## DISCUSSION.

Mr. W. D. CRUICKSHANK in opening the discussion, said he did not speak as an expert in this branch of engineering. He congratulated the author on his scheme, which, as far as he (the speaker) could judge, was thoroughly practical. He did not agree with the author's strictures on the present boats. The "time honoured and slow moving ferry" had a great deal more to commend it than was usually supposed. Having been connected with this service for over twenty years, he believed he was correct in stating that there never had been any loss of life due to the running of the ferry steamers. Mr. Howarth said the "present vessels could be improved beyond recognition," but there was no justification for such a remark; for any radical change was rendered in a satisfactory manner, as far as all reasonable requirements were concerned. The cost given by Mr. Howarth, *i.e.*, £185,000, appeared to Mr. Cruickshank to be very low, but from Mr. Howarth he found that this steel way would weigh 2 tons to the lineal foot, and taking its length at 1,300ft, the total would be 2,600 tons. Ordinary bridge work steel had been constructed in the colonies for less than £25 per ton, and as Mr. Howarth had allowed £90 per lineal foot, the whole structure finished would amount to about £117,000. The tunnelling, 740 yards, at £80 per lineal yard, would be £59,000, bringing it up to £176,000, and this would leave £9,000 for laying rails and other expenses. He was not in a position to check these figures, but trusted some member would do so. Referring to tunnelling generally, he gave a slight *resumé* of this branch of engineering to illustrate its phenomenal advance. In 1857 the Mont Cenis tunnel was commenced at both ends, and the work carried on by hand for over three years, when

rock drilling machines were introduced. Taking the hand rate of progress, it would have taken 30 years to complete the job, whereas with the machines it was finished in 13 years and one month from date of commencement. Its length was a little over $7\frac{1}{2}$ miles, and it cost £224 per lineal yard. The St. Gothard tunnel, commenced in 1871, $9\frac{1}{4}$ miles long, finished in 1880, cost £142 per lineal yard. The Arlberg tunnel, $6\frac{1}{3}$ miles, occupying $3\frac{3}{4}$ years in construction, an average progress of about 10 feet per day, cost £108 per lineal yard. At the present time a double line of railway tunnel could be excavated and finished in the colonies for about £65 per lineal yard, and as Mr. Howarth's tunnel was only $\frac{2}{3}$ the sectional area, it should cost less; but as he had allowed £80 per yard, possibly the nature of the material to be passed through might account for this. The proposed method of construction was commendable, inasmuch as the central double flanged girder was plain and simple in all its details, and the wings carrying the roadways were all easy, straightforward work. The cement covering should, in salt water, be almost indestructible. As a whole, the scheme bore the impress of careful thought, and presented few engineering difficulties, was eminently practical, and much superior in every way to any of the previously proposed methods of tunnel connection.

Mr. BURGE said that the method proposed by Mr. Howarth for tunnelling under the harbour found them almost equally ignorant, because such work was almost a new experience to them. He was inclined to agree with the last speaker as to the necessity of this scheme, but that was a matter that hardly came within their scope, as they should confine themselves to the matters before them. They had to deal with the merits of the scheme, assuming some sort of communication to be necessary. As a resident of North Shore, he would be sorry to go down in the tunnel when there was a good ferry available. That was not the question, however, and as far as he could judge, it was a well thought out scheme as submitted in the paper. If there

was any improvement to be suggested, it was that the gradients might be carried down lower, so as not to interfere with the present depth of the water, and it would be worth the additional expense incurred.

Mr. GRIMSHAW agreed that the tunnel might be brought down a little lower. He thought it would give a greater security to the tunnel itself, and he saw no difficulty in that being done.

Mr. J. T. HAYCROFT said that no one would doubt, even from a cursory inspection of the drawings that the author had devoted very considerable time and study, to the scheme now before them, but in the opinion of the speaker, Mr. Howarth had failed in producing a project which could not be objected to not from one, but many points to view. The speaker, in critising this scheme, did not wish to be considered as doing so in captious spirit, and so that the criticism might fulfil its function, and perhaps lead to its improvements. He considered the first point of failure in the scheme to be in the fact that it only provided accommodation for people who might happen to have money in their pockets, as the travellers by the present ferry system must have. No scheme, whether tunnel or bridge, connecting North Sydney with this city, would, in his opinion, be acceptable to the public, which did not provide, besides a means of rapid transit by electric tram or otherwise, a means of free transit to pedestrians and vehicular traffic. Another point about the author's scheme, which, however, he might be able to explain and which, if it existed as stated in the paper, would render it inoperative or incapable of competing successfully with congested traffic, was a fact that the out-going cars from the city would run into a terminal dock at Milson's Point Railway Station. The scheme to be effective should be circular in action; the cars from the city should be able to discharge their freight at Milson's Point, and be capable of immediately taking in a return freight to the city without any shunting operations. The particular design of the tunnel or sub-aqueous viaduct, had evidence of considerable thought on the

part of the author. One point, however, which would bear elucidating, was how it was contemplated to make a water-tight joint at the junctions of the separate spans resting on the piers; was it intended to take the sag out of the tubes as they laid on the piers in their initial stage, before bolting two lengths together? As the author did not propose to use the outer casing of his bridge for anything except moulding his concrete, would it not be as well to do away entirely with same, and when building the tubes on land, to use temporary timber casing, which could be removed as the concrete got sufficiently hard, to permit of launching of the tubes? Much more facility for ramming the concrete would be provided by the use of an outer timber casing, and the cost of same, if made of steel, avoided. No fear of foul air existing in the tunnels need be entertained, if the author's scheme were carried out, in fact, less ventilation than he provided would be sufficient.

