Discussion.

The PRESIDENT, in moving the vote of thanks to the Author, observed that in his Presidential Address he had referred to several works in connection with harbours, railways, and irrigation in India, but for want of time had been unable to mention many other important works, and he thought the work described in the Paper was a fine example of a great work accomplished in a very short time. The expenditure appeared to have been about £2,250,000 up to May, 1915, since when something like £3,250,000 had been expended on the works described in the Paper. Perhaps the most prominent feature from the engineering point of view was the wisdom and foresight exercised by Major Tulloch, who, when he drew out the original design as long ago as 1872, foresaw the possibility of Bombay growing into the huge city it had now become, and so built the dam in such a manner that it could be heightened from time to time in order to supply the growing needs of the city. The works that had been carried out represented practically the final raising of the dam and impounding of the river Tansa, for which Major Tulloch had provided. Before the "completion works" were commenced, the supply to Bombay was about 45 million gallons per diem, and it had been doubled by the works. A notable matter in connection with the work was the provision for the further growth of the city of Bombay, in that a survey had been made and a preliminary scheme got out for bringing in the waters of the Vaitarna river, which was in another valley. It was proposed to put a weir across that river and to lead the waters into the Tansa lake by means of a tunnel through the intervening summit. That would practically double the present water-supply, which was itself twice the supply of a few years ago. The construction of the 82 miles of 72-inch pipe-line in 16 working months was a fine example of the rapid execution of the work. In one month 11 miles of single pipe, weighing about 7,000 tons, had been laid, and he questioned whether that could be bettered anywhere in the world. The works included quite deep cuttings. A number of little streams had to be crossed and bridged, and in particular the Bassein creek, which was divided by an island into two channels at the point where it was crossed by the pipe-line. His own firm had passed the bridge plans, and that was how he had come in contact with the works. The Author referred (p. 96) to the sinking of the caissons carrying the girders of the larger bridge, which had been done without kentledge.

The President.

The President. Kentledge was an important factor in the sinking of monoliths, wells, or caissons. There might have been still less trouble if a little kentledge had been put on to overcome the skin-friction, which was bound to exist. The appalling death-rate from sickness was very much like that instanced in his Presidential Address, on the Periyar dam. It was in the same sort of country—the Ghat section running parallel to the west coast of India—where the annual rainfall ranged probably up to 200 inches in the highest parts, although the average was only a little more than 100 inches. The area was infested with malaria, and among both Indians and European engineers the mortality was very high. There were also smallpox, typhoid, and plague, and the accomplishment of the work was a remarkable instance of engineering work in India. He thought the engineers in charge, from Major Tulloch, more than 50 years ago, to Mr. Trivess Smith, under whose direction the present works had been carried out, had displayed engineering skill of the highest order; and The Institution was very much indebted to the Author for his admirable description of the work.

Mr. Cotterell. Mr. A. P. I. COTTERELL had been rather struck by a remark made by Mr. Clerke in 1893, in the Paper to which the Author referred, that " the capabilities of the Tansa gathering-ground were in excess of any demands which Bombay was ever likely to make upon it." He could not help thinking how unsafe it was to prophesy. The Tables given by the Author showed how the demand, due to increase of both population and demand per head, had steadily grown. He noticed that, 22 years after Mr. Clerke had written those words, already 31 million gallons per diem were being supplied from Tansa, although Mr. Clerke, when he made the remark about the capabilities of the Tansa gathering-ground, stated that the impounding dam had been built to supply 41 million gallons per diem, which, with the other sources, was considered at the time to be probably more than Bombay would ever require from Tansa. Eleven years afterwards Bombay was requiring 63 million gallons per diem, of which the Tansa source contributed 48 millions, 7 million gallons more than had ever been thought likely, whilst provision was now made for a delivery of 90 million gallons per diem from Tansa, the total supply, including that from other sources, being 105 million gallons. The Tansa area was even regarded as insufficient for the future demands, and a largely increased catchment-area was foreshadowed. The demand per head had grown since 1915, and it was now given as $49\frac{1}{2}$ gallons per head per diem. But was there any probability that the demand would cease at that? Was it not possible that it would go still higher? It would be interesting to know to what extent

Mr. Cotterell.

