width of groove, depth of paving setts, &c., may fairly be left to the engineer’s decision in each particular case. Where, however, metal-work has to be brought some 16,000 miles, freight is an item of considerable importance; if the item of duty has to be superadded, and with freight and landing charges, has to be taken into consideration by the shipper, cost f.o.b. at home, becomes correspondingly increased, and looking at the great weight of the continuous, or almost continuous, iron sleepers in use in Liverpool, it must be held that some superstructure which will combine the good points of Deacon’s system with a notable reduction in weight is much to be desired.

The Gowan and the Barker rails are perhaps the most extensively used patterns, and they illustrate the two principles of renewable wearing surface only as opposed to a general renewal. Both are heavy and costly. In Europe, owing to the present low prices of metal, and to the saving in trouble which it effects, the Gowan rail is being more and more universally adopted. A glance at the section shows that as regards strength, it not only suffices, but largely exceeds any demands which can possibly be made upon it. In all grooved rails, however, of course the duration of the rolling surface is limited by the depth of the groove, and some time or other renewals
become necessary. Should the price of metal rise, it might therefore become a very serious matter for shareholders; while in any case, at this distance from manufacturers, the item of freight is always to be considered.

The troubles caused by repairs and renewals have hitherto been one of the greatest sources of loss to and prejudice against tramways, and I will therefore just mention two systems in which the pavement need never be disturbed after the rails have once been properly laid down.

These are the Deacon and the Channel-rail systems. The Deacon rail has stood the test of the heaviest traffic in England—that of Liverpool; it is doubtful, in fact, if any tramway in the world, except perhaps that in Tenth Avenue in New York, has to stand heavier shocks and jars from the ordinary street traffic. It may here be appropriate to remark that it is not only the traffic of the tram-cars themselves that tells upon the roadway, although that may be terribly severe if a system of haulage be permitted where very heavy loads have to be moved rapidly by mechanical means. The wear and tear resulting from such a traffic as is carried daily, for instance on the rails in Elizabeth-street, in Sydney, is something which must be seen and studied to be realised; but this kind of wear and tear can nearly always be reduced by a judicious reduction of speed, and of the moving load allowed. The wear and tear which tramway proprietors dread most comes from ordinary heavy-wheeled vehicles, such as drags, waggons, and lorries driving over and along the line. It is this which renders it necessary to expend so much money and ingenuity in securing strength and solidity in our roadway,

A glance at the drawing which represents the so-called Channel rail will make it clear, however, that strength and solidity may be secured, together with all the other advantages of the Deacon system without having to pay freight on such a considerable weight of metal.

The Channel rail has not yet received a sufficient trial to warrant my speaking with absolute certainty as regards its lasting qualities, but I can see no reason to doubt them. I am, however, personally interested in it, and I therefore prefer reserving any further statements regarding its qualities for some more suitable occasion, when I may feel freer to advocate what I believe to be its claims to take a premier place in any first-class tramway system.

I have now, Mr. President, to the best of my ability carried out my promise to introduce the subject of haulage on the Melbourne Tramways. I feel deeply how imperfectly I have treated my subject, and I can only reiterate what I said at the
commencement of my first paper, viz., that I greatly regret that some better qualified member of our association had not been called upon to open up the subject.

DESCRIPTION OF THE DRAWINGS OF THE CHANNEL RAIL.

The rail itself is a compound structure, and consists, first, of a channel bar B, of unequal section, the high side forming the narrow inside of the visible rail surface; and, secondly, of the rail proper A, which is angle-bar, the vertical web of which is formed with a head like an ordinary railway bar. This rail A rests upon the bottom of the channel-bar B, against the short vertical sides and bottom of which it is forced by the wedging action of the taper head F, of the bolt E, which presses on the one side against the inner guard web of the channel-bar, which is rolled to fit the taper of the bolt-head, and, on the other side, upon the vertical web and flange of the rail A, through the medium of the loose key K. The bolt thus not only holds the rail securely down to the timber bedding, but keeps it firmly pressed against the channel-bar. A single turn back of the screw E releases the loose key K, and the lower flange of A being notched, the rail can be lifted out, and a fresh one substituted in an exceedingly short time. The holding-down bolt passes through the timber and into a claw-nut beneath. When hard wood is used, a "coach" screw may be substituted, but we consider the through-bolt better in every way, even in hard wood. To preserve the gauge, correct cross-ties of iron D are let into the timber bearing, and notched to receive the channel-bar, and as this can only be laid down in the notches, the line cannot ever be put down to wrong gauge if the ties are correctly notched when manufactured—not a difficult matter. The keys K are about 2½ inches in length.

The principal figure shows the Channel-rail system with a longitudinal bearing of cement, which is constructed in the following manner: The surface of the ground being levelled, the plates G, which act as nuts for the bolts E, are placed thereon with the bolts in position, and at the correct distances defined by pierced wooden templates of equal width with the outside of the channel iron B. The road pavement is then put down so as to leave a vacant space MM below the ends of the setts and in the line of the bolts. Into this trough is poured up to the level HH a well-moistened cement mixture, containing one part of Portland cement to about three of good sharp sand. This cement enters the interstices of the setts, which are thus converted into a continuously-supported pavement along the line.
Deacon's Way, as laid by Mr. Dinscombe, Liverpool.
Scale 1/4
of the rail. While the cement is soft the Channel-rail is dropped upon it, the holes in the base being sufficiently large to pass over the bolt-heads, and pumped down to the correct level; and, as the cement hardens, the rails may be put in place, the keys KK—in this case at each side of the bolt-heads—inserted, and the bolts screwed down. It may be advisable to grease the bolts, or coat them with a boiled soap solution, to prevent the cement adhering. The two other figures show a modification of the system, with a double groove, which has many advantages under certain circumstances. The principal advantages claimed for this system are:

1. Simplicity of manufacture.
2. A simple and strong fastening, easily accessible from the surface, which adjusts all wear and tear and compression.
3. Easy renewal of rail without disturbing the street surface.
4. An efficient and simple rail joint without special fastenings.
5. A good vertical and horizontal support for the paving setts next the rails.
6. No necessity to break up the street for repairs.

This system is equally well adapted to substructures of metal, glass, slag, or stone, with or without intervening cushions.