Discussion.

The PRESIDENT said the members, he was sure, would all be glad to hear that there was a chance of the Panama work being completed. It was a magnificent scheme, even if carried out on the medium level adopted by the Technical Commission. No doubt it would be infinitely better if it were a sea-level canal all through. The Paper was rather an unusual one to be read at the Institution, but its importance, the Council thought, made it desirable to put before the members the latest information on the subject. He noticed that the dry-weather flow of the River Chagres was about the same as the dry-weather flow of the River Thames at Teddington, but no doubt the flood-discharges were enormously greater. He thought the members would agree with him that the thanks of the Institution were due to Mr. Ford for his interesting Paper. The President.

Mr. ALFRED HOLT opened the discussion with great diffidence, first expressing his thanks to the Author for the interesting information he had given. To himself certainly in many respects it was a considerable surprise, and he would have been glad if some indication had been given of the date of the period to which the Author referred. The subject was one in which he had taken a great interest for a long time; it was perhaps the greatest engineering problem before the world; but unfortunately it was also largely a political question. His attention had been first drawn to it in March, 1862, when he had spent the greater part of that month at Colon, endeavouring to arrange through communication with the west coast of America *viâ* the railway, which had then been a new thing. At that time he had been the manager of a steamship enterprise between Liverpool and Colon. Having been a railway engineer, a pupil of one of the Past-Presidents of the Institution, he had been interested in railway matters as well as in other matters connected with the enterprise, and had come necessarily a good deal in contact with the engineers as well as the commercial agents of the railway. It had been a very important thing to him that an enterprise in which he was much interested should not be ruined or injured by a canal, if one were made, and consequently he had discussed with the engineers of the railway the possibility of a canal being made, although none at that time had been at all seriously proposed. Those gentlemen, Mr. Holt.

Mr. Holt. with knowledge of the isthmus, and appreciating perfectly the only practical alternative, namely, Nicaragua, had been clearly of opinion that Panama was the best route to choose for a canal, should one be made. Their opinion had been the root from which his own had grown. Intermittent but impartial study of the subject for many years had confirmed him in it, and he was pleased to see that the Author, though he had hardly the courage of his convictions, pointed the same way. It was with a view to submit that opinion to the Institution that he had attended that evening. He would formulate his proposition thus: That the Panama route and a sea-level canal alone satisfy the requirements of the case. He had at intervals been consulted on the subject by gentlemen having, or assuming to have, directions from Washington to sound English opinion. The first occasion had been about 1863; it had occurred again in 1875, and again through the United States Consul in Liverpool in 1893. In every case he had taken up the position he now took, and he found he could not give his reasons more clearly than by quoting from his reply to the last-mentioned gentleman, dated the 19th January, 1893:—

"My opinion results from study of the question, based on information I received on the isthmus, mainly from the engineers of the Panama railroad, in 1862. I am a civil engineer, and the possibility of a canal, though none was then definitely suggested, frequently formed the subject of interesting conversation. The opinion I gleaned from them, and still hold, is that a canal on any route must be a work of extreme difficulty, but that the vicinity of the railroad is, weighing everything, the best. As an outsider I have followed all subsequent developments, and was interested to notice that M. de Lesseps, whose canal instinct is unquestionable, however his methods may be criticised, accepted that route. Practically speaking, Nicaragua is the only competing one. On it the works may be cheaper, but the canal, when made, much less useful. A very formidable series of locks will have to be passed, and though these may not be prohibitory of traffic, they must necessarily narrow the regions to and from which trade will take the isthmus route. I apprehend the United States will regret the Nicaragua Canal, should it be made through their influence. Their regret will take this form, 'Why did our desire for a separate national enterprise prevent the best being made?' The original conception of the French company, namely, a lockless canal with gates at the Pacific end only, approved itself to me as the best 30 years ago, and does so still. It is an enormous work, but I assume that 30 or 40 millions sterling, honestly spent, would in 12 years to 20 years finish it. The maritime nations should commit themselves to pay an impartial assessment, based on their proportionate interests, and the work, for humanity's sake, should be carried on during the good season only; transport is cheap, and healthy places are close at hand. The Chagres River, I have always thought, might be allowed to discharge into the canal; the Atlantic end, where the ground lends itself to the purpose, being prepared for its reception at each intersection. That river has a very small watershed, and would cease, after a year or two, to bring down much débris; what it did bring in the earlier years being removed by that cheapest known mode of excavation, dredging. Difficulty from it would be of

rare occurrence, and would soon be negligible. I have described what, to my mind, should be done, but the greater question remains, how are the nations to be prevailed upon to do it? For any canal transcends a profit-making company's powers. Money loss will attend any effort; it must be national. On that question I offer no opinion, but would hope that if two sensible nations like England and the United States would take the lead, it could be done." Mr. Holt.

That letter had given his opinion then, as it did now. The Manchester Ship Canal had been the subject of great interest and much heated controversy in Lancashire at the time Mr. de Lesseps had come to Liverpool to advocate the Panama Canal, and he had been much pressed to bless with his approval the local project; but he had abstained from doing so, and his gestures on learning that a ship-canal with locks was projected, did not indicate belief in the success of the scheme. It might be said that Mr. de Lesseps had accepted locks at Panama, but the fact was that he had stoutly stood against them so long as the funds available had appeared to be sufficient to produce a lockless waterway, and his acceptance of them had been a counsel of despair: in fact, he had openly given it as his opinion, in a lecture on the Suez Canal before the Société des Gens de Lettres, at Paris, that unless the Atlantic and Pacific could be united by simply piercing the isthmus from sea to sea without locks, like the Suez Canal, the scheme could not possibly succeed as a commercial enterprise. Mr. Holt had had much experience of the Suez and other canals, and he was convinced that Mr. de Lesseps's instinct had been right. It was not to be denied that locks could be traversed, but that a canal with many locks would be avoided was to him a matter of conviction. Should the Nicaragua Canal be made, he prophesied that the Panama Canal would also be made. The interval might be a long one, but the Nicaragua Canal would not set the question at rest, and in the turn of the wheel some nation or nations, some company or companies, would build what would be a useful canal, that at Nicaragua remaining for a few vessels driven to it by sentiment and not by profit. On one not very important point he slightly differed from the Author, believing that a gate or gates would be necessary at Panama. The tidal range was fully three times that at Suez, and there were occasions when the current produced by that tidal range at the southern end of the canal was very inconvenient to navigation. Moreover, gates at Panama would enable a current to be set up at will through the canal in either direction, a power which it might be desirable to have at all times, and which, during the final stages of construction, might even be useful. He felt some apology was needed for his somewhat dogmatic state-

Mr. Holt. ments, but they were the result of lengthy thought and considerable experience, and he could not but think that a clear expression of opinion by members of an Institution which held a position both of authority and impartiality might cause the realities of the case to outweigh natural prejudice, and might possibly end in effecting something for the permanent good of mankind.

