Correspondence.

General Abbot.

General Henry L. Abbot remarked that the Paper was so complete and so logically arranged that little suggested itself to him as interesting to add in regard to the subject, but a few words in relation to studies subsequent to the date of the report of the International Technical Commission might not be out of place. There could be no doubt that the ideal canal would be one without locks and without curves. This standard had been kept in view in the studies of the project, calling for the minimum possible number of locks, and the minimum possible curvature in location. In regard to the first condition, no plan, to his knowledge, had yet been suggested which would afford satisfactory regulation of the floods of the Chagres River in a canal without locks. Since the valley of this stream must be followed for an important part of the route, it was absolutely necessary to resort to the well-tested plan of providing reservoirs to restrain the great floods; and this demanded a system of dams and locks. To reduce the number of these locks to a minimum was the important object of study. The most advantageous level for the projected Lake Bohio demanded two of them, each with a lift of 29 feet 6 inches. If the summit-level of the canal could be kept down to this height above the sea, three locks would still be required to make the descent to the Pacific, the one at Miraflores being practically a tidal lock similar to those at the entrances of the Kiel and North Sea canals. This level, however, required such extensive excavation at the continental divide that it might perhaps involve unnecessary delay in the completion of the work, with interest charges (when the completion of the work was so near) which would be onerous to a private company. The problem thus took the form of devising a project which, without involving the loss of any work already performed, should permit this summit-level to be adopted ultimately if it were found that the excavations could be completed in time. This condition was fulfilled in the project adopted. Following the conservative principle of recommending nothing which did not commend itself as certainly practicable within the estimates, the Technical Commission favoured the medium level of the three suggested, leaving the final choice between this and the lower level to be made later, when the actual progress of the work had established which was preferable.

General Abbot. It might be added that, in the minds of some at least of the members of the Commission, further information was desired as to the relative volumes contributed by the three basins into which the valley of the Chagres above Bohio was divided, a matter which had an important bearing upon the question of the division of the flood-volumes to be held in reserve in the two lakes, a division which was not the same in the two lower plans. Taking advantage of the delay in resuming active operations on a large scale, which had resulted from other causes, the new company, during the past eighteen months, had re-established the observation-station at Alhajuela and had made measurements of daily discharge in connection with a tide-gauge recording automatically the water-level.[1] The data thus secured, in combination with similar measurements made at the old stations at Gamboa and Bohio, had now enabled this question to be definitely settled. With previous measurements, covering over 10 years, they showed that 60 per cent. of the discharge at Bohio, and 82 per cent. of that at Gamboa, passed annually at Alhajuela; that in the large freshets these proportions varied between 82 per cent. and 63 per cent. of that at Bohio, and between 83 per cent. and 80 per cent. of that at Gamboa; and that during the dry season these proportions were 70 per cent. and 90 per cent. respectively. It was thus certain that the additional flood-reserves contemplated at Alhajuela, with a summit-level coinciding with that of Lake Bohio, were entirely practicable; and, in addition, that the Chagres furnished in the dry season, with the reserves projected, an ample water-supply to permit the passage of 23,000,000 tons of freight annually, whichever level were adopted. There remained therefore only the question of interest costs to be considered; and he quite agreed with the Author that the lower level was to be preferred if this matter of interest costs could be ignored. This conclusion was in perfect accord with the recommendations of the Technical Commission, upon which, it should be remembered, had rested the duty of limiting its specific recommendations to what known facts warranted with certainty. It had always seemed to him that so adjusting the project as to reserve the decision of this important point until actual progress in the work should have determined which level was preferable, was one of its most commendable features. It was to be remembered also that the delays and objections attendant upon lockages had been much exaggerated before actual

[1] "Rainfall and Drainage in the Upper Chagres River," H. L. Abbot, *Monthly Weather Review*, June 1900.