the water was used for trade purposes. There was no doubt that the Municipality was wise in retaining further catchment-areas for future use. With a growing population, as well as a growing demand per head, it was obvious that the time would come when a supply from the adjoining Vaitarna area would be needed. He believed Major Tulloch in his first proposals had mentioned another river, the Bhotsu, lying to the south-east, which might be brought into use for Bombay, but the Author had not mentioned the possibility of utilizing that river. Had the proposal been definitely abandoned? In view of the probability of using an enlarged catchment-area, he thought that the title of the Paper was not, perhaps, altogether a happy one, because it would scarcely be possible a few years hence to talk of the "Tansa Completion Works." When the catchment-area was increased to three times its present area of 52·5 square miles, would the Tansa dam, even when it was heightened by 15 feet, as was proposed, enable the Tansa reservoir to make proper use of the largely increased discharge. [The PRESIDENT said it was proposed to build another weir across the Vaitarna river which would provide a new impounding-area.] The impounding would have to be done at Tansa because the Vaitarna valley did not lend itself to adequate storage-capacity. Probably dependence was being placed on the increase in capacity of the Tansa reservoir from 35,000 million gallons to 60,000 million gallons by the raising of the dam; but that did not seem to be enough for the largely increased catchment-area proposed. An important feature of the pipe-lines was the adoption of steel in preference to cast iron for the pipes. How would steel compare with cast iron regarding permanency? To what extent had the cast iron been permanent? Was corrosion taking place, and would it take place still more with the steel? He believed it was generally acknowledged that steel was far more susceptible to corrosive action due to dissolved oxygen than was cast iron or wrought iron. Although cast iron did rust, steel was likely to corrode still more rapidly when it was attacked by hydrogen ions, dissolved oxygen, or acid in the water. What was the chemical analysis of the water—was it hard or soft? If it contained much dissolved oxygen it might have an adverse effect upon pipes that were only $\frac{3}{8}$-inch in thickness, which seemed to be very thin indeed. The engineers had no doubt obtained useful experience from the steel mains laid in 1915. How far were such extremely thin mains protected against external corrosion when laid underground? The Paper described the means taken to protect pipes laid above ground, but it was not stated how acid water or any other corrosive agent was prevented from attacking the outside of the pipes, Mr Cotterell. especially where they were laid in the neighbourhood of sewers which were likely to leak. He suggested that concrete of some sort would have been a wise provision and might have been used. Had the engineers considered the use of reinforced concrete for pipes of large diameter, and, if so, what were the reasons why it had not been employed? Properly made concrete was so imperishable for purposes of that sort that he thought it would have been well worth while to adopt that kind of pipe. From the Author's Tables it appeared that the coefficient taken by Dr. Unwin for the discharge through the 72-inch mains was, rightly, on the safe side. From the remarks made by the late Mr. Clerke in his Paper, it would appear that he had found from actual experiments that in the aqueduct, which certainly must have been of rougher material than steel mains, a lower coefficient of roughness could exist than the coefficient Dr. Unwin appeared to have adopted. No mention was made of the loss of head due to the reduction in area of the pipes at the valves. Had any calculation been made as to what head was lost with the venturi-shaped taper at the 36-inch valves? The cross connections were a distinct advantage, and gave more elasticity in the leading mains, especially when supplying more than one reservoir. The Author had emphasized the very large flood-discharge of the Tansa catchment-area as fully bearing out the provision made by the engineer in the first place. Since that time a great deal more had been learned about abnormal discharges for short periods. Rain-gauges showed that rainfalls were very intense for short periods, and in England it had been found that the figures for the total rate of flow during a specified period given by the late Dr. G. J. Symons, F.R.S., had frequently been very much exceeded. Judging by analogy, he had no doubt that in England the rate of discharge during flood was very much higher than had formerly been calculated for waste-weirs, and it was likely that many of the waste weirs of storage-reservoirs needed revision. The Paper described an immense reservoir, such as was not often seen in this country, and a daily water-supply more comparable with what was used in America. He would never forget his first view of the great Croton reservoir that formed the main supply, through the Croton aqueduct, of New York's population of at least 7 millions, at a rate of flow per head far in advance of that provided by the Metropolitan Water Board of London. Apparently Bombay was going in the same direction. Its consumption per head exceeded the supply per head to London, and it might go higher yet. There seemed no end to the quantity of water that communities needed. There was no period when it was possible to write finis to the public supply provided by engineers, Mr. Cotterell.

and for that reason he deprecated the word "completion" even in the title of the Paper, because in his opinion there would be no completion of the works of water-supply to Bombay, or to any other large aggregation of people, until the world was very different from what it was at present.

Mr. Binnie.