Mr. Wells. Mr. L. B. WELLS remarked that, like Mr. Holt, he had been agreeably surprised to find that so much had been done, and that the expenditure at Panama had not been so fruitless as he had always imagined. The longitudinal section showed a very large quantity of earthwork to have been completed, but in this connection cross section shown in Fig. 4, Plate 6, must not be lost sight of in estimating the quantity remaining to be done. The level which the Commission had adopted as the best under the circumstances appeared to save about £900,000, and he thought it would be a pity that such a sum should stand in the way of a better canal at a level of 66 feet above the sea. He regretted that the Author had given so little definite information, having apparently taken it for granted that the members were all conversant with the report of the Technical Commission, which was not the case. For his part he was not afraid of locks, and was sorry to hear Mr. Holt express such a strong opinion against them. Seeing the large ships passed in numbers through locks in this country and in America, he did not think there was anything to fear in using them. The Manchester Ship Canal had a series of locks, and the entrance lock at Eastham was certainly a much more difficult one to navigate than could be found anywhere in passing along a canal with comparatively still water. There the Mersey ran sometimes at 5 knots or 6 knots an hour, and yet the lock was navigated with comparatively little difficulty by ships carrying up to 6,000 or 7,000 tons, and the sea-borne tonnage for 1900 had amounted to 2,800,000 tons. The Sault Ste. Marie Canal had a rise of 18 feet 6 inches, with two locks side by side. In 1890, 25,643,073 tons net freight had been carried—20,532,493 tons eastward and 5,110,580 tons westward bound. Shipping equal to carrying 41,000,000 tons might therefore be assumed to have passed the locks, notwithstanding the fact that the canal was closed by frost for about 150 days in the year. This compared with 9,865,630 tons net register passing through the Suez Canal in the previous year. It was evidently necessary to build a lock at Panama, and that would govern to a large extent the number of passages which could be made; but he thought it would be a great many years before there was traffic enough to overcrowd the lock. With regard

Mr. Wells.

to Nicaragua, some 10 years ago he had had to examine that project, having been sent to New York to report on the plans and sections, and to make himself conversant with the scheme. It appeared to him to be a good one. As he had said, he was not afraid of locks. He had formerly been Engineer, for 10 years, of the Weaver Navigation, which was dependent on locks, and which had been a forerunner of the Manchester Ship Canal, Sir Leader Williams having been one of his predecessors on the Weaver Navigation. The Panama upper level was 126 feet, and the surface of Lake Nicaragua was 110 feet, above mean sea-level. Certainly, if the Panama Canal was made, the 66-foot level was the one he hoped to see adopted. It was a mistake to rate Mr. de Lesseps as a great engineer. He had been a very eminent man, but, above all, a diplomatist, and had not been trained as an engineer. Speaking at Manchester, when the enlargement of the capacity of the Suez Canal had been under consideration, Mr. de Lesseps had advocated the making of a second channel, parallel to the first, with a strong bank between, to prevent the waters of the one from flowing into the other. Such a proposal was absolutely opposed to sound engineering practice, as exemplified throughout the world, and would have crippled the usefulness of the canal, while adding enormously to the cost. The great advantage of the Nicaragua route was that although it was 170 miles in length, by placing dams in the river valleys a large expanse of water—and, for a considerable length, very deep water—would be provided for ships; so that there would be only 28 miles of cut canal of narrow section, the rest of the passage being made through an ample water-way. This compared with 42 miles at Panama, and he was sure it would be a very great advantage in navigating to have the width and depth of water which would be afforded by Lake Nicaragua. It was a matter of extreme importance that Britain should have some control of whichever waterway was made between the Atlantic and the Pacific, having regard to the vast interests she had on the shores of the Pacific. The report of the Isthmian Canal Commission to the United States Government appeared to be conclusive as to the necessity of adopting either the Nicaragua or the Panama route. The Darien country had been explored, and although for a length of 80 miles the width of the Isthmus did not exceed 40 miles, and narrowed in one place to 31 miles, the height of the intervening land and other difficulties made a canal through this region impracticable. The Commission stated that much of the machinery found on both the Nicaragua and the Panama routes was out of date, and had been neglected, and they put a very low

Mr. Wells. estimate of value upon it. He thought it would have assisted the members in examining the question if the section issued had been to a somewhat larger scale, and had been coloured. A departure of that sort would be an advantage, not only to the "Proceedings," but in leading the way to clearer description of engineering works in the technical journals.

Mr. Donaldson. Mr. H. F. DONALDSON considered that the somewhat unusual character of the Paper made it perhaps more interesting, especially at a time when the whole matter was prominently before the public. The Author appeared to think that the Panama scheme was the best, and it did seem to have advantages. It was a matter of great regret to him that 10 years ago, when he had been sent to Nicaragua, time had not permitted of his going over to Panama; but other members of the party had gone along the Pacific shore, and back by way of Panama, and he did not think the evidence which they had given, as to the state in which they had found the plant at that time, had borne out the statements in the Paper. The Author attributed a considerable amount of value to the plant even at the present time, when it was 10 years older. He did not mean to say it had no value, but he thought the value must be, to a very large extent, negligible. He had seen some of that plant working at Nicaragua, where there had been four dredgers altogether. Two had been at work, but he had gathered that the other two worked for a day and then lay up for a week. He had been given to understand that the plant, except such small quantities of it as had been kept under cover, and of which the bright parts had been painted, was in a somewhat similar state. The Culebra cut was referred to in the Paper as having been carefully examined. He would like to ask whether the Author could state to what depth borings had been taken; how much, if at all, below the bottom of the canal, according to either the medium or the lower scheme. If borings had been taken at any depth, he would also like to know whether rock had been found, and if so, of what depth, whether its consistency was uniform, or whether it had been found to soften as the depth increased. At Nicaragua and other places it had been found, after carrying borings well into what appeared to be quite hard rock, that the rock gradually became more and more friable, until a sort of soapstone was reached, which seemed to be largely affected by the action of water. He would like to know whether that was the case in the Culebra cut; if so, its stability would be threatened by serious difficulties later on. With regard to the lock canal, Mr. Holt had expressed a strong preference for a sea-level canal, but he imagined

that as a shipowner Mr. Holt would not much care to pay the rates which would have to be charged on ships if a sea-level canal were again attempted and carried to completion; he would save in rates by going upstairs and coming down again rather than by going all the way on the ground-floor. Mr. Donaldson did not fear locks. He had seen them worked with 17-foot levels on the Sault Ste. Marie Canal on Lake Superior, through which a considerably larger tonnage passed in 5 months than passed through the Suez Canal in 12 months. Of course there the vessels were continually going backwards and forwards, and the skippers and crews knew exactly what they had to do when they came to the lock; but in an interoceanic canal want of experience would be corrected in time, as it would come about that most ships using the canal would do so regularly. With regard to the advantages of the Panama over the Nicaragua route, there was of course that of distance, but he thought it was quite possible that if both canals were made it would be found that the passage through the Nicaragua Canal could be effected as quickly as that through the Panama Canal, owing to so much of the Nicaragua Canal being through large deep basins where speed need not be restricted. With regard to the water which was to come into the canal, he was not quite clear as to how the water of the Chagres River was to be dealt with. Spill-ways were spoken of in the Paper, and were calculated to pass a certain quantity of water under given conditions. He did not know whether there was any additional provision at the Alhajuela dam in the way of control, or whether dependence was to be placed on spill-ways alone. He would like to know whether it was intended to have anything in the way of sluices, of Stoney or any other type, to control the water at a lower level than at the top of the flood-water, so that the canal level could be maintained more nearly uniform by lowering levels in anticipation of floods. He thought that was a rather important matter in relation to the working of the Canal. The Alhajuela dam seemed to him to be the key of the position, and he gathered that it was the one point in the scheme on which the Commission did not speak with certainty, because the ground through which the aqueduct had to pass was apparently of a treacherous nature, and had not been so exhaustively surveyed. Were it not for the construction of the reservoir above the Alhajuela dam, pumping would be the only means by which the water could be retained, not only in the Bohio section, but in the upper section, and for a canal of the magnitude of the Panama or Nicaragua Canal, such a method of maintenance would, in his opinion, prove prohibitively

Mr. Donaldson.