General Abbot.

experience on the Manchester Ship Canal had furnished exact data. For example, in 1890 the time lost in passing a single lock having a lift of 29 feet 6 inches had been estimated by the able Commission of engineers called to advise the Receiver, upon the best information then available, at 65 minutes. Careful observations on the Manchester Ship Canal had now reduced this time to 33 minutes. Indeed a conservative estimate now placed the entire time of transit from ocean to ocean by the lower project at only 11 hours, involving a loss of only about two hours from lockages. Another matter, to which for ease and safety in passing a ship-canal enough consideration was often not given, had engaged the attention of the Technical Commission. This was the importance of gentle curves. A strong wind astern or abeam, acting on the immense surface exposed by modern ocean steamers, was a very serious matter in passing a sharp curve. As to this important element, nature and a careful study of the project had placed the canal at Panama at the head of the list of such works, existing or projected; and this had more to do with the commercial success of a ship-canal than a few modern locks. For instance, the Suez Canal had been originally constructed with a minimum radius of 700 metres (736 yards), which actual experience had led the company to increase to 1,800 metres (1,968 yards). As some slight improvements had been made in details since the date of the report of the Technical Commission, on which the Author based his figures, it might be of interest to give the curves on the final drawings now adopted by the company.

Radius in Metres.	Length in Kilometres.	Percentage of Total Length of Canal.
4,000	3·4	4·5
3,500	6·6	8·7
3,000	16·7	22·0
2,500	6·9	9·0
2,000 minimum	0·7	1·0
Straight	41·4	54·8
Totals	75·7	100·0

These figures, with the locks as projected for the lower plan and the ratios adopted between the area of cross section of the canal and the midship section of ships of commerce, joined to the usual absence of troublesome winds on the Isthmus of Panama, justified the belief, above stated, that the transit of 46 miles

General Abbot. between the two oceans would be effected in the period of 11 hours; and hence that the canal would be little inferior to one at the sea-level, which the immense cost and the difficulty of regulating the floods of the Chagres would, in his judgment, render hardly practicable.

Mr Cay. Mr. W. DYCE CAY, with the view of appreciating the subject, had prepared the following Table to show the geographical effect the construction of the Canal would have; the distances were in nautical miles, and were measured mostly on great circles, and they did not take account of currents or other nautical matters.

	By Suez Canal.	By Cape of Good Hope.	By Cape Horn.	By Panama Canal.
	Nautical Miles.	Nautical Miles.	Nautical Miles.	Nautical Miles.
Southampton to Shanghai	10,400	14,000	17,000	12,900
,, ,, Melbourne	10,800	11,700	12,400	12,400
,, ,, Auckland	12,100	13,000	11,400	11,100
,, ,, Manila	9,900	13,500	16,600	13,300
New York to Shanghai	12,400	14,700	16,800	10,300
,, ,, Melbourne.	12,800	12,400	12,200	9,800
,, ,, Auckland	14,100	13,700	11,200	8,500
,, ,, Manila	11,900	14,200	16,400	10,700

The distance from Panama to Shanghai was upwards of 8,000 miles. From this point of view it appeared that, except in the case of New Zealand, the trade of Europe with Asia and Australasia would gain nothing in point of distance by the construction of the Panama Canal. Its advantage would be in the case of trade with the Pacific Coast of the Americas and with the islands of the Pacific. In reference to the scheme and estimates of the Technical Commission, as described in the Paper, he observed that the Pacific maritime section comprised a channel in the sea 3½ miles long, 165 feet wide at the bottom, and excavated, in hard rock, to 40 feet below mean-tide level, or 30 feet deep at low tide, and he considered the width insufficient, keeping in view the length of vessels anticipated, for which locks 780 feet long were to be provided. The price for the excavation of the rock, 3*s.* 4*d.* per cubic yard, also seemed to him inadequate. It would add to the great interest of the Paper if the Author would give the estimate of the sea-level canal scheme, which he mentioned as best, if attainable. If Panama was the only site for such a project, it would be a pity to occupy it by a lock canal, as no doubt there would in time be a large traffic.