Mr. W. J. E. BINNIE observed that the work described in the Paper was remarkable for its low cost and for the expedition with which it had been carried out, especially when the difficulties under which it had had to be undertaken were considered. Malaria seemed to have been very bad. When work had a bad name on account of sickness, it was necessary to pay higher wages to attract labour. He had had to deal with the same problem in Johore. The Gunong Pulai range of hills, where a reservoir was to be constructed, was considered to be one of the most unhealthy parts of the peninsula, and it had been found impossible to open it up for cultivation, on account of the mortality amongst the coolies. The Singapore Municipality had determined to carry out anti-malarial measures before any labour force was introduced on the field, and those measures had been so successful that it was now comparatively a health resort. It was a granite area, with springs issuing from the rocks, and in those springs the mosquito (*Anopheles maculatus*) multiplied rapidly. The springs in the neighbourhood of the labour camp were now carried underground in drain-pipes, which prevented the sunlight from getting to the water. When the pipe-line, which was 38 miles long, was constructed, it was impossible to carry out measures in an endeavour to secure good health amongst the workmen, such as had been carried out at the dam, and unfortunately there had been a great deal of sickness. In constructing a reservoir the fact that people were going to live on one spot for 3 or 4 years, made it economically possible to render the place safe; but when a certain area was occupied for a few months only, as had been the case in the construction of the pipe-line, it became impossible to adopt measures which would thoroughly protect the health of the labour force. With regard to the method described on p. 100 of protecting the interior of the pipes from corrosion, the experience gained with the older pipes at Tansa would be available to indicate what corrosion might be expected in the new main, and he regretted that the Author had neither given information as to the carrying-capacity of the old main at various times, nor stated whether external corrosion was taking place. The pipe-line at Singapore passed through a number of swamps and through jungle with rotting vegetation on the ground. It had been found, as a result of analyses made of the soil every

Mr. Binnie. ¼ mile, that the ground in the jungles was so acid that it was ultimately decided to protect the pipes externally from corrosion by surrounding them with concrete. Where the pipes passed through swamps they were carried on platforms resting on piles, about 2 feet above water-level. Where they passed through rubber estates or along roads no special steps had been taken to avoid external corrosion, except the application of ordinary hessian wrapping. As the water was very soft and liable to corrode the pipes internally, they were lined with mortar. The pipes, which were welded, were delivered at two depots, where the lining was spun inside by the centrifugal process by the Hume Pipe Company, who had taken a sub-contract for that work. The water was liable to act on mortar, and a final protection was given by two coats of bituminous paint, which was applied cold to the mortar. The men who tried to put hot bituminous paint on the Tansa pipes had suffered severely, and he thought the same measure of protection would have been given if two layers of cement wash had been applied after the scale had been removed. With regard to the covering of the Bhandarwada reservoir with the unreinforced concrete arches, his firm had covered a service-reservoir at Birkenhead, about 4 acres in area, with unreinforced concrete domes resting at six points on pillars, the groins formed by the intersection of the domes being reinforced. The domes were 6 inches thick in the middle, increasing to 13 inches at the springing, and the total cost was only £146 per 1,000 square feet covered. The work was done in 1914–15, and the present-day cost would be about twice that figure. Table II (p. 115) was very interesting, but unfortunately, from the Author's statement (p. 110) it appeared that the average rainfall taken could not be considered to be the true average for the drainage-area. In all probability that was very much higher than the figures set out in the Table, which apparently indicated that an average of about 60 per cent. of the rainfall actually flowed down the stream. That percentage, however, was far too high for India. The discharges in relation to rainfall which obtained in various parts of the Malay Peninsula might be of interest to the members of The Institution, and he therefore gave the following information :—