Mr. Donaldson. costly. He agreed with the Author that, for the ultimate benefit of the working of the canal, it would be preferable to adopt the lowest summit-level conveniently possible, and, judging from the figures put forward, the comparatively small increase of cost required for the adoption of the lowest of the three levels should be faced. Besides all other advantages, the saving in working-expenses would be material, and might easily amount to a sum which would provide an adequate return for the increased prime cost. As to the advantages of Nicaragua over Panama, he would draw attention to the maintenance of the two undertakings. One large item of cost in maintenance would undoubtedly be dredging. The Panama scheme had two large basins, one above the Alhajuela dam and one the Bohio lake; both of these would form settling-grounds for the material brought down in suspension by flood-waters. The former was intended to be deep, and would therefore be effective; the deepest part of the latter was, generally speaking, the canal itself, and it was conceivable that deposits would take place there, and necessitate constant dredging in order to enable deep-draught navigation to be carried on. Nicaragua, on the other hand, had numerous basins, the normal depths of which were to a large extent greater than that of the canal, and which therefore afforded area for silting to take place for many years with no detriment to the working-levels of the canal. This seemed to be an advantage of considerable magnitude, and one not lightly to be lost sight of. At the same time, the conditions under which it appeared possible that the Nicaragua Canal might be built were such that it might appear desirable that the Panama Canal should be built in opposition to it, so as to avoid the protective restrictions against anything but American trade which were whispered at present. Were only one canal to be built, and that with equal rights for all users, he would record his vote for the Nicaragua route; if for no other reason, because, were that canal built, as he thought it could be, for 40 millions sterling, it would be permanently a more valuable property than the Panama Canal, which would have to bear, in one way or another, the burden of the enormous capital of upwards of 70 millions sterling.

Mr. Vernon-Harcourt. Mr. L. F. VERNON-HARCOURT observed that, as British member of the International Jury for Civil Engineering at the Paris Exhibition, 1900, he had had the opportunity of visiting officially the exhibit of the Panama Canal Company, and also of hearing the various descriptions of the work which had been given by the authorities of the new Company to the Jury. The models of the canal and the Culebra cutting had been very interesting, as had

also been the various cross sections and photographs shown. With regard to the depth to which the canal should be taken, evidently it was the view of the authorities that it ought to be carried down to the lower level. That course would be rather more costly; but, till sound rock had been reached, it had been considered doubtful whether the extra excavation could be carried out in the time allowed by the concession for the completion of the works, which he understood was nearly 10 years more, and that was the point which dominated the question as far as the Company was concerned. He had also been given to understand that sound rock, easily worked, had been reached; but this was more than verified by the Author, who described it as hard basalt. Undoubtedly the new Company had done better in one respect than the old one —namely, they had attacked the key of the position, the Culebra cutting, instead of working at both ends in order to show that the work was getting on very quickly, and that so many miles had been done. He was convinced that there must be a regulating tidal lock at the Panama end of the canal, which, indeed, formed part of the original scheme for a level canal, but which the Author and the Company appeared to consider unnecessary. Experience with regard to the tides on the Manchester Ship Canal was not favourable to admitting tides into a canal. He had been surprised at first to hear that the tide had so little inconvenienced the work as far as it had gone; but the section showed that the greater part of the excavation hitherto executed was below low water. The difficulties would increase when the work was carried further inland in the maritime section of the Panama end of the canal. It would be certainly unwise to have a tide flowing up and down the canal, confined within banks for about 4 miles, with a rise at springs of 20 feet, which was a much greater rise than the tide in the Manchester Ship Canal, viz., 8½ feet. The new Company had not given him to understand that the plant was in a bad state, as described by Mr. Donaldson; but they had admitted that it was somewhat antiquated. The wagons, for instance, of the old Company were side-tip wagons; and the new Company regretted they had not the means to get end-tip wagons and other more modern and powerful plant which might facilitate the work. The new Company, however, appeared to be conducting the work under very difficult conditions with considerable ability. In the scheme under consideration the Company had the advantage of forming Lake Bohio, which, although not very deep, gave lake-navigation in place of a comparatively narrow cutting. With regard

Mr. Vernon-Harcourt.

Mr. Vernon-Harcourt.

to Nicaragua, he had had occasion to look into the subject in 1895, and it had struck him that the estimate at that period that the Nicaragua Canal could be made for something like £13,000,000 must be very much under the mark. That had proved to be the case, because in December last the Report of the American Isthmian Canal Commission had stated that the Nicaragua Canal would cost about £40,000,000 sterling, and that the Panama Canal could be constructed for something like £28,000,000 to £31,000,000, giving the advantage so far to the Panama Canal. It had been said also that work to the value of about £6,500,000 only had been done upon the Panama Canal; and there was the further serious objection raised to the construction of such a canal upon leasehold property. Apparently the old Panama Company had only obtained a lease from the Colombian Government for 99 years; but he believed the Suez Canal was in much the same position, and that somewhere about 1966 the Suez Canal would revert to the Egyptian Government. The Commission referred in their report to the uncertainty as to the price at which the Panama Canal might be obtained from the new Company, and ended their report by saying they thought the American Government could make the Nicaragua Canal as cheaply in the end as it could purchase and finish the Panama Canal. It was easy to propose the construction of a tide-level canal at Panama; but the all-important question was, where was the money to come from? He had been convinced for some time past that the only way in which a ship-canal could be made across the isthmus was by a Government; and the only Government which was likely to take it up was the Government of the United States. There were one or two difficulties with regard to the Nicaragua route. The site of the harbour at Greytown was being silted up by the San Juan River, which formed a delta. That disadvantage might possibly be overcome by dredging and other works. Another thing mentioned in one of the earlier reports on the Nicaragua route was that it was liable to earthquakes; and it had been suggested that an earthquake would tend to consolidate the earthwork of the dams converting the river valleys into lakes. He did not think it would be desirable to consolidate by that means an earthen dam which was retaining a large quantity of water. He thought the tendency of events was towards constructing the Nicaragua Canal, although he had come to the conclusion some 6 years ago that the Panama Canal would be the cheaper one to make; and, as an engineering undertaking of great merit and importance, partially executed, no one could

help wishing to see the latter brought to a successful completion. It was, however, to the advantage of the United States, to construct the Nicaragua Canal as a means of communication by water between their eastern and western coasts, because that route on the Atlantic side was about 280 miles, and on the other side something like 670 miles, nearer to the United States; and that was a very important consideration, assuming the two canals to be otherwise equally good. Mr. Vernon-Harcourt.

Mr. J. A. SANER had had the opportunity of seeing the plans, and more especially the plans which had been before the Technical Commission, and he could bear testimony to the amount of work involved in them, and the excellent way in which they had been prepared. He thought the data contained in those plans would be ample for forming an opinion on the scheme. The Author appeared to think that 98 feet above mean sea-level was too high for the summit-level, and personally he was inclined to agree with this view. It was well known that locks in such a canal would form a serious hindrance to the navigation. He was connected with a navigation which had spent, comparatively speaking, enormous sums of money in order to do away with old locks or to increase their size, so that the delay to the traffic would be minimised. He thought that if the whole summit section could be lowered to the next pair of locks it would be a great improvement, and from the figures given in the Paper it did not seem that the cost of the lower scheme would be very much greater. It would have one advantage in that it would do away with two locks, if not three, and with the feeder canal, which, he thought, might prove a source probably of danger, and, at any rate, of continual expense for maintenance. The cost of maintenance of two sets of locks, with the lock-keepers, would be heavy, and in the long run it would probably be found better to go right through from one side to the other with only one pair of lifts at each end. A serious defect seemed to be that the subsequent removal of the summit-level section would practically be an impossibility. From the Paper it appeared that the rock in that section, being basalt and granite, was very difficult to remove by dredging; in fact, if the canal were built as shown, it would probably remain so permanently, and it would not be possible to lower the summit-level afterwards without very serious inconvenience to the traffic. He had thought at first that if the upper part of the cutting was of softer material it would be possible to lay the sills of the top locks level with the bottom sills, and to do away with the forebay altogether. By such means the water Mr. Saner.