Mr. Choron. Mr. L. CHORON, of Paris, remarked that the Paper gave a clear

account of the present position of the matter from a technical point of view. The Author was not correct, however, in stating that the Technical Commission's principal reason for putting aside the plan for a sea-level canal had been its cost and the impossibility of its yielding a profit as a commercial scheme. The reason had not been the cost[1]—which perhaps might not be a much more important matter than in the case of the plan adopted—but the grave technical difficulties presented by the problem of regulating the Chagres River and protecting the canal against its floods. With a lock canal and the great central lake of Bohio this problem admitted of easy solution; without that lake it was almost insoluble. Hence the Author's view, that the nearer a lock canal approached to the sea-level the better it would be, was not altogether justified, because really the inherent difficulty of the regulation of the Chagres River would be seriously increased by lowering the level of the lake of Bohio below that adopted by the Technical Commission. Mr. Choron.

Mr. FARGUE, of Paris, wished to point out that the Technical Commission had not, as stated by the Author, rejected the plan for a canal at the sea-level on account of its excessive cost,[1] and he observed that such a canal would be an ideal solution of the question only if the Chagres River did not exist. Having regard to the torrential regimen of that river and its affluents, a canal at sea-level would constitute a defective solution of the problem, because, quite apart from its heavy expense and the length of time its construction would require, it demanded very complicated works, the success of which was very uncertain. It was for this reason, principally, that the Technical Commission had rejected the plan. The Commission had preferred the medium plan, because it presented a satisfactory and practical means of regulating the floods of the Chagres River and its affluents by a reservoir at Alhajuela and a large reach, the lake of Bohio forming a second reservoir. If the level of this lake were fixed lower than the height adopted by the Commission grave difficulties would have to be encountered, such as excessive height of the Bohio dam, diminution of the efficiency of the lake as a means of controlling floods, and excessive currents in the narrow parts of the lake. In other respects the Paper gave a correct summary of the plan accepted by the new company for the completion of the canal. Mr. Fargue.

Mr. A. FTELEY, of New York, remarked that the Paper came at an opportune time, when the expected decision of the Congress of the United States, in regard to the construction of a maritime Mr. Fteley.

[1] Compare statement, *post*, p. 206.—SEC. INST. C.E.

Mr. Fteley. canal between the Atlantic and Pacific Oceans, might soon have an important influence on the destinies of the New Panama Canal Company, and when engineers were especially interested in its operations. The new Company, immediately after its organization, had obviously recognized the inadequacy of the engineering records left by its predecessors and the impossibility of prosecuting its work with any kind of certainty without further study of the great problem to be solved. One of its first acts had consequently been to order fresh engineering investigations and to so arrange its operations that, while progressing with the work at a comparatively moderate rate, every step would tend, concurrently with the surveys and other engineering studies, to establish beyond a doubt the basis on which ultimate construction should proceed. In accordance with that programme, no excavation had been made at places where difficulties were not expected, and where the nature of the materials to be encountered was known, the excavating operations being limited to the points (especially the Culebra cut) at which great depths were to be reached, and where it was important to ascertain the geological characteristics of the lowest strata. In addition to the open excavations, shafts had been sunk and tunnels had been driven; borings and soundings had also been made at all places where it was expected to erect the masonry structures connected with the work. By this wise disposition of the preliminary capital entrusted to it, the Company had been able to remove all doubt as to the conditions under which the work was to be done, and to establish the fact that no difficulties were presented which had not been previously overcome elsewhere; the large amount of work already done had also enabled the Company to establish, with a reasonable degree of correctness, the figures adopted for the estimates of cost. Owing, however, to the very magnitude of the undertaking, new elements entered into the problem, such, for instance, as the possibility of procuring and maintaining, without serious labour disturbances and without consequent loss of time, the large number of workers necessary for the proper prosecution of the work. This difficulty had been obviated, to a large extent, by eliminating as far as possible the necessity for skilled labour; this result being especially attained by the wholesale introduction of concrete for all the parts of the masonry structures to which this material was well adapted. The gauging of the flow of rivers, to which the Author made a short reference, was a subject of vital importance for the success of the undertaking, and it had been studied with much care. With the aid of the numerous measurements of rainfall and of river-flow made for a number of