Klang Water-Supply—Ayer Kuning Gauge.—The drainage-area was 242 acres and ranged from about 100 to 600 feet above mean sea-level. It was situated about 8 miles from the coast, in the Straits of Malacca, the latitude being 2½ degrees N. The gauge had been kept since 1904, and the following figures applied to the years 1904–1922 inclusive. The average rainfall was 92·4 inches, Mr. Binnie. the driest year (1908) having a rainfall of 73·53 inches, and the wettest year (1915) having a rainfall of 104·74 inches. The mean rainfall of the driest three consecutive years (1907–9) amounted to 81·31 inches, or 88 per cent. of the average. The average discharge was 23·4 per cent., the minimum (1908) amounting to 10·5 per cent. of the rainfall of that year, and the maximum (1916) amounting to 33·5 per cent. of the rainfall of that year. The average discharge during the driest three consecutive years was 12·8 per cent. of the rainfall of those years. *Singapore Island.*—The drainage-area was of granite, and ranged from about 80 to 350 feet above mean sea-level. Records (measured at the Peirce reservoir, about 1 degree N.) were commenced in 1898 by Mr. R. Peirce, M. Inst. C.E., late Chief Engineer to the Municipality, after whom the reservoir had been named, and the following figures applied to the years 1898–1921 inclusive. The average rainfall was 95·1 inches, the driest year (1907) being 72·9 inches, and the wettest year (1913) having a rainfall of 127·8 inches. The mean rainfall of the driest three consecutive years (1900–1902) amounted to 83·1 inches or 87·3 per cent. of the average. The average discharge was 53 per cent. of the rainfall, the minimum (1915) amounting to 33 per cent. of the rainfall of that year, the maximum (1909) being as high as 83 per cent. of the rainfall of that year. The average discharge during the driest three consecutive years amounted to 51 per cent. of the rainfall of those years. An evaporation-gauge kept at that reservoir since 1912 gave a mean loss from the water-surface of 74·7 inches per annum for the years 1912–1921 inclusive. *State of Johore.*—The new works for the supply of Singapore were situated on the Gunong Pulai range of hills in the State of Johore. Those hills ranged from sea-level to a height of about 2,100 feet, and were distant about 40 miles from the town. The drainage-area was almost entirely granite, and was similar to that of the Peirce reservoir except that more solid rock was exposed at the surface. In both cases the drainage-area was covered with dense jungle. Two streams, known as Pulai II and Pulai III, had been gauged since 1922, and another, known as Pontian Ketchil, since 1924, the total drainage-area amounting to 5,000 acres. There was but little variation in the rainfall on the drainage-area, and in the relation between rainfall and discharge. The records had been kept for too short a time to be of much value when considering variation, but they pointed to an average discharge amounting to 46 per cent. of the average rainfall of 110 inches.

Mr. Williamson. Mr. JAMES WILLIAMSON observed that the Paper was of particular interest by reason of the very large steel conduit described. Not

Mr. Williamson. many such conduits had so far been constructed in Great Britain, although the present tendency was to adopt steel in preference to cast iron, especially for pipes of high capacity. He was particularly interested in the question of the life of such steel pipes, and when in Grenoble in 1925 he visited the works of Messrs. Bouchayer and Viallet, who made pipe-lines for power-stations. That firm had been making such pipe-lines for more than 40 years, and had records of most of the pipe-lines they had supplied. In the early stages, no doubt, the pipe-lines would have been of wrought iron. Some of the pipes were very thin, and they had records of pipes $\frac{3}{16}$ inch thick which had been buried for about 42 years and were still in service, and, so far as they were aware, no pipes they had supplied had failed from corrosion. The cost of the 72-inch pipes given by the Author was extraordinarily low. The manufacture and supply of the pipes had cost, in sterling, about £4 per foot, and the laying and jointing had cost 6*s*. per foot. What was the cost of making the pipe-track, apart from the major works such as the large bridge? The question of the collapse of a section of the pipe was of interest, and there was no doubt that, even with one of the air-valves (which seemed to be only 3 inches in diameter) open, the collapse was bound to occur. The formula given for the collapsing pressure of the pipes was remarkable for the number of significant figures given. While that formula might give the theoretical collapsing pressure for a circular pipe, there were two factors in that particular pipe which would greatly reduce the figure. It was stated in the Paper that the plates had not been rolled to a perfect circle, there being at each end 8 inches of flat plate. If that was so, the maximum off-set from the true circle at the flat portion of the pipe was about $\frac{1}{2}$ inch. A pipe of that form was manifestly much less able to resist external pressure than was a circular pipe. Another factor was that in such a large pipe the difference between the water-pressure at the top and that at the bottom was sufficient to deform the pipes; and under low internal pressure when the pipes were filled with water that factor tended to increase both the original deformation and the liability to collapse under a vacuum. From Figs. 5, Plate 2, the expansion-joints seemed to have a lap of about 6 inches. It was stated that they occurred at intervals of 1,000 feet, and also on either side of each of the anchorages. It was not clear how close the anchorages were, but it was stated that there were anchorages at every sluice-valve, which valves were at 4-mile intervals. There did not appear to be anything to limit the travel in either direction of one pipe inside the other. The tendency with a pipe-line laid on