Mr. Saner. could be gradually lowered as the upper section was dredged deeper; but if the upper section was granite and rock of a similar nature, it would be impossible to do that. Another important point was the increased area of the pound into which the Chagres River would flow. The Author went a little farther and said that the canal should be carried down eventually to a level canal from the Atlantic to the Pacific. Of course that would be desirable in some ways, but a point then arose which he had never seen mentioned, although it might be considered a somewhat far-fetched idea, viz., that there might be a permanent current from the Atlantic into the Pacific. It was known that there were ocean currents across the Atlantic, notably the Gulf Stream, and at present there was a barrier many thousand miles in extent, from north to south, which prevented that stream from going across the Pacific, as it presumably would, and diverted it northwards. But, should a canal be cut at the sea-level throughout, it was conceivable that a current from one side to the other might be set up. Of course, on the Pacific side, that current would be met at tide time by the incoming tide, and would be assisted by the receding tide; it would be trifling in amount, but it was worth considering. The Author mentioned that the tidal influence would not be felt very far up; but Mr. Saner knew the tidal influence was felt up the Manchester Ship Canal for 20 miles, and as the Panama Canal would only be a little over 40 miles long, it would probably be felt almost throughout. In any case, if the canal were built as proposed, the tide would be felt at the first lock and would rise considerably higher there than at the entrance to the canal. One thing which would have to be guarded against was undue motion of the water in locks with a rise of 30 feet, and care would have to be taken in the details to see that the scouring action of the water in the locks was so directed as to cleanse them from detritus and mud. It had been a fault in some of the later arrangements of sluices and modern locks that the scouring of the water when the lock was filled and emptied, instead of washing the detritus away, deposited it in the gate recesses and behind the gates, causing a great deal of trouble in spoon-dredging and also damaging the gates. Of course a Commission like the one which had had the matter under consideration would see to such details as that, and, with regard to the locks, as far as possible care would be taken to have everything in duplicate, so that in case of such accidents as, unfortunately, had taken place on the Weaver Navigation and on the Manchester Ship Canal, where lock-gates had been entirely carried away, there would be no

difficulty in fitting a spare gate to any place. The amount of work which had been done already, apart from all political and other considerations, showed the Panama route to be the correct one. Mr. Saner.

Mr. J. C. FERGUSSON observed that there was one large factor in the excavation of the Panama Canal which, if properly made use of, might reduce the cost of the work; he alluded to the vast body of water that would be conserved behind the Alhajuela dam, 130 million cubic yards of water at 190 feet above mean sea-level. If that water were used for excavation by hydraulic mining, as had been done in California, he thought a great saving might be effected. The supply canal from the Alhajuela dam to the ship-canal was to be 9½ miles long, and it was calculated to carry 33 cubic yards of water per second. That was equal to 36,000 miner's inches of water, which was capable of tearing down and carrying away between 75,000 cubic yards and 150,000 cubic yards a day. The total excavation of the Culebra and Emperador cuttings was 26,000,000 cubic yards. That was a very large amount, but when compared with the débris from hydraulic mining in California, in 1879–81, it fell short of the amount of work done there under very extraordinary circumstances. According to the report of the State Engineer of California, in the two years between 1879 and 1881, there had been over 92 million cubic yards of débris from hydraulic mining. The cost of hydraulicking gravel rarely exceeded 6*d.* per cubic yard, and was very often under 2½*d.* With regard to the service of a miner's inch of water, he might state that the North Bloomfield Company had washed 11,000,000 cubic yards with 2,390,000 miner's inches, or at the rate of 5 cubic yards per miner's inch, but that had been from benches between 100 feet and 290 feet high. When the banks were low, of course that amount of work could not be done. The La Grange Company had washed 2,433,000 cubic yards with 1,713,000 miner's inches of water, from benches between 10 feet and 18 feet high, or about 2 cubic yards for every miner's inch of water. At the Carriboo hydraulic mine in British Columbia, the duty of a miner's inch was frequently over 6 cubic yards. There could be no cheaper method of removing earth, gravel, and loose stone than by hydraulicking. A few years ago the Canadian Pacific Railroad Company had removed a large bluff of gravel from their line, and although they had had to put in special plant to do the work, the engineer had informed him that the company had saved in money; and that was a case in which a large railway company which always worked in the very cheapest manner had resorted to hydraulicking. In the case of the Panama Canal there would be no special outlay Mr. Fergusson.

Mr. Fergusson. needed for plant, as the Alhajuela dam and the supply canal were already included in the estimates, and formed the chief feature in the proposed scheme of the canal. In his opinion it would be well if the Alhajuela dam and the supply canal were made first, so that the vast quantity of water conserved every season could be made use of through monitors to tear down and carry away millions of cubic yards of gravel, stones, and débris. He was aware it had been stated that in the Culebra cutting the rock was hard. He had seen a large number of photographs of the work, and they all showed that the excavation was being carried out in steps, one above the other, upon which railway lines were built and steam-navvies were worked. It was evident that a great deal of the material could be moved by hydraulicking. He did not want to be misunderstood in using the term; he did not mean ground-sluicing, or the action of a river in flowing through a country. Anyone who had examined the valley of a large river could hardly fail to notice that millions of cubic yards of material had been displaced and carried away before the river had found its present bed or channel. Miles of country might be seen alongside the Frazer River where the benches rose one above the other to a height of 800 feet. A thousand miles up the Yantze River there was a gorge 1,500 feet deep, cleanly cut by the river's action. By the term "hydraulicking" he meant working the banks by means of water delivered under pressure through a monitor, and in that way even very heavy material might be dealt with. He had seen boulders weighing over 1 ton carried through the sluices and deposited in the dump. He noticed the estimated cost of the supply-canal was put down at £694,000 sterling, and he could not help feeling that that estimate was extravagant. His opinion was based upon the cost of hundreds of miles of canals, ditches, flumes, pipe-lines and siphons, constructed in California and British Columbia. In California water had to be brought in that manner hardly ever less than 25 miles, and sometimes as much as between 100 and 290 miles, to do the work. He was aware that the chief factors in hydraulicking were a head of water and a dump. The supply-canal would furnish the water, the head, even if the sluices were made through the bed rock, could be obtained, and as far as the dump was concerned, the material had not to be carried very far, because if it were removed from the line of the canal, the work was done. According to the Author the important question was, whether the canal could be completed for 21 millions sterling. He could only say that he would be very glad to obtain the contract himself to do the work at that figure, and his method

of working would be by hydraulicking. In conclusion, he called attention to the plan of the Canal, which represented a portion of the continent of America. Anyone, looking at that map, would find that the Pacific Ocean was marked on the east and the Atlantic Ocean on the west. He did not mean to say that the map was drawn wrongly, because it represented only a small section of the Isthmus of Panama, but he did say that it appeared wrong to draw a map of a portion of America showing the Pacific Ocean on the east side and the Atlantic Ocean on the west side! He apologised to the Author for raising a laugh about his map, but he would suggest that if, instead of putting the words Pacific Ocean on the right-hand side, he put there the words "Bay of Panama," the plan would conform better to the common idea of the relative position of the Pacific and Atlantic oceans and would prevent confusion. Mr. Fergusson.