Mr. Fteley.

years by the old Company, and, subsequently, with increased accuracy by the new administration, it had been possible to ascertain the regimen of the Chagres and of other minor streams, and the formulas deduced therefrom by high hydraulic authority had been corrected and substantially confirmed as each year afforded new data. A valuable document recently prepared by the Company on this important matter brought the results to date, and left no doubt that the greatest freshets could be controlled by the various structures designed for that purpose, while the minimum flow, aided by the intended provisions for water-storage, was ample for feeding the canal. In discussing the various designs for the profile of the canal, the Author had given good reasons for his preference for a lower altitude of the summit-level. The reduction in the number of locks, the shortening of the time for the passage of vessels, the increase of the available storage in the upper basin, and the elimination of the feeding-channels from the Alhajuela dam to the canal, would be valuable improvements, and the necessary extra cost of the excavation probably would not exceed the estimated cost of the structures which would then be dispensed with; but the important element of the time required for construction must not be lost sight of. When studying the plan involving the higher level, the time necessary for the execution of the various parts of the undertaking had been so calculated that the excavation on the one hand, and the masonry structures on the other, could be completed simultaneously, thus reducing to a minimum the number of years necessary for the performance of the work. When, however, the Company undertook to organise the work on a large scale in view of speedy and ultimate completion, the operations could progress for a considerable time without finally deciding on the altitude of the summit-level: mechanical means for the excavation of large masses of materials were constantly being perfected, and if, during the early progress of the work, it were found by actual experience that the lower level could be adopted without any risk of extending the period of construction beyond reasonable limits, it was to be supposed that the Company would not hesitate to place the summit-level at the lower altitude. From an engineering standpoint, the Panama Canal did not present any special difficulties of construction; and the quantity of work already done, the existence of the large number of auxiliary establishments of all kinds now on the ground, and the presence of the Panama Railway across the isthmus, gave it a great advantage in the matter of the time

Mr. Fteley. needed to complete the undertaking. It now remained for the American Congress, after weighing the comparative political, climatic, commercial and engineering values of two different routes, to decide whether it would elect to build an independent canal at public expense, at the risk of encountering the competition of the Panama Canal Company, which was ready to push its own undertaking with private capital, with evident chances of completing it far in advance of the rival enterprise.

Mr. Fülscher. Mr. FÜLSCHER, of Berlin, considered that the Paper contained a satisfactory account of the various circumstances which were of importance in forming an estimate of the value of the work already done, and a judgment as to the prospects of the completion of the undertaking. He entirely agreed with the Author in his preference for the project with the lowest summit-level, and he had already published his views on this point.[1] He would point out, however, that the advantages of this plan, as mentioned by the Author, had been fully considered by the Technical Commission, and that only their aim at limiting to the utmost the money and time required for completing the canal—that was to say, purely financial considerations[2]—had caused them to recommend the carrying out of the medium plan in the first instance.

Mr. Hunter. Mr. W. H. HUNTER desired to express his sense of the value of the service rendered by the Author in submitting his Paper to the Institution, and in eliciting discussion on the proposals for the completion of the operations required for the piercing of the isthmus advanced by the New Panama Canal Company; more particularly as a crisis had been reached in the long history of effort, both of a political and technical nature, which had been put forth for many years past in order to arrive at a satisfactory determination of the questions connected with the inter-oceanic canal, and a final settlement, whether for good or ill, must be reached without much further delay. As the only English engineer who had had an official connection with the New Panama Canal Company (and who had, therefore, personal responsibility for the Company's project and for the Report of the Technical Commission, in which that project had been described), he deeply regretted that circumstances had rendered it impossible for him to be present at either of the meetings of the Institution at which the Paper had been discussed. The Author had wisely abstained from complicating the Paper by any examination of the political problems, as

[1] *Centralblatt der Bauverwaltung*, 1899, p. 181.

[2] Compare statement, *ante*, p. 203.—SEC. INST. C.E.