One small point in the paper needed correction, that was a reference to a part of the committee's report on City and Suburban Railways. The committee did not suggest, as stated by the author, that the bridge, if constructed, should consist of one span of 1,500 feet, or two spans of 700 or 800 feet, with a central pier not obstructing navigation, which the author remarked he could not understand. The recommendation was, that if possible, the bridge be thrown across in one span; but if such were not possible, two spans of 500 to 700 feet, with a central pier, would meet the requirements of a bridge not obstructing the navigation of the harbour. The author, when reading the paper, on mentioning he had taken the elastic limit of steel at 16 tons, referred to the proposed bridge across the Hudson, where he stated the working stress was 25 tons per square inch. This statement was referred to subsequently in the discussion which followed, and one speaker stated it must have been a misprint. Such, however, was not the case, in fact, the author was below the mark in stating 25 tons. Having gone so far, a few words on this structure might not be out of

place, as it would show what was being done in other countries in a somewhat similar condition of things between Dawes' and Milson's Points. The bridge was to be suspension, 3,100 feet clear span, with a headway of 150 feet over high water; it was to accommodate six lines of railway. Mr. Theodore Cooper, A.I.C.E., one of the most eminent members of the profession in the world, had specified that the cables, when subjected to the maximum stress, should not be subjected to more than 27 tons per square inch. The wire in the cables should have a minimum length of 1,800 feet, without weld, joint or splice, and should not be less in diameter than No. 3 Birmingham wire gauge=0·259 inches, and possess an ultimate strength of 90 tons per square inch. To show that these requirements were practicable, the Union Bridge Co. sent in a tender to build such a bridge for £5,000,000 within three years The author was, no doubt, aware that the War Department, which, throughout America, had the right of vetoing any schemes interfering with free navigation, declined to sanction a cantilever type of bridge where it was proposed to erect a suspension bridge. The author fixed the prices of bridge he illustrated as suitable for this crossing, at three quarters of a million, say, with land resumptions, one million, a sum which compared very unfavorably with his tunnel scheme; but he (the speaker) was of opinion that a bridge to accommodate two lines of electric tramway, two carriage ways, and two footpaths could be constructed for much less, and still be no obstruction to navigation; he (the speaker) was engaged on such a design, not to exceed £250,000, and which would necessitate no land resumptions. In conclusion, he was of opinion the author was deserving of unqualified praise for the energy and acumen displayed in the design submitted for discussion.

Mr. Norman Selfe said the author deserved the thanks of the community, as well as of the Association, for his valuable contribution to the subject of direct communication between Sydney and the Northern Shore of Port Jackson. Proposals for a bridge at this site go back at least 40 years, a design for a

single span girder having been made by a Mr. Henderson in 1857. One could not criticise all the details without bestowing a good deal of time and trouble on calculations, or being in possession of information which is not given in this paper, as to the exact nature of the bottom of the harbour at that spot. Mr. Howarth, in reply, would perhaps kindly say if the section shown was approximate only, or drawn from actual borings, and if a soft unreliable bottom above the rock had been proved. Assuming that the present bottom was not solid enough to carry a tube without the assistance of a ballast dyke, the necessity for the submerged piers was apparent; and admitting the correctness of the proportions and estimates given by the author, no disinterested person would deny the many merits of the proposal, or contend that it was not well adapted to afford communication with Milson's Point for certain kinds of traffic, at a very moderate cost, if it could be carried out without accidents. He, therefore, trusted that he would not be misunderstood or be thought to in any way depreciate the merits of this submerged bridge or tunnel, if, while fully recognising in it a solution of the problem—how to connect the tramway and local traffic at Milson's Point with the city—he tried to prove that it did not meet the most important and primary requirements of the public, which were daily forcing themselves more and more to the front, and demanding recognition at the hands of the Government. The connection of Sydney with the North Shore was a large and important question, and although the Chief Commissioner of Railways, when giving evidence at the Royal Commission, more than five years ago did not at that time think it was an important one from the railway point of view, the subsequent opening of the line at Milson's Point had entirely altered matters. The population between the Point and Hornsby Junction had lately progressed, and was still increasing by leaps and bounds, and the traffic was already at least tenfold what it was then. Bearing in mind that the distance from the Point to Hornsby Junction was 13 miles, while