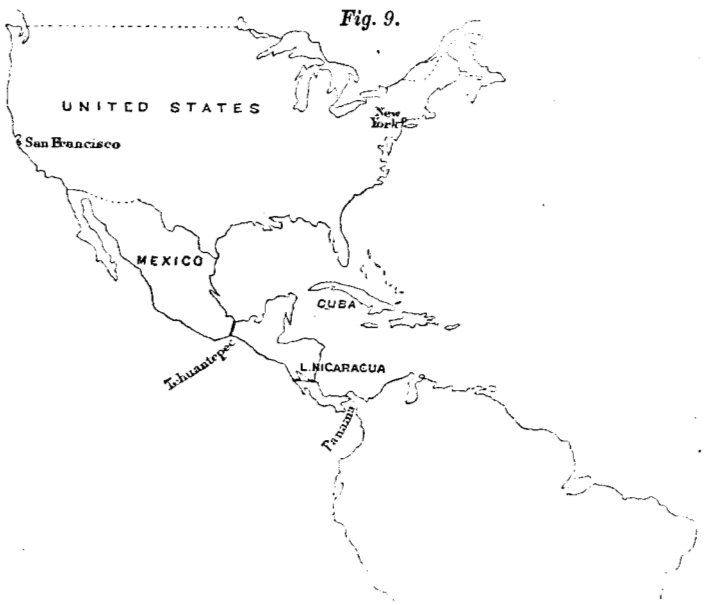
Mr. J. MELDRUM did not propose to enter into engineering details, though they were undoubtedly interesting. First, he wished to point out, however, that both the Panama and Nicaragua routes were situated in districts decidedly subject to earthquakes, and no engineer would require to be told what would be the effect on the lock-gates of a very slight disturbance. The result would be that the whole of the canal would be paralysed and every vessel in that reach of the canal would be stranded. Secondly, it appeared to him that the Author had minimized the probable effect of the inbreak of the River Chagres. Such an incursion would undoubtedly interrupt the whole traffic of the canal. It was an event which might occur any year, notwithstanding any works that might be built to prevent it. Thirdly, as something had been said about the Nicaragua Canal, he might remark that he would not care to estimate the probable cost of maintaining a canal dredged in the low swamps through which that canal passed. Turning to the commercial or economic view of the routes, he would take the Author's estimate that it would cost £21,000,000 sterling to complete the Panama Canal and that £51,000,000 had already been spent. Assuming that, of the £51,000,000 something like £20,000,000 represented the available assets—that was, that work had been done of that value—it meant that the canal would ultimately cost £41,000,000 sterling. The cost of the Nicaragua Canal had been estimated at £30,000,000 sterling, which, as experience of such projects showed, might easily run into the same figure of £40,000,000. To pay only 4 per cent. on that outlay a net revenue of £1,600,000 per annum was needed, or a gross revenue of not less than £3,000,000 sterling. It was almost Mr. Meldrum.

Mr. Meldrum. impossible to estimate what the traffic on the canal would be, but in another work of a similar nature in which he was interested it had been estimated that a traffic between the two oceans of over 2,000,000 tons per annum would have to be provided for. On those 2,000,000 tons per annum there would need to be a charge of between 20*s.* and 30*s.* per ton, and that would undoubtedly kill a certain portion of the trade. In those figures he was more or less supported by the results on the Suez Canal. There, with an expenditure of rather over £16,000,000 sterling, the rates had varied between 13 francs and 9 francs per ton on the registered tonnage of the vessels. Comparing that expenditure, £16,000,000 with £40,000,000, that would mean a charge of something like 25 francs to 30 francs. This estimate, however, was made on the assumption that all vessels would pass through fully laden, which was incorrect, because the eastward and westward traffic were not nearly equal. Putting aside for the moment the necessity of a canal to the United States—as now that that country had undertaken responsibility in the Indian Ocean it would be necessary for them to avoid the possibility of having to send men-of-war round by Cape Horn, which, in the event of a conflict with a first-class power, would probably mean the loss of some vessels—the question was, what competition the canal would have to meet. First, the route by Cape Horn, with its many disadvantages; and, secondly, interoceanic railways. The earliest of the latter was the Panama Railway itself, even with its bad gradients and its want of terminal facilities. But there was a younger and more powerful rival in the field to which he desired to call attention, namely, the route through the extreme south of Mexico, what was known as the Isthmus of Tehuantepec. About 350 years ago Charles V. of Spain had written to Cortes, the conqueror of Mexico, asking him to make close investigation as to the possibility of finding a waterway through that isthmus, to which Cortes had replied that if it could be found it would make the King of Spain ruler of so many countries that he might be called the "Lord of the World." Passing over all reference to the numerous schemes for canal or ship-railway connection, and coming to more recent dates, in 1893 the Mexican Government had built a railway from ocean to ocean. It had been of a temporary nature and, having no terminal facilities, had only served local traffic. In 1898 the Government had entered into contracts with Messrs. Pearson and Son, of Westminster, the firm with whom he had the honour of being connected, by which it had been arranged that that railway should be put into first-class condition for heavy

traffic, and that terminal ports should be constructed. Messrs. Pearson had undertaken the management of the system for 50 years. He would not weary the members with the details of the scheme except to give data for comparison with other schemes for inter-oceanic communication. The railway, which was of standard gauge, was 192 miles in length. When altered it would have a ruling gradient of 1·6 per cent., compensated for curvature, otherwise a ruling gradient of 1 in 60. Harbours would be built at the two ends with a depth of 10 metres, or 33 feet, of water, the length of quays being about 1 kilometre at each end to begin with, with

Mr. Meldrum.

Fig. 9.



abundant facilities for extension. The harbours would be fitted with the best appliances known to engineering science for the handling of heavy traffic, most probably by electric power. The entire system would be open in not less than 3 years from the present date, and Messrs. Pearson would then be prepared to handle the whole traffic of the Pacific. As a matter of fact, while theorists had been thinking and commissions had been sitting, a single British firm, backed up by the Mexican Government, had solved the commercial difficulty. With the appliances which it was proposed to adopt there, the total charges from ship to ship would not exceed between 10*s.* and 12*s.* per ton, and goods arriving at

Mr. Meldrum. one ocean would in less than 24 hours be alongside at the other terminus. The position therefore was this. There were two canal schemes proposed, with expenditures which might be fairly put at not less than £40,000,000 sterling each, with probabilities of interruption of traffic from accident, from insurrection, and from war. Without alluding to possible difficulty between Great Britain and the United States as to Nicaragua, he thought it was quite within the limits of possibility that the Nicaragua Canal might be closed at any time. These canals, requiring such heavy expenditure, would have to compete with a fully-equipped modern scheme the whole cost of which would not exceed £5,000,000 sterling, and the canal, with charges probably from 25*s.* per ton upwards, would be met by the other scheme, with charges not exceeding 12*s.* per ton. The accompanying map, *Fig. 9* (p. 187), would show the relative positions of the several schemes, and it would be seen that the Mexican Gulf entrance to the Tehuantepec route was nearer to San Francisco than New Orleans was by the Southern Pacific Railroad. He mentioned the point because it had been always the aim of the Americans to get a short connection between the west coast and the Mexican Gulf. Between those two points the Tehuantepec route had the advantage of 1,600 miles over the Panama route; and between New York and San Francisco an advantage of over 1,100 miles; and generally it brought the east coast of the United States nearer to the west coast by over 1,000 miles over the Panama route, a saving of distance which he thought fully compensated for the delay involved in the discharge of vessels, by using the railway rather than the canal.