Mr. Hunter.

numerous as they were intricate, which had so important a bearing upon the Trans-isthmian Canal question, or by any disquisition upon the comparative merits or demerits of rival routes for the canal; nevertheless, British interests of enormous magnitude were involved in these problems, and British engineers could not afford to ignore them; while the final settlement of the claims of those who, upon the one hand, urged that the canal on the Panama route should be completed, and those who, on the other, desired that a waterway on the Nicaragua line should be commenced (all possibilities of other routes had been eliminated), must be of something more than mere academic interest to members of the Institution; more particularly as it might turn out that Great Britain would find, in respect of the Panama Canal, an opportunity as great, and with consequences as far-reaching, as that which, in respect of the Suez Canal, had presented itself in 1875. At the present juncture the points to be decided, so far as the Panama Canal project was concerned, were not whether all the details of that project were perfect in their conception and in their elaboration; or whether the level of the pond, which was to form the summit of the canal, should be some 98 feet above the mean level of the sea, as recommended, tentatively, by the Technical Commission, or some 67 feet, as preferred by the Author; but whether the project as a whole was a feasible one; whether the canal could be constructed upon the lines and for the sum suggested; and whether, having been constructed, it could be worked and maintained without interruption to traffic and consequent dislocation of trade interests. He ventured to suggest that the Paper, written from the point of view of an impartial eye-witness, furnished valuable information upon which answers to the foregoing questions might be founded, and he desired only to draw attention, by way of amplification, to one or two special matters which were of paramount importance in their bearing upon the points at issue. The proceedings of the promoters and founders of the original Panama Canal, culminating as they had done in a scandal which had shocked the moral sense of the civilized world, had created a prejudice, not only against the persons concerned in the proceedings, who had been universally and justly condemned for the part they had played, but against the project which they had gone so far towards destroying; and it was therefore only fair that it should be made known and should be clearly understood that the new Company, whether in the person of its directors and its officers, in the constitution by which it was governed, or in the methods which it had adopted, was entirely distinct from and

Mr. Hunter. opposite to the old Company, which, for all practical purposes, was absolutely defunct. The Author had rightly indicated one of the important factors which made for the ruin of the old Company in the almost entire absence of reliable surveys and other technical data when operations had been commenced on the isthmus. Neither time nor trouble had been spent in obtaining the necessary information. The scheme had been worked out and the design had been elaborated by the engineers as the work had progressed, with the inevitable result that disaster had ensued, the only wonder being that the disaster had been so long delayed. An examination of the documents, the elaborate and accurate contoured plans, the carefully levelled sections, the tabulated returns of results of borings, gaugings, etc., supplied to the members of the Technical Commission would be sufficient to convince any expert of the difference between the methods pursued by the old Company and by the new, and would remove any fear as to repetition of the fatal error committed by those responsible for the affairs of the old Company in beginning and in attempting to carry on their operations without reliable data of any kind. The exhaustive investigation of the natural conditions of the district through which the line of the Panama Canal ran had had one result of an important and a gratifying kind; for it had shown that the greatest of the difficulties which lay in the way of the successful achievement of the canal and of its subsequent working, viz., those due to the vagaries of the turbulent and uncertain River Chagres, could be effectively met. The gaugings of the flow of that river, which had been made with constant regularity for several years, had formed the subject of close study by General H. L. Abbot, late of the United States Engineers, whose researches into and publication on the flow of the Mississippi were so well known and so highly valued; and his figures showed that the regulating works, to be provided by the construction of the dams at Alhajuela and Bohio, would, at once, enable the most violent of the Chagres floods to be controlled, and ensure an ample supply of water for the working of the canal over a period of drought more extended than any recorded in history.[1] Another difficulty which was regarded by some as almost insuperable was the unknown character of the material composing the Cordilleras at the point at which it was necessary to cut through that mountain chain for the formation of the canal. This applied more particularly to the two mounds known as Emperador and Culebra

[1] *Ante*, p. 200.