from Redfern to the Junction it was 21 miles, and that in various schemes for the city railway extension, both "Official" and "Private," Wynyard Square had been selected for one of the city railway stations (a central site for a starting point, which a bridge would make at least eight miles nearer to Newcastle via North Shore than via Strathfield), and noting what was indubitable, that with "improved times" the whole district from Chatswood to Thornleigh would soon vie with the suburban line in the density of its population, we were brought face to face with the point as the primary one for consideration in any bridge or tunnel project, namely—direct railway communication from these northern suburbs in the heart of the city without transhipment. As a matter of secondary consideration, the local service of the inhabitants closely surrounding Milson's Point, now so well served by tramway and steam ferry, was also extremely important; and to meet this local service, Mr. Howarth's proposal presented great attractions. A correspondent in the daily press asked if Mr. Howarth's bridge would not cause a silting up of the harbour; most probably it would not, but it would certainly reduce the waterway, and, therefore, increase the velocity of the tide perhaps a mile or a mile and a half per hour at "springs"; with of course increased scour that would probably remove silt from, instead of causing it to be arrested at that site; that, however, would be a question for the harbour authorities to discuss. It would be granted, for the purposes of the discussion, that there would be no objection to the scheme on that score; we, therefore, admitted that the tunnel was admirably fitted to carry a tramway traffic and also foot passengers, should there be many foot passengers found to prefer paying the same toll for walking through the tubes as was now paid to the steamers; but as there seemed to be no idea in the author's proposals to carry the railway trains through, we would pass on to the consideration of the proposed bridge for making that most important connection. It had often been urged against engineers, that they were continually marring the

features of some lovely landscape by their giant structures. An engineering structure should harmonise with its surroundings, other things being equal, if it was possible to do so. In a great open estuary like the Forth, when conditions that absolutely tied the designers to certain spans and positions for their piers, the great Forth Bridge had a meaning and told its tale well; but to take a single span out of that mammoth structure, and straddle it across Port Jackson, from Dawes' Battery to Milson's Point, where a single span was quite unnecessary, to a sensitive person was simply horrid. You would not only dwarf all the surroundings by the immensity of the structure, but you would take all the poetry out of the situation by its coarse, exaggerated, and pretentious appearance; and instead of improving on what nature had so lavishly bestowed, you would set up a permanent eyesore in the two enormous towers, like permanent scaffolds 300 feet high, that would go far to ruin the reputation of our beautiful harbour; quite as much as the Cremorne Coal Heap atrocity, so much discussed lately, was ever likely to do. The waterway of the harbour at that spot was, when compared with other parts, sufficiently wide for at least tenfold the shipping that now passed through; and if piers were erected, they would enable the authorities to separate and confine the traffic of vessels going either way to their respective and proper channels. There were, therefore, advantages rather than objections to a bridge with piers, unless it should turn out that the increased cost of such piers would exceed the reduced cost of the bridge with the lesser spans, and that was hardly likely, because no section of the harbour had yet been made public, that would suggest any extraordinary difficulty in connection with piers at the bridge site. Coming to the general design that a bridge to North Shore should assume, it might be safely said that no one with taste and cultivation could look at arched bridges such as the one over the Mississippi, at St. Louis, without admiring their grace and elegance as compared with the cheaper girder structures, or

even the best Cantilever bridges. If it could not be called handsome or elegant, nothing could be more appropriate or dignified than the appearance of the Forth Bridge; but since the successful completion of that grand work, so admirable on its own side, numbers of imitations of it, or portions of it, had been proposed for most ineligible situations, utterly differing in requirements, conditions, and surroundings, and some of these proposals had been made for crossing branches of Sydney Harbour. In opening this paper, Mr. Howarth said, in referring to the Royal Commission on City Railways and North Shore Bridge, the Committee decided that whenever it might be desirable to build a bridge, it should be advisable to give it a clear headway of 160 feet, and one span of 1,500 feet, or two of 700 or 800 feet (*vide* report page 68), but the first paragraph on that page 68, concluded thus:—"On the whole, it may be concluded that for ocean steamships and for the larger sailing vessels with their top-gallant masts 'housed,' there need be no greater headway for the bridge than 150 feet." True, a suggestion was made in the following paragraph of 164 feet, but it had very little weight for the following reasons. The extra height of headway, if adopted, would only be an advantage for very exceptional vessels, at very exceptional times, and granted that one vessel every month had to lower her top-gallant masts to go under 150 feet, at a cost of £20, the annual charge would be say £240, which would be as nothing compared to even the interest on the extra cost of the higher bridge, but that first cost would only be a matter of secondary importance; the matter of first importance was the grade of the railway, on which depended the traction for the trains. With a bridge only giving 150 feet high, the ruling grade of the Milson's Point line, that was only 1 in 50, could be maintained right on to a city railway station, say in Wynyard Square, while to get over a steeper bridge would involve the extra haulage, and the additional wear and tear on say 100 trains a day, involving terrible inconvenience and enormous