Mr. Hawkshaw. Mr. J. C. HAWKSHAW, Vice-President, had read the Paper with great interest, the more so because he had been present at the meetings in Paris in 1879, when the matter had been first brought forward by Mr. de Lesseps. He had gone there with his father, Sir John Hawkshaw, Past-President Inst. C.E., who had been one of those specially invited by Mr. de Lesseps to be present at the Congress which he had summoned at the rooms of the Geographical Society in Paris, for the purpose of discussing the various projects for making a canal across the isthmus. The project brought forward by Mr. de Lesseps at that meeting had been for a canal on the level from ocean to ocean, without locks. It had been intended to pass under the Culebra dividing-range, through a tunnel sufficiently high to admit of the passage of vessels. From the information given at the time it had been evident that very great difficulties would have to be met before such a canal could be made. If he remembered rightly the Chagres River rose 40 feet in a few

hours, with a width of 1,200 feet. His father had pointed out that unless some steps were taken to regulate and control the river it would cease to flow on its course to the Atlantic, and would take the shorter course through the tunnel to the Pacific and render the tunnel useless for the purpose of navigation. Years before that meeting, American engineers had investigated the question of making a canal across the isthmus. They had been represented in Paris by Admiral Amman and Mr. Menocal, whose name had been heard so much in connection with the Nicaragua route. The American engineers had certainly been then in favour of the Nicaragua route, and they had had very complete plans prepared at that time. One great advantage in that route was that the lake which would form the summit-level of the Nicaragua Canal acted as regulator of the rivers which flowed out of it, and up the valleys of which the canal would have to pass. In fact the Nicaragua Lake did naturally what would have to be done artificially on the Panama Canal by dams and storage-reservoirs. The problem presented by the Chagres River seemed to him to have been very completely considered by the present promoters, and if the river could be regulated for the estimated cost the canal would be cheaply carried out as far as that was concerned. It would be a much more difficult matter to deal with that river with the canal on the level without locks than it would be with the canal raised across the ridge, and this modification of de Lesseps's proposal had rather simplified the problem of dealing with the Chagres. All engineers must wish success to those who were proposing to complete the canal on which so much had been spent, and which could not fail, if carried out, to be a benefit to the commerce of the world in general, and more especially to that of this country.

Mr. Hawkshaw.

Mr. W. PILKINGTON had been struck by the difficulty that seemed to arise from the great difference between the low-water discharge of the Chagres River, of 26 cubic yards per second in dry seasons, and the enormous quantity of 3,400 cubic yards per second at the time of torrential floods; and it appeared to him that if the Alhajuela dam were used for the high-level locks and the water were maintained at a high level, there would not be receptive capacity for the great downpour at the time of floods, and an accident might occur; which would not be the case if the dam fixed in that spot were used in the first place simply to control the destructive power of the Chagres River. When he had been in those latitudes, some 15 years ago, one of those destructive floods to which Mr. Hawkshaw had referred had taken place, and the

Mr. Pilkington.

Mr. Pilkington. engineer's opinion of the matter had been that the destructive power of the Chagres River would inevitably prevent the successful construction of the canal. Bearing in mind those facts, and knowing that at that level the total rainfall during the wet season amounted on the average to 29½ inches in three months, he thought the estimate in the Paper of 3,400 cubic yards per second was none too large. His object in drawing attention to that point was to advocate getting rid of those upper locks altogether and making the canal at the lower level. The quantity allowed for as the maximum storm-water discharge was 576 million tons of water in 48 hours, nearly double the combined capacity of the two reservoirs, the one being 130 million cubic yards and the other 160 million cubic yards, or together 290 million cubic yards. The Author deserved thanks for having brought the question forward.

The President. The PRESIDENT observed that there were one or two points arising out of the Paper which might, he thought, have been very instructively discussed if the materials had been supplied. Figures had been mentioned for minimum flow and maximum flow, but they could not be compared with anything known in this country, because no drainage-area was given. The area of the Chagres watershed was not stated above the point where the discharges were measured or estimated. There was not a word about the rainfall, neither the mean of a long term, nor heavy falls in short periods, nor similar details which would have been really useful. The relation of the maximum to the minimum flow was a matter in which many members were very much interested, and that was not given in the Paper in the way in which it was generally considered in England. There was the minimum, but the maximum was given over 48 hours, which he understood to mean the average discharge during the 48 hours, and that, of course, must be considerably less than the true maximum. On a drainage-area he had to do with at the present time very great fluctuations occurred. He was dealing with 46,000 acres in the Elan Valley, and there had been so low a discharge as 4½ million gallons per day from that area; he had estimated in the provision for the works that there might be in time of maximum flood 700,000 cubic feet per minute, which was about 6,300 million gallons per day. That meant 15 cubic feet per acre per minute. He had already gauged rather over 11 cubic feet from the whole area, and in the previous week from about 20,000 acres there had been something like 13 cubic feet per minute per acre. These were all the factors necessary for arriving at definite conclusions, and it was rather a pity such details were not given in the Paper. It appeared to him

that the Commission, in fixing the summit-level of the canal at 98 feet above the sea, were making a mistake. He thought, with the Author, that the 62-feet level would be much preferable. The Bohio dam was intended to hold the water up to the 62-feet or second lock-level, and there it formed an enormous lake of very much larger capacity than that at Alhajuela. If the level of the canal were fixed there, many of the difficulties would be overcome. The Author referred to the channel which was required to bring the water from the Alhajuela reservoir into the 98-feet level. It had to be an artificial channel made through a very difficult country, and might prove extremely costly. As he understood it, if the 62-feet level were taken, then the discharge from the Alhajuela dam would come by the river itself into the enormous reservoir formed at Bohio, which would very much simplify the whole thing. He saw no difficulty if ample spill-ways, as the Americans called them, were provided from the Bohio reservoir with proper controlling sluices to get rid of the great volume of flood-water. The difference in cost between the 62-feet and the 98-feet levels appeared to be only £800,000, and a good deal of that sum might be absorbed by the difficulties which, as the Author pointed out, would arise in constructing the great channel required to bring water for lockage purposes from the Alhajuela reservoir down to the 98-feet reach. The President.

The AUTHOR, replying in writing to the Discussion, remarked that he had been much gratified by the interest shown in the Paper. As the President had observed, the Paper was somewhat unusual in character, and in its preparation he had been so careful to avoid all mention of the rival Nicaragua route that Mr. Holt apparently believed "he had not the courage of his opinions" as to the absolute superiority of the Panama route from every point of view. In this connection it was sufficient to refer to his official connection with, and public advocacy of, the Panama route in the Press, as representative of the Colombian Government, and as its Consulting Engineer in the pending negotiations with the United States Government for the completion of the Panama Canal; but he had felt that, in a Paper dealing exclusively with the engineering features of the Panama Canal, all disparaging statements or comparisons with the proposed Nicaragua Canal should be avoided, as an unfair attack upon important financial or political interests, and consequently an improper use of the privileges of the Institution; while such comparisons would be quite proper and in fact unavoidable in a discussion of the subject. It should also be borne in mind that the construction of a canal across the Central American isthmus was The Author.