(Fig. 2, Plate 6), which were the points of maximum depth and difficulty in the whole length of excavation. It was feared that the excavation could never be completed, and colour had been given to the fear by the fact that what at one time had looked like being an extensive slip had made itself apparent on one side of the Culebra cut. The directors of the new Company had taken, at the very outset of their proceedings, very definite steps to settle these questions in a decisive way. At great cost they had driven an exploratory gullet right through the length of deepest excavation, had widened out the gullet until one of its sides became coincident with that of the intended permanent cutting, and had sunk shafts from its floor to depths nearly corresponding with that of the bed of the canal itself. The experience gained from these works, the manner in which they had withstood the extremes of the tropical climate, taken together with the character of the materials disclosed during their execution, had disposed of all reasonable fears, and, as the Author had said, "actual demonstration" had proved that the great Culebra cutting could be completed and maintained. The whole subject of the Panama Canal was one more than ordinarily tempting to a man who had been concerned in the preparation of the project for its completion, and who would be glad of an opportunity to enlarge upon it; but space forbade, and he would only further express his conviction as to the effect a careful study of the whole project could only have on the mind of any impartial member of the Institution. That effect would be the same as such study had already had upon the minds of the members of the American Commission (presided over by Admiral Walker), which had been appointed by President McKinley to consider the whole question of inter-oceanic communication. They had approached the question without any bias in favour of the Panama route (whatever they, or some of them, might have had in favour of other proposals), and had placed on official record their decided opinion that the Panama Canal project, as elaborated on behalf of the new Company under the auspices of the International Technical Commission, was a sound and feasible one, that the work could undoubtedly be carried through to completion and could be efficiently maintained, and that at or about the sum which the Technical Commission had estimated it would cost. Mr. Hunter.

Mr. WILLIAM JAFFREY remarked that, of the various routes which had been proposed for canals to connect the Atlantic and Pacific Oceans across Central America, only two seemed now to occupy attention and to have been investigated in a systematic manner, and for those two routes alone had practical proposals for Mr. Jaffrey.

Mr. Jaffrey. canals been worked out more or less completely. These were the Panama and Nicaragua Canals, and it was to be regretted that the Author had not also given for purposes of comparison a summary, accompanied by a plan and sections, of the proposed Nicaragua Canal, so that both schemes might have been fairly presented and their merits discussed. In both cases considerable sums had been expended in preliminary works, and in surveys and studies of the physical conditions to be met in the execution of the works. At Panama, however, the surveys and observations appeared to have been carried out in a much more thorough and detailed manner, and over a longer period of time, than at Nicaragua, so that the basis for preparing a scheme of works and estimating the cost and time required for execution was more complete than in the case of the latter route. The most striking feature about the Panama Canal, since the disastrous collapse of the old Company, was the systematic and thorough manner in which the new Company had gone into the main points of the problem, thus enabling the International Technical Commission to set forth clearly and in considerable detail one, or rather three, practicable schemes for a canal across the isthmus. Of the three schemes, he agreed with the Author in the opinion he expressed that the low-level plan with Bohio Lake as the summit should be adopted. Two locks would thus be dispensed with, which would mean a saving of about a couple of hours' time to a vessel passing through the canal, and the Bohio Lake would form a large reservoir for supplying the locks on both sides of the summit instead of on one side only, as in the plan favoured by the Commission. The classes of work proposed were all simple in character and had been well tried, so that the element of risk in the undertaking had been minimised as much as possible. The question of economy in first cost appeared, however, to have received too much consideration, and to the estimated cost of the scheme, the cost of harbours at both ends of the canal would have to be added. The ends of the canal or the approach channels to it ought to be within well-sheltered basins which would allow vessels to enter and leave in all states of weather. Three-and-a-half miles of approach channel in the open sea, as at Panama, could not be considered satisfactory; neither could the unsheltered end at Colon. Sheltering harbours would probably cost another £4,000,000, and there was in addition the question of interest on the expenditure during construction which might be set down at £4,000,000 to £5,000,000; so that, even should the estimates be not exceeded in the matter of quantities and rates, and the sum set down for contingencies prove sufficient,