Mr. Williamson. a slope was usually for the movement resulting from the effects of expansion and contraction to take place in one direction. There would be more tendency for the pipes to move bodily downhill than uphill, and at some stage the accumulated movement, if the anchorages were only at intervals of 4 miles, might be such that the pipes would part altogether. He knew of at least three cases in which disaster had occurred on power pipe-lines laid on a much steeper slope, with a small range of movement at the joints. The loss of head in such a main was always a matter of interest, and little definite information had been published on the subject. He had found an interesting case in France (*Usine de Champ*) on a pipe-line 3·3 metres (10·8 feet) in diameter. The upper portion was of reinforced concrete and the lower part was of riveted steel. Careful measurements had been made to determine the actual losses in the concrete and steel portions respectively, the latter being of somewhat similar construction to the Tansa pipes, but with smaller plates and more riveting. Kutter's coefficient for the concrete portion ranged between 0·011 and 0·012, whereas in the steel part it was about 0·014. The approximate equivalent value of Kutter's coefficient for the formula given by Dr. Unwin was about 0·014. Therefore he thought, as a previous speaker had said, that it had been taken advisedly a little on the safe side. The formula $V = 171{\cdot}4 m^{0{\cdot}723} i^{0{\cdot}527}$ had been published in more than one book for new, asphalted, single-riveted, wrought-iron and steel pipes. According to that formula the calculated loss of head for exactly the same conditions as the Tansa pipe was about half the calculated value given by Dr. Unwin's formula, and he thought the former was to be entirely discredited. The discharge of the Tansa catchment-area, which worked out at 528 cusecs per square mile, was quite to be expected in such a locality, in view of the concentrated rainfalls during the monsoons in India.

Mr. Telford. Mr. J. C. Telford remarked that he would like to record his appreciation of the Paper. He had the privilege of knowing something about the work—in fact, before the Author took up his official position in Bombay, Mr. Telford explained to him the proposals regarding the pipe-line and the method of manufacture. He had been closely in touch with the Author throughout the contract, and he thought the Paper covered the ground so fully that there was very little left for him to say. One or two points, however, had arisen in the discussion, to which he would like to refer. The Vehar pipe, laid in 1912, was of steel and 48 inches in diameter. He inspected that pipe in 1926 and found it to be in excellent condition externally. It was coated with a bituminous

Mr. Telford covering. He had had no opportunity of seeing inside it. In connection with the sinking of the caissons for the Kasheli bridge, he thought the President had not quite appreciated the Author's statement that no kentledge was used. The kentledge was in the form of the concrete casing. The cylinders were 14 feet in diameter, and the well was 7 feet in internal diameter ; therefore the concrete walls were 3 feet 6 inches thick. In many cases the walls extended above the bed of the river for 25 or 30 feet while sinking, and, when it was desired to add to the weight, the depth of concrete was increased. Experiments had been made with various types of collapsible shuttering, but nothing had been found better than the insertion of rings of corrugated sheets of No. 26 gauge, which were strutted to the sides. The Author had omitted to give the total weights of the 60-inch and 57-inch pipes, which were respectively 2,100 tons for the 60-inch and 16,500 tons for the 57-inch pipes. The specified tensile strength of the steel used was rather low. He had been told unofficially that that value had been adopted to give German contractors a chance. The weight of plates given in the Paper as 80,000 tons was approximate ; the actual weight that left Middlesbrough was 78,100 tons. No protection whatever was used on the plates when they were sent from Middlesbrough, and, with the exception of the bending of a few scarfs, no damage at all occurred. The experiment was made of bolting the plates together in batches of four, but it was found, when the plates were in the ship, that the bolts holding one batch had been pushed through the plates in the adjacent batch, and that practice was abandoned. It had been found by preliminary experiments that it was better not to crimp the plates, because, unless there were two sets of dies, a different radius was obtained for the plates, and they were not so readily closed by hydraulic riveters as was the case when they were flat. The plates were purposely left flat on the edges, which gave a total flat in the pipe of 10 inches. The flat did not occur at the top of the pipe, and therefore the theory put forward by Mr. Williamson did not apply. The joint actually occurred about 2 feet 2 inches above the horizontal diameter. The liability of the expansion-joints to come out of their sockets had been mentioned. Concrete anchorages were placed at intervals of approximately 4 miles. The lap of the expansion-joint was between 3 and 4 feet, and by calculation it had been ascertained that the lap given would not allow the total creep to permit the pipe to come out of the socket. Figs. 5, Plate 2, showed the joint pulled out to the maximum extent. It was remarkable that the collapsed pipe referred to on p. 106, which was steadily raised by pumping until it got to within about a foot from its normal position, stuck in that position, and then very suddenly resumed its original shape. Unless pointed out, the place where the collapse occurred would not be noticed, there being merely a slight kink along the edge where the pipe had folded over. With regard to Mr. Cotterell's remarks concerning the additional supply, he thought it was contemplated that the Vaitarna river should be impounded and connected by a pipe to the present Tansa lake. He quite agreed that in years to come the word "completion" in connection with the works would not be correct. Indeed, provision had already been made for a third pipe, particularly in the bridges. There were cast-iron pipes now carrying water to Bombay which dated as far back as 1883 and 1884, and were in excellent condition. There was also the steel pipe he had referred to. A curious thing about the cast-iron pipes in Bombay was the considerable accumulation of deposit which took place in them, and he was looking forward to getting inside the big steel pipes to see what the condition of the deposit was in them. Pipes laid in Bombay in places where sewage was liable to be present were encased in concrete. With regard to the question of spun concrete lining for pipes, it was Mr. Telford's opinion that cracks were liable to take place, and that more damage resulted from water getting behind the concrete than would occur if it were possible to get at the metal and paint it regularly. The Author's reference to the deaths caused by malaria must be taken as referring to the survey camps and to the labour employed on earthwork for the pipe-track. The contractors for the pipe-line decided early that they would take great precautions in connection with their labourers, and he was thankful to say that there had not been more than 150 casualties. There had been properly organized medical examination of all employees, and doctors and sanitary inspectors in the field; and the camps had always been pitched on healthy spots where water could be laid on. Where it had not been possible to do that, water had been carried—sometimes 4 or 5 miles—by special clean tanks to the camp. Labour had been transported from the camps to the working positions, and back again at night. It should be observed that the cost of preparing earthworks was not included in the prices given for pipe-laying. Mr. Telford.