The Author. a question of such vast importance, outside of its purely engineering aspects, that decision as to the ultimate plans to be adopted was necessarily modified to a very large extent by commercial, financial, concessionary, political or international exigencies. Yet, connected intimately as he was, and had been, with every phase of the question, and giving due weight to such modifying circumstances, he unhesitatingly declared his attitude towards the relative merits of Panama and Nicaragua as wholly in favour of Panama on every separate count. Mr. Holt's enquiry, as to the period referred to in the Paper, was opportune, as a great deal had occurred since its preparation which was of the greatest importance to the canal, viz., the appointment of the United States Commission of Engineers to report on all Isthmian Canal routes, the publication of their preliminary report, and the international negotiations over the lapsed Hay-Pauncefote Treaty, which had been intended to modify the still-existent Bulwer-Clayton Treaty between Great Britain and the United States, and, lastly, the entirely new aspect given to the whole question by the direct offer from the Colombian Government to the United States of the control and ownership of the Panama Canal on certain favourable conditions, neither antagonistic to existing treaty-stipulations nor unjust to the present French company's concessionary rights. All of which certainly brought within a far more measurable distance the definite and final solution, with reasonable guarantees of a neutral canal, built by the United States Government, and not necessarily worked on a purely commercial basis for profit with excessive rates on shipping (hence an ideal set of conditions for the engineer to develop the best possible canal); and such a solution, he maintained, could only be reached at Panama—never at Nicaragua. The Paper had been written immediately after the Author's visit of inspection to the works, on behalf of the Colombian Government, in February, 1899, so that some considerable progress had been made deeper into the Culebra. It had been forwarded to the Institution some time in September of the same year. The greater part of the figures and actual surveys and plans which accompanied it had been obtained officially from the Panama Canal Company, whose work he had had ample and frequent occasion to verify on the ground; and in answer to the concluding remarks of the President of the Institution on the subject of rainfall, and in fact every other detail in which the Paper might have been found wanting, he would point out that full information might be found in the very elaborate reports prepared not only by the Canal Company's engineers but by

the various American Government commissions, which, from their voluminous nature, it would be impossible to condense within the limits of the Paper. For the purposes of all sluice and spill-way calculations the engineers had been most careful to use the maximum figure given, which was the actual maximum observed in a long period of years, and they had further assumed, what was highly improbable, that such maximum might be maintained for 48 consecutive hours, not, therefore, the average maximum in 48 hours. Such an assumption gave an ample factor of safety; and with regard to the question of average rate of discharge or "run off," he could assure the President that the investigations had been particularly complete, and were available to any member who cared to pursue the subject. With reference to Mr. Donaldson's questions on sluices and controlling works, the most elaborate plans had been prepared both for the Gigante or Bohio sluices and at Alhajuela dam for controlling both the basins, but he was unable to state if the Stoney or any other specific type has been finally adopted by the company's engineers. As to the nature of the substrata, there need be no apprehension whatever. Among the reports were complete geological sections based on borings and excavations which had been made on the most extensive scale down to and even 100 feet below sea-level in some cases, notably at the dam site of Bohio, for the foundation as proposed on the solid rock there found at varying depths, the maximum being 100 feet below sea-level. Again, in the Culebra cuts, examination-pits or wells had been sunk, besides occasional borings, nearly down to sea-level; the pits were lined with a skeleton iron frame about 5 feet in diameter permitting the most thorough examination of the strata, and the samples taken from depths far below the proposed bottom levels of the canal showed that the materials did not soften or disintegrate after removal, and were certainly found to become harder as the depth increased. This fact was also evident in the 150 feet of perpendicular height already exposed in the sides of the cut at Culebra summit, which had remained for years with absolutely no protection, and showed no sign of deterioration from the weather, standing as they did with faces at almost any angle between 45° and the vertical. In this respect alone, and on every mile of its length, the superiority of the Panama over the Nicaragua Canal was beyond question. Almost at right angles across the Culebra cuts at frequent intervals were almost perpendicular dykes of volcanic origin, 5 feet or 6 feet thick, of a kind of black basalt. Upon their intrusion they had undoubtedly metamorphosed to a large

The Author.

The Author. extent by heat and pressure the rock between, which was not granite, but partly conglomerate, indurated sandstones and shales of varying character, easily shattered in the upper strata and increasing in hardness with the depth. Whilst he was unable to give the proper geological classification of the material encountered throughout the great cuts, it might be of interest to refer to the extensive deep lock-excavations of the old company at Obispo, which had stood exposed for nearly 15 years. They were of an extremely hard dark-coloured sandstone; the surfaces of fracture at the sides of the cutting were as sharp as though blasted a week ago; the mass was solid without rifts of any kind, and was perfectly watertight, the lower part of the lock-basin being always full of water to a depth of 30 feet in the driest weather, although left just as blasted, without lining of any kind. These excavations were, of course, at a lower elevation than Culebra, but they appeared to him to be in the solid bed-rock underlying the whole isthmian divide, and through which a sea-level canal would certainly cut, and would thus be confined between perpendicular walls of as great a height as might be desirable, having regard to economy in excavation and safety in the upper ledges of the cut in the softer material. From these statements as to the character of the material it would be evident that in his opinion the suggestion of Mr. Fergusson to excavate by monitors or to carry out any other form of hydraulic work was not practicable to any useful extent, even with the head of water obtainable from the Alhajuela dam. Monitors could do nothing against the faces of the Culebra cut even at its present depth, and even if head enough could be got for the upper strata the work would so interfere with the lower rock-excavation as to render it out of the question. With regard to Mr. Vernon-Harcourt's questions on the sea-level canal, he firmly believed that at Panama it could be so built at a cost within 50 million sterling, and within 20 years; he also believed that it would eventually be so built on account of its obvious advantages, apart from the possibility that it might be built by the Government of the United States regardless of the doubt whether, on such a basis of cost, it would or would not be, at first, a profitable investment. Such a doubt would, of course, be fatal to the canal as a purely commercial undertaking, and its consideration had been consequently excluded by the French Canal Company as a possible solution of their problem. Its perfect feasibility as a safe engineering achievement was nevertheless beyond question, and if it were so built there were many reasons which would incline him to recommend a pair of controlling gates or, practically, a lock near

Obispo where the Chagres met the line of the canal and turned towards the Atlantic. This lock would exclude, if, or when, desirable, the flood-waters of the river from three-fourths of the canal; they could best be taken into the canal from that point to the sea in a very broad and ample channel which, together with the controlling works of the Alhajuela dam, would leave no room whatever for apprehension as to their destructive power; but as to the best method of dealing with the Chagres for a sea-level canal, there were several possible solutions, either including it in the canal below Obispo, as here suggested, with controlling works at Alhajuela, or throwing it bodily into the Pacific through a tunnel above those works. The discussion as to how far up the canal the Pacific tide would be felt was largely an academic one, even for a sea-level canal, as it would probably be found cheaper and safer and just as convenient to add a tidal lock at the Panama end and avoid the increased excavation below low tide for many miles of the canal; for even with the controlling gates or lock at Obispo and tidal lock at Panama, as proposed, the canal would still be practically a sea-level canal, only occasionally convertible into a lock-canal during heavy floods, and without any fear of a continuous current from one ocean to the other, suggested as a possibility by Mr. Saner in speaking of the Gulf Stream and ocean currents, etc. With regard to the present value of the plant on the ground, there would, of course, be much difference of opinion among engineers. He, however, could not consider it a negligible quantity in a comparative estimate with Nicaragua, for he included in the expression "plant" the existing construction-tracks, and he had seen a considerable quantity of the old machinery in constant effective use for several years past, and knew that in those regions permanent way, dry-docks and workshops were costly to construct and equip, and, no matter how much out of repair, were still cheaper to resuscitate than to build anew, especially across such bottomless swamps, virgin forests, and rough hill-country as existed on the 192 miles of the proposed Nicaragua Canal route. New and better types of dredgers, excavators, carriers, locomotives, and rolling-stock generally would certainly be needed in profusion, but as to the side-tip wagons mentioned by Mr. Vernon-Harcourt, he had especially examined them and observed their operation, and he did not share the company's regrets, but considered them a very effective type of wagon for the conditions at Panama. The popular impression voiced by Mr. Wells, as to the advantages of the lake and waterways already existing at Nicaragua towards the construction of a canal there

The Author.