the works as a whole would cost not less than £30,000,000. If to this amount there was to be added, as the Author appeared to suggest, a sum of about £21,000,000 to represent the interest of the old Company on the expenditure it had incurred, then the canal would have a capital of over £50,000,000. From a commercial point of view a capital such as this would be prohibitive, as sufficient traffic at reasonable rates could not be passed through the canal to pay working-expenses and interest on such a sum. The traffic-carrying capacity of the canal, owing to the locks, would be much restricted as compared with, say, the Suez Canal, which was free from locks, and any future widening of the canal and construction of additional locks to meet increased traffic would be exceedingly costly. The engineering problems of the Panama Canal could be effectually dealt with, but the financial problem, which the Author had not gone into, was in reality the essential point of the question. Mr. Jaffrey.

Colonel VAN ZUYLEN, of the Hague, fully agreed with the Author in all his observations and propositions. In a Paper read before the Dutch Royal Institute of Engineers in February, 1899,[1] he had expressed a similar opinion of the work of the new Company, and had recommended the completion of the Panama Canal in the manner indicated by the financial commission of the Paris Congress in 1879, which had proposed that the Panama Canal should be made by co-operation of the colonial, commercial, and maritime nations, as they would all profit by it. This sound idea had been put aside in 1879 by the great personal influence and the self-consciousness of Mr. de Lesseps, who had declared that he did not want the slackening intervention of any Government, as he could very well make the Panama Canal with the aid of private capital. The Author's remark that the construction of a great waterway between the Atlantic and Pacific Oceans was not so remote as was generally believed, and that the prospects in favour of Panama were much better than was generally supposed, meant perhaps that a satisfactory compromise would be made between the United States and Colombia as to the ownership and the administration of a future Panama Canal. If so, his opinion was, that the United States would complete the work, and that they would adopt the lowest lock-level plan practicable—perhaps in the end the sea-level canal, if further investigations proved that there were no technical objections against it, and that Colonel van Zuylen.

[1] Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1898-99, p. 80; and Minutes of Proceedings Inst. C.E., vol. cxxxix. p. 393.

Colonel van Zuylen.

it was only a question of more time and more money for the Culebra cut, which extra costs would be regarded as more than compensated by the advantages of an open canal; whereas there was but little doubt that the ultimate cost of its maintenance and working would be considerably reduced compared with those of a lock-canal. He had been very glad to find in the Author such a strong partisan of the sea-level canal plan, on behalf of which he had done his best for more than 10 years past—that was to say, since the period when, as a member of the international "Commission d'Etudes," called together in 1889, by the Receiver of the Panama Company in liquidation, he had had the opportunity of making an exhaustive study of the past and future of the waterway-plans between the two oceans. The Author did not mention this Commission nor its Report, published in 1890, although this report had rendered great service both during the negotiations with Colombia and the new Company and in the later work of the latter. It had been especially on his proposition that the general report had been concluded in the following words:—

> But the question (international co-operation) is rather a political than a financial difficulty. As the Committee of the Congress of 1879 has rightly observed, the guarantee of the interest on the stock, however great, would not be too heavy a charge for the budgets of all the maritime nations together. This mighty co-operation would re-establish confidence and at the same time make it possible to guarantee the interests of those who have been justly called the pioneers, and to give to the canal itself the dimensions necessary for a waterway open to any nation of the world.
>
> Should this conception be a dream? Many serious persons think the co-operation plan practicable; they have found partisans both in Europe and in America. In fact this would be the best solution of the difficulties affecting an enterprise worth the whole world's interest, and any government attempting to solve the question in that way would deserve all praise.