Mr. C. T. A. Hanssen remarked that he had never heard of any pipe-laying operation that had been carried out with such expedition as had been shown in the Tansa completion works, which clearly demonstrated the importance, from the standpoint of both time and economy, of using mechanical applicances instead of human labour. He had had experience of lining and encasing "Bonna" steel pipes with reinforced concrete, and as far as he knew at present they would last for many years. Cracks in the reinforced concrete Mr. Hanssen

Mr. Hanssen. were very minute, and if they occurred, they tended to be filled very quickly by the deposit from the water. Such pipes seemed to be far less liable to the formation of deposits inside than were either cast-iron or steel pipes. They had been in use on the Continent for 30 years or so, and appeared to remain absolutely intact inside and outside. Wherever there was very pure water, as in Manchester, where such pipes had now been successfully used for 2 years under pressure, they were exceedingly satisfactory. A tender for "Bonna" pipes had been submitted for the work described in the Paper, but the contractors had not been able to compete with the very thorough organization that had been able to lay steel pipes at such an extraordinarily low cost. The Tansa pipe had cost about £23 per ton, laid and jointed. The price quoted in England for thinner plates was £22 to £24 10*s*., but he thought the $\frac{3}{8}$-inch plates could be had for about £20 per ton. There was, in addition, the cost of transport to India, import duty, handling in Bombay, and conveyance to the field, which would bring the cost of plates alone to £25 per ton. That the pipes should have been laid and jointed for £23 per ton, when the ordinary cost of the steel in this country was about £20, could only be due to the remarkable organization which had been applied to the execution of the contract.

Sir Alexander Gibb. Sir ALEXANDER GIBB remarked that he had had the privilege of visiting the work when it was in course of construction, and he would like to endorse what had been said of the way in which it had been carried out. Before he visited the work he heard a good deal about it, and what had struck him most forcibly was, firstly, the expeditious way in which everything was done, and secondly, the low cost, which seemed to him almost unbelievable. He was of opinion that this latter was entirely due to the way in which the work had been laid out. Although the shops had been practically in the jungle, all the appliances and plant had been up-to-date, and work had been turned out there in a way that would be a credit to any workshops in this country. He congratulated the Author on his simple and clear description of the works. The track for the pipe-line was very much like a light-railway track: it was rough and ballasted, and the pipes were laid side by side, with a light railway adjoining. He was struck by the fact that there appeared to have been no waste of money at all. It was a good workman-like job, carried out at the minimum of cost, and was an example of what engineers ought to do in a case of that sort. He had carefully examined the outside of the old pipes and had been able to see very little corrosion or rust on either steel or cast iron.

*** The Author's reply will be found at p. 134.