The Author. for ocean steamers, was wholly erroneous. The water at Nicaragua, though certainly tinted blue on any conventional map, must (for all the use that it would be as a saving in the cost of construction on the 192 miles of canal 35 feet deep, as was now proposed by the American Commission) be considered dry land for practically three-fourths of the total length, and any such statements as that of there being 28 miles only of canal to construct out of 192 miles at Nicaragua were to be deprecated as entirely misleading. In fact, with the exception of about 30 miles only, in the lake, and some 15 miles to be raised in the San Juan River by the San Carlos dam, the whole Nicaragua Canal route was practically in dry ground, and much of it, especially the 22-mile channel to be dredged in the lake itself, was likely to be more costly, both as to execution and maintenance, from the very fact of its being covered with 4 feet or 5 feet of water or soft mud. Again, the Nicaragua route entailed numerous cuts almost as heavy as the Culebra, also innumerable dams, heavier, more costly and more doubtful as to safety or possibility of construction, than at Panama. As to the figures brought forward by Mr. Meldrum on the relative advantages of Messrs. Pearson's Tehuantepec, or any other trans-isthmian railway, the tonnage (dependent of course on the rate to be charged) which would pass through the Panama Canal, even in the early years of its operations, might be 5 million tons, and considering the great tonnage of the Suez Canal and the three-fold greater tonnage of the American lakes passing through the Sault Ste. Marie Canal, the future development of traffic for an isthmian canal was likely to be enormous, but was certainly impossible of accurate estimation at present. In any case, however, he was of opinion that the circumstances under which the canal was likely to be built would permit the adoption of a freight rate much lower than that at Suez, probably not exceeding 6*s.* per ton; but even if it were to be 12*s.* (20*s.* being entirely out of the question) the double trans-shipment on any competing railway, however well managed, could never compare with through carriage by water on a single bottom *viâ* Panama; so that the Tehuantepec, as well as all other isthmian railways, would probably have to develop local traffic for a living, and most of them could certainly do this. The Panama Railway was, of course, a part of the canal property, and would disappear as a through freight-carrier on the completion of the canal, but even if it did not, its enormous advantages over Tehuantepec as a competing railway alone were too obvious to need discussion; while the three other prominent lines which connected, or would ultimately connect,

the Atlantic and Pacific Oceans across Costa Rica, Guatemala and Mexico, doubtless regarded their through carrying business more as a contingent or possible extra source of income rather than the mainstay of their permanent business. Otherwise they were likely to be disappointed when any canal was built. As to the relative advantages in geographical position of one or other of the canal or railway routes across the isthmus, as regarded traffic between certain ports, the amount of traffic affected in any case by 200 miles one way or the other would be so insignificant compared with the total volume of the trade through any canal, that it could not be regarded as a ruling factor or even as a very important factor in the choice of a route; whilst the volume of tonnage likely to be attracted away from Suez was so dependent on the rates to be charged and other financial and political conditions under which the Panama Canal would be constructed, that, though interesting as matter for speculation, it was beyond the scope of this discussion. Certain points were relevant, however, and should be mentioned. The Panama Canal, with its 46½ miles of straight or moderately curved channel, could certainly be traversed by any steam- or sailing-ship within daylight of a single day, whether with or without locks, while he maintained that at Nicaragua, because of the wretched alignment and great length proposed, 192 miles, sailing craft could not be towed through at all without serious interference with the quicker steam-traffic and an excessive cost for towage; while even steamships would need practically the daylight of 3 days to get through. Navigation by night would be too dangerous for large vessels, if not quite impossible, as over more than three-fourths of the mileage the average speed, owing to the curves and the risk of grounding on hard bottom, dangerous influence of winds and currents, bad steering in shallow water, etc., would not be more than 5 knots per hour, the conditions being wholly different from those at Suez, since effective lighting at Nicaragua would be impossible. Thus in the actual passage through the canal itself, the difference of time in favour of Panama, in all cases, would certainly more than neutralize the accidental difference in particular voyages in favour of the Nicaragua or Tehuantepec routes, due to their geographical position; hence the figures given by Mr. Meldrum, unless carefully analysed, were extremely misleading, in that they applied, without differentiating, to a canal in Nicaragua and to a railroad in Mexico some 500 miles apart. Mr. Meldrum was also mistaken in saying that the Author had minimized the possible effect of flood incursions from the Chagres River on a sea-level canal at Panama. As he had shown, he con-

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The Author. sidered the problem of controlling the Chagres floods an extremely simple one, susceptible of several different solutions, though certainly too costly to permit a purely commercial canal to be excavated down to sea-level. On the other hand, he was amazed at the unprecedented problem presented at Nicaragua and the method proposed for its solution, that was, the control of the level of Lake Nicaragua so as to maintain a constant depth over the estimated excavations in the lake channel itself, some 22 miles, and for 40 miles down the San Juan River. This necessarily constant level was to be maintained by a dam built 60 miles away from the lake, which dam must provide for the constant flow of the San Juan River. Its crest must therefore be considerably below the desired lake-level, and the San Juan River in the driest seasons was over 1,000 feet wide and 6 feet deep at the San Carlos dam site, with a current of at least 2 knots. Could the Lake of Nicaragua (150 miles long by 60 miles wide) be maintained at a practically constant level, adopted beforehand without the aid of any data of experiments on works of such magnitude elsewhere, by the small San Carlos pond created 60 miles away from it with a dam at any height allowing for the enormous discharge of the San Juan River? And who among engineers was competent to design with any degree of certainty the controlling works which would accomplish that feat and make it other than a huge and doubtful experiment, involving, possibly, an enormous extra expenditure in deeper excavations in the lake and upper San Juan than had been estimated for, to maintain the constant depth? There were other doubtful and dangerous problems on the Nicaragua project, while at Panama the danger point was long past, in that everything yet to be done there, the labour question, the harbours, etc., was established as practicable, not only elsewhere but by actual experience on the ground itself and work already done there. Hence, even with the equality of talent, experience, and impartial criticism brought to bear on the two problems by the present American Isthmian Canal Commission, whose final report was yet to be published, he would accept without question their Panama figures and yet very seriously question their Nicaragua estimates as of less intrinsic value. But even their preliminary and somewhat paradoxical report already published, gave the preference as to cost and other features to Panama; their recommendation of Nicaragua as best for the United States being based on the limitations imposed upon them under the law of their appointment, which introduced difficulties of a purely concessionary character which had since been removed by the recent offer of the Government of Colombia as previously stated.