A special note concerning the completion of the sea-level canal had been appended to the other reports of the Commission, and thus the suggestion of what he was convinced was the best solution of the question had retained a place among the proposals. It had been almost eliminated by the International Technical Commission, but, with the Author, he was glad to be able to submit it to the Institution. The dam at Alhajuela, which stored up all the water from the basin of the Upper Chagres (more than half the drainage-area of the river) was indispensable—even in the case of a lock-canal at the lowest level—to store up the flood-waters, and to discharge them in the Lake of Bohio. The same dam and the lake it formed would be able, by means of a tunnel through the Cordilleras, to throw the water of the Upper Chagres into one of the valleys at the southern slope of the mountains,

and so on to the Pacific Ocean somewhere north-east of Panama. The orology of the Cordilleras, north-east of the Culebra Pass, was not sufficient to justify suggestions as to the length of the tunnel or its cost; but his conclusion was that any nation deciding on the completion of the Panama Canal as a national labour, or any coalition of all the mercantile nations deciding to treat it as a really international work, should not give preference to any lock-canal before the question of the possibility of making an open sea-level canal had been thoroughly studied, for it was but too evident that no lock-canal, however low of level, could offer the same facilities for traffic as an open canal. Since 1879 different Commissions had studied the estimate of the traffic likely to make use of a canal between the two oceans. The Commission of the Congress of 1879 had estimated it at 7,250,000 tons a year; the Technical Commission in 1900 had anticipated 4,000,000 tons a year for the first 12 years after the opening of the canal, and thereafter 6,000,000 per annum; and, if he was not mistaken, the third Commission, called together by the new Company, had been studying the question for the past 2 years without having come to a conclusion. His personal opinion was that estimation of the actual state of the traffic was a very difficult matter indeed, but that many millions must not be spent for such a grand work as an interoceanic canal only to satisfy the want of the moment, or even of the first half-century to come. One look at the map of the world and the certainty that the countries surrounding the Panama Canal were growing, would convince anyone that a lock-canal suited for a yearly transit of 15,000,000 tons—which was certainly a maximum—with locks of 33 feet lift, would soon prove to be quite insufficient. An objection which might be made against the sea-level canal was, what the Author called the popular idea, that such a canal without locks was an impossibility on account of the difference of tide-level in the two oceans. He quite agreed with the Author that the currents caused by a maximum difference of level of 10 feet over a distance of 50 miles could not be of great velocity, but those who were against the sea-level canal would object that, in a narrow canal, especially in the Culebra cut, every current was dangerous for navigation, and should, therefore, be avoided. It might be answered that there would not be the slightest difficulty in shutting off the canal (at Miraflores) by tidal locks of 10 feet lift, which would not sensibly impede the almost unlimited traffic.

Colonel van Zuylen.

The AUTHOR, in reply to the Correspondence, observed that his reply to the Discussion, taken in conjunction with the valuable

The Author.

The Author. additional information given by some of the distinguished gentlemen who had recorded their views in writing, would elucidate sufficiently the few points raised. He was pleased to find that the Paper had called forth such a number of confirmatory opinions from those well able to judge in so important a matter. He found only one matter in which apparently he had misunderstood the motives which had actuated the Technical Commission in rejecting the sea-level solution for the Panama Canal, which, as stated by Messrs. Choron and Fargue, had really been due to technical objections and to fear of the Chagres flood-problem, and not on account of cost, as stated in the Paper. Whilst he regretted this misinterpretation of the Commission's attitude towards that important question, he desired to express again his emphatic and entire disagreement with their views, and to endorse the opinion of Colonel van Zuylen. There were several perfectly simple and feasible solutions for the sea-level canal, and cost alone rendered its construction, at the present time, impossible as a commercial undertaking. He hoped for favourable solution of the present diplomatic difficulties in the way of the construction of such a canal, either by international co-operation or by authority delegated to the United States alone for a neutral sea-level canal under their immediate management and responsibility, as the safest, cheapest and most satisfactory solution in the interests of the commerce of the whole world. He felt sure the Government of Colombia was actuated by the same desire, and would certainly on its part make every effort to render this possible. He hoped to have, at a later date, the opportunity of reporting again to the Institution the progress of this great and fascinating problem, the solution of which would certainly rank among the greatest engineering achievements of the twentieth century, as an example of the important services rendered to mankind by the Civil Engineering profession.

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12 February, 1901.

JAMES MANSERGH, |President, in the Chair.

The Discussion upon the Paper on "The Present Condition and Prospects of the Panama Canal Works," by Mr. J. T. Ford, occupied the